Celebrating the Past - Redefining the Future.

Proceedings of the 125th annual conference of the New Zealand Institute of Surveyors (NZIS)

in conjunction with the

SIRC NZ 2013 - GIS and Remote Sensing Research conference.

SIRC NZ 2013
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NZIS Proceedings

Boundary disputes: The price of federalism

Brian Ballantyne[1]
brian.ballantyne@nrcan.gc.ca

[1] Surveyor General Branch, NRCan

Federalism causes boundary disputes for Aboriginal lands in Canada, acknowledging that New Zealand has fewer disputes per capita; has a different statutory context; and is not a creature of federalism. However, there are two significant constants between the two countries: The nature of land conflicts between Crown and Aboriginal peoples; and the principles used to resolve such conflicts: fiduciary duty, honour of the Crown, duty to consult and minimal impairment of parcels.

Canadian federalism is reflected in the division of powers. The federal Crown is responsible for Indians and lands reserved for the Indians; the 10 provincial Crowns are responsible for property and civil rights. Thus, the federal Crown is responsible for 3,100 Indian Reserves with an area of 35,524 sq km, allocated across 575 First Nations having a population of 370,000. The provinces are responsible for the abutting lands; either as ungranted Crown land or by administering lands in fee simple.

Between these two constitutionally-distinct types of land exist eight types of boundary disputes: The province as active opponent (extinguishing accretion); implicit opponent (claiming travelled roads); mild irritant (regulating accretion); passive-aggressor (asserting that wetlands excepted from patents); innocent bystander (encroaching fee simple interests); unwitting dupe (claims from third parties); the lesser of two evils (in litigation); implicit dropper-of-the-wall (regulatory lacuna for Aboriginal title). Although this is not an indictment of federalism, the law of unintended consequences rears its head.

See full paper – p. 77

Saudi Arabia/Kuwait Boundary – Survey, Mapping and Pillar Emplacement

Vince Belgrave[1]
vincebelgrave@gmail.com

[1] Sounds Surveying Ltd

This project involved a number of components including aerial photography, mapping, surveying and pillar construction. It was won by New Zealand Aerial Mapping (NZAM) with a consortium of local and overseas companies and was managed by Vince Belgrave. The work was undertaken between September 2010 and August 2012.

The project requirements were to remove the 150 small existing boundary and partition zone markers and replace them with more substantial markers. In addition, a new survey datum would be established, primary control network, ground control points for aerial photography and new maps at three scales of 1:25,000, 1:100,000 and 1;250,000. Documentation including an Atlas and technical reports were also required.

The existing markers were set out in the 1960s using conventional survey techniques and coordinates recorded in latitude and longitude in terms of Clarke 1880.
The new pillars were required to be emplaced in the exact location of the old markers and coordinated in terms of ITRF2008.

New digital aerial photography and orthophoto maps were required.

The boundary area consists of the international boundary between the two countries and also a neutral zone marked by the partition zone lines whereby oil revenue from within the zone is shared equally between them.

This presentation will describe the process to survey and map the international boundary and partition zone, construct new pillars and negotiate the difficulties associated with working in this region.

Keywords: Boundary, Surveying, Aerial Photography, Mapping, Saudi Arabia/Kuwait

A Nationwide Adjustment of New Zealand's Geodetic Data

Miriam Broadbent[1], Nic Donnelly[1]
mbroadbent@linz.govt.nz

[1]Land Information New Zealand

Land Information New Zealand (LINZ) maintains a geodetic survey control system that is comprised of a hierarchy of networks. Since the early 1990s, over 500 individual Global Navigation Satellite System (GNSS) campaigns have been carried out to coordinate the geodetic marks in these networks to provide a geodetic infrastructure for New Zealand. To date, coordinates have been generated from an adjustment of each campaign, in terms of the higher order control connected to in that survey. While this approach is computationally efficient, it makes it more difficult to identify errors and marks which may have moved. Adjacent marks may not be included in the same campaign, leading to inconsistencies in coordinates.

In 2012, for the first time, all NZ geodetic GNSS data collected by LINZ and its contractors since the early 1990s was combined into one nationwide adjustment, consisting of approximately 450,000 observations and 75000 coordinates (25,000 marks). The LINZ National Geodetic Office (NGO) is currently analyzing the adjustment to resolve errors and conflicts, determine appropriate observation weightings and test coordinates against appropriate accuracy standards. Once complete, the nationwide adjustment will enable the generation of a consistent set of coordinates for all geodetic marks in terms of the LINZ PositioNZ stations, the highest accuracy points in New Zealand Geodetic Datum 2000 (NZGD2000).

Keywords: national adjustment, NZGD2000, geodetic network, survey control system, coordinate accuracy

SEE EXTENDED ABSRACT – p. 32

Boundary Makers: Land Surveying in nineteenth-century New Zealand

Giselle Byrnes[1]

giselle.byrnes@cdu.edu.au

[1] Faculty of Law, Education, Business and Arts, Charles Darwin University, Darwin, Australia

Land surveyors in nineteenth-century New Zealand were, quite literally, at the "cutting edge" of colonisation. Among the advance guard of new settlers to walk the land and assess its potential for future development, the early land surveyors were an extraordinarily influential, but often overlooked group of colonists. Indeed, much of the modern map of New Zealand is testimony to the efforts of the early surveyors and their attempts to inscribe the land with new meanings and definitions. Most surveyors were aware, however, that they were not 'first-time explorers', but were traversing landscapes that were already known, named and mapped by Maori. In the early period of organised British settlement, from the 1840s to the 1860s, surveyors' efforts to name, tame and claim the land were, therefore, much less an exercise in possessing the land outright; rather, their work translated the meaning of land from one cultural framework into another. From the 1860s, however, and especially with the aggressive activities of the Native Land Court from 1865, the work of land surveyors took on a more potent role as Maori land permanently transitioned from customary tenure to Crown-derived titles and subsequent private ownership. This essay briefly considers the colonising efforts of the early colonial land surveyors during the second half of the nineteenth-century following the assertion of British sovereignty in 1840 and their negotiation of cultural and physical boundaries.

Trimble NZ's role in the revolution of hydrographic surveying and its global impact, from 1990 until today.

Gary Chisholm[1]
gary.chisholm@trimble.co.nz

[1] Trimble Navigation Ltd

Can anyone remember the days before GPS? In those days positioning for hydrographic surveying in NZ was a labour intensive task.

This presentation explains some of the changes that swept through NZ from 1990 and how this NZ company lead some of those changes with software development and integration with DGPS and then RTK GNSS. While Trimble NZ helped solve the hydrographic challenge in NZ it then took its solutions and presented it to the global market. The presentation shows how today Trimble NZ contributes to the efficiencies that precise marine construction technologies that are essential in the development of many ports and harbours worldwide. The NZ surveyor is shown as the innovative professional who designs and installs these systems.

The audience will learn how positioning requirements for marine construction tasks such as dredging, bridge construction, coastal engineering and piling use a variety of survey sensors and integrated software for cost efficient and productive results.

Keywords: hydrographic, marine positioning, GNSS, Trimble NZ, NZ surveyors

The Importance of New Zealand Digital Parcel Fabric

Andrew Clouston[1], Felicity Powell[2], Mike Ladd[2], Adrian Slack[3]
aclouston@linz.govt.nz

[1]Land Information New Zealand
[2] Opus International Consultants (Opus)
[3] Business and Economic Research Limited (BERL)

The accurate determination of property boundaries play their part in the certainty of property rights enjoyed by all New Zealanders and are often taken for granted. With the use of geospatial information changing the way individuals and organisations work together and make decisions, certainty is now demanded in the digital world as well as the physical.

In late 2012, Land Information New Zealand commissioned customer and economic research to better understand the value of digital parcel boundary accuracy to users of this information and to the New Zealand economy, and to identify which aspects are most in need of improvement.

So is there a case for significant investment to improve it?

The presentation focuses on the key findings from the research and highlights:

1. the variety of uses that the digital parcel fabric is being put to, and the lost opportunities due to inaccuracies
2. A look into different geographic scenarios for improving the accuracy of the digital parcel boundaries
3. the impact that an improvement in the accuracy of digital parcel boundaries has (or could have) on individuals, organisations and the economy at large

Keywords: Cadastral parcels, Improvement, Economic benefits, Geospatial information

Surveying the Profession.

Brian J Coutts[1]
Brian.Coutts@otago.ac.nz

[1] School of Surveying, Otago University

Surveying is generally regarded as an occupation that has achieved professional status. Its origins are in the area of measurement and measurement science but it also has a history of understanding of land law and land management. Colonial development in New Zealand, and in other British colonies in the 18th, 19th and 20th centuries required further skills to be developed in allied areas such as municipal engineering and town planning. The era of electronics began a change in the technology surveyors used and the digitisation of data has brought further change. Questions are being asked as to whether the profession has, as a result of these advances, undergone fundamental change such that it requires redefinition.

Additionally, the arrival of computerised mapping data has now established a new area of speciality in the preparation, manipulation and use of mapping data. Have the specialist who operate in this new area of specialisation created a new profession, or are they able to be accommodated within the definition of surveying?

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Updating the NZGD2000 deformation model

Chris Crook[1], Nic Donnelly[1]
ccrook@linz.govt.nz

[1]Land Information New Zealand

In 2013 Land Information New Zealand (LINZ) is publishing a new version of the NZGD2000 deformation model which includes patches for the Christchurch earthquake sequence and other significant events. This is the first updated since NZGD2000 was originally established. It will involve determining the deformation due to these events, defining a format for and publishing publishing the model, and building tools to assist using the deformation model.

When NZGD2000 was formulated it was defined as a semi-dynamic datum, meaning that coordinates are defined by their location at epoch 2000.0, and current locations are determined by applying a deformation model. There has been much discussion since then about how this will be maintained in the face of earthquakes and other deformation events, and as we obtain more accurate information about the secular deformation model.

As time passes the relative accuracy of NZGD2000 coordinates of points is degrading due to deformation. Generally this has had little impact on users, as the secular deformation is quite uniform on a local scale.

However as more survey work is using remote CORS stations it becomes important to include the deformation model in calculations. In areas affected by recent earthquakes the deformation needs to be considered even for local work. These factors are drivers for updating the deformation model.

This paper discusses the development and implementation of the deformation model and describes how it might be used in practice.

SEE EXTENDED ABSRACT – p. 40

Has NZGD2000 exceeded its use by date?

Paul Denys[1] and Chris Pearson[1]
pdenys@surveying.otago.ac.nz

[1] School of Surveying, Otago University

The current coordinate system, the New Zealand Geodetic Datum 2000 (NZGD2000), was introduced in 2000 to replace the terrestrial based New Zealand Geodetic Datum 194 (NZGD1949). When NZGD1949 was established, plate tectonic theory had not been accepted and the coordinates of the 1st Order trig stations were never adjusted to account for this motion. In New Zealand, this has lead to relative deformation in the order of five metres over a 100 year period.

GPS based campaign data observed in the 1990's was used to realise NZGD2000 as well as determining the National Deformation Model (NDM). Since that time, survey technology has allowed practioners to observe longer lines to a far greater level of precision. For example, it is common practice to survey blocks of land relative to the PositioNZ network stations, which may be 100km or more away. To be compatible with NZGD2000, the relative motion to distant survey control must be accounted for. Typically this is achieved with the use of the NDM.

Today, surveyors are very aware of the effects of earthquakes that affect the survey system. While some deformation is imperceptible (e.g. slow slip events), over time these natural events distort the survey system. LINZ accommodates some deformation events in the NDM through the use of deformation patches. Others, for example the Dusky Sound earthquake, or East Coast slow slip events have not been. While the deformation may be small, it will accumulate and may cause significant errors in time.

Surveying Applications in Response to the Christchurch Earthquakes

Phil Dewar[1]
phil@foxsurvey.co.nz

[1] Fox and Associates Ltd

Following the Canterbury earthquakes of 2010 and 2011, many measurement applications have been required including land deformation monitoring, building assessment and monitoring, and boundary definition.

This paper presents examples of how GNSS, total station, precise levelling and laser scanner equipment were applied in response to these earthquakes: Least squares networks combining GNSS, total station, and precise level observations were used to monitoring land and buildings; laser scanner and total station observations were taken to many structures to assess their vertical condition; precise levelling has also been used to assess the condition of building floor slabs.

Many on-going challenges have also arisen regarding boundary definition across vast parts of Christchurch, where the land has suffered significant irregular distortion. Some examples of this, along with our approaches to reconciling the differences, will be presented.

Keywords: Canterbury earthquakes, Least squares networks, Distorted boundary definition

Learning Outcomes:

Cadastral boundary definition in areas of significant irregular distortion.

Applying least squares networks to monitoring control surveys using several measurement techniques.

Update on LINZ initiatives for coordinated approaches to managing imagery and elevation data

Andrew Ferrel[1], Rachel Gabara[1], Julia Hodge[1], Bjorn Johns[1]

bjohns@linz.govt.nz

[1] Land Information New Zealand

Land Information New Zealand (LINZ) is developing a National Imagery Coordination Programme with the primary objective of implementing a coordinated approach to the acquisition and dissemination of imagery that will improve its ease of access and use, achieve better value for public sector investments, and drive economic growth. We will provide an update on the programme status and recent developments of relevance to the New Zealand geospatial community. LINZ is also in the early stages of developing a similar approach to digital elevation data for which community input is sought, and an overview of this programme is also provided.

Keywords: imagery, elevation, DEM, open access, spatial data infrastructure

Learning from the past – defining units into the future

Josie Fitzgerald[1]
Josie.Fitzgerald@aurecongroup.com

[1] Aurecon NZ

The location of unit boundaries in relation to the built structure can be problematic for unit owners and Body Corporates as the requirement to protect the integrity of the structure is necessary, but the ownership of that structure and therefore the responsibilities and where the costs lie, is not always clear.

The leaky buildings and weathertightness issues that have come to light over the last decade have put the microscope on unit boundaries. Aurecon has provided interpretations of unit boundaries in relation to the built structure on unit plans across New Zealand for the Weathertight Homes Resolution Service (WHRS). These reviews have highlighted that the need to accurately define the unit boundary and get it in the right place in relation to the structure is critical and continues to be critical under the Unit Titles Act 2010.

This paper calls on our experience with WHRS and brings together technical input and advice from a range of professionals who are experienced in unit title developments, and highlights some of the critical issues that we as surveyors need to consider when setting the locations of unit title boundaries.

Keywords: Unit Title Boundaries, Leaky Homes, Weathertightness, Body Corporates, Apartment Buildings

Local tie survey at the Warkworth Radio Astronomy Observatory

Paula Gentle[1], Alex Woods[2], John Dawson[3]

[1]Land Information New Zealand
[2] Department of Transport Planning and Local Infrastructure, Office of the Surveyor-General, Victoria
[3]Geoscience Australia

In 2008, the Auckland University of Technology commissioned New Zealand's first Very Long Baseline Interferometry (VLBI) capable radio telescope at the Warkworth Radio Astronomy Observatory. Shortly after this, Land Information New Zealand (LINZ) established a deep-braced continuous GNSS station adjacent to the radio telescope. The Warkworth Observatory is the first and only site within New Zealand that is capable of measuring both VLBI and GNSS observations.

Joint VLBI and GNSS observations are instrumental in improving New Zealand's connection to the International Terrestrial Reference Frame (ITRF). New Zealand's own NZGD2000 is based on ITRF1996 an earlier version of the reference frame. To enable data from the Warkworth Observatory to be included in the ITRF2013 realisation, determining the accurate relationship between the radio telescope and the GNSS antenna became a priority.

The Warkworth co-location survey was undertaken by LINZ in late 2012 with the assistance of key agencies in Australia and New Zealand. The final local tie solution was completed in early 2013. Indirect observation of the radio telescope invariant reference point and GNSS antenna reference point was performed from a network of terrestrial survey control marks. This extended abstract describes the GNSS, EDM traversing and EDM levelling observations and the analysis process used to achieve the millimetre accuracy connection.

Christchurch – A Moving Target
Finding the Optimum Solution for Benchmark Control

Brent George[1]
george@aasurvey.co.nz

[1]Andersen & Associates

Significant earthquake events affect many aspects of people's lives. In terms of the infrastructure of a city after a major event, emergency repair and rebuild works require a reliable benchmark control network that can deliver reasonable three-dimensional post-earthquake (current) coordinates in terms of a well defined datum.

Following the four major Canterbury and Christchurch earthquakes in 2010 and 2011, the Christchurch City Council (later in conjunction with SCIRT) required the prompt and efficient re-establishment of a city-wide skeleton benchmark network that would adequately serve the immediate needs of a variety of users as an "emergency response".

The earthquake event in September 2010, and repeated events in February 2011, June 2011 and December 2011 enabled each emergency response solution to be refined and enhanced. This included the consideration of the timing of the survey; the size of the network; the capture methodology to be employed; identification of authoritative origin or source coordinate values; the data analysis expected; and the publication of the deliverables.

This presentation provides an overview of the operational processes and procedures that were employed in Christchurch City following each event, and offers an opinion on an optimum solution for an emergency response benchmark control network.

Keywords: post-earthquake benchmark control; emergency response

Scanning the past for a perspective on the future

Richard Hemi[1]
richard.hemi@otago.ac.nz

[1] School of Surveying, Otago University

What is the future for surveyors in the acquisition of spatial data? Are advancements in mass data survey technologies such as terrestrial and laser scanning, Lidar, remote sensing, etc going to significantly reduce involvement for surveyors or is a sound knowledge of surveying principles still necessary to plan and undertake these surveys?

In November 2012, the University of Otago's School of Surveying was asked to support the university's Anthropology department in its study of the Micronesian ruins of Nan Madol. Noted for its impressive megalithic architecture of walled island structures built from volcanic rock, Nan Madol is a little known site of significant heritage value. During the same university summer period other scanning projects were undertaken in and around Dunedin in conjunction with the Geography department and the Historic Places Trust. These projects provided an opportunity to learn some of the principles of planning, acquiring data and operating laser scanners in the field.

The conclusion drawn was that surveying procedures employed during scanning field work will have a significant effect on the quality of the data obtained both in terms of spatial accuracy and final resolution. Understanding the influence of good target geometry and layout, the resolution needed for strong target determination, and how to obtain a satisfactory final surface resolution are important competencies required of a scanning surveyor. There is much to learn for the prospective scanning surveyor in the field - and that is without considering the next big question about post-processing, enhancing and presenting spatial data.

University Education – Surveying is a transformative business

Christina Hulbe [1]
Christina.Hulbe@otago.ac.nz

[1] School of Surveying, University of Otago

Universities aren't only in the knowledge business; they are also in the transformation business. As teachers and mentors, university staff help students build new knowledge and skills on whatever foundations they bring with themselves to our classrooms. As scholars, we turn theories and observations into new ways of thinking and into solutions for real world problems. As members of the university community, we do the same for the academic programs and institutions in which we work.

Making the most of this transformative power will be important as New Zealand meets the economic and environmental sustainability challenges of the 21st century. Universities must think carefully about resource management while striving to meet the needs of students, faculty, the nation, and the region. In this, we are no different from any other business, except perhaps that we have a special charge to always be looking forward to the far horizon.

In the School of Surveying, part of looking forward is maintaining our strong commitment to professional practice education while at the same time growing our research profile. These are complementary goals; indeed, a growing research enterprise orients our teaching toward the future and creates opportunities for students and staff alike. We will find those new opportunities in the changing ways people in all sectors are collecting and using spatial data, through helping give meaning to concepts like sustainability and resilience, and by continuing to value and promote interdisciplinarity.

Archaeology and history of seismic events: is the past a key to the future?

Bruce McFadgen[1]
arch.research@actrix.co.nz

[1] School of Maori Studies, Victoria University of Wellington

Humans and their hominin forebears have lived with seismic events for hundreds of thousands of years. Despite the devastation earthquakes have caused to landscapes, towns, and cities, communities have been extraordinarily resilient and resistant to moving away to safer locations. Paradoxically, this has had positive cultural and economic benefit for human societies. Recent archaeological research suggests that human physical development is closely related to tectonic plate boundaries, and that civilisation itself is a result of seismic activity. For the modern capitalist economic system, earthquakes, along with other calamitous events, have played a Schumpeter-like role of creative destruction, and stimulated economic development. This talk briefly reviews the effects of seismicity on human communities, and some of the implications for how we might respond to future events: 1. We should not be surprised that people want to stay put after a large earthquake; 2. despite the damage and upheaval, the economic outcome will probably be ultimately beneficial, although this might take some time to become evident; 3. destruction provides an opportunity for modernisation and replanning, although if past events are a guide, this should not be left to elected councils to implement.

Keywords: earthquakes, civilisation, economy, creative destruction, cultural benefits.

SEE EXTENDED ABSRACT – p. 47

Cadastral 507- Removing Limitations

Llyod McGarvey[1] and Mark Smith[1]

[1] Land Information New Zealand

The Land Transfer (Compulsory Registration of Titles) Act 1924 came into force on 1 April 1925 and provided, for the first time, the concept of a title for which the boundaries were "limited-as-to-parcels". This concept was introduced to enable the compulsory registration of land into the Torrens system of land registration introduced by the Land Transfer Act 1870.

The 1924 Act allowed for the issue of Land Transfer titles endorsed as being "limited-as-to-parcels" for parcels of land for which there were no accurate surveys available at the time of issue to establish if the parcel was subject to adverse possession. Uplifting this endorsement required a survey to be completed of the land in the title to determine the extent of exclusive continuous occupation enjoyed by the title holder since issue of the "limited-as-to-parcels" title.

A limited title was expected to be a short term expedient measure and yet many titles with the "limited-as-to-parcels" endorsement remain.

In the 88 years since 1925, recent evidence suggests that not all surveyors are confident to complete surveys to uplift limitations.

The statutory and case law relating to this activity has been relatively static during this period but there has been misinterpretation of the legal requirements in an increasing number of cases.

This presentation will review the legal requirements and the published papers on the matter over the last 88 years and, by the use of examples, will expose that misinterpretation and provide a direction for future surveys which aim to uplift limitations.

Keywords: Limited Titles; occupation; hierarchy of evidence; documentary boundaries; possessory boundaries.

Geospatial Virtual Field Trips for New Zealand Schools

Geoff O'Malley[1]
gomalley@linz.govt.nz

[1]Land Information New Zealand

Last year, Land Information New Zealand agreed to fund three geospatial Virtual Field Trips (VFT) to help school students improve their understanding of the spatial sciences as well as the associated career opportunities.

The series of field trips are all focused on how geospatial, or location-based, information is being used to support the recovery and rebuild in Canterbury. The rebuild relies on geospatial information – from understanding where underground infrastructures like electricity and water pipelines are, to information on property boundaries, land use and ownership.

The first VFT took place in August 2012, and the second in May 2013. Virtual Field Trips use multimedia and web technologies to enable school students from participating schools to interact with inaccessible places and people without leaving their classroom.

The first field trip focussed on surveying technology for the measuring and mapping of land movement as well as understanding boundaries, land parcels and how land subdivisions are designed and constructed. The second field trip built on that foundation and described how the council's consents process uses location-based information during the Canterbury rebuild. The field trip also explained aspects of hydrographic surveying, topographic mapping and the use of aerial imagery.

Any NZ registered teacher can access and use the material from the geospatial virtual field trips for free with their classes - see www.learnz.org.nz.

Keywords: Location-based information, Virtual Field Trips for schools, surveying technology, geospatial, spatial sciences, Canterbury rebuild

The Emerging Global Political Environment and New Zealand

Robert G Patman[1]
robert.patman@otago.ac.nz

[1] Department of Politics, University of Otago

Since the late 1980s, the global political context has been profoundly affected by the aftershocks of the end of the Cold War and the impact of deepening globalization. These changes seemed to make the world a much smaller but more fragmented place. Yet globalization is a restless and overarching 'mega-trend' that continues to disturb traditional power structures and is expected, over the next two decades, to accelerate significant societal, economic, geopolitical, environmental and technological developments in the international system. To date, New Zealand has been a major beneficiary of the post-Cold War global environment. But there are no grounds for complacency. It is argued in this presentation that a globalizing international environment will prove to be far more demanding in terms of New Zealand's foreign and security policies than either a bipolar or unipolar landscape. Amongst other things, New Zealand must manage its close relationship with two rival great powers, the US and China; respond to domestic and international pressures to take on a greater leadership role with respect to global warming; be prepared to make a substantial peacekeeping contribution to trouble-spots after Afghanistan; and maximize its national policy and intellectual resources within the country by building closer relations between academic specialists and government agencies charged with the implementation of policy.

Sustainable Development,
An Environmental Geodesist's perspective from Hong Kong

Merrin Pearse[1]
merrin@coordinate4u.org

[1] Coordinate4u

You often hear the terms sustainable development and climate change being talked about, though what do those terms really mean to you. As surveyors we are used to looking at objects from different angles, so how about we take some time to explore the terms sustainable development and climate change from different perspectives. What are the first things that come to your mind when you think of sustainable development? Is it designing subdivisions that make wise use of the land area? Orientating building platforms to make best use of solar energy? Maybe you think of designing systems to use the minimum amount of resources during its lifetime (e.g. designing stormwater pipes to only use gravity rather than requiring pumps). What about changing perspective to now think about keeping your business growing while increasing your profitability? This raises the question about how you measure profitability. Do you prepare triple-bottom line accounts that take into account environmental, social, and economic costs? What about your own sustainable development? How does your professional development contribute to society? What local climate changes are you promoting? Are you really passionate about something that from your perspective is helping humanity remain part of life on earth? Do you share that with others? Merrin's passion is connecting people with nature. Now living in Hong Kong, Merrin will call upon personal experiences as a geodesist working on international projects to share new perspectives on New Zealand.

Keywords: Sustainable Development, Financially Rewarding, Personal Fulfilment, Perspective , Reflection

Learning outcomes: Take time to pause and acknowledge what the New Zealand survey profession has achieved both locally and internationally, reflect on what your individual motivations are and how they are serving your community. By practitioners taking time to consider from a wider perspective their role, they can be better placed to serve and contribute to the sustainable development of the survey profession for another 50 years.

SEE EXTENDED ABSRACT – p. 52

PositioNZ-PP: An online GPS processing application for New Zealand

Chris Pearson[1], Chris Crook[2], Aaron Jordan[2], Paul Denys[1]
Chris.pearson@otago.ac.nz

[2] School of Surveying, University of Otago
[2] Land Information New Zealand

This presentation describes progress in the development of a GPS processing engine for NZ using the PositioNZ CORS network. While there are other services like this, LINZ decided to create its own system to allow the development of coordinates in the NZGD 2000 datum. The GPS processing engine identifies and the three best PositioNZ station and initiates GPS processing. This step generates a set of ITRF2000 coordinates at the epoch of observation which still must be transformed to NZGD2000. Because of New Zealand's location on the Pacific Australian plate boundary, models of tectonic deformation are necessary to correct coordinates from the epoch of observations and the reference epoch (2000.0). PositioNZ-PP uses of two subroutines for this purpose. The Station Predictive Model corrects coordinates for the PositioNZ stations for tectonic motion and projects coordinates to the epoch of observation. The New Zealand Deformation Model uses a model of the velocity field and the co-seismic displacement from earthquakes to transform the user coordinates to NZGD2000 at epoch 2000.0.

The web interface is under development and the Station Predictive Model and the New Zealand Deformation Model are currently being upgraded to incorporate the recent earthquakes in New Zealand. It is hoped that the system will be ready for deployment by the end of 2013.

Keywords: GPS processing, earth deformation web applications, New Zealand deformation models

Leaning outcomes: understand new web tools that will be available to NZ surveyors

Tekapo Canal Refurbishment

Maurice Perwick[1] and David Mundy[2]
maurice.perwick@eliotsinclair.co.nz

[1] Eliot Sinclair
[2] IX Survey

In April 2012, Eliot Sinclair and IxSurvey were commissioned to survey the Tekapo Canal to create a DTM for CarpiTech NZ Ltd for the refurbishment of the canal with a rubber liner. The canal was known to leak in areas of fill and was to be sealed with a liner.

The surveys were carried out using RTK and post-processed GPS/GNSS observations to seed a site calibration with Geoid. The daily surveys, topographical and hydrographic, used the same technology and methods to record site levels and navigate and log boat positions and attitude. The data was checked and processed on site each night. The data was integrated and checked against a design model for outages, weed and transformational anomalies.

The combined datasets were used to create a DTM which was sectioned at 10m and 50m distances along the canal for the purpose of determining the quantities of liner to seal the canal.

The presenter will outline the technical aspects of the project and the logistics of carrying out the survey with eight men, two boats and one crane.
The methodologies of marrying in the datasets and processing the data to create profiles will also be outlined.

Keywords: Hydrographic Survey, Multi Beam & Single Beam, RTK Topographical Survey, Site Calibration and Geoid Model, Use of Large Cranes to Launch Survey Boats, Marrying Datasets to Export Profiles

The how and why of the Canterbury earthquake sequence

Martin Reyners[1]

m.reyners@gns.cri.ca

[1] GNS Science, Lower Hutt

A detailed tomographic inversion for 3-D crustal structure (the earthquake-wave equivalent of a medical CAT scan) has provided insight how and why the Canterbury earthquakes occurred. Both the nature of the faulting which occurred and the spatial and temporal development of the aftershock sequence were largely controlled by two crustal structures: 1) a very strong crust underlying the region at about 10 km depth, and 2) volcanoes on Banks Peninsula which erupted during the period 12-6 million years ago. The combined effect of these structures has been to produce a very energetic and prolonged aftershock sequence. Rupture of the Greendale Fault in the Mw 7.1 mainshock produced extensive fracturing in the surrounding greywacke rocks. Geodetic data indicate minimal afterslip following this earthquake. Subsequent fracture healing may have transferred postseismic strain further east, culminating in the destructive Christchurch earthquake 172 days later. Significant afterslip as measured by GPS stations began after the 2011 December 23 Pegasus Bay earthquakes (Mw 5.8, 5.9). These earthquakes completed a linkage between areas in the west and east where postseismic strain could be accommodated by (mostly aseismic) creep in ductile regions in the mid-crust. No such ductile regions exist in the intervening region, and here postseismic strain had to be accommodated by brittle creep, resulting in lots of large aftershocks. The message from this sequence for geodesy is that the pattern of strain build-up and release in earthquakes depends strongly on the underlying crustal structure.

Keywords: Canterbury earthquakes, tomography, crustal structure, GPS, afterslip.

Surveying for the Stronger Christchurch Rebuild Team

Chris Scott [1,2]
Email address

[1] SCIRT Survey Manager (August 2011 – June 2013)
[2] Beca

To rebuild the shattered infrastructure in Christchurch is a huge part of an enormous project. We've spent over 140,000 hours so far to service circa 200 civil designers in SCIRT's quest to rebuild the infrastructure within 5 years.

This project has demanded a vastly different surveying model to traditional infrastructure projects, one that incentivises the collaboration of 14 consultancies, turns data around quickly, consistently and focuses all parties on a single goal. This presentation talks through the SCIRT alliance model and the surveying within it. It discusses the challenges, the trials, tribulations and the successes.

“Non tanquam pictor, sed tanquam mathematicus”, Photogrammetry, Remote sensing and the surveying discipline

Pascal Sirguey[1]
pascal.sirguey@otago.ac.nz

[1] School of Surveying, Otago University

For over a century, photogrammetry has been at the very heart of the surveying discipline and map-making process. In New Zealand, aerial surveys have been used to create topographic maps since the late 1920s. As imaging capabilities have dramatically improved through the development of new sensor technologies (e.g., digital sensors), as well as satellite platforms, now enabling observations to be made from space with unprecedented resolution, the means to obtain topographic information over large areas have evolved. New techniques have emerged and gained a large momentum over the last decade, such as LiDAR. However, the principles of photogrammetry remain relevant and have also evolved. The Multiray photogrammetric technique now allows dense and accurate point clouds to be derived from multiple image overlaps and is competitive with LiDAR products. New platforms such as Unmanned Aerial Vehicles (UAV) offer new opportunities for surveyors as many can now engage into aerial mapping without the logistical burden of plane operations. Furthermore, imaging of the earth’s surface from space via optical or radar technologies offer spatial resolutions that now approach the requirements of some surveying tasks. In this context, the photogrammetric method has greatly evolved, becoming part of the wider discipline of remote sensing, placing it at the centre of the surveying profession. This paper offers a brief overview on how the discipline of remote sensing has gone hand in hand with land surveying and what it can offer in the future to this profession.

Keywords: Photogrammetry, remote sensing, aerial surveys, aerial mapping, spatial imagery

SEE FULL PAPER – p. 64

Coastal Erosion and Property Loss

Mick Strack[1]
mick.strack@otago.ac.nz

[1]School of Surveying, Otago University

It is apparent that our coastal boundaries are increasingly vulnerable to the power and encroachment of the sea. Riparian and Littoral land parcels with natural ambulatory boundaries are subject to loss and gain of land due to the natural movements of the water. Coastal proprietors should be well aware of the threat and the potential for loss, but the increasing rates of loss seem to have taken some proprietors by surprise. When the laws of accretion and erosion are applied to river boundaries, there may be a balanced gamble about whether land will be gained or lost. But on coastal boundaries the predominant trend is for more sea encroachment and land is only being lost. Additionally, land parcels that may once have been remote from the sea, either spatially or legally (i.e. when there may have been an intervening strip of land – road or reserve- on the sea boundary) are now being encroached upon. The proprietors then either defend their rights to protect their own land or demand that local government defend it, otherwise they are demanding compensation for land lost. The responsibilities, liabilities and remedial action are not easily defined and/or implemented. This paper addresses examples and discusses some issues from a property law perspective.

Keywords: coastal property, sea level, erosion, managed retreat

Affordable location technology

Derek Barnston[1], Robin Brill[1], Abigail Harding[1], Neil Jamieson[1], Mike Ladd[1], Nick Stillwell[1]
Nick.Stillwell@opus.co.nz

[1] Opus International Consultants (Opus)

Location technology is not new and can be traced for thousands of years back to celestial navigation and even the use of smoke signals. For the last 30 – 40 years with the arrival of the Global Positioning System (GPS) and more recently the rise of mobile computing and other wireless navigation methods, location technology is now integrated into many parts of everyday life. In the land transport sector of New Zealand there is potentially a gap between technology that is available and its use on the ground.

This research seeks to bridge that gap and provides support to the NZTA goal of increasing the use of appropriate location technology by its key providers (contractors and consultants). Initially consultation with these key providers was undertaken to understand the requirements for location technology and any lessons learnt from previous implementations, then a literature and technology review and evaluation was undertaken leading to a number of conclusions and recommendations.

Mapping grade GNSS and consumer grade GNSS combined with mobile GIS and imagery are seen to be good options for immediate use. Other promising technologies include augmenting GNSS with ground based networks like Locata or other wireless systems (Bluetooth, Wifi, Ultra wide-band). There is also great potential for the wider use of ground based LiDAR for desktop surveys.

The use of these technologies requires clear guidance from the NZTA. Our research recommends an update of current NZTA manuals to include clear sections on guidelines for the use of location technology and clear accuracy requirements.

Keywords: Affordable, Positioning, Transport, Accurate GNSS

Registered Professional Surveyor: To be, or not to be - that is the question

Rebecca Strang[1]
rebecca.strang@aurecongroup.com

[1]Aurecon NZ

This presentation will summarise the findings of a questionnaire sent to NZIS Registered Professional Surveyors in June 2013. The objectives of the questionnaire were to find out how and in what situations current Registered Professional Surveyors are using their title (for example, to certify plans or documents and to market themselves), how valuable they perceive the title to be, their reasons for becoming a Registered Professional Surveyor (RPSurv.) and how the RPSurv application process is perceived by those who were not previously Registered Surveyors under the Survey Act 1986.

The survey findings will be relevant to current Registered Professional Surveyors and those Members considering applying to become a Registered Professional Surveyor.

Keywords:
Registered Professional Surveyor, Marketing, Professional development, Admissions process, Career

Realising the Queen's Chain from the part to the whole
A New Zealand national mapping system displaying public walking access

George Williamson[1]
george.williamson@walkingacces.govt.nz

[1]NZ Walking Access Commission

The "Queen's Chain" has been embraced by New Zealanders from the time Queen Victoria gave early land surveyors the instructions to preserve land along waterways for public use. The concept is part of New Zealand's heritage.

One of the objectives of the NZ Walking Access Commission, established in 2008, is to provide the public with reliable information on land over which the public have walking access – including the "Queens Chain". The Commission built a unique GIS – based system (the Walking Access Mapping System -WAMS) with the vision of it steadily becoming the preferred entry point for outdoor recreation access information for all New Zealand.

It aligns with the government's geospatial strategy by enhancing public access to government-held information.

The paper discusses the technical and practical challenges encountered in planning, building and implementing a national 'free to use' mapping system for displaying public access areas, including unformed legal roads and other public land, from multiple public and private information sources, with very small resources. WAMS is highly rated by users, which raises strategic challenges in respect of ongoing investment.

This paper identifies and discusses the implications of building and owning public-facing information systems and the critical importance of other systems including the national cadastre and standardised metadata.

Keywords: Public access/Queens chain, Unformed legal roads, National cadastre/standardised metadata, NZ Walking Access Commission/Walking Access Act 2008, Walking access mapping system, WAMS

Extended Abstracts

A Nationwide Adjustment of New Zealand's Geodetic Data

Miriam Broadbent[1], Nic Donnelly[1]
mbroadbent@linz.govt.nz

[1]Land Information New Zealand

Abstract

Land Information New Zealand (LINZ) maintains a geodetic survey control system that is comprised of a hierarchy of networks. Since the early 1990s, over 500 individual Global Navigation Satellite System (GNSS) campaigns have been carried out to coordinate the geodetic marks in these networks to provide a geodetic infrastructure for New Zealand. To date, coordinates have been generated from an adjustment of each campaign, in terms of the higher order control connected to in that survey. While this approach is computationally efficient, it makes it more difficult to identify errors and marks which may have moved. Adjacent marks may not be included in the same campaign, leading to inconsistencies in coordinates.

In 2012, for the first time, all NZ geodetic GNSS data collected by LINZ and its contractors since the early 1990s was combined into one nationwide adjustment, consisting of approximately 450,000 observations and 75000 coordinates (25,000 marks). The LINZ National Geodetic Office (NGO) is currently analyzing the adjustment to resolve errors and conflicts, determine appropriate observation weightings and test coordinates against appropriate accuracy standards. Once complete, the nationwide adjustment will enable the generation of a consistent set of coordinates for all geodetic marks in terms of the LINZ PositioNZ stations, the highest accuracy points in New Zealand Geodetic Datum 2000 (NZGD2000).

Key words: GNSS/GPS, Least squares adjustment, SNAP, Survey Control

1. Background

New Zealand Geodetic Datum 2000 (NZGD2000) consists of multiple networks. Historically, the Order 1 control layer was the backbone of the geodetic system. Order 2 control surveys were coordinated by connecting to Order 1 control and adjusted in terms of Order 1 by fixing the coordinates of the Order 1 marks. This process was applied down to Order 5, the most widely available level of control in New Zealand. Order 5 control surveys were connected to any nearby higher order stations whose coordinates were used as fixed control for Order 5 coordination. This system has worked reasonably well; however, any errors or anomalies in higher orders are propagated through the hierarchical network structure and affect the coordination of lower orders.

We now have 35 PositioNZ Continuously Operating Reference Stations, which are Order 0. It is the PositioNZ stations that link NZGD2000 to the global datum through the inclusion of some in the International Terrestrial Reference Frame (ITRF). Maintaining alignment with the ITRF is critical as this is the reference frame used for global positioning technologies, such as GPS. So, it is the PositioNZ marks that are now the backbone of New Zealand's geodetic system.

The concept of the National Geodetic Adjustment is to merge all observations which have been used to coordinate geodetic control in the past into one national adjustment, and to then adjust all geodetic marks together in terms of the Order 0 control.

2. Improving Accuracy Through A National Adjustment

The overall aim of a nationwide adjustment is to improve the accuracy of coordinates using existing data. The United States has taken this approach and Australia is currently working on their national adjustment. Essentially, advances in computing power mean that it is now possible to run a single adjustment containing tens of thousands of marks, which improves accuracy of coordinate generation in several ways.

2.1 Improving Accuracy Among Adjacent Marks

One of the drivers of the national adjustment is to ensure the geodetic system achieves the accuracy required by the Surveyor-General. Achieving this accuracy ensures the marks are fit for their intended purpose. The local (or relative) accuracy among nearby marks is particularly important, as most surveys are carried out over relatively small areas, using control marks in the immediate vicinity.

The Standard for the geospatial accuracy framework (LINZS25005) requires testing of local accuracy against all other marks of the same or better accuracy within a given radius.

Figure 1 below, shows an example of this situation where two nearby marks have never been tested together. EJGX and ENAG are 124 m apart but were surveyed at different times by different geodetic contractors. The local accuracy between these two has not previously been tested, as they were in separate adjustments. Having the national geodetic network in one adjustment allows full rigorous testing of all marks in the network. Where failures are identified, further observations may be collected to strengthen the network.

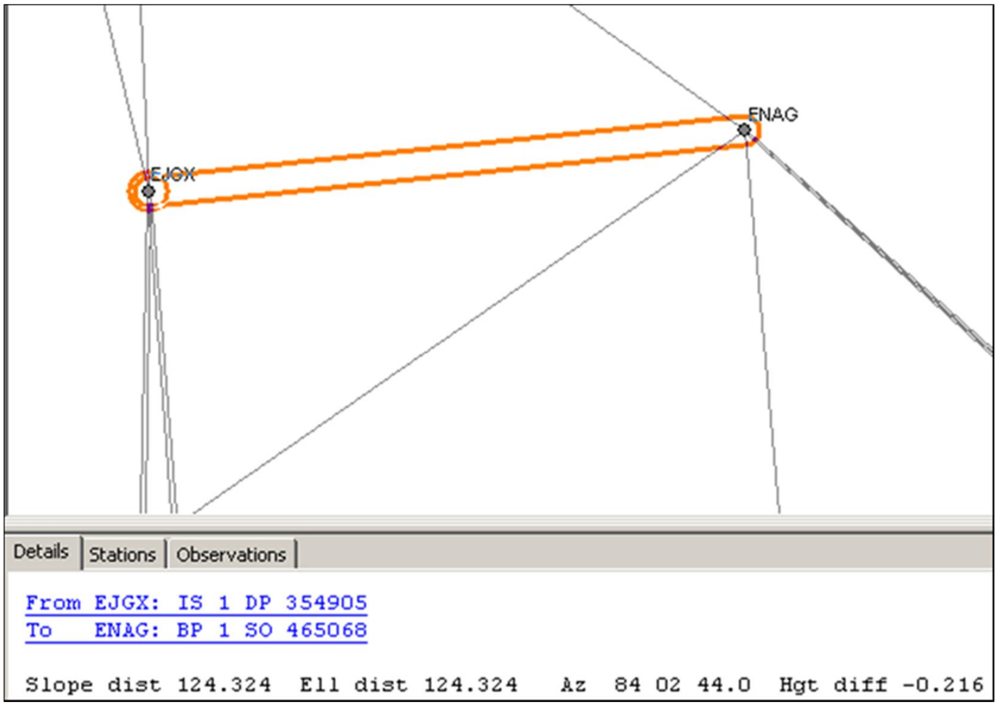


Figure 1. Two geodetic marks in separate surveys, not tested against local accuracy standard

2.2 Improving Accuracy Relative to CORS

The use of CORS in surveys is becoming more common. It is therefore important to improve the coordinates of geodetic marks relative to PositioNZ stations. Many geodetic marks were coordinated before the Order 0 marks were established, however subsequent surveys may have tied them more tightly to PositioNZ (whether directly or indirectly). The national adjustment will ensure that any such connections have as much impact as possible.

2.3 Historical Data Re-Analysis

Another more general reason for the national adjustment is to compare the observations from all geodetic surveys since the mid 1990s to identify outliers and improve coordinates. Since the first surveys in the 1990s, GNSS equipment and satellite geometry have improved considerably. Furthermore, both LINZ and its contractors have been developing better methods of network analysis, so reanalyzing historical data can identify errors and inconsistencies that were not previously obvious.

2.4 Accurate Normal-Orthometric Height Determination

A fourth driver is related to the geodetic heighting system. Currently LINZ is undertaking the Vertical Datum Improvement Project, which includes work to better model the geoid in New Zealand. More accurate ellipsoidal heights will enable LINZ to refine datum offsets to enable better conversion to levelling datums.

3. Process Overview

The National Adjustment Project is currently in progress. Figure 2 below shows the planned steps to complete the project.

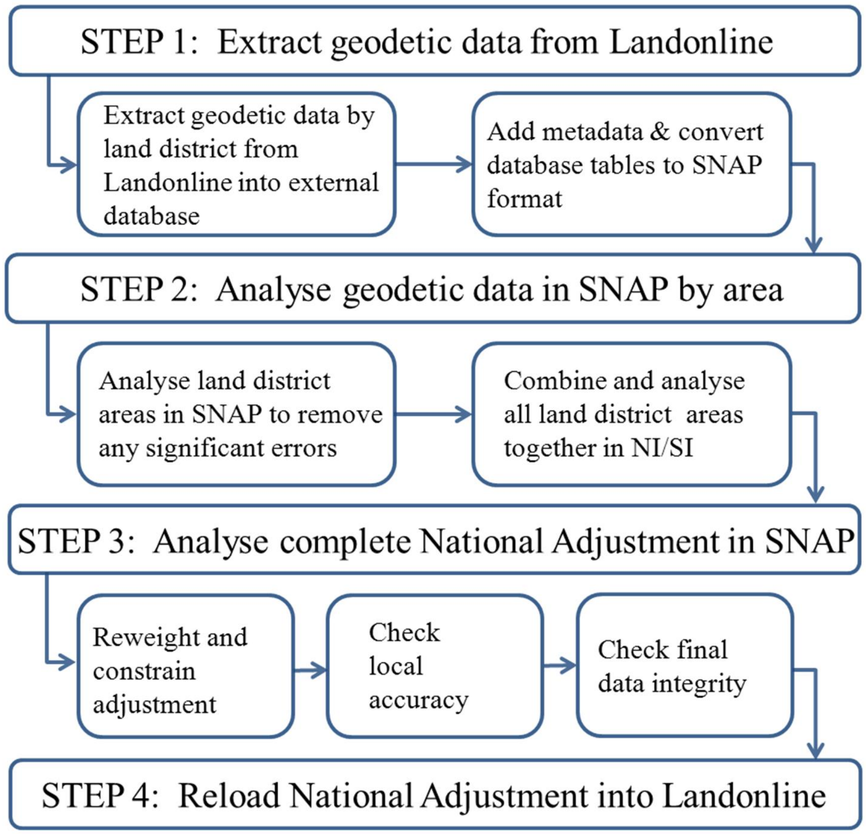


Figure 2. National Adjustment Project Workflow

As of August 2013, the project is up to Step 2, and two thirds of the way through the process of analysing land district areas.

3.1 Step 1 – Data extraction

Step 1 of the process has been completed and all geodetic observations in each land district have been extracted from Landonline into an external database. An observation is considered to be in a land district if the midpoint of the observation lies within the land district boundary.

The national adjustment consists of over 140,000 baselines and 25,000 marks from over 650 surveys carried out by about 50 surveying firms.

After the extraction process from Landonline, extra metadata about the methodology of the survey (i.e. static/ rtk), the Order of survey, and the surveying firm was added to the database. The database tables were then converted to the Survey Network Adjustment Package (SNAP) format ready for analysis.

3.2 **Step 2 – Data analysis**

Step 2 is to analyse individual areas of New Zealand to remove any significant conflicts. The adjustment is set up using a mark data file and vector file in a unique SNAP format created for the national adjustment. Only Order 0 marks are held fixed. Expected errors consist of constant and proportional components for the east, north and up vector components. For Orders 0-3, the constant components are set to 3mm East, 3mm North and 6mm Up. The proportional components are set to 0.4ppm East, 0.4ppm North and 0.8ppm Up. Similarly, for Orders 4-5 the constant error components are 4mm, 4mm and 8mm, and the proportional components are 0.5ppm 0.5ppm 1ppm.

The process is to run the adjustment and starting with the worst standardised residual, resolve any outliers until the worst outliers are within Order 5 accuracy tolerances.

4. Adjustment Analysis

4.1 **Outlier survey analysis**

One of the analysis techniques used when investigating a conflict at a particular mark, is to divide the baselines going to a mark by survey and then use SNAP to compare the positions. This allows identification of an outlier survey.

For example, XXXX was identified as a mark with conflicting data. There are 5 surveys that have observed XXXX so the position observed by each of these surveys is given a unique identifier. When SNAP is subsequently run, five positions result, one for each survey. Differences between the resulting positions can then be compared within SNAP.

Figure 3 below shows the difference in distance between XXXX1 and XXXX3. The difference of interest is the height difference of 0.121m. XXXX3 has a similar height difference to all the other surveys of this mark. Many independent sessions from the four other surveys agreed well, so the observations from the survey XXXX3 were rejected at XXXX, leaving the surveys that agree to produce the adjusted coordinate.

If the outlier survey is the most recent undertaken at the mark, care must be taken using this analysis strategy as the mark may have been disturbed.

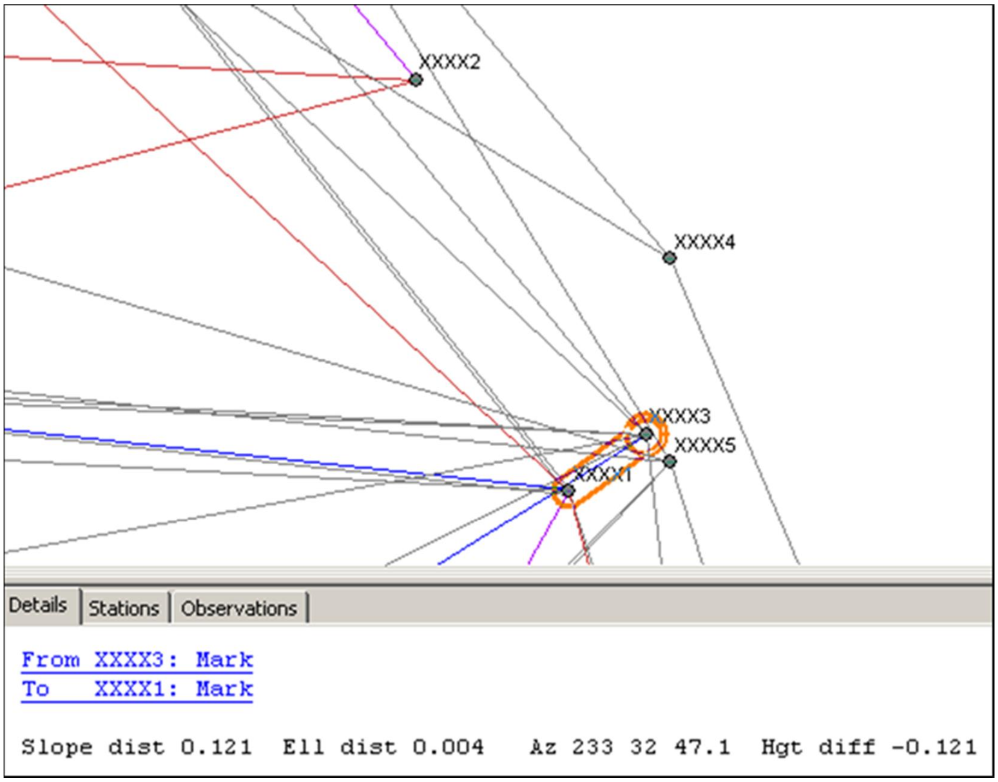


Figure 3: Height difference between two surveys at the same mark

For marks coordinated by only one survey job this technique is also used to compare multiple sessions within that work to identify outlier sessions.

4.2 **Outlier observation analysis**

In Figure 4 below, there are 8 baselines going to ZZZZ (see the list inside the figure with the date and time provided). Surveying took place in February on two different days and then again in April. In April, ZZZZ was observed 6 times in quick succession; these 6 are considered to be one session and not independent of each other as satellite geometry is largely unchanged. However, SNAP treats these as independent sessions based on the input data, and because the 6 observations in session 3 fit well together, they have a strong influence on calculating the best position for ZZZZ. So during the analysis process all the baselines are divided up into independent sessions, much the same as in the example above, to remove the false redundancy effect of non-independent multiple observations as in session 3. The result of this particular mark analysis was that sessions 1 and 2 were in terms of each other, whereas session 3 was the outlier. All the observations in session 3 were subsequently rejected from the adjustment.

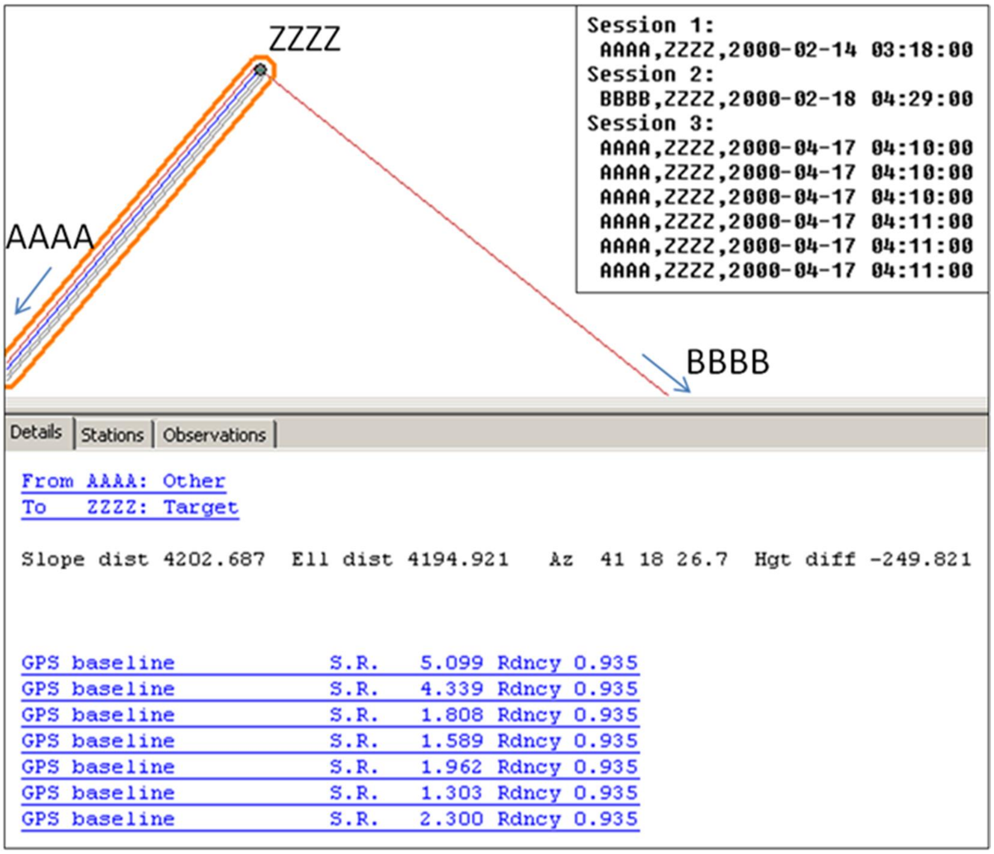


Figure 4: Non-independent observations

Next Steps

4.3 Weighting

Weighting is used to give different categories of observations different levels of influence on the calculated coordinates. For example, a vector calculated from 24 hours of GNSS data will be more accurate than a vector between the same two marks calculated from 10 minutes of data. A weighting scheme needs to reflect as closely as possible the true accuracy of the data.

Once all gross and systematic errors have been removed from the adjustment, the vectors can be grouped into various categories based on common characteristics. Each category will be analysed to determine the overall accuracy of vectors in that category. This information will then be used to weight the adjustment.

4.4 Constraints

Constraints are used to connect an adjustment to a datum, or to impose some conditions on the adjustment. The traditional approach of holding fixed all marks of a more accurate Order than the survey being adjusted assumes that the fixed coordinates are error-free. Clearly this is not the case. An Order 4 coordinate, for example, will have errors propagated from the Order 1, 2 and 3 surveys through which it is connected to the datum, as well as errors from the Order 4 survey. The assumption is that the errors in the fixed coordinates are an order of magnitude smaller than the errors in the observations being adjusted. Technology improvements mean that this is often not the case. For example, an Order 5 survey carried out in 2013 will sometimes be more accurate than an Order 3 survey carried out in the late 1990s.

By combining all the observations, irrespective of Order, into a single adjustment, coordinates can be calculated using far fewer constraints. For example, one option is to hold fixed only the Order 0 coordinates (PositioNZ stations). Another option is to move away from fixed constraints and allow Order 0 coordinates some freedom to move, within the constraints of the weighting applied. The impact on the final coordinates of the various options needs further investigation.

5. Summary

The National Adjustment Project will provide more accurate geodetic control countrywide.

Various techniques are being used to interrogate the data to improve it. Further work is still required to combine all geodetic GNSS observations for the whole country, find an effective weighting strategy, and determine appropriate constraints.

It is a project still in progress and the final result will be discussed in a later paper.

Updating the NZGD2000 deformation model

Chris Crook[1], Nic Donnelly[1]
ccrook@linz.govt.nz

[1]Land Information New Zealand

Abstract

In 2013 Land Information New Zealand (LINZ) is publishing a new version of the NZGD2000 deformation model which includes patches for the Christchurch earthquake sequence and other significant events. This is the first update since NZGD2000 was originally established. It will involve determining the deformation due to these events, defining a format for and publishing the model, and building tools to assist using the deformation model.

When NZGD2000 was formulated it was defined as a semi-dynamic datum, meaning that coordinates are defined by their location at epoch 2000.0, and current locations are determined by applying a deformation model. There has been much discussion since then about how this will be maintained in the face of earthquakes and other deformation events, and as we obtain more accurate information about the secular deformation model.

The deformation caused by earthquakes that occurred in Canterbury since 2010 has degraded the local relative accuracy of NZGD2000 in that region. This is addressed by including "reverse patches" in the deformation model and updating the coordinates in that region. At the same time the effect of other significant earthquakes is being addressed, and the national velocity model improved.

These changes will maintain the accuracy and usefulness of NZGD2000 datum and NZGD2000 coordinates, and better support the increasing use of GPS and point positioning.

Introduction

In 1998 Land Information New Zealand (LINZ) introduced the semi-dynamic datum New Zealand Geodetic Datum 2000, NZGD2000 (Grant et al. 1999, Blick et al. 2003). The semi-dynamic datum defines coordinates in terms of a fixed reference frame (ITRF96 at epoch 2000.0), and defines a deformation model that allows the corresponding location to be calculated at other times, in particular to determine the current location.

The deformation model manages the disparity in the usage of NZGD2000 coordinates – on the one hand representing a physical location in terms of a global reference system, and on the other hand as generally static identifiers of features in databases. With ongoing relative movement up to 5cm/year across New Zealand, coordinates of features that were physically correct in 2000 could now be more then 60cm out of terms with each other. Earthquakes have introduced additional discrepancies of up to a few metres.

The deformation model needs to be maintained. The original velocity model was based on observations between 1992 and 1998. These have now been extrapolated 15 years, almost three times the observation period from which they were derived. The survey errors and distortion due to deformation events during the observation period are now multiplied by three. Additionally the model does not account for effects of earthquakes since 2000. The revised model includes an improved national velocity model, and patches for eight significant earthquakes since 2000.

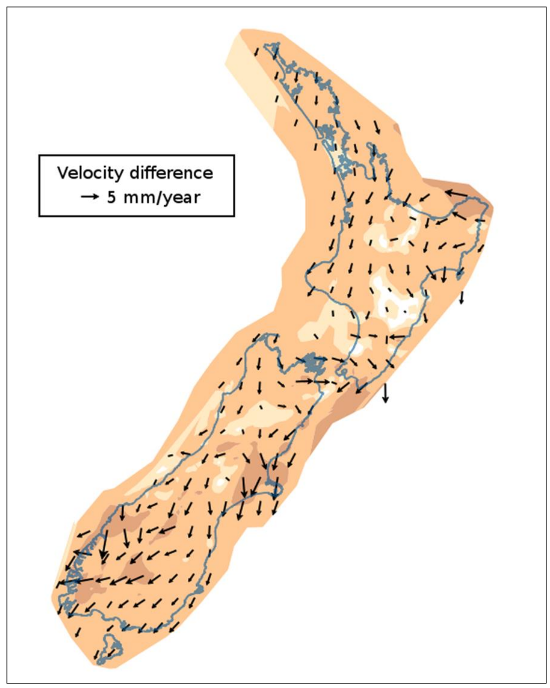


Figure 5: The difference between the original NZGD2000 velocity model and the 2012 version

Updating the national velocity model

The new national velocity model is based on both campaign GPS and continuously operating reference stations (CORS) observations from January 1992 to February 2011, except that observations from the South Island after the Darfield earthquake in September 2010 are not used. This period does include four significant earthquakes that have affected the South Island (detailed below). The modelled deformation due to these events is subtracted from the observations to substantially remove their influence.

