Proceedings of Spatial Knowledge and Information - Canada (SKI-Canada) 2011, March 3-6 in Fernie BC, Canada.

Volume 1

Proceedings Editor
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We invite you to read the proceedings of the 2011 conference of Spatial Knowledge and Information Canada, the 3rd SKI conference. It will be held March 3-6 in Fernie BC, Canada. The intent of Spatial Knowledge and Information Canada is to bring together (digital) Geographic Information researchers and their students from across Canada. We define Geographic Information research broadly as any geographic research in which computation is its main focus. The prime computational platform is Geographic Information Systems although we include Geographic Information Science, geomatics, remote sensing, geospatial web 2.0 (Geoweb) and volunteered geographic information (VGI), and spatial statistics and computational modeling. We encourage theory and practice and we invite research on the widest range of applications from GIS-transportation and health to GIS in education and business. We also stress work-in-progress, our reasoning being that the conference will stimulate additional avenues of exploration.

The 2011 conference is being held in partnership with the GEOIDE Network Center of Excellence, who this year gave us a very generous award to fund ALL student presenters and create student awards. Over 70 researchers, university faculty, students and interested parties from across Canada are registered and plan to attend. The conference is composed of 48 scientific papers. We are delighted to have as our keynote with David Mark (expat Canadian), who presents on *Cultural Differences in Geographic Information: Why Geographic Categories Matter for GIS*.

SKI also will hold its first workshop, Hands-on with Neogeography: a VGI/Open Street Map (OSM)/Application Programming Interface (API) Participant Activity where participants will not only get acquainted with the concepts but will conduct a mapping party to expand the geographic information for Fernie. This workshop was conceived and conducted by students. The conference concludes with a planning meeting on the final day, where we will plan our conference in 2012, our first venture towards the eastern side of the country, near Quebec City.

A substantial focus of the conference continues to be the promotion of Canadian student research on Geographic Information. We greatly expanded our student presentations: this year, we're excited to have 35 presentations by undergraduate, Master's, PhD students and postdoctoral fellows. We plan to award seven outstanding students substantial awards for their research and presentation quality. These will be listed on the website, http://rose.geog.mcgill.ca/ski/. We extend our congratulations to the prizewinners and to all our student presenters!

Please enjoy the extended abstracts of student and faculty in these two volumes, visit the SKI-Canada site, http://rose.geog.mcgill.ca/ski/ and attend the 2012 conference.

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Volume 1

Enhancing citizen science participation in Geoweb projects through the instance-based data model

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Abstract

The increased popularity of user-supplied content on the Internet provides an opportunity to convert volunteered user information into a scientifically viable resource. Geoweb is a technology that combines geographic and user supplied data online. Yet, broader participation by members of the public in Geoweb is often constrained by varied levels of domain expertise of potential project participants. Further, if a Geoweb project is to have scientific utility, an additional constraint maybe placed upon participation – conformity with conceptual requirements of a given scientific domain. In this paper we propose an instance-based model of data collection and citizen science knowledge integration with scientific domain. To test the assumptions of the model, we propose an experiment to: (1) test of the applicability of basic-level categories to citizen science observations and (2) to determine if subjects are able to describe a phenomenon using a small number of observable features.

Background and Relevance

User-supplied content on the Internet is growing at a staggering rate (Anderson 2007). Projects like Facebook, Wikipedia, YouTube, and Twitter, have millions of users. Users are increasingly transitioning from a mere audience to creators and shapers of the online content. The willingness of people to share information has the potential to facilitate engagement of citizen scientists online (Sieber 2006). According to Goodchild, for example, humans are effective sensors of biological and ecological change (Goodchild 2007). New Internet tools further allow users to reference their observations to a specific geographic location. This is the premise of Geoweb projects like OpenStreetMap, Google Maps, Wikimapia. A number of Geoweb projects have an explicit scientific component, such as eBird (www.ebird.com), E-Flora BC (www.geog.ubc.ca/biodiversity/eflora/), and iSpot (http://ispot.org.uk/).

Yet, a traditional approach to citizen participation in scientific data collection tends to be constraining due to the requirement to understand the language, structure and concepts of the scientific domain. In cases where a phenomenon needs to be identified, such as in many Geoweb projects with a biological component, traditional approaches rely on the need for a positive identification of species. These requirements may be unrealistic for novice volunteers, and limit the scope of potential participation.

To combat this limitation, we propose an approach to data collection and storage that does not require users to identify and classify observed phenomena. Instead, users will have an option to record any observable attributes associated with the sighting. The attributes will also serve as a bridge between the scientific domain of the project and representation of reality by its non-expert participants, thus allowing crucial information to be communicated and collected. We propose a data collection interface based on Bunge's ontology (Bunge 1977) and cognitive theory of basic categories (Rosch, Mervis et al. 1976).