The period of observations also includes several slow slip events (SSEs) that have been observed in north east and central New Zealand. These events have been observed in time series from CORS stations, recurring approximately every three to six years with a magnitude of a few centimetres. These have been treated as part of the continuous velocity. The model is supplemented with the Nuvel-1A NNR global tectonic model to extend beyond mainland New Zealand – in particular to include the Chatham Islands.

Name	Date	Magnitude	Max H	Max V
Secretary Island (Fiordland)	**22 August 2003**	7.2	0.27	0.72
Macquarie Island	**24 December 2004**	8.1	0.015	0.005
George Sound (Fiordland)	**16 October 2007**	6.7	0.13	0.27
Dusky Sound	**15 July 2009**	7.8	1.74	0.39
Darfield	4 September 2010	7.1	3.20	1.75
Christchurch	22 February 2011	6.3	0.31	0.48
Christchurch	13 June 2011	6.3	0.22	0.13
Christchurch	23 December 2011	6.0	0.25	0.36

Table 1: Events included in the NZGD2000 deformation model. Max H and Max V are the maximum horizontal and vertical deformation on or near the land area of

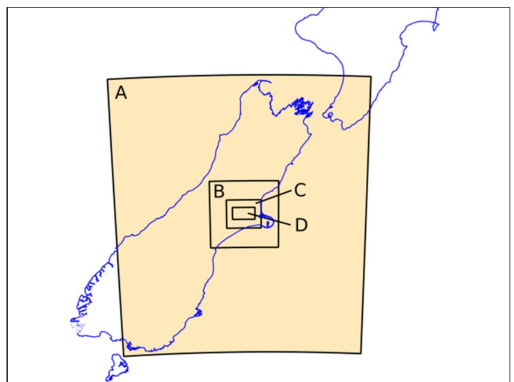
The revised velocity model differs from the original by up to 7 mm/year – amounting to 9cm since 2000 as shown in Figure 5.

Patches for significant earthquakes

The deformation model also has to account for the earthquakes that have caused significant deformation since 2000. Those considered are detailed in Table 1.

These events are included as "reverse patches" in the deformation model. That is, the NZGD2000 coordinates for affected marks are updated to include the deformation due to each event, and the patch is used to calculate coordinates at dates before the event.

This means that the NZGD2000 coordinates no longer represent the location of points at epoch 2000, since they include the deformation due to these events which occurred after 2000. On the other hand they do not include the secular deformation (from the velocity model). One way to think of this is to imagine that the earthquakes had happened before



Grid	No Lon	No Lat	Size Lon (deg)	Size Lat (deg)
A	52	54	0.15	0.125
B	50	59	0.075	0.0625
C	84	118	0.0375	0.03125
D	141	306	0.01875	0.015625

Figure 6: Outline of the grids used to represent the deformation due to the Darfield earthquake. The table shows the number of longitude and latitude grid values, and the longitude and latitude size of the grid cells in degrees

2000 – the coordinates would then represent the locations at 2000.

The process of creating a deformation patch is discussed in some detail by Winefield et al (2010) using the Dusky Sound (2009) earthquake as a case study. Each patch is based on an underlying geophysical model, which in turn is based on observations such as campaign and CORS GPS data.

The patches are implemented as nested grid models, using a finer grid where the deformation is more complex, generally nearer the epicentre of the earthquake. The extents and resolutions of the grids ensure that the difference between the gridded model and the geophysical model on which it is based do not compromise the LINZ network accuracy standards (LINZ 2009).

Specifically the grid includes the extents within which the model deformation is greater than 0.0012m and 0.012ppm[1]. The resolution ensures that the (horizontal) error due to gridding is less than 0.0012m. The coarsest grid size has spacing of 0.15 and 0.125 degrees in longitude and latitude respectively – each finer grid divides this by 4. The smallest grid size used has approximately 200m grid cells. Even this fine grid spacing introduces significant gridding errors near the surface faulting associated with the Darfield earthquake, though there the gridding errors are outweighed by those inherent in geophysical modelling (see Table 2).

Figure 6 illustrates the grids used to represent the Darfield earthquake deformation.

Accuracy of patches

Whilst the patches are derived from geophysical models calculated using well-established scientific techniques, like any model, they are only an approximation of the complexity of the real world. For example, the geophysical model assumes that the Earth's crust is elastic. This is not strictly true, and means that modelling errors are greater in areas subject to the greatest forces, near the fault plane. The patches also do not account for localised deformation, such as liquefaction. This limits their use in significant parts of Christchurch.

The accuracy of a patch can be assessed by comparing the movement predicted by the patch with that observed by GPS. Table 2 shows the results of this comparison carried out for Canterbury. In this case all four patches from the four major earthquakes to affect the region were analysed together. Note that while the values in the table are being used here to indicate the accuracy of the model, in reality they also reflect errors in the pre and post-earthquake GPS data. Furthermore, the relative accuracy of the patches is far better than the absolute accuracies considered here. As expected, the fit of the model to the observations improves with increasing distance from the fault.

[1] Calculated by multiplying the local accuracy standard for National Reference Frame survey network by 0.4 – a somewhat arbitrary number derived in Winefield et al (2010).

Description of Region	Horizontal (m)	Vertical (m)
Up to 2500m from Darfield fault rupture	0.536	0.256
2500 to 7500m from Darfield fault rupture	0.251	0.161
7500 to 15000m from Darfield fault rupture	0.129	0.072
Remainder of Canterbury, excluding those parts of Christchurch impacted by liquefaction and other localised deformation	0.058	0.062

Table 2: Differences (at 95% confidence level) between observed and modelled movements with increasing distance from the Darfield fault rupture

Impact on survey control

The deformation due to the Canterbury earthquakes means that the local relative accuracy of the coordinates is no longer consistent with their coordinate order. Applying the reverse patch will generally improve the relative accuracy, but the errors of the geophysical model from Table 2 will still be present. This is the case for the areas close to the Darfield earthquake faulting, and in much of Christchurch where liquefaction and slumping has moved marks. In these areas the orders of mark coordinates are reduced.

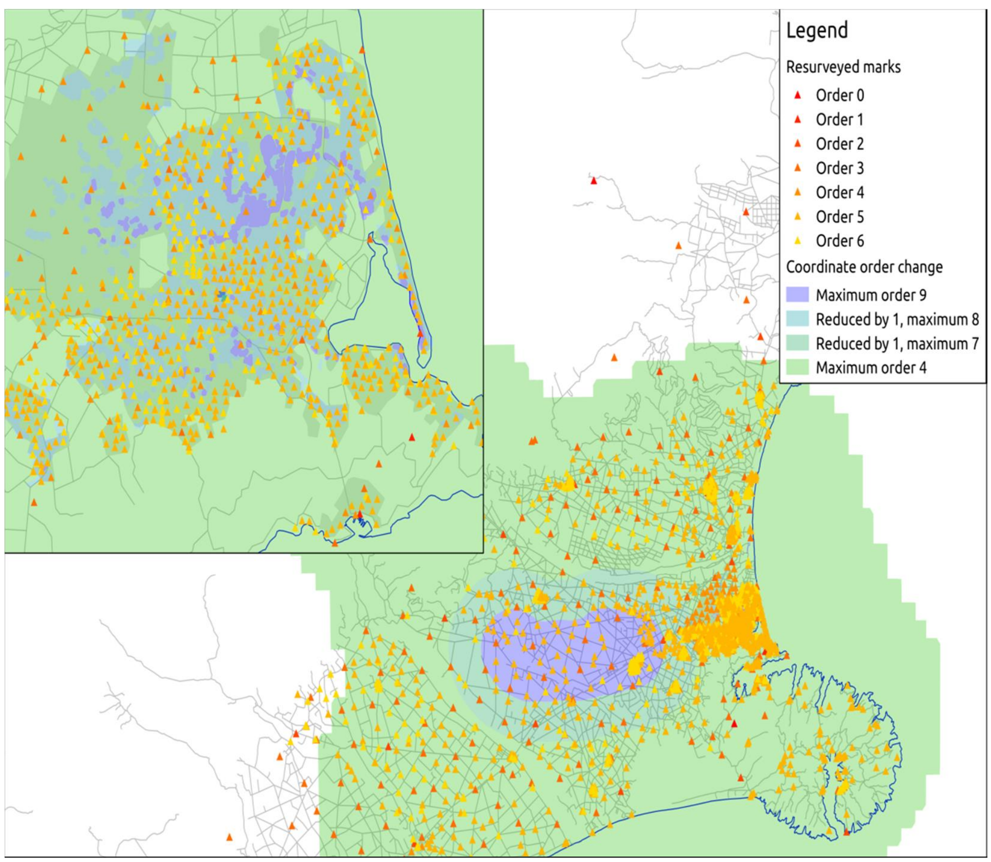


Figure 7: Impact of the Canterbury earthquakes on survey control. The coloured areas show where the orders of existing coordinates have been degraded as their accuracy (after patching) is no longer expected to match their order. The resurveyed marks shown are those with order 6 or better coordinates.

The mass degradation of coordinate orders means that in these areas there is no control for cadastral and other surveys. In order to maintain the spatial infrastructure in these areas LINZ has therefore contracted extensive resurveys of survey marks. The affected areas and resurveyed marks are shown in Figure 3.

Implementation in GIS databases

The use of reverse patches requires updating NZGD2000 coordinates to include the deformation due to the patch events. Figure 8 shows the magnitude of the horizontal coordinate change. In principle, coordinates in other GIS systems (including the LINZ survey and title database, Landonline) must be updated. In practice, the extent to which this will be done will depend on the accuracy requirements of the databases. For Landonline, coordinates of all features are updated where the change is greater than 5cm. Where the change is less only higher order geodetic marks are updated. The total coordinate change for all patches is available for download from LINZ at http://apps.linz.govt.nz/ftp/geodetic/NZGD2000_20130801_coordinate_update.zip.

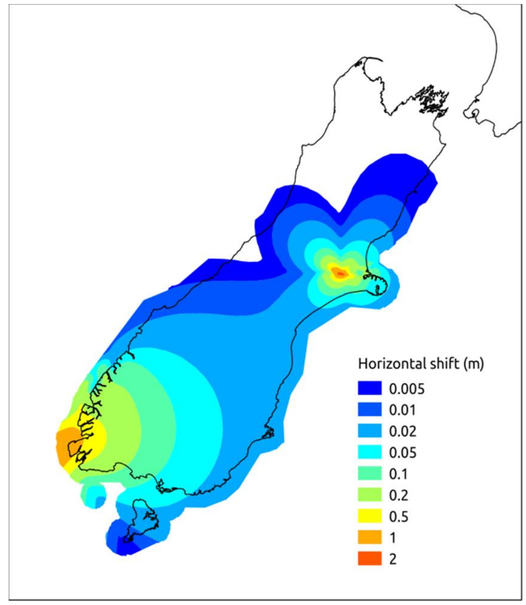


Figure 8: Size of the coordinate change to implement the reverse patches. Changes greater than 0.05 m are applied to all coordinates in Landonline. Smaller changes are only applied to higher order geodetic marks.

Conclusion

The update to the NZGD2000 model is the first of potentially several such updates that were expected when the datum was established. The timing of this update is primarily driven by the Canterbury earthquakes and the need to provide coordinates with good local relative accuracy in that region. However the new model also includes a much improved velocity model that will improve the accuracy of positioning in terms of CORS networks and the ITRF datums. This is clearly seen when the old and new deformation models are compared with the time series of daily coordinate solutions from CORS stations, for example in Figure 9.

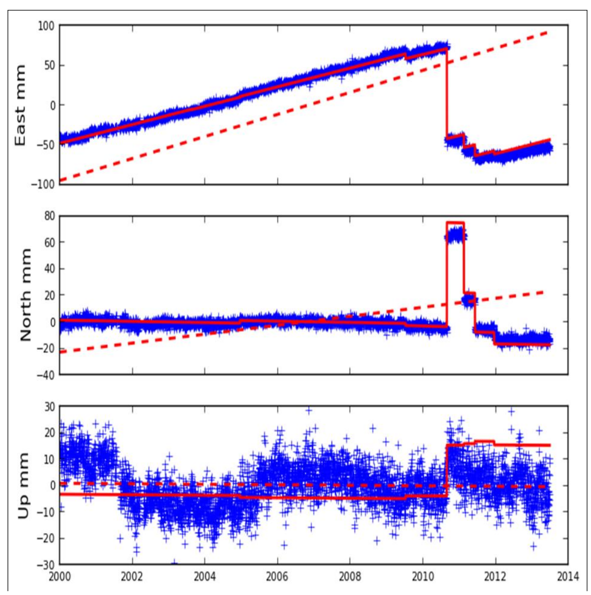


Figure 9: Comparison of the original deformation model (dotted line) and new deformation model (solid line) with the time series of daily solutions at the McQueens Valley CORS site (time series are detrended)

Maintaining the deformation model will ensure the continued usefulness of the NZGD2000 datum and of NZGD2000 coordinates which would otherwise fall short of the accuracy requirements of users.

Acknowledgements

The velocity model and patch fault models were developed by John Beavan of GNS Sciences. We are indebted to his work and contribution to the NZGD2000 datum. The implementation of the deformation model was greatly assisted by discussions with Chris Pearson of the University of Otago and Richard Stanaway.

More detailed information about the deformation model is available on the LINZ website at http://www.linz.govt.nz/nzgd2000.

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Archaeology and history of seismic events: is the past a key to the future?

Bruce McFadgen[1]
arch.research@actrix.co.nz

[1] School of Maori Studies, Victoria University of Wellington

Abstract

Humans and their hominin forebears have lived with seismic events for hundreds of thousands of years. Despite the devastation earthquakes have caused to landscapes, towns, and cities, communities have been extraordinarily resilient and resistant to moving away to safer locations. Paradoxically, this has had positive cultural and economic benefit for human societies. Recent archaeological research suggests that human physical development is closely related to tectonic plate boundaries, and that civilisation itself is a result of seismic activity. For the modern capitalist economic system, earthquakes, along with other calamitous events, have played a Schumpeter-like role of creative destruction, and stimulated economic development. This talk briefly reviews the effects of seismicity on human communities, and some of the implications for how we might respond to future events: 1. We should not be surprised that people want to stay put after a large earthquake; 2. despite the damage and upheaval, the economic outcome will probably be ultimately beneficial, although this might take some time to become evident; 3. destruction provides an opportunity for modernisation and replanning, although if past events are a guide, this should not be left to elected councils to implement.

Keywords: earthquakes, civilisation, economy, creative destruction, cultural benefits.

1. **Human Development**. Humans and their hominin forebears have lived with seismic activity for hundreds of thousands of years. Recent archaeological research suggests that tectonic instability has been extremely important for human physical and cultural development. In the African Rift Valley, recurring earthquakes and volcanism resulted in a varied and rich physical and topographic environment. It was an environment favourable for human development, where a weak, slow, but intelligent and innovative, biped could withstand the ravages of carnivorous, predatory animals, find a safe haven for raising its young, and have access to prey animals that were important as a meat supply to sustain its enlarged brain (Bailey and King 2011). Closer to the present, ancient civilisations show a very close correlation with tectonic plate boundaries (Force 2008). Disruption by tectonic events is thought to have accelerated cultural change, leading to increased cultural complexity in the communities affected (Force and McFadgen 2012), forcing Neolithic cultural development, and stimulating the development and course of civilisation (Force and McFadgen 2010). Anthropological studies show that calamities can induce cultural change in the communities affected (Hoffman 1999). Tectonic activity is a major cause of environmental change, and can, for example, create barriers to movement, alter surface

drainage, and stimulate erosion and deposition, requiring communities to resettle and adapt to changed conditions. Adaption to such changes is thought to be one of the major factors that contributed to humans developing into the innovative species that they are today (Bailey and King 2011).

2. **Earthquakes**. On a tectonic planet, earthquakes are normal. They often have disastrous outcomes for society, but this is more a consequence of societies' lack of preparedness than of the earthquake itself (cf. Oliver-Smith 1999). While society might view earthquakes in a generally negative way because of the damage they can cause, the disruption they create is usually short-lived; in the longer term, they can have a positive character that can be extremely important for society.

New Zealand sits across a tectonic plate boundary. Tectonic activity along the boundary is the process that built the mountains, fed volcanism, altered the constituents and nature of rocks, and controlled the geomorphology of the landscape. It has provided many of the resources that society takes for granted: rocks and minerals; good soils; high, snow-covered mountains that stimulate tourism and recreation; a good water supply for drinking and renewable energy; and geomorphological features such as Wellington Harbour, that have been and still are, important for economic development. But tectonic processes can also have their down-side, and the results of earthquakes can be very severe.

Earthquake hazard becomes a disaster only in the context of a specific society (Oliver-Smith 2002). Earthquake shaking was not an issue for Maori who, unlike Europeans, had no multi-story masonry buildings. However, uplift and subsidence in coastal areas altered their food supply by removing or adding resources such as coastal lagoons, and required people to adapt to changed environments (McFadgen 2007). Since European settlement, the situation in New Zealand has changed, and there has been considerable loss of life and destruction of built structures from earthquakes (e.g. Napier, 1931).

3. **Vulnerability**. A hazard event, such as an earthquake, is an agent; it is capable of producing an effect in the right circumstances. A disaster, on the other hand, is the process whereby the hazard event impacts on a population (Garcia-Acosta 2002). The vulnerability of a population is the degree to which the population is unprepared for a hazard that becomes active, and this determines its effect (Garcia-Acosta 2002). Vulnerability can exist in several situations: natural, physical, social, economic, political, cultural, ideological, and educational. How catastrophic a disaster is depends largely on the state of unpreparedness of a society. Christchurch was unprepared in September 2010, despite a history of earthquake activity (Elder et al 1991), which included two events that demolished the spire of Canterbury Cathedral. As Bob Parker observed, "Everyone agreed that Wellington, which is on a major fault line, could suffer catastrophes such as the earthquake which struck (Christchurch); but not Christchurch" (Parker 2012: 17).

4. **Resilience and adaption.** For whatever reason people first settled along tectonic plate boundaries, many populations today – in villages, towns, cities, and megacities – are still located there, and in many instances their histories are punctuated with devastating losses of people through the effects of earthquakes (Jackson 2006). Despite the devastation that earthquakes have caused to landscapes, towns and cities, the communities affected have often been extraordinarily resilient, and often extremely resistant to moving away to safer locations, tenaciously preferring to stay put and rebuild on the same sites. This pull to stay put after an earthquake can be extremely strong and is well-illustrated by Yungay, at the foot of the Andes in Peru, following the magnitude 7.7 earthquake in 1970 (Oliver-Smith 1979, 1986). Yungay was a town of about 4500 people located in a valley. The earthquake triggered a landslide of rock and ice "the height of a ten story building" that careered down the valley at speeds of up to 435km/hour. Over 4000 inhabitants were killed, yet the survivors insisted on returning to, and rebuilding, close to the original site, even though they knew that future events were likely. To the survivors it was home, where their families and friends had lived, and died.

Paradoxically, this tenacity seems to have had positive cultural and economic benefits for human societies; coupled with adaption and innovation, it would have played an important role in the development of civilisation by helping ensure continuity of settlement and culture.

5. **Economic Outcomes.** Large earthquakes are a dichotomy; they present both a danger and an opportunity (Cleaver 1988). With other calamitous events, they have played a Schumpeter-like role of creative destruction in North America since the 17th Century, by stimulating economic development through destruction (Rozario 2007). Throughout the world, cities struck by earthquakes have, in most cases, been rebuilt on the same sites and have flourished (Robinson 2012). Napier in 1931, a city ruined by a magnitude 7.9 earthquake followed by fire, in which 161 persons were killed in Napier alone (Hill & Gaillard 2013), rebounded economically and physically within a remarkably short time (Chapple 1997).

6. **Rebuilding.** After earthquakes in the 17th and 18th centuries, re-planning of cities was designed to save lives. Innovative measures taken to prevent loss of life, and still valid today, include: enforced abandonment of dangerous sites; streets widened and straightened to allow safe movement through debris; height restrictions, fire precautions, and earthquake resistance for buildings; and parks for safe haven for survivors (Tobriner 1980). Today, however, these measures are frequently ignored (Bryant and Allan 2013). Open space, for example, which can provide safe refuge during a large earthquake, and a temporary home in the days immediately following, is rarely considered during planning for recovery (Allan and Bryant 2010).

As time passes after earthquakes, people forget, and precautionary measures are modified or ignored (Tobriner 1980). Increasing emphasis on democracy gives an affected society more say in reconstruction, but after large earthquakes people tend to become conservative and resist change (Oliver-Smith 1979, Parker 2012, Bryant & Allan 2013). Local councils overseeing reconstruction may be lobbied by vested interests (Fowler 2007), or expert advice may be ignored (Tobriner 1980), or a local council may be dysfunctional (Parker 2012). Where responsibility for reconstruction is with an independent or non-elected entity, the outcome may be different and include innovation and re-planning, e.g. Sicily 1693 (Tobriner 1980), Lisbon 1755 (Tobriner 1980, Rozario 2007), Napier 1931 (McGregor 1998, Hill & Gaillard 2013).

7. **Conclusions.** This brief review of the effects of seismicity on human communities, and some of the implications for responding to future events, suggests that: 1. people resist change and want to stay put after a large earthquake; 2. despite damage and upheaval, the economic outcome will probably be beneficial, although this might take time to become evident; 3. destruction provides an opportunity for modernisation and re-planning, although if past events are a guide, this should not be left to elected councils to implement.

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Sustainable Development – An Environmental Geodesist's perspective from Hong Kong

Merrin Pearse[1]
merrin@coordinate4u.org
[1] Coordinate4u

Abstract

You often hear the terms sustainable development and climate change being talked about, though what do those terms really mean to you. As surveyors we are used to looking at objects from different angles, so how about we take some time to explore the terms sustainable development and climate change from different perspectives. What are the first things that come to your mind when you think of sustainable development? Is it designing subdivisions that make wise use of the land area? Orientating building platforms to make best use of solar energy? Maybe you think of designing systems to use the minimum amount of resources during its lifetime (e.g. designing stormwater pipes to only use gravity rather than requiring pumps). What about changing perspective to now think about keeping your business growing while increasing your profitability? This raises the question about how you measure profitability. Do you prepare triple-bottom line accounts that take into account environmental, social, and economic costs? What about your own sustainable development? How does your professional development contribute to society? What local climate changes are you promoting? Are you really passionate about something that from your perspective is helping humanity remain part of life on earth? Do you share that with others? Merrin's passion is connecting people with nature. Now living in Hong Kong, Merrin will call upon personal experiences as a geodesist working on international projects to share new perspectives on New Zealand.

Keywords: Sustainable Development, Financially Rewarding, Personal Fulfilment, Perspective , Reflection

The terms sustainable development and climate change are often talked about. What do these terms mean to you? How would you describe Sustainable Development and Climate Change to someone? Perhaps by reference to Polar Bears, Ice Melting, Sea Level Rise and big Weather Events?

As surveyors we are accustomed to looking at objects from different angles, so how about we take some time to explore the terms 'sustainable development' and 'climate change' from different perspectives. From a surveying perspective what is sustainable development? Is it designing subdivisions that make wise use of the land area or orientating building platforms to make best use of solar energy? Perhaps it is designing engineering services to minimise resource use during a projects' lifetime? The list could be quite long.

So how do I describe Sustainable Development? Well the short version is "The wise planning and reuse of natural capital today, in ways that better support their future reuse and so provide improved human and social capital outcomes". Natural Capital is the elements of nature that produce value (directly and indirectly) to people, Human Capital is the knowledge and skills of individuals, and Social Capital is the quality of relationships between people such as trust and connectedness.

The key mechanism for sustainable development to really happen is better planning and design. In terms of climate change, climate will keep changing, however humans should not be trying to speed up or inhibit that change through poor planning and design. Unfortunately the term climate change often polarises people into either supporting or rejecting the concept. People arguing their position rather than making appropriate changes to their personal or business approach does not help us move towards more sustainable development models.

Our business models need to change whether there are financial limitations or not, as we are wasting many resources. In Hong Kong there is currently no apparent shortage of Government money for large infrastructure projects. Comparing International Monetary Fund official reserve assets for Hong Kong[1] (US$303,582 million for a population of 7.1 million) against New Zealand[2] (US$17,639 million for 4.4 million people) we can see that there is approximately US$40,000 more per person in Hong Kong. Keep in mind that the land area of Hong Kong is 1,100 km^2 compared to 268,680 km^2 in New Zealand.

There continues to be massive roading projects in and around Hong Kong. The Hong Kong – Zhuhai – Macao Bridge (HZMB) project includes a 29.6 km dual 3-lane carriageway in the form of bridge-cum-tunnel structure comprising a tunnel of about 6.7 km and two artificial islands. The cost is estimated to be US$2.55 Billion[3] of which HKSAR is contributing US$1.1 Billion (equivalent 6% of NZ's official reserve assets). Costs aside, one of the main concerns is the potential for an extra 80 000 vehicles to use the bridge per day, causing more traffic congestion than Hong Kong already faces, though due to planned limitations on cross-border vehicle permits, daily vehicle use may be only 11,600 of that capacity.

With New Zealand's high use of hydro-electric power generation it is interesting that Hong Kong has recently built a hydropower system. It does not use dams on a river though, as Hong Kong does not have any significant rivers. Instead the Tuen Mun Water Treatment Reservoir supply pipes are used to generate electricity. When the second generator is installed the system will generate 3 million kwh annually which is enough to support the use of 180 air conditioners a year.[4] This project is managed by the Water Supplies Department, which is responsible for obtaining approximately 80% of the territory's water from Mainland China. However, at the same time the Drainage Services Department has built an 11km long 7.8m diameter drainage tunnel on Hong Kong Island to channel rainwater to the sea.[5] Surely during heavy rain this water could be generating electricity or at least storing it for use where drinking quality water is not required.

Hong Kong is one of the world leaders in waste generation per capita per day at 1.36kg[(6)]. In total there is approximately 9,000 tonnes of Municipal Solid Waste generated per day, with nearly 3,000 tonnes being putrescible waste. Currently almost none of this decomposable waste is being turned either into compost or energy (via anaerobic-digesters). To address the waste issue the Hong Kong Government is relying on building a new offshore island for an Integrated Waste Management Facility (IWMF). The central component of this initiative is a Waste-to-Energy Incineration system, with a capacity of 3,000 tonnes per day. Cost estimates are around US$2 Billion to construct the IWMF, which will make it the most expensive incinerator constructed in the world. There are other locations that would allow a very similar facility to be built in about half the time at half the cost, and also with lower daily operation costs. How is it that strong political and commercial interests can apparently drive the decision making process towards such overly expensive options that are funded by tax-payers?

In terms of access to survey and title information New Zealand is very advanced. In Hong Kong Survey Plans and Title Registration are still operated by different departments within different buildings. The Land Registry provides land registration services, while the Lands Department is responsible for all land matters in the Hong Kong Special Administrative Region. The Lands Department comprises three functional offices, being The Lands Administration Office, The Survey and Mapping Office and The Legal Advisory and Conveyancing Office. The Survey and Mapping Office is the official land survey and mapping agency for Hong Kong. It sets up and maintains the geodetic survey control network, carries out land boundary surveys and aerial surveys, and produces maps in both paper and digital forms.

Online Hong Kong data often needs users to sign-up or click "I agree" plus there are significant charges for downloading data to use for value added services, which is very different to the LINZ Data Service. Both jurisdictions have however adopted an underlying common reference frame of ITRF, so data can be easily overlaid. Many countries around the world still do not have their primary datum defined in terms of ITRF/WGS.

Another perspective to consider is changing your own perception on how to grow your business while at the same time increasing your profitability. This raises the question about how you measure profitability. Do you prepare triple-bottom line accounts that take into consideration environmental, social, and economic costs? One of the key measures used at a country level to show economic progress is Gross Domestic Product (GDP). However, from a Sustainability perspective this measure is flawed, as it does not work from the principle of the "whole to the part". It does not consider the negative impacts of a business on the environment (our natural capital) or negative impacts on people (our social capital). A simple example is, where money is spent producing and using military weapons on other humans increases GDP, however as we know, war destroys so much of our natural environment and shatters communities.

Here are two simple tools that are useful in helping assess if a project is a sustainable development. The first, from 'The Natural Step' is the four Sustainability Principles,[7] which state that in a sustainable society, we will:

1. Reduce and eventually eliminate our contribution to the systematic accumulation of materials from the earth's crust.

2. Reduce and eliminate our contribution to the systematic accumulation of substances produced by society.

3. Reduce and eliminate our contribution to the on-going physical degradation of nature.

4. Reduce and eliminate our contribution to conditions that systematically undermine people's ability to meet their basic needs.

The second tool, Max Neef's classification of fundamental needs, considers core Human Needs. Maslow's Hierarchy of Needs is commonly known, though Max Neef's classification of fundamental needs is not as well known. Manfred Max-Neef, a Chilean economist, has defined nine fundamental human needs, which are considered to be universal across all cultures and historical time periods.

They are: subsistence, protection, affection, understanding, participation, leisure, creation, identity and freedom.[8] In this system, there is no hierarchy of needs (apart from the basic need for subsistence or survival), rather, simultaneity, complementarily and trade-offs are features of the process of needs satisfaction.

The concept of complementarily is what is so important, if we as the human species want to remain as part of the biosphere on Earth.

What about your own sustainable development? Are you inadvertently promoting local climate changes? How does your professional development contribute to society? Are you really passionate about something that from your perspective is helping humanity remain part of life on earth and are you sharing this with others?

Surveyors know many different ways of measuring direction and progress. Humans have developed some amazing tools and with further considered thought we can transition to a more sustainable future for both the spatial positioning industry and for humanity as a whole.

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REFERREED PAPERS

SURVEYING: THE PROFESSION

Brian J COUTTS
brian.coutts@otago.ac.nz
School of Surveying, University of Otago, PO Box 56, Dunedin, New Zealand.

Abstract

Surveying is generally regarded as an occupation that has achieved professional status. Its origins are in the area of measuring and measurement science but it also has a history of understanding of land law and land management. Colonial development in New Zealand, and in other British colonies in the 18th, 19th and 20th centuries, required further skills to be developed in allied areas such as municipal engineering and town planning. The distinguishing features of a profession are examined in the context of the international literature. The discipline of surveying in New Zealand is then compared to the principles drawn from the literature.

Key Words: professions, land surveying.

Introduction

The words "professional" and "professionalism" are widely used in the common speech. However, they are not necessarily confined to a reference to people who are members of a recognised profession. There are professional golfers, professional jugglers and professional comedians, and in this context the term is used to refer to those who earn their living from an activity in order to distinguish them from amateurs. Sportspeople "turn" professional. The concept is extended when such people, or anyone else, are described as demonstrating "professionalism". Here the word is harder to define, but it is suggested that it means to carry out a task in such a way or to such a level, that it demonstrates some of the attributes that, while remaining undefined, might be expected of a member of a profession.

Such common use of these terms in the general sense confuses any discussion about the status of an occupation as a profession. In order to adequately discuss whether an occupation is a profession, it is necessary to understand something of the origins and derivation of what once were called the "learned professions".

What distinguishes a Profession

The word "profession" originates from the verb "to profess", that is, one who had taken the vows of a religious order (O'Day, 2000; Armstrong, 1994; Dyer, 1985). From the time of the Middle Ages there were three accepted or recognised "learned" professions, namely the Church, the Law and Medicine (O'Day, 2000). The Free Dictionary defines the learned professions as "one of the three professions traditionally believed to require advanced learning and high principles" (The Free Dictionary by Fairfax, www.thefreedictionary.com/learned+professions) and also identifies these as law, medicine and theology. A profession was a "calling" and the call had come from God and it was God to whom they were accountable (O'Day, 2000).

Over time the number of occupations falling under, or claiming the status of, a learned profession has grown steadily. Fone (2010) interprets from O'Day (2010) "the development of an educated class between the non-working leisured classes and the merchants, traders, craftsmen and labourers who comprised the working population of [England]" generated those occupations which are now called the professions. She further proffers "that during this period there was a growth of groups of men in the law, the church, and medicine with a common educational background and steeped in the ideology of service to the 'commonweal'" Fone (2010, p.1). The period identified by O'Day (1450-1800 AD) represents the end of the Medieval Era, and embraces the Renaissance, the Reformation, the Age of Enlightenment, the rise of science and the Industrial Revolution. Printing allowed the greater production of books, education became more wide spread, and the influence of the church was diminishing.

This elicits the first clue as to the fundamental requisites of a profession, which may be generally referred to as *education* and *service.* This view is supported by Wilensky (1964). It is no surprise that the range of new occupations desirous of claiming the status of a profession began to enlarge as education spread though Western civilisation. Other writers through the 20th century, beginning with Abraham Flexner in 1915, have created lists of criteria that they have claimed would need to be met in order for any occupation to be considered to have professional status. In some cases these lists become lengthy (see Routledge, 2011) and appear to be more of the nature of criteria for professional behaviour, rather than those criteria by which a profession may be recognised. In many cases these so called criteria could equally apply to other skilled occupations or trades and are not exclusive to professions. With the exception of Greenwood (1957) there is little challenge to Flexner's (1915) criteria in the subsequent literature, but largely extensions to, or expansion of, them.

Flexner (1915) listed five criteria, and the subsequent literature does not contest these, but tends rather to expand upon them. Flexner (1915) lists the following: specialised knowledge applied without bias; application of the knowledge to practical problems; theory and practice that can be educationally communicated; a trusted self-regulating professional body that confers professional status; and an ethic that puts client's and society's interests ahead of the self-interest of the practitioner. While Wilensky (1964) reduces the list to two items, he does so by incorporating several related criteria together and in so doing loses nothing of Flexner's concepts.

Generally the issue of the sociology of professions has dissipated and the topic is rarely discussed (Saks, 2012). That aside, it is an appropriate place to start if there are doubts as to whether an existing occupation has changed significantly and in such a way that its classification as a profession is compromised, or that there are aspects of the discipline or specialties that may be considered to have achieved such status independent of their parent body.

Education

Higher education has been a facet of professional status since the beginning. The early physicians and lawyers who were considered to be professionals had received their education firstly in the church as supplicants, but then they had specialised in their chosen discipline. Although there were healers outside the church, they would not have been considered professional, and in some cases were viewed as healers or novices at best, and possibly witches at worst. The literature on professions is in general agreement that the education, or learning, for a profession is required to be formal, complex, lengthy and of practical use to society. That is, there is an intellectual component to be applied to professional tasks. In order to ensure that it is to some extent standardised and sufficient, self-regulating professional bodies have come into existence. These bodies set criteria for entry into their particular profession. They may also have developed criteria for keeping up competence in their field, as well as mechanisms to deal with those who fall behind in the maintenance of their continuing competence or allowed their knowledge to become out-dated. Proof of having reached the original required level of knowledge and understanding is found either by setting examinations by the professional bodies themselves or now more commonly, delegating that task to accredited universities. Professional bodies have other important functions as well, and these will be discussed later.

In earlier times reference was made to the "learned" professions. Flexner (1915) raises the question of whether there are non-learned professions. He concludes there are not. It must be assumed, therefore, that as the term has fallen into disuse, but that the expectation is that the principle has been absorbed into the concept of a profession to such an extent, that it is now considered to be superfluous and an unnecessary additional descriptor for a profession. The learning required for entry into a profession is formed into a "body of knowledge", will be codified by the profession's society, and will be taught, maintained and added to by professional schools, which are usually associated with universities.

Service

Origins in the church leads to the other main attribute of a profession. That is, that the profession is carried out in the service of humanity, or more particularly for the benefit of the society in which the practitioner resides. The professions are frequently referred to as a "calling", reminiscent of the ecclesiastic origins, and it is expected that the calling will be for life. Unlike other occupations, a profession is a vocation, and having once entered the profession it is not expected that the practitioner will leave it, even if there is a movement into specialisation or to a "fringe" or related occupation or profession.

The principle of service is such that the discipline is carried out impartially, that is, any client asking the same question would expect to get the same answer. A member of a profession is expected to exercise independent judgement based on access to the complex body of knowledge that defines the individual profession, and to interpret that body of knowledge in novel contexts so as to solve problems in the interest of the client. The solution should not be influenced by the interests of the practitioner. This is exemplified in the law, where lawyers are "called to the bar" and become servants of the Court. There is, therefore a bond of trust between the client and the practitioner of a profession that the practitioner will apply their complex knowledge impartially to the problem or task presented by the client.

Furthermore, the level of service will not be related to the level of payment received by the practitioner. Whatever the task the member of a profession is engaged in, the same best efforts will be applied in finding the appropriate solution for the client and for society in general, irrespective of the reward offered. Continuing use of the Hippocratic Oath administered to those graduating in medicine remains an historic aspect of entering the medical profession. Such behaviour as might be considered professional is usually found encapsulated in a code of ethical behaviour. Such codes are established, administered and policed by the professional body (or bodies) related to the specific profession.

So while any practitioner expects to make a living from the practice of their profession, it is not the prime motivation for entry . . . or should not be. Service to society is the primary motivation of the true professional in that they have been "called" to this particular vocation.

Professional Bodies

Professional bodies perform significant functions in assisting an occupation to become, and to maintain, the status of a profession. With respect to education, and in the first instance, professional bodies define the body of knowledge, a proven understanding of which is required before admission to the professional level of an occupation. Formerly the body of knowledge was passed on from one generation to another in ways similar to an apprenticeship, but is now usually administered by specific colleges or universities, who employ members of the profession to both educate aspiring entrants, and to add to the body of knowledge.

Many professional bodies will also require some demonstration of continuing competence or proof of keeping up-to-date with advances in the profession in order to maintain membership of the profession or accreditation as a public practitioner. They may also provide the opportunities to members for keeping abreast of the latest developments through continuing education (CE) or continuing professional development (CPD).

With respect to the principle of service, professional bodies prepare and enforce codes of professional conduct or codes of ethics. In some instances, it is possible to distinguish between professional misconduct and unprofessional conduct. Professional conduct can be construed to indicate when a member of a profession acts in a manner that indicates that they are not competent in the technical aspects of the profession. Unprofessional conduct can indicate that the behaviour has been in breach of the standards of professionalism expected as set out in the code of professional practice. Investigations into these issues may be carried out by the one body, or may be shared, as they are in surveying in New Zealand, between a professional society and a licensing body. That is between the Cadastral Surveyors Licensing Board (CSLB) which will deal with technical competence in the cadastral area only, and the New Zealand Institute of Surveyors (NZIS) which deals with competence in other aspects of land surveying as well as all of the case of breaches of professional conduct.

Business versus Profession

Many practitioners in professions now are employed by businesses or by government agencies. This is different from the past when most members of professions were in sole practice or in partnerships with similarly or complimentary members of professions. This can lead to compromising positions with respect to their ability to act in a professional manner (Wilensky, 1964 p.148), (Freidson. 1988-89, p.430), (Bowie, 1988).

Key factors in the exercise of a profession are impartiality, neutrality and autonomy. If a member of a profession is employed in a hierarchical organisation, they may be subject to constraints on their ability to fully exercise their professional judgement due to policy directives within their organisation or to the requirement to conform to instructions from more senior professional or management staff. Their position may also be compromised if they have entered into business arrangements on their own account, where they use their professional skills to advance or promote their own private interests. In these situations there becomes a very fine line between being a business person and being considered a practicing member of a learned profession. While the occupation remains a profession, the ability of individuals to fully exercise their discipline in a professional manner, will depend on the skill of the individual practitioner in such cases.

Is Land Surveying a Profession in New Zealand?

According to the criteria suggested by Flexner (1915) and Wilensky (1964) the discipline of land surveying qualifies as a profession. Education was standardised in 1900 through the New Zealand Institute of Surveyors and Board of Examiners Act 1900. The methods of training set up under this legislation, articled cadetships, have progressively been replaced by university degrees. The concerned bodies, the NZIS and the CSLB, have passed the education component of becoming a member of the surveying profession to these accredited courses. Parallel events in Australia have occurred, and since the 1892 Melbourne Convention there has been reciprocation between the two countries with respect to cadastral qualifications.

The body of knowledge has been codified by these institutions and incorporated into the current curriculum at the University of Otago's School of Surveying. The body of knowledge is based on the NZIS "Definition of a Surveyor", a policy adopted in 1992 (see Appendix A). That body of knowledge includes determining the boundaries and rights to land and natural resources; measurement of built and natural features; services such as project management, land use planning and subdivisional design, land development engineering; the management, interpretation and provision of geographic and hydrographic information; and precise engineering, industrial and scientific measurement. At the international level the International Federation of Surveyors (FIG) also has a "Definition of the Functions of the Surveyor" (FIG, 2004) (see Appendix B).

Professional bodies have existed in the region since the Institution of Surveyors Victoria (ISV) was founded in 1874, becoming part of the federal Institution of Surveyors Australia (ISA) in 1951. The New Zealand the Institute of Surveyors formed in 1888. The NZIS has had incorporated in its Rules (until the 2013 change to its constitution) Part V Conduct of Members. This included sections on ethics, professional conduct, public practice and advertising, followed by sections that dealt with the procedure to be followed in cases of breaches of the Rules and available penalties (NZIS, 2003). Under its newly adopted Rules, the Council of the NZIS is required to "adopt a code of conduct and/or other policies which it requires to cover the ethical, professional and other obligations of Members . . ." (NZIS, 2013).

The altruistic service provided by the profession at the national level has been largely by way of input into relevant legislation through negotiations with government officials and submissions to Select Committees of the Parliament (for example, the Unit Titles Act 2010, the Cadastral Survey Act 2002, the Resource Management Act 1991). At the regional or local level NZIS branches have input into regional and district plans. Additionally, many members make their skills available to sporting, cultural or not-for-profit organisations on a pro bono basis.

Conclusion

From the above discussion, land surveying does meet the criteria defined in the literature to claim the status of a profession. The range of activities by which the surveyor is able to contribute to society is well defined at both the local and international level. The range is quite broad, and at the international level incorporates branches of surveying that in New Zealand would be considered separate disciplines (such as valuation).

A further criteria mentioned occasionally in the literature is the ability, or requirement, for any individual member of a profession to remain within the bounds of his or her expertise, and to recognise when other specialist input is required (Wilensky, 1964. p.141). Conversely, as knowledge advances in all areas, some professional functions are delegated to those with lesser educational qualifications who have not met the criteria for membership of the profession. Supporting para-professionals or technicians are related to most professions, although sometimes the distinctions are blurred.

It must be recognised that to act professionally, or to bring professionalism to one's occupation, is not sufficient to claim that the occupation is a profession. There is much more to it than that. While it is possible to analytically examine whether any particular occupation is, or is not, a profession, the final judgement will be made by society in general. Society will also confer professional status on an individual, from their own interpretation of the meaning of the word, irrespective of their education and service, and based on the observation of their interaction with the clients and the society they serve.

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APPENDIX A.

NZIS POLICY 1: Definition of a Surveyor

A surveyor is a professional, skilled in measurement and resource management, who serves the public by the collection, provision and analysis of information on the extent and identity of land, water and other natural resources including legal, economic and environmental aspects and the provision of advice and services for their development, use and sustained management.

In particular, by virtue of their academic qualifications and professional training, surveyors;

a) identify and determine the boundaries and rights to land, water and other natural resources whether above, on or below the surface;
b) measure land, natural features and structures constructed thereon;
c) provide support for the land title system and assist in settling questions of land ownership;
d) evaluate land and other natural resources for their economic, social and development potential;
e) provide services for land and property development in respect of;
    i) project management;
    ii) land use planning, concept and subdivisional design, and economic analysis;
    iii) land development engineering;
f) advise on and undertake management of land and property acquisition, utilisation and disposition;
g) advise on the ethics of natural resources development, prepare and present applications and carry out the legal processes required for natural resources management;
h) manage, interpret and provide geographic and hydrographic information and data associated with the identification, characteristics and use of land and other resources;
i) advise on the sustainable use and conservation of natural resources; and,
j) carry out accurate and precise measurements for engineering, industrial and scientific purposes.

Adopted by: NZIS Council Date: 20/21 March 1992

APPENDIX B

FIG Definition of a surveyor

Summary

A surveyor is a professional person with the academic qualifications and technical expertise to conduct one, or more, of the following activities;

- to determine, measure and represent land, three-dimensional objects, point-fields and trajectories;
- to assemble and interpret land and geographically related information,
- to use that information for the planning and efficient administration of the land, the sea and any structures thereon; and,
- to conduct research into the above practices and to develop them.

Detailed Functions

The surveyor's professional tasks may involve one or more of the following activities which may occur either on, above or below the surface of the land or the sea and may be carried out in association with other professionals.

1. The determination of the size and shape of the earth and the measurement of all data needed to define the size, position, shape and contour of any part of the earth and monitoring any change therein.
2. The positioning of objects in space and time as well as the positioning and monitoring of physical features, structures and engineering works on, above or below the surface of the earth.
3. The development, testing and calibration of sensors, instruments and systems for the above-mentioned purposes and for other surveying purposes.
4. The acquisition and use of spatial information from close range, aerial and satellite imagery and the automation of these processes.
5. The determination of the position of the boundaries of public or private land, including national and international boundaries, and the registration of those lands with the appropriate authorities.
6. The design, establishment and administration of geographic information systems (GIS) and the collection, storage, analysis, management, display and dissemination of data.
7. The analysis, interpretation and integration of spatial objects and phenomena in GIS, including the visualisation and communication of such data in maps, models and mobile digital devices.
8. The study of the natural and social environment, the measurement of land and marine resources and the use of such data in the planning of development in urban, rural and regional areas.
9. The planning, development and redevelopment of property, whether urban or rural and whether land or buildings.
10. The assessment of value and the management of property, whether urban or rural and whether land or buildings.
11. The planning, measurement and management of construction works, including the estimation of costs.

In the application of the foregoing activities surveyors take into account the relevant legal, economic, environmental and social aspects affecting each project.

"*NON TANQUAM PICTOR, SED TANQUAM MATHEMATICUS*" –

Not as an artist but as a mathematician, Photogrammetry, Remote sensing, and the surveying discipline

Pascal SIRGUEY
Pascal.Sirguey@otago.ac.nz
School of Surveying, University of Otago, PO Box 56, Dunedin, New Zealand.

Abstract

For over a century, photogrammetry has been at the very heart of the surveying discipline and map-making process. In New Zealand, aerial surveys have been used to create topographic maps since the late 1920s. As imaging capabilities have dramatically improved through the development of new sensor technologies (e.g., digital sensors), as well as satellite platforms, now enabling observations to be made from space with unprecedented resolution, the means to obtain topographic information over large areas have evolved. New techniques have emerged and gained a large momentum over the last decade, such as LiDAR. However, the principles of photogrammetry remain relevant and have also evolved. The Multiray photogrammetric technique now allows dense and accurate point clouds to be derived from multiple image overlaps and is competitive with LiDAR products. New platforms such as Unmanned Aerial Vehicles (UAV) offer new opportunities for surveyors as many can now engage in aerial mapping without the logistical burden of plane operations. Furthermore, imaging of the earth's surface from space via optical or radar technologies offer spatial resolutions that now approach the requirements of some surveying tasks. In this context, the photogrammetric method has greatly evolved, becoming part of the wider discipline of remote sensing, placing it at the centre of the surveying profession. This paper offers a brief overview on how the discipline of remote sensing has gone hand in hand with land surveying and what it can offer in the future to this profession.

Key Words: Photogrammetry, remote sensing, aerial surveys, aerial mapping, spatial imagery.

Introduction

While on a trip down the Danube Sir Henry Wotton (1568-1639) met Johannes Kepler (1571-1630) in Linz in 1620 (Wotton, 1672, pg. 298-302). Kepler was a mathematics teacher in what is today the capital of Upper Austria. As Wotton was impressed by a realistic drawing of a landscape found in Kepler's study, Kepler explained how he completed the drawing himself *"non tanquam pictor, sed tanquam mathematicus"* (not as an artist but as a mathematician). In a letter to Lord Francis Bacon (1561-1626), Wotton would then provide one of the earliest descriptions of Kepler's *camera obscura* (Kepler, 1604, pg. 297), a clever design of a portable camera (Figure 1) which allowed the natural appearance of landscapes to be reproduced faithfully and objectively (Wotton, 1672, pg. 300). In his description, Wotton stressed immediately the opportunities offered by this technique to *Chorography*.[i]

"This[ii] I have described to your Lordship, because I think there might be good use made of it for Chorography: for otherwise, to make Landskips by it were illiberal, though surely no Painter can do them so precisely." (sic)

In doing so, Wotton may have been among the first to have perceived the potential of remote sensing techniques in surveying sciences.

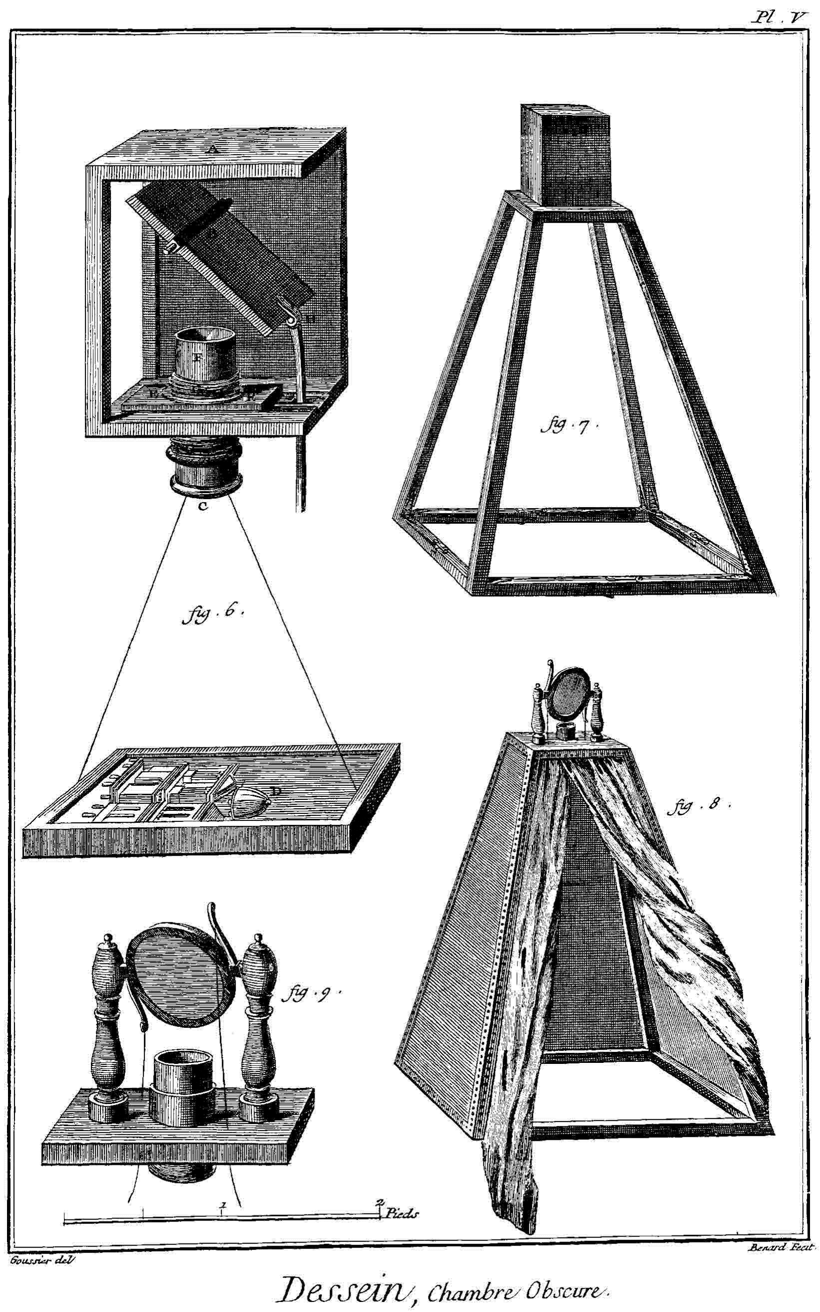


Figure 10. Portable camera obscura (Reproduced from Encyclopédie, 1763, pg. 217).

More than 200 years later, Louis Daguerre (1787-1851) perfected the invention of Nicéphore Niépce (1765-1833) who succeeded in producing the world's first permanent photograph in 1825.[iii] While defending the purchase of the patent of the photographic process by the French Government in 1839,[iv] Member of Parliament and future Director of the Paris Observatory François Arago (1786-1853) alluded specifically to the benefit of the photographic process for surveyors:

> *"Nous pourrions, par exemple, parler de quelques idées qu'on a eues sur les moyens rapides d'investigation que le topographe pourra emprunter à la photographie."* (Arago, 1839, pg. 48)

> *"We could, for example, talk about some ideas we had on the rapid means of investigation that the surveyor may borrow from photography."*

About 10 years later, the young surveyor Aimé Laussedat (1819-1907), Captain in the French Army Corps of Engineer, developed the mathematical principles governing "*Métrophotographie*" (Laussedat, 1899). This would later become known as *Phototography*, then *Photogrammetry*,[v] or the process of making measurements from photographs based on the laws of perspective. Subsequent to several successes of his new technique in mapping historical monuments, Laussedat completed the first comprehensive photogrammetric survey of a township in 1861 (Laussedat, 1899, pg. 29-21, see also Figure 2).

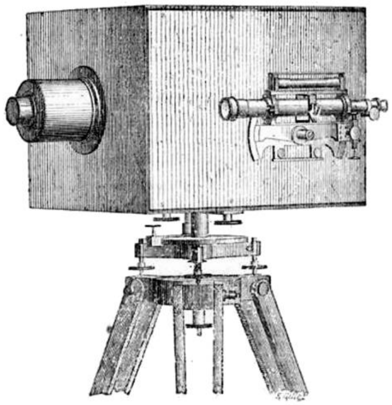
Photographic survey was put to the test by Édouard Deville (1849-1924, appointed Surveyor General of Canada in 1885) during the challenging Canadian Surveys. Deville significantly advanced the technique and demonstrated its superiority over traditional plane table survey in terms of time, practicality, and cost.

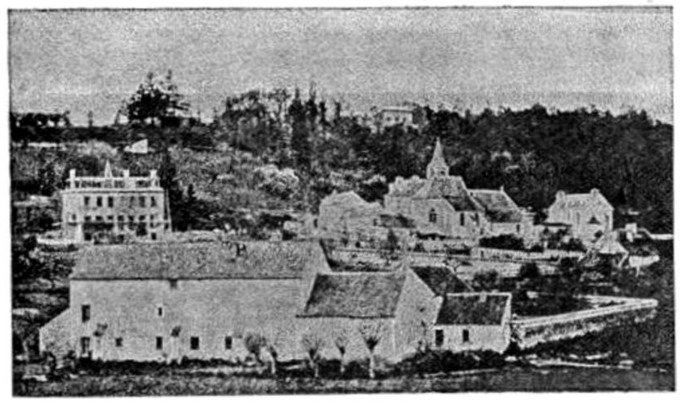
> *"This shows that the plane table survey would cost at least three times as much as the camera survey. In reality the difference is greater, (...)"* (Deville, 1897, pg. viii)

Deville brought considerable improvements to photogrammetry, such as the design of a light tripod-mounted camera (Deville, 1895, pg. 139-146) or the first mapping instrument based on the display of a stereo-pair in 1896 (Deville, 1902). However, he failed initially to foresee the potential of elevated platforms to capture aerial photographs, such as captive Balloons which were used as early as 1858 by Gaspard-Félix Tournachon (aka, *Nadar*, 1820-1910).

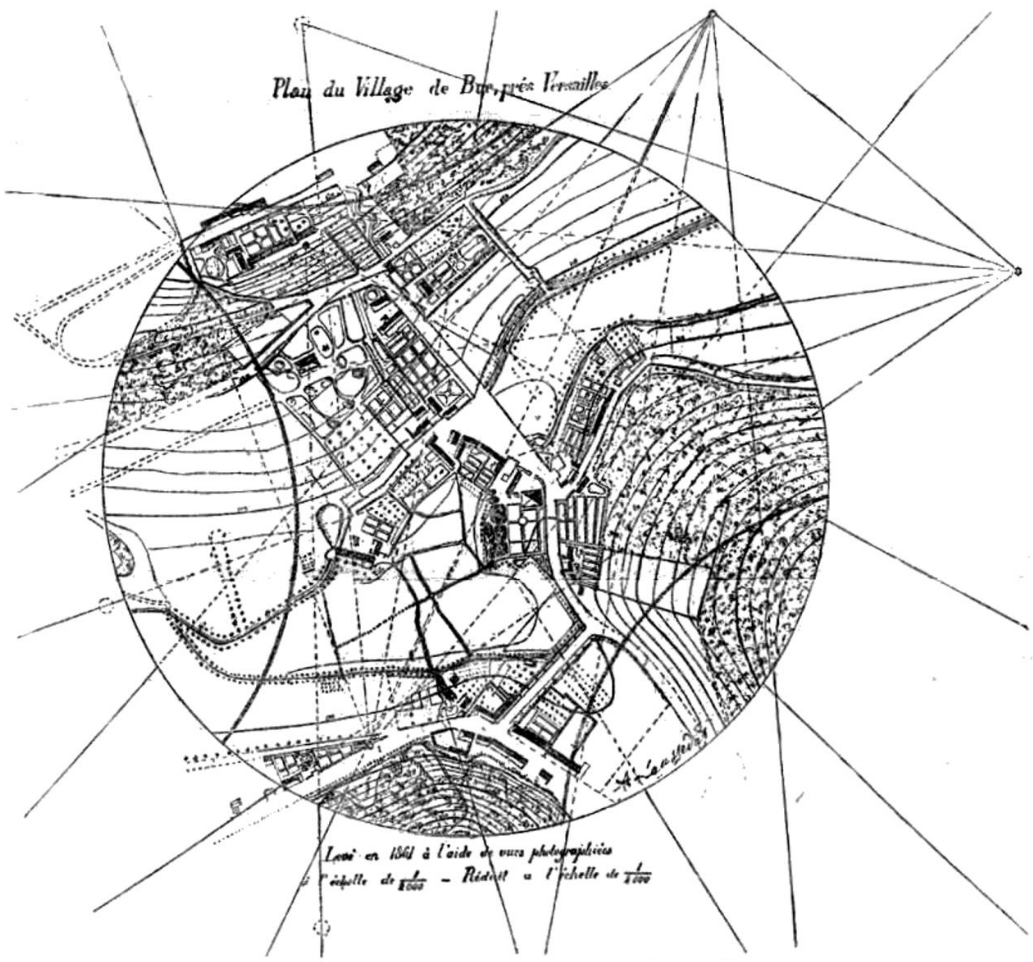
> *"The other class of surveys comprises those made from balloons. It is very doubtful whether the method will ever be found practical and prove of more than theoretical interest. It requires the consideration of an entirely new system of survey by means of photographs taken on plates placed horizontally or nearly so."* (Deville, 1895, pg. 224)

Fig. 15.





Vue prise de la station n° 1 du plan ci-dessous.



Plan d'un village levé en 1861 à l'aide de la Photographie.

Figure 11. First comprehensive topographic survey obtained by photogrammetric method, township of Buc, near Versailles, France (Laussedat, 1899). (Top left) illustration of the camera used for the survey (reproduced from Fig. 15, pg. 30); (top right) photography captured from station 1 (reproduced from Pl. II); (bottom) final topographic map of Buc (reproduced from Pl. II).

The development of aerial photogrammetric surveying was nonetheless anticipated by Cornele B. Adams who filed a patent in 1893 (Adams, 1893, pg. 1) whereby he stated:

> *"My invention has for its object to produce a method of obtaining aerial photographs, in such a manner, that the pictures obtained can be converted into topographic maps, to delineate not only the horizontal positions and distances of the objects correctly, but from which the altitude of the objects can be quickly and accurately ascertained, and such results obtained without the aid of other field instruments."* (Adams, 1893, pg. 1)

The start of aviation in 1903 would then provide a practical platform from which images could be captured specifically for topographic mapping, land use surveys, or city planning. Since then, and for over a century now, the imaging of the earth's surface, and, by extension, the photogrammetric processing of such imagery has been at the very heart of the surveying discipline and map-making process. As the imaging capabilities have dramatically improved through the development of new sensor technologies (e.g., digital sensors), as well as satellite platforms, now enabling observations to be made from space with unprecedented resolution, the principles of photogrammetry remain relevant and have evolved, becoming part of the wider discipline of remote sensing which places it at the centre of the surveying profession. This chapter provides a brief review of photogrammetry and other remote sensing techniques for surveyors.

From aerial imagery to LiDAR in New Zealand

The New Zealand aerial survey begins

Although oblique aerial photography appears to have been captured in New Zealand as early as 1918 (Conly, 1986, pg. 17), vertical aerial surveys for the purpose of mapping were initiated by the New Zealand Permanent Air Force (NZPAF[vi]) in 1925 (Phillips, 1976; Conly, 1986, pg. 17). Robert J. Crawford from the Department of Lands and Survey (L&S) completed the first topographical mapping by photogrammetric methods in 1931 (Marshall, 2005). This resulted in the acquisition of more specialised photogrammetric equipment by L&S and the creation of a photogrammetric unit known as the *Aerial Mapping Branch*.

The private sector also invested early into aerial surveys as Piet van Asch and his associates formed *New Zealand Aerial Mapping Ltd* (NZAM) in Hastings in March 1936 (Conly, 1986, pg. 33). Although NZAM soon became a contractor of L&S and other public agencies for the collection of aerial imagery, only L&S had photogrammetric capabilities until 1953, when a photogrammetric unit was set up at NZAM upon the advice from Surveyor-General Russell Dick (Conly, 1986, pg. 120). New participants in aerial surveying in New Zealand emerged, such as *Aerosurveys Ltd* created by Tauranga surveyor T.A. Kenny in 1959 (Phillips, 1976). The latter, as well as the associate company *Aerial Surveys Ltd* formed in 1963 in Nelson were both purchased later by *Air Logistics (NZ) Ltd* established in 1977 now renamed *Aerial Surveys (AS)*.

In 1996, the *Department of Survey & Land Information*[vii] was restructured to form the two entities of *Terralink NZ Ltd* (privatised in 2001 and known today as *Terralink International Ltd* (TIL)) and *Land Information New Zealand* (LINZ). The production and delivery of cartography and photogrammetric products was passed on to *Terralink*. As TIL does not operate aircraft, its imagery acquisition has been outsourced to New Zealand providers such as NZAM and AS, as well as overseas providers such as Qasco on occasion.[viii] NZAM remains the greatest supplier of aerial imagery in New Zealand (Slack *et al.*, 2012) while all of the above companies retain photogrammetric expertise for the processing of the imagery.

Beyond aero-triangulation, which arguably forms the cornerstone of good photogrammetry, the production of photogrammetric products such as Digital Surface Models (DSM) and Digital Terrain Models (DTM, or Bare Earth Model) still requires a large amount of manpower. This is due to the extensive editing process involved in the production of a high quality Digital Elevation Model (DEM). This becomes all the more true as the demand for finer spatial resolution and better resolved DEMs increases. In this context, it is worth noting that reliance on external providers becomes standard practice in the industry to address a substantial share of the production and editing tasks associated with large photogrammetric surveys.**Error! Bookmark not defined.** In particular, India has obtained a reputation in this domain due to its rapid adoption of digital photogrammetry fuelled by huge domestic requirements (Kumar, 2000).

LiDAR rises

The past decade has seen the rise of a new technology to obtain highly accurate topographic data and DEMs. Light Detection And Ranging (LiDAR) has become one of the methods of choice for topographic mapping and a promising remote sensing tool for surveyors (Flood, 2001). Despite some issues associated with data filtering and reduction (Liu, 2008), airborne LiDAR has benefitted from appealing capabilities such as the penetration of the laser beam used for sensing through vegetation canopies. By yielding several returns, the signal can be processed to derive dense and highly accurate 3D point clouds of both DSM and DTM data, while photogrammetry remains limited to the DSM and a user best guess for the DTM through heavily vegetated areas.

Airborne LiDAR has also proven successful in hydrographic surveying as the blue/green wavelength penetrates water bodies and enables shallow bathymetry to be mapped up to 70m depending on water turbidity and sea bed reflectance (Guenther *et al.*, 2000). In New Zealand, LiDAR bathymetric surveys have been undertaken in the South Island by the survey company *Fugro* since 1999 for the Royal New Zealand Navy. Recently, LINZ has contracted *Fugro* to undertake a new bathymetric LiDAR survey in the Waikato region.[ix]

While most historic aerial survey companies now offer aerial LiDAR acquisition and processing, the versatility and accuracy of LiDAR has also made it a powerful remote sensing tool for ground based surveys where dense point clouds are required to depict areas and structures accurately. Thus, laser scanning, or terrestrial LiDAR, has become a standard tool for many survey firms. LiDAR technology finds further application in other contexts of capturing new geospatial data. For instance, TIL has pioneered the large scale commercial use of mobile mapping technology (*StreetCam3D*™) in New Zealand*,* a technology that involves a vehicle-mounted laser scanner associated with panoramic digital photography capable of capturing and delivering a comprehensive and highly accurate 3D model of the street environment.

The photogrammetry strikes back

Although the momentum gained by LiDAR technology in the last decade may have justified predictions that LiDAR would become the standard method to collect topographical information in the near future, there has been a revival of the optical photogrammetric method. The increasing use and improved quality of digital cameras, along with the rapid growth of hardware and software capabilities, such as that enabled by multicore processing on Graphics Processing Units (GPU), have enabled *Multiray* photogrammetry (Leberl *et al.* 2010). This involves the processing of every pixel in numerous image overlaps. This results in redundancies that allow point density in the order of 100 point/m^2 to be obtained while airborne LiDAR is usually operated at 1-10 point/m^2 (Figure 3).

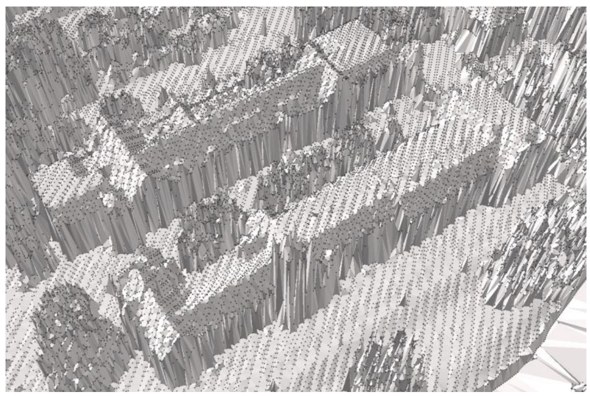
In fact the strategy of image acquisition has changed as the need to limit image quantity is alleviated by rising computer capabilities. Since the number of images required can now be increased, multi-view acquisition geometry offers more potential for multiray photogrammetry and enhanced capability of capturing surface texture. This, in turn, allows finer, better quality DEMs to be derived. Subsequent statistical processing thus enables *Multiray* photogrammetry to yield DSM with accuracy and density that now compete with, or exceed that of LiDAR, while being a more cost effective way due to larger coverage and reduced logistics involved (Leberl *et al.,* 2010).

Unmanned Aerial Vehicle (UAV), a new hope…

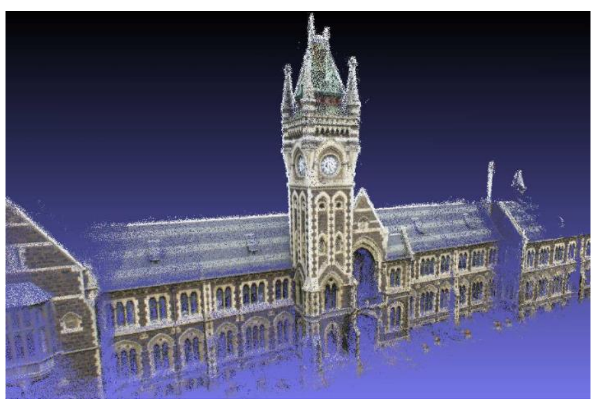
This revival of photogrammetry finds synergies with the recent development of Unmanned Aerial Vehicles (UAV). This new type of platform, whether remote controlled or automated, offers low-cost alternatives to traditional aerial surveys, as well as new opportunities to capture and repeat the acquisition of imagery and topographic data for surveyors (Kerle *et al.*, 2008). UAV operations have been pioneered in NZ in 2006 by the *Geospatial Research Centre* (GRC), a joint venture between University of Canterbury and University of Nottingham (UK). UAV technology is gaining momentum as it finds increasing commercial applications in the surveying industry due to the limited logistics involved with the considerable benefit of large and accurate datasets being captured.

Although only few New Zealand survey firms seem to have invested in UAV technology to date, the synergies between automated multiray photogrammetric processing and UAV-based imagery is being pioneered by companies such as Dunedin-based firm *Areo Ltd* (2006) and partner *Hawkeye UAV* Ltd (2009) which offer low cost highly resolved DEMs and orthophotomosaics for which a large demand can be foreseen. The potential offered by these new instruments has also not escaped the attention of leaders in survey equipment development such as *Trimble,* who recently purchased *Gatewing*, thus becoming one of the leading UAV manufacturers. This fuels the potential of these technologies to contribute to the surveying industry.

(a)



(b)



(c)

Figure 12. (a) 3D model of the University of Otago Clock tower made from manual interpretation of Dunedin 2007 aerial survey. (b) aerial LiDAR survey of University of Otago Clock tower (Data courtesy of Dunedin City Council, 2009). (c) 3D model of the University of Otago Clock tower made from overlapping photographs processed with automated multiray photogrammetric software Areoscan.

The combination of highly resolved DSM with photorealistic imagery also offers new opportunities for display, interpretation, and analysis. Geo-visualisation techniques such as 3D rendering and/or 3D vision, along with comprehensive spatial analysis can thus take better advantage of the highly resolved and accurate third dimension. Urban design is another discipline that will benefit from such technology as development proposals can be assessed and evaluated more comprehensively in a virtual but realistic environment supported by this comprehensive dataset. This may involve the simulation of shadows cast by proposed buildings throughout days and years, as well as the assessment of impact on visibility, the line of sight, or the effect of buildings on wind patterns.

Space-borne remote sensing

Prelude

Over the last 50 years, satellite platforms have offered new perspectives for Earth observations. Although largely publicly funded with most applications being geared towards scientific research, space-borne Earth observation programs have quickly matured. Since Landsat 1 (1972) demonstrated to a wider public the potential for space remote sensing, this technology as marked numerous successes. The launch of Landsat Data Continuity Mission (Landsat 8) in February 2013, and the development of the Sentinel program by the European Space Agency (ESA), are some of the many examples of current efforts that reaffirm the commitment to maintain the systematic capture of imagery of the earth's surface from space.

In this context, the principles of photogrammetry have long been applied to optical satellite sensors in order to enable 3D mapping from space. For instance, sensors such as ASTER (1999-) or ALOS (2006-2011) have been specifically designed with multi-angle telescopes allowing scenes of the Earth Surface to be imaged in 3D (Toutin, 2002). Alternatively, platforms such as those of the SPOT program have relied on steerable vision to capture stereo images based on successive overpasses. Nevertheless, satellite imagery has up until now found only limited operational use for surveying applications. This is likely due to a relatively coarse pixel size (5-30m) that has not fully met the accuracy requirements of most surveying tasks. This limitation is fading as spatial resolution has dramatically improved along with the rise of a commercial era of space remote sensing.

The commercial era of space observations

Since the launch of IKONOS (1999) by *GeoEye Inc*., imagery of the Earth from space has been available at 1m resolution. This resolution was rapidly exceeded by the 60cm resolution of QuickBird (2001) from the *DigitalGlobe* company. The latter sensor quickly supported a large share of the imagery available in *Google Earth*. Both companies have now improved their capacity of very high resolution observations with the launches of GeoEye-1 (2008, 50cm) and WorldView 1&2 (2007, 2008, 50cm). These sensors have specifications that are now close to and compete directly with aerial surveys, while steerable vision also enables the production of highly resolved DEMs. The rapid expansion of the market for such imagery is further illustrated by the recent merging of both companies under *DigitalGlobe Inc.* at the start of 2013. In this context, it can be anticipated that space imaging will contribute towards a growing number of surveying applications.

More sensors dedicated to very high resolution with metre to sub-metre resolution are also available such as the KompSAT (2006, 1m). More recently, the Pleiades I&II (2011 & 2012, 70cm) developed by the French space agency CNES have been designed specifically to support stereo imaging of large areas, thus opening a new era for updating large scale maps without reliance on aerial surveys (Cantou *et al.*, 2006).

Alternative remote sensing techniques for surveyors

The principles of photogrammetry have been generalised to other forms of space imagery, including that from active systems such as side looking RAdio Detection And Ranging (RADAR). Stereo imaging from Synthetic Aperture Radar (SAR) has thus been implemented successfully on-board the Space Shuttle in 2000 to yield the global and widely used SRTM DEM at 30-90m resolution (Farr *et al.*, 2007). This process is known as *radargrammetry* and enables a new revolution for topographic mapping to be foreseen. This is evidenced by the dual satellites mission TerraSAR-X/TanDEM-X from the German Aerospace Center (DLR) which will deliver a global DEM at about 10m spatial resolution and less than 5m relative vertical accuracy (Wessel *et al.*, 2013).

Radar remote sensing has also permitted the detection and mapping of ground and structure motion via Interferometric SAR (InSAR) techniques. For example, centimetre magnitude coseismic displacements of the 2010 Darfield earthquake could be mapped in 3D (Hu *et al.*, 2012). Given the magnitude of displacements capable of being measured from space, it is again foreseeable that an increasing number of surveying firms will find commercial opportunities in this technology. Furthermore, recent advances in image processing have generalized the concept of image interference to optical imagery, so that very small ground displacements, even at sub-pixel level, can now be measured from high resolution sensors (Leprince *et al.*, 2007; Beavan *et al.*, 2012).

Finally, the wider field of geodesy is also being addressed by space observation. For example, the GRACE (2002) and GOCE (2009) missions have allowed unprecedented observations of the Earth's gravity field. This has yielded a much improved representation of the Earth's Geoid, and in turn a better accuracy for elevation measurements made by surveyors in the field.

Coordination of imagery in New Zealand

With the growing use and need of imagery, a number of initiatives have been taken in New Zealand to coordinate the capture, repository, and delivery of imagery products, including LiDAR datasets. While both historical actors TIL and NZAM maintain and distribute their own library of aerial photos, several governmental initiatives deserve to be mentioned. First, the Ministry for the Environment has negotiated coverage of New Zealand with SPOT5 imagery in the context of the Land Use and Carbon Analysis System (LUCAS) to measure and monitor the carbon stocks of New Zealand's forests and soils. Second, the club-funded

KiwImage project initiated in 2007 by the NZ Fire Service is providing a low-cost near complete coverage of very high resolution satellite data (QuickBird) for New Zealand. The imagery acquired on an All of Government license is now managed and distributed by LINZ. Finally, the New Zealand Geospatial Office at LINZ is seeking to inventory all LiDAR data acquired in New Zealand. All these efforts have been consolidated into the National Imagery Coordination Programme developed by LINZ and promoting full open licensing of imagery. As the total expenditure on imagery acquisition over the past two years is close to NZ$6M, these initiatives further demonstrate the growing commitment of New Zealand into geospatial data and technologies (Slack *et al.*, 2012).

Conclusion

Remote sensing techniques have been central to the surveying disciplines for over a century. Today, traditional aerial photogrammetry is only one of the multiple means for surveyors to acquire topographical data. LiDAR and radargrammetry, from terrestrial to space-borne systems have provided new alternatives for high quality data capture. Nevertheless, the photogrammetric method is still relevant and current as low cost alternatives to aerial mapping become available with the rise of UAVs. While a number of survey firms have invested in laser scanner equipment, it can be anticipated that UAV will also become a tool of choice for surveyors. Finally, one can foresee an increasing reliance on space imagery as resolution and accuracy approaches the needs of more surveying tasks. This will require some degree of adaptation given the highly specific set of skills and resources required to process these data.

Acknowledgments

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[i] *Chorography*: the systematic description and mapping of particular regions (Oxford Dictionaries). In the 17th Century, Chorography is associated with topography, cartography, and map-making.
[ii] This refers to the description of the portable *camera obscura*.
[iii] Nicéphore Niépce invented the Heliographic process, a precursor to the photographic process.
[iv] The invention would then be declared a "Gift free to the World" (Arago, 1839, pg. 52).
[v] The name was supposedly coined by geographical explorer Dr. Otto Kersten in 1867 from discussions with Albrecht Meydenbauer, the German "father" of photogrammetry (Albertz, 2007).
[vi] NZPAF became Royal New Zealand Air Force (RNZAF) in 1934.
[vii] Formed out of a restructure of L&S in 1987.
[viii] Personal communication from John Kotrotsos, Imagery Manager, Terralink International Ltd.
[ix] Personal communication from Hugh Parker, Hydrographic Surveyor, Fugro LADS Corporation Pty, Ltd.

KEYNOTE ADDRESS

Boundary disputes: The price of federalism

Dr. Brian Ballantyne,
Brian.ballantyne@nrcan.gc.ca

Surveyor General Branch, NRCan

Deflecting criticism:

Lest you be tempted to dismiss this topic as irrelevant to New Zealand (i.e. boundary disputes/federalism? Say what?), let's address three truisms. The first truism: There are significantly fewer boundary disputes in New Zealand than in Canada, even after normalizing for population, number of parcels, frequency of subdivision and rate of transfer.[2] There are many explanations for this – including the ubiquity of mortgage surveys in Canada on fee simple lands[3] – but there are two assertions here: That federalism causes boundary disputes for parcels of Aboriginal lands in Canada, and that this is of interest to you.[4]

The second truism: There is a significantly different statutory and constitutional context in New Zealand than in Canada. Canada has nothing to compare to the Treaty of Waitangi; NZ has nothing to compare to the Constitution Act (1982). From the perspective of Aboriginal rights, the Constitution is a very good thing, for it entrenches such rights in s.35: "The existing aboriginal and treaty rights of the aboriginal peoples of Canada are hereby recognized and affirmed." This means that the Crown does not have the unfettered authority to extinguish such rights; rather the Crown has a duty to conduct itself honourably.

The third truism: New Zealand is not bedeviled by federalism, not being a creature of a confederation of existing colonies and having long-ago jettisoned the provinces. Canada is a creature of federalism, whereby the respective powers of the federal Crown and the provincial Crowns are set out in the Constitution. Indeed, confederation was often driven (or impeded) by issues of land tenure, parcels and boundaries. For example, Ontario's interest in expanding west was one of the primary reasons for Confederation in 1867.[5] Conversely, Prince Edward Island's reluctance to join Canada in 1867 was based on its desire to retain its antiquated lease-hold system.[6]

Despite these differences between New Zealand and Canada, this examination of federalism causing boundary disputes is relevant to New Zealand because of four constants between the two countries:

- The nature of conflicts between Crown and Aboriginal peoples over land.
- The legal and ethical principles that apply to resolving such conflicts.

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[2] Conyers. Why New Zealand has fewer title and boundary disputes than Ontario. Paper for Survey 455H. University of Toronto. December 1993.
[3] Such surveys often "start a fight" because they rouse sleeping dogs: Interview of George Walker by Charlie Weir. *ALS News*. p51. June 2013.
[4] Federalism is also indicted as a cause of boundary disputes in harbours and in the offshore: Ballantyne: *Water bounds of riparian lands: That fuzzy shadowland*. SGB. 50pp. 2013.
[5] Sprague. The Manitoba land question. *The Prairie West: Historical readings*. pp118-135. 1992.
[6] Bitterman & McCallum. Fishery reserves in Prince Edward Island. 28 *Dalhousie LJ* 385. Fall 2005.

- The onus upon land surveyors to proffer only impartial expertise.[7]
- The methodology for re-establishing boundaries.[8]

Thus, what follows resonates for Maori land, for Aboriginal title in New Zealand and for New Zealand surveyors. Also, of course, it's a window into an enchanting world.

Cross-pollination:

There is much cross-pollination between New Zealand and Canada on surveying issues, as they pertain to Aboriginal title (and rights) and to boundaries (and parcels). This cross-pollination is to be expected, to the extent that the principles of the English common law were to apply in both jurisdictions,[9] so far as they were applicable to the circumstances of the region.[10] For example, the mantra from an 1886 New Zealand case[11] – "Neither the words of a deed, nor the lines and figures of a plan, can absolutely speak for themselves. They must in someway or other, be applied to the ground" – is regularly invoked in Canada. In the other direction, Hayes' recent monograph on the law of movable water boundaries[12] borrows generously from Canada – the epigraph from Lambden and 15 pages from Ontario legislation.

However, let's focus on the Crown-Aboriginal nexus at the parcel boundary, with one caveat: I do not intend to set out the New Zealand context for dealing with Maori land and boundaries of such parcels. Such carrying-of-coal-to-Newcastle is both wearying and overweening. Suffice to say that the procedures available for Aboriginal land grievances are similar between the two countries – negotiate directly, litigate or appeal to statutory tribunal.[13] Courts on both sides of the Pacific lean heavily on principles from the other jurisdiction.[14] The Supreme Court of Canada defined meaningful consultation with First Nations as obliging the Crown to make changes to its proposed action based on information gleaned, and relied on New Zealand's *Guide for Consultation with Maori* for insight.[15] Conversely, the New Zealand courts have, since at least 1987, referred to decisions of the Supreme Court of Canada in defining and discussing fiduciary duty, the honour of the Crown and the nature of Aboriginal rights and title.[16]

Admittedly, there is some difference as to what sort of duty is owed by the Crown to First Nations and to Maori, respectively: a fiduciary duty or some duty analogous to a fiduciary duty. A fiduciary duty arises in situations where one party (such as a First Nation) is in a vulnerable position compared to another party (such as the Crown). The distinction, from the perspective of reestablishing boundaries of parcels, is largely irrelevant. Both duties are characterized by a partnership:

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[7] The advice must not be influenced by deep pockets (clients) or trousering (bribes): Ballantyne. *Expertise at the boundary: Vox expertorum*. ALSA Seminar. April 2010.
[8] Generally Accepted Surveying Principles.
[9] Durie. FW Guest Memorial Lecture 1996. Will the settler settle: Cultural conciliation and law. University of Otago. September 25, 1996.
[10] NZ: *English Laws Act* 1858; Canada: *North-West Territories Act* 1886.
[11] *Equitable Building & Investment Co. v. Ross* (1886), 5 NZLR 229.
[12] Hayes. *Elements of the law on movable water boundaries*. MAF. 2007.
[13] NZ: Waitangi Tribunal, established by the *Treaty of Waitangi Act*, 1975. Canada: Specific Claims Tribunal, established by the *Specific Claims Tribunal Act*, 2008.
[14] Frame. The fiduciary duties of the Crown to Maori. *Waikato Law Review*. v13. pp70-87. 2005.
[15] Ministry of Justice Guide: *Haida Nation v British Columbia* [2004] 3 SCR 511, at para 46.
[16] *New Zealand Maori Council v. AG* [1987] NZLR 641; *McRitchie v. Tarankai Fish and Game Council*, [1999] 2 NZLR 139.

- Founded on good faith, honour, trust, mutual cooperation, openness, consultation, reasonableness and fairness;[17] and
- Rooted in persuading Maori and First Nations that their rights were best protected by reliance on the Crown[18] (at a time when there was military parity)[19]

What is relevant is that the Crown must act honourably towards Aboriginal land in both countries: "emphasis on the honour of the Crown is important, the Treaty of Waitangi being a positive force in the life of the nation.[20]

Minimal impairment of land:

Canadian federalism is reflected in the division of powers between the federal Crown and the 10 provincial Crowns. The former has responsibility for Indians, and lands reserved for the Indians, by virtue of s.91(23) of the Constitution. The latter has responsibility for property and civil rights in the Province by virtue of s.92(13) of the Constitution. This means that Canada (the federal Crown) has responsibility for 3,100 Indian Reserves with an area of some 35,524 sq km, allocated across 575 First Nations having a population of about 370,000. The provinces have responsibility for the abutting lands; either directly as ungranted Crown land or indirectly by patenting and administering lands in fee simple. Between these two Constitutionally-distinct types of land, of course, is a boundary.

In the context of Reserves, the Crown owes a duty to First Nations thrice:

- Prior to creating a Reserve, the Crown must mediate between Aboriginal peoples and others.[21]
- After creating a Reserve, the Crown has an "obligation to protect and preserve the Band's interests from invasion or destruction."[22] Although the Crown might well have a public duty to expropriate Reserve lands it must take "only the minimum interest required" to ensure "minimal impairment of the use and enjoyment of Indian lands by the First Nation."[23] This means that after a decision is made to take the land in the public interest, the Crown must turn its mind to the terms of the taking. If an easement will suffice, then a fee simple interest must be eschewed, thus leaving the parcel within the Reserve.[24]
- First Nations sometimes surrender parts of Reserve. The Crown owes a fiduciary duty to a First Nation when it participates in the removal of land from a Reserve,[25] so as to prevent "exploitative bargains."[26] A free and informed decision is a necessary but not a sufficient condition to surrender. If the transaction is exploitative, then the Crown must "withhold its own consent."[27]

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[17] *NZ Maori Council v. AG* [2007] NZCA 269.
[18] *Wewaykum Indian Band v Canada*, [2002] 4 SCR 245.
[19] Belich. *I shall not die: Titokowaru's War, 1868-1869*. 1996.
[20] *Ruahine v. Bay of Plenty Regional Council*, [2012] NZHC 2407; *AG v Mair*, [2009] NZCA 625.
[21] *Wewaykum Indian Band v. Canada*, [2002] 4 S.C.R. 245.
[22] *Guerin v. The Queen*, [1984] 2 S.C.R. 335.
[23] *Osoyoos Indian Band v. Oliver (Town),* [2001] 3 S.C.R. 746.
[24] *BC Tel v. Seabird Island Indian Band*, 2002 FCA 288.
[25] *Halfway River First Nation v. BC Ministry of Forests*, 1999 CanLII 470 (BC CA).

[26] *Blueberry River Indian Band v. Canada*, [1995] 4 S.C.R. 344.
[27] *Semiahhmoo Indian Band v. Canada*, 1997 CanLII 6347 (F.C.A.).

Outside the Reserve context, both Crowns – federal and provincial – have a legal duty to consult and possibly accommodate First Nation, Métis or Inuit communities, when the Crown has knowledge of a an established or potential Aboriginal right and contemplates conduct that might affect that right.[28]

Typology of boundary disputes:

I work for the federal Crown, which has an obligation to protect First Nations' interests in Reserves from invasion or destruction. This duty to minimally impair Reserve lands guides us as we re-establish Reserve boundaries and as we confront eight types of boundary disputes caused by federalism:

- Province as active opponent of Canada ("It's ours, piss off"): Example A - The Qu'Appelle Valley in Saskatchewan meanders across a wide flood plain, meaning that there are both gradual and sudden shifts in the boundaries of Reserves that abut the river. The bed of the river is vested in the province, and the parcels across the river from the Reserves are mostly patented in fee simple by the province. Owing to a provincial regulation that extinguished the doctrine of accretion in 1966, the province now refuses to consent to Canada's survey plan[29] that show the Reserves getting larger through accretion. Example B - The Rama Reserve in Ontario is bounded and bisected by a few watercourses. The Ontario Court of Appeal[30] held that non-tidal watercourses vest in the riparian parcel; that *ad medium filum* carries the day regardless of navigability. In response, Ontario enacted legislation in 1911 that vests navigable watercourses in the province at the time of Crown grant, and now argues that such legislation applies to the Reserve that was created in 1850. Thus, although Canada has re-established the Reserve as running to the middle thread, the province argues that the boundaries are at water's edge.
- Province as implicit opponent of Canada ("It's ours by default, we dare you to argue otherwise"): In 1938, British Columbia transferred to Canada the title to all Reserves in the province, with the exception of travelled roads through Reserves. It is now difficult to ascertain whether a road that is travelled in 2013 was travelled in 1938. The province, however, consistently argues that current travel is the best indicator of travel in 1938, and claims such roads. The effect is often that Canada argues that there is no boundary (by virtue of there being no evidence of a road in 1938) while the province argues that there are two boundaries (either side of such a road).
- Province as mild irritant ("We might concede that it's yours, if you jump through some hoops"): All parties agreed that land had accreted to Opaskwayak Cree Nation Reserve. However, the province refused to consent to a survey plan of the Reserve, on the grounds that provincial legislation required that a separate survey be done of the accreted area. Such a position would have meant that the area would have to be added to the original Reserve through two Orders in Council. Canada argued successfully that the provincial legislation

[28] *Haida Nation v. British Columbia,* [2004] 3 S.C.R. 511*;* Taku *River Tlingit First Nation v. British Columbia*, [2004] 3 S.C.R. 550; *Mikisew Cree First Nation v. Canada*, [2005] 3 S.C.R. 388.
[29] It is Surveyor General policy that a province consent to all survey plans of Reserve boundaries before such plans are confirmed, pursuant to the *Canada Lands Surveys Act*, s.29(3).
[30] *Keewatin v. Kenora*, (1908) 16 OLR 184.

applied only to provincial Crown land and had no application to Reserve land, but the debate consumed much energy over three years.

- Province as misguided passive-aggressor ("It's yours, you deal with it"): Papaschase Reserve in Alberta was surrendered in 1889, and the 39 sq mile parcel was subdivided into 183 smaller parcels (each of 160 acres) and patented by Canada to settlers. Recently, the province has advised the City of Edmonton that wetlands were not patented, but remain vested in Canada as unsold, surrendered lands. Edmonton, as a consequence, has issued stop-work order to subdivision developers on the basis that they did not have title to the wetlands,[31] and put the onus on Canada to demonstrate otherwise. Canada resolved the imbroglio in favour of the developer. There is nothing in the legislation, the policies of the day or in the patents to suggest that the wetlands were reserved by (or excepted to) the Crown; moreover, Edmonton had no evidence to suggest otherwise.

- Province as innocent bystander ("Say what?"): In 1878 the Nanoose Reserve on Vancouver Island was surveyed, and the First Nation has resided there since. Sadly, in 1884 a survey of abutting provincial Crown land erred in re-establishing the east boundary of the Reserve, such that a few fee simple parcels now encroach onto Reserve by a few metres. The error was revealed in 1998, and the two Crowns - federal and provincial - agreed that the 1878 boundary was correct. The encroachments remain, however. The fee simple owners argue that the Reserve boundary was not established until 1938 (when British Columbia transferred all Reserves to Canada), after the establishment of their parcel boundaries in 1884.

- Province as unwitting dupe ("They don't want it"): A parcel of fee simple land was added to Membertou Reserve in Nova Scotia in 2012; the parcel is bisected by a creek. Provincial legislation (dating to 1917) vests the beds of all watercourses in the province, regardless of navigability. It is the Surveyor General's opinion that the creek was not part of the fee simple parcel, and thus is not part of the reserve. However, land administrators within the federal Crown argue that the trivial nature of the creek means that the province has no interest and that the creek is part of the Reserve. The bun-fight is retarding the construction of a highway interchange.

- Province as lesser of two evils ("Pick your poison"): Treaty 8 was negotiated in 1898/99 between First Nations and the Crown, and had as its westerly boundary "the central range of the Rocky Mountains." The boundary was never surveyed. A group of First Nations now argues that the boundary is the Arctic-Pacific watershed; British Columbia argues that that the boundary is the central range within the Rocky Mountains – the Rocky Mountain watershed where the water flows on one side to the east and on the other side to the west. The distance between the two boundaries is 100 km. Owing as much to litigation fatigue as to boundary principles, Canada chose to oppose the province.

- Province as implicit dropper-of-the-ball ("OMG"): The Tsilhqot'in Nation is in the throes of litigation claiming aboriginal title to various parcels of land in central British Columbia. Canada has opposed the claim, despite it being over unceded provincial Crown land, because of a regulatory lacuna. To wit, there is a gold mine in the claim area. To the extent that it is provincial Crown land, then provincial mining and environmental regulations apply. However,

[31] Ecologists agree that these wetlands have no ecological value.

should the court grant Aboriginal title, then provincial regulation is inapplicable and Canada cannot impose its regulations within the provinces.[32]

To sum up:

This is not an indictment of federalism. However, the law of unintended consequences rears its head, because federalism also leads to conflicts between the two levels of government as to the spatial extent of the lands of Aboriginal peoples.[33] Indeed, such conflicts might well be inevitable. Nor do I suggest that the provincial Crown is always (or even, mostly) the bad guy. Rather, I suggest that the boundary disputes arise simply because there are two Crowns as a function of federalism, each with differing responsibilities.

[32] For the assertion that the Tsilhqot'in Nation should not be forced to define the bounds of parcels that it claims, because "the idea of boundaries is a Eurocentric principle" see: MacLaren, et al. Tsilhqot'in Nation v. British Columbia. *Survey Review*. 43. pp.123-136. April 2011.
[33] A topic for another discussion is the extent to which federalism encourages surveyors from the two Crowns to form an implicit alliance. This tyranny of the profession is akin to the camaraderie felt between opposing criminal layers – prosecutor and defence lawyer.

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Challenges in the Geospatial Sector

Nicholas Chrisman[1]

[1]Geospatial Sciences
RMIT University, Melbourne, Australia
Phone: +614 346 868 063
Email: nicholas.chrisman@rmit.edu.au

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1.0 INTRODUCTION

The geospatial sector (or whatever one wants to call it- Geographic Information Science? Geomatics?) must address certain fundamental questions over the long term. Most of these questions remain the same, though the answers depend on the particular state of technology at the time. This written paper cannot address every one of them, but the oral presentation may wander a bit more widely.

The first question relates to the algorithmic complexity of geospatial solutions. Section 2 will consider the impact of increased computer capacities over the past forty or fifty years. This will exceed the scope of an extended abstract, so a conclusion will follow.

2.0 HAS MOORE'S LAW BEEN PROTECTING US FROM OUR LACK OF INNOVATION?

Since Gordon Moore proposed that transistor density double every two years (back in 1965), this general rule of technological evolution has held. Exponential growth in computing capacity has certainly altered the world we live in, but the full power of this increase has been diminished by a lack of attention to algorithmic complexity. While hardware platforms are ever more powerful, the software side has experienced a phenomenon of 'bloat', summarized by what is termed 'Wirth's Law'. In the field of GIS, there has been more emphasis on user interface than on innovation in the basic processing methods. Consequently, certain opportunities have been lost.

2.1 Technological change

Few technological changes have been so carefully observed, reconsidered, and dissected as the computer age of the last fifty/sixty years. It is a surprisingly rich story, and exceptional compared to many other technologies. In the field of geographic information, we tend to take computing for granted - as a base level of what we do - yet the particular history has consequences (Poore and Chrisman, 2006). This paper will concentrate on the exponential growth curve for computing performance that has persisted much longer than anyone predicted. In 1965, Gordon Moore, then an executive with Fairchild Semiconductor, observed that the density of transistors on integrated circuits had been doubling about every two years (Moore, 1965). Through the grapevine of rumour and incomplete citations, this observation was repackaged as 'Moore's Law' – that chip power doubled every 18 months. As Figure 1 shows, the actual rate is closer to doubling every two years, at least for the count of transistors on microprocessor chips.

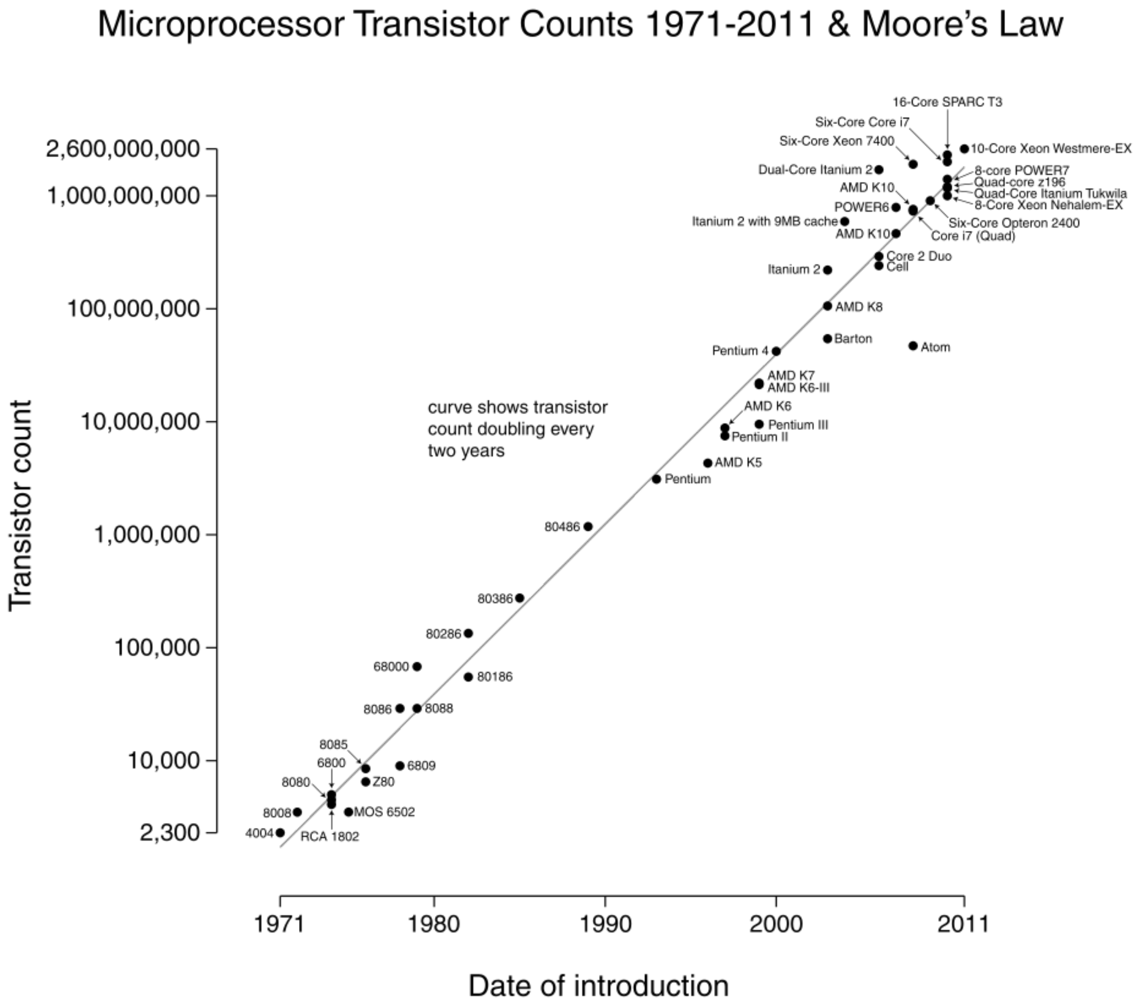

Figure 1: Transistor Counts for Microprocessors 1971- 2011; Source: Wgsimon, http://en.wikipedia.org/wiki/File:Transistor_Count_and_Moore%27s_Law_-_2011.svg Used under Creative Commons license.

Moore's pronouncements concerned the manufacturing of integrated circuits, the cutting edge of many developments. The exponential curve is often related to processor speeds (which are also linked to Figure 1), but it applies just as directly to memory capacities.

2.2 The Great Moore's Law Compensator (TGMLC)

As most computer users have been able to realize, the expanded power of computers comes with inconveniences. If our use is just of processor power, then smaller faster chips deliver directly. For a field like geographic information, however, we are quite constrained by our massive datasets. In passing from 40Mb drives not so long ago to 100Gb (and more), we may have increased the problem size at least as fast as we have increased the power of our computer.

This effect is called (in strong irony) the Great Moore's Law Compensator (TGMLC) by some. Wirth (1995) stated: "Software is getting slower more rapidly than hardware becomes faster". There are some studies that show how successive versions of Windows use more and more computer capacity (Orion, 2003). The result is that a new computer appears to perform about as well under the new operating system when it may have double the raw power.

2.3 Analysis of geospatial algorithms

The key question for the geographic information field is if the shoe fits our field. Are we losing out on increased computer capacity? The first observation concerns that amount of data available. Over the past thirty years the data volumes have expanded dramatically. Data for cartographic purposes that once occupied up to a megabyte have mushroomed to fill the space available. Part of this is due to file formats that are less and less concerned with compaction and efficiency. The problem with huge memory space is that programmers feel no need to conserve it. Programs bloat, as operating systems squirrel away stuff they might like to remember some day or another.

What does algorithmic complexity mean for geographic problems? It is usually quite easy to develop solutions based on a ‘brute force’ comparison of all objects in one set with those in another. The early programs for polygon overlay did exactly this, compared all the polygons in one input file with those in the other (for example, MAP/MODEL from the 1960s). For simple cases, this worked well enough, but the computer requirements grew quadratically (with the square of the input bulk to process). Michael Shamos proposed a ‘divide and conquer’ strategy that worked across the data in a sorted manner. This computational paradigm swept across the practitioners of GIS, including the team at Harvard (see Chrisman, 2006, p. 128). With a simple band-sweep, the complexity could be reduced from $O(N^2)$ to $O(N^{1.5})$. With even more care, the key operations could be cut to $O(N \log N)$. To cite a specific example (performed in 1983), for an overlay of statewide groundwater data in Wisconsin, the brute force approach would require 900 million comparisons of segments pairwise. The band sweep checks on 19 million, and the more finely tuned algorithm in WHIRLPOOL (Dougenik, 1980; Chrisman and others 1992) only made 2 million checks. This reduction was observed for a case of 30,000 polygons against 30,000 polygons. A reduction by a factor of 450 sounds good, but that is just the start. If the problem size is increased by a factor of 100 (up to 3 million polygons, something quite possible with many kinds of analysis), the brute force approach would require 10000 times more resources. By contrast, the WHIRLPOOL algorithm would require 145 times more computing resources. Thus, the effect of a good choice of algorithm becomes more and more apparent with increased problem size.

The intermediary band sweep algorithm shows a 1000 fold increase, not the factor of 145 in the more optimal approach. Sadly, the way that the GIS industry developed, the simpler band sweep algorithm was the one actually commercialized and adopted in major software packages for at least a few decades. What this means is that computer had to get faster by a factor of eight to make up for the choice of a suboptimal algorithm at the smaller size (30,000 polygons); for 3,000,000 polygons, it takes a speed increase of 60. We have indeed seen such increases in speed since 1980, but the power of the computer was absorbed by the use of suboptimal algorithm and the tendency to increase the problem size.

A few authors have made note of algorithmic complexity in recent years (Manson 2001; Wang 2008). Their work is more oriented towards complexity science, and the power of simulations and agent models. There is little attention paid to the archaeology of the antique algorithms that persist long beyond their useful lifetime in the bowels of various computer packages.

5.0 CONCLUSIONS

Some of the challenges in the geospatial sector are of our own doing. We have failed to learn lessons from the past, and we have failed to adapt to current conditions. Fortunately there is some hope that things may improve if we pay attention.

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An Enduring and Natural Real-Time Challenge

George Benwell

School of Business
University of Otago. Dunedin, New Zealand
Phone: +64 3 479-8115 Fax: +64 3 479-8171
Email: george.benwell@otago.ac.nz

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ABSTRACT

Spatial systems and associated paradigms have now existed for close to a third of century – at least in contemporary and computerised formats and forms. Furthermore, their function has, in my opinion always usurped their form. This paper is a response to these assertions and notes the apparent inadequacies of the present data structures and models and the total inadequacies of systems with respect to real representations of the perceived reality about us. I postulate that a substantive challenge still lies before spatial researchers that encompasses real time representations of the world surrounding us. Can't ponder that? Well, simply look outside the window, observe the natural world you see. It is dynamic, responsive, interconnected, colourful and alive. It is not naturally pixelated, vectorised, linear or planar. It is nothing more or less than real, apparently truthful and natural. A spatial system is none of those. Can our research close the hiatus between what exists outside and inside a spatial system?

How do different science disciplines represent and compute over 'space'?

Mark Gahegan [1]

Centre for eResearch
University of Auckland, New Zealand
Phone: +64 9 923-1819
Email: m.gahegan@auckland.ac.nz

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1.0 INTRODUCTION

GIScientists and spatial information theorists are certainly not alone in their fascination for spatial representation and reasoning. Many research disciplines use space (and time) as the primary means for organizing and analyzing their data and so have sophisticated conceptualizations (and related computational systems) to represent and analyze the objects and fields it contains. One might reasonably expect that the conceptual models developed by these diverse research communities to exhibit differences, but are there also universal concepts and relations that might form a common ground among the various sciences?

The answer could have important implications for the teaching and learning of spatial concepts, and also for the design and implementation of multi-scale (inter-disciplinary) spatial systems, as well as to facilitate interoperation and sharing of analysis and storage methods.

The approach taken here is to examine the computational systems that a variety of different disciplines have developed to represent and compute over space, in order to understand the similarities and differences that these reveal about the conceptualization of space itself. Working with researchers in many disciplines to utilise high-performance computing and eScience capabilities has presented the opportunity for the author to study both the conceptual models methods and the application codes used to represent space across the sciences. This is in contrast to the ethnographically-based approaches that work with a research community and use interviews, questionnaires or observation to surface up the norms of spatial understanding. In this sense this study is not about what researchers say they do, but what they actually do, algorithmically, when they do spatial computing.

Many abstract methods exist for representing the mathematical properties of space, and for operating on contained objects independent of any assumed scale. For example geometry, topology, spatial information theory and scale-space methods in computer vision are all branches of research that are thought to universally apply across spatial scales. Montello (1993) argues that whereas the abstract nature of many spatial properties allows them to be considered in a scale-invariant manner, scale nevertheless has an important effect on the perception and cognition of space. And while neither premise is disputed here, it begs the question: are spatial properties indeed addressed in a scale-invariant way across the sciences? If they are, this suggests there are universal aspects to the representation and analysis of space—and to objects in space (for example see Myers et al., 2005).

2.0 SCIENCE AT DIFFERENT SCALES

So how do different science communities represent, and analyse spatial concepts? We begin by examining the range of scales involved. The range of spatial scales is typically divided into four distinct regions: (i) subatomic, (ii) atomic to cellular, (iii) human, and (iv) astronomical, as shown in Table 1, below.

Table 1. The continuum of scale: http://en.wikipedia.org/wiki/Orders_of_magnitude_(length)

Section	Range (m)		Unit	Example Items
	≥	<		
Subatomic	0	10^{-15}	am	electron, quark, string, Planck length
Atomic to cellular	10^{-15}	10^{-12}	fm	proton, neutron
	10^{-12}	10^{-9}	pm	wavelength of gamma rays and X-rays, hydrogen atom
	10^{-9}	10^{-6}	nm	DNA helix, virus, wavelength of optical spectrum
Human scale	10^{-6}	10^{-3}	µm	bacterium, fog water droplet, human hair[1]
	10^{-3}	10^{0}	mm	mosquito, golf ball, football (soccer ball)
	10^{0}	10^{3}	m	human being, football (soccer) field, Eiffel Tower
	10^{3}	10^{6}	km	Mount Everest, length of Panama Canal, larger asteroid
Astronomical	10^{6}	10^{9}	Mm	the Moon, Earth, one light-second
	10^{9}	10^{12}	Gm	Sun, one light-minute, Earth's orbit
	10^{12}	10^{15}	Tm	orbits of outer planets, Solar System
	10^{15}	10^{18}	Pm	one light-year; distance to Proxima Centauri
	10^{18}	10^{21}	Em	galactic arm
	10^{21}	10^{24}	Zm	Milky Way, distance to Andromeda Galaxy
	10^{24}	∞	Ym	visible universe

Obviously, geography and GIScience are concerned with problems that relate almost exclusively to the human scale. But across the full range of spatial scales, different scientific challenges may change how space is conceptualized and analyzed. In GIScience, for example, our conceptualization of space typically includes, geometry (shape, distance, direction), topology, proximity, coordinate and georeferencing systems, projections, and a duality between field- and object-based representation.

3.0 QUESTIONS SPECIFICALLY ADRESSED

In this talk, the use of computational models of space, related algorithms and data structures are reviewed for the following science disciplines (in increasing scale order):

- computational chemistry (quantum chemistry),
- bio-molecular modelling,
- geography (GIScience),
- star mapping and
- cosmology.

Findings are presented for spatial computing as used by each community, and in conclusion a table is presented that compares their: (i) model of space, (ii) reference frame used, (iii) decomposition and sampling approach, (iv) measurements and (v) instances used in analysis.

Two motivating questions drive the work reported here:

1. Do the above spatial concepts that are common in GIScience play important roles at all scales, and how does the scale (and the discipline that works at a particular scale) affect their relative importance?
2. Are there concepts, algorithms and data structures in use across other spatial communities that are not usually found in GIScience but might be useful?

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Extending Point-pattern analysis to polygons using vector representations

Peter Whigham

[1]Department of Information Science
University of Otago. Dunedin, New Zealand
Phone: +64 3 479-7391 Fax: +64 3 479-8311
Email: peter.whigham@otago.ac.nz

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1.0 INTRODUCTION

Point pattern analysis is a fundamental approach in many disciplines. The concept of clustering, interaction between elements in space such as repulsion or attraction, and the overall structural description of a set of spatial objects often forms the basis for confirming hypotheses related to patterns driven by an underlying process. Pattern descriptions are generally based on the degree of clustering or dispersion based on a comparison with a random (typically Poisson) process. Simple methods for analysis include functions based on distance, such as the nearest neighbour distance and the empty space function. The development of 2nd order methods (Lieshout and Baddeley, 1996) for estimating these pattern types have led to Ripley's K and associated transforms (such as the L function), which are now a common approach in ecology and vegetation science.

Although point patterns have a wide range of application, the approximation of an object as a point can lead to a number of errors regarding the observed pattern statistics. In particular, a vector object represented as a centroid increases the distance between objects and may therefore mask patterns of clustering that may exist in the areal data. In addition vector objects may overlap, have holes or complex shape, all of which are eliminated by a reduction to a point representation.

The extension of point pattern analysis to a grid-based approach using O-ring statistics was first proposed by Wiegand and Moloney (Wiegand and Moloney, 2004), and extended to handle 2nd order statistics (Wiegand, Kissling et al., 2006). This approach used a categorical raster representation where the cell size (scale) was selected based on the smallest object to be represented. An object was represented by a grouping of adjacent cells. This approach has been successfully used in a number of ecological studies including habitat loss and fragmentation (Bruggeman, Wiegand and Fernandez, 2010), forest stand structure (Barbeito, Pardos et al., 2008) and the influence of grazing on species interactions and stress (Graff and Aguiar, 2011). Although allowing areal objects to be assessed in terms of Ripley's K and other measures, the grid-based representation meant that objects could not overlap. In addition, the simulation models required for comparing the observed patterns in space to a random configuration were restricted to rotating each object by 0, 90, 180 or 270 degrees and then randomly shifting the object within the grid.

This paper introduces a vector-based approach to realising distance-based and K-statistic measures which allows overlapping objects and arbitrary rotation during simulation. In addition, since the objects do not have to be mapped to a raster representation, the scale of the data is represented by the original detail used when the data was collected.

2.0 VECTOR-BASED PATTERN STATISTICS

The following pattern statistics for polygons are implemented in the open-source package R (R Development Core Team ,2011), and use the "sp", "spatstat" and "rgeos" libraries for point and vector representation, geometric operations and display. Issues regarding randomisation of patterns, edge correction and details for each algorithm will be given in the appropriate section. For the purposes of comparison to a point-based measure the operations will be compared to point patterns and random simple polygons generated with the point as a centroid.

2.1 Empty Space Distance

The empty space distance function represents the nearest distance to a polygon from an arbitrary location within the border window of the dataset. This is calculated for a set of point locations as a grid within the border window. Figure 1 shows a point-based empty space function as a map and a corresponding map for random rectangles with the point as the centroid.

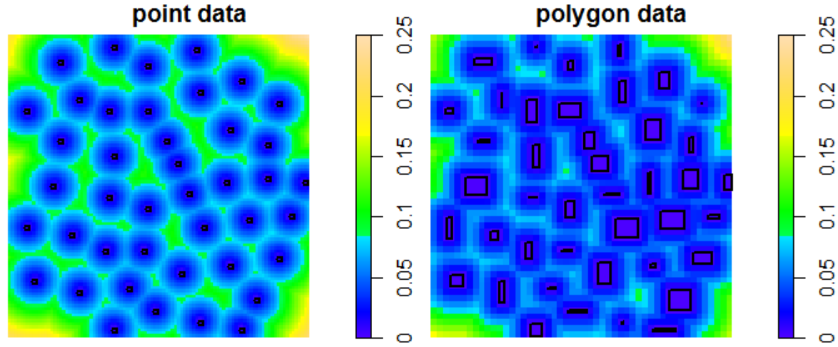

Figure 1. Empty Space Distance function for a set of points and random polygons with the same centroid

Although Figure 1 is useful for visualisation, it does not assess the degree of clustering or dispersion with the data. For this to occur we define an empty space function F which defines the cumulative distribution function of the empty space distance. See Baddeley (2008) for details of this definition for point-based processes. One issue that arises with all functions estimated from a sample of points within a study region is the correction for bias due to edge effects. With point data this is often done based on the empirical cumulative distribution function. For polygons a similar approach is used, however any operation that increases the size of a polygon beyond the study window is clipped. The empty space function F(r) defines the observed number of points found from an arbitrary point with increasing distance (r). A comparison of this count versus a Poisson process is used to compare the observed distribution to a random point pattern with the same intensity. Hence if $F(r) > F_{pois}(r)$ this indicates that the points are regularly space, while $F(r) < F_{pois}(r)$ implies the point pattern is clustered. For points this can be formally defined, however with polygons a simulation is required that distributes the polygons randomly within the study region and calculates the F statistic for each randomisation. For both point and polygon patterns a confidence interval can be created that indicates a significance level based on the number of simulations. A significance level of 0.05 is obtained when the number of simulations is 39 (Baddeley, 2008).

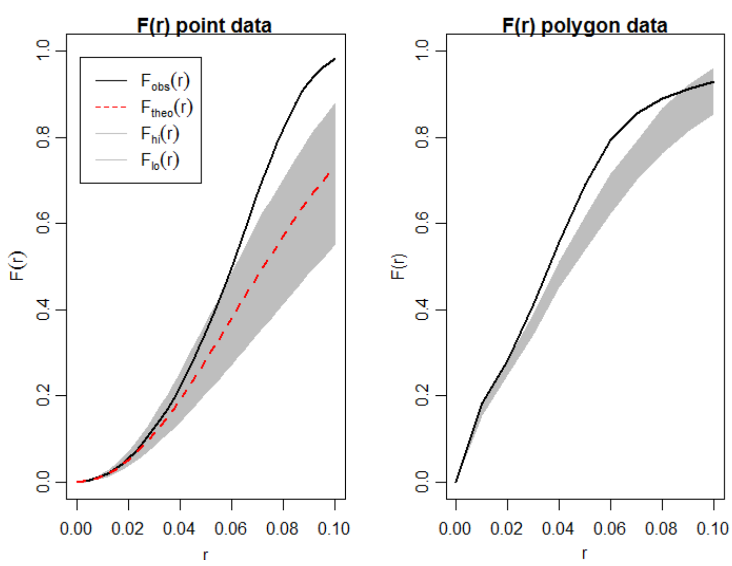

Figure 2. Empty space function F(r) for the point and polygon data

Fig. 2 shows the empty space function F(r) for the point and polygon data with a 95% confidence interval for a simulated poisson process. The main feature to note is that the polygon data shows regularity in the distribution of the polygons for smaller distance values (r). In addition there is a suggestion of random patterning for large r. Hence the use of points to approximate the polygon data underestimates the amount of regularity in the data, even though the randomised polygons for each point are quite small (see Fig. 1).

2.2 Ripley's K Estimate

The K function was first introduced by Ripley (Ripley, 1977) based on the distance between observed points for stationary patterns. Hence, given an intensity of points λ, Ripley defined $\lambda K(r)$ as the expected number of points that would be found within a distance r of an arbitrary observed point. A theoretical Poisson model can then be compared against the observed K(r) to indicate clustering or dispersion (regularity) within the pattern.

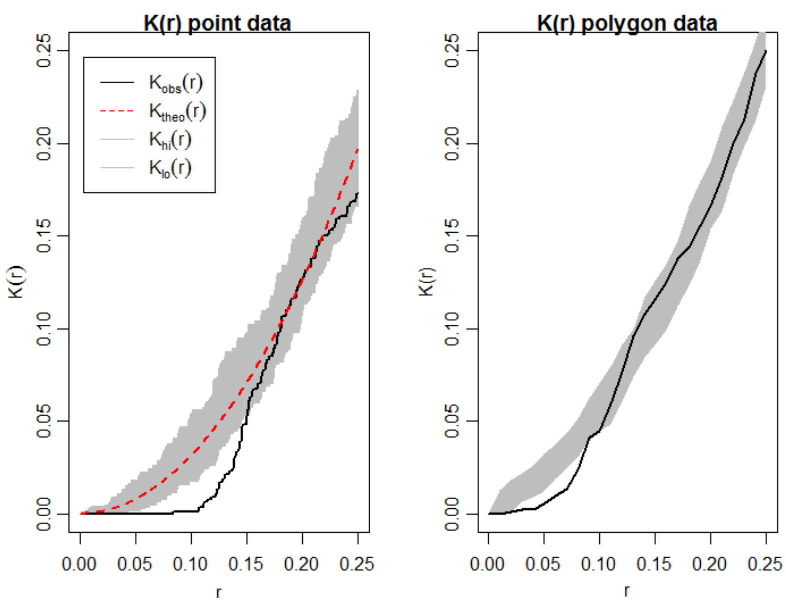

Figure 3. Ripley's K(r) estimate for point and polygon data

Figure 3 shows the effect of polygon objects approximated with point centroids for Ripley's K estimate. For the point data the indication is that the points are dispersed for distances up to $r \approx 0.15$, whereas the polygon data suggests a random pattern once $r > 0.8$. There is also some suggestion that for the polygon data there is a clustering at a distance scale of approximately 0.13, whereas the point estimate for K(r) does not suggest clustering at any scale. Clearly patterns may change significantly if objects are represented as points rather than their correct areal representation. Figure 4 shows an example using real polygon data.

2.3 Randomization of polygons within a window

The use of simulations for estimating the poisson model for polygons has one significant difference from a point pattern – polygons may overlap. If the original polygon dataset had overlaps (or the objects of interest could overlap) then randomisation of the polygons is simple. However, many polygon patterns are constrained to not overlap, and therefore the randomisation of these polygons must also satisfy this property. Unfortunately the random placement of polygons within a window without overlap is a difficult problem to solve efficiently. The current approach is that if overlapping is not allowed a set number of trials are conducted for each polygon, placing it randomly within the window until no overlap occurs. If the polygon cannot be placed it is ignored and the process continues until all polygons have been tried. This may result in fewer polygons being used for the Poisson estimate, however it avoids issues with overlapping randomisation creating artefacts that are especially noticeable when $r \approx 0$.

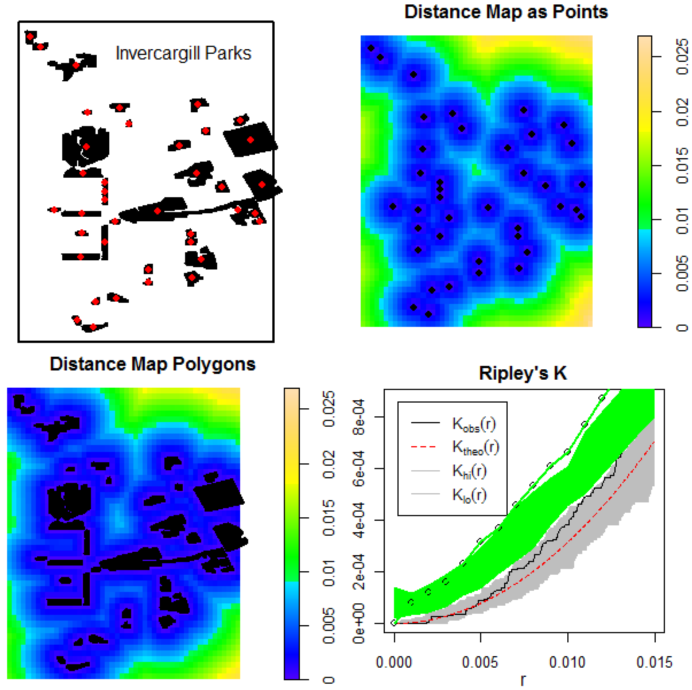

Figure 4. Ripley's K(r) and Distance maps for Invercargill Parks. The polygon Ripley's K is in green

3.0 CONCLUSIONS

This paper has presented the extension of two standard point-based functions to estimate whether a polygon dataset exhibits random, clustered or dispersed (regular) patterns in space. The reduction of polygons to points is likely to bias the estimate of the distribution properties of these data and therefore these types of operations are required if a true measure of the patterning in space is to be estimated. Other standard point-based functions have also been extended to polygon representations and will be described in detail in later publications.

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Towards a 'pattern language' for spatial simulation models

***David O'Sullivan*[1] *& George L. W. Perry*[1,2]**

[1]School of Environment and [2]School of Environment
University of Auckland. Private Bag 92019, Auckland 1142, New Zealand
Phone: +64 9 373-7599 Fax: +64 9 373-7434
Email: {d.osullivan, george.perry}@auckland.ac.nz

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1.0 INTRODUCTION

Computational models are widely used in fields from spatial ecology to transportation, and from archaeology to urban geography. Explicitly spatial simulation models are increasingly commonplace, and exhibit a seemingly broad diversity of underlying structures. The challenges of documenting such models are such that it can be difficult to see past details of specific models in order to generalise findings from any particular model. This is a challenge to making progress in computational model-oriented science.