By shifting the focus from a predefined classification to the instance and its attributes, we do not need to model a domain *a priori* in terms of classes of interest (Parsons and Wand 2000). It is sufficient to ensure that the application has a comprehensive collection of classes, and each class contains a set of qualifying attributes (properties of a phenomenon that establish its membership with possible classes). However, despite the theoretical power of the instance-based model there is limited research that deals with its practical implementation. In particular the issue of effective attribute management remains unaddressed. With potentially large number of attributes attached to each instance, collecting, storing and presenting attributes can be a challenge. Rosch et al. (1976) noted the reality is made of an "infinite number of discriminately different stimuli" (p. 382). This research further proposes an adoption of a cognitive concept of basic categories as a filter to manage large numbers of attributes.

In order for an instance-based approach to be effective, two broad assumptions should hold true: (1) users identify unknown phenomena using basic categories, and (2) there is a short list of identifying attributes of a phenomenon that users are capable of observing. In order to test these assumptions, we propose an experiment to verify the applicability of the basic categories to the online context of Geoweb applications. We also wish to determine if users observe a small number of identifying features of a phenomenon.

Methods

The subjects of the experiment are first year business students from Memorial University. The choice is justified by the diversity of the backgrounds as the first year business course is an elective for many undergraduate programs. Bailenson et al. warned about a tendency of undergraduate students to use scientific biological taxonomy when classifying phenomena (Bailenson, Shum et al. 2002). However, we argue that students of the first year business course are likely to have limited exposure to biological nomenclature. In addition we will control for prior taxonomoic knowledge via a pre-experimental questionnaire that asks for details on background knowledge in biology. The stimulus set contained 30 images of plants and animals likely to be encountered by citizen scientists. The stimuli belong to a variety of biological genera. Some contain relatively obscure and unknown species, such as boreal felt lichen, while others are more charismatic – bald eagles, moose, coyotes. Not all stimuli, therefore, can be positively identified by all subjects, which is a realistic representation of various levels of citizen science expertise (Coleman, Georgiadou et al. 2009). In the experiment, the subjects were instructed to identify or describe the species in the image displayed. These descriptions can be in terms of categories or attributes. The talk will present the findings of the experiments that offer support for the instance-based approach to citizen science participation.

Conclusions and Implications

The result of the experiment has implications for developing participatory models of citizen science. By testing ways users identify known and unknown phenomena in the context of a Geoweb project, we have gained experimental support for the instance-based attribute model. People tend to recognize basic categories when faced with both familiar and unfamiliar objects. Basic categories become a useful entry point of a citizen science interface. The intuitiveness of basic categories streamlines the process and increases interface usability. The interface is then designed around a set of attributes that permits inferences about subcategory membership and guide users through identification process. This approach allows for a broader audience to engage in scientifically-oriented projects, as non-experts do not need to know exactly the phenomenon that was observed. This has far-reaching implications for the scientific community as data generated by many “eyes on the ground” increases the likelihood of rare or unusual species being detected. Some potential uses of data collected this way might be unanticipated. For example, long term data can be useful to identify benchmark conditions in the event of a natural or anthropogenic disaster (e.g., the Gulf oil spill, climate change issues etc.) and can guide preventive and restoration strategies.

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What Motivates Governments to Adopt the Geospatial Web 2.0?

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Abstract

The Geospatial Web 2.0 (Geoweb) has the potential to transform the ways governments conduct their operations. The Geoweb can be used to mobilize citizens for measuring, monitoring, and managing geo-referenced phenomena. Considerable research is underway on understanding citizen's motivations to volunteer geographic information. We explore what motivates governments to adopt these technologies and content.

Background and Relevance

The Geospatial Web 2.0 (Geoweb) has the potential to transform the ways governments conduct their operations. The Geoweb is that collection of geographic specific Web 2.0 platforms (e.g., Everyblock, Google Earth) and the content enabled by those platforms. The Geoweb can be used to mobilize citizens for measuring, monitoring, and managing geo-referenced phenomena. Since these everyday people have local access to many events and incidents, they can provide near real time information and knowledge. For example, citizens report real time weather data to government agencies and research institutions in Citizen Weather Observer Program (http://www.wxqa.com). At the time of shrinking budgets and resources, governments may be able to maintain their competitive advantage with Geoweb-enabled citizen contribution (also called volunteered geographic information or VGI).

Should governments wish to realize the potential of the Geoweb, they must understand how to attract and retain citizens in investing their skill, time and effort in contributing content. We have some understanding of citizens' motivation (e.g., Coleman et al., 2009; Budhathoki et al., 2010; Budhathoki, 2010). Our interest, and the focus of this paper, is in what motivates government to adopt these new web 2.0 technologies and informational content. To the best our knowledge, no study has investigated the government side of the motivation equation. In this paper, we report initial findings. Since governments are major producers and users of geographic information, their adoption (or rejection) can significantly influence the diffusion and anticipated benefits of the Geoweb. Hence, the Geoweb in government is highly relevant research because it may shape the future production, sharing, and use of geographic information.

Methods and Data

The result reported in this paper is the preliminary outcome of a literature review and analysis of select cases of the Geoweb use in government. As no study has investigated the Geoweb in government, we are developing a framework and motivational baseline that can subsequently be used to study government's adoption and use of the Geoweb. In the next stages, we will employ both qualitative and quantitative methods for testing/refining the framework with structured interviews of of public sector developers of Geoweb applications.

Results

Governments have traditionally enjoyed their monopoly in the production and provision of geographic information, in part because of an economy of scale (Goodchild et al., 2007). This monopoly has largely continued even after the invention of digital technology including GIS and spatial data infrastructure. As a result of such a monopoly, coupled with the absence of adequate technology for users to interact, scrutinize and challenge the government-sourced geographic information, most governments are accustomed to a one-way supply-driven model of geographic information (Budhathoki et al., 2008). They make assertions depending on what they provide and exercise both legislative and professional authority in doing so.

Governments at all levels—national, state and local—are beginning to show an interest in the Geoweb, a technology that challenges tradition. The Geoweb operates in the absence of conventional authority and trust, an environment markedly different than how governments are used to functioning. Consequently, government's interest in Geoweb appears paradoxical. Even within this paradox, our research shows that governments have motivation for the Geoweb. We briefly describe ten preliminary motivations in the following paragraphs.

Government does not have knowledge and resources to tackle problems unilaterally. According to Stoker (1998, 26),"[g]overnance means living with uncertainty and designing our institutions in a way that recognizes both the potentials and limitations of human knowledge and understanding". Hence, governments will be motivated to use the Geoweb to *capitalize on citizen input as a way of broadening extending their knowledge base*. Challenge.gov (http://www.challenge.gov) exemplifies this point. Challenge.gov calls on citizens to contribute information to the government for collaboratively solving problems. Similarly, the US Geological Survey has begun to explore the potentials of citizen inputs in mapping (http://cegis.usgs.gov/vgi/). The recognition of the value of citizen contributions constitutes a remarkable shift from top-down governance approaches and, digitally, is enabled by the Web 2.0 read-write web.

Governments are often considered laggards in adopting innovation and there is pressure for them to show modernity or progressivity. Governments do compete with each other for resources and jobs, particularly municipal governments and innovation allows them to show a competitive advantage, for example to attract knowledge workers. Similarly governments are under some pressure from their constituents to catch up with their rapid adoption of Web 2.0. Thus governments may adopt the Geoweb to *demonstrate innovation*. Innovations such as Web 2.0-enabled applications and data fusion can offer new way to deliver services, for example San Jose, CA, USA's provision of Keyhole

Markup Language (KML) files of its planning data (http://www.sanjoseca.gov/planning/data).

As citizens gain access—and get accustomed—to the Geoweb such as Google Maps services, they will likely expect the same from governments. Governments, particularly democratic ones, have to *be responsive to citizen demand*. This demand may act as a powerful motivation for governments to adopt and use the Geoweb. In a sense the citizen here is seen as a consumer and the web as the enabler of addressing that customer base and revamping their service delivery (Deloitte Research, 2000). Deloitte Research argues this bottom-up responding to citizens will more likely lead to service improvements than top-down legislative mandates. This demand will not be homogeneous. A hallmark of Web 2.0 is its supposed responsiveness to the long-tail of individuals' needs, needs that are not met by majority issues dominated distribution mechanisms of Web 1.0 (O'Reilley, 2005). Heretofore, we have posited that motivations have positive connotations. Treating constituents like consumers is very much a neoliberal response, where governments are expected to behave like businesses and should respond to the same efficiencies drivers as the private sector.

Efficiencies like cost minimization as well as performance enhancement are perpetual concerns for governments (Lynn et al., 2000). Web 2.0 promises that governments can do more with less. The Apps for Democracy project in Washington, DC, is estimated to have returned 50 times more value than the cost invested (http://www.appsfordemocracy.org/about/). Utilizing citizen-created data and applications—which are free or can be created with much lower cost—can allow governments to reduce their own data collection. Ironically, increased digitalization of societies actually increases strain on government resources, as it requires greater expenditures on digital technologies. Nonetheless, governments may be motivated towards the Geoweb as a means to *optimize and redirect their limited resources* to activities of public benefit. Mayo and Steinberg (2007) recommend that the U.K. government investigate existing websites, data and apps before it develops its own.

Governments may view the Geoweb as a new tool to *enact/respond to regulation* as part of their mandates or their standard operating procedure. For example, building inspectors are beginning to use Google Maps as a reference images to ensure that they go to the correct building. In Greece, officials have caught tax-evaders by using these same images to identify undeclared swimming pools (Yahoo! News, August 14, 2010). Certain of these uses verge on threats to privacy (Krumm 2009); governments might nevertheless see the potential for the Geoweb in these uses.