Complexity science (Coveney and Highfield 1995, Mitchell 2008) is one over-arching framework which may be useful in thinking about these issues. However, even two or three decades (perhaps more, see Weaver, 1948) since its inception, complexity remains defined as much by the simulation models that constitute its major objects of study, as by any *a priori* or foundational definition of concepts. Noting the importance of building models to complexity science it is useful to consider one influential approach: *pattern-oriented modelling* (POM; Grimm et al. 2005, Grimm and Railsback 2012). In POM, when building a computational model of a system, the first task is to identify multiple patterns that the target system exhibits, which can serve as filters to inform model assessment. While the term 'pattern' is suggestive of the spatial behaviour of a system, Grimm et al. intend it to be understood to also cover temporal, statistical, or dynamical system behaviours. While POM was originally presented in the context of individual based models in ecology (Grimm et al. 2005), more recently it has been advocated for computational model building generally (Grimm and Railsback 2012).

POM is primarily intended to guide selection among alternative model structures, rather than as a bottom-up approach to model design. The approach we advocate here may be considered a further elaboration of the "patterns for model structure" step in POM (Grimm and Railsback 2012, page 301), where from the very earliest stages of model development attention is paid to general spatial properties of systems so that overall model elements are chosen that are likely to prove fruitful.

2.0 A SET OF BUILDING-BLOCK MODELS

Focusing on the spatial pattern outcomes of models allows us to organize the wide variety of spatial models into a manageable number of categories to use as starting points for model development. Below we briefly sketch a possible categorization of building-block models. These categories will be considered in more detail in our presentation at the conference.

2.1 Aggregation and segregation

A corollary of Tobler's 'first law of geography' (1970; see also Sui 2004) is that many systems consist of regions of similar attributes organized into patches. Many simple spatial processes yield such patterns, among them iterative *local-averaging* and its binary equivalent of *majority rule automata*. The latter is a particular instance of *totalistic automata* (Chopard 1998), many of which also produce subtly aggregated spatial patterns. *Interacting particle systems*, an alternative to cellular automata models, include *contact processes*, *succession models*, *voter models* and *exclusion processes* (Liggett 1999, Durrett and Levin 1994). The last of these is a version of Schelling's model of residential segregation (Schelling 1971, Zhang 2009), and confirms the value of making connections across the literature on spatial models. Whereas the processes above are 'bottom-up', an alternative is *iterative subdivision* of a system, either as a spatial 'tree' (Morgan 2011), or via a proximity polygon approach (Okabe et al. 2000).

2.2 Random walk

The *random walk* is a fundamental stochastic process, with a natural spatial interpretation (see e.g., Rudnick and Gaspari 2004). Numerous variants on the random walk exist, including *correlated walks* (Bovet and Benhamou 1988). A key distinction is that between diffusive and super-diffusive processes (*Lévy walks* or flights), the latter having attracted considerable attention in the movement ecology literature in recent years (Viswanathan et al. 2011). Consideration of the motivations underpinning movement yields models where walkers decide their next step by choosing among options in a differentiated landscape, most often a target resource. An early *foraging model* was described by Simon (1956). Behavioural rules where the choice of next target location is based on a simple calculation of the benefit-to-cost ratio can yield realistic movement patterns for many plausible spatially structured resources (Boyer et al. 2006). Another family of movement models is provided by various *flocking models*, where interaction among nearby individuals is a key driver (Schellink and White 2011).

2.3 Percolation and growth in heterogeneous spaces

Our third category of models focuses on the interaction between movement and spatial structure. While the literature on *percolation systems* (Grimmett 1999) is primarily concerned with the relationship between top-down random assignment of sites in a system to among fixed categories and the resulting spatial structures, this relationship is also central to the behavior of dynamic processes of growth. The spatial structures in a percolation system control the dynamics of spread in such systems. Closely related to percolation systems is a broad range of discrete growth models, related to the stepwise spread of invasive phenomena (e.g., fire, disease, urbanization). The most basic model is the *Eden growth model* (Eden 1961), along with a number of variants (Herrmann 1986). A related system of interest is *diffusion-limited aggregation* (Witten and Sander 1981). Many of these basic models have informed the development of models of urban growth, particularly work by Batty and Longley (1994).

3.0 CAVEATS AND CRITICISMS

We freely acknowledge that any attempt at a 'broad-brush' categorization of models is inevitably open to question. The point is not whether or not our classification is 'correct', but that this approach, by systematizing previous work on spatial models, can allow more rapid development of useful models building on that work.

A more substantive criticism is that our building-block models promote a phenomenological approach to model building, focused not on the mechanisms that lead to particular outcomes, but on the outcomes themselves. This might *force* particular patterns to emerge rather than *allowing* them, as advocated by Grimm and Railsback (2012, page 301). Nevertheless, we consider it useful to break system behaviour into categories such as averaging, diffusion, movement, succession, and so on, as part of the abstraction process inevitably demanded by model building. Furthermore, where a complicated model is composed of building-block models, any forcing is likely to be minimal since interaction among the building-blocks will determine overall outcomes. As do Grimm and Railsback, we recommend not blind adoption of building-blocks, but experimentation with multiple alternatives.

More philosophically, the distinction between phenomenological and mechanistic models is not clear-cut. Even the normal distribution can be considered 'mechanistic' seen from a particular perspective—as the outcome of an additive process or random walk. Even the most detailed of 'mechanistic' models ultimately remains a simplified mathematical model at some level of abstraction (see also Couclelis 1984). In a slightly different context, Scott Page (2011, page 250) argues that "discipline-specific assumptions that enhance realism can extend core models to make them useful within disciplines", and our approach is in keeping with this view.

4.0 VALUE OF THE BUILDING-BLOCK APPROACH AND FURTHER WORK

The approach to spatial model building we propose, advocates that we attend more closely to previous work in the field of spatial models. Rather than approach every spatial modelling task *de novo* we suggest considering the various spatial processes operating and spatial patterns exhibited at different scales, and using these, along with our knowledge of existing spatial models, expressed in terms of building-blocks, to inform more rapid and effective model development. One way to think of this approach is as a suggestion that we add local averaging, voter models, succession models (and so on) to our 'modelling toolkit', alongside the normal distribution and other familiar basic models, which are routinely used when we approach the analysis of any system.

Becoming more familiar with building-block models provides practical benefits in model development. First, is the potential for more rapid development of relatively complicated models. Second, knowledge of building-block models provides a basis for *neutral models* for use as null models, whether for assessment of real world outcomes, or as a testing ground for more central areas of interest in a system. Third, the modular model development that building-block models promote may allow for the structural evaluation of models, building on POM's "patterns for model structure" (Grimm and Railsback 2012, page 301).

An avenue for further work is the development of a more organized classification of our building-block models. In other fields, particularly architecture and urban design (Alexander et al. 1977), but also software engineering (Gamma et al. 1995), well understood components for the solution of complicated design problems have evolved into *pattern languages*. In pattern languages a *design pattern* is a template solution to commonly encountered design problems. We consider our building-block models to be roughly equivalent to such design patterns. Crucially, in pattern languages, design patterns are considered not in isolation from one another but as an *interrelated set of components* that can be combined to solve arbitrarily complicated problems in the domain of interest. Also significant is the idea that patterns are *hierarchically organized* and in a network of interdependencies, so that selection of one particular pattern for use suggests that other related patterns may also be useful. Our building-block models lack hierarchical organization or any mapping of their interrelationships. We will briefly present preliminary thinking on this aspect of our approach, to show how our building-block models might form a basis for development of a pattern language for spatial simulation modelling.

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O'Sullivan, D, and G. L. W. Perry (2013) Towards a 'pattern language' for spatial simulation models. Presented at the *109th Annual Meeting of the Association of American Geographers*, Los Angeles, CA, April 9–13.

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Geographical Vector Agent Modelling for Image Classification: Initial Development

Kambiz Borna, Pascal Sirguey & Antoni Moore

School of Surveying
University of Otago. Dunedin, New Zealand
Phone: +64 3 479 7698 Fax: +64 3 479 7586
Email: borna_kambiz@ymail.com; pascal.sirguey@otago.ac.nz; tony.moore@otago.ac.nz

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1.0 INTRODUCTION

Concomitant with the development of remote sensing imagery, image classification methods have added object-based image classification (OBC) to the prevailing pixel-based approach. The main distinctive characteristic of this method is to identify meaningful geographical objects, namely image objects, rather than individual pixels. At a primary level, image-objects are collections of contiguous pixels that are supposed to depict homogeneous thematic meaning, even if there is a variety of spectral values for the pixels within the object. Objects thus hold more information than pixel-based approaches, which only account for spectral content.

Despite the desirable and vast improvements that OBC has allowed, it still relies on a sequential process of segmentation of the image into objects followed by their classification. Nevertheless, this classical approach of OBC lacks the ability to complete the image segmentation by taking advantage of the thematic meaning of the object being created, as well as the procedural knowledge being generated during this process.

This limitation can be overcome by a dual approach which simultaneously runs the segmentation from pixels to interest objects, as well as the thematic classification of the objects being generated. Here we propose to implement this improved workflow by using geographical Vector Agents (VA). VAs are objects that have the ability to control and alter their shape and attributes in order to evolve in accordance with the nature of the phenomena being modelled. In this context, VA must support a dynamic geometry that can support both the segmentation and classification of the image in parallel.

2.0 VECTOR AGENTS

VA is a type of Geographic Automata in the sense that it is a processing mechanism characterized by states, transition rules, space and spatial behaviour (Benenson *et al.*, 2004). It addresses the limitations of Cellular Automata (CA) (Figure 1(1)) such as the assumption of regularity and the inability of movement of cells (Benenson *et al.*, 2004) by allowing a dynamic geometry (Figure. 1(4a)). VAs are geometric objects that can represent dynamic/static and regular/irregular vector boundaries with the potential to model a wide range of geospatial phenomena in the context of the geographic automata system (GAS) (Hammam *et al.*, 2007; Torrens *et al.*, 2003).

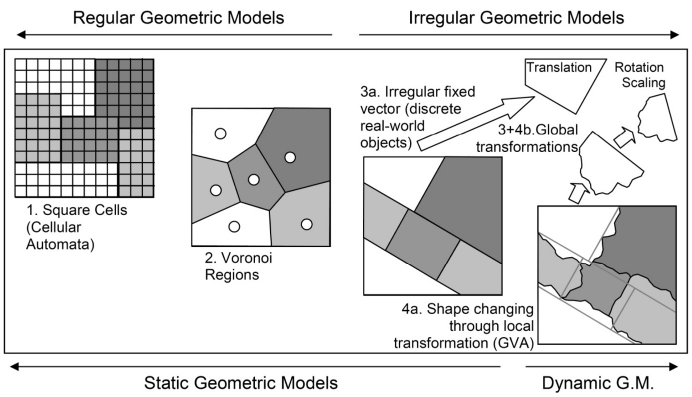

*Figure 1: Various methods of discrete spatial modelling, arranged on a continuum from regular to irregular geometry, and static to dynamic models (*Moore, 2011*).*

By enabling a state and spatial behaviour to be modelled based on geometric and contextual information, VA have the potential to model phenomena like image objects in a manner that approach better the parallelism of human interpretation, as opposed to the sequential processing of the OBC.

3.0 IMAGE OBJECT GEOMETRY IN THE CONTEXT OF THE VECTOR AGENT

An image object can be formed by aggregating pixels into a static irregular polygon (Figure. 2). To overcome the static geometry, the geometry of image objects is redefined in the context of the VA. In this sense, the image objects can be in point, line and polygon form and also they can change their geometry during the evolution process from point to the polygon. The points are a subset of the lattice points corresponding to the centre of pixels of the raster being classified. Furthermore, image objects can perceive and support the topological relationships, splitting and aggregation process, thus describing the geometry and topology in tandem.

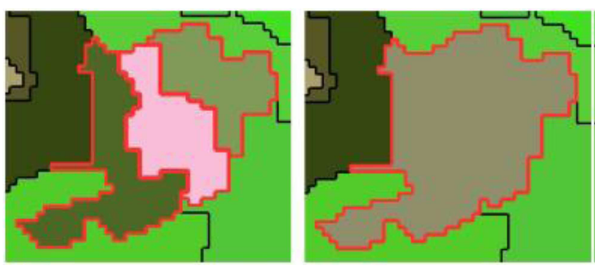

Figure 2: An irregular and static geometry of image objects representing (left) small scale and (right) large scale phenomena, respectively.

3.1 Image Objects Construction and Evolution

A winged-edge data structure represents an object by a set of faces, edges and vertices (Haidacher, 2011). The winged-edge is the central part of this data structure and is defined by a set of two vertices, two faces, and the successor and predecessor edges (Fig. 3). The use of the winged-edged data structure provides for a static irregular polygon so additional operations are required in order to support a dynamic geometry intended for the VA-based image objects classification (Figure. 4).

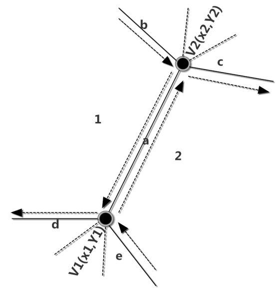

Figure 3: winged-edge data structure is a set of faces (1, 2), vertices (V1, V2), predecessor edges (b, e), and successor edges (c, d).

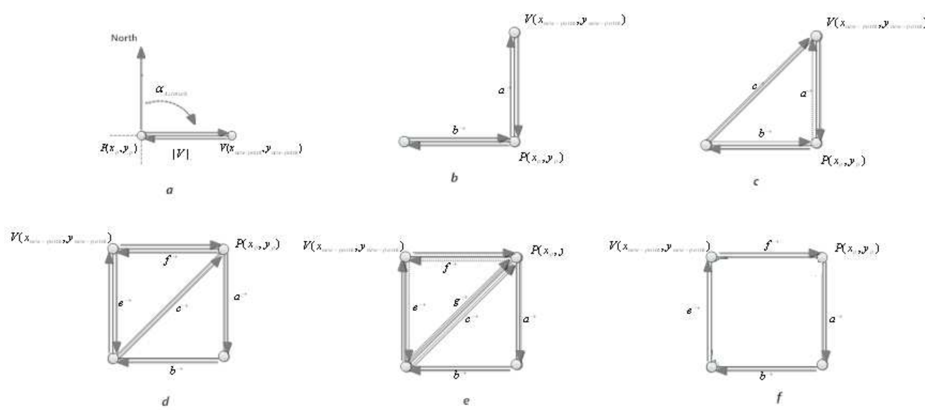

Figure 4: four elementary operations are required to change the image objects geometry: (a) vertex displacement, (b, c) edge joining, (d) edge displacement , and (e, f) edge remove.

Four elementary operations are defined to allow the geometry of vector agents to change dynamically:

1. Vertex displacement: this places a new vertex in the space image (Figure. 4a) and connect two vertices together by two half-edges.

2. Half-edge joining: this constructs a new edge based on a twin edge that is formed by two half-edges (Figure. 4b, c).

3. Edge remove: this forms a new polygon by the merging of two polygons (Figure. 4d, e).

4. Winged-edge displacement: a new edge is constructed based on two vertices (Figure. 4f), if there is a vertex in the effect neighbourhood of a new vertex.

To implement the above geometry in image space, we define a set of rules that consists of: (a) the initial geometry of image object is automatically formed as a point in the pixel centre; (b) each point can generate a new point along four cardinal directions by a constant distance that is specified by cell size r (c) the maximum length of each edge is equal to $r\sqrt{2}$; (d) each edge can be divided into two half- edges; (e) each new point has three reference points; and (f) an edge can be created if there is a point in the local neighbourhood of the new point, i.e., if the characteristics of the corresponding pixel meets some pre-defined criteria allowing it to belong to the VA.

Figures 5 & 6 illustrate how these rules are implemented by the image object, thus allowing its iterative evolution. First, a point is automatically initialized in space. Second, the first edge is randomly constructed by finding a second point in the local neighbourhood in space (Figure. 5a).The new edge being created consists of two half edges. Third, the first polygon is formed by finding the third and fourth point in image space. To do this, two half-edges (known as a twin edge) are combined to construct the first polygon (Figure. 5b). After the fifth point is placed in space, a new edge can be created where there is a point in the local neighbourhood of the new point (Figure. 5c, d). From here, the evolution process continues to reach a geometry that is associated with a homogeneous thematic class in the underlying raster image (Figure. 5e, f, g). An example of the evolutionary process of an image object is also illustrated from an initial square over one thousand iterations, in figure 6.

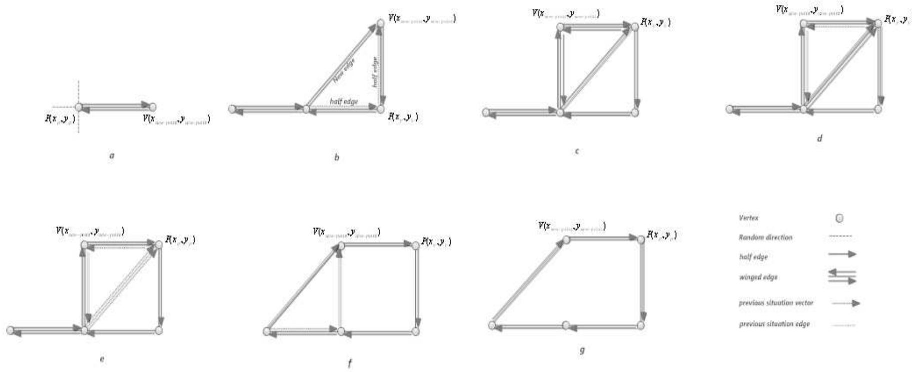

Figure 5: How an image object is born and evolves in the image space: (a) initializing by random point and construct the first edge, (b) to form the first polygon, and (c, d, e, f, g) to evolve an image object to reach interest the geometry of a thematic object.

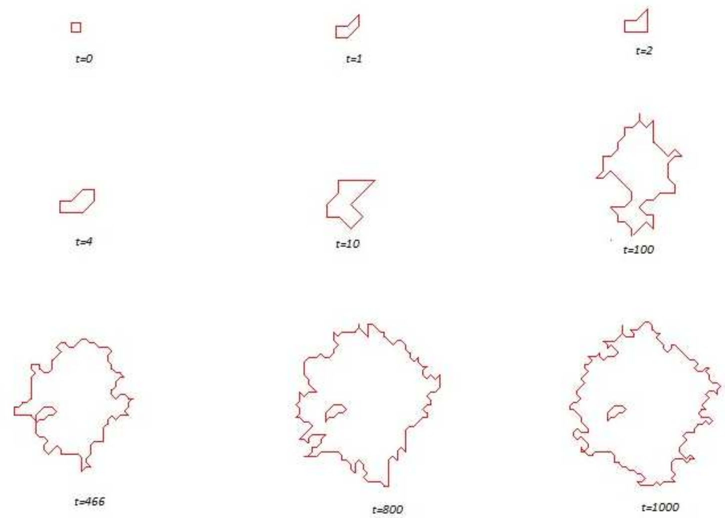

Figure 6: Simulation result for first 1000 time steps in the agent modelling shell Repast Simphony representing how an image object uses the four aforementioned operations to transform its geometry.

4.0 IMPLEMENTATION BASED ON A SYNTHETIC IMAGE

Many real world problems involve multiple measures of performance, or objectives, which should be optimized simultaneously (Fonseca et al, 1995). Classical OBC associates image objects from an initially fully segmented image into meaningful thematic classes. The proposed methodology simultaneously supports image segmentation and classification in tandem.

To implement this approach, we defined an initial simple scenario in which possible VA attributes are limited to the pixel value of a synthetic image formed by pixels of only 4 different values (Figure. 7). Three agents are initialized in image space and evolve according to the above-mentioned set of rules. Figure 8 illustrates this evolution and how VA aggregate themselves depending on the geometry and contextual properties, here the pixel value of the underlying raster image. VA evaluates how best to grow and merge until reaching an acceptable model of the image object's class (Figure. 8). Although simplistic at the moment, this approach provides many opportunities for refinements that can address the problem of image classification in a profoundly innovative way.

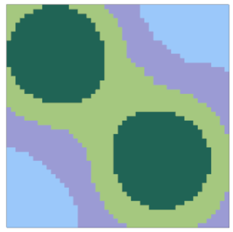

Figure 7: the synthetic image.

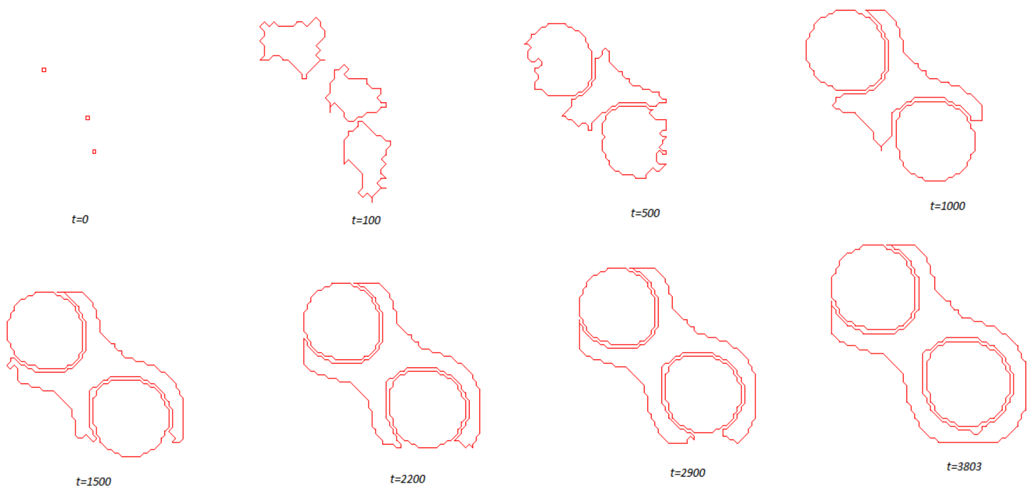

Figure 8: Simulation result for two classes, namely dark and light green colour to illustrate how the VA evolves under the constraint of the underlying raster image.

5.0 SUMMARY

The main concept of an innovative VA-based classification method was proposed, in order to execute simultaneously the process of image segmentation and classification. This research has highlighted some abilities of the VA to support a dynamic geometry for image objects. Further investigation should be performed to deal with issues of interaction between image objects, identification of initial classes, implementation of sophisticated feature space criteria to support classification, and the dynamic evolution of VA attributes during the iterative process.

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GIS modelling in support of earthquake-induced rockfall risk assessment in the Port Hills, Christchurch

Biljana Lukovic, David Heron, William Ries & Chris Massey

Natural Hazards Division
GNS Science, Lower Hutt, New Zealand
Phone: +64 4 570-4756 Fax: +64 4 570-1440
Email: b.lukovic@gns.cri.nz

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1.0 INTRODUCTION

The Mw 6.2 22nd February 2011 Christchurch earthquake, centred 6 km southeast of Christchurch City on the northern edge of the Port Hills, resulted in maximum vertical peak ground accelerations of 2.2 g and ground shaking intensities exceeding MM10 which caused rockfalls over some 65 km^2 of the Port Hills (see Figure 1).

The Port Hills are the eroded remnants of a large volcanic centre which has been breached by the sea to form Lyttelton Harbour. The landscape of the upper part of the volcano is dominated by cliffs of hard but fractured rock with long sloping aprons below. On the lower flanks the cliffs are fronted by flat ground. Urban development exists up to the base of the cliffs on the lower flanks and on the slopes above these cliffs.

The earthquake shaking dislodged boulders from cliffs and slopes in the upper part of the Port Hills and over 6000 boulders rolled down-slope. Cliffs on the lower Port Hills also collapsed but the impact was less widespread as the debris fell onto flat ground. Cliff top recession occurred on most of the cliffs that failed in the Port Hills but was worse on the lower slopes where in some locations the cliff retreated 6m. Rolling boulders and collapsing cliffs hit about 200 homes and killed 5 people, resulting in widespread evacuations.

Immediately after the earthquake geologists were in the field recording the location and size of fallen boulders and cracks associated with cliff recession and mapping the failed cliff faces. Large aftershocks on 16th April, 13th June and on 23rd December caused further boulder rolls and cliff collapses. LiDAR was flown after each event and a LiDAR dataset from before the February earthquake was obtained. Terrestrial Laser Scans were also made of each cliff face following each event.

2.0 GIS MODELLING

GNS Science was tasked by Christchurch City Council to assess the life-safety risk posed by earthquake-induced rockfalls in the Port Hills which included the risk from boulder rolls and cliff collapse. The results were used to support the formulation of a robust land-use and rebuild policy.

A pilot study (see Figure 1) covering 10 of the worst affected areas was used to develop risk models and once ground verified were extended to the whole of the Port Hills. GIS was the main tool used in the development of the risk models, but information generated using other tools and techniques was also heavily used in this process.

2.1 Boulder Rolls

Field work mapped 5,719 individual boulders that fell within the pilot study area. Individual boulder location, and in some instances size, runout distance, travel path, and triggering earthquake were captured into a GIS database.

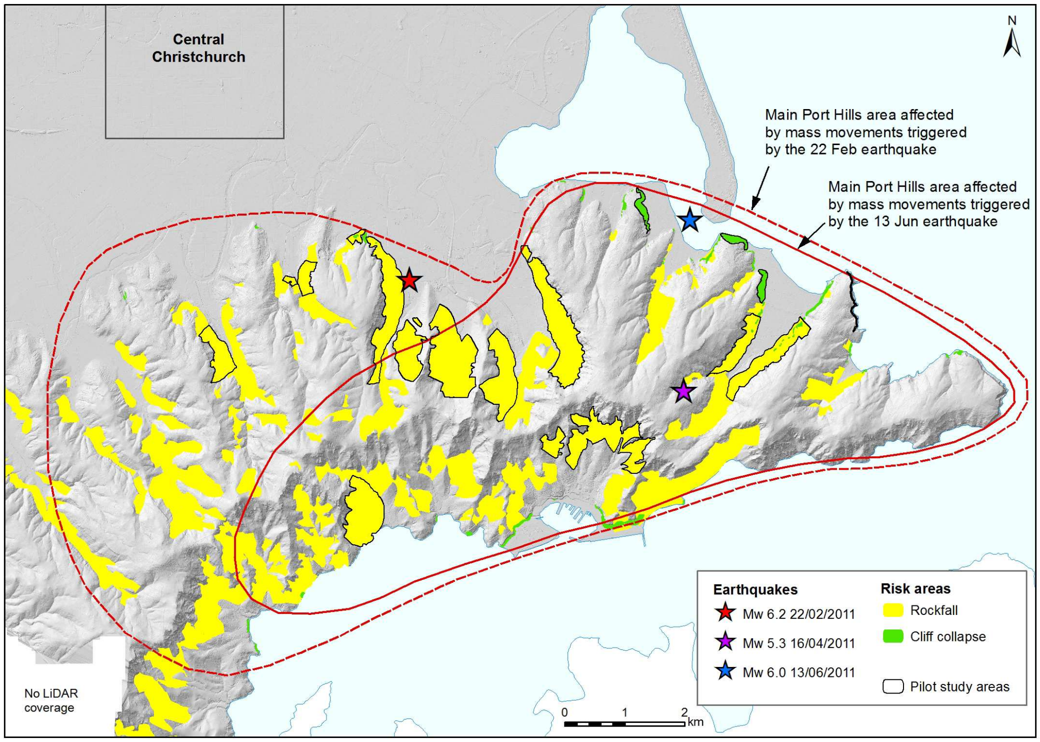

Figure 1: Location map showing areas affected by rockfall.

GIS-based analyses of the main boulder roll source areas using the post-22 February 2011 LiDAR elevation model indicated that all boulders came from slopes steeper than 35°, with the greatest numbers coming from slopes steeper than 45°.

Runout of the mapped boulders was first characterised by examining their downslope distance from the toe of the nearest source area and comparing the results with commonly used empirical runout models. The shadow-angle model (Lied 1977) was chosen as the best fit. The ArcINFO Visibility tool was used to model shadow angles at 2° increments ranging between 21° and 31° from the toe of the source (see Figure 2). The outputs were overlain with the fallen boulders to establish the number of boulders passing different shadow angles for each of the areas within the pilot study. The downslope limit of potential boulder runout could not be defined using only the shadow-angles, and input from other 2D rockfall modelling software and field mapping was necessary.

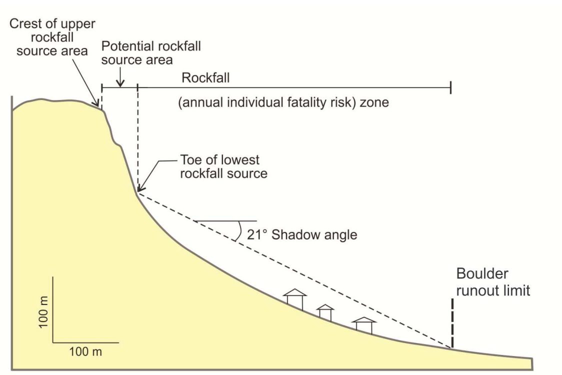

Figure 2: Boulder roll model using the shadow angle methodology.

The annual individual fatality risk from boulder rolls was determined by combining the annual probability of a rockfall-initiating event, the probability that a person is present at a location when the event occurs, the probability of that person being in the path of one or more boulders, and the probability that when present and in the path of a boulder, that person would be killed. The risk values were calculated for each of the modelled shadow angles in each of the 10 pilot areas. The shadow angle lines with attached risk values were converted to points and Natural Neighbour Interpolation used to model risk over the affected area, after which the resulting grids were classified and converted to risk polygons (see Figure 3).

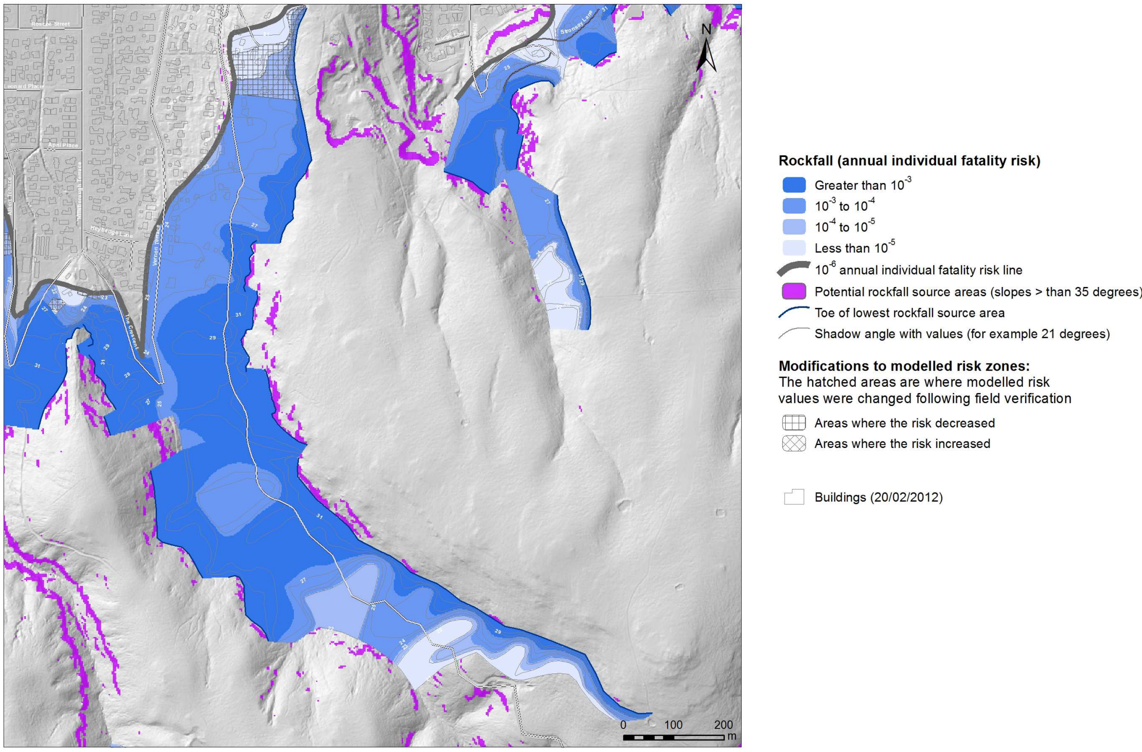

Figure 3: Rockfall (boulder roll) risk map showing source areas, risk polygons and areas modified following field verification.

Using the developed methodology the analysis was extended to include the entire Port Hills area. The risk values developed for the pilot areas were applied to similar slope morphologies in the non-pilot area and risk polygons were generated in the same way.

2.2 Cliff Collapse

Field mapping and analysis of the failed cliffs showed the main factors influencing cliff collapse were cliff height, cliff steepness, and the peak ground motions which could be amplified by topography and the geological materials present. The main life-safety risks associated with cliff collapse were from debris avalanches, which in places comprise tens of thousands of blocks, falling onto homes built at the base of the failing cliffs and the accompanying cliff top recession which impacted homes built on the cliff top (see Figure 4).

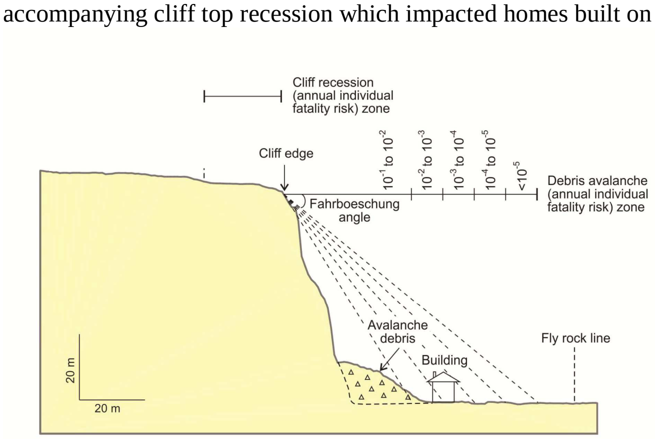

Figure 4: Cliff collapse model using the Fahrboeschung methodology and showing cliff recession.

Debris Avalanche
The LiDAR datasets were used to estimate the volume of material that accumulated below the cliffs following each earthquake using simple differencing methods. Estimates of debris volume made from LiDAR for each earthquake were compared to estimates of the volume of material that fell from the cliffs as determined from Terrestrial Laser Scans when available.

Field mapping indicated that cliff height was the main control on how far debris travelled from a failed cliff. Fahrboeschung lines (Heim 1932) were modelled for view angles between 60° and 31° from the cliff top using the ArcINFO visibility tool and the volume of material within each zone calculated. The Fahrboeschung model (see Figure 4) showed a good fit to the data.

The annual individual fatality risk from debris avalanche was determined in the same way as for boulder rolls. The risk values were calculated for each Fahrboeschung angle in each of the pilot areas and risk modelled using the same methodology. The risk values developed in the pilot area were applied to Fahrboeschung lines modelled for the rest of the Port Hills.

Cliff Recession
The LiDAR datasets were used to establish the cliff top position prior to and after the February earthquake and following each large aftershock. The cliff top was defined as the position where the slope exceeded 40° and where rock was apparent.

Using the derived cliff top positions it was possible to determine the length of each cliff top that failed in each of the earthquakes and how far the cliff had receded at any point along its length. The land upslope of the pre-February earthquake cliff top position was divided into zones 1 m wide for a distance of 30 m from the cliff top, and these were intersected with the post-February earthquake cliff top position. This allowed the area in each of the 1 m zones to be calculated and therefore the proportion of the cliff that failed, as a function of distance from the original cliff position, to be determined. This process was repeated for each aftershock in each of the pilot study areas.

The results were analysed along with cliff height measurements, descriptions of the geological materials present and earthquake accelerations to provide an assessment of the probability of a failure occurring in the future. The annual individual fatality risk from cliff top recession was determined in the same way as for boulder rolls and the risk values developed in the pilot area were applied to the rest of the Port Hills.

3.0 FIELD VERIFICATION

The initial risk models for boulder roll, debris avalanche and cliff recession were field checked by independent consultants and the risk zones modified where necessary (see Figure 3). Changes were typically made where field verification identified additional source areas or modifications to the source areas, and where the risk zones did not take into account the localised topography causing funnelling or deflection of boulders.

4.0 CONCLUSIONS

GIS was used to model the risk associated with boulder roll, debris avalanche and cliff recession in the Port Hills. Modelling was based on datasets resulting from field mapping of individual rockfalls and debris avalanches, 2D rockfall trajectory modelling, LiDAR surveys and Terrestrial Laser Scans, and made extensive use of the ArcINFO Visibility and Interpolation tools. Life-safety risk zones were developed, field checked and modified, and provided to Christchurch City Council for use in developing land-use and rebuild policies (Massey *et al.* 2012a, 2012b).

ACKNOWLEDGEMENTS

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Predicting potential anchor ice formation sites in coastal Antarctic Waters

Greg Leonard[1], Andrew Pauling[2], Sarah Mager[3] & Inga Smith[2]

[1]National School of Surveying
University of Otago, Dunedin, New Zealand
Email: greg.leonard@otago.ac.nz

[2]Department of Physics
University of Otago, Dunedin, New Zealand

[3]Department of Geography
University of Otago, Dunedin, New Zealand

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1.0 INTRODUCTION

The term anchor ice (see Figure 1) describes clusters of ice attached to the beds of rivers, lakes and the sea. This ice is an important vector for the mobilization of bed sediments and also serves an ecological role as a food source, habitat and potentially fatal environment for biological communities. In Antarctica, ice shelves and their associated plumes of supercooled water are believed to be a main driver behind the formation of anchor ice due to a process commonly referred to as an "ice pump". Relatively warm, salty seawater contacts the basal plane of an ice shelf causing it to melt. The resultant melt water, which is more buoyant than the ambient water due to its relative freshness, rises along the base plane becoming potentially supercooled in the process due to the pressure dependency of its freezing point with depth. Such plumes have been demonstrated to significantly enhance the growth of landfast sea ice in waters adjacent to an ice shelf front as the plume is swept out from underneath an ice shelf due to underlying currents. Anchor ice growth may be initiated in those regions where plumes intersect the local seafloor.

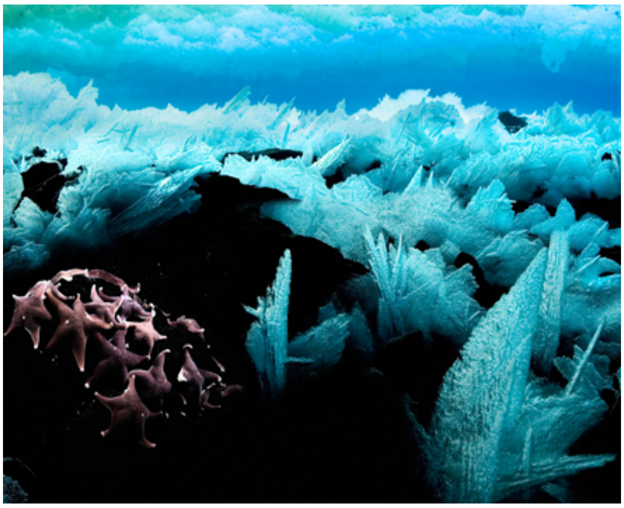

Figure 1: Anchor ice on the seabed in McMurdo Sound. Photo credit John B. Weller.

A recent review paper on anchor ice formation (Mager *et al*., 2013) identified the ice pump process as a significant driver of anchor ice formation in Antarctic coastal waters. One key observation from their work is that there have been no reports of anchor ice in Antarctic waters at depths greater than 30 m, even though an ice pump could theoretically initiate anchor ice growth at greater depths. It is not known how far beyond the edge of an ice shelf a supercooled plume may persist, although current work undertaken in McMurdo Sound indicates that this may be up to a maximum of around 250 km (Hughes, 2013). Information on where anchor ice is likely to form will be useful for Antarctic researchers investigating benthic ecosystems, sediment transport and sea ice / ice shelf interactions. In this study we aim to identify potential sites suitable for anchor ice formation around the Antarctic continent through the use of a 1st order geospatial model that is informed by the current understanding of anchor ice formation processes in Antarctica.

2.0 METHODS

Key inputs to the geospatial model are the Antarctic Digital Database (SCAR, 2012) and digital elevation models (DEMs) of Antarctic coastal waters and parameterizations of anchor ice formation processes. Pan-Antarctic DEMs include Bedmap2 (Fretwell *et al.*, 2013) and the International Bathymetric Chart for the Southern Ocean (IBCSO 1.0) (Arndt *et al.*, 2013), however, a recently undertaken comparison between Bedmap2 and IBCSO yielded elevation anomalies upwards of ± 2.4 km (See Figure 2). Thus a synthesis of pan-Antarctic and regional or local bathymetry products is necessary to produce the accuracy required to predict anchor ice formation sites as the depth of the seafloor is a critical factor in this endeavour. We make use of marine trackline bathymetry data and regional bathymetric data (where available) to validate and adjust, where necessary, larger scale bathymetry models. The marine trackline data from research vessels is readily available via data centres such as the National Geophysical Data Center (NGDC) while regional bathymetry data is available from national-body research institutes (e.g. GNS, Australian Antarctic Division, etc.).

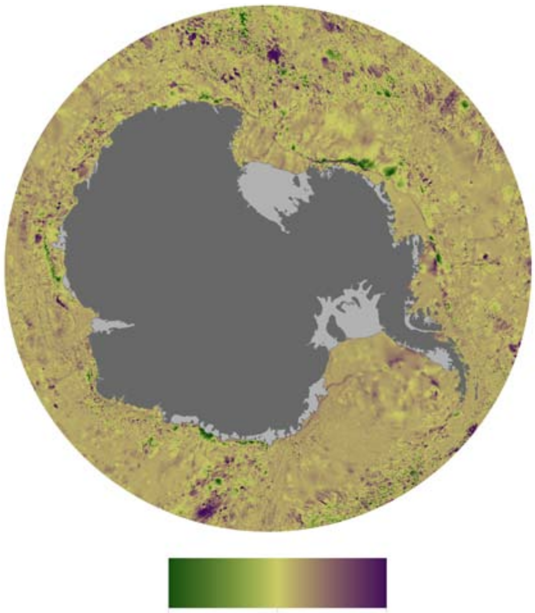

Figure 2: Comparison of Bedmap2 and IBCSO bathymetry. Pixel resolution is 500 m.

Once the trackline bathymetry data is sourced and collected, location and elevation data is extracted from the trackline bathymetry data using the open source software package MB-System and stored in an ESRI file geodatabase. In regions where there is sufficient density of tracklines and local bathymetry data, these will be combined to create ESRI Terrain models of the local seafloor. These terrains are then compared to gridded bathymetry data to determine potential erroneous data, and where there is sufficient data, a 3D surface of the coastal sea floor will be generated, following the method of Basu and Malhotra (2002). An example of a terrain model constructed from a synthesis of regional and pan-Antarctic bathymetry data for McMurdo Sound in shown in Figure 3. Ultimately this process will be replicated for suitable coastal regions across the entire Antarctic continent, although in this paper we are only presenting work undertaken in McMurdo Sound. Once the bathymetric data has been synthesised for a particular region, a 1st order geospatial model is constructed and used to locate intersections between ice shelf plumes and the local seafloor, and hence predict potential anchor ice formation sites. Model sensitivity will be examined by modifying key input parameters, such as plume depth and extent and degree of supercooling.

3.0 SUMMARY

This works represents the first steps towards predicting anchor ice formation sites along the entirety of the Antarctic coastline. It builds on work that has been undertaken over the past two summers at the University of Otago that included the review of current literature to determine the state of knowledge of anchor ice formation processes and the extent of anchor ice observations, the identification of likely formation processes for Antarctic anchor ice and the construction of a preliminary prediction model for McMurdo Sound. This work is expanded on here by refining the underlying bathymetry models and assessing model sensitivity to key input parameters. It is envisaged that the output from the modelling work will provide the basis of a future field-based study examining the physical and chemical characteristics of anchor ice.

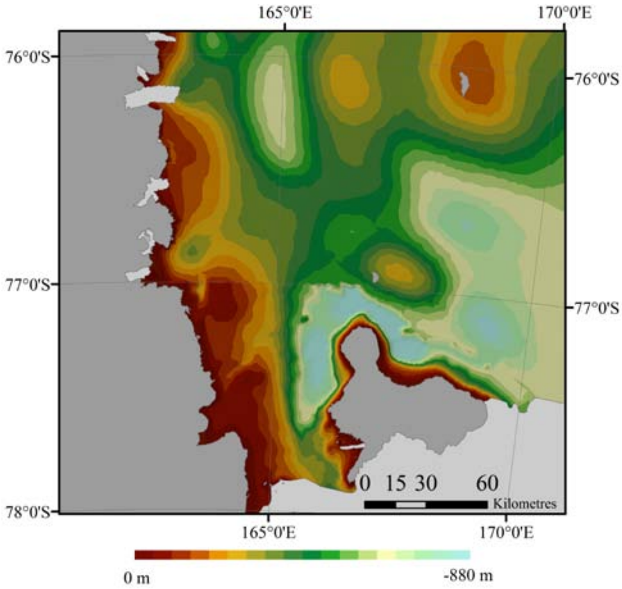

Figure 3: ESRI Terrain model of McMurdo Sound Antarctica shown in a Lambert Conformal Conic projection. GNS regional bathymetry is used for areas south of the 77th parallel, while Bedmap2 bathymetry is used for areas to the north of the 77th parallel.

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Recent Ice Wastage on the Tasman Glacier Obtained from Geodetic Elevation Changes

Sebastián Vivero[12], Pascal Sirguey[2], Sean J. Fitzsimons[1], Delia Strong[3], Alvaro Soruco[4]

[1]Department of Geography
University of Otago, Dunedin, New Zealand
Email: shvivero@gmail.com

[2]School of Surveying
University of Otago, Dunedin, New Zealand
Phone: +64 3 479-7698
Email: pascal.sirguey@otago.ac.nz

[3]GNS Science
Fairway Drive, PO box 30-368, Lower Hutt 5040, New Zealand
Phone: +64 4 570-4227
Email: D.Strong@gns.cri.nz

[4]Instituto de Investigaciones Geológicas y del Medio Ambiente
Universidad Mayor de San Andrés, La Paz, Bolivia
Email: alvaro.soruco@gmail.com

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1.0 INTRODUCTION

Mountain glaciers and ice caps cover an area of 740,000 km^2 (Radić and Hock, 2010) and store ca. 0.7% of the total ice volume available on the Earth's surface (Dyurgerov and Meier, 2005). Meltwater runoff originated from mountain glaciers can play an essential role for providing water resources for human consumption, irrigation systems and hydroelectric power generation (Barnett *et al*. 2005). Among the 3144 glaciers located in New Zealand the Tasman Glacier is the country's largest glacier with an area of ca. 100 km^2 in 1978 (Chinn, 2001). Since the early 1990s it has undergone a rapid frontal retreat associated with the concomitant expansion of a proglacial ice-contact lake. Historical and more recent data indicates an increasing in the thinning rates in the lower glacier (Hochstein *et al*. 1995; Quincey and Glasser, 2008), but the lack of recent glacier-wide information about elevation change precluded a more accurate representation of the contemporaneous ice volume loss.

In this paper, elevation and volume change of the Tasman Glacier and its tributary glaciers were measured between 1986 and 2008 using the photogrammetric processing of vertical aerial photographs, and bathymetric data of Tasman Lake. Detailed analysis of the multitemporal DEM enabled the geodetic surface elevation and mass balance changes to be quantified. Our analysis revealed diverse spatial patterns of thickness and volume change, varying between the tributaries and within and between elevation bins.

2.0 DATA AND METHODS

Two sets of vertical aerial photographs were acquired in 1986 and 2008 by New Zealand Aerial Mapping Ltd (NZAM). Forty-nine colour frames and 13 panchromatic frames were scanned at 14 µm resolution, yielding an average ground spatial resolution of 50 cm and 80 cm for the 2008 and 1986 aerial photographs, respectively. In order to perform an aerial triangulation, we measured 10 GCPs near stable features outside the glacier area using a Trimble R8 differential GPS, with occupation times between 10 and 15 minutes. Mt John Observatory tracking station was used during the post processing step, yielding GCP locations with an uncertainty of ±0.01 m. In addition, we employed data from a bathymetric survey of the Tasman Lake performed in 2008 by a research team from Massey University. About 913 discrete water-depth points were measured using a Hummingbird 323 DualBeam Plus echo-sounder and with a vertical accuracy estimated as ±6 m (Dykes *et al*. 2011).

GCPs, tie points and on-board GPS instrument data were used to perform an aerial triangulation in Leica Photogrammetry Suite (LPS) 2011 (Figure 1). The DEMs were generated at 5 m regular grids using a nonlinear interpolator method based on a fifth-order polynomial function. In addition, bathymetric data were interpolated, gridded and adjusted to the 2008 DEM to create a comprehensive ice surface elevation model. Elevation changes were calculated as the difference between the two DEMs on a pixel basis (Etzelmüller, 2000). Errors associated with the differential DEM and the derived volume and mass balance were considered using the method of Barrand and others (2010).

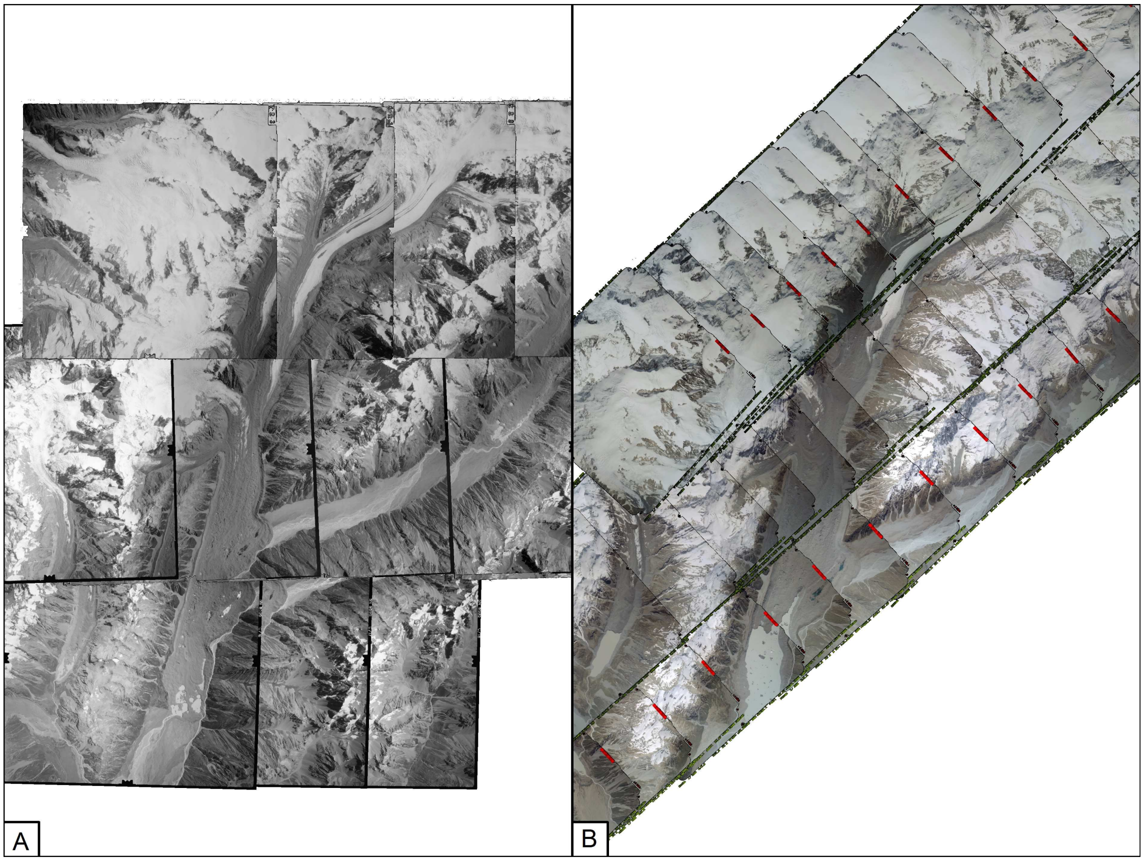

Figure 1: (A) 1986 aerial triangulation of the study area. (B) 2008 aerial triangulation of the study area.

3.0 RESULTS

Complex elevation changes were found in the debris-covered area below the Hochstetter Confluence. Glacier elevation changes originated from glacier downwasting, ice flow, and local rockfall deposits. In general, high rates of ice loss are found in the lower glacier between the terminus and the upper limit of the Hochstetter Confluence (Figure 2). However, tributary glaciers exhibit contrasting differences in elevation change that appears to be related to the aspect of the tributaries. Thus, tributaries on the western side of the main Tasman Glacier exhibit significantly larger change rate than those on the eastern side. We found that the overall Tasman Glacier and tributaries lost $19.72 \pm 0.05 \times 10^8$ m^3 of ice between February 1986 and February 2008. This ice wastage corresponds to an area-averaged geodetic balance of -0.87 ± 0.002 m w. eq. yr^{-1}. The main Tasman Glacier accounts for ca. 85% of this ice volume loss. Of the remaining 15% of the total ice loss, the second most important contributor is the Hochstetter Glacier, reaching $1.37 \pm 0.02 \times 10^8$ m^3 of ice loss or 7%. The ice volume lost due to the expansion of the Tasman Lake reaches $5.53 \pm 0.015 \times 10^8$ m^3, whereas the ice volume lost due to downwasting equates to $14.18 \pm 0.05 \times 10^8$ m^3.

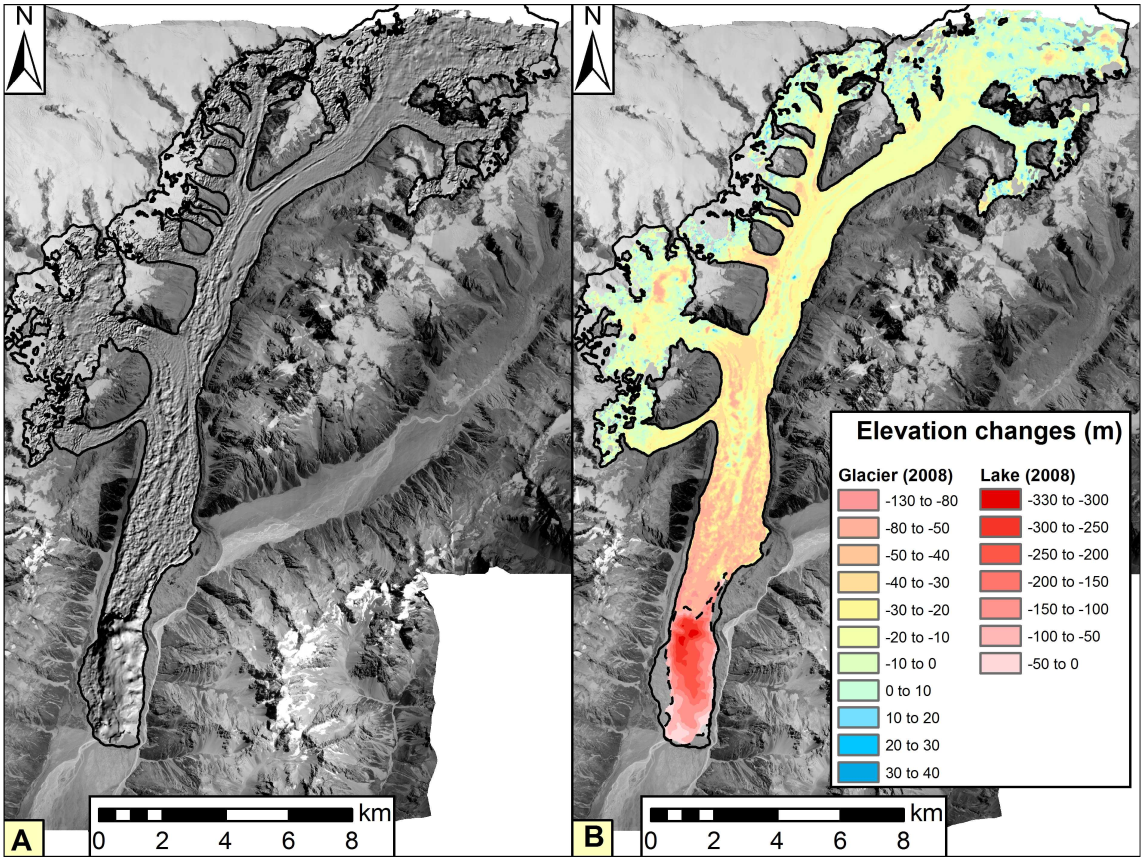

Figure 2: Glacier elevation changes between 1986 and 2008. (A) Hillshade representation of the elevation changes. (B) Elevation change for the glacier (continuous black line) and lake (dashed black line) areas. White gaps within the glacier represent areas without photogrammetric restitution. The orthophotomosaic from 1986 is displayed as a background.

4.0 CONCLUSIONS

The Tasman Glacier has lost a large mass of ice as the terminus has retreated, calved and thinned. From 1986 to 2008 the average annual rate of terminus retreat was -194 m yr^{-1}. For the same period, the loss in volume of the Tasman Glacier and its tributary glaciers corresponds to ca. 2 km^3, where the main Tasman Glacier accounts for ca. 85% of this ice loss. The present work has demonstrated the importance of using recent bathymetric data to fully calculated volume change in glaciers with recently developed ice-contact lakes. Although seemingly essential, the inclusion of bathymetric data in geodetic mass balance measurements on calving glaciers has attracted little attention. We estimated that the geodetic mass balance values on calving glaciers reported elsewhere may be biased toward less negative values due the lack of concomitant bathymetric measurements.

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Modelling Ice Retreat on Kilimanjaro Using GIS

***Rosie Wood*[1], *Pascal Sirguey*[1], *Nicolas J. Cullen*[2]**

[1]School of Surveying
University of Otago. Dunedin, New Zealand
Phone: +64 3 479-7698
Email: pascal.sirguey@otago.ac.nz

[2]Department of Geography
University of Otago. Dunedin, New Zealand

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1.0 INTRODUCTION

Since the late 1800's the ice fields on the top of Mt. Kilimanjaro have been retreating (Cullen *et al.*, 2006, Hastenrath, 2006). In order to document and analyse this demise, the mapping of the ice bodies has been addressed by several studies. This relied on multiple techniques such as ground photogrammetry (Klute, 1920), or more recently using satellite imaging. Recently, Cullen *et al.* (2013) revisited the mapping of glaciers and produced a set of eight outlines of ice extent over Kilimanjaro for the past 100 years. These maps are depicting the unabated retreat of the ice mass and allow the rate of retreat to be analysed.

Contrasting topographic settings such as aspect, slope, and height of glaciers have a potential influence on the retreat of glaciers (Hastenrath and Greischar, 1997, Cullen *et al.*, 2006, Racoviteanu, 2008, Thompson *et al.*, 2009). On Kilimanjaro, rates of areal retreat have been found to vary across different domains of the mountain from 2.32% to 5.23% between 2000 and 2007 (Thompson *et al*., 2009). Alternatively, Cullen *et al.* (2013) identified three contrasting glacier zones (western, plateau, and southern regions) exhibiting areal rates of retreat of 0.043, 0.034, and 0.021 km^2/yr, respectively. Under the assumption that these rates hold true since retreat started, it can be estimated that the plateau, except the Ruesch Crater, was entirely covered with ice around 1830.

The new dataset established by Cullen *et al.* (2013) provides an opportunity to further characterize the retreat of the glaciers. In particular, the complex geometry and pattern of retreat complicated the use of typical measures such as the planimetric retreat rate of the glacier terminus to characterize the demise. Thus, only the areal extent has been considered and exhibited an approximately linear retreat rate allowing projections to be made with regard to the disappearance of ice (Cullen *et al.*, 2013). This study uses geographic information systems to characterize further the disappearance of glaciers by considering the planimetric rate of retreat of the boundaries of ice bodies on Kibo. Firstly, the topographic settings of the ice boundaries were investigated as potential drivers controlling the planimetric retreat rate. Secondly, a linear model of boundary retreat was formed that allowed the glacier outlines of the plateau region to be interpolated between the documented epochs.

2.0 DATA AND METHODS

A series of eight digital outlines of Kilimanjaro glaciers from the past one hundred years was used to characterise the retreat of the glacier's boundaries and to interpolate the extent of the ice bodies between known epochs (Cullen *et al.*, 2013). A distance model was created that provided the shortest Euclidean distance from equally spaced points along each glacier outline to the outline of the previous or the next epoch. Underlying topographic variables such as elevation, slope, and aspect were retrieved for each point from the analysis of the 30m SRTM DEM. On the relatively flat plateau region, where most of the boundaries are ice cliffs, the aspect variable derived from the SRTM DEM was unreliable to represent the orientation of the cliffs. The direction of the normal vector to the outline at equally spaced points was considered as a better representation of the cliff's orientation. The correlation between the planimetric retreat rate of the boundary and each morphometric measure was investigated by considering the entire set of glacier outlines, as well as outlines from each of the three regions identified by Cullen *et al.* (2013).

Over the plateau region, the retreat rate of the ice cliffs was derived for equally spaced points along each outline and for each pair of documented epochs. This allowed the location of the cliff to be interpolated between each epoch pair by intervals of no more than 10 years. The area of the interpolated outlines was computed and its trend was compared with the trend inferred from the observation points. This process was to reveal whether the inherently complex geometry of the glacier outlines allowed both the planimetric retreat of the boundary and the corresponding glacierized area to obey linear trends simultaneously. In turn, it provided reliability to the interpolated outlines between documented epochs.