It is beyond the capacity of individual agencies to address pressing and complex public issues, from climate change to terrorism. GIS has already been found to be an effective means to exchange geospatial information across agencies (Nedović-Budić, 2004), although challenges remain in interoperability. As intra- and inter-organizational collaboration becomes increasingly important (Dovey & Eggers, 2008) and as the Geoweb promises to surmount these interoperability challenges, governments will find the Geoweb to *further intra- and inter-agency collaboration.*

A major character of a democratic government is to ensure that its citizens have opportunity to participate in political and policy discourse (Moon, 2002; Shrier, 2008). The visual power of maps and the ease-of-use of the Geoweb may provide ample opportunity for governments to establish or strengthen two-way conversations with citizens (Ganapati, 2010). Governments may wish to use the Geoweb to *empower and engage citizenry*. This motivation hearkens back to original debates about the empowerment potential of GIS (Sieber, 2006), for example, that empowerment and democratization potentials of GIS were illusions or diversions from realpolitik (Pickles 1995).

Lobby groups wish to be similarly empowered to influence public policies in their favour. Kakabadse et al. (2003, 48) contend that "[t]he imbalance created by lobbying is probably one of the most serious issues confronting current liberal representative democracy models". Disintermediation has long been a hallmark of Internet applications—if geospatial information was made more directly available to the public then it may be potentially less susceptible to distortion and filtration. Governments may use the Geoweb as a tool to *minimize the role of intermediaries (disintermediate) and lobbyists*. For example, U.S. President Obama highlighted lobbyist influence as one of the major issues in 2008 election campaign and the attempts to use Web 2.0 by his administration can be seen as a technique to minimize intermediaries and directly address the people.

The Geoweb may *contribute to open government*, making government activities more transparent (Ganapati, 2010). The concept of increased transparency in government borrows ideas from Open Source Software and other open movements, that government is DIY (Do It Yourself). In such a model of an open and a network model of governance, decision making presumably improves as many eyeballs examine the data to ensure quality of local content, either through feedback, updates or new ideas for data (Eynon & Dutton, 2007; Rhodes, 1996). Apps for New South Wales in Australia refers to it as unlocking the potential of government information (http://www.information.nsw.gov.au/apps4nsw). Indeed, this is very much what originally drove the release of GIS data: where data became recognized as an end in itself and not necessarily a means to the end of policy making (Onsrud et al., 2004).

A tool of expression can also be used for repression. According to the HerdictWeb, Tunisian government's online censorship reached an apex in the weeks of the recent political unrest (http://www.herdict.org/). Governments may *use the Geoweb as a tool of repression* to its citizens or certain groups or individuals. As the Geoweb provides people' movement in space and time, it can offer means of surveillance for government (Morozov 2011).

Conclusions

Literature suggests that the government's adoption of the Geoweb is driven by wide range of endogenous and exogenous factors. As the Geoweb is much easier to use than the technologies of desktop and the Internet GIS* of 1980s and 90s, governments' adoption of this emerging geospatial paradigm will largely depend on how well we understand and address motivational issues. Even after understanding government motivations, we anticipate that this new form of public participation will likely collide, for example, in terms of data accuracy and precision, consistency, and authenticity, with the existing institutional processes. Unless governments devise means to reinvent institutional frameworks and organizational practices, Geoweb implementation in government will be a challenge.

We have painted a largely positive picture of the adoption of the Geoweb. As we began to suggest above, the Geoweb could just as easily be turned to, for example, surveil the public or respond to neoliberal impulses in governance. Also, we expect new motivations to emerge as we conduct our research. Further research is required to best understand these varied factors.

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* It is a testable hypothesis on how much successful government adoption of the Geoweb depends upon the .shp or .tab files developed by traditional GIS.

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Unfolding Participatory Urban Design, Capturing Spatial Feelings and Emotions in Digital Space

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Abstract

This research aims to create a tool that allows participants to engage in citizen controlled urban design in a dynamic 3D environment. The citizens will be guided by a methodology developed in Christopher Alexander's more recent work in the process of unfolding and generative codes (Alexander & CES 2002, 2002, 2004 2005). This will take place within the three-dimensional design software Google Sketchup, supplemented with ruby script applications that utilize the Google Sketchup application programming interface (API). Currently, 3D modeling and design software is ill-suited for facilitating public participation. The software requires high levels of technical training, and is designed only for a single user. Furthermore, Christopher Alexander's methodology for urban design relies heavily on capturing and communicating the personal feelings and emotions that one experiences from a particular place. Current 3D modeling software is also unsuited for capturing and managing data such as this. Starting with Google Sketchup's relatively simple user interface, I will create ruby plugins that walks users through an unfolding process of urban design. This application will show how 3D design software can be the centre of a public design process. This application will also show that by storing, and building off of human feelings and emotions in digital space, these attributes will become inherited naturally into a design project. This is in opposition to the normal procedure where a 3D model attempts to create and convey an emotional reaction from its finished product.

Background and Relevance

This project comes from a noticeable deficit in urban design regarding its use of 3D software to involve the public in the design process. I have found that a part of an urban designer's role is to not only communicate their designs with the public, but to also engage the public in the design process (George 1997, Kosof 1982, Moughtin 2003, Arida 2002). Although urban designers are regularly doing both of these, 3D software and design tools are almost entirely seen as a tool of communication and not as a tool for active public participation in design. I believe all forms of public participation in urban design can benefit from 3D software, however I chose to use Christopher Alexander's recent work on unfolding and generative codes because although it is participatory in nature, it relies heavily on one's willingness to communicate their feelings and emotions that spaces elicit. This type of data provides both unique challenges and opportunities for working with 3D software. Although emotions themselves are not physical objects that can be modeled in space; they are enticed or connected to real geospatial locations that exist in a 3D dimensional world. Using Arnstein's ladder of citizen participation (Arnstein 1967) I am aiming to get closer to the "partnership" rung on the ladder. I believe that including citizens directly in the design process in a 3D environment is closer to this goal then merely communicating urban design through 3D technology, which is often only the "placation" rung on Arnstein's ladder. Furthermore, 3D technology is traditionally fairly technocratic in use, such that the citizens must rely on the expert. However, my communal approach to 3D technology in design intends to shrink the technological divide in this field. Finally, I believe my research is related to spatial knowledge and information because although 3D models are often made without regard for geographic context, the design tools and methodology I will be building are firmly anchored by their geographic location. Not only does urban design require an adequate spatial context, the methodology of Christopher Alexander's is completely reliant on interpreting and "feeling" real geographical landscapes. With this, I will be attempting to create a way of managing metaphysical data within a 3D geospatial infrastructure.

Methods and Data

This project begins with Google Sketchup and its API. Google Sketchup was chosen for several reasons. To begin with, Google Sketchup offers a free version of their software, which is a huge start in decreasing the technocratic divide. As well, their API is unmatched by other available 3D modeling software. The API plus Google Sketchup's very user friendly interface will be utilized to create plugins in the Ruby programming language that will be loaded into Google Sketchup. The plugins will take the users through a step by step process unfolding their design for a particular area. Some key aspects of this process include the use of a carefully organized method of organizing different layers that the users will contribute. These layers not only represent specific parts of the unfolding process in 3D space, they will also often contain spatial located data related to emotions and feelings. With any participatory process there must a means of handling differing opinions and conflicts. I acknowledge that with any groups, sometimes compromise is not an option, however, attempting diffuse and mitigate as many potential conflicts as possible is an important step in any participatory activity. The Ruby plugin will also utilize layer management to ensure every participant, or group is able to have his specific opinion represented within the 3D landscape if they disagree with the results of the group discussions.

Results

The predicted results of this research are a functioning Ruby plugin for Google Sketchup, as well as an analysis on the systems usability and success at reaching the previously mentioned goals. My results will show that 3D tools can be used in a public participatory context, even if that is not what they were initially designed for. Unfortunately I will not be able to say definitively as whether or not citizens feel more engaged in the design process without a real trial run with citizen participants. Due to time restriction this was not feasible for this project. Live testing will be the next step in this applications implementation process. The finished plugin will however be uploaded to numerous sites that distribute ruby plugins for Google Sketchup, and the code will remain unscrambled, leaving for the possibility for anyone who chooses to change or improve upon the plugin. The results will also demonstrate that feelings and emotion based data when geolocated and stored within a visual layer, are powerful tools that can shape the entire design process and decide the final design, inverting the current norm of trying to render a model that portrays specific predetermined emotions and feelings.

Conclusions

In conclusion this project, although still in its development stages, will be complete by March 2011 and produce a fully functioning Google Sketchup plugin that will allow for urban designers and citizens to work together in designing a location in a structured 3D environment. They will be guided each step of the way through the process of unfolding as described by Christopher Alexander. People imagine the world in three dimensions and there is a need for these people to be able to express their desires for a geographic setting without strictly relying on design professionals. 3D tools will always be at the forefront for communicating with the public, and designers will always have their place, there is simply a need to open these tools to a broader citizen user group.

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Creating and Testing a Portable Template for Municipal-Level Adoption of the Geospatial Web 2.0

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Abstract

Governments throughout the world have begun to use Geospatial Web 2.0 (Geoweb) technologies to increase the efficiency and effectiveness of their operations and to better connect to the electorate at large. Despite the broad enthusiasm for the Geoweb, the technical development aspects required to create a Geoweb site presents a significant barrier to adoption. At the municipal level, developing a Geoweb site can be an overly technical challenge, as user-friendly tools often come with limited functionality and free tools require computer programming expertise. When looking at the Geoweb development landscape there is a lack of a solution that is low-cost, feature rich, and easy to set up.

This presentation introduces the audience to recent work developing and testing a Geoweb template designed for use and widespread distribution at the regional municipality and community levels. We describe the rationale for the selection of specific technologies, design choices made to include specific Geoweb functionality, the packaging of programming code components, and the construction of a technical manual to guide potential users with little previous knowledge of Geoweb development. We then introduced this manual to two groups of undergraduate students conducting participatory mapping research with a community-based watershed management organization located in rural Quebec. Our experiences with these students serves as a test case used to further refine the portable Geoweb template for future use at the municipal and community level.