3.0 RESULTS

The analysis of the rate of retreat of the glacier boundaries with respect to topographic variables failed to reveal any clear or systematic pattern, whether considering the entire set of outlines or within each region. This contrast with the fact that the areal extent retreat rate appears clearly related to morphometric variables (Cullen *et al.*, 2013). It is hypothesized that the shortest distance model may have failed to resolve the ambiguities associated with the trajectory of the glacier outlines, especially given the complex geometry of the set of polygons. This may have been further impaired by the large time span between some of the documented epochs. Furthermore, the relatively poor quality of the SRTM DEM in this steep region, and the fact that its unique epoch (February 2000) failed to resolve the changing topography associated with the glacial retreat may have yielded uncertainties in the derived variables that could have contributed to the noisy and uncertain relationship.

The lack of any clear empirical relationship between the boundary retreat rate and topographic variables compromised the use of the morphometric measures to design an elaborated model of boundary retreat. Instead, the interpolation of glacier outlines between epochs was only attempted on the plateau region as the geometry of the ice bodies was less subject to follow the underlying topography. Winkler *et al*. (2010), who surveyed the retreat of an ice cliff between 2005 to 2008 reported retreat rates of about 1.4cm a month during the beginning of March to mid-October and 13cm a month the rest of the year (or using simple math, 69cm a year). Although it was difficult to identify precisely the exact location of the cliff, results from this study revealed retreat rates ranging from 2 to 75cm per year between 2003 and 2011. A linear retreat rate of the ice boundary was thus assumed to estimate the position of the ice cliffs between each epoch pair. The interpolated outlines are shown in Figure 1. The modelled areal extent of the plateau glaciers obtained from the interpolated outlines was compared with the retreat from the observations and shown in Figure 2. This suggests that, despite the complex geometry of the ice bodies, a linear rate of retreat of the ice cliffs between two epochs is an appropriate assumption to depict observed changes in ice extent in the plateau region. In turn, it is argued that the shape of the interpolated extents can be regarded as relevant candidates of the ice extent at the undocumented epochs.

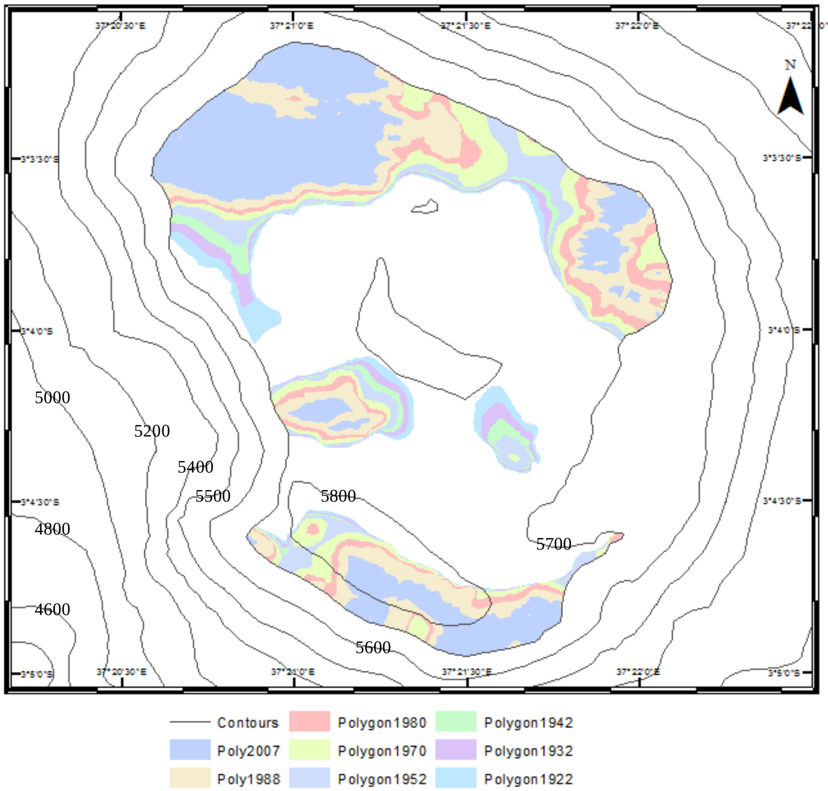

Figure 1. Interpolated ice extents between documented epochs.

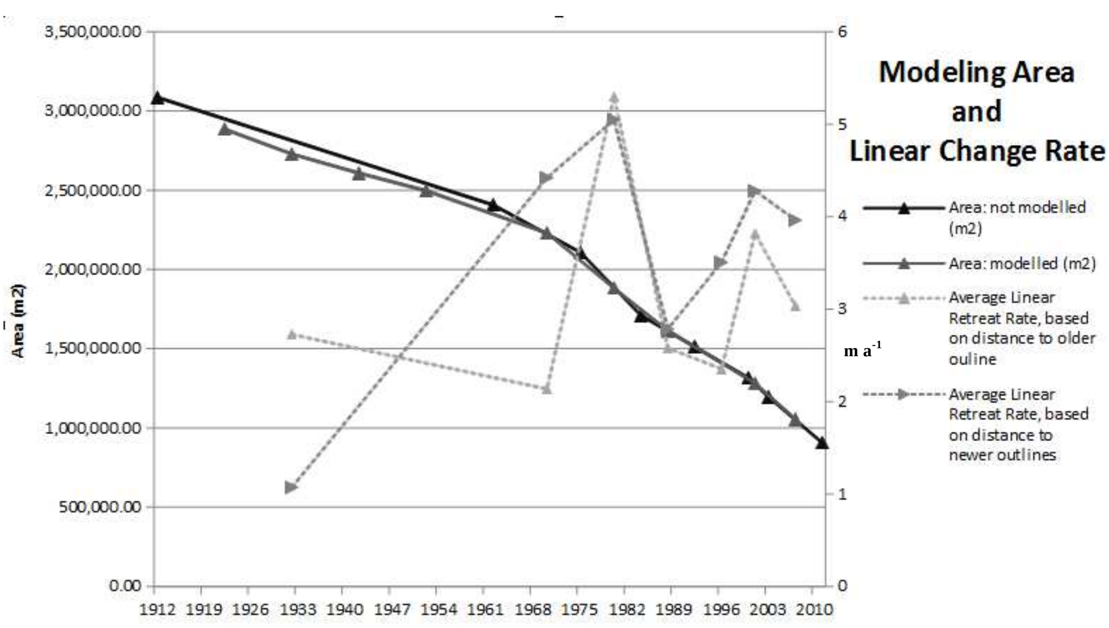

Figure 2: Area of the glaciated plateau for observed and interpolated epochs.

4.0 CONCLUSIONS

The lack of correlation between topography and distance between outlines could have been expected when considering all regions due to the large variation controlling the ablation of ice. It was however unexpected to find so little signal from the topography to govern the planimetric retreat of the ice boundaries in each region when analysed independently. Despite this, it is anticipated that a model of this kind may be used to characterize the retreat of glaciers when the geometry is not complex and clearly constrained by the underlying topography.

Interpolated outlines of the glacier extent could nonetheless be obtained for the plateau region based on a simple assumption of a linear retreat of the ice boundaries. This proved valid to generate outlines for which the areal extent matched closely to the observed trend, making the interpolated outlines credible. This approach could form the basis of extrapolations to predict the pattern of ice retreat, as well as to obtain an alternative estimate of the date at which the summit of Kilimanjaro was totally covered by glaciers.

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Snowfall detection in Antarctica using MODIS ground infrared reflectance

Bob Noonan [1], Pascal Sirguey [2], Wolfgang Rack [3], Wendy Lawson [4]

[1] Centre for Atmospheric Research,
University of Canterbury. P.O. Box 4800.Christchurch, New Zealand
Email: bob.noonan@pg.canterbury.ac.nz

[2] School of Surveying / Te Kura Kairūri
University of Otago. P.O. Box 56. Dunedin 9054, New Zealand
Phone: +64(0)3 479 7698 Fax: +64(0)3 479 7586
Email: pascal.sirguey@otago.ac.nz

[3] Gateway Antarctica,
University of Canterbury. P.O. Box 4800. Christchurch, New Zealand
Email: wolfgang.rack@canterbury.ac.nz

[4] Department of Geography,
University of Canterbury. P.O. Box 4800.Christchurch, New Zealand
Email: wendy.lawson@canterbury.ac.nz

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1.0 INTRODUCTION

Information about snow accumulation in Antarctica is difficult to obtain, but crucial for surface mass balance (SMB) and climate studies. Remote sensing methods to detect snowfall in non-permanently snow covered areas have limited use in Antarctica (Eveland et al., 2012) where only limited contrast exist between the deposited snow and the pre-snow surface. The interpolation of measurements from field based snow studies (Arthern et al., 2006; Giovinetto and Zwally, 2000; Vaughan et al., 1999) and the results of climate modelling studies (Monaghan et al., 2006) therefore, often support the determination of snowfall and snow accumulation events. However, these data are irregular in nature and/or have coarse spatiotemporal resolution.

Bindschadler et al. (2005) successfully captured accumulation events in Antarctica from passive microwave emission (85 GHz) and altimetry data with a relatively coarse resolution (12.5 km). Recently, Wiebe et al. (2013) retrieved grain size using bands 2 and 5 in the near and shortwave infrared of the Moderate Imaging Spectroradiometer (MODIS) sensor, installed on the Terra and Aqua satellites. They stressed the possibility of detecting snow fall based on the observed decrease in snow grain size. An advantage of MODIS observations is the ability to obtain a spatial distribution of such observations several times a day over Antarctica, thus allowing the spatio-temporal pattern of snow accumulation to be depicted at a resolution of 250 m.

Towards the goal of improving the modelling of SMB and climate of glaciers in Antarctica, this study presents a simple method to detect snow fall in topographically challenging terrain in Antarctica by monitoring the temporal evolution of MODIS ground reflectance in the near and shortwave infrared.

2.0 METHOD AND DATA

The area of study includes the Byrd glacier and Darwin-Hatherton glacial system (DHGS) (Figure 1). The Byrd glacier is a major transporter of ice from the East Antarctic Ice Sheet (EAIS), estimated to contribute ~18% of the total inflow to the Ross Ice Shelf. It is believed that changes to this glacier may affect the stability of the EAIS due to its large catchment area (Stearns, 2011). The glacier system is composed of areas of exposed blue ice, as well as of permanent snow cover. Surface height/albedo data have been recorded for two summer periods by Automatic Weather Stations (AWS). Additional data is also available from an AWS located south of the Byrd glacier (Sinclair et al., 2010). Two AWS are located over blue ice on the Darwin and Hatherton Glacier, one AWS is positioned on rocks near the outlet of Darwin Glacier, the last is located on permanent snow cover. Data were acquired over two austral summers: December/January 2007/2008 and 2008/2009.

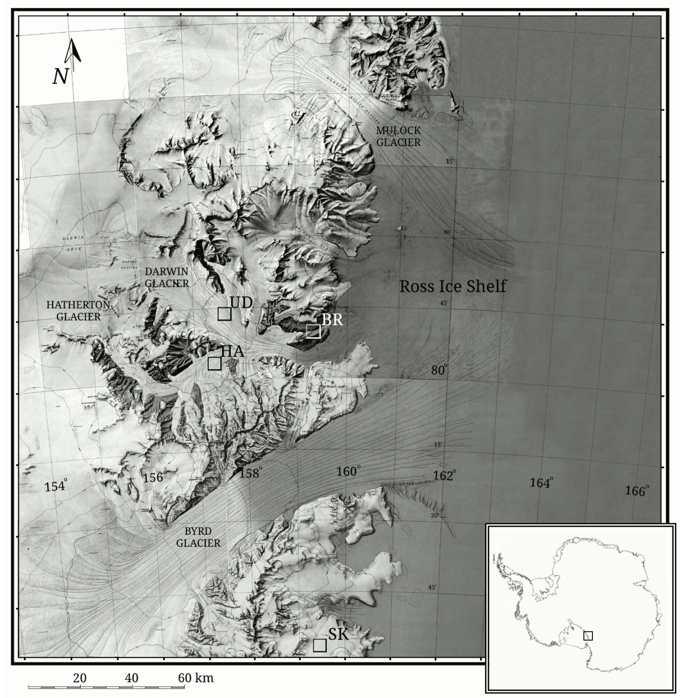

Figure 1: Location of the Byrd, Darwin and Hatherton glaciers, and locations of automatic weather stations (marked with squares) used in the validation of the results. Weather stations are: UD: Upper Darwin, HA: Hatherton, BR: Brown Hills, SK: Skinner Saddle.

892 Level-1B Swath products from MODIS-Terra (MOD02QKM, MOD02HKM, MOD021KM, MOD03) were used, representing more than seven images per day. These products provide calibrated radiance at the top of the atmosphere. The L-1B data were normalized to ground reflectance using the topographic and atmospheric correction available in the MODImLab™ toolbox (Sirguey et al. 2009a).

The DEM used for the topographic correction of the MODIS products was constructed primarily from ASTER GDEM V2 data projected to the MSLC2000 cartographic system. Large height discontinuities in the GDEM dataset were replaced with elevation data from the Radarsat Antarctic Mapping Project DEM data (RAMPv2). Finally, spurious heights errors were cleaned manually.

The temporal evolution of ground reflectance in MODIS band 2 (Near Infrared, NIR) and band 5 (Shortwave Infrared) were explored to characterize the change of the surface properties (Sirguey et al., 2009b), and identify snow accumulation events. An empirical approach of the signal based on difference indexes and ratios was preferred to the fully physically-based approach of Wiebe et al. (2013). Time series of reflectance and associated indices from locations corresponding to the AWS locations were compared to AWS surface height and albedo data, as the latter two variables supported the identification of new snow events.

3.0 PRELIMINARY RESULTS

Snow fall and its subsequent depletion was positively identified over areas of blue ice using only band 2, due to the large contrast between the high near-infrared reflectance of fresh snow (~75%) and the low reflectance of blue ice (~56%). The detection of new snow events over existing snow could not be revealed by band 2 only, due the stability of the NIR reflectance. The signal in a selected shortwave infrared band (MODIS band 5) provided additional information about the changing optical properties of the surface, particularly for those areas already snow covered. Thus the ratio of band 2 and 5 exhibited the largest signal that could be related to new snow events identified based on AWS data (Figure 2). Noise in the time series remains due to cloud cover and changing imaging and illumination geometries. Nevertheless, it was found that only including MODIS images from a certain period of the day (15:00 UTC) greatly reduces the noise in the signal although it removed ~80% of the available data.

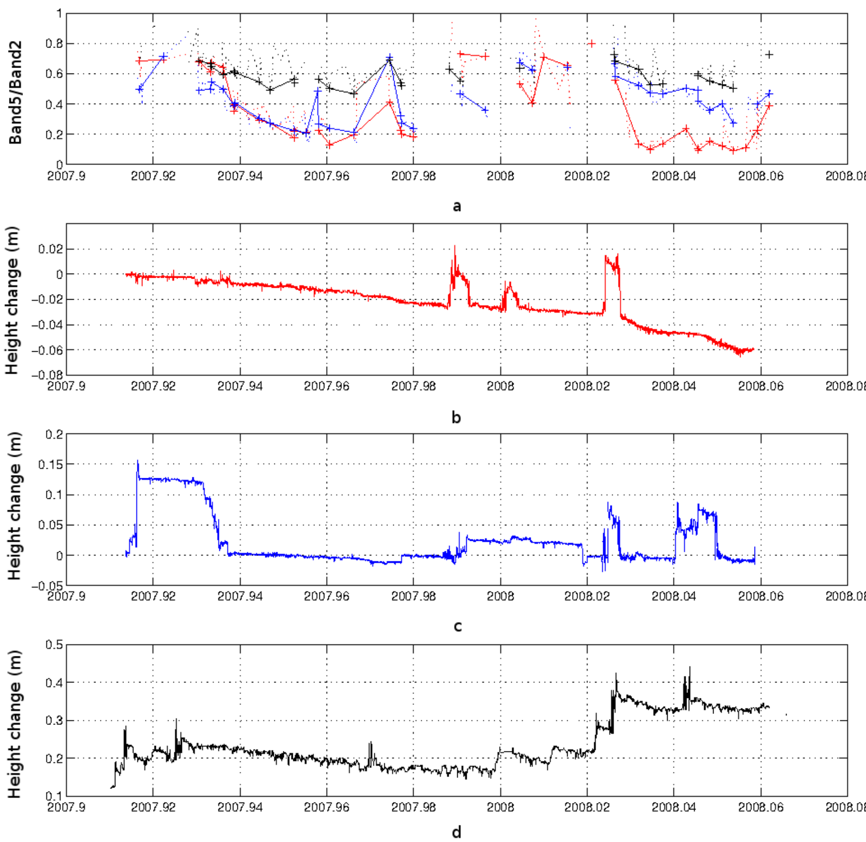

Figure 2: Comparison of (a) Band5/Band2 reflectance ratio, with surface height data from the (b) Hatherton, (c) Upper Darwin, (d) Skinner Saddle AWS (Figure 1). Colors used for AWS in plots (b-d) correspond to line colors in plot (a). Period of analysis is 1/12/2007 to 31/01/2008; time given as decimal year.

4.0 CONCLUSION

The use of corrected ground reflectance in MODIS band 2 and 5 has proved efficient at detecting new snow events in Antarctica. Despite the apparent stability of the snow reflectance, the ratio of band 2 and 5 enhanced the contrast between new snow and aging snow, thus facilitating its detection. Furthermore, the times series supported a highly resolved temporal evolution of the snow reflectance on areas of blue ice that could support the parameterization of albedo for SMB modelling.

More efforts are needed to improve the quality of the signal, including a refinement of the cloud detection, and interpolation of data gaps. The approach also has several drawbacks as data are restricted to day light hours in spring, summer and autumn, (times of low solar zenith ($<75^{o}$)), and cannot provide details on snow depth and density. Nonetheless the information generated will be of considerable use in validating precipitation patterns generated by climate models, ablation patterns generated from surface mass balance models and to provide surface information for use in climate models.

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Hotspots of Hector's Dolphins On the South Coast

***Judy Rodda*[1] *and Antoni Moore*[1]**

[1]School of Surveying
University of Otago, Dunedin, New Zealand
Phone: +64 3 479-7585 Fax: +64 3 479-7586
Email: judy.rodda@postgrad.otago.ac.nz
Email: tony.moore@otago.ac.nz

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1.0 INTRODUCTION

The decision making process used by the NZ government with respect to conservation issues today, requires specific, descriptive output regarding research summaries. Implementing the use of a global, linear regression may inform stakeholders about the general importance of parameters of interest for a study area or a species of interest. However, the broad brush stroke of the global model may well obscure what is happening at a localised and spatially important scale. Temporal data are difficult to visualise. The field of geovisual analytics is producing new methodologies to incorporate time series, specifically utilising spatially significant output from Geographically Weighted Regression (GWR) to explore the complexities of spatial-temporal relationships such as 14 years of cod-invertebrate symbiosis on the Newfoundland Shelf (Windle et al. 2012), coastal water quality patterns in south Australia (Bierman et al. 2011), and from information visualisation research, exploring the combination of spatial statistics with geovisual analytics (Andrienko et al. 2007; Demšar et al. 2008a; Demšar et al. 2008b; Andrienko et al. 2010a; Andrienko et al. 2010b; Foley & Demšar 2013; Andrienko & Andrienko 2013).

Hector's dolphin, *Cephalorhynchus hectorii,* which is the only endemic dolphin species from the South Island of New Zealand, is distributed in three primary population strongholds. These strongholds lie along the West Coast South Island (WCSI), East Coast South Island (ECSI), and the South Coast South Island (SCSI) (Clement 2005; Ministry of Fisheries 2011)(Figure 1). The most current estimates of Hector's dolphin South Island abundance are incorporated into the legend in Figure 1, in conjunction with the three stronghold areas mentioned. Few spatial analyses of Hector's dolphin distribution studies have been conducted (Clement 2005; Rayment et al. 2009) and those have been concentrated on the ECSI within the boundaries of the Marine Mammal Sanctuary established at Banks Peninsula. This research reports results from a project consisting of spatial/temporal modelling of the distribution of the SCSI dolphins at Te Waewae Bay.

1.1 Te Waewae Bay

There have been 25 years of research projects in and associated with the Marine Mammal Sanctuary at Banks Peninsula on the ECSI. However, the Hector's dolphin residing in and utilising Te Waewae Bay on the SCSI were without the benefit of a marine mammal sanctuary until 2008. This body of data represents the first time data were collected on this species in Te Waewae Bay, and all data were collected prior to a sanctuary being established. A preliminary abundance and distribution research project was conducted at Te Waewae Bay in 2004 by the Department of Conservation. Distribution data were collected throughout autumn 2004 and again in summer 2004/2005 by Green, Chateris, and Rodda (2007). From December 2004 through November 2006, Rodda continued collecting Hector's dolphin distribution data on a monthly schedule, along four offshore transects (Figure 2) at Te Waewae Bay.

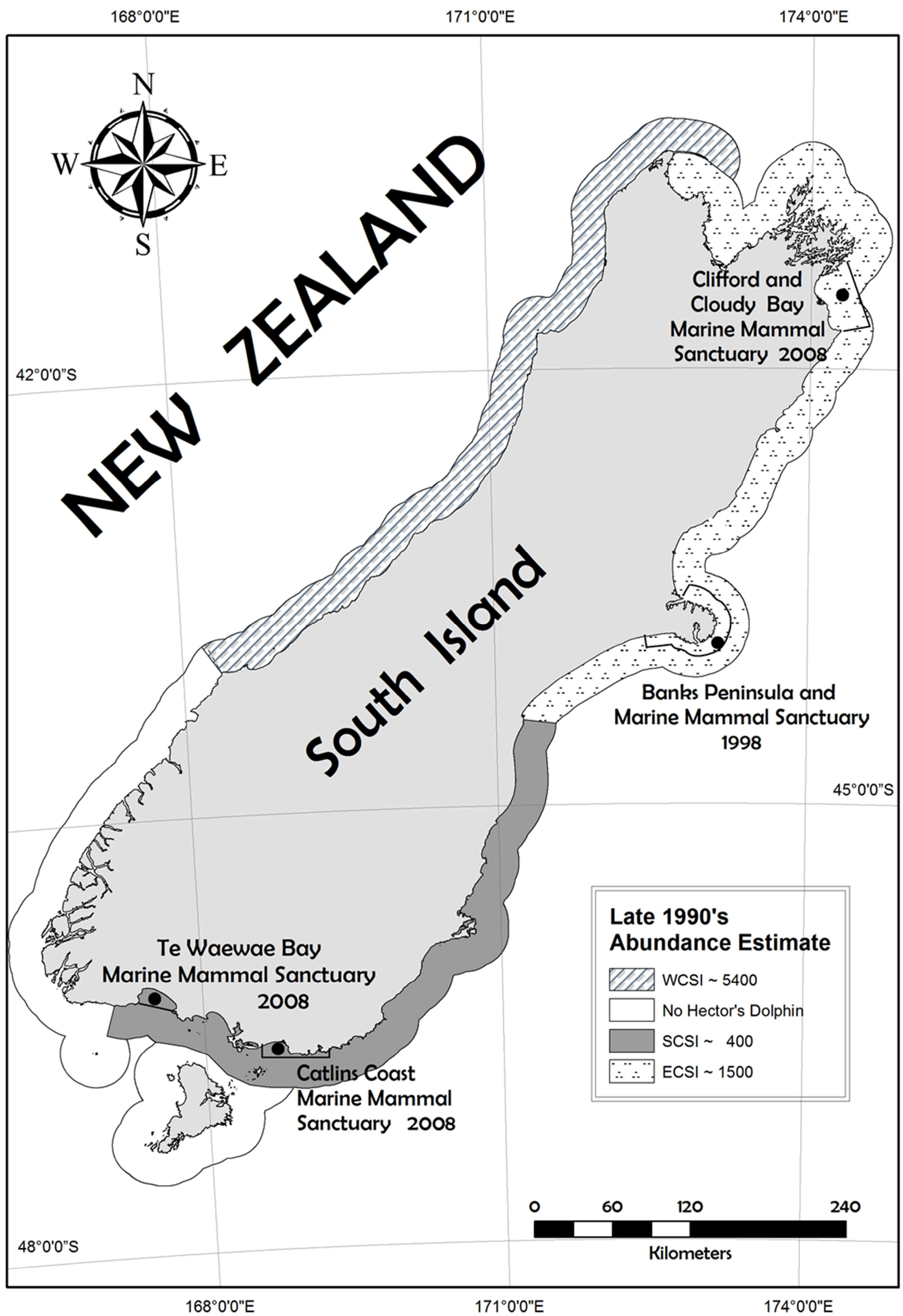

Figure 1: Map of the South Island, New Zealand showing the four South Island marine mammal sanctuaries established in 1998 and 2008. The three Hector's dolphin population strongholds are shown coloured or pattern filled with the approximate abundance estimate from the late 1990s.

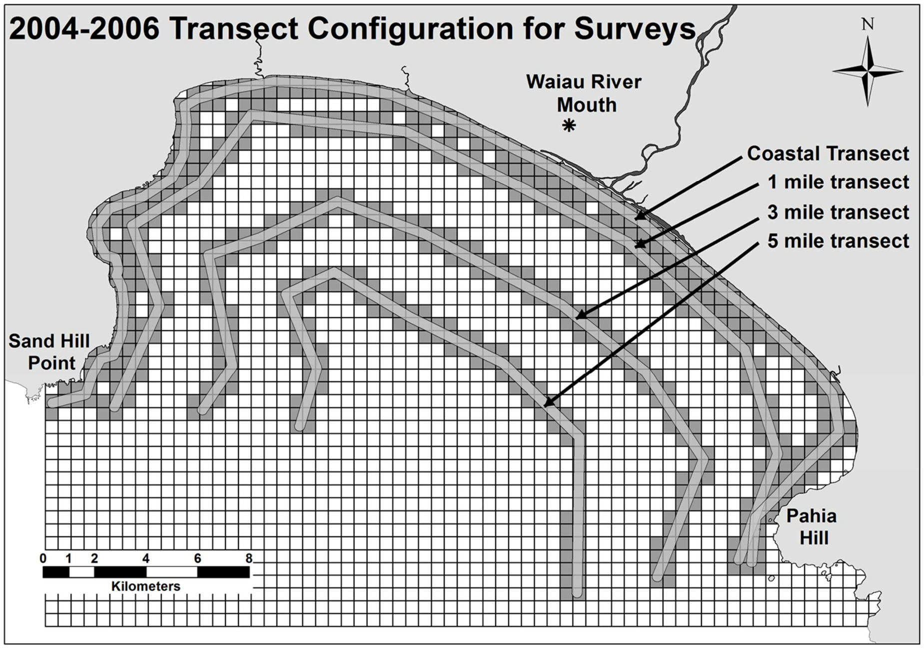

Figure 2: Te Waewae Bay showing 500m x 500m grid squares superimposed across the bay. The transect lines that were to be completed each month shown as 400m wide (light grey) lines and the total minimum number of grid squares the transect lines intersect (dark grey squares).

1.2 Geographically Weighted Regression

Geographically Weighted Regression (GWR) was introduced by Brunsdon et al. (1996) GWR is a spatial analysis technique that utilises linear regression in a local framework, rather than a global framework for data analysis. Global analyses of data sets summarise information gathered across the entire spatial extent under study and will represent the similarities across a spatial area while local analyses are useful in looking for differences that may exist within the extent and be influencing variability observed in results (Fotheringham et al. 2002)

Summarily the benefits of GWR models are that local modelling often improves model specification, producing a better or lower Akaike Information Criteria Corrected (AICc) value. GWR improves understanding impacts of spatial autocorrelation and spatial non-stationarity in terms of the spatial extent, processes, and variables (Fotheringham et al. 2002; Foody 2005; Windle et al. 2010). The primary issues affecting spatially explicit modelling are spatial autocorrelation (SAC) and spatial non-stationarity; both issues can be collated under the heading of spatial dependency (Demšar et al. 2009). SAC is described as a property of the modelled data, while spatial nonstationarity is a property of the modelled relationship (Osborne et al. 2007). To determine whether there were statistically significant environmental variables that were contributing to the spatial patterns observed in the Te Waewae Bay Hector's dolphin data, GWR was chosen as the analytical statistic, because GWR offers local modelling which counters some of the issues of spatial autocorrelation and spatial nonstationarity.

2.0 METHODS

Spatial and temporal distribution plots of the total number of tracks surveyed, and dolphins encountered were overlaid on a 500 x 500 m grid across the study area (Figure 2). Sightings per unit effort (SPUE) represent the total dolphins observed in each grid square divided by the number of times each grid square was surveyed. The SPUE output was entered in a kernel density calculation, having a 3200 m search radius, producing maps of the mean density of dolphins per km^2 for each time period. Environmental variables were collected in conjunction with the distribution data.

Hotspots based on dolphin density were identified; however hotspots are not necessarily statistically significant. Therefore, methodology was needed:

- to test for statistical significance of the hotspot analysis output
- to account for spatial autocorrelation
- to measure the local spatial variation

GWR was chosen as it has been shown to accommodate for autocorrelation, spatial variation and can provide robust statistical output.

Modeling was performed as a two-step process using GWR 3.0 software available from this website http://www.st-andrews.ac.uk/geoinformatics/gwr/gwr-software/ (Charlton et al. 2003). Data were analysed in the first instance using the global regression model commonly referred to as the Ordinary Least Squares model (OLS). OLS, being a linear regression method, does not take into account spatial attributes. Variables were added to the regression model in a stepwise fashion, one variable at a time. Transformations of individual variables were considered after examining the scatterplot matrix for deviations from normal distributions. The second step was to run GWR models in the same manner as the OLS models, adding variables in a stepwise fashion, and doing variable transformations based on the scatterplot matrix results.

3.0 RESULTS

3.1 Hotspots

Examination of distribution data from the maps of the Kernel Density Estimates confirmed the presence of both spatial and temporal hotpots of Hector's dolphin presence within Te Waewae Bay. Four hotspots were discovered and all four found to be in relatively close proximity to a freshwater source flowing into the bay. Due to having data accessible for only one of those four freshwater outlets, the Waiau River, it was chosen to be the focal site to measure the distance of each group of Hector's dolphin to the primary freshwater source (Rodda & Moore 2012)

3.2 Ordinary Least Squares (OLS)

Both untransformed and transformed variables were used in OLS calculations to obtain the best linear regression model that was also biologically meaningful. Amongst the models run, model ranking results were presented as the AICc values where the lowest values indicate the better model, the OLS range in this study being 4461 to 4475. A check of how well the OLS model fit the data was presented as R^2 (coefficient of determination). A perfect fit to the model would give an R^2 value equal to 100%; all values in these models fell within 48% and 49% which indicates that there are strong predictor variables missing from the model and/or that spatial nonstationarity is present.

3.3 Geographically Weighted Regression (GWR)

Models using the same variables of untransformed and transformed values as the OLS models were run using using GWR 3.0 software. The GWR models showed an improved (lower) range of AICc values from 4419 to 4425, and R^2 values improved 5% to 7%. Both of these metrics showed improvement from the OLS model indicating a better overall model. The variable that consistently showed the greatest significance throughout all modelling was the distance to the Waiau River or distance to the primary freshwater source.

4.0 CONCLUSIONS

In the best case scenario for ecological research, data from before an event is collected and then data after an event in order to attempt comparing magnitudes of change arising from the event. These data represent 'before the event' information gathered about the population of Hector's dolphin from 4 to 2 years before the introduction of a marine mammal sanctuary (the event). Results from GWR models constructed and presented here, indicate that the SCSI Hector's dolphins have statistically significant spatial distributions that are in close proximity to the primary freshwater source in Te Waewae Bay. Analysis of distribution data from WCSI and ECSI Hector's dolphin population strongholds would be required in order to discern whether proximity to freshwater outflow might be a significant environmental factor related to the distribution for these two population strongholds as well. A subsequent research question would be to ask how changes in freshwater accessibility and flow may impact, or have impacted, the distribution of Hector's dolphin around the South Island of New Zealand.

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Visual data mining of generalized and optimized spatiotemporal animal paths

Antoni Moore[1], Mariano Rodriguez Recio[1,2], Judy Rodda[1,2], Jim Watts[2] & Philip Seddon[2]

[1]School of Surveying
University of Otago. Dunedin, New Zealand
Phone: +64 3 479-7589 Fax: +64 3 479-7586
Email: tony.moore@otago.ac.nz

[2]Department of Zoology, University of Otago

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1.0 INTRODUCTION

The space-time characteristics of animal locations can provide information about their interactions with habitat resources and other animals, including humans. The spatial data collection and mapping tasks this implies are a key facet of spatial ecology research. The mapping of animal locations requires sampling in space and time and has typically been achieved through direct observation including radio-telemetry, representing just a small window into the overall animal spatiotemporal behaviour. Remote tracking technology has now become accurate, compact, efficiency powered and financially viable enough for devices to be unobtrusively attached to free-ranging wildlife. Accordingly, we have moved from a data-sparse to a data-rich situation, a phenomenon happening on a much larger scale with humans and GPS data from mobile devices.

The data that can be collected about a single animal, if densely sampled over an extended period of time, can be too complex to depict in a single visual representation, such as a map. Adding the spatiotemporal data for conspecifics, or for other animals, of different species, along with environmental map layers depicting habitat characteristics, will only increase this complexity. Therefore, some kind of transformation (generalization) or summarization of the data is required. This can be achieved through spatial analysis or geovisualization, the former applying techniques such as path density or statistical summaries to make the data interpretable (another more recent example is compression of trajectory data based on semantic content – Richter et al, 2012).

2.0 GEOVISUALIZATION

While straightforward plotting of data will represent the animal track as a mass of points connected by straight lines, there are visual transformations that can be used to make the data interpretable. This visual data mining relies on the human user to see patterns in the data that would otherwise be hidden, but which may be facilitated by how the data is visually represented.

A geovisualisation method has been developed for spatiotemporal paths, an adaption of Laube's REMO matrix (Laube et al, 2004) a graphing of space-time trajectories into a grid of episodes (with the path divided into portions, each attached to a specific time interval, temporal scale defined as the situation dictates) and specific entities, with dominant direction of movement being symbolised in the grid (Figure 1). Laube used this to illustrate spatiotemporal behaviours such as constancy, concurrence and trend-setting.

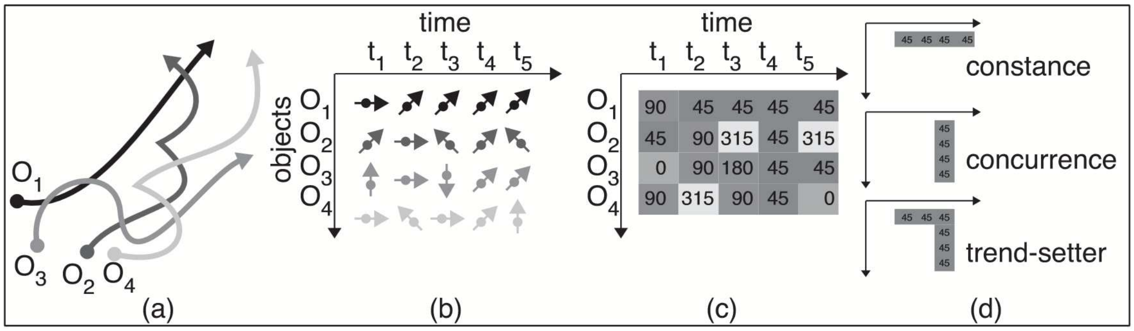

Figure 1: Laube's generalization of space-time trajectories in the REMO matrix (Laube et al, 2004)

3.0 OPTIMIZED SPATIOTEMPORAL TRAJECTORY MINING

The further development of this approach tries to build in some representation of proximity, through the optimal reordering of entities, defined by running simulated annealing on the data. Therefore if two entities are close to each other in space at a particular time then reordering will seek to make them close together in the grid (Fig. 2).

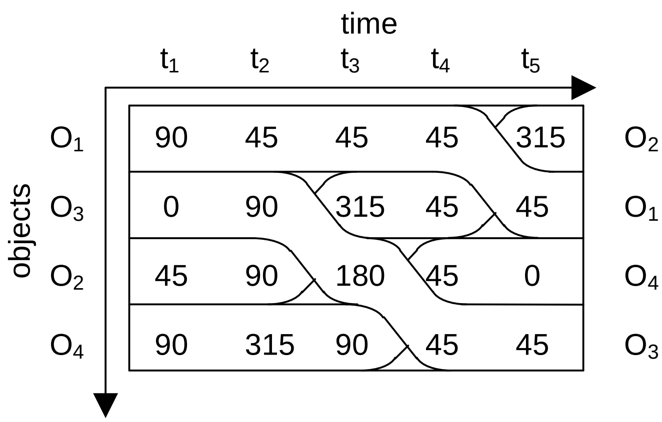

Figure 2: Development of the visualisation method using the data in Figure 1, optimizing row ordering based on proximity

The symbology of the adapted grid will also be considered, specifically via the use of line thickness on the dividing line between adjacent entities in the grid to represent a continuous variable: physical distance separation. The colour rendering (e.g. use of the Munsell colour circle) of the directions stored in the grid will be discussed.

Three ecological case studies of differing spatiotemporal scales will be used to illustrate this representation in action. These are:

- Seasonal sampling of Hectors' dolphin location in a large south coast bay ($220km^2$) for a duration of 2 years (although the data was collected by observation and GPS on board a boat, the data derived is a good initial test).
- Daily sampling of buff weka on a large alpine farm comprising a ridge and valley system for a duration of around four months.
- Hourly sampling of feral cats and hedgehogs in a large alpine valley for just over a year (though not at all times for all animals)

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Using GIS to Survey Landscape Values

Lars Brabyn[1], & Greg Brown[2]

[1]School of Social Science
University of Waikato. Hamilton, New Zealand
Phone: +64 7 838-4466 Fax: +64 7 838-4633
Email: larsb@waikato.ac.nz

[2]School of Geography, Planning and Environmental Management
University of Queensland. Brisbane, Australia
Phone: +61 7 3365-6654 Fax: +61 7 3365-6654
Email: greg.brown@uq.edu.au

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1.0 INTRODUCTION

Landscape values are fundamental to a functioning society, and many of these values are location specific or may vary with changing geographical context. Such values include aesthetics, economic, place attachment, and recreation. The surveying of these values is important for understanding place and making environmental decisions. This research demonstrates how public participatory GIS can be used to collect landscape values, which can be combined with the NZ Landscape Character Classification to understand landscape preferences.

New Zealand landscapes are world renowned and central to our national identity, quality of life and tourism industry (Peart, 2004). This research identifies key values people attribute to landscapes in the Otago and Southland DOC Conservancies, by using a method that combines the internet and GIS. This new method enhances landscape suitability analysis and provides substantive perception information to inform debates on future land use.

There are many layers that contribute to the physical character of landscapes, including landform, water, land-cover, and infrastructure. Likewise there are many dimensions to how people perceive landscapes, which include culture, place attachments, identity and aesthetics (Peart, 2004). When proposed land uses generate significant controversy, such as proposals for wind farms or infrastructure developments, obtaining knowledge about landscape values to inform these debates is always difficult because landscape involves both the physical landscape and human perception. Psychophysical analysis is generally deemed the most theoretically valid method for landscape assessment (Daniel and Vining 1983), and typically this has involved asking people to rank landscape photos. The main problems with this method are the cost, small sample sizes (typically < 100) and the inadequacy of single photographs as a representation of a landscape. Consequently, the traditional psychophysical approach has proven insufficient in providing adequate empirical findings to reliably identify key landscape values and to inform land use decisions.

2.0 NEW ZEALAND LANDSCAPE CLASSIFICATION

This study uses the NZ Landscape Classification (NZLC) developed by Brabyn (1996) and subsequently updated (Brabyn, 2009). The NZLC is a classification of character, not quality, and is built from the unique combinations (spatial overlays) of six landscape components—landform, landcover, infrastructure, water, dominant landcover, and water views. The purpose of landscape classification is to provide a frame of reference for communicating landscape research, just as a plant classification improves communication for botanists. The classification system uses common language to describe the landscape components and component categories. The six landscape components have the potential to produce many thousands of landscape classes—unique combination of components—which may be impractical for some applications.

3.0 PPGIS DATA COLLECTION

There has been considerable research in the last decade to identify landscape values using participatory GIS methods to inform national parks and protected area management (Brown & Weber, 2011), residential and tourism development (Brown, 2006; Raymond & Brown, 2007), and coastal area management (Alessa, Kliskey, & Brown, 2008).

PPGIS websites for each of the regions were developed after consultation and pilot testing with DOC staff. PPGIS data collection consisted of two parts; (a) spatial attribute mapping using a custom Google® maps application, and (b) general survey questions assessing participants' familiarity with conservation areas in the region and selected socio-demographic information. A total of 608 participants were recruited January through March 2011through a random mail sample of households in the Southland and Otago regions, by visitor contact at conservation areas, and by advertising in media outlets such as local newspapers.

The spatial attributes to be identified by participants included the following landscape values: scenic/aesthetic, recreation, economic, ecological, social, historical, and wilderness. Participants were instructed to drag and drop markers representing these values to the appropriate location on a Google® base map. The map showed the shaded relief and standard topographical detail so that participants could accurately locate particular places. PPGIS mapping precision by participants was enforced by only allowing the placement of markers if the participant had zoomed-in to a predetermined zoom level (Level 12) in Google® Maps (approximately 1:100,000 scale).

4.0. DATA ANALYSIS

To prepare the spatial data for analysis, we intersected the seven PPGIS landscape values with the six NZLC landscape components (landform, landcover, dominant landcover, water, water view, and infrastructure) and the NZLC landscape classes, which are combinations of the six landscape components. This produces a large table consisting of all the points collected, the landscape value associated with the point, the categories for each of the six landscape components, and the landscape class. This data was analysed using frequency counts, and residual analysis.

Frequency counts involved summing the numbers of landscape values falling within each landscape component and landscape class. This identifies the most popular landscape components and classes associated with different landscape values. However, simple frequencies can be misleading when landscape classes are disproportionately over or under-represented in the study region. If a landscape class is uncommon but has many landscape values, or if a landscape class is abundant but does not have high value counts, these findings merit attention. To account for proportional differences in landscape classes, residual analysis is used.

Residuals analysis involved calculating the total area (ha) and the percentage area of the study site for each landscape component category. The landscape value counts, expressed as a percentage of the total count, were compared with the percentage area of the landscape to produce standardized residuals. Residuals analysis provides useful information by indicating which landscape values are significantly over or under-represented in the different landscape categories. A residual is defined as the difference in the observed frequency and the expected frequency. A standardized residual is calculated by dividing the residual value by the standard error of the residual. Standardized residuals are a normalized score like a z score without units and if greater than 2.0, indicate significantly more landscape values than would be expected given the size of the area, while standardized residuals less than -2.0 indicate fewer landscape values based on the size the area. Standardized residuals provide an indicator of over- or under-representation of landscape values, but cautious interpretation is warranted because expected counts are based on landscape component areal proportions. Because PPGIS participants do not randomly locate landscape values, there is not an a priori expectation that the landscape values be distributed by areal proportionality. We included analysis of standardised residuals to account for the possibility of distributional bias based on landscape component area within the study region.

5.0 RESULTS

The method used in this study has produced results that are plausible and consistent with previous landscape perception studies in New Zealand. In addition, the scale of this study exceeds other landscape perception studies in NZ; we analysed 8,824 landscape value points from 608 participants providing information on 2,761 unique landscape classes. This is a large number of participants compared to traditional landscape perception studies in NZ. For example Fairweather and Swaffield (1999) study of perceptions in the Coromandel region had 88 participants. The results indicate that the general public associate particular values with specific landscape components at a regional scale. Greater than expected landscape values were associated with urban areas, water features, indigenous landcover, and mountains. Fewer than expected landscape values were associated with flatter, agricultural landscapes. The method demonstrated the capacity to assess small landscapes features, such as islands and ski lifts, as well as large mountainous landscapes. Our analysis confirmed previous studies indicating human preferences for landscapes with natural features, mountains, and water. Our analysis also revealed more subtle landscape relationships not previously published. From the top 25 landscapes classes valued water in the form of lakes, estuaries, and views of the ocean and enclosed sea appear most frequently (8 times). Water is a known landscape attraction and this study confirms the importance of water in the landscape. Water is valued in a range of landcover and landform contexts, even in agricultural areas with low topography. Mountainous areas, particularly high mountains with glaciers and alpine tussock are also highly valued (e.g., 14 of the top 25 landscapes include mountains and high plateaus). Many of these landscape classes are dominated by indigenous vegetation. These findings are consistent with previous landscape perception studies dating back to the 1800s and early 1900s that describe the high country as picturesque and sublime (Nightingale and Dingwall, 2003). Swaffield and Foster's (2000) review of South Island's (NZ) high country found that low intensity farming (low producing grassland) in the mountains provides iconic landscape views. Our results show moderate landscape values associated with developed grassland (6 out of 25) even with low topography and without water. This finding has not been substantiated in previous studies in NZ but should not appear surprising. People enjoy the vernacular landscape, perhaps because they are common and easily accessible.

6.0 CONCLUSION

The combination of PPGIS data with a landscape classification system provides a powerful, alternative for landscape assessment compared to traditional psychophysical landscape assessments that use photos. The method described herein provides an efficient method for assessing landscapes at the regional scale and could be replicated in other regions or countries that have a landscape classification system. The use of classification systems is common in the natural sciences because these systems provide an important frame of reference for communication, and yet, their adoption in the social sciences has lagged. Without the NZLC, our detailed examination of the relationships between landscape values and physical landscapes would not have been possible. To advance landscape research, the development of landscape character classification systems appears essential.

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Current status and future directions of mobile GIS

Markus U. Müller[1], David Medyckyj-Scott[2], Andrew Cowie[2], Tim-Hinnerk Heuer[2] and Pierre Roudier[2]

[1]Landcare Research – Manaaki Whenua
University of Waikato Campus, Hamilton, New Zealand
Phone: +64 7 859 3700 Fax: +64 7 859-3701
Email: muellerm@landcareresearch.co.nz

[2]Landcare Research – Manaaki Whenua
Massey University Campus, Palmerston, New Zealand
Phone: +64 6 353 4800 Fax: +64 6 353 4800
Email: [Medyckyj-ScottD|CowieA|HeuerT|RoudierP]@landcareresearch.co.nz

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1.0 INTRODUCTION

Mobile GIS as a term describes the deployment and usage of Geographical Information Systems (GIS) on mobile devices, i.e. small, hand-held computing devices that typically have a touch screen or miniature keyboard. Like mobile device technology in general, mobile GIS is a fast-moving field. Mobile GIS is related to the fields of location-based services, Web-GIS and mobile computing. In the following paper we give an overview of the current status of mobile GIS, with a focus on the most important technologies in regard to current market shares. We will also discuss several use-cases and technology demonstrators that are currently being developed within Landcare Research, as well as possibilities for future development. The overall aim of the article is to present a description of the current status of the field as well as providing a starting point for those interested in mobile GIS from a software development or research perspective.

2.0 CURRENT STATUS OF MOBILE GIS TECHNOLOGY

2.1 Mobile devices and operating systems

Mobile devices are one of the high-tech areas that are very dynamic, innovation driven and predicted to have considerable growth potential especially in those areas of the world termed emerging markets. The market is currently dominated by smartphones and tablet computers. The term "smartphone" was coined around 1997. Smartphone development took a major step forward after Apple Inc. introduced the original iPhone in 2007, which used a touchscreen as its main means of interaction. Apple Inc. has also had a significant role in the establishment of the modern tablet devices market, i.e. those using touchpads, with the release of the iPad in 2010. The current market for mobile devices consists mainly of phones and tablets of different sizes that use touchpad technology. The most dominant platforms are Android, iOS and Windows Phone, each having separate and different software development kits (SDK) (Koetsier 2013). In the following only these three platforms will be considered.

Touchpads have some specific features that are important for the geospatial field offering new ways of interaction with dynamic maps. In particular touchscreen-devices are a game changer in dealing with the challenge of designing user interfaces of GIS for non-specialists.

2.2 Products and projects

Considering the huge number of mobile GIS software products and projects, we will focus on the most important ones in regard to market share (Google Maps, Bing Maps, iOS maps and ArcGIS) and in the area of Open Source (OpenLayers).

Different types of mobile GIS apps can be distinguished based on the provided functionality and use cases. One major group of apps consists of the widely known map apps Google Maps, Bing Maps and iOS maps. The overall functionality of these three apps is similar, the major use cases being search e.g. POI, navigation and location based services. They three packages also bundle in their own spatial data including street maps, satellite pictures and 3D-views. There are possibilities to add customized data to some degree (for example using Google My Maps), including lines and polygons. There is no support for adding or interacting with thematic maps. All of these Map apps include SDKs that allow customization.

ArcGIS mobile can be considered representative of fully-fledged, proprietary Mobile GIS apps. These applications are general-purpose tools that allow users to add thematic data (ArcGIS App) or even edit and update geometries and attributes. Also included is an SDK that allows the development of specific applications.

A number of Open Source projects support mobile devices, mainly in the form of web applications but only a few of them in the form of native applications. The OpenLayers project is probably the project with the highest number of users and instances. Both the current (v2) as well as the upcoming version 3 include mobile examples.

3.0 A CONTINUUM OF DEVELOPMENT APPROACHES

3.1 Platforms and programming languages

The number of mobile SDKs and corresponding map SDKs is very high and not all of them can be considered here. Generally there is a continuum of approaches between a web app and a native app (Figure 1).

Figure 1: Development approaches for mobile apps

The continuum begins with web applications that are responsive i.e. adapt their layout to smaller devices. At the other extreme are native apps that are programmed using one specific SDK and will only run on one of the platforms. In between these two extremes are approaches that are based to varying degrees on web technology and therefore also differ in regard to them being specific to a platform and the level of web development skills (HTML, CSS, JavaScript) required to develop apps upon them.

3.2 Some technology experiments

Landcare Research is currently in the process of developing and evaluating demonstrators built using different kinds of mobile technologies. The major use cases are:

- Provision of land resource or biodiversity information to users such as farmers, land managers or conservationists
- Access to and collection of data in the field by specialists e.g. soil data, vegetation plots, pest monitoring
- Display of maps in the context of responsive websites. Maps and other content can be linked to each other.
- Citizen science – collection of data by non-specialists e.g. the creation and validation of a citizen driven national land use map, crowd sourced identification of photographed and described insects, etc.

Besides leveraging existing web development skills, our intention is to use Free/Open Source software to stay independent from specific vendors, to save on license costs and to give us the possibility of making our developments available to the wider public by contributing to the respective Open Source projects.

Our first set of demonstrators have been based on web-technologies to leverage existing web browser based development. They are OpenLayers applications that are either made responsive or are converted to cross-platform apps using PhoneGap. In the following we will show examples of these two approaches.

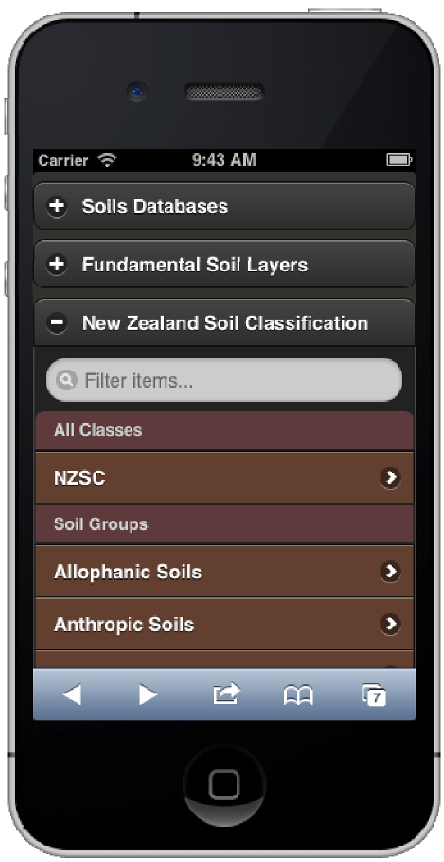

Figure 2: Layer menu of the mobile soils app displayed in an iOS sumulater

The first example is the mobile soils app which is a mobile GIS app for Android, developed using traditional web technologies, and converted to native app via PhoneGap. Figure 2 shows its layer menu that allows the user to choose from a variety of available soil information, while Figure 3 shows how maps are displayed; in the example the New Zealand Soil Classification.

Figure 3: Map display of the mobile soils app on an Android phone

The second example is the Antarctic Environments Portal, a cooperation project between Antarctica New Zealand and Landcare Research, which includes an OpenLayers-based mobile/web GIS app (Figure 4). The aim of the portal is improvement of communication between scientists and policy makers in regard to the environmental management of the Antarctic. It is developed as a responsive website using the Twitter Bootstrap framework.

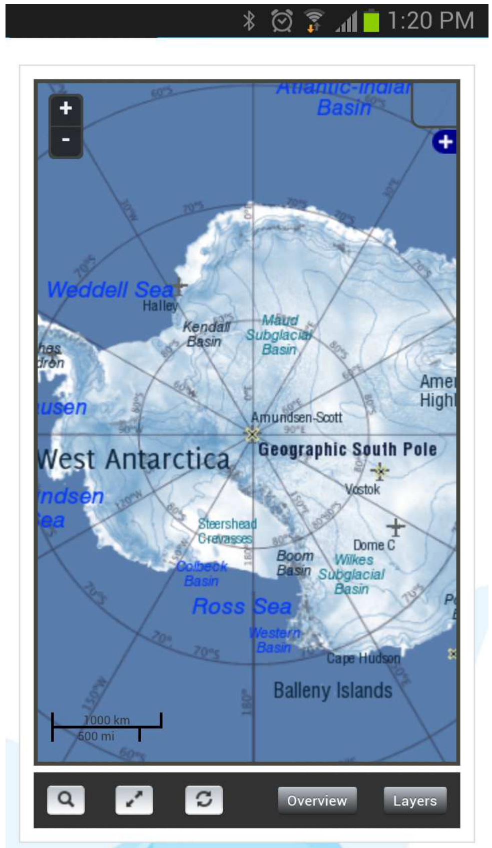

Figure 4: Map display in the Antarctic Environments Portal on an Android phone

Where more complex GIS functionality is required in a mobile app, other Open Source GIS projects are more appropriate, e.g. QGIS. The user interface of QGIS is based on Qt, a cross-platform application framework. As Qt is already ported to Android and iOS, this technology stack might be an alternative to the aforementioned OpenLayers/PhoneGap combination supplying richer GIS functionality although not based on web technologies.

4.0 NEXT STEPS

Comparing analyses of the direction of mobile GIS even just a few years ago with now (Brovell & Magni 2007, Solyman 2005) certain trends have become clearer. There is a fragmented development environment and a growth in the importance of touch-screen technology. Web-based development or at least development based on web technologies is helping leverage cross-platform development costs but at the expense of the ability to use platform-specific or very new functionalities. At the same time the distribution of native apps via app stores is driving native development against pure web development approaches. Approaches like PhoneGap, which allow the re-use of web technology but resulting in native apps might be a feasible approach but this needs more research using technology experiments.

We will discuss a number of additional topics that pose interesting research questions:

- Offline use
- Transfer of data from mobile to server
- User interaction with complex data models
- Mobile collaboration
- Mobile augmented reality
- Mobiles as sensor

- Mobile and cloud computing

5.0 SUMMARY

Mobile GIS is a highly dynamic field that is providing new research opportunities for GIScience particularly as these devices are bringing geospatial capabilities to large numbers of relatively naive geospatial users and allowing new ways of interacting with spatial data. Landcare Research is currently in the process of undertaking a number of technology experiments and intends to develop best practice guidelines for those developing mobile applications and ideas for further research and development.

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Finding the Quality in Quantity: Establishing Trust For Volunteered Geographic Information

Jeremy Severinsen[1], Femke Reitsma[2]

[1]Department of Geography
University of Canterbury. Christchurch, New Zealand
Land Information New Zealand
Phone: +64 3 374-3856
Email: jeremy.severinsen@pg.canterbury.ac.nz

[2]Department of Geography
University of Canterbury. Christchurch, New Zealand
Phone: +64 3 364-2987 Ext. 4180
Email: femke.reitsma@canterbury.ac.nz

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1.0 INTRODUCTION

In the modern environment of Web 2.0, the increasingly connected nature and online presence of societies and communities across the world is drastically and continually altering the role of the 'user' of spatial information. The proliferation of new, mobile, and spatially aware technologies has resulted in the ability for ordinary citizens to not only consume, but also produce data and contribute local expertise to spatial datasets in volumes that are increasing exponentially (Seeger 2008). Where this crowdsourced data explicitly or implicitly captures a location and associated detail, it is now widely referred to as 'Volunteered Geographic Information' (VGI) (Goodchild 2007), and is eliciting great interest from the scientific community. This data is a rich source of near real time information, and marks a significant paradigm shift in the creation and dissemination of geographic information, from a top down authoritative approach to a democratic model with the end user also acting as a data producer (Budhathoki et al 2008, Goodchild 2008), or a phenomenon now referred to as 'Neogeography' (Goodchild 2007). With all of these factors sparking interest in this new tsunami of information, questions have emerged surrounding issues of integration with authoritative datasets and spatial data infrastructures (SDIs), hinged on how the quality of VGI can be accurately determined.

The large volumes of VGI already found on the internet have been created by a heterogeneous and often disparate group of authors often with no reference to, and little understanding of, relevance and coordinated quality standards and protocols. For this reason, VGI has become accepted as somewhat of a "Pandora's Box", with re-users often reluctant to incorporate this rich data source into any scientific analysis for fear of these perceived shortcomings, a fear which could be considered justified for many, but unfounded for an equal number of volunteered geographic features.

The aim of this research is to remove this ambiguity surrounding VGI by quantifying the level to which a particular VG feature can be deemed 'trustworthy', and enable this knowledge to be translated into a rich and ongoing source of information, to be put to productive re-use under the same principles that guide interoperable data sharing inherent in any Spatial Data Infrastructure (SDI). By ascribing a numerical value to this trust rating this research seeks to close the feedback loop for VGI and facilitate a means by which user-created content is not only relevant for other user groups, but also enable reuse of this data by actors traditionally seen as authoritative producers. In this way, crowdsourced information could be used to augment a variety of fundamental datasets, and thus cement the place of VGI within the geographic data value chain.

Furthermore this research presents a data structure that will capture all of the information required to make a accurate assessment of quality. By capturing this against an individual feature, this information will maintain transitivity with that feature, and enable a consumer of that data to accurately extract VGI of a known quality from the vast quantity that exists in the world of Web 2.0.

2.0 PRIMARY QUALITY INDICATORS

Three primary factors have been identified for use in determining trust in a volunteered geographic feature, and can be summarised as author reputation, spatial precision and temporal quality.

Of the three broadly identified components to quantify trust for VGI, author reputation is probably the most widely discussed across a range of academic disciplines, as well as having more deeply established roots in both social and semantic network analysis. The terms “credibility”, “reputation” and “reliability” are often used interchangeably when assessing the source of a particular piece of crowdsourced data, and a large body of academic research has focussed on the idea that the credibility of a source of GI can be used as a proxy for the inherent quality of that data (Flanagin and Metzger 2008).

There has been significant research into the concepts of trustworthiness and expertise as components of credibility (Elwood 2008, Heipke et al 2010, Golbeck et al 2003, Golbeck & Hendler 2004, Coleman et al 2009, Van Exel et al 2008, de Longueville et al 2010). Expertise is generally accepted to be the result of one or both of two factors – some form of formal qualification, or experience. Furthermore, Goodchild (2008) explored the concept of expertise as derived from experience, described as a contributor’s “activity space”. In simple terms, this concept argues that local knowledge surpasses any formal qualification for the contribution of quality VG features. Consequently, if a feature is contributed by a local about their local environment, then it can be expected that this feature could be given a quality rating that would equal or surpass that ascribed to a contributor with formal geographic training or experience.

Furthermore, as existing facilitated VGI solutions have matured, so too have comparisons between the data collected through portals such as OpenStreetMap and more traditionally authoritative sources (Du et al 2012, Haklay et al 2010, Craglia 2007, Osterman & Spinsanti 2011, Heipke 2010, Haklay 2010). Without an authoritative reference dataset, however, the spatial characteristics of quality are the most difficult to incorporate into a trust calculation for VGI, without extending this research into a study of the semantic web and ontological considerations, which are outside of the scope of this work. Given these restrictions a more appropriate means to measure spatial precision is through map scale. The more familiar an author is with a created feature’s real world counterpart, the more likely that contributor will be to create the feature at a smaller scale, with a higher level of detail and spatial precision. Therefore by collecting scale information at capture, a subsequent user of that feature could infer judgement on the author’s knowledge and expertise, and thus the extent upon which the spatial accuracy and precision of the feature could be relied (De Longueville et al 2010). This approach is proposed in this case.

Finally, in many respects the real value added by VGI is its currency. VGI has been employed in several coordinated responses to natural disasters due to the speed at which up to date information can be collected and disseminated (Zook et al 2010, Poser et al 2010), therefore reinforcing the information relevance, and augmenting traditional authoritative sources. It is essential to not only capture information about a feature’s creation and most recent edition, but to also place this into the context of general change in its immediate area – due to a lack of change to a real world object, a feature with an aging creation date may still accurately reflect that object, and therefore remain current and relevant. A feature may also be one of many, although slightly separated, instances of the same real world object, created by a number of users. Parker et al (2012) state that VGI is likely to be most relevant to the user when a geographic feature is dynamic rather than static in nature. Any quality assessment of the temporality of VGI must therefore account for the context of its surrounding features and general surrounding activity, through an assessment of a feature’s currency and provenance (Ye et al 2011).

3.0 PROPOSED VGI-TRUST ALGORITHM

Based on the factors identified as having a measurable impact on the quality of geographic information, this research presents an algorithm that assesses these factors at an appropriate weighting. At a high level, this algorithm will include information about the data author, aspects of its spatial precision, and information on its provenance and currency, or temporal quality, each of which are ascribed a weighting within the formula. The model will be tested with volunteer contributions in post-earthquake Christchurch, where contributors will be asked to augment the Topo50 map series produced by Land Information New Zealand with user information on the changed state of the city.

One of the primary drivers of this research is to establish an algorithm that produces a trust rating for VGI that is easily interpreted, and can inform any re-user of these data as to the inherent quality of a given feature, irrespective of that user's expertise and training in the spatial sciences. As such, the "trust rating" is a measure between 0 and 10, with 0 marking a feature that cannot be relied upon in any way, and 10 being a feature that can be considered of exceptional quality. By establishing this rating system, quality percentiles can be inferred, as can degrees of trust, and these can be applied to fitness for purpose assessments for data reliance.

4.0 CONCLUSIONS

Crowdsourced geographic information is now prolific in the online world, and the issue with this increase in VGI is the question of trust. How can an end user of VGI quickly and effectively determine the quality of that data? This research is a starting point for practical quality analysis of VGI, through an analysis of a series of factors that will be collected during a facilitated case study, in order to produce an algorithm that could provide an estimate of quality for the vast spectrum of volunteered features. This research can logically be extended to include the examination of the semantic web and volunteer ontologies, both to further enhance the assessment of spatial precision and as a content quality indicator in its own right. These considerations are at this time outside of the scope of this research.

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Commuting in Wellington: a geographic econometric analysis of commute mode, residential location and car ownership

Mairéad de Róiste[1], Toby Daglish[2], Yiğit Sağlam[3] & Richard Law[2]

[1]School of Geography, Environment and Earth Sciences
Victoria University of Wellington. Wellington, New Zealand
Phone: +64 4 463-6431 Fax: +64 4 463-5186
Email: mairead.deroiste@vuw.ac.nz

[2]Institute for the Study of Competition and Regulation (ISCR)
Victoria University of Wellington. Wellington, New Zealand
Phone: +64 4 463-5562
Email: toby.daglish@vuw.ac.nz & richard.law@vuw.ac.nz

[3]School of Economics and Finance
Victoria University of Wellington. Wellington, New Zealand
Phone: +64 4 463-9989 Fax: +64 4 463-5014
Email: yigit.saglam@vuw.ac.nz

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1.0 INTRODUCTION

Infrastructure underpins modern cities: connecting people to amenities, education and employment. Understanding how this works is the domain of transportation modelling, a discipline that has been underutilized in New Zealand. Interpreting travel patterns and household/individual behaviour at the micro level has important implications for economic growth and quality of life.

The transportation modelling literature has provided frameworks for analysing decisions about where to live, how to get to work and how many cars to own (Bhat and Guo, 2007; Cao, Mokhtarian and Handy, 2007; Salon, 2009; Matas and Raymond, 2008). Studies of such decisions usually draw on discrete choice models (McFadden, 1978; Bhat, 2000; Train, 2009) and assume that people, in deciding where to live, are concerned about neighbourhood characteristics and time taken to get to work. Figure 1 displays a typical situation, where an individual must decide which location to live in. Further, conditional upon having chosen a home location, the individual must choose how many cars to own and how to get to work. A standard trade-off is between relatively expensive housing close to downtown, which affords a cheaper commute (in both time and monetary terms), versus cheaper housing further from downtown. When comparing commuting strategies, the individual may trade off expenses (driving generally being more expensive than walking/cycling or using public transport) against time taken. To implement a discrete choice model, it is important to evaluate alternatives available to the individual that are not observed in the data, since these facilitate the researcher's understanding of why an individual made the choice actually observed. Evaluating possible commute times for individuals who could potentially live in many locations and employ many commute modes is computationally expensive. Studies generally rely upon level of service (LOS) surveys provided by civic authorities (Bhat and Guo, 2007) or very sparse random sampling of potential locations (Salon, 2009) to minimise computational cost.

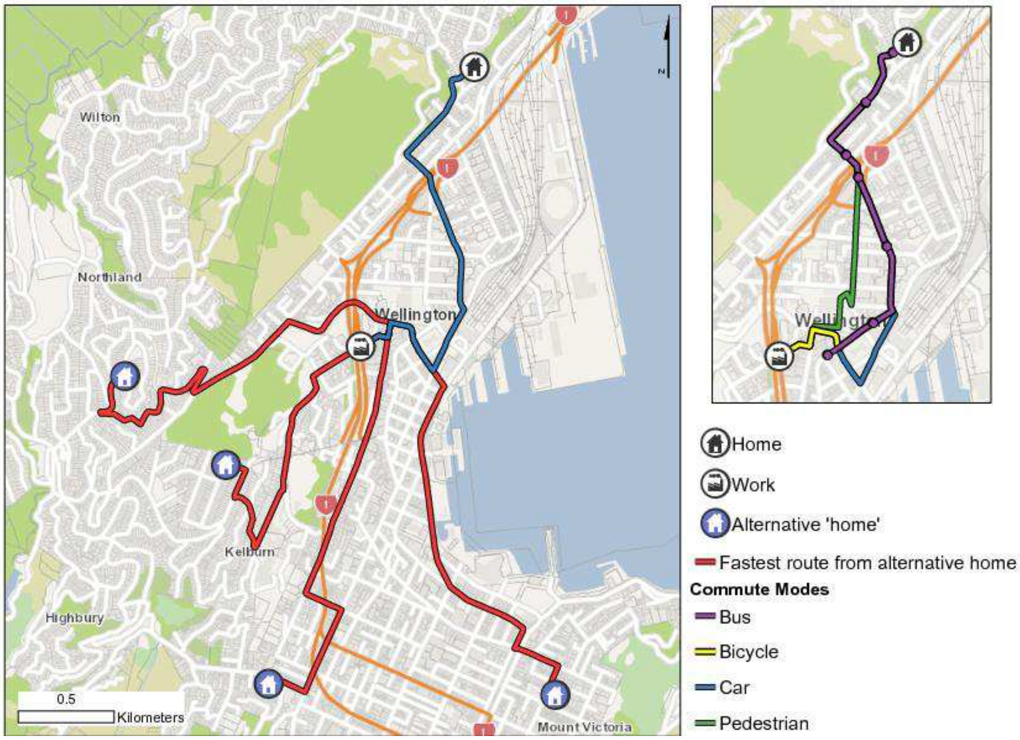

Figure 1: A sample of alternative home locations with the fastest commute route. Inset shows the fastest routes possible using alternative commute modes.

This paper describes an ongoing geography and economics interdisciplinary study which explores the decisions of where to live, how to get to work and how many cars to own using NZ Household Travel Survey (HTS) data for Wellington. With this survey, we can quantify the factors that influence these decisions. By sampling a greater number of potential home locations (200 alternatives per individual commuter), this study will more accurately model residential choices and allow us to assess the effect of geographically varying neighbourhood characteristics. Through a more realistic route network, we also improve the modelling of commuting alternatives.

2.0 NETWORK ANALYSIS

Geographic Information Systems (GIS) have an important role to play in this area of econometric enquiry. The authors created an accurate network of the Greater Wellington Region's road, pedestrian and public transport routes. This network can model the different commuting choices for drivers, cyclists, pedestrians, and public transport users in both time and monetary costs.

The HTS currently provides travel information on 25,000 individuals in 10,200 households nationwide, gathered since 2003. Survey participants record demographic information and log all their travel for two consecutive days. By data mining this travel log, we can categorise workers according to how they commute, and analyse this in relation to their home and work locations and the number of vehicles they own. By calculating the costs of the real and alternative commutes, we can estimate why people make the choices they do (residential location, commute mode and car ownership levels) and do not choose the alternatives.

To provide these costs, we calculate walking, cycling, public transport and driving commutes for the HTS commuters within the Greater Wellington Region from actual and simulated home locations to their work location (Figure 1). The routes will record time taken, distance and cost. For the Greater Wellington Region, this comprises of over 1,000,000 potential commuting routes. Processing these routes is highly computationally intensive and will be conducted using ArcGIS software over the university's Condor distributed computing system.

The route network was largely constructed from publicly available data from a variety of sources. In modelling hypothetical commuting choices, the network can account for a variety of characteristics of any route. Three such characteristics are noted here. First, the average speed of cyclists and pedestrians is influenced by hill slope, with a downhill incline providing for increased average speed up to a certain slope angle. Conversely, travelling uphill is always harder than on the flat. Second, when solving for the shortest possible route between places via public transport, restrictions were noted for 'premium' public transport services. An example of this distinction would be comparing the Airport Flyer (a relatively more expensive airport shuttle that stops in residential and commercial areas) to a cheaper passenger train. The model can use this information to restrict or allow such 'premium' services and quantify the marginal costs and benefits in terms of both time and money. Third, it is possible to specify a time penalty to represent waiting for (or transferring between) public transport services. This can be a static number (five minutes for all modes), varied by mode (five minutes for buses, seven for trains), or based on a function (very small for high-frequency, never-late services; very high for those that are low-frequency and unreliable). Quantifying this last parameter is a current goal of the project, dependent on securing suitable data related to service punctuality.

3.0 CONCLUSIONS

The HTS data allows us to categorise households according to how they commute, and analyse this in relation to their home and work locations, and the number of vehicles they own. We have modelled where the HTS participants actually live and plan to extend this to account for alternative locations of where they could live.

The GIS modelling in this project underpins econometric modelling of important household decisions and the project is ongoing. We have created the network dataset and calculated routes across four different commute modes (driving, public transport, walking and cycling) from the real home location to the participants work location. This modelling will be extended to alternative home locations. Potentially the econometric analysis of the GIS data created could allow us to explore many interesting hypotheses:

1. To what extent do school zones and local school performance influence property prices and residential decisions?
2. Do residential and commuting preferences differ significantly between rural and urban areas?
3. How does accessibility to the road and public transport networks affect house prices?

The interdisciplinary study has the potential to contribute to a number of important policy areas within New Zealand. Local governments control the provision and reliability of public transport, the layout of parks and recreational spaces, and also the growth of cities through the Resource Management Act. All these policies have potential impacts on people's decisions over where to live and how to commute (Cao, Mokhtarian and Handy, 2007). For optimal road development, emissions control, and managing New Zealand's exposure to oil price shocks, it is important for central government to know the effect of changing costs of commuting (both in terms of time and dollar values) on the use of vehicles (Donovan et al., 2008; Kennedy and Wallis, 2007).

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Flow direction algorithms in a Hierarchical Hexagonal Surface Model

Joseph W Wright, Antoni Moore & Greg Leonard

School of Surveying
University of Otago. Dunedin, New Zealand
Phone: +64 3 479-7585 Fax: +64 3 479-7586
Email: joseph.w.wright@otago.ac.nz

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1.0 INTRODUCTION

This study proposes a Hierarchical Hexagonal Surface Model (HHSM) for storing and indexing large spatial arrays. HHSM uses an intrinsically hierarchical indexing system that creates interesting opportunities for neighbourhood based operations, multi-level analysis and forming adaptive surfaces. Research into surface models that depart from traditional uniform rectangular raster approaches is motivated by changes in data availability. Models developed for hydrological analysis of large areas make assumptions about geomorphology that are not always appropriate in urban areas, primarily due to the land shaping forces of human activity. The hydrological response of an urban surface compared to an undeveloped or rural area can vary signficantly due to important hydrological features that occur at very fine spatial scales. The regular spacing and inconsistent connectivity of conventional raster based surface models limit the capability of hydrological models to represent urban areas. Research has previously demonstrated hexagonal data sampling has advantages over rectangular grids for hydrological modelling (Brimkov et al, 2001, de Sousa et al, 2006). Therefore, hierarchical hexagonal data structures are needed that can adapt to the urban hydrological environment.

2.0 HHSM DATA STRUCTURE

2.1 Indexing

The proposed data structure uses the Hexagonal Image Processing (HIP) referencing system described in Middleton & Sivaswamy (2001). This referencing system shares many characteristic with the Quadkey used in Bing Maps Tile System (Microsoft, 2013). Characteristics in common include describing position with a single ordinate and having each position ordinate beginning with the ordinate of the pixel of the coarser Level of Detail (LOD) that contains it. Unlike the Quadkey, however, HIP uses a hexagonal partition of space. Each coarser HIP LOD is formed by aggregating 7 hexagons together in a Generalised Balanced Ternary (GBT) (Gibson & Lucas 1982). The value of each digit within a HIP index ranges from 0 to 6 and represents the rotation of a base vector by multiples of $\pi/3$ radians, except 0, which defines the centre of the GBT. The centre of each HIP cell is the centre of the 0 hexagon of its children. The outlines of the cells are only true hexagons on a single predefined base level (L0) and the orientation of the array rotates with each subsequent scaling. A three LOD HIP structure with both HIP ordinates and (x, y) coordinates is shown in Figure 1.

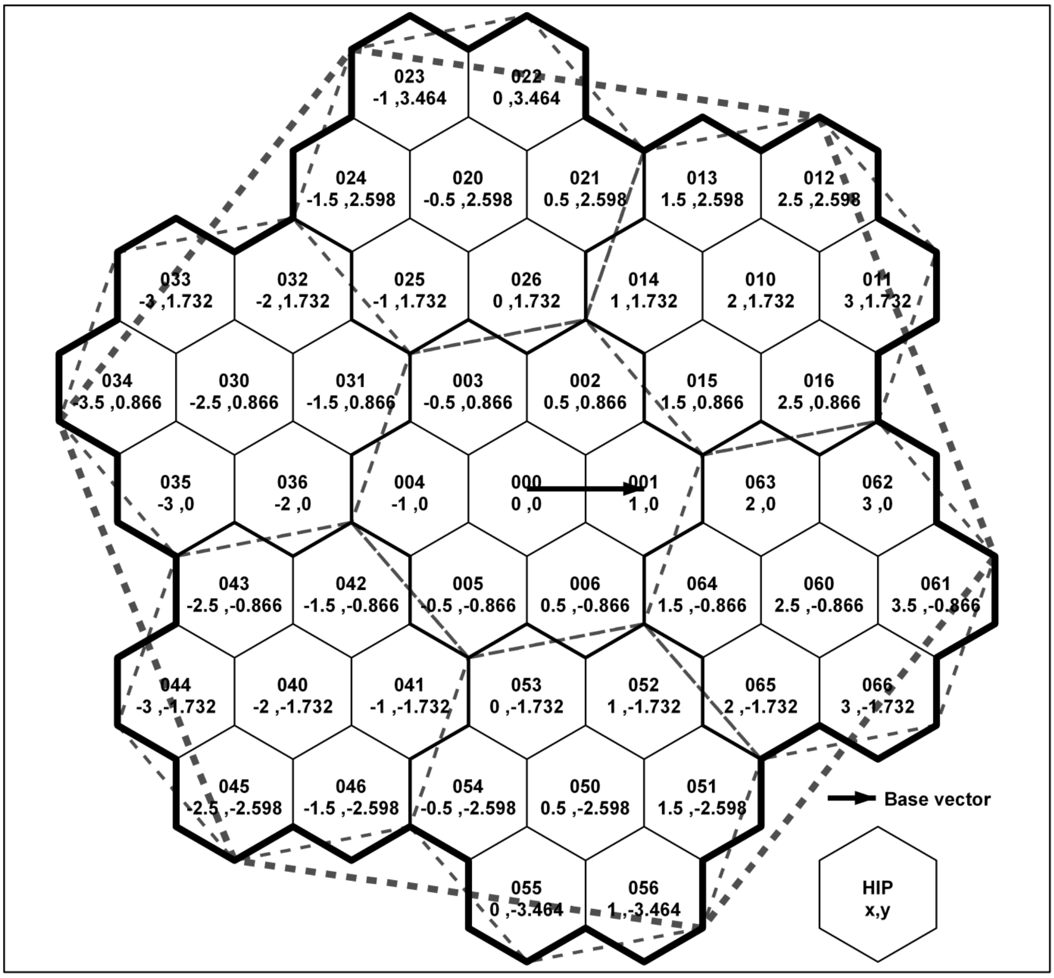

Figure 1: The HIP referencing system for part of a 3 level HIP partition of space. Hexagons are grouped into aggregates of 7 for each coarser LOD. Voronoi tessellations are shown for all three levels.

2.2 Storage

The HHSM decomposes the HIP array into consistently indexed tree and array components. The division between the two components is defined by an aggregation value that sets the maximum size for the array component. Data is stored as one or more arrays where each digit of the HIP index up to the aggregation value is the ordinate of a dimension within the array. As there are 7 possible locations within each hexagon, the array is a $7_1 \times 7_2 \cdots \times 7_n$ array, where n is the LOD. Therefore, the array part of a HIP ordinate is also the Cartesian coordinate of the value within the 7^n array. The remaining digits of the HIP ordinate define the key of a B-tree index on which the array is stored. Excessively large trees or arrays both adversely affect performance. To improve performance a combination of tree and array storage, implemented using the Python module PyTables, is used in this study. The combined tree-array format in PyTables can process arrays that are larger than can be stored in a system's memory.

2.3 Level of Detail Pyramids

LOD models permit representations of the same data at different resolutions. Frequently LOD can also vary across a terrain (Floriani et al 2005). They are typically formed by sub-sampling the data or by selective refinement and are often used to create multi-resolution models that vary in detail depending on distance from a view point, an application that requires real time rendering. Here the use of LOD is not to facilitate graphical display but to reduce the number of cells required for modelling without reducing model accuracy. A coarser LOD HHSM pyramid layer consists of a new array with 1/7th as many hexagons. HHSM can efficiently form LOD pyramids for two reasons. Firstly, the coarser resolution pixel HIP ordinate is the same as the beginning of its children in the finer levels of detail, making it a trivial task to relate the positions of cells in different LODs to each other. Secondly, the 7 values of a GBT at the finest LOD in an n level HIP are stored adjacent in dimension n of the array. This can be exploited to quickly summarize each hexagon, and in this fashion a pyramid of coarser resolutions can rapidly be built. A schematic of a 5-level data structure, with an aggregation value of 3 and its pyramid layers is shown in Figure 2. The coarser resolution aggregates are, in fact, not hexagons but complex fractal shapes. However, they can be simplified to the Voronoi tessellations of the centre of each cell, forming rotated hexagons (see Figure 1).

2.4 Adaptive Surfaces

An adaptive surface can be created by applying a decision rule to determine the LOD required for a given area. For instance, the decision rule may be that if all the L0 children of a given polygon are within a set limit of their mean, then only the parent is required in the adaptive surface. Applying such a rule is similar to a quad-tree division of space, effectively forming a hept-tree. It is possible to apply the hept-tree adaption algorithm to either elevation or flow direction arrays. The decision rule can be used to preserve hydrological significance minimising cell numbers without losing accuracy in representing hydrological behaviour.

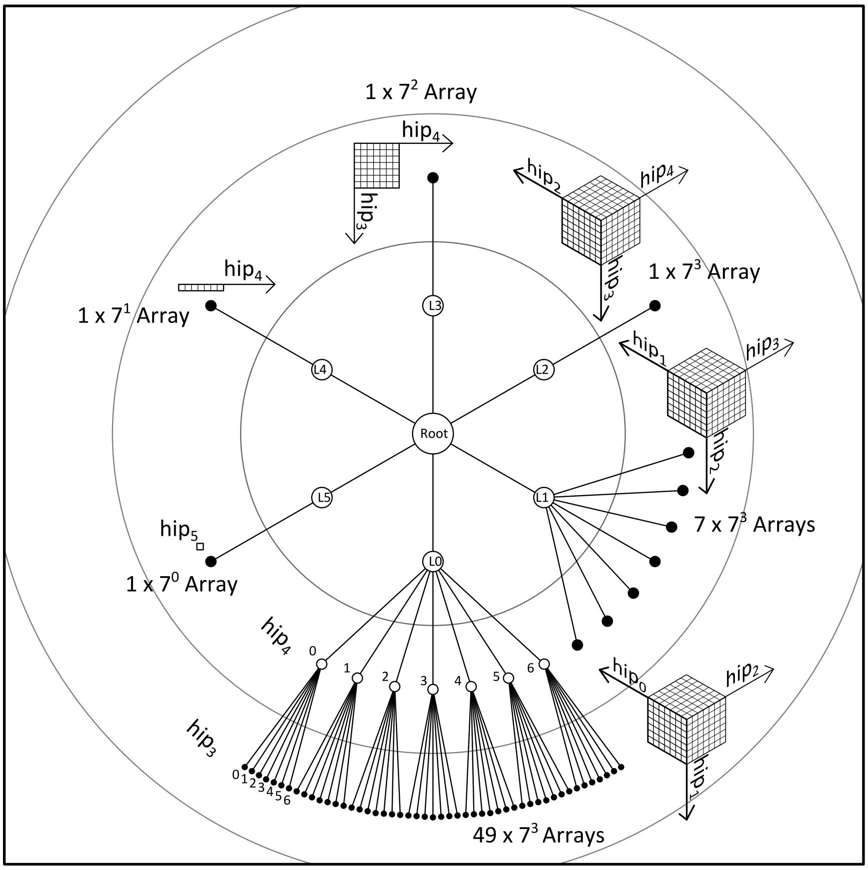

Figure 2: Schematic representation of the data structure of 5-level HHSM (L0) with pyramids (L1 – L5), aggregating at level 3. The 5-digit HIP index is decomposed to hip_4 hip_3 hip_2 hip_1 hip_0. The location of each digit is shown.

3.0 FLOW DIRECTION IN HHSM

There are a number of ways of determining D8 like flow direction solutions within the HHSM, which generate distinctive behaviours not seen in rectangular arrays. The basic premise of D8 flow direction is that flow is attributed in the direction of the steepest downslope neighbour (O'Callaghan and Mark, 1984). Many alternatives to this approach are possible, however, here only the D8 method is considered, with the additional factors of hexagonal sampling and adaptive cell size. The obvious corollory of the D8 in hexagonally sampled space is the D6, where the flow direction is the steepest downslope neighbour of the six nearest neighbours. However, for multi-level analysis and modelling, the D6 flow direction algorithm is complicated by the angle of rotation between HIP levels because the directions of the neighbours at a given level are not represented in the neighbourhoods of coarser and finer levels.

4.0 CONCLUSIONS

The HHSM is a robust and simple method to store and process hexagonally sampled data. A combination of tree and array storage permits very large arrays to be processed effectively. LOD pyramids, variable density surfaces and multi-level analysis are all possible using HHSM. Flow direction algorithms in HHSM have aspects not present in flat rectangular raster structures, which have potential to model complex surfaces more effectively.

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Our waste our way: a spatial study of household waste management in Betio, Tarawa, Kiribati

Kotee Bauro Teburea, Antoni Moore & Greg Leonard

National School of Surveying
University of Otago, Dunedin, New Zealand
Email: kbteburea09@gmail.com

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1.0 INTRODUCTION

There is an increasing concern over solid waste disposal on the islands of Kiribati in the Pacific Ocean. This is especially true on South Tarawa, which is the urban centre of Kiribati (Carden, 2003). The trend over the last few decades (see Figure 1) has been for people from the rural islands of Kiribati to migrate to South Tarawa for educational and employment opportunities (Secretariat of the South Pacific, 2012). An effect of the increased urbanisation is that the people residing on South Tarawa have changed from traditional subsistence living to a more "westernised" lifestyle. As a result, the demand on imported goods together with their high level of packaging has greatly increased the volume of solid waste produced in South Tarawa. The inability to manage this waste effectively has been identified as a major outcome of this increased waste generation rate (Carden, 2003).

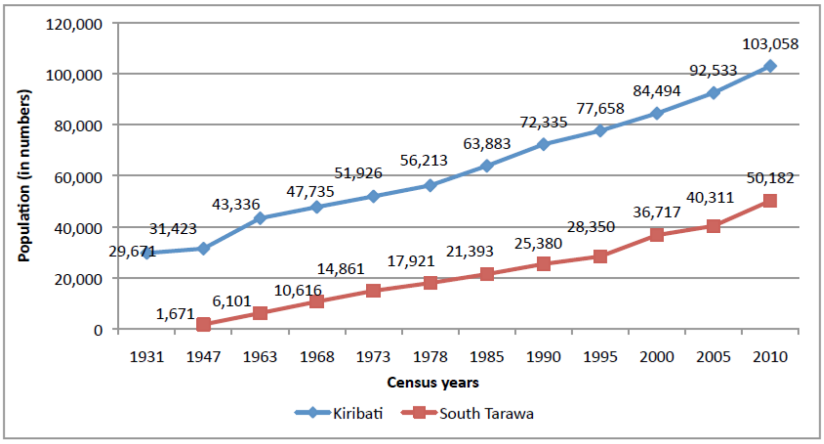

Figure 1: Population trends for Kiribati and South Tarawa for the period 1931 – 2010 (Secretariat of the South Pacific, 2012).

Betio is one of the main towns of South Tarawa with a population of 15,755 in 2010 and a land area of 1.7 square kilometres (National Statistics Office, 2010). It is overcrowded and littering in common areas such as beaches can be readily seen (see Figure 2). In Betio, the task of collecting and disposing of household waste is carried out primarily by the Betio Town Council (BTC). In addition, New Zealand has funded a project called the 'Green-bag household project', which started in March 2012, to end in-organic waste littering and other disposal practices over terrestrial and marine ecosystems to produce a cleaner and healthier environment. (Bwatee, 2013). One of its objectives is to get the public to put their waste into green bags that are then collected at scheduled intervals. The Green-bag truck collects the green bags, which should contain only inorganic household waste, once a week.

Figure 2: Example of household waste dumped on a beach near Betio.
Photo taken by K.B. Teburea on 10 April 2013.

The aim of this study is to encourage the people of Kiribati, especially those residing on Tarawa, to assist in maintaining a clean environment by effectively managing their household waste. A thorough analysis of all of the factors resulting in improved waste management is beyond the scope of this study. Therefore, this study focuses on the use of geospatial analysis techniques to predict whether changes to the way in which the BTC manages solid waste collection in Betio will lead to improved solid waste handling. This involves determining how the system is currently managed, finding out what influences the choices local residents make regarding their household waste and coming up with alternative management techniques together with key performance indicators to assess the expected outcomes of these proposed techniques. It is expected that improvements to management of household waste will potentially extend the life and usability of landfills in Kiribati (Leney, 2006). Learning ways to manage household waste can be a preliminary stage for young and adult residents in keeping their environment clean for future generations.

2.0 METHODS

The following steps are undertaken in this study:

a. Collection of data on the current waste management system in Betio including the location of current collection sites, informal dumping sites and the attitudes of the residents towards the management of their household waste;

b. Creation of a fully connected network of Betio, prior to travelling salesman and location-allocation stages of analysis (e.g. Yeh and Chow, 1997), to analyse the current collection system and determine feasible alternatives in terms of more efficient collection routes and definition of more optimal waste collection points; and

c. Synthesis of resident behaviours and attitudes with the geospatial model outcomes to predict changes in waste management outcomes resulting from alternative collection systems.

2.1 Collection of field data

Spatial and questionnaire data were collected during a period of fieldwork undertaken from 2 – 14 April, 2013. Once ethical approval had been obtained, data was collected from randomly selected household residents on Betio, who agreed to participate in the research. The number of participants was 200, aged 20 and upwards. Household residents were given one questionnaire per household covering topics such as type of household, the nature of waste disposed, storage, possible use of and disposal of waste, attitudes towards waste collection and disposal, problems encountered in waste collection and disposal, suggestions for improved disposal and collection, and awareness of waste policy and management. The questions were given in two languages (Kiribati and English). Location of their household waste sites was also collected using a Trimble Nomad GPS handheld receiver. The spatial and questionnaire data were linked via a common reference number for the household. The spatial data collected was complemented by a contextual dataset consisting of roads, buildings and coastline. Semi-structured interviews with relevant people working at the Betio Town Council were also conducted as part of the research study. An overview of Betio that roughly indicates the spatial extent of the area covered in the fieldwork is shown in Figure 3.

Figure 3: Islet of Betio (Source: SOPAC).

2.2 Travelling salesman and location-allocation modelling

Network routing and location-allocation modelling will be applied to the data collected during the fieldwork, which has been modified to derive a fully connected road network with waste dumping nodes or points attached to them. Network routing will be used to calculate the shortest route on the network that can collect rubbish from all nodes – this is therefore a travelling salesman problem. Location-allocation modelling will establish the placement of new nodes, given the population distribution and the mapped locations of informal dumping (see Longley et al, 2011 for more information on these techniques).

2.3 Data synthesis

The outputs from the questionnaires will be used to inform the location-allocation model and construct a number of scenarios. These outputs include, but are not limited to, participants' views on whether the rubbish is being collected regularly enough and what interval it should be collected at, the manner in which residents currently informally dispose of their household waste, particularly when the council truck does not collect the rubbish from assigned areas, and what sort of containers the residents place their household rubbish in for collection. Analysis of the questionnaire outputs will also indicate the number of participants who are aware of the policy or awareness regarding waste management, as this these data can inform the government of the best options (such as radio and newspaper advertisements, door knocking, etc.) for increasing community or individual awareness of waste disposal, as well as aid in the enforcement of waste disposal policies.

3.0 SUMMARY

Addressing the problem of informal waste disposal on Betio, Kiribati Islands, the current state of household waste management, policies for waste containment and enforcement and household waste management issues (collected by questionnaire and interview) were analysed, along with the mapped locations of household waste dumping sites, before the suggestion of practical alternatives for waste disposal, collection and management on a household and island-wide scale.

More specifically, this project will generate a set of data and output maps, derived from spatial analysis, on locations of informal dumping sites as well as recommendations for locations of centralized dumping nodes, and the optimal route on the road network visiting them all. This can be used in future decision support on Betio household waste management decisions. The project has also generated a resource of opinions held by Betio inhabitants about household waste management on Betio, which may be valuable in future decision making.

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Sources of uncertainty in a Cellular Automata for vegetation change

Rachel Whitsed and Lisa Smallbone

Institute for Land, Water and Society
Charles Sturt University, Albury-Wodonga, Australia
Phone: +61 2 6051 9641 Fax: +61 2 6051 9897
Email: rwhitsed@csu.edu.au

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1.0 INTRODUCTION

When farmland is abandoned – stock and human disturbance removed – pasture is rapidly taken over by woody vegetation. This has ecological implications; for example the amount and spatial relationship of shrub and tree patches affect the makeup of the bird community, as different resources available in patches support different bird species. As tree dispersal depends on the presence of a seed source nearby and other local conditions, and can be measured in discrete annual time steps, a Cellular Automata (CA) is a natural fit for modelling this phenomenon.

In the context of GIS, a CA consists of a raster where each cell can be in one of a finite number of states at each time step. Cell states change simultaneously at each time step according to a set of rules, depending on the current state of the cell and its neighbours. Simple local rules can give rise to larger, dynamic, global structures (O'Sullivan and Unwin 2002).

As computing and GIS capabilities have grown, CA models have developed from experimental mathematics (Gardner, 1970) to a recognition of their application in natural sciences and geography (Wolfram, 1984; Couclelis, 1985) to useful models in human and environmental geography. Examples include urban growth and land use change (Batty & Xie, 2005), fire spread (Yassemi *et al.,* 2008), invasive plant species propogation (Dragićević, 2010), plant competition (Matsinos and Troumbis, 2002) and vegetation dynamics (Balzter *et al*., 1998).

2.0 MODEL DEFINITION AND RULES

2.1. Study area

The study area covers approximately 114,800ha between Rushworth and Heathcote in central Victoria, Australia. The vegetation occurring on abandoned farmland in this region is mainly composed of eucalypt tree species and the perennial shrub *Cassinia arcuata* (drooping cassinia). Patches are either tree or shrub dominated, and to a lesser extent pasture dominated.

2.2. Model definition

Our model is a stochastic CA, with a relaxed definition of neighbourhood. The starting raster for the model is made up of 10m cells with a value of tree, shrub or pasture, classified from aerial photography. For trees, the age is also estimated, as this determines when it matures enough to become a seed source. In addition rainfall probability values are estimated for each year of the model run. This value reflects the probability that a seed will establish, given the rainfall patterns in any given year. The model proceeds in annual time steps following the rules outlined below.

2.3. Model rules

The following assumptions apply to our model:

1. Multiple seed sources will not alter the probability of a tree establishing
2. A tree remains a tree and continues growing (i.e. cannot die and revert to pasture or shrub)
3. Shrub can change to tree (can be out-competed) or remain shrub, but cannot revert to pasture
4. Pasture can change to tree if there is a seed source (tree at least 20 years old) within 20m
5. Shrub can change to tree if there is a seed source (tree at least 30 years old) within 20m (shrub delays tree establishment)

The model rules are shown in Table 1.

Table 1. Model rules at each time step

Current state	Conditions	Next time step	Probability
Tree	N/A	Tree	1
Pasture	Any tree >20 years within 10m	Tree	*A* * rainfall probability
Pasture	Any tree > 20 years within 20m	Tree	*B* * rainfall probability
Pasture		Shrub	current shrub density within 100m radius * *C* * rainfall probability
Shrub	Any tree > 30 years within 10m	Tree	*A* * rainfall probability
Shrub	Any tree > 30 years within 20m	Tree	*B* * rainfall probability

A, *B* and *C* are constants (see Results)

If none of the above rules apply, then the cell state remains unchanged.

3.0 SOURCES OF UNCERTAINTY

Model uncertainty can be expected to increase with complexity. According to Childress *et al.* (1996), the main part of the art of ecological modelling is compromising among modelling objectives, ecological realism and computational tractability, in order to control complexity.

Sources of uncertainty include:

- *Cell size and structure*: In GIS, cells are generally regular squares, leaving the choice of cell size as a source of uncertainty. Cell size is a trade off between unambiguous classification and computational cost. The cell size should also reflect neighbourhood processes. The model could be run at various spatial resolutions, however this can add a huge computational burden.

- *Cell occupancy*: Uncertainty is introduced both through the problem of mixed cells (a cell may contain multiple vegetation types), and uncertainty in classification (a young tree may be misclassified as shrub or pasture). The incorporation of fuzzy sets can handle input data uncertainties (Dragićević, 2010).

- *Neighbourhood size and shape*: In traditional two-dimensional CA, the neighbourhood is usually defined as the four or eight cells immediately adjacent to the cell in question. Many model applications relax this rule however. This decision needs to be driven by ecological knowledge, and is closely linked to cell size.

- *Transition rules*: These rules must also be founded in ecological theory. They can be refined empirically, but it is difficult to define the uncertainty related to transition rules.

- *Probabilities in stochastic rules*: In a stochastic model, probabilities that a rule will apply are estimated. These probabilities can reflect uncertainty in the ecological process (how likely it is that a seed will establish?) and will result in a different model outcome each time it is run.

- *Time step*: CA require a discrete time step where all cells update simultaneously. The choice of time step again should reflect ecological processes.

- *Future conditions*: When the model is used for future predictions or scenario modelling, there will be many unknowns introduced. Many of these can be handled by constraining scenarios.

- *Unmodelled variables*: All models must decide which variables to include and which to exclude. Some of the uncertainties introduced here (e.g. by ignoring soil type) can be partially addressed with the probabilities in stochastic rules.

- *Unknown factors*: There will be factors influencing the outcome of the model that simply are not known. This uncertainty could be randomly incorporated into the model.

The model outputs aim to at least acknowledge these uncertainties, while incorporating techniques for handling them, including fuzzy sets, stochasticity, sensitivity modelling and multiple model runs to estimate confidence intervals.

4.0 RESULTS

The model was tested on a small number of paddocks comprising just over 2,000ha within the study area (10km south-west of Murchison). The cell size (10m), the time step (1 year) and the transition rules were not varied. At this stage limited sensitivity analysis has been run varying the probabilities for establishment of trees and shrubs.

Calibration was carried out by varying the values for A, B and C (see Table 1) and minimising RMSE for the resulting proportions of tree, shrub and pasture in three locations within the study site (circles with 250m radius) (see Figure 1). The model parameters are set with $A = 0.1$, $B = 0.02$ and $C = 0.35$.

Figure 1 shows predicted vegetation change from 1970 to 2070 for one run of the model. In locations with few trees, shrubs quickly spread, with trees eventually dominating. Pasture only remains in paddocks that are not abandoned. Figure 2 shows the proportions of vegetation in the three locations shown in Figure 1 from 1970 to 2070. In all three locations, pasture rapidly declines as shrubs and trees increase. Proportions vary, but masks 1 and 3 show typical patterns of shrubs initially increasing and then starting to decrease, while trees continue to increase and eventually dominate. In mask 2 shrubs rapidly dominate because of the low starting proportion of trees. Although the proportions appear to stabilise, this reflects the 30-year delay for new trees to establish and mature enough to take over shrubs.

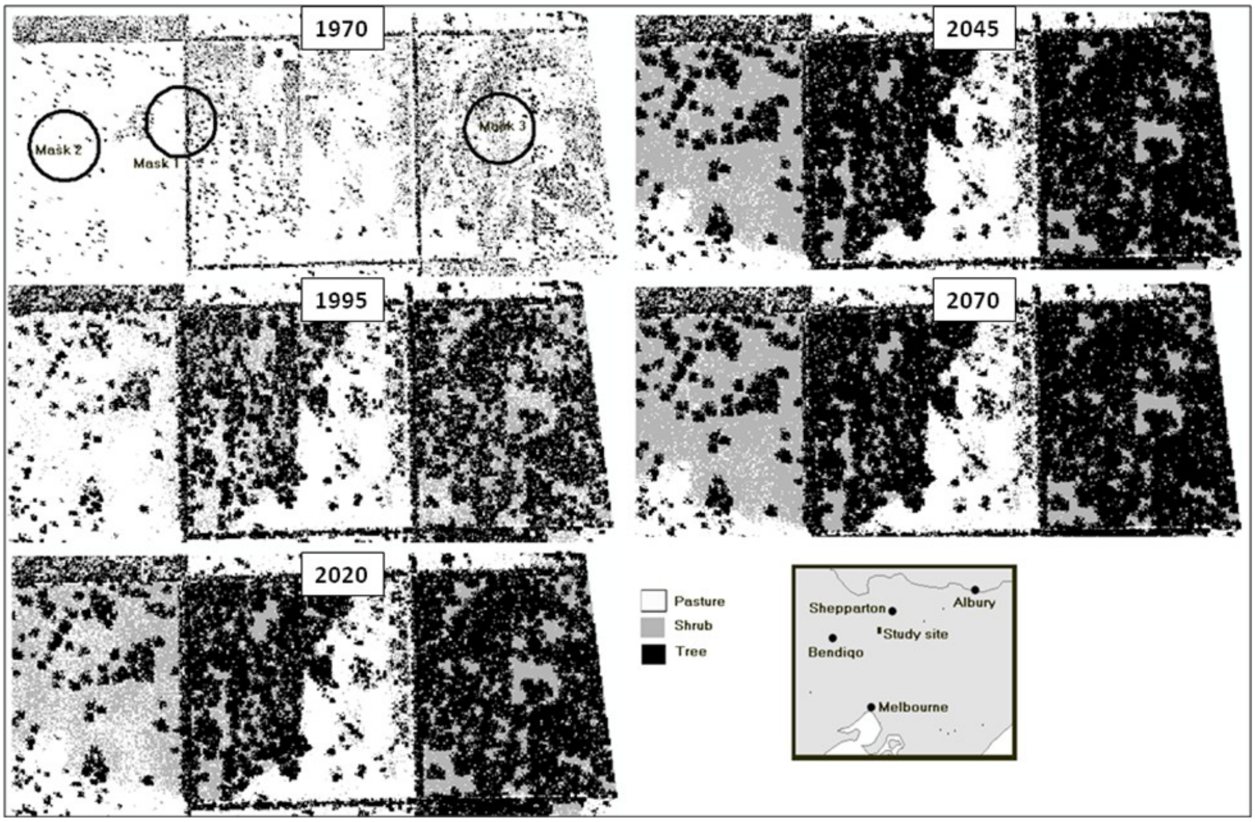

Figure 1: Predicted vegetation cover 1970 – 2070.

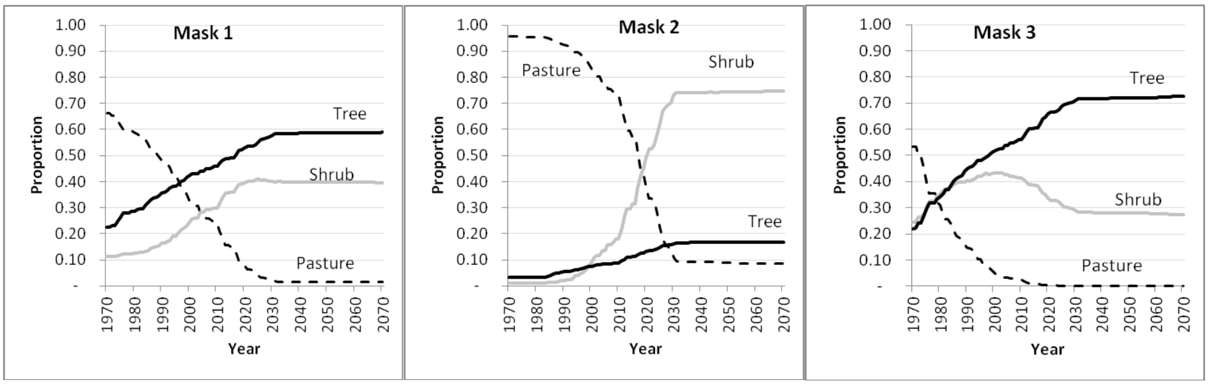

Figure 2: Change in proportion of pasture, shrubs and trees from 1970 to 2070

5.0 DISCUSSION

CA are difficult to calibrate, and sensitivity modelling is a useful tool for estimating parameters. In modelling future scenarios, probabilities and confidence intervals allow a range of vegetation proportions to be predicted rather than exact values in each location. The model estimates the relative proportions of these vegetation types under future rainfall and abandonment scenarios (not included here for brevity).

Including uncertainty explicitly in the modelling is important for explaining and understanding the model outcomes and for future decision making. Regrowth has the potential to provide important habitat for species and reconnect a fragmented agricultural landscape. By incorporating uncertainty, management options for different outcomes can be fine tuned to maximise the benefits.

6.0 CONCLUSION AND FUTURE WORK

This research is still at the initial stages; however the results show that it is possible to realistically model vegetation change using CA. The next steps are sensitivity analysis on neighbourhood size and shape, rainfall probabilities and introducing fuzzy sets for cell states.

For the 2,000ha testing raster, aerial photographs are available for 1970, 1982, 1989, 1999 and 2007. This allows for robust calibration and validation. The ultimate aim is then to model future scenarios under different rainfall and human disturbance conditions, and assess the resulting landscapes for the biodiversity benefit to the woodland bird community.

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A Simplified Approach for Classifying Urban Land Cover using Data Fusion

***Amit A. Kokje*[1], *Jay Gao*[1]**

[1]School of Environment, Building 201n, 10 Symonds Street,
The University of Auckland, Private bag No. 92019, Auckland, New Zealand 1142

Contact: **akok004@aucklanduni.ac.nz,**
Phone: 64 9 373 7599 ext. 82924,
FAX: 64 9 373 7434

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1.0 INTRODUCTION

Many government agencies and other organisations currently rely on geospatial systems for decision making. Consequently, regular acquisition and updating of geospatial datasets is a priority. Updating geospatial information in changing urban areas is always a challenging task. Geospatial information is usually updated by conventional methods such as surveying and manual editing of geospatial datasets, which are labour intensive, time consuming and costly (Wrzesien et al. 2003). Hence automation of such data updation procedures is of great interest in geospatial community. Conversely high resolution (Hi-Res) remote sensing data offering a detailed view of large coverage areas can be beneficial for automated procedures where information derived by converting pixel based information to meaningful thematic data. Such pixel based land cover extraction procedures are widely used in landscape analysis (Luck and Wu, 2002). However compact juxtaposition associated with urban features and limited number of available spectral information, induces scalar and spectral noise in thematic maps derived from such land-use land-cover (LULC) classification procedures. This crucial problem of urban land cover delineation is targeted in the current study by integrating complementary LiDAR data with Hi-Res WorldView-2 images for downtown Auckland, aiming to develop a simplified procedure for identifying various LULC commonly found in urban areas suitable for geo-spatial applications.

Extraction of land cover information from Hi-Res satellite imagery from those parts of the urban area characterised by a diversity of land-use types is difficult. For instance, central business districts contain a variety of building type, impervious surfaces such a roads and a range of other land-use types comprising as parks, gardens and water bodies. Vegetation and water bodies can be distinguished by their unique spectral properties. Impervious areas on the other hand comprise of a wide range of features such as buildings, roads (motorways, arterials, dirt, and sidewalks), parking lots and other impervious surfaces. These manmade features are made up of complex materials such as metal, glass, concrete and asphalt, which may be spectrally similar and thus difficult to differentiate purely on spectral reflectance obtained from imaging sensor (Herold et al. 2003). Additionally, shadows cast by high-rising features diminish direct solar irradiance for the neighbouring objects which may leads to partial or total loss of radiometric information in affected areas. As a result pixel based image analysis methods may induce thematic inaccuracies in identifying the objects in the shadowed areas While extreme spatial, textural and geometrical diversity further persuades spectral and scalar noise in the thematic map derived (Donnay et al. 2001). Use of additional information such as 3D LiDAR data, complementary to the spectral data of satellite images has been attempted successfully to extract various urban features such as buildings (Rottensteiner et al. 2002; Tao et al. 2002; Sohn et al. 2007; Chen et al. 2009), roads (Hu et al. 2004; Tiwari et al; Chen et al. 2009) and vegetation (Rutzinger et al. 2007; Holmgren et al. 2008). Yet, drawbacks such as lack of robustness in adapting to various interpretation parameters and automation hamper the effective use of LiDAR data and Hi-Res images for LULC extraction. Furthermore, many of the current methods are customised to target single feature identification and extraction, limiting their applicability to other types of urban scene.

With above in mind, the current study aims to facilitate identification of simplified feature classification procedure integrating LiDAR data and hi-res satellite images in order to recognise various LULC commonly found in urban areas. The study focuses on effective fusion of LiDAR products such as digital elevation model (DEM), with that of multispectral satellite imagery to identify various feature segmentation parameters. Instead of using LiDAR elevation as complementary data source during image segmentation, the research investigate use of normalised Digital Surface Model (nDSM) as a prime image segmentation parameter yielding better results in spectrally similar features. The progressive feature identification and extraction approach proposed is expected to minimise classification inaccuracies caused by spectral and spatial complexity of the image content.

2.0 Method

The area is Auckland city, specifically the core of the central business district (CBD). The CBD is located on the northern shore of a narrow isthmus and extends from the Auckland waterfront on the Waitemata Harbour (Fig. 1).

Fig. 1 Study area: - Auckland CBD (Google earth, digital Globe 2009)

The imagery was acquired from Worldview-2 (DigitalGlobe) multispectral imagery on 30th October 2010, covering approximately 25 km² of central Auckland is used as primary data source (figure 2a), of which around 3 sq. km area comprising of CBD is considered for this study. 2005-06 LiDAR data was provided by New Zealand Aerial Mapping Ltd. (NZAM). The data supplied in LAS point cloud format comprising both ground and above ground points at an average density of 1 point/m².is used as complementary datasets to satellite imagery (figure 2b).

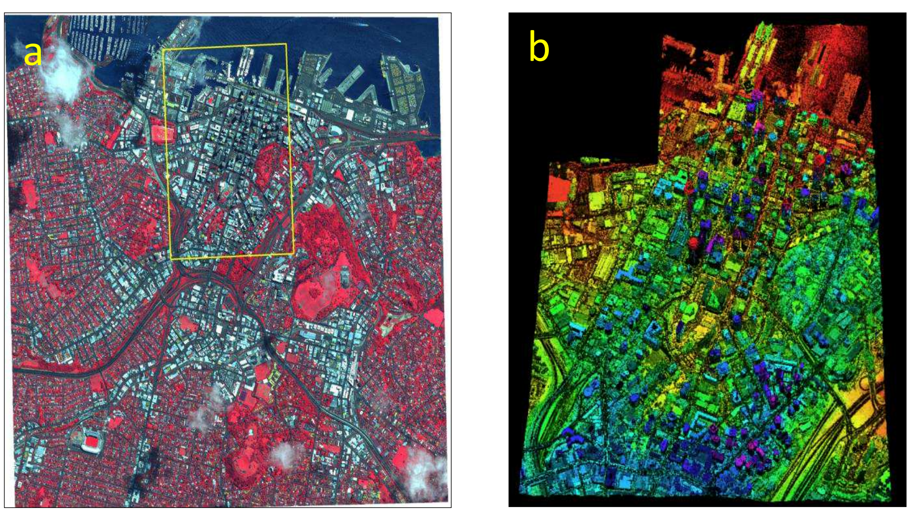

Figure 2: Data used a) Worldview-2 multispectral imagery, b) LiDAR data

In an object-based feature identification approach, multi-resolution segmentation algorithm in eCognition environment is applied (figure 3). nDSM data offering object elevation information is considered as main segmentation parameters supported by spectral information (NDVI, ZABUD and red spectral channel) applied to group various urban features based on homogeneity criteria. In a new approach, all image objects obtained from segmentation process, differentiated into intermediate ground and above-ground classes based on elevation data. A hybrid supervised and Rule-set based parametric classification is performed on the intermediate (ground, and above-ground) classes identified, to obtain various land features.

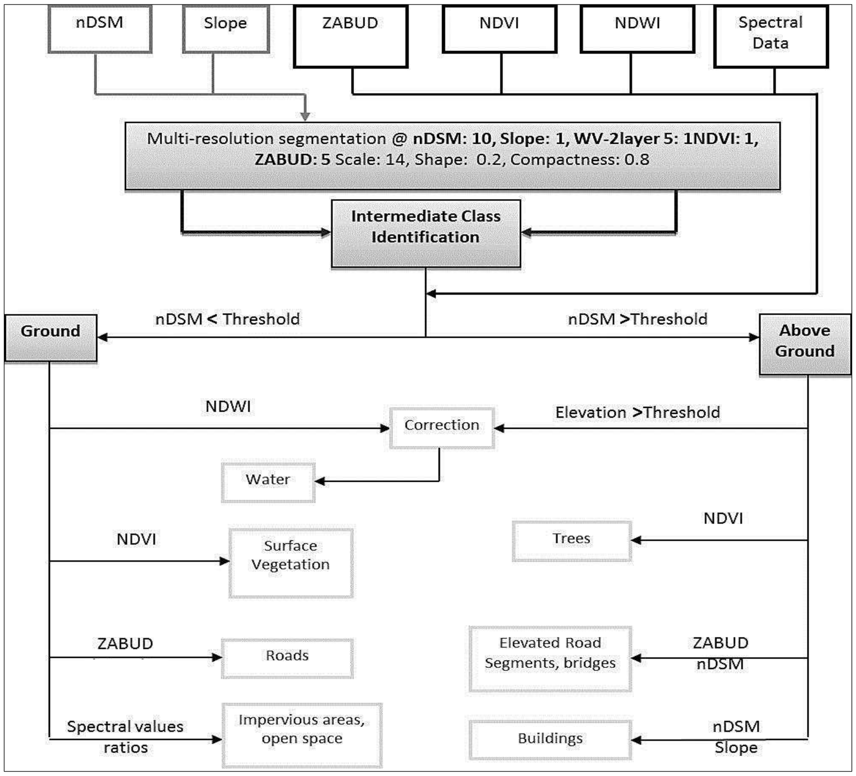

Figure 3: Methodology opted for the land feature identification

For data segmentation and classification, nDSM and slope derived from LiDAR data in conjunction with spectral components significantly improved the segmentation process, yielding better pixels grouping in spectrally complex impervious areas. Additionally, effect of shadows on segmentation region (figure 4a) is reduced dramatically by applying active LiDAR nDSM (figure 4b) data devoid of any shadows.

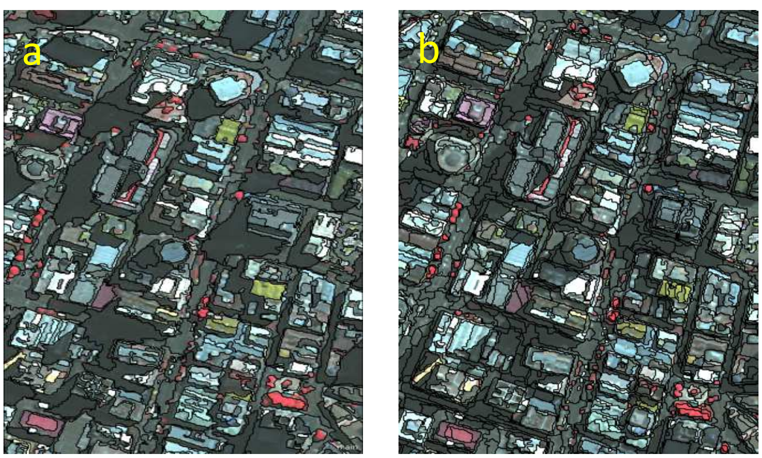

Figure 4: Effect of shadows on image segmentation (a) and after applying nDSM (b)

Feature classification process based on the proposition that all the image objects (features) in a given area can be divided into ground and above-ground based on the elevation. Using this condition, intermediate classes (ground and above-ground) are derived from nDSM threshold (Figure 5b).

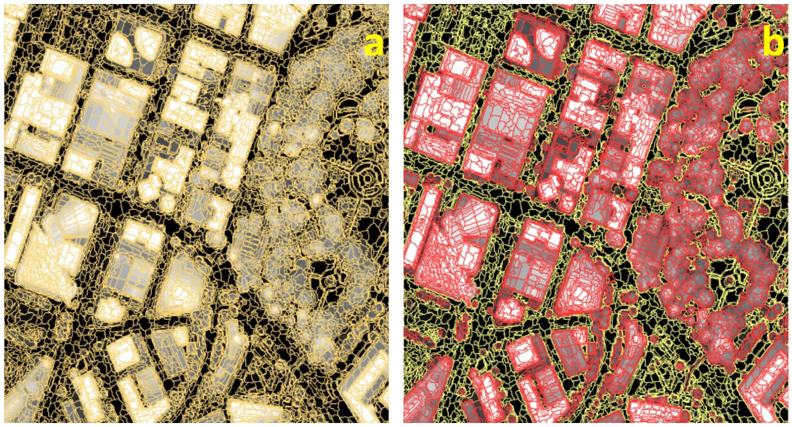

Figure 5: a) image segments and b, transitional classes ground (yellow) and above-ground (red) based on nDSM threshold.

Based on the elevation, land-cover classes are categorised into intermediate ground and above-ground classes (table 1), enabling simplification of parametric rule-set for classifying land features.

Ground	Above Ground
Water	
Grass, ground Vegetation	Trees
NA	Buildings
Roads	Elevated road segments,
Asphalt roads, Impervious surface, open space	NA

Table 1: Land feature categorised based on elevation

In a stepwise classification approach, features categorised as ground are classified using sample based standard nearest neighbour (SNN) feature space optimisation. Based on samples, average for layers 3, 4 and NDWI, while ratio for layers 6, 3 and ZABUD identified from feature-space optimisation applied to designated classes. As identified in table 1, water, ground-vegetation, roads, asphalt roads impervious surface (concrete) and open spaces are obtained from classification of intermediate ground class (figure 6).

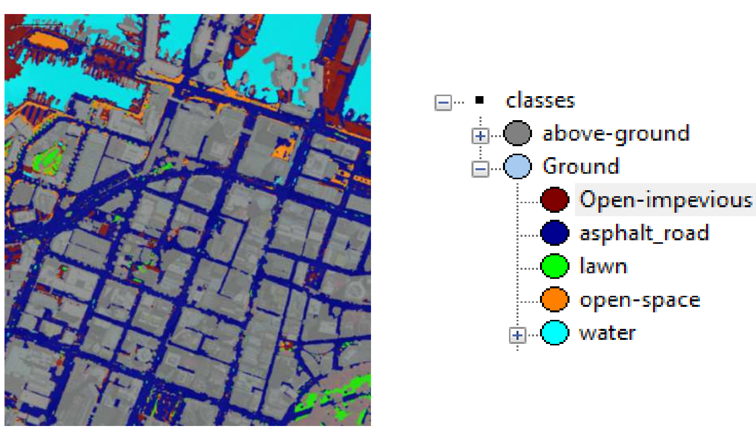

Figure 6: Various land features under intermediate class 'ground" is recognised.

A rule-set based corrections stage is applied on individual classes to remove any localised misclassifications. Due to spectral and spatial complexities associated with features in above-ground class, individual parametric rules are applied to extract trees and buildings (low, med and high rise) (figure 7).

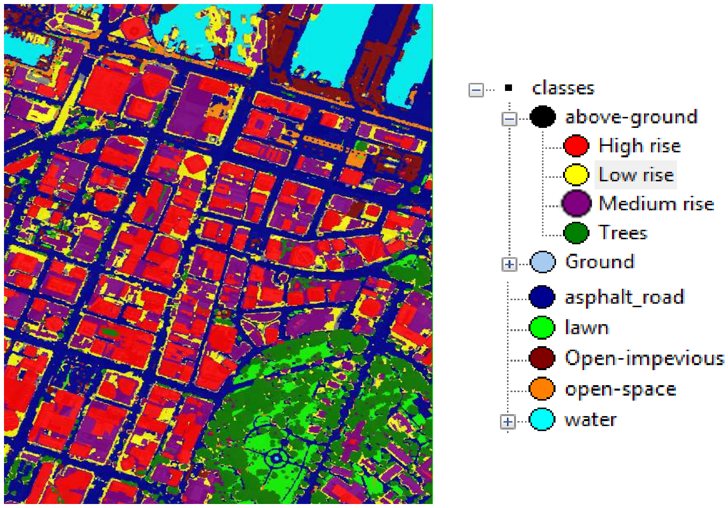

Figure 7: Sub classification of intermediate ground and above ground classes, yielding land features.

3.0 Results

Initial analytical tests confirm accuracy of 93% for objects classified under transitional ground feature class. Pre classification of image segments into intermediate classes (ground and above-ground) segregated the parameters associated with individual land-covers to either of the two, restricting their influence to a particular land-cover class. For example, shadows induced significant inaccuracies (figure 8a) when identical standard NN parameters were applied on image objects not differentiated into ground and above-ground, while LIDAR base pre-classification drastically reduces the influence of shadows (figure 8b).

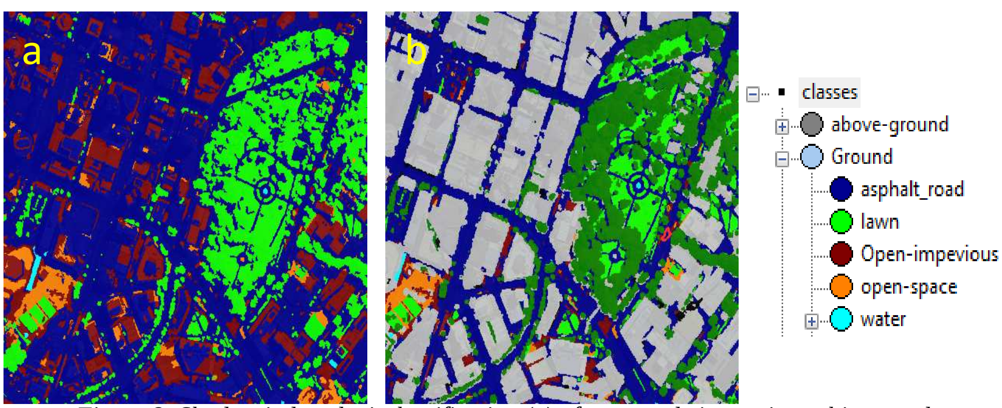

Figure 8: Shadow induced misclassification (a) of man-made impervious objects and corrected classification using LiDAR (b).