Background and Relevance

The Geospatial Web 2.0 (Geoweb) is an online framework for collecting, distributing, and using geospatial data in a collaborative manner (Hudson-Smith, Crooks, Gibin, Milton, & Batty, 2009; Rouse, Bergeron, & Harris, 2007). The Geoweb consists of multiple components, such as geographically referenced data sources and digital earths, that all can be interlinked, or 'mashed up' via application programming interfaces (APIs) to create an online map (Haklay, Singleton, & Parker, 2008). The Geoweb is multi-directional, in that it supports use both in a traditional 'read-only' manner, and in a Web 2.0 'read-write' fashion that encourages users to contribute and share information (Gorman, 2007). The Geoweb is built on the development of free or low cost online mapping platforms, such as Google Maps and Open Layers, the provision of open, shareable data from governments, organizations, and companies, and the acknowledgement that individuals can provide information based on their own experience (volunteered geographic information, or VGI) (Goodchild, 2007; Hudson-Smith, et al., 2009).

Governments throughout the world have begun to use Geoweb technologies to increase the efficiency and effectiveness of their operations and to better connect to the electorate at large (Ganapati, 2010; Lemuria Carter, 2005). For example, many governments in Canada and the United States now provide free access to geospatial data to all citizens. This data can then be used, or "mashed up" by citizens, advocacy groups, and private businesses to create new, innovative products and analysis, such as crime maps, maps of public sector expenditures, and community economic development instruments.

Despite the broad enthusiasm for the Geoweb, the technical development aspects required to create a Geoweb site can present a barrier to adoption (Cinnamon & Schuurman, 2010). While at the national and provincial levels there may exist resources and expertise to develop these types of tools, this can be lacking at the municipal and community levels. One approach to circumvent this has been via "Apps for Democracy" style contests (www.appsfordemocracy.org), effectively outsourcing Geoweb development tasks to skilled citizens or private developers in exchange for prize money and fame. For municipalities without the resources or engaged developer base to run these type of contests, developing a Geoweb site can be an overly technical challenge, as user-friendly tools often come with limited functionality and free tools require computer programming expertise. When looking at the Geoweb development landscape there is a lack of a solution that is low-cost, feature rich, and easy to set up. This research addresses relevant questions concerning the future development path of the Geoweb, primarily the deployment and sustainability of the technology in limited resource environments.

Methods and Data

We describe the development of an on-line, interactive platform that uses Geoweb technology as a two-way information conduit to engage citizens in environmental management issues. Developed with support from a team of Quebec government ministries, this platform is one component of a three-year project that will evaluate the potential for the Geoweb to support citizen participation in land-use decision-making in the largely agricultural municipality of Acton, 100 km east of Montreal, Quebec. One goal of this project is to make available the platform and manual to other municipalities within Quebec interested in using the Geoweb.

This presentation describes two phases of the Geoweb platform development: technical development and portability assessment. For the technical development phase, we used Google Maps API and custom AJAX components to developed a Geoweb platform where users can add a point to a map and fill out a developer-specified form. Both the point and form information are then immediately added to a MySQL database and are viewable to other platform users. This system provides a rapid way for individuals to add VGI to a map. This platform has been designed to minimize the amount of coding and expert-level technical knowledge required for set up. Accompanying the development of the Geoweb platform is an instructional manual targeted towards non-technical users at the municipal and community levels.

The portability assessment phase of the project introduced the Geoweb platform and instructional manual to two groups of senior undergraduate students enrolled in a McGill university semester-long project course. These students had little previous exposure to the Geoweb or web development in general, though several had taken introductory GIS courses. These groups worked with the corporation de devéloppement de la rivière Noire (CDRN), a local watershed management organization to gather community input on major points of erosion on agricultural lands. Students worked with CDRN and citizens to create participatory maps using two different Geoweb platforms; 1) a simple Google My Maps, and 2) a more fully-featured site developed with our Geoweb template and instruction manual containing code snippets and tutorials. After the participatory mapping projects were completed, we interviewed the McGill student groups and representatives of CDRN to document their perspectives on implementing and using these two Geoweb platforms. In our interviews we focused questions on ease-of-use, feature availability, fit to task, and resources required for installation and maintenance.

Results

From a technical development perspective, the Geoweb template and manual present an option to users that is low-cost and comparably feature rich. From an ease-of-deployment perspective, our experiences with the McGill/CDRN erosion mapping project indicate that though promising, there are significant constraints to deploying the Geoweb at the community level. Specifically, need arose for a technologically-adept 'chauffeur' to help with deployment. This raises questions about the ability for the Geoweb template to be distributed widely to user populations. For example, potential users with previous web development experience may be able to easily deploy the Geoweb template, but these skills are unevenly distributed. In comparing the student experiences using the simple Google My Maps implementation and the Geoweb template, it became clear that there was a tradeoff between an approach that was easy to deploy, yet lacking features (Google My Maps), and feature rich, but more difficult to deploy (Geoweb template). This indicates that for future Geoweb implementations, developers must strongly consider the feature set required for their particular task before selecting an approach, or potentially risk selecting a technology that is either too difficult to deploy or too simple in feature set.

Conclusions

The various technologies that undergrid the Geoweb are in a rapid state of change. Despite continuous improvements there exists a need for a feature-rich, low-cost, and easy-to-deploy Geoweb solution, appropriate for limited-resource environments, such as municipalities and community groups. This research developed a potential solution in the form of a Geoweb template and instructional manual. This template and manual were tested by two groups of McGill undergraduate students working with a community watershed monitoring group to conduct participatory mapping. These groups developed Geoweb platforms using both the Geoweb template and a basic Google My Map. In comparing these two implementations, the students and community group identified key trade-offs between the difficulty of deployment and the feature set. This highlighted several potential adoption constraints that could impact the success of the Geoweb template when distributed to other user groups.

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“Let the young ones do it”
How digital divides influence the use of the Geoweb by farmers and food advocates in rural Canada.

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Abstract

This study draws on a community-based research project in the North Okanagan Valley of British Columbia to examine the use of the Geoweb in rural Canada and to understand how the Geoweb “maps” onto the digital divide.

Background and Relevance

Digital divides within and between communities is a long-standing dilemma in Canada’s digitally engaged society. Digital divides are often portrayed in the literature as a split between those citizens who have access to information technology compared to those who do not (Servon, 2002). The recent move from Web 1.0 to Web 2.0 and with that the emergence of the Geospatial Web 2.0 (Geoweb) has opened a wider door to the interaction of non-experts to both create and disseminate spatial knowledge (Garrett, 2006; Haklay et al., 2008). With the Internet reaching deeper into rural Canada coupled with an ever-increasing reliance on the Web for communicating diverse forms of knowledge, the divides seem to be shifting (Compaine, 2001; van dijk & Hacker, 2003). Both Crampton (2009) and Elwood (2008) point to the digital divide as a critical factor of the effectiveness of the Geoweb to engage citizens in the mapping process. Thus, it is important to extend an understanding of use of the Geoweb to include skills and usage constraints, as these will challenge the uptake of Geoweb.

Methods and Data

This study draws on a community-based research project in the North Okanagan Valley of British Columbia to examine the use of the Geoweb in rural Canada and to further understand how non-expert citizens can access and use the Geoweb. The project developed Geoweb applications to map out the local food system with local food advocates and farmers. Semi-structured interviews with participants from local food action groups and regional farmers informed this study. In addition, the researcher throughout the course of the project utilized participant observation techniques. Data includes interview transcripts from 10 participants along with field notes.

Results

The results of the study suggest that there are ongoing divisions within communities to utilize digital technologies, which include access but also expand to skills and are influenced by age. In particular, members of volunteer organizations who describe themselves as an older generation, feel challenged by the ever-changing and expansive nature of the Web. At the same time, participants recognized the relevance of using the Geoweb to expand networks and increase support for food security concerns within the region. From these results, several recommendations are offered to overcome the divides found in this study and are discussed as an example of rural and small Canadian communities.

Conclusions

The study demonstrates that there are both challenges to the use of the Geoweb in rural Canada, but also opportunities for volunteer based organizations to utilize these sources of spatial knowledge. It is suggested that the Geoweb is not yet a tool on which citizens can universally draw. Instead, it is dependent on a number of factors that influence participation in the mapping process. Several key issues need to be addressed to surpass the digital divides. These issues begin with access to the Internet in rural Canada but extend to training for volunteer organizations and combating preserved barriers because of age.

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Where does OSGeo and Rural Development Intersect? Education and Mentorship

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Abstract

This talk looks at the state of Open Source Software and Geographic Information Science (GIS) in East Africa. Open Source software is becoming the approach many governments are moving towards and GIS is a tool that enhances rural development at all stages of planning, monitoring and evaluation. This presentation evaluates these opportunities using a year-long case study in Ethiopia that documents the effective roll out of these technologies. The talk concludes with the description of a project called Mapping Across Borders that allows for the rapid scaling up of Open Source GIS education through online open access education materials and mentorships between Canadian students and East African NGOs

Background and Relevance

Open source software is evolving quickly. Governments in the global north and south are applying new technologies and reducing their dependencies on foreign, expensive and closed source software. Governments such as Germany, France, Australia and South Africa are committed to free and open source software and as a result Open Source Geographic Information Systems (OSGeo) is gaining ground on closed source software options (Mutula & Kalaote, 2010). However, while some governments are utilizing OSGeo to their benefit, neither governments or civil society institutions (CSOs) are utilizing the software in East Africa, especially Ethiopia where this presentation focuses.

Due to pricing, availability of trained staff and budgets, the only non-governmental organizations in Ethiopia that are using GIS are international CSOs. Counter to this trend, this paper argues that it is the domestic CSOs that could benefit most from using GIS, as they are often the implementers at the field level. It was therefore recognized that using OSGeo software combined with training could have a significant impact on the way that projects are designed and implemented by domestic CSOs in Ethiopia.