Usage of elevation information derived from LiDAR enables simplification of rule-sets for spectrally identical features such as grass or natural turfs and trees. As both comprises of vegetation, differentiation between trees and grass would otherwise require much complex and more feature oriented (texture, shape, scale etc.) classification parameters. With pre-classification of similar objects to ground and above-ground, trees and grass features are separated by applying minimal information (mean NDVI and ratio-ZABUD). ZABUD, an index modified from original ZABUD derived by Lewinsky (2006) for delineating built-up area from LandSat-ETM+ sensor, proved to be effective in identifying asphalt features such as roads. During the investigation the original index is successfully modified to incorporate spectral channels in the WsorlDView-2 image. A typical ZABUD image (figure 9) exhibits very low spectral response and negligible impact of shadows, making it ideal for demarcating road segments in shadowed regions.

Figure 9: Typical ZABUD index image

4.0 CONCLUSIONS

A simplified hybrid approach of elevation based segmentation is investigated in the current research. Evaluation carried out prior to accuracy assessment indicates enhancement in feature segregation in spectrally complex urban areas. Features which otherwise prove difficult to differentiate, effectively segregated by applying LiDAR nDSM. A streamlined method based on early separation of ground and above-ground features followed by hybrid supervised- rule set classification approach based on parameters such as NDWI, NDVI, ZABUD etc. can be very beneficial in standardising a methodology which will be applicable in all urban scenarios.

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Geospatial Modelling of Complex Land Use Cover Change: How to Determine the Adequacy and Significance of Variables.

Isaac Kwadwo Nti & Philip Sallis

Geoinformatics Research Centre
Auckland University of Technology, Auckland, New Zealand
Phone: +64 9 921 9999 ext 6592
Email: isaac.nti@aut.ac.nz and philip.sallis@aut.ac.nz

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1.0 INTRODUCTION

The physical landscape is increasingly changing due to effects of natural phenomena and activities of mankind. In view of this, the challenge of modelling the ever changing physical landscape or land use cover (LUC) of the earth has resulted in the creation of diverse models to depict these variations. Most of the current models have been applied to urban growth or deforestation, which is a study of only one LUC class, or at most two(binary) LUC classes (Dietzel & Clarke, 2007; Huang, Zhang, & Lu, 2008; N, Sawant, & Kumar, 2011). It is less complicated to model the change of binary LUC classes, but becomes more complex when considering five or more LUC classes. Complexity of the LUC model increases in the order of (n^2 –n) transitions, where n is the number of LUC classes. An additional complicating factor is that the inherent error of each transition contributes to the overall calibration and validation of the model making it difficult to arrive at a precise "best fit" result. Thus many settle for binary LUC classes.

Another challenge is the determination of reaching a satisfactory degree of the significance of drivers or variables for inclusion in a LUC change model. Most of the operational LUC change models were developed for either specific projects or locations using specific driving variables therefore they are not generic and cannot be adapted for other locations.

The SLEUTH model is a cellular automaton model, developed with predefined growth rules applied spatially to gridded maps of the cities in a set of nested loops, and was designed to be both scalable and universally applicable. Urban expansion is modelled in a modified two-dimensional regular grid. Maps of topographic **S**lope, **L**and use, **E**xclusions, **U**rban extents, road **T**ransportation, and a graphic **H**illshade layer form the model input.

Although the SLEUTH LUCC model and others have been applied to many locations globally, modellers are unable to modify the drivers influencing the change because the assumption is that the drivers of change are the same at every location, which is a fundamental conceptual flaw. When applying such models to different locations modellers can only adjust the coefficients of the driving parameters during calibration phase but cannot introduce new variables.

The aim of the paper is to determine the adequacy and significance when considering the variable and parameter set of components that describe a LUC change model. Also the authors seek to answer the question "What are the measures we can use for this determination?"

2.0 LAND USE COVER CHANGE (LUCC) MODELLING

LUCC modelling methods such as Cellular Automata (CA) and Agent Based Modelling (ABM) have the capability of determining the variables influencing the transition from one LUC class to another. CA LUCC models employ **transition rules and set of parameters of variables** to model LUCC from time t_1 to t_2. In the real world these transition rules and variables are not known but in LUCC models, modellers have to compute transition rules for specific LUCC(s). In order to ascertain that the chosen transition rules and variables are acceptable, comparison of the simulated maps with the observed (reference) is carried out to have the goodness-of-fit of the parameter set (Visser, 2004, p.85). The goodness-of-fit depicts how well the transition rules and the set of parameters fit the LUCC for the specified period. Thus LUCC model calibration process is finding the optimal/more realistic transition rules and variable parameter sets so that the modelled change matches real change.

When considering a variable and parameter set of components for LUCC model, **one has to determine the adequacy and significance of each variable before including it into the system**. The Weights of Evidence (WoE) approach was used to measure the adequacy and significance of variables of the model. The WoE method has an advantage over other statistical methods, such as Logistic or Linear Regression, in that **it is not constrained by statistical assumptions of parametric methods (which spatial data violate)**. The only assumption for Weight of Evidence method application is that **all variables are spatially independent.** Thus, a pairwise test of spatial variable maps measuring Cramer's Coefficients, the Contingency Coefficient and the Joint Information Uncertainty are applied to assess the existence of a correlation between two variables. Any pair of variables showing strong correlation will introduce double "influence" in driving a transition, therefore one of such variables is removed.

The Bayesian method is applied in computing Weights of Evidence, whereby the effect of a spatial variable on a transition is calculated independently of a combined solution. The Weights of Evidence represent each variable's influence on the spatial probability of a LUC transition from LUC class $k \Rightarrow l$.

Given a binary map of spatial pattern, B (defining the presence or absence of spatial pattern) and a map of land use cover transition(s) D, the weighting factors W^+ and W^- can be calculated from the ratios of conditional probabilities and could be stated as follows:

$$W^+ = ln\left\{\frac{P(B|D)}{P(B|\bar{D})}\right\} \quad and \quad W^- = ln\left\{\frac{P(\bar{B}|D)}{P(\bar{B}|\bar{D})}\right\} \qquad \text{Equation 1}$$

where B and $\bar{B}$ stand for the presence and absence of binary spatial map pattern respectively and, D and $\bar{D}$ stand for presence and absence of land use cover change event respectively(Agterberg & Bonham-Carter, 1990; Goodacre, Bonham-Carter, Agterberg, & Wright, 1993). The contrast, C, is a measure of the spatial association between the binary pattern and the events is given by

$$C = W^+ - W^- \qquad \text{Equation 2}$$

In order to determine whether magnitude of the contrast is statistically significant, is tested using the variance of the contrast $s^2(C)$ and can be expressed as

$$s^2(C) = \frac{1}{area(B \cap D)} + \frac{1}{area(B \cap \bar{D})} + \frac{1}{area(\bar{B} \cap D)} + \frac{1}{area(\bar{B} \cap \bar{D})} \qquad \text{Equation 3}$$

The contrast(C) indicating whether there is a relationship between B and D is said to be statistically significant with 95% probability if $|C| > 1.96\, s(C)$.

From Equation 1 then, $ln\{D|B\} = ln\{D\} + W^+$

Where W^+ is the Weight of Evidence of occurring transition $k \Rightarrow l$, given a spatial variable pattern B, then the post- probability of a transition $k \Rightarrow l$, given a set of spatial variable data (B, C, D,... N), is expressed as follows:

$$P\{k \Rightarrow l | B \cap C \cap D \ldots \cap N\} = lnD + W_B^+ + W_c^+ + W_D^+ + \cdots + W_N^+ \qquad \text{Equation 4}$$

Equation 4 represents the degree of association of spatial pattern or variables with occurrence of event ($k \Rightarrow l$). Thus the probability that a cell will transition from $k \Rightarrow l$ is given in Equation 4 in terms of the weights of the spatial variables influence on each transition.

In this work LUC data for Auckland region for the years 1990 and 2000 were used and classified into seven LUC types – natural forest[1], planted forest[2], grassland[3], cropland[4], wetland[5], settlements[6] and other lands[7]. The work was implemented using the DINAMICA EGO modelling software. Figure 1 shows the workflow process employed in this work.

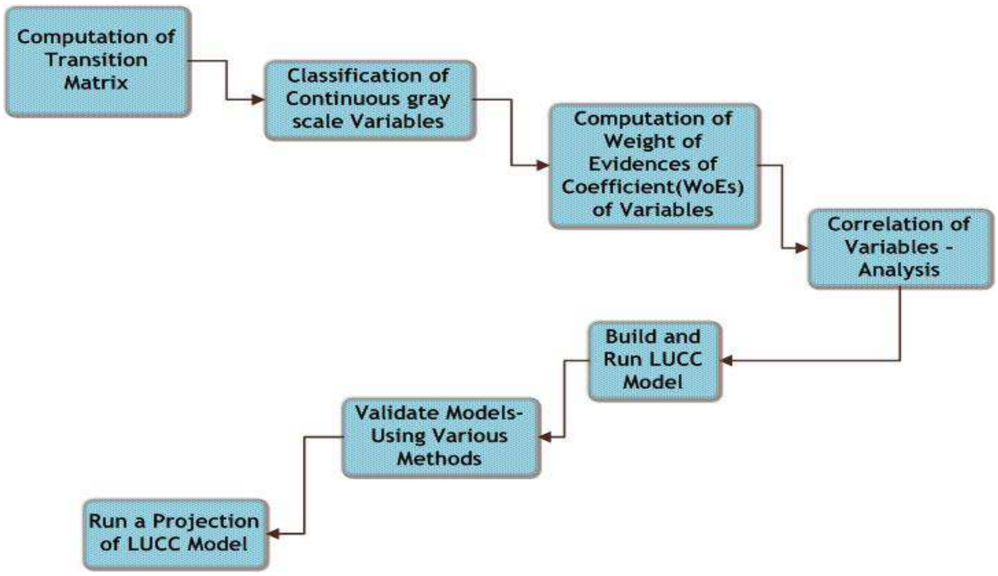

Figure 1: A workflow process of LUCC modelling.

3.0 RESULTS AND CONCLUSION

Using LUC raster map of 100X100m resolution the Markovian matrix as shown in Table 1 shows the number of cells per each transition. It remarkable to note that both cropland(4) and wetland(5) had not gone through any change in Auckland area between 1990 and 2000.

During the implementation phase, all the spatial variables were tested against each transition considered in the model. Table 2 presents a summary of a set of variables which had significant influence per transition, it is important to note that two variables, hillshade and soil, were not included in any of the transitions because they were not having any significant impact. The marked “red” boxes showed correlation with other variables so were not included in modelling that transition.

Table 2 reveals that each transition has unique sets of variables influencing a specific LUC transition and furthermore all transitions don’t have the same set of variables. The WoE method was employed to demonstrate that each LUC transition $k \Rightarrow l$ has a set of unique variables influencing the change and this specific to Auckland area.

		LUC Map for 2000						
	From \ To	1	2	3	4	5	6	7
LUC Map for 1990	1	----	70	280	0	0	30	0
	2	0	----	60	0	0	0	0
	3	0	6052	----	0	0	640	10
	4	0	0	0	----	0	0	0
	5	0	0	0	0	----	0	0
	6	0	0	0	0	0	----	0
	7	0	50	29	0	0	50	----

Table 1: Transition Matrix

Variables\Transitions	1->2	1->3	1->6	2->3	3->2	3->6	3->7	7->2	7->3	7->6
Elevation		✓			✓	✓				
Slope		✓			✓	✓				
Hillshade										
Reserved		✓			✓	✓				
Soil										
Distance to Rivers		✓			✓	✓	✓			
Distance to Major Roads	✓	✓	✓	✓	✓	✓	✓			
Distance to Minor Roads	✓				✓	✓		✓		
Distance to 1(Natural Forest)				✓	✓	✓				
Distance to 2(Planted Forest)	✓	✓			✓	✓		✓	✓	
Distance to 3(Grassland)		✓							✓	
Distance to 6(Settlements)	✓	✓	✓	✓	✓	✓		✓	✓	✓
Distance to 7(Other lands)	✓	✓		✓	✓	✓				

Table 2 : Results of Spatial Variables and their influence per LUC transition

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The fear factor: Examining the spatial variability of recorded crime on the fear of crime in New Zealand

Gregory Breetzke[1] & Amber Pearson[2]

[1]Department of Geography
University of Canterbury. Christchurch, New Zealand
Phone: +64 3 365 8114 Fax: +64 3 364 2999
Email: gregory.breetzke@canterbury.ac.nz

[2]Department of Public Health
University of Otago, Wellington. New Zealand
Phone: +64 4 918 6192 Fax: +64 4 389 5319
Email: amber.pearson@otago.ac.nz

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1.0 INTRODUCTION

In this work we attempt to gauge the effect that recorded crime at three different spatial levels (own neighbourhood, surrounding neighborhoods, and broader region) has on fear of crime among the citizens of New Zealand. We do this drawing on data from a national social survey of 7249 residents and using reported crime obtained from the New Zealand Police service.

2.0 MATERIAL AND METHODS

2.1 Data

The data used to measure recorded crime in New Zealand was obtained from the New Zealand Police. The crime information obtained included the location (x, y coordinate), date, time, and hour of day as well as a unique code for each crime incident for the years 2008-2010 for the whole country. Other neighborhood-level data for this project was obtained from the Statistics New Zealand census dataset for 2006. Both the crime and census data were aggregated to the census areal unit (CAU) level. Individual-level data was obtained from the New Zealand General Social Survey (NZGSS) of 2010.

2.2 Dependent variable

Fear of crime data was measured using two items extracted from the NZGSS:
1. How safe do you feel walking alone during the day in your neighborhood?
2. How safe do you feel walking alone at night in your neighborhood?
Respondents were asked to indicate a response to the above questions on a 4-point Likert-type scale, where 1 was “very safe” to 4 being “very unsafe” (alpha = 0.66). To aid analysis, the items were combined into a continuous scale using principal components analysis (mean = 0; standard deviation = 1; and range -0.985 to 2.603). Higher values provided an indication of greater fear.

2.3 Independent variables

2.3.1 Individual level variables
A total of ten individual-level variables were utilized in this research. *Gender* was a dummy variable (male = 1; female = 0). A measure of *Prior Victimization* was employed to determine whether the respondent had previously been a victim of crime. *Prior Discrimination* was extracted from the NZGSS (yes = 1; no = 0). Both *Employment status* (employed = 1; unemployed = 0) and *Social marital status* (with partner = 1; without partner = 0) provided an indication the economic and social state of respondents. The *Length of stay in New Zealand* was a continuous variable. *Median income* provides a measure of wealth of each respondent; *Dependent children* (yes = 1; no = 0), *Age* (continuous variable) and *Maori/Non-Maori* (yes = 1; no = 0) conclude the list of individual-level independent variables.

2.3.2 Neighborhood level variables
Neighborhood-level variables include *NZDep*.. The *Social fragmentation index* is an index of neighbourhood-level social fragmentation developed by Ivory *et al* (2012): the higher the measure, the higher the social fragmentation. *Racial heterogeneity* was created by multiplying the percentage Maori by the percentage non-Maori. Higher values indicated more racially mixed neighborhoods. *Residential stability* was measured as the percentage of residents within the CAU that had been living there for less than five years. Lastly, the *Total alcohol outlets* measure assessed the total alcohol outlets in the individuals' CAU. The crime rate was calculated using New Zealand Police crime data for average over 2008-2010. The *Crime* rate was calculated as the number of crimes per 100,000 people per CAU. Three separate spatially lagged variables were next created each providing an increasingly diffuse measure of crime in the country: *Crime (lag1)* was created using a first orders rooks contiguity matrix; *Crime (lag3)* contained a third *order rook contiguity* weights whilst the final crime measure, *Crime (lag10)* was intended to measure crime levels over a broader area, and was calculated using a tenth *ordered rooks contiguity* weight. The descriptive statistics for the neighborhood level independent variables used in the analysis are presented in Table 1.

2.4 Modelling framework

The first baseline OLS multiple regression model examined the relationship between the fear of crime and the combined individual, and neighborhood level variables. The crime variables were then added separately and distinctly to the baseline model in columns 1 to 4 of Table 2. Last, all four crime variables were added to the baseline model in column 5.

3.0 RESULTS

The crime rate within the individuals' own neighborhood was found to have a weak but positively significant effect on fear of crime (β=0.103; significant at $p < .01$). The independent inclusion of the spatially lagged crime variables (Table 2, columns 2-4) resulted in only one other significant finding and that was for the variable Crime (lag10) in column 4. In this instance crime within the broader environment was found to be negatively associated with feelings of fear and vulnerability among respondents. All of the models constructed exhibited a moderately weak fit to the fear of crime data (R^2 adjusted for degrees of freedom ranged from 0.147 for the baseline model to 0.150 for the full model (column 5)).

4.0 DISCUSSION

4.1 Individual level

Being male was found to be positively and significantly related to fear of crime. Individuals who had previously been a victim of crime or have previously been discriminated against also were found to be more fearful. Similar to previous work both locally and internationally older and poorer people were found to be more fearful of crime (see Evans and Fletcher, 2000; New Zealand Ministry of Social Development, 2010). Last, non-Maoris were found to be significantly fearful of crime.

4.2. Neighborhood level

With the notable exception of the residential stability measure, all other neighborhood level variables were found to be significantly related to fear of crime. The neighborhood deprivation score was found to be positively associated with fear of crime suggesting that individuals residing in more deprived neighborhoods experience significantly greater fear of crime. A positive relationship was found between the social fragmentation index and fear suggesting that individuals residing in socially fragmented neighborhoods exhibit more fear. Interestingly, the total number of alcohol outlets was found to be negatively associated with fear of crime suggesting that individuals residing in neighborhoods with high numbers of alcohol outlets experience significantly lower fear of crime. This finding was consistent across all models.

Regarding the substantive aim of this study, the crime rate within an individuals' own neighborhood was found to be positively and significantly associated with fear after controlling for various individual and neighborhood level predictors. Individuals residing in high crime neighborhoods, report higher levels of fear. Crime occurring within the surrounding neighborhoods of individuals was not found to be related to self-reported feelings of fear. This finding suggests that individuals are more concerned about events, particularly crime, occurring within their neighborhoods than in those adjacent to them. Finally, the results of this research indicate that crime occurring within the broader spatial setting of the individual has a negative association with fear of crime. The higher the crime across a large swathe of the city, the lower the feelings of fear exhibited. One possible explanation for this finding could be that individuals may perceive crime occurring outside their own immediate and/or surrounding neighborhoods as being a problem for 'them' and not for 'us'. Why worry about crime and its effects when it is not occurring near to me?

5.0 CONCLUSION

This article has made several important contributions to the existing literature on fear of crime research. First, this study demonstrated a direct link between neighborhood crime rates and fear of crime in New Zealand. Second, the study has demonstrated that neighborhood crime levels impact fear of crime among residents of a neighborhood differentially. Crime within an individuals' own neighborhood influences their fear of crime but crime occurring within neighboring communities have little or no effect on feelings of safety and security. Third, it is clear from this research that other individual- and neighborhood level factors, such as gender, age, and racial heterogeneity, can impact an individuals' fear of victimisation. We believe however that the results presented here are sufficiently valuable to merit further investigation; and that they provide an important empirical platform for future fear of crime research in New Zealand.

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Table 1: Descriptive statistics of the neighbourhood-level independent variables

	Mean	SD	p25	Median	p75
Deprivation score	995.09	68.91	941	983	1034
Social fragmentation	0.11	0.88	-0.5	-0.1	.5
Racial heterogeneity	2717.13	3066.91	702	1656	3600
Total alcohol outlets	6.46	14.61	1	3	6
Residential stability (%)	53.86	12.01	45.83	53.57	61.11
Crime	2687.22	3840.86	1047.84	1972.63	3225.81
Crime (lag 1)	2556.23	2796.85	1050	1804	3131
Crime (lag 3)	2099.03	1875.12	1059	1657	2546
Crime (lag 10)	2079.15	2610.34	1044	1554	2389

Table 2: Regression models of rates of crimes on the fear of crime (*n* = 8552)

	Variables	Baseline model	(1)	(2)	(3)	(4)	(5)
Individual level	Gender	.338**(.016)	.338**(.016)	.338**(.016)	.338**(.016)	.337**(.016)	.336**(.016)
	Prior victimisation	.116**(.020)	.112**(.020)	.112**(.020)	.112**(.020)	.111**(.020)	.111**(.020)
	Discrimination	.085**(.025)	.084**(.026)	.085**(.026)	.085**(.026)	.087**(.026)	.086**(.026)
	Employment status	-.022(.020)	-.014(.021)	-.015(.021)	-.015(.021)	-.014(.021)	-.013(.021)
	Social marital status	-.002(.016)	-.002(.017)	-.003(.017)	-.003(.017)	-.003(.016)	-.002(.017)
	Dependent children	-.003(.010)	-.002(.010)	-.002(.010)	-.002(.010)	-.002(.010)	-.002(.010)
	Length of stay in New Zealand	.028(.052)	.031(.054)	.030(.054)	.030(.054)	.028(.053)	.030(.054)
	Median income	-.103**(.018)	-.106**(.019)	-.106**(.019)	-.105**(.019)	-.106**(.019)	-.108**(.019)
	Age	.003**(.001)	.003**(.001)	.003**(.001)	.003**(.001)	.003**(.000)	.003**(.001)
	Maori/Non-Maori	-.094**(.025)	-.092**(.026)	-.091**(.026)	-.089**(.026)	-.084**(.026)	-.086**(.026)
Neighbourhood level	NZDep	.002**(.000)	.002**(.000)	.002**(.000)	.002**(.000)	.002**(.000)	.002**(.000)
	Social fragmentation index	.029*(.011)	.033**(.012)	.031**(.011)	.031**(.011)	.027*(.011)	.027*(.012)
	Racial heterogeneity	.084**(.025)	.089**(.026)	.086**(.026)	.086**(.026)	.084**(.026)	.086**(.026)
	Residential stability	.001(.001)	.001(.001)	.001(.001)	.001(.001)	.001(.001)	.001(.001)
	Total alcohol outlets	-.003**(.001)	-.004**(.001)	-.003**(.001)	-.003**(.001)	-.003**(.001)	-.004**(.001)
(Crime variables)	Crime[a]	-	.103**(.318)	-	-	-	.107**(.330)
	Crime (lag1)	-	-	.512(.282)	-	-	.219(.330)
	Crime (lag2)	-	-	-	-.494(.442)	-	.745(.603)
	Crime (lag10)	-	-	-	-	-.131**(.387)	-.201**(.542)
	Adjusted R^2	.147	.148	.147	.147	.148	.150
	Akaike Info Criterion	14283.93	13782.57	13793.02	13791.77	13781.12	13772.42

*p < .05, two-tailed test; ** p < .01, two-tailed. Standard error in parenthesis; a. Coefficients and SE multiplied by 10,000

Where do women travel to give birth within New Zealand?

Pauline Dawson[1]

[1]Department of Women and Children's Health
University of Otago. Dunedin, New Zealand
Phone: +64 3 474 0999 x 8727
Email: pauline.dawson@otago.ac.nz

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1.0 INTRODUCTION

The objective of this study is to analyse the travel patterns of New Zealand women regarding the location of the facility selected for birth. Previous studies have been conducted in New Zealand which investigated access to maternity facilities and maternity provider availability in rural areas (Beere & Brabyn 2006; Brabyn & Skelly 2002; Hendry 2009; Farry, Thompson, Robertson, Benwell & Williamson 2008). Hunter et al. (2011) has also examined why women choose their place of birth, however there has been no investigation into the place of birth related to maternal residence and preferences of the birthing mother at the census mesh block or physical address scale. Some international studies (Grzybowski et al. 2011; Pitchforth et al. 2009; Gjesfjeld & Jung 2011) have touched on these issues, but the New Zealand Maternity system is unique and our population is sparsely spread, so study is required acknowledging these factors.

In 2012, a pilot study matching birthplace against residential area unit was conducted using spatial data from Statistics New Zealand, the results and limitations of which will be presented here.

This pilot study has led to a Master of Midwifery thesis which will collate and analyse residential location and birth place co-ordinates from Southern District Health Board (SDHB) and private facility records in the context of mesh block-level census data and road networks. A survey of all birthing women will conducted alongside the geospatial analysis to look for reasons behind travel patterns.

2.0 2012 PILOT STUDY

2.1 Data

Statistics New Zealand provided area unit-level instances of women birthing at each maternity facility in New Zealand for the 2011 calendar year. The data was generated from birth registration information. Homebirth data was excluded for the purposes of this pilot study, due to issues around potential identification of individuals and also the literature suggests that the choice to birth at home may involve different factors than for travelling to a maternity facility (Hunter et al. 2011; Abel & Kearns 1991).

2.2 Findings

The pilot study supports the findings of previous studies, such as Hunter et al (2011) who suggested that women from areas with high populations of Māori and Pasifika women were more likely to travel to the closest, often primary, birthing facilities. It also confirmed that the concentration of birthing women reflected areas with a younger demographic e.g. women of child bearing age.

The generalised nature of the data set limited the number of conclusions that could be drawn, however a number of patterns show promise for more detailed study.

In some areas women appeared to be by-passing primary and secondary birthing facilities to birth at a tertiary facility. The concentration appeared to be greater than expected for birthing mothers for whom a tertiary unit birth would be clinically indicated. A more detailed set of data and further analysis is required to confirm this.

2.3 Problems Encountered

2.3.1 Ethics - Identification of individuals

Area unit as the smallest geographical unit available without going through an ethics-approval process, as mesh block data in some areas may have the potential to identify individuals.

2.3.2 Area Unit vs Mesh Block

The aggregation of data to area unit prohibited accurate demographic and network analysis and hence identification of further geographic factors behind travel patterns.

2.3.3 Why?

While the existing data illustrates where women are travelling, it gives no indication as to why. Detailed location and census data, in combination with personal surveys will allow the application of spatial statistics techniques at a scale not yet performed in New Zealand.

3.0 ONGOING STUDY PLANS

3.1 Thesis Proposal

The proposed thesis is a mixed methodology project comprising of three parts. The first is a replication of the pilot study with 2012 data to highlight any temporal patterns. The second part is to obtain birthplace locations, geocoded to residential address from Southern DHB and private facility records for a 12 month period. These two data sets will be validated and compared. The microdata generated will allow for more accurate analysis of movement with techniques not performed in the pilot study. Emergency transfer data will also be assed in relation to chosen place of birth.

The third section will be a six month survey of all women birthing in the Southern DHB region. The questionnaire will contain demographic questions and some simple questions pertaining to the reasons for choosing their place of birth.

3.1.1 Anonymising Data

A large part of this research will require residential address data to be anonymised to ensure that the confidentially of individuals in all data is respected. One of the biggest challenges of the project will be addressing this issue while still maintaining the integrity of the spatial data, especially with respect to roading network topologies. It is planned that a process can be developed to obfuscate the data set to allow the results to be presented. For example, it would be possible to retain the microdata with the use of automation via a script and shift the resulting data in some way that will still accurately portray any geographical relationships. Exploration and testing of various GIS techniques to achieve anonymisation needs to be completed before ethics approval can be obtained.

3.1.2 Mapping the survey

It is anticipated that some survey data of factors important to women and their families in regard to choice of birthplace can be quantified spatially. Each facility will be weighted by desirability and then compared to travel patterns predicted using unweighted factors such as drive time (Haynes & Fotheringham 1984).

4.0 CONCLUSION

The pilot study using geospatial data and GIS tools to track women's travel patterns related to the location and facility they chose to given birth raised a number of ideas for further study. However it also highlighted issues related to micro data and ethics involved when using spatial tools for health research.

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DEFINITIONS

Primary Maternity services
The Primary Maternity Facility, in conjunction with the Lead Maternity Carer (LMC) or DHB Co-ordinated Primary Midwifery care, provides primary maternity inpatient services during labour and birth and the postnatal period until discharge home for uncomplicated births. Facilities do not provide obstetric specialists or anaesthetic options such as epidurals.

Secondary Maternity services
Secondary maternity services are provided where women or their babies experience complications that need additional maternity care involving Obstetricians and other Specialists.

Tertiary Maternity services
Tertiary maternity services includes additional maternity care provided to women and their babies with highly complex needs who require consultation with and/or transfer of care to a multidisciplinary specialist team.

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Spatial aspects of a comparative study of Active Transport to School and Motorized Transport

***Antoni Moore*[1], *Melanie Middlemiss*[2], *Claire Hodge*[3], *Paula Skidmore*[4] *& Sandra Mandic*[3]**

[1]School of Surveying
University of Otago. Dunedin, New Zealand
Phone: +64 3 479-7589 Fax: +64 3 479-7586
Email: tony.moore@otago.ac.nz

[2]Department of Information Science
University of Otago. Dunedin, New Zealand
Phone: +64 3 479-8142 Fax: +64 3 479 8311
Email: melanie.middlemiss@otago.ac.nz

[3]School of Physical Education, Sport and Exercise Sciences
University of Otago, Dunedin, New Zealand
Phone: +64 3 479-5415; Fax: +64 3 479-8309
Email: sandra.mandic@otago.ac.nz; clairelhodge@gmail.com

[4]Department of Human Nutrition
University of Otago. Dunedin, New Zealand
Phone: +64 3 479-8374 Fax: +64 3 479-7958
Email: paula.skidmore@otago.ac.nz

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1.0 INTRODUCTION

Active transport to school (ATS) is a convenient way to integrate physical activity into everyday life, maintain or increase physical activity level and may develop into environmentally sustainable travel practices over a lifetime. Adolescents' transport choices to school are influenced by demographic, individual, family, school, social and environmental factors. Age (Pabayo et al, 2011), male gender (Babey et al, 2009; Larsen et al, 2009), fewer vehicles at home (McDonald, 2008), low socio-economic status (SES) (Babey et al, 2009; McDonald, 2008), neighbourhood social environment (Hume et al, 2009), shorter distances from home to school (Babey et al, 2009; Larsen et al, 2009; McDonald, 2008), lack of parental concerns for safety are positively associated with a higher likelihood of ATS (Carver, 2010). More recent studies identified environmental factors associated with ATS including neighbourhood factors, route to school (Panter et al, 2010), distance to school (Babey et al, 2009; Larsen et al, 2009; Bringolf-Isler et al, 2008; Timperio et al, 2006), topography, street connectivity (Timperio et al, 2006), land use mix (Larsen et al, 2009; Panter et al, 2010), residential density (Larsen et al, 2009), busy intersections, intersection density (Timperio et al, 2006), and neighbourhood walkability (Kerr et al, 2006). This study compared individual characteristics and objective measures of built environment between ATS users and motorised transport (MT) users in Otago adolescents living within 4.8 km from their school.

2.0 METHODS

The study sample combined data from participants from Otago School Students Lifestyle Surveys 1 and 2 recruited from 22 schools in the Otago region, New Zealand. Students (n=2018) in school years 9 to 13 completed an anonymous online questionnaire. In this analysis we included the 1,325 students who lived within 4.8 km from school (the maximum distance for which ATS is likely to occur – McDonald, 2007). Students answered questions related to demographics, transport to school, physical activity and sedentary activities, and perceived peer and parental support for active transport to school. Environmental factors included urban versus rural residential area, safety perceptions, distance to school, and objectively measured built environment variables related to the home neighbourhood, school neighbourhood and route to school.

2.1 Distance from Home to School

Distances from home to school was one of the variables and were calculated on the connected transport network using ESRI ArcGIS 10. In a comparison study set in Australia, GIS-calculated distances were found to be statistically similar to distances measured from GPS data collected by the students on their route to school (Duncan and Mummery, 2007). These results agree with Stigell and Schantz's (2011) comparative study in Stockholm, though these authors note that both GIS and GPS-derived distances significantly differ from the map-measured identified commuter routes used as truth. Briefly, the students' home addresses were geocoded to give a mapped home location. School address points were extracted from reference spatial data. In the next step, an integrated and connected road and track network was constructed in the GIS. The home and school point locations were attached to this network. Finally, Python scripting was used to calculate the shortest travel distance on the network for each subject, using the edges (roads, tracks) and nodes (home, school, road / track intersection points) forming the network.

2.2 Intersection Density

The intersection density variable was calculated as a count of intersections along the route from home to school. The junction layer from the dissolved network dataset was used as it contains a junction point for every location where three or more roads intersect. Each route, calculated previously, was then intersected with the junction data to obtain a count of only those junctions that fall on the route. This process was repeated with a 200m buffer around the route to obtain the buffered intersection density variable. In this case, a 200m buffer along the route was generated, this buffered region was intersected with the junction data and a count of those junctions within the buffered region was obtained. This section of work was performed using the route and junction shape files generated previously in ArcGIS 10.0 and code written in R 2.16.1.

2.3 Residential Density

The residential density variable was calculated using a 400m buffer around each student address. This buffer was intersected with the reference address data used previously to obtain a count of all address points that fall within a 400m radius of each students' home address. An assumption has been made in the calculation of this variable: that a single address point in the reference data represents a single residence (though there are some address points which potentially represent multiple residences). Land parcel data was considered as alternative reference data, but many single land parcels had multiple addresses, and some had none.

2.4 Land Use Mix

The land use mix variable along the school routes was calculated as the mean land use mix entropy. For each route from home to school as calculated earlier, the land use mix was evaluated and the mean land use mix entropy was calculated according to the formula:

(1) *Mean land use mix entropy* = $\{\sum_k [\sum_j P_{jk} ln(p_{jk})]/ln(J)\}/K$ (Cervero,1997, p. 206)

where: p_{jk}= proportion of land-use category j within a half-mile radius of the developed area surrounding hectare grid cell k; j = number of land-use categories; and K= number of actively developed hectares in tract.

The Dunedin City Council reference data was used for these calculations. This only covers the Dunedin region and therefore the land use mix variable was unable to be calculated for students attending schools outside the Dunedin region (545 students). The land use reference data classifies the land into broad classes such as residential, commercial and industrial. The mean entropy calculation results in a value for each route of between 0 (the land use mix along the route is of a single class) and 1 (the land use mix along the route is evenly distributed among all land use classes). This section of work was performed using the route shape files generated previously in ArcGIS 10.0 and code written in R 2.16.1.

2.5 Topography

The topography of each route was evaluated through the altitude difference and total altitude gain variables. Several steps were undertaken to obtain the altitude along each route from home to school calculated previously. The first four steps were performed using tools in ArcGIS 10.0: 1) The Densify tool was used to insert vertices along the route. 15m intervals were used in order to match the resolution of the digital elevation model. The digital elevation model used was (the University of Otago School of Surveying 15 metre resolution DEM – Columbus et al, 2011); 2) The Feature Vertices to Points tool was then used to create points at each of the vertices along the route; 3) The digital elevation model was then used with the Add Surface Information tool to interpolate heights for each of the vertices; 4) The elevation values along the route were output for subsequent evaluation; and 5) The final step was performed using R to read the elevation values and obtain the difference in altitude between home and school, and the total altitude gain (amount of altitude climbed in total) along the route for each student. Differences between ATS and motorized transport (MT) users were compared using the Mann-Whitney test (for continuous variables) and chi-square analysis (for categorical variables).

3.0 RESULTS

A total of 1,325 students (age 14.9±1.3 years; 53.9% boys; 74.1% urban) who lived within 4.8 km from school were included in these analyses. Among these students, 55.4% of students used ATS (51.2% walking and 4.2% cycling), 10.1% bus, and 34.5% car. Rural students were more likely to use ATS compared to students living in urban areas (72.6% vs. 49.4%; $p<0.001$). Compared to MT users, ATS users lived closer to school (1.3±1.0 vs. 3.0±1.2 km; $p<0.001$) and in areas with greater residential density (376±167 vs. 340±182 houses within 400 m; $p=0.027$) and less altitude gain on the route to school (19.7±101.5 vs. 48.7±42.4 m; $p<0.001$). Intersection density on the shortest route to school (ATS: 7.3±2.9 vs. MT: 7.2±2.4 intersections/km; $p=0.154$), number of intersections around the school (ATS: 4.8±3.0 vs. MT: 5.3±3.7 intersections; $p=0.468$) and residential density in the school neighbourhood (ATS: 75.3±30.0 vs. MT: 77.9±37.9 houses; $p=0.064$) were not different between ATS and MT groups. In urban areas, a lower land mix use index was observed both in the home neighbourhood (ATS: 0.22±0.10 vs MT: 0.26±0.11; $p<0.001$) and school neighbourhood (ATS: 0.24±0.13 vs. MT: 0.29±0.14; $p<0.001$) of ATS users compared to MT users.

4.0 CONCLUSIONS

Adolescents who live within 4.8 km from school and use ATS live attend schools in neighbourhoods with a more favourable built environment for ATS compared to MT users. ATS users live closer to school and in areas of greater residential density. In urban environments, ATS users live in neighbourhoods and attend schools in the areas of lower land-mix use compared to MT users. However, not all indicators, intersection density for example, were significant.

Future school- and community-based ATS interventions should focus on implementing changes in the physical environment to improve pedestrian and cycling infrastructure and traffic safety in school neighbourhoods and on the common routes to school. The factoring of busy roads and intersections should also be a feature of further study, though Duncan and Mummery's (2007) study has noted that there is significant difference between count of busy intersections gained by GIS as opposed to GPS means, so a change of data collection strategy is implied too.

One other factor for future investigation is how active transport to school behavior has changed over time. One would anticipate a greater proportion of students walking to school in the past, with motorized transport not being so prevalent. An exploration of this allied with possibly changing societal attitudes may yield interesting results.

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Statistical analysis of LiDAR-derived structure and intensity variables for tree species identification

***Zhenyu Zhang*[1], *Xiaoye Liu*[1] & *Wendy Wright*[2]**

[1]School of Civil Engineering and Surveying, and Australian Centre for Sustainable Catchments
University of Southern Queensland, Toowoomba, Queensland 4350, Australia
Phone: +61 7 46311980 Fax: +61 7 46312526
Email: zhenyu.zhang@usq.edu.au

[2]School of Applied Science and Engineering
Monash University, Churchill, Victoria 3842, Australia

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1.0 INTRODUCTION

Tree species identification is part of decision support for sustainable forest management and native forest conservation (Brandtberg 2007; Koch et al. 2006). The traditional methods for tree species identification were based either on an interpretation of large-scale aerial photographs or a field inventory work. These methods are labour intensive and time consuming (Franklin 2001). Although remotely sensed data have been widely explored for forest applications, passive remote sensing techniques still fall short of capturing three-dimensional forest structures, particularly in uneven-aged, mixed species forests with multiple canopy layers (Lovell et al. 2003). Fortunately, it has been shown that active remote sensing via airborne LiDAR (light detection and ranging) with capability of canopy penetration yields such high density sampling from the top and interior of the canopy and understorey vegetation that detailed description of the forest structure in three-dimensions can be obtained (Zhang et al. 2011).

Species classification at individual tree level using LiDAR-derived variables has been attempted for coniferous forests, deciduous forest, and mixed coniferous, deciduous and other forests. All these studies were performed using either: a) LiDAR derived structure variables, or b) intensity variables or c) both structure and intensity variables. In contrast to the present study, most of the above studies were carried out in open, conifer or deciduous forests of even-aged of relatively homogenous structures. Accordingly, priority can now be given to test the suitability of LiDAR data for delineating the structure of complex forest types, particularly for cool temperate rainforest and neighbouring uneven-aged mixed forests in severely disturbed landscapes.

The overall objective of this study is to use the statistical analysis of both structure and intensity variables derived from airborne LiDAR data for the classification of the cool temperate rainforest (the Myrtle Beech) and the Silver Wattle forests at individual tree level in the Strzelecki Ranges, Victoria, Australia. Specific objectives include the normality test of LiDAR-derived variables, tree species classification by linear discriminant analysis, examining of the contribution of the LiDAR intensity variables to the classification results and accuracy assessment using the error matrix.

2.0 MATERIALS AND METHODS

2.1 Study Area

The study area is in the eastern Strzelecki Ranges, southeast Victoria, Australia. Prior to European settlement the Strzelecki Ranges were densely vegetated by wet forest (also referred to as wet sclerophyll forest) and cool temperate rainforest. The Ranges have experienced widespread land clearing since European settlement. Subsequent agricultural abandonment and a frequent wildfire history have resulted in severely disturbed landscape in the Strzelecki Ranges. The landscape has undergone further significant changes with the establishment of large scale plantations in the area since the mid-twentieth century (Noble 1978). Currently, areas bordering cool temperate rainforest in the Eastern Strzeleckis are a mosaic of different land use histories involving both natural and human disturbances, and so a very complex forest structure in the remnant patches of cool temperate rainforest and adjacent forests including wet sclerophyll and plantation forests prevails. This study focuses on an area with cool temperate rainforest distribution in the Eastern Strzeleckis, which covers an area of 1.82 km^2 with elevations ranging between 322 m and 448 m.

2.2 Data

LiDAR data were collected using an Optech ALTM Gemini LiDAR system at a flying height of 1,100 m above ground between the 11th and 23rd of October 2009. The laser pulse repetition frequency is 70 kHz. The laser scanner was configured to record up to 4 returns for one laser pulse. The average point density was 4 points per square metre, and the laser footprint diameter was 0.3 m. The LiDAR data used for this project was documented as 0.20 m for vertical accuracy and 0.25 m for horizontal accuracy. The LiDAR data were classified into ground and non-ground points by the vendor and were delivered in binary LAS 1.2 file format (ASPRS 2008).

Ecological Vegetation Classes (EVCs), which describe the spatial extent of vegetation types, are the basic regional scale mapping unit used for forest ecosystem assessments, biodiversity planning and conservation management in Victoria. The EVC mapping was undertaken first by the interpretation of aerial photographs and the process was designed to outline native vegetation patches and any obviously related patterns. The range of aerial photograph patterns was then field checked and lists of plant species were recorded (Davies et al. 2002; Boyle and Lowe 2004). The EVC data were used as reference data in this study.

2.3 Methods

The LiDAR ground data were used to create a DEM (digital elevation model) with one metre horizontal resolution (grid size) while the first returns of non-ground LiDAR data representing the laser returns from tree canopy were used to generate a DSM (digital surface model) for the study area. A canopy height model (CHM) was computed by subtracting the DEM from the DSM. The TreeVaW software developed by Popescu and Wynne (2003) was used to identify the location and crown size of individual trees from the CHM in the study area. Extracted LiDAR points for each of the individual trees were used to create tree height profiles representing the spatial distribution of the vertical structure of individual trees. The *k*-means clustering algorithm was performed on the height profile to determine the crown base height of each individual tree. It is the LiDAR point data from above the crown base that are used in deriving canopy variables. The variable names and descriptions derived from heights and intensity values of laser returns within tree crowns are listed in Table 1.

Table 1 LiDAR-derived structure and intensity variables and description

Variable	Description
MaxH	Maximum crown height
Depth	Depth (or extent) of tree crown
MeanH	Mean crown height
StdDev	Standard deviation of heights of laser returns within a crown
Density	Ratio of the number of laser returns in the crown to the total number of laser returns within the area defined by a crown diameter
MeanI	Mean intensity value of laser returns within a crown
StdDevI	Standard deviation of intensity value of laser returns within a crown
MeanIF	Mean intensity value of first laser returns within a crown
StdDevIF	Standard deviation of intensity value of first laser returns within a crown

If passed the normality assessment, the one-way ANOVA was performed on these variables to see if each of these variables can be used to distinguish one tree species from the other. Linear discriminant analysis with cross-validation was performed to classify the tree species and assess the classification accuracy. The cross-validation, often termed a jack-knife classification (Burns and Burns 2008), successively classifies all individual trees but one to develop a discriminant function and then categorizes the tree that was left out. This process was repeated with each tree left out in turn (Burns and Burns 2008).

3.0 RESULTS AND DISCUSSION

The results show that using LiDAR-derived structure variables, 83.2% of the individual trees of the Myrtle Beech and Silver Wattle were correctly classified using linear discriminant analysis with cross-validation. If using only the intensity variables, an overall classification accuracy of 74.6% was achieved. An overall accuracy of 86.4% was achieved by using both structure and intensity variables in the discriminant analysis with the cross-validation. The overall classification accuracy increased from 83.2% (using only structure variables) to 86.4% (using both structure and intensity variables). With the inclusion of the intensity variables, both producer's accuracy and the user's accuracy for the Myrtle Beech and the Silver Wattle increased. For example, the producer's accuracy increased from 87.6% to 91.2% and the user's accuracy increased from 69.1% to 73.4% for the Myrtle Beech. It is seen that the approach in which the LiDAR-derived canopy structure variables are analysed together with the related intensity variables produced accurate classification results: 84.0% of the Silver Wattle trees and 91.2% of the Myrtle Beech trees were correctly classified; and the likelihood of misclassification is reduced in terms of the omission error and the commission error.

This study showed the successful identification of tree species (the Myrtle Beech and the Silver Wattle) at individual tree level in our study area. The results of this study demonstrated the contribution of LiDAR-derived intensity variables to the identification of the Myrtle Beech and the Silver Wattle tree species at individual tree level. Although relatively low classification accuracy was obtained when only using LiDAR-derived intensity variables, the combination of both the structure and intensity variables in the discriminant analysis allowed individual Myrtle Beech and the Silver Wattle trees to be identified with high accuracy. The outcome of this study is such as to encourage further tests of the extent to which the LiDAR data may be applied in vegetation community mapping, particularly for rainforest and neighbouring forests in a severely disturbed landscape. Studies such as this one will also serve to increase the understanding of the value of the LiDAR intensity data to improve the accuracy of forest type classification and tree species identifications.

4.0 CONCLUSIONS

This study demonstrated the applicability of LiDAR-derived variables referring to canopy structure and laser return pulse intensity for the identification of the Myrtle Beech (the dominant species of the Australian cool temperate rainforest in the study area) and adjacent tree species – notably, the Silver Wattle at individual tree level. The results show that an overall classification accuracy of 86.4% can be achieved when both structure and intensity variables were included in the discriminant analysis with the cross-validation in the study area. The overall classification results are only 74.6% when just using the intensity variables in the analysis, but combination of the structure and intensity variables in the discriminant analysis did improve the accuracy of classification results, indicating the contribution of the LiDAR intensity variables to the classification results. It is expected that calibrated LiDAR intensity values will improve the application of LiDAR data in forest classification and tree species identification.

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Spatial techniques for multi-source national planted forest assessment and reporting

***Barbara Hock*[1], *Tim Payn*[1]**

[1]Scion
Sala Street, Rotorua, New Zealand
Phone: +64 7 343-5899 Fax: +64 7 348-0952
Email: peter.whigham@otago.ac.nz

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The national assessment of New Zealand's planted forests is required for economic and environmental monitoring and for international reporting to organisations such as FAO and the Montreal Process. Spatial techniques can aid in determining national planted forest information; two approaches are described in this presentation. Firstly a number of national spatial datasets were investigated for their potential to contribute to the reporting on forest sustainability indicators. Secondly, spatial data was combined with non-spatial data to develop visual representations for enhanced reporting.

For the investigation of national spatial datasets for reporting, one of the issues was to determine how well national datasets meet sustainability reporting requirements. One method to determine this is to compare national data with data at a higher resolution; from this the error margins in the reporting can be estimated. For example, one of the Montreal Process (MP) indicators (4.3.a) requires reporting on the proportion of forest management activities that meet best practice for protecting water resources. Riparian strips around waterways is one such practise; by overlaying GIS data of different resolutions for a number of case study areas and summing the differences in the riparian areas of each data set, it was determined that the resolution of the national datasets would be inadequate for reporting on riparian practices. Using the same case study data, the effect of deducting the riparian areas from the national planted forest area (MP 2.a Area of forest land for wood production) indicated that the national datasets could over-estimate the land under productive forestry by up to 6%.

Monitoring based on sampling provides another avenue for generating reporting data; national datasets were used to guide the locations of national monitoring sites. A sampling approach developed by Environment Waikato for monitoring significant soil erosion, based on aerial photography evaluations of sample points on a 2km grid, was applied to the whole country. The grid points were overlaid in GIS with land cover and erosion susceptibility data, and the sampling intensity of particularly the highly erodible forest lands was determined. This verified that the approach would be useful for national soil reporting (MP 4.2.b Area of forest land with soil degradation) though implementation of the approach on only areas of high risk could miss impacts elsewhere.

Water quality monitoring is another field that relies on a sampling approach; planted forest water quality reporting (MP 4.3.b water bodies in forest areas with significant changes) is based on those national water quality monitoring sites specifically for monitoring water flows from exotic forest catchments. The locations of these monitoring sites were assessed based on national GIS datasets. Land cover, river and catchment data were combined to analyse whether the existing water monitoring sites are representative of exotic forest catchments, and to identify potential additional sites. The analysis determined that a number of the existing planted forest monitoring sites have other production land uses up-stream from their locations, such as grazed pasture. In addition, different types of river environments are were found to be underrepresented in the national approach for monitoring water from planted forest. A number of new sites were recommended for this monitoring.

Finally, a number of visual representations of the sustainability data were explored for the reporting of national forest data. The aim was to provide a quick overview of the state of sustainability indicators. The approach needed to cope with such issues as mixing quantitative and qualitative data, and variable numbers of indicators for different sustainability criteria.

The assessments covered in this presentation have made valuable contributions to substantiating and presenting the information in New Zealand's national planted forests reporting, including for a proposed new planted forests portal.

The Use of GIS for Agroecology, Medicinal Flora and Public Access aspects of an *iwi*-run Farm

Antoni Moore[1], Marion Johnson[2], Janice Lord[3], Sam Coutts[1], Mariana Pagan[1], Jeremiah Gbolagun[1] and G. Brent Hall [1,4]

[1]School of Surveying
University of Otago, Dunedin, New Zealand
Phone: +64 3 479-7589 Fax: +64 3 479-7586
Email: tony.moore@otago.ac.nz

[2]Centre for Sustainability: Agriculture, Food, Energy and Environment (CSAFE)
University of Otago

[3]Department of Botany
University of Otago

[4]Esri Canada
12 Concorde Place, 9th Floor
Toronto, Ontario, M3C 3R8
Canada

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ABSTRACT

The application of GIS has been important for resource management and environmental planning. The Maori notion of *kaitiaki* or guardianship of land and resources can also be incorporated into resource management through the use of GIS; links with *tipuna* (ancestors) and *turanagwaewae* (a place of belonging) are also fostered with GIS (Pacey, 2005). Combining indigenous knowledge and a GIS, if achieved sensitively, and mindful of culture, security and property rights, gives the advantage of capturing and storing cultural and traditional values and concepts, along with geographic data (Landcare Research, 2013). Used in this way and at this level, management of the GIS requires community participation, becoming an example of a Public Participation GIS (Weiner, et al., 2002). An example of such an implementation in New Zealand was reported on by Harmsworth et al. (2005), who describe an *iwi* (tribe) – led GIS project founded on local participation, in Motueka, Nelson. This principle of "active participation" is stated locally (NZ) as integral to indigenous farm management (Science for Environmental Policy, 2011).

Te Putahi farm, covering some 449 hectares of Banks Peninsula (Canterbury). is owned by Wairewa runanga (a Ngai Tahu papatipu runanga) and managed by two trusts. Like many Maori trust farms, the runanga wish Te Putahi to become a more biodiverse and eco-friendly farm but also require an economic return. Tourism may provide an option for additional income, particularly if the farm is managed according to the principles of agroecology, the application of various ecological principles to enhance agricultural production (Nga Pae o te Maramatanga, 2012). Specifically, indigenous agroecology is being adopted, which draws upon local traditional knowledge systems, agroecological practices and socio-cultural dynamics. To increase biodiversity on the farm and to foster cultural activity, Te Putahi are assessing the possibility of planting rongoa (Maori traditional medicine) species on areas of the farm that would benefit from being retired from grazing, such as stream margins and eroding banks. Animal health is likely to be enhanced through a broader diet and the allelopathic compounds found in rongoa species, and the community will benefit from having access to native species. High value timber plantings can be interspersed providing a future income and/or carbon credits.

This presentation will introduce Te Putahi as a Maori trust farm, managed on principles of indigenous agroecology and briefly describe some of the GIS-based projects run out of the Indigenous Agroecology Project Group (Johnson et al, 2013). These all are referenced relative to a baseline contextual dataset surveyed in 2011, and include:

- the design and implementation of a time-stamped spatial database to house baseline data and agroecology monitoring data (e.g. biological – invertebrates, vegetation; chemical – pH, nitrates; physical – temperature, stream velocity) in years to come (Pagan, 2013)
- the use of spatial analysis, specifically multi-criteria analysis (Malczewski, 1999) fed by topographic data indicators and botanical knowledge to identify areas of the farm that could sustain growth of plant species with medicinal properties for the benefit of animal stock health (Coutts et al, 2012)
- using cost path analysis to define public access paths to the farm, with slope, visibility and distance to gully bottom as input. The major checking criterion for the paths generated is diversity of medicinal plant species seen from the path, as generated in the previous project.

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Putting 'Te Kawa a Maui' (Maori Studies) on the Map

Bruce McFadgen[1] & Ocean Mercier[2]

School of Maori Studies
Victoria University of Wellington
[1]Phone: +64 4 21 111 9996 Fax: +64 4 463-5243
[2]Phone: +64 4 463-7457 Fax: +64 4 463-5243
Email: bruce.mcfadgen@vuw.ac.nz
Email: ocean.mercier@vuw.ac.nz

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The 'Te Kawa a Maui Atlas' is a project set up in 2010 to enhance the learning experiences of students in Te Kawa a Maui (the School of Maori Studies), Victoria University of Wellington (Mercier et al. 2013). We have introduced map-based group and individual assessment to ten Maori Studies courses. Student research in these courses has been collated and now contributes to a school-wide, publicly available Google Maps database of their work. Our motivation was to promote student engagement by involving them in a school-wide project, introducing a visual, place-based element to their learning, tasking them with projects of relevance to their local communities, and teaching skills in relevant mapping techniques, such as Google Earth, GPS and GIS.

One course includes practical, hands-on exercises that introduce students to maps, map projections and coordinate systems, and the concepts of accuracy and precision. Field-based tuition teaches how to set up a handheld GPS, and how to check that it is giving the right position. The students are taken through a project that requires them to download archaeological site data from an online data-base, check the data in the field, and where appropriate, to correct it. The data is then imported to Quantum GIS, processed, and exported to Google Earth for presentation. We comment on how students respond to these technologies, on the usefulness of the learning experiences to our students, and the potential for map-based assessment to be used more widely in cultural studies.

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Representing 3D data in a cadastral database – Queensland Case

Sudarshan Karki [1 2], Rod Thompson [1 3] & Kevin McDougall [2]

[1]Department of Natural Resources and Mines
Queensland Government, Australia

[2]Faculty of Engineering and Surveying
University of Southern Queensland, Australia

[3]Delft University of Technology
The Netherlands

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ABSTRACT

Urban environments have seen the growth of infrastructure and buildings above and below the ground due to limited availability of urban land. Cadastral jurisdictions have traditionally represented properties as a closed polygon with associated registered rights: termed as two-dimensional (2D) cadastre. Modern cadastral jurisdictions are facing increasing pressure to register and represent properties above and below ground: termed as three-dimensional (3D) cadastre. The cadastre has traditionally been designed around properties on the surface of the land, called base parcels, which has made the storage and representation of 3D data in a 2D database very challenging.

It is important to understand the general complexities of a 3D cadastre as well as particular 3D related needs within each cadastral jurisdiction. There are Institutional issues such as 3D specific legislation, policy, standards; and technical guidelines; Operational issues such as registration of 3D properties and their interaction with current 2D properties; and Technical issues such as 3D parcel construction; 3D validation; 3D data capture and storage; and 3D data representation. This paper focuses on the Operational and Technical issues to identify and discuss the problems faced by the cadastral jurisdiction of Queensland and propose possible solutions to improve the storage and representation of 3D cadastral data in the existing digital cadastral database.

Queensland cadastre allows the registration of all mathematical 3D shapes and differentiates between building and volumetric shapes in the plan representation on the paper. This has given rise to complex examples of 3D shapes registered in Queensland cadastre; however, the digital cadastral database does not store 3D geometry data. Currently, the paper plan is the legal document for the geometrical data, while the records stored digitally in the Titles Office are the legal record of rights. The digital cadastral database (DCDB) models the real world cadastral situation and connects to other databases to provide a comprehensive search and visualisation facility for surveyors conducting field surveys as well as the Department to update and maintain records of cadastral transactions. The Electronic Access to Registry Lodgement (EARL) project is in its second phase, where legal paper plan data are converted to digital records and stored in the database; however, in the last phase of the project, the legal document will be the electronic record. This has created a push for the electronic lodgement as well as the DCDB to be capable of storing, visualising and manipulating accurate legal records of 3D data. Additionally, as the cadastral data is being used by other stakeholders for their various applications, the DCDB is required to be capable of GIS operations such as neighbourhood or locality searches, intersections, buffers or other spatial analysis.

There are two possible solutions identified and deliberated in this paper. First, the 3D objects could be stored in a special repository which is outside the main cadastral database, but is linked to the base parcel through parcel identifiers. The advantage is that the existing data structure is not disturbed and is easier to effect a database transition. The disadvantage is that the repository will not be able to support 3D searches and spatial analysis; and the effects on the 3D property when the underlying base parcel undergoes a transaction need to consistently

well-defined. The second solution is to include all parcels (2D or 3D) in the one data base, and it is suggested that the method identified in the newly developed ISO standard called Land Administration Domain Model (LADM) (ISO19152 2012) be adopted. The advantages are that all GIS functions will be possible, and the relationships between parcels and other information classes will be consistent. The disadvantage is that significant time and resources need to be allocated to build and modify the model to suit particular jurisdictional requirements. In order to facilitate either of these options, the Open GIS Consortium (OGC) which is currently managing LandXML should ideally create explicit classes which will support 3D geometries. The advantage is that the requirements of an electronic legal record will be satisfied and surveyors will be able to lodge electronic plans with 3D data. By contrast, the current LandXML does not have explicit classes for 3D faces or solids.

This paper provides a background on the current cadastral situation in Queensland with emphasis on 3D cadastre, builds on the current research, and proposes two possible scenarios which can be developed to provide an independent or combined solution for a full 3D cadastral implementation that can be used by any cadastral jurisdiction.

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A read, append, prune (RAP) formalism for spatio-temporal information

***Geoff Hay*[1], *Peter Whigham*[2] & *G. Brent Hall*[1]**

[1]School of Surveying
University of Otago. Dunedin, New Zealand
Phone: +64 3 479-7585 Fax: +64 3 479-7586
Email: geoff.hay@otago.ac.nz
Email: brent.hall@otago.ac.nz

[2]Department of Information Science
University of Otago. Dunedin, New Zealand
Phone: +64 3 479-7391 Fax: +64 3 479-8311
Email: peter.whigham@otago.ac.nz

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1.0 INTRODUCTION

In the land administration domain, there is a need for software applications that are capable of faithfully recording the history and state of national land resources, which are easily adaptable to meet varying needs that occur within and across jurisdictions, and which are easily evolvable to meet growing sophistication in the requirements and uses of such spatio-temporal information (see, for example, Van der Molen, 2002). The faithful recording of history includes the chronology and causes of changes to spatial and thematic value data, the full retention of data in the face of continuous updating, and the faithful representation of the many and widely varying and evolving concepts and practices underlying land, its use, and its associations with people, organisations and government.

Critical to long-lived, authentic, and evidential record keeping software applications is their ability to also accommodate change over time in the concepts and practices they implement while at the same time maintaining support for existing information and its representation that accumulates over time. These needs are not well-supported by conventional geographic information systems (GIS) and this has been attributed the inadequacy of the relational model in representing the temporal dimensions of time-varying information and evolving schema, and structural limitations in the representation of domain concepts and record keeping practice in general (Raper, 2000, Gounaris and Theodoulidis, 2003, Ekweozor and Theodoulidis 2004).

In response to these needs, this paper proposes a read, append, prune (RAP) information theory that addresses domains where the concepts and practices of information are non-stationary with respect to both space and time. The model mirrors the essential concepts and practice associated with formal record keeping and as such is not limited to the land administration domain. Conceptually, the variation (or heterogeneity) in the concepts and practices that occurs across contexts (and space), is similar to the variation that occurs across time since the impact of these heterogeneities on implementation is essentially the same (Galante et al, 2005, Roddick et al, 2001). An implementation that allows varying conceptualisations (e.g. schema, processing modules) to coexist can be more easily evolved since there is less need to migrate existing representation as new concepts and practices are implemented. Such an implementation should thus be capable of supporting the spatially varying conceptualisations. This alludes to an implementation that supports an emergent and evolving representation through a non-delete amendment-based temporal model of information and implementation.

2.0 RELATED WORK

Append-only and non-delete strategies for data have long been considered essential concepts in temporal record keeping and faithful history recording (see, for example, Hunter, 1988; Roddick *et al*., 2000). Associated with this is the notion of limitless data storage capacity and the conclusion that removing the concept of delete makes database operations generally simpler (Copeland, 1982). Entity, attribute, value (EAV) models of data have been employed successfully in medical applications to address the problems of record heterogeneity that results in large numbers of nulls in records (Nadkarni *et al*, 1999). The ideas of flexible schema and emergent schema have also been considered in response to the problems of schema evolution in application areas that require rapid response to changes in the problem space, and areas where the schema is difficult to know in advance of implementation or for which there are competing hypotheses (Roddick *et al*, 2001, 2007).

Some of these ideas date from the early days of computing. However, they were generally ignored due to the then predominant focus on efficient use of limited memory and processing capacity that resulted in systems that do not allow redundant data, which require data to be deleted (or overwritten), and which rely on essentially static and predefined models that are difficult to evolve and reuse. Interestingly, the technological basis of the 'cloud' supports the reinvigoration of these ideas and a result has been a move away from conventional relational technologies and methods in favour of more evolvable and less ridged information models (see, for example, Cattell, 2011; Strauch, 2011; Taylor, 2009). The `cloud' essentially assumes spatio-temporal non-stationarity in both its applications and data models. For example, similar in concept to EAV models, Facebook and Google utilise multidimensional maps of key/value pairs which do not have a predefined list of columns and, as such, are able to add dynamically new attributes to records and can thus support varied and emerging conceptualisations (Chang et al., 2006, Sarkissian, 2009, Lakshman and Malik, 2010). Through its promise of unlimited storage and processing capability, the concept of 'the cloud' provides a platform in which concepts of time and record keeping associated with an append-only information model can be reconsidered (Furht, 2010).

3.0 READ, APPEND, PRUNE (RAP)

An append-only theory assumes that all data are retained. Implicitly, it assumes that all schemas associated with data are also retained, and that the schemas of data can evolve over time without intervention. Schema evolution that only involves the addition of elements does not impose the need to migrate data which is required when schema elements are to be removed. Logically, if schema can evolve seamlessly, then so must the applications and 'stacks' that rely on them. An append-only theory therefore should include the notion that not only are data appended, but their schema, and the implemented applications that provide processing and query, and human interaction, are also append-only and can accumulate. Essentially, once an item has been appended and has impacted the stored information, its impact can never be removed. This does not, however, preclude the notion that data or implementation can be removed from use, i.e. retired or made inaccessible. This, and all other change including schema change can be achieved with the concept of amendment.

Amendment is logically required in an append-only theory since data values and implementation artefacts cannot be deleted from the reality they have impacted. Amendment relates to the appending of new information or understanding, and to an intention with regard to an effect on existing information and understanding. An amendment conceptually modifies an existing value, attribute or entity or creates new attributes and entities. Various specialised amendment intentions can be defined and these include retirement, expiration, invalidation, and accumulation. Amendment is logically a bi-temporal concept since amendments are time-ordered both in the order in which they are recorded and the order associated with the time at which their intention becomes valid and affects a domain. Thus, amendments can be logically arranged into chains of facts representing, for example, time-varying attributes and their values, or the logical evolution of implementation artefacts that comprise a software deployment.

In addition, an amendment can, as part of its implementation, impose new kinds of understanding as well as create new values. This notion underpins the concept of variable and evolvable schema where the appending of a new value may in fact add a new attribute to an entity instance. Thus, individual entities may have unique and time-varying schema. For spatial data, this means that each spatial object instance may have an independent and unique set of attributes. The evolving understanding can be imposed through the appending of a new version of an implementation artefact such as a user interface application or service that contributes a new process or understanding and which potentially imposes a different understanding for new records.

The concepts of read and append are interrelated in the sense that the particular understandings imposed by an implementation through its set of valid append operations may also be used to understand the results of read operations. This alludes to a dual nature to service implementation and is an extension of the application-based transaction and query paradigm associated with cloud-like application models described above, and the idea of cloud services and software-as-a-service (SaaS) (Furht, 2010).

The conventional concept of pruning relates to the removal of nodes (whether they are attributes, value data, semantic descriptions, or implementation artefacts) that are redundant or irrelevant to a context. Pruning does not relate to the management of the large volumes of data that might be expected to accumulate under an append-only theory. Here, pruning simply acknowledges the legal requirements of privacy and authentic archival or destruction of records associated with retention and privacy policy implementation. Pruning is a function that processes intentions defined by amendments. Generally, pruning makes inaccessible certain facts (or implementation) either within a specific context (which might be a temporal context) or for all contexts and hence does not violate the append-only theory.

4.0 CONCLUSION

The RAP theory alludes to an architectural model that separates time-referenced amendments, semantic descriptions, and application or implementation modules such as services and service applications, allowing these to vary across space and over time. The theory is eminently suitable for underpinning a cloud-like implementation of formal record keeping that supports spatially, contextually varying and evolving data, understanding, and implementation.

The theory has impacts for the way in which spatial information and spatial change is managed and recorded and potentially for the implementation of GIS which are conventionally reliant on relational databases for the implementation of thematic attributes. A RAP-based data store allows the domain specific or contextual information to be recorded separately from the spatial representation thus allowing the form of individual records to vary across space and across spatial records, and for the particular spatial representation to vary across thematic records. Hence, it also allows the particular spatial representation to vary both in sophistication and accuracy across records and over time for individual records, thus potentially modelling more closely actual and evolving reality. It also allows temporal relations, for example, parent/child associations, between spatial objects to be explicitly recorded and for temporal relationships to be considered along with spatial relations, for example, spatial and temporal overlap where objects can be allowed to overlap in space only if they do not overlap in time. Ultimately it reduces the coupling between spatial representation, the implementation of which is reasonably stable, and the domain specific models that are highly variable across space and context. The RAP model for evolvable spatio-temporal record keeping forms the basis of an approach to the development of a widely applicable and long-lived GIS for land administration described by Hay (2013).

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Linking geospatial databases using stratigraphic names: principles and practice

***Delia Strong*[1]*, Soren Haubrock*[2]*, Mark Rattenbury*[1] *& Nick Mortimer*[3]**

[1]Department of Regional Geology
GNS Science. Lower Hutt.
Phone: +64 4 570-4227
Email: D.Strong@gns.cri.nz

[2]Information Services Section
GNS Science. Lower Hutt.
Phone: +64 4 570-4630
Email: S.Haubrock@gns.cri.nz

[3]Department of Regional Geology
GNS Science. Dunedin.
Phone: +64 3 479-9686
Email: N.Mortimer@gns.cri.nz

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1.0 INTRODUCTION

GNS Science is the custodian of several New Zealand earth science geospatial databases (Figure 1), including the nationally significant Rock Catalogue and Geoanalytical Database (PETLAB), the recently completed 1:250 000 Geological Map of New Zealand GIS database (QMAP) and the New Zealand Stratigraphic Lexicon (StratLex) On-going work aims to link these and other GNS Science databases together so that end users can move seamlessly between them, and benefit from the combined power of specialised attributes. Enhanced database connectivity will allow users to search across multiple databases to efficiently and authoritatively answer increasingly complex geological questions such as "what is the average calcium content of the Amuri Limestone in Canterbury?" and "to what extent does groundwater chemistry reflect the host rock chemistry?" These types of questions can be analysed and portrayed using GIS functionality.

A pilot project to improve database interconnectivity has recently been completed at GNS Science, linking PETLAB and QMAP using stratigraphic unit names from StratLex. It is now readily possible to use GIS software to query, display and analyse data from across the databases whereas formerly such an exercise would have been cumbersome and time consuming.

2.0 GNS SCIENCE DATABASES

GNS Science hosts several key New Zealand earth science databases that are available online at http://www.gns.cri.nz/Home/Products/Databases (Figure 1). These include

- QMAP (1:250 000 Geological Map of New Zealand)
- PETLAB (Rock Catalogue and Analytical Database)
- StratLex (New Zealand Stratigraphic Lexicon)
- Strong Motion Database
- Active Faults Database of New Zealand

- GERM (Geological Resource Map Database)
- Geothermal Groundwater Database
- FRED (Fossil Record Electronic Database)
- PBE (New Zealand Petroleum Basin Explorer).

All of these databases are 'stand-alone' entities, and each contains a wealth of information that is used by researchers, registered industry members and universities. Most, or at least parts of most, are open file and public domain. StratLex is an online stratigraphic lexicon (Mildenhall & Coomer, 2008). It is a glossary of all stratigraphic unit names in past and current usage in New Zealand (Keyes, 1991). One way geoscientists describe 3D volumes of rocks on a 100 m -100 km scale is by dividing them into so-called stratigraphic units. These units are typically a combination of rock type (e.g. sandstone) and age (e.g. (Jurassic). Boiling these attributes down to a single stratigraphic name (e.g. Mataura Group) allows geologists to efficiently and effectively tailor their queries of point databases. Examples of some commonly known stratigraphic units are Takaka Marble, Auckland Basalts, Separation Point Granite, Waikato Coal Measures, Rangitikei Supergroup. Stratigraphic names are hierarchical, for example a "high level" Supergroup can consist of many Groups which can consist of many Formations which can consist of "low level" Members. The hierarchical structure makes it possible to search using high-level stratigraphic names for broad queries which include constituent lower-level terms.

PETLAB contains more than 177,000 records of rock and mineral samples from on- and offshore New Zealand and worldwide; over 48,000 of these samples have geochemical, geophysical and/or other analytical data. The rock and mineral sample data in PETLAB is contributed by GNS Science, all New Zealand universities, industry members, and international universities and research institutes, thus making it an invaluable "one stop shop" for anyone who uses rock and mineral data in their work. The QMAP GIS database contains digital point and polygon geological data from the 1:250 000 scale Geological Map of New Zealand (Rattenbury & Isaac 2012 NZJGG), which was also published as a collection of 21 individual printed maps, texts and GIS datasets. Recently QMAP has progressed to a 'seamless' GIS coverage of New Zealand that has joined the 21 individual GIS datasets and dissolved their common boundaries.

Both PETLAB and QMAP have their own informal, free text entry, stratigraphic name fields. Of course, it is preferable to use just a single reference list of controlled names. To connect GNS databases together and enable better use of stratigraphic names the following was done (1) StratLex was chosen to be the reference database; (2) a subset of "preferred" hierarchical names was designated within StratLex. Mostly these were names used by the QMAP project; (3) new StratLex tables were defined that would enable connection to other databases; (4) a large programme of data cleansing of PETLAB was undertaken, to ensure that existing informal stratigraphic names conformed to the new "preferred" reference list.

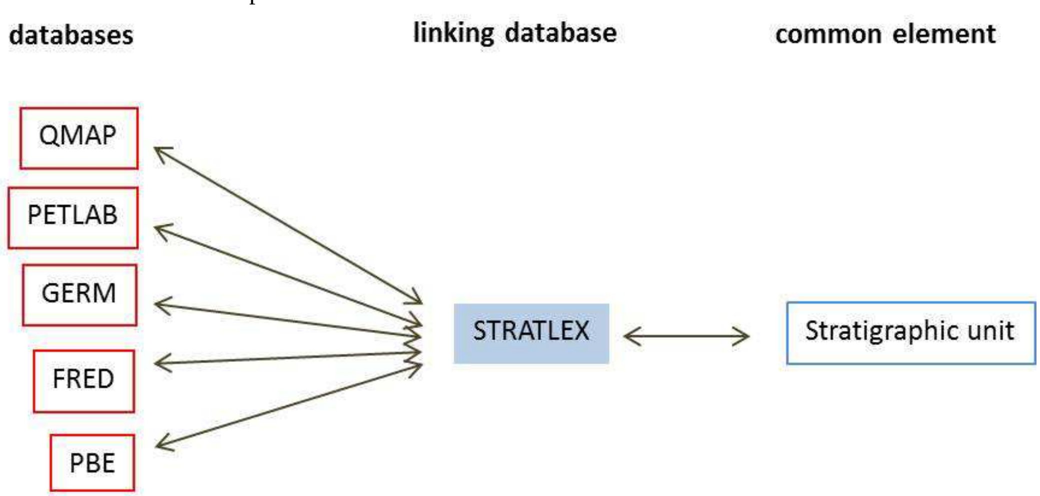

Figure 1: A schematic representation of the some of the major GNS Science earth sciences databases, and how they can be connected using hierarchically organised stratigraphic unit names.

3.0 DATA QUALITY ASSURANCE

The connection of the PETLAB, QMAP and StratLex databases required minor modifications of the existing database structures, as well as a series of data processing steps.

3.1 Standardisation of Stratigraphic Unit Names

The New Zealand Stratigraphic Lexicon (StratLex) requires stratigraphic unit names to follow certain name conventions, and new records need to be reviewed before they can be added to the database. The formality of those names can differ, and the records used in QMAP only form a "preferred" hierarchical subset of all stratigraphic unit names available in StratLex. Therefore some initial work was done to identify and mark those units that are to be used for the procedure of harmonising the database with names used in QMAP. These steps included simple tasks such as uppercase/lowercase conversion as well as correcting spelling mistakes.

3.2 PETLAB Data Cleaning

Decades of free text entries in PETLAB resulted in many stratigraphic unit names being misspelled, abbreviated or superseded by the recently completed QMAP series. These inconsistencies needed to be fixed by following a sequence of tasks. First, for each QMAP region a working spreadsheet was created, consisting of all the PETLAB sample records for the map region, complemented by two additional fields for each record: the QMAP stratigraphic unit name that is co-located with this sample, and additional (potentially valid) QMAP stratigraphic unit names that exist within a distance of 400 metres of the sample. All existing PETLAB unit names that fully matched those from the "preferred" hierarchical subset from StratLex were identified and accepted. For the remaining records (106,460 records across all 21 QMAP regions), ArcGIS software was used to display the samples over a seamless QMAP geology map so that correct lithostratigraphic names could be determined based on the formal names published in StratLex and the authoritative QMAP geological mapping (Figure 2). In many cases the stratigraphic unit names that were given to PETLAB samples during original data entry could be easily correlated with a valid stratigraphic unit name from QMAP and StratLex. In other cases, no clear match could be made and in these instances expertise was sought from QMAP geologists in order to identify the most appropriate match.

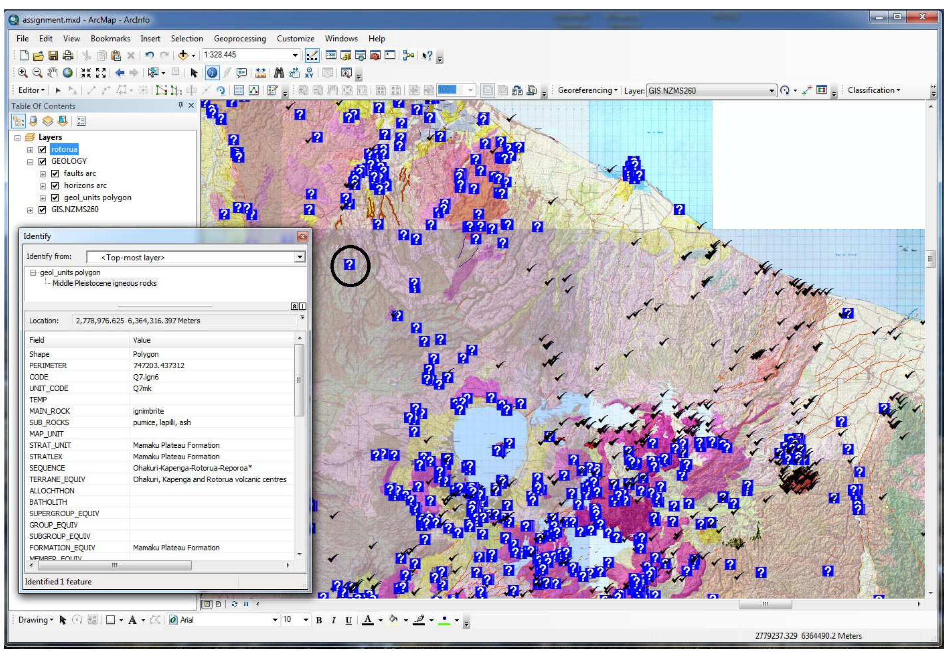

Figure 2: A screen shot from ArcGIS showing the data cleaning stage of the enhanced database connectivity project. Here, black ticks represent PETLAB samples that have a 1-1 match with a stratigraphic unit name from StratLex and QMAP. Blue question marks represent samples that do not. The base map is QMAP seamless geology of the Rotorua area with a hillshade DTM and NZMS260 topography behind it. The identify box shows the seamless QMAP attributes for the geology unit that the circled sample falls in.

4.0 APPLICATIONS

As a result of the PETLAB data cleaning, all New Zealand sample records in the database have a new (formal) stratigraphic unit name assigned. The stratigraphic unit names that were originally assigned when records were entered into PETLAB have not been overwritten; rather, where they have been superseded they are now designated as 'informal' stratigraphic unit names and are still available to search across. New entries to the PETLAB database are required to take a 'formal' stratigraphic unit name from a fixed "preferred" hierarchical list based on the QMAP and StratLex databases.

GIS software can now be used to display and analyse data across the PETLAB and QMAP databases based on common stratigraphic unit names. This enables users to ask more complex questions than was possible using either database as a stand-alone entity and to portray the results in map form. An early application of the enhanced database connectivity has been to produce maps showing mean analytical data for major and trace elements, averaged from PETLAB data and applied to the QMAP GIS data (Figure 3). This work goes some way towards identifying potential geochemical baselines and anomalies across all of New Zealand.

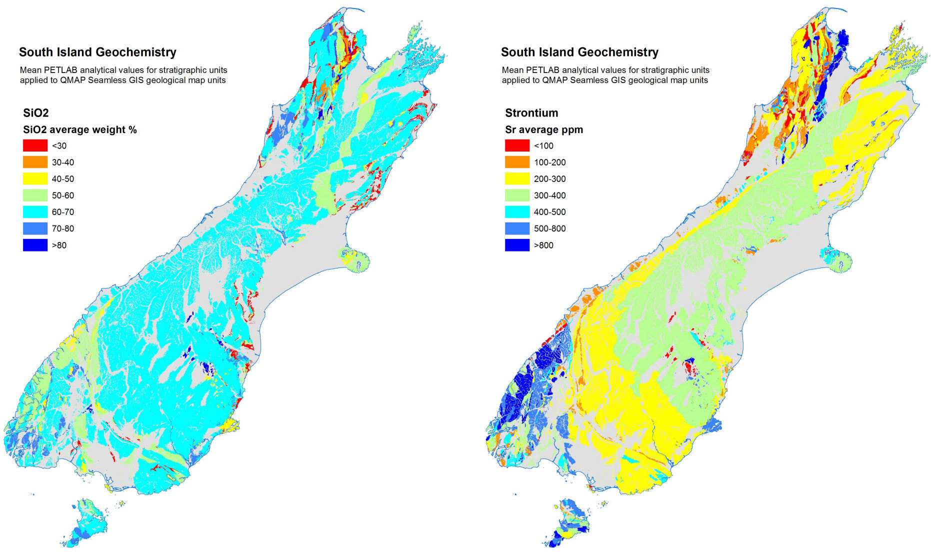

Figure 3: Maps of the South Island showing PETLAB mean weight per cent SiO_2 (left) and ppm strontium (right) values for stratigraphic units, applied to QMAP Seamless GIS geological units

5.0 CONCLUSIONS

The implementation of standardised stratigraphic nomenclature has greatly improved the functionality of PETLAB and QMAP databases and expanded their cross-database capabilities through enhanced connectivity. The ability to classify and examine data from several databases in a GIS portrayal means that more powerful geological questions can be asked, and answered. This can be applied to a range of geological investigations including mineral exploration and groundwater research.

Further work that will follow from the PETLAB-QMAP-StratLex enhanced database connectivity project includes: **(a)** making the chronostratigraphic (age) information on formations and plutons that is already in StratLex available for searching by other databases, for example "search for all formations that are (i) solely within the Late Eocene, or (ii) span the Late Eocene"; **(b)** connecting other GNS Science earth science databases to StratLex. One useful one would be the GERM database thus enabling searches such as "all gold occurrences that are hosted in Karamea Suite granites". To achieve these outcomes principally involves application development (including parsing of various time, period and stage criteria) as well as database cleansing and editing.

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Using different atmospheric correction methods to classify remotely sensed data to detect liquefaction of the February 2011 earthquake in Christchurch

***Amelie Broszeit*[1], *Salman Ashraf*[2]**

[1]Department of Remote Sensing
Julius-Maximilians University Würzburg. Würzburg, Germany
Phone: +49 17699092454
Email: ameliebroszeit@gmx.de

[2]Regional Geology Department
GNS Science, Lower Hutt, New Zealand
Phone: 04 5704624 Fax: 04 5701444
Email: s.ashraf@gns.cri.nz

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1.0 INTRODUCTION

The 2010 - 2012 Canterbury earthquake sequence caused widespread damage. Much of the damage to residential buildings and infrastructure in and around Christchurch city was caused by permanent ground damage including liquefaction.

Remote sensing imagery provides information across a spatially widespread area to assess damage distribution following natural disasters. Satellite images (from the RapidEye and GeoEye-1 sensors) and aerial imagery, captured shortly after the February 2011 earthquake, showed liquefaction damage occurred over large areas of the Canterbury region.

This paper's main objective is to use different reflectance correction algorithms and test which provides the best results for classifying liquefaction. The study compares two reflectance correction models; the cosine of the solar zenith angle (COST) model (Chavez, 1996) and the atmospheric and terrain correction (ATCOR2) model (Richter, 1996) which calculates ground reflectance for a flat surface. The ATCOR2 model uses MODTRAN (moderate resolution atmospheric transmission) radiative transfer code (Berk et al. 1998) to calculate a broad range of predefined atmospheric correction functions stored as look-up tables (Richter, 1997). This is followed by a comparison of the results computed from supervised classification of images that were derived from different reflectance correction methods on RapidEye and GeoEye-1 imageries.

Atmospheric correction is an important processing step that removes time- and scene-dependent effects from remotely sensed data (Mahiny & Turner, 2007) and extracts quantitative information accurately (Liang, 2001). Many studies (Gebreslasie et al., 2009; Mahiny & Turner, 2007; Wu et al., 2005) have made comparisons between different atmospheric correction methods that demonstrate the significance of atmospheric correction for improved vegetation classification and change detection from remotely sensed data. Remote sensing images have been widely used to detect Earthquake damages. Mitomi et al. (2002), Oommen et al. (2010), Ramakrishnan et al. (2006) and Yusuf et al. (2001) have worked on detecting liquefaction using medium resolution aerial and satellite images; however, the effect of atmospheric correction to improve liquefaction detection is not well established.

2.0 MATERIALS AND STUDY AREA

Images from RapidEye and GeoEye-1 satellites and from a digital camera were taken shortly after the February earthquake. The RapidEye image, which was taken on the 24th of February 2011, has a 5 meter spatial resolution in 5 spectral bands. The GeoEye-1 image was taken on the 27th of February 2011 and has a spatial resolution of 1.65 meters in 4 spectral bands. The colour infrared (CIR) aerial image was taken on the 24th of February 2011 and has a spatial resolution of 0.5 meters in 4 spectral bands. All three images cover a large area over the Canterbury region, from 43° 29’ 46.83” S and 172° 39’ 40.07” E in the north to 43° 31’ 38.51” S and 172° 39’ 41.62” E in the south. The study area is located in the Avonside-Richmond area in 1-2 km north of Christchurch city (see Figure 1).

The earthquake happened on the 22th of February 2011 reaching a magnitude of 6.2 on the Richter scale. In the Avonside-Richmond area, liquefaction was widespread, on meadow areas as well as on streets and parking lots (see Figure 1). The three different images show the same area in three different spatial resolutions.

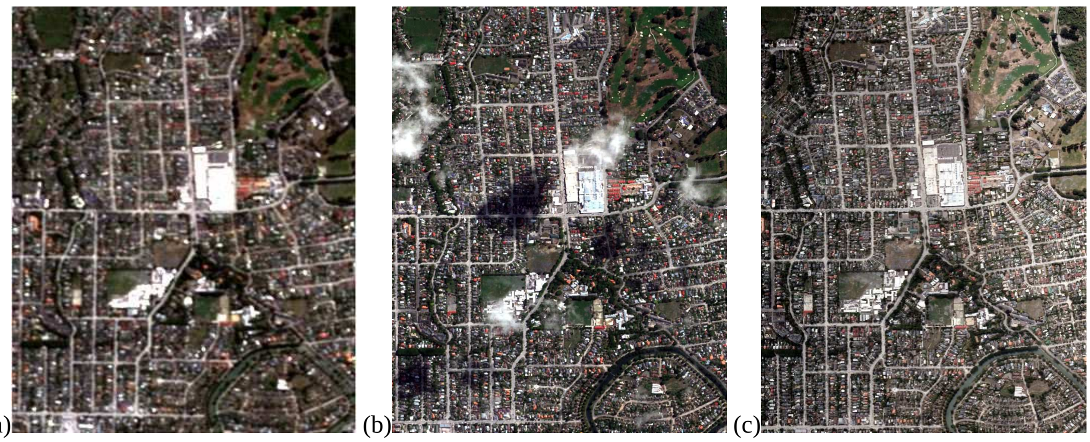
(a) (b) (c)


Figure 1: *(a) true colour RapidEye (5 m resolution), (b) true colour GeoEye-1 (1.65 m resolution), (c) true colour aerial photo (0.5 m resolution)*

3.0 DATA PROCESSING

The data processing shown in figure 2 has been applied on these images.

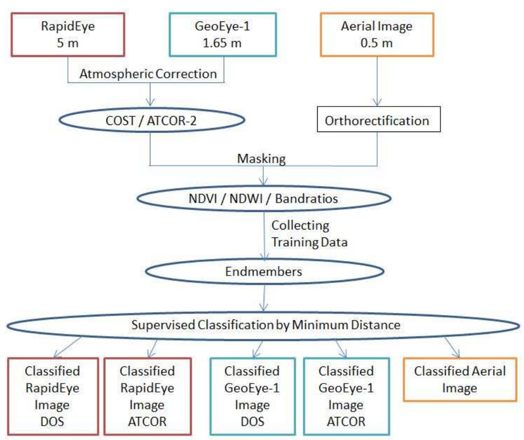


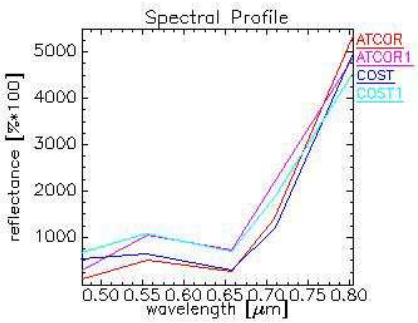
Figure 2: *Flow chart of the data processing*

3.1 Pre-Processing

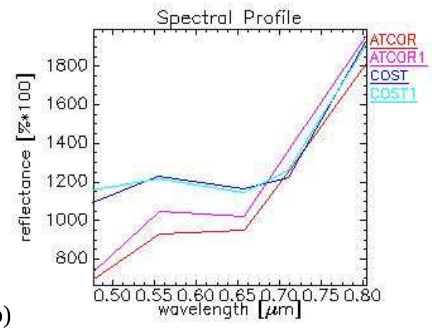
On both satellite images, two different reflectance correction models were applied. The COST model converted image pixels first into the Top-of-Atmosphere (ToA) radiance and from there into the ToA reflectance using information from the metadata of these images. A fixed value of 1% of ToA radiance was used as the path radiance to remove the haze from these images (Chavez, 1988). The ATCOR method used a radiative transfer calculation based on the MODTRAN 5 code.

Figure 3 and 4 show examples of the spectral response showing the average of 15 random pixels in the RapidEye and GeoEye-1 image using the COST and ATCOR method. The (a) profiles show that the spectral profiles are similar for vegetation but in the (b) profiles, the spectral profiles for liquefaction show the COST method values to be higher than the ATCOR values.

After the conversion to reflectance, the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Water Index (NDWI) were calculated to remove potentially non-liquefaction pixels from the data. After masking out vegetation and water pixels, different band ratios were applied to remove as many pixels as possible to achieve an image which contains pixels having a spectral profile similar to the spectral profile of liquefaction as shown in figures 3 (b) and 4 (b).



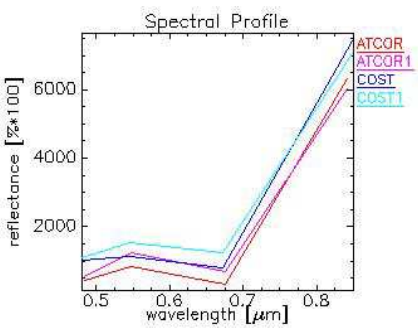
(a)



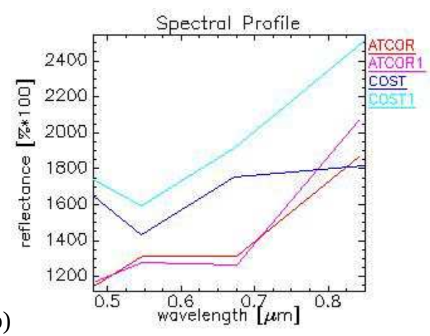
(b)

Figure 3: *RapidEye mean spectral profiles of (a) vegetation and of (b) liquefaction.*

Figure 4 shows examples of the results in the GeoEye-1 image using COST and ATCOR methods.



(a)



(b)

Figure 4: *GeoEye-1 mean spectral profile of (a) vegetation and of (b) liquefaction*

3.2 Classification of RapidEye, GeoEye-1 and Aerial Data

The classification of liquefaction is done by using the Minimum Distance supervised classification algorithm. The collected endmember spectra (consisting of about 15 pixels or more) such as different types of liquefaction as well as different urban types which are still left in the image were digitised directly from the image by hand digitising. These spectra were used as input for the classification. The resulting classes were manipulated using ENVI's n-D Visualizer tool.

4.0 RESULTS

The Minimum Distance classification method was tested on the COST and ATCOR reflectance RapidEye images, the ATCOR reflectance GeoEye-1 image and the aerial image. Classification has not applied on the COST reflectance GeoEye-1 image for this study; this is because a fixed value used to correct the atmospheric scattered path radiance (haze) from each band of this particular image (due to the presence of cloud) showed inconsistent spectral signatures for the liquefaction profile when compared with the ATCOR data (see Figure 4 (b)). The classification results from all images were then compared for accuracy.

The supervised classification accuracies are presented in table 1. Field data recently collected for the liquefaction mapping were available to test the accuracy of image classification (Brackley, 2012). Comparison of the overall accuracy of the three images, computed from RapidEye and GeoEye-1 reflectance images as well as from the aerial image, show that the ATCOR model applied on the RapidEye image shows the best Overall Accuracy with 72.47 %.

Table 1: *Comparative data of supervised classification accuracies for all three images*

Classified Images	**RapidEye**		**GeoEye-1**	**CIR Aerial Image**
	ATCOR	COST	ATCOR	
Producer's Accuracy (%)				
Liquefaction	82.02	72.50	61.84	33.00
No Liquefaction	62.92	52.50	55.26	66.00
User's Accuracy (%)				
Liquefaction	68.87	60.42	58.02	49.25
No Liquefaction	77.78	65.63	59.15	59.62
Overall Accuracy (%)	**72.47**	**62.50**	**58.55**	**49.50**

There were similar reflectance signatures between liquefaction areas and some roofs and concrete surfaces. As a result there was partial success in eliminating non-liquefaction pixels from the data. Higher overall classification accuracies of RapidEye data were due to its higher spectral resolution, whereas higher spatial resolution images (GeoEye-1 and aerial) show lower classification success as there are more pixels having similar reflectance between liquefaction areas and roof/concrete surfaces. The figures 5-7 show the classification results of the same area at different spatial resolutions.

In figure 5, the classification on the ATCOR reflectance image shows the area of liquefaction more accurately than the classification on the COST reflectance image, as there is a better distinction between liquefaction and non-liquefaction areas.

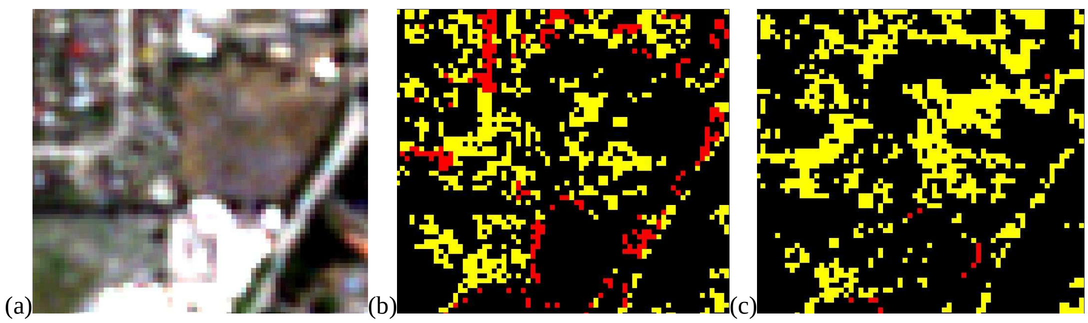


Figure 5: *(a) true colour RapidEye image, liquefaction is shown by the grey colour in the centre right of the image, (b) Minimum Distance classification after ATCOR reflectance correction, (c) Minimum Distance classification after COST reflectance correction (yellow: liquefaction, red: roof/concrete surfaces)*

The classification on GeoEye-1 ATCOR reflectance image in figure 6 (b) shows the liquefaction class less accurate compared to the RapidEye image. It is due to its low spectral resolution which leads to difficulties in classifying liquefaction and non-liquefaction pixels.

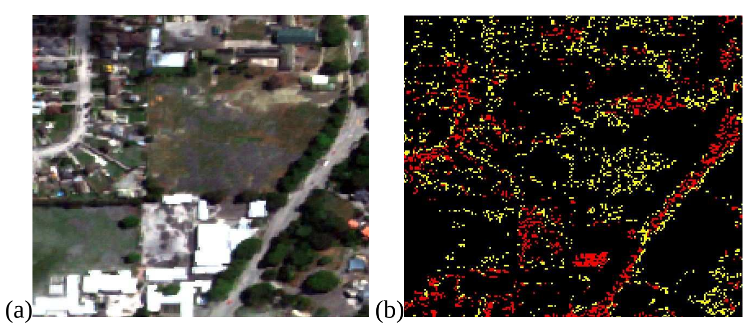


Figure 6: *(a) true colour GeoEye-1 image, (b) Minimum Distance classification after ATCOR reflectance correction (yellow: liquefaction, red: street, buildings).*

The classification of the CIR aerial image in figure 7 resolves liquefaction areas with more details compared to satellite images; this is because during the pre-processing fewer pixels were masked out thus leave behind many materials (such as roofs and roads) classified as liquefaction. This causes the low Overall Accuracy of 49.5 % (see Table 1) for the classification applied on the aerial image.

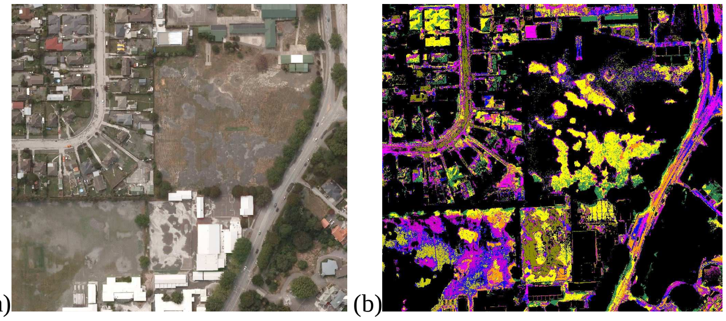

(a) (b)

Figure 7: *(a) true colour CIR aerial image, (b) Minimum Distance classification (yellow: liquefaction, magenta: concrete, sea green: embankment, blue: grey roof)*

The classification applied on the COST reflectance corrected image shows lower overall accuracy than the classification applied on the ATCOR reflectance corrected images. This is because the COST method selected the lowest pixel values of each band automatically to remove the atmospheric haze from the data. The ATCOR method uses specific atmospheric and sensor geometry parameters to achieve a better reflectance conversion compared to the COST method.

5.0 CONCLUSIONS

The study used two different reflectance algorithms applied on data with different spatial and spectral resolution to detect and classify liquefaction.

The Minimum Distance classification applied on the RapidEye ATCOR reflectance corrected image shows the highest Overall Accuracy with 72.47 %. The ATCOR method results proved more accurate than the COST method.

The results show that it is difficult to get a precise classification of liquefaction in urban areas. The classification fails to distinguish in many places between liquefaction, roofs and concrete surfaces. As compared to previous studies (Oommen et al. and Ramakrishnan et al.), a low spectral resolution (i.e. lack of shortwave infrared band) of these images is also a limiting factor in detecting soil moisture/liquefaction.

A possibility to improve the results would be to use LIDAR data to eliminate building structures. Further processing using object-based classification is another option to improve classification accuracy.

ACKNOWLEDGEMENTS

The authors would like to acknowledge USGS EROS Hazards Data Distribution System (HDDS) for providing the data.

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Meeting the Challenges of Teaching Spatial Technology for Archaeology at the University of Otago

Mark D. McCoy

Department of Anthropology & Archaeology
University of Otago, Dunedin, New Zealand
Phone: +64 3 479-8748 Fax: +64 3 479-9095
Email: mark.mccoy@otago.ac.nz

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University of Otago, Dunedin, New Zealand
August 29th – 30th 2013

***Keywords*:** archaeology, spatial technology, geographic information science

Archaeology has traditionally been among the early adopters of new spatial technology owing to our need to record the spatial location and contexts of our finds, generate spatial statistics to evaluate competing hypotheses, discover new sites through remote sensing, create digital models for public interpretation, and manage historical properties as cultural resources. Naturally, this presents a challenge in training students who must learn anthropological archaeology in tandem with aspects of surveying and geographic information science. In this poster, I highlight several recent projects as examples of how we at the University of Otago are meeting this challenge.

Implementing Automated Photogrammetry for the New Zealand eScience Infrastructure (NeSI) Facilities

Steven Mills[1], David Eyers[1], Zhiyi Huang[1], Kai-Cheung Leung[1], and Xiaoxin Tang[2]

[1]Department of Computer Science
University of Otago. Dunedin, New Zealand
Phone: +64 3 479-5450 Fax: +64 3 479-8311
Email: `{steven,dme,hzy,kcleung}@otago.ac.nz`

[2]Shanghai Key Laboratory of Scalable Computing and Systems
Department of Computer Science
Shanghai Jiao Tong University, China
Email: `tang.xiaoxin@sjtu.edu.cn`

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***Keywords and phrases*:** Photogrammetry, Image-based reconstruction, High performance computing, New Zealand eScience Infrastructure

1.0 INTRODUCTION

In this paper we discuss current work to implement automated photogrammetry software for the New Zealand eScience Infastructure (NeSI) high performance computing (HPC) facilities. While the problem of reconstructing a 3D scene from a set of 2D images has been well studied, relatively little research has been published on how to exploit HPC infrastructure in order to process very large scenes. Recent results have shown that many thousands of images can be processed to create reconstructions of large areas (Agarwal, et al., 2009). This work makes use of a cluster of computers, but relatively little information is provided as to how the various tasks are distributed among the nodes in the cluster. Other research has focussed on a single computer containing multiple processors, using of both traditional CPUs and graphics processing units (GPUs) to perform this task (Fram, et al., 2010).

The techniques discussed here are suitable for both terrestrial and aerial photogrammetry. In aerial photogrammetry it is more common to have good priors for the camera positions (from GPS) and possibly orientation (from inertial sensors), and surveyed ground control points are often used to provide either absolute positioning or an independent verification/validation of the results. This additional information provides useful constraints on the solution, but we are primarily concerned with image-based reconstruction.

2.0 THE NEW ZEALAND ESCIENCE INFRASTRUCTURE

NeSI's aim is to provide "High Performance Computing (HPC) facilities to New Zealand, supporting researchers across the public research sector and private industry" (New Zealand eScience Infrastructure, 2013). The NeSI resources include the BlueFern supercomputer and several clusters located at the University of Canterbury, the University of Auckland, and the National Institute for Weather and Atmospheric Research (NIWA). Their main HPC facilities at the time of writing are summarised in Table 1**.**

Facility	Nodes	Cores/Node	Total Cores	Clock Speed	RAM/Node	Total RAM
BlueGene/P	-	-	8196	0.8 GHz	-	8192 GB
P575/POWER6	58	32	1856	4.7 GHz	64-128 GB	5376 GB
P755/POWER7	13	32	416	3.3 GHz	128 GB	1664 GB
Intel Cluster	76 194	12 16	4016	2.8 GHz 2.7 GHz	96 GB 128 GB	32 TB
Intel Big-memory nodes	3	10	30	2.4 GHz	512 GB	1.5 TB
Intel Visualisation Cluster	5	8	40	3.03 GHz	96 GB	480 GB

Table 1: Summary of NeSI high performance computing facilities – http://www.nesi.org.nz/facilities.

In addition to conventional CPUs, 21 of the Intel Cluster nodes and all 5 of the Visualisation Cluster nodes are equipped with Nvidia Tesla graphics processing units (GPUs). These are very efficient at performing a single instruction on multiple data streams (SIMD computing). While initially developed for graphics processing tasks, where many thousands of points or triangles are processed every frame, GPUs are increasingly being used for other computationally intensive tasks (Huang, et al., 2008), including those related to photogrammetry (Fram, et al., 2010). The Tesla M2090 cards in the general purpose Intel Cluster provide 448 processor cores at 1.15 GHz, and 16 of the nodes have two GPU cards each. The Visualisation Cluster machines each have two cards with 512 cores at 1.3 GHz. A further 5 nodes have two Nvidia Tesla K20 GPU cards, and each card provides 2496 cores.

3.0 COMPUTATION AND COMMUNICATION IN PHOTOGRAMMETRY

The computational process for taking two-dimensional images and producing three-dimensional model can be divided into three main phases, based on the degree of interaction between data from each image. This is illustrated in Figure 1, and shows an increase in the degree of interaction that must be modelled as processing is carried out.

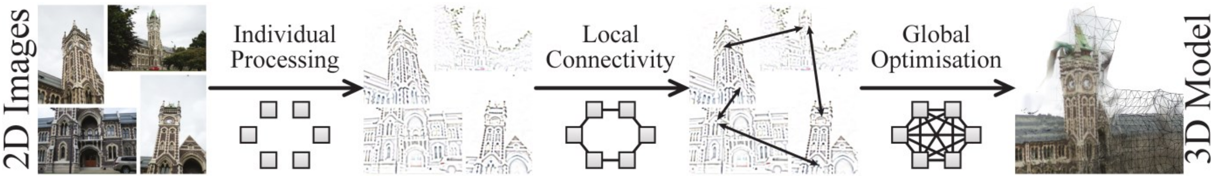

Figure 1: Main stages in an image-based reconstruction pipeline.

In the first stage images are processed individually. This typically includes correction for lens distortion; adjustment for photometric and lighting changes; and keypoint detection and description. The second stage considers local connections between images. The main task here is usually the computation of fundamental or essential matrices between image pairs, or of trifocal tensors between triplets of images. These computations are based on pairwise correspondences computed between overlapping images. The final stage is bundle adjustment to globally estimate the scene structure. While parameters associated with disparate parts of the scene may not directly influence each other, this process involves all of the data in a single computation.

3.1 Individual Image Processing

The initial stages of computation can be carried out independently on each image. The main computation at this stage is the extraction and description of keypoints for later matching (Lowe, 2004), but correction for lens distortion and lighting changes may also be required. Since the processing of each image is independent, and we typically have many more images than processors, this stage is 'embarrassingly parallel' – distributing the tasks across a number of processors is simple, and we do not need to consider communication between processes.

3.2 Local Connectivity

The next phase of computation involves only local connectivity. The most computationally demanding task at this stage is feature matching (Sipla-Anan & Hartley, 2008). These feature matches are then used to estimate the relative pose of the cameras. This may be done between each pair of cameras to compute fundamental or essential matrices, or using triplets of cameras to compute the trifocal tensor (Hartley & Zisserman, 2003). These tasks are still relatively independent, but the fact that overlapping pairs or triplets of images are used means that there is some communication between computational nodes. Our recent research (Mills, et al., 2013) has shown that dynamic scheduling algorithms can be used to distribute these tasks across a cluster of computers in such a way that these communication costs do not impact on performance. In some cases we have even observed super-linear speedups, where improved cache and memory use means that doubling the number of computers in the cluster more than halves the computation time required.

3.3 Global Optimisation

The final stage of processing is bundle adjustment – a large, sparse, non-linear least squares optimisation task (Triggs, et al., 1999). This problem is computationally very demanding, and recent research has investigated implementations on single multi-core machines (Agarwal, et al., 2010). The techniques identified in this research reduce the time and memory requirements, and could be well-suited to application on NeSI's BlueGene/P HPC facility. Implementation on a cluster of compute nodes, where communication costs between nodes are much higher could prove more difficult, and remains an open area for research.

4.0 HETEROGENEOUS COMPUTING

As well as considering the patterns of computation and communication it is important to consider the range of processors that are available in modern computers. Mutli-core processors have largely replaced single core machines with quad-core processors being typical in consumer level computers. High performance workstations typically contain two or more individual processors, each with four to eight processing cores, and HPC facilties often provide clusters of such workstations. Alongside this, there is increasing use of GPUs for general purpose computing. No single solution will work well in all cases.

For example, while kd-trees are often used for efficient matching of features, they require many test-and-branch operations, which are not well suited to GPU implementation (Garcia, et al., 2008). Our research has supported this claim, and shown that while this task scales well across a cluster of computers, scaling on a single multi-core machine is more difficult (Mills, et al., 2013; Tang, et al., 2013).

5.0 CONCLUSIONS

Large-scale photogrammetric reconstruction from imagery is a computationally demanding task. As the number of images grows, the use of HPC facilities such as those provided by NeSI for this task becomes increasingly important. Our current research has identified three phases in the image-based reconstruction pipeline with increasingly complex communication required between sub-tasks. These communication patterns lead to a corresponding increase in complexity when implementing these algorithms for HPC facilities. In addition to the communication costs, attention must be paid to the heterogeneous nature of modern computing hardware, with multi-core processors, general purpose GPU computation, and clusters of compute nodes potentially requiring different approaches to each problem.

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NZIS Programme

Wednesday 28th August 2013	NZIS
12noon	**Registration desk opens- Foyer -St David Lecture Theatre Complex**
1500	Communication Forum
1700-1830 approx	Annual General Meeting
1830 at end of AGM	**Including 2 book launches:** 100 Fathoms Square – by Bruce Alexander and Larry Wordsworth Survey Marks – by Mick Strack
1830 - 2000	**Welcome Function and Opening**
	Evening free to Dine at leisure

Thursday 29th August 2013	NZIS Combined with Geospatial Research	
0730 - 1730	Registration desk open	
0900-0915	Mihi Whakatau : Mark Brunton, University of Otago	
0915-0920	Presidential welcome: Andrew Stirling	
0920-1000	Plenary : **CheeHaiTeo , President FIG**	
1000-1020	Hon Maurice Williamson	
1020	TRADE Presentation : ESRI Donny Sosa	
1030	**Tea break**	
	Session 1 : Geo-spatial 101 *supported by OPUS International Consulting*	
1100-1120	Update on LINZ initiatives for coordinated approaches to managing imagery and elevation data: *Bjorn Johns*	
1120-1140	Scanning the past for a perspective on the future: *Richard Hemi*	
1140-1200	Geospatial Virtual Field Trips for New Zealand Schools: *Geoff O'Malley*	
1200-1220	The Importance of New Zealand Digital Parcel Fabric: *Andrew Clouston*	
1220 -1320	**Lunch**	
1320-1400	Plenary :**Nick Chrisman, RMIT**	
	Session 2 : Geo-Spatial 102	
1400-1420	Photogrammetry, Remote sensing and the surveying discipline: *Pascal Sirguey*	
1420-1440	Affordable location technology: *Nicholas Stillwell*	
1440-1500	TRADE Presentation: Quality Planning MFE, Kirsty van Reenan	
1500-1540	**Tea break**	
1540 - 1730	**Workshops**	
W1	LINZ – Establishing and Replacing Control Marks	Room 3
W2	Using the LINZ Data Service: a practical guide: *Jeremy Palmer*	St David
W3	12d Mapping : *Lane Irwin*	Room 2
W4	Urban Design Forum 1: *Phil Rhodes*	Room 1
1900 -2300	**NZIS Decade Reunions- Forsyth Bar Stadium**	

Friday 30th August 2013	**NZIS - School of Surveying Day**	
0730 – 0840	Breakfast Session: Young Professionals: *Nigel Bamford*	
0845	**Welcome to Friday**	
0845-0915	Plenary **: Brian Ballantyne, Lawyer , Surveyor**	
0915-0945	Plenary : **Giselle Byrnes, Darwin University**	
0945-1000	NZIS Award of Excellence Presentations	
1000-1030	**Tea break**	
	Session 3 : Survey Methods 201 *supported by Global Survey*	
1030-1100	GNS Science: *Martin Reyners*	
1100-1120	Surveying Applications in Response to the Christchurch Earthquakes: *Phil Dewar*	
1120-1140	Christchurch - A Moving Target. (Finding the Optimum Solution for Benchmark Control): *Brent George*	
1140-1210	Surveying for the Stronger Christchurch rebuild (SCRIRT): *Chris Scott*	
1210 -1310	**Lunch**	
	Session 4 : Geodesy 202	
1310-1340	Plenary :**George Benwell, University of Otago**	
1340-1400	A Nationwide Adjustment of New Zealand's Geodetic Data: *Miriam Broadbent*	
1400-1420	Has NZGD2000 exceeded its use by date?: *Paul Denys*	
1420-1440	Updating the NZGD2000 deformation model: *Chris Crook*	
1440-1500	Plenary : **Harlene Haynes, Vice Chancellor , University of Otago**	
1500-1510	TRADE Presentation: Quick map. Murray Black	
1510-1540	**Afternoon Tea**	
1540 -1730	**Workshops**	
W5	LINZ Cadastral Workshop	
W6	Urban Design Forum 2: *Phil Rhodes*	
W7	Urban Renewal Warehouse Precinct Tour: *Glenn Hazelton (DCC) and Stephen McKnight*	Room 2
1730–1900	**Party at Basil Jones's-** Food platters and 1st drink provided, followed by cash bar. **The Link building - University of Otago**	Room 1
1900-2000	**Tour of Survey School**- **Evening free to dine at leisure**	Off site

Saturday 31st August 2013	**NZIS Future Focus Day**
0730- 0800	Breakfast served: Women's breakfast
0800- 0840	Breakfast session : Women's Breakfast: Christina Hulbe, Dean School of Surveying, University of Otago
0845-0915	Plenary :**Tony Sewell, Ngai Tahu Property Chief Executive**
0915-0945	Plenary: **Robert Patman, International Politics**
0945-1000	Trade Presentation: Global Surveys. Richard Harrison

1000-1030	**Tea Break**
Concurrent	**Session 5 : Land Tenure 301**
1030-1100	Learning from the past- defining units into the future: *Josie Fitzgerald*
1100-1120	Realising the Queen's Chain from the part to the whole. A New Zealand national mapping system displaying public walking access: *George Williamson*
1120-1140	Coastal Erosion and Property Loss: *Mick Strack*
1140-1200	Archaeology and history of seismic events: is the past a key to the future?: *Bruce McFadgen*
1200-1220	Sustainable Development, An Environmental Geodesist's perspective from Hong Kong: *Merrin Pearse*
Concurrent	**Session 6 : Positioning 302**
1030-1100	Saudi Arabia/Kuwait Boundary - Survey, Mapping and Pillar Emplacement*: Vince Belgrave*
1100-1120	Local tie survey at the Warkworth Radio Astronomy Observatory: *Paula Gentle*
1120-1140	PositioNZ-PP: an online GPS processing application for New Zealand: *Christopher Pearson*
1140-1200	Trimble NZ's role in the revolution of hydrographic surveying and its global impact, from 1990 until today: Gary Chisholm
1200-1220	Tekapo Canal Refurbishment: *Maurice Perwick*
1220-1320	**Lunch**
1320-1330	TRADE presentation : Grant Sime, Regional Manager, Fulton Hogan Ltd
	Session 7 : Professional Issues 303
1320-1350	**Plenary: Christina Hulbe, Dean, School of Surveying**
1350-1410	Cadastral 507 - Removing Limitations: *Mark Smith*
1410-1430	Surveying The Profession: *Brian Coutts*
1430-1450	Registered Professional Surveyor: To be, or not to be - that is the question: *Rebecca Strang*
1450-1500	Trade Presentation: Fulton Hogan, Grant Sime, Regional Manager
1500-1530	**Tea break**
1530-1630	**Plenary : Jamie Fitzgerald**
1630-1700	Consultants division
1630-1700	Young Surveyors Group
1900	Pre dinner drinks at Toitu Settlers Museum where guests will also be able to experience the transport section of the museum, Conference dinner will be held In the Josephine foyer of Toitu Settlers museum.

SIRC NZ 2013 Programme

THURSDAY 29th AUGUST 2013 (SHARED WITH NZIS CONFERENCE)

(programme starts in the main St.David's lecture theatre)

9.00 Mihi Whakatau - Mark Brunton, University of Otago

9.15 Welcome from NZIS President Andrew Stirling

9.20 Keynote: CheeHai Teo, President of the International Federation of Surveyors (FIG)

10.00 Hon. Maurice Williamson

10.20 Trade Presentation: Eagle Technology – Matt Lythe

10.30 Morning Tea

(remaining presentations in Room 5 – St. David's mezzanine floor – except where otherwise stated)

11.00 Session 1: GIScience, Spatial Analysis and Spatial Modelling
(Chair: Nick Chrisman, RMIT University)

- How Do Different Science Disciplines Represent and Compute Over 'Space'?
  Mark Gahegan (University of Auckland)
- Extending Point-Pattern Analysis to Polygons Using Vector Representations.
  Peter Whigham (University of Otago)
- Towards a 'Pattern Language' for Spatial Simulation Models.
  David O'Sullivan and George Perry (University of Auckland)

12.00 Poster Session: 5 minute introductions
(Chair: Akbar Ghobakhlou, Auckland University of Technology)

- Linking Geospatial Databases Using Stratigraphic Names.
  Delia Strong, Soren Haubrok, Mark Rattenbury and Nick Mortimer (GNS Science)
- Using Different Atmospheric Correction Methods to Classify Remotely Sensed Data to Detect Liquefaction of the February 2011 Earthquake in Christchurch.
  Amelie Broszeit (University of Wurzburg, Germany) and Salman Ashraf (GNS Science)
- Meeting the Challenges of Teaching Spatial Technology for Archaeology at the University of Otago.
  Mark McCoy (University of Otago)
- Implementing Automated Photogrammetry for the New Zealand eScience Infrastructure (NeSI) Facilities.
  Steven Mills, David Eyers, Zhiyi Huang, Kai-Cheung Leung (University of Otago) and Xiaoxin Tang (Shanghai Jiao Tong University, China)

12.20 Lunch

13.20 Keynote: Nick Chrisman, RMIT University, Australia: *Challenges in the Geospatial Sector*
(Main St David's Lecture Theatre; Chair: Tony Moore, University of Otago)

14.00 Session 2: Spatial Modelling
(Chair: David O'Sullivan, University of Auckland)

- Geographical Vector Agent Modelling for Image Classification: Initial Development.
  Kambiz Borna, Pascal Sirguey and Antoni Moore (University of Otago)
- GIS modelling in Support of Earthquake-Induced Rockfall Risk Assessment in the Port Hills, Christchurch.
  Biljana Lukovic, David Heron, William Ries and Chris Massey (GNS Science)
- Predicting Potential Anchor Ice Formation Sites in Coastal Antarctic Waters.
  Greg Leonard, Andrew Pauling, Sarah Mager and Inga Smith (University of Otago)

15.00 Afternoon Tea

15.40 Session 3: Snow / Ice Remote Sensing and Spatial Analysis
(Chair: Lars Brabyn, University of Waikato)

- Recent Ice Wastage on the Tasman Glacier Obtained from Geodetic Elevation Changes.
  Sebastian Vivero, Pascal Sirguey, Sean Fitzsimons (University of Otago), Delia Strong (GNS Science) and Alvaro Soruco (Universidad Mayor de San Andres, Bolivia)
- Modelling Ice Retreat on Kilimanjaro Using GIS.
  Rosie Wood, Pascal Sirguey and Nicolas Cullen (University of Otago)
- Snowfall Detection in Antarctica Using MODIS Ground Infrared Reflectance.
  Bob Noonan (University of Canterbury), Pascal Sirguey (University of Otago), Wolfgang Rack and Wendy Lawson (University of Canterbury)

16.25 Session 4: Animals in Space-Time
(Chair: Mairead de Roiste, Victoria University Wellington)

- Hotspots of Hectors' Dolphins on the South Coast.
  Judy Rodda and Antoni Moore (University of Otago)
- Visual Data Mining of Generalized and Optimized Spatiotemporal Animal Paths.
  Antoni Moore, Mariano Rodriguez Recio, Judy Rodda, Jim Watts and Philip Seddon (University of Otago)

16.55 End of Session

19.00 - 23.00
Conference dinner at Forsyth Barr Stadium (Entrance J, Level 4) - buffet meal, refreshments and entertainment

FRIDAY 30th AUGUST 2013

8.55 Welcome, housekeeping

9.00 Session 5: Public Participation GIS, Mobile GIS and Volunteered GI
(Chair: Mark Gahegan, University of Auckland)

- Using GIS to Survey Landscape Values.
  Lars Brabyn (University of Waikato) and Greg Brown (University of Queensland, Australia)
- Current Status and Future Directions of Mobile GIS.
  Markus Muller, David Medyckyj-Scott, Andrew Cowie, Tim-Hinnerk Heuer and Pierre Roudier (Landcare Research)
- Finding the Quality in Quantity: Establishing Trust for Volunteered Geographic Information.
  Jeremy Severinsen (Land Information New Zealand) and Femke Reitsma (University of Canterbury)

10.00 Morning Tea

10.30 Session 6: Urban Applications
(Chair: Greg Breetzke, University of Canterbury)

- Commuting in Wellington: A Geographic Econometric Analysis of Commute Mode, Residential Location and Car Ownership.
  Mairead de Roiste, Toby Daglish, Yigit Saglam and Richard Law (Victoria University of Wellington)
- Flow Direction Algorithms in a Hierarchical Hexagonal Surface Model.
  Joseph Wright, Antoni Moore and Greg Leonard (University of Otago)
- Our Waste Our Way: A Spatial Study of Household Waste Management in Betio, Tarawa, Kiribati.
  Kotee Bauro Teburea, Antoni Moore and Greg Leonard (University of Otago)

11.15 Session 7: Land Use / Land Cover Modelling
(Chair: Pascal Sirguey, University of Otago)

- Sources of Uncertainty in a Cellular Automata for Vegetation Change.
  Rachel Whitsed and Lisa Smallbone (Charles Sturt University, Australia)
- A Simplified Approach for Classifying Urban Land Cover using Data Fusion.
  Amit Kokje and Jay Gao (University of Auckland)
- Geospatial Modelling of Complex Land Use Cover Change: How to Determine the Adequacy and Significance of Variables.
  Isaac Nti and Philip Sallis (Auckland University of Technology)

12.00 Lunch

13.00 Keynote: George Benwell, University of Otago: *An Enduring and Natural Real-Time Challenge*

(Main St David's Lecture Theatre; Chair: Peter Whigham, University of Otago)

13.40 Session 8: Crime and Health Applications
(Chair: Shawn Laffan, University of New South Wales)

- The Fear Factor: Examining the Spatial Variability of Recorded Crime on the Fear of Crime in New Zealand.
Gregory Breetzke and Amber Pearson (University of Canterbury)
- Where do Women Travel to Give Birth within New Zealand?
Pauline Dawson (University of Otago)
- Spatial Aspects of a Comparative Study of Active Transport to School and Motorized Transport.
Antoni Moore, Melanie Middlemiss, Claire Hodge, Paula Skidmore and Sandra Mandic (University of Otago)

14.40 Harlene Hayne, Vice Chancellor of the University of Otago (Main St David's Lecture Theatre)

15.00 Trade Presentation: QuickMap – Murray Black

15.10 Afternoon Tea

15.40 Session 9: Forestry and Agricultural Applications
(Chair: Rachel Whitsed, Charles Sturt University)

- Statistical Analysis of LiDAR-derived Structure and Intensity Variables for Tree Species Identification.
Zhenyu Zhang, Xiaoye Liu (University of Southern Queensland, Australia) and Wendy Wright (Monash University, Australia)
- Spatial Techniques for Multi-source National Planted Forest Assessment and Reporting.
Barbara Hock and Tim Payn (Scion)
- The Use of GIS for Agroecology, Medicinal Flora and Public Access Aspects of an Iwi-run Farm.
Antoni Moore, Marion Johnson, Janice Lord, Sam Coutts, Mariana Pagan, Jeremiah Gbolagun (University of Otago) and G. Brent Hall (Esri Canada; University of Otago)

16.25 Session 10: Maori and Land Information Management
(Chair: Greg Leonard, University of Otago)

- Putting 'Te Kawa a Maui' (Maori Studies) on the Map.
Bruce McFadgen and Ocean Mercier (Victoria University of Wellington)
- Representing 3D Data in a Cadastral Database - Queensland Case.
Sudarshan Karki, Rod Thompson (Department of Natural Resources and Mines, Australia) and Kevin McDougall (University of Southern Queensland, Australia)
- A Read, Append, Prune (RAP) Formalism for Spatiotemporal Information.
Geoff Hay, Peter Whigham (University of Otago) and G. Brent Hall (Esri Canada; University of Otago)

17.10 Conference Close