Methods and Data

From September 2009 to August 2010 an OSGeo based training and mentorship project was conducted by the author. Using Quantum GIS (QGIS.org), which is able to harness the power of GRASS GIS (http://grass.fbk.eu/) in a much more accessible and familiar interface, GIS education programmes were developed and delivered to over sixty students from more than a ten organizations. This project developed, utilized and evaluated training materials (manual, slides, glossary and step-by-step guide), national census data from the Ethiopian Mapping Agency and OSGeo software installation file. While the training was being conducted the students participated in focus group discussions and at the completion of the sessions students completed surveys on the effectiveness of the course and associated materials.

Figure 1: OSGeo training seminar in Addis Ababa, Ethiopia

Following the OSGeo training programmes, trainees returned to their rural workplaces and implemented what they had learned. To fill in knowledge gaps, a backstopping program was undertaken at the field level with students. These field visits included data collection exercises using GPS units, data analysis and cartography. During the field process, students were interviewed to identify elements of the training programme that needed more attention.

The maps that students made using the training were an integral output from the training and demonstrated the learning outcomes that the backstopping work facilitated. While the first maps that students made were often based on GPS coordinates of the interventions they had been working on, their second efforts however where often much more complex and involved much of the more sophisticated methods in the training seminars such as terrain modeling and watershed delineation (Fig 2).

Results

Results from this empirical research identified that the training program was a success in that it was able to facilitate a knowledge transfer and encourage the use of OSGeo in Ethiopia. However, the methods used in this case study are not sustainable over the long course of development. The training program relied on an expert to be present in Ethiopia to facilitate training seminars and follow up visits in the field i.e. it was predicated on the skills of one key person and the program ends when that person is no longer available. Further, this program only works with the knowledge of one expert, which precludes the ability to leverage multiple viewpoints and experience for students. However with the advent of high quality OSGeo software like Quantum GIS and the ability of Web 2.0 collaboration a unique opportunity exists to rapidly scale up the training and mentorships fostered in Ethiopia.

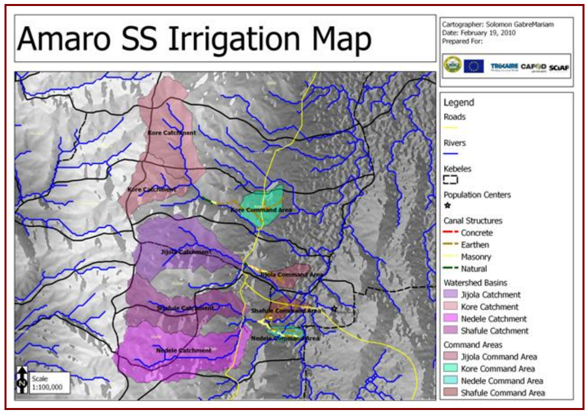

Figure 2: Irrigation Canals in Southern Ethiopia

Conclusions

The success of the OSGeo training and mentorship program led the author to understand that there was opportunity to be successful applying this model on a wider scale. To meet this challenge a new project named Mapping Across Borders has begun. Mapping Across Borders (MAB) is a project that links students and young professionals in Canada who are long on expertise with CSOs can provide that much needed experience with real projects and benefit from OSGeo training. MAB will allow students and mentors to work together without needing costly travel, both in terms of financial and environmental impact by employing Wiki style community editing of training programs, submission and marking of assignments online and providing a project space where partnerships between mentors and students in the global north and south, respectively. This project is the key component of the authors ongoing Masters thesis at the University of British Columbia. Ongoing progress is documented at www.mappingacrossborders.org

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Enhancing Operational Land Use Decisions for Sage-grouse Recovery in Alberta

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Abstract

The primary purpose of this study is to analyze the relationship between sage-grouse dynamics and the temporal and spatial changes of development footprints in southeastern Alberta.

Background and Relevance

The sagebrush steppe of southwestern Canada and northwestern US provides important habitat for over 100 avian species and 70 mammalian species (Knick and Rotenberry 1995, Paige and Ritter 2000, Knick et al. 2003, Holloran 2005). Following European settlement, substantial areas of sagebrush steppe habitat have been altered by human activities such as agriculture or natural resource extraction (Schneefas 1967, Braun et al. 2002, Knick et al. 2003, Holloran 2005). These landscape changes have been detrimental for a number of grassland and sagebrush dependent species (Knick et al 2003, Schroeder et al 2004, Aldridge 2005, Holloran 2005).

As a sagebrush-obligate species, sage-grouse (*Centrocerus urophasianus*) have been particularly affected by environmental changes over the past century. Throughout North America, their range has been reduced by 56%, and much of the remaining habitat is highly fragmented (Autenrieth 1986, Schroeder et al. 2004). Individual populations have declined by 15-90% since the early 1970's and many are at risk of extirpation (Connelly and Braun 1997, Aldridge and Brigham 2003, Connelly et al 2004). Sage-grouse habitat in Canada currently represents about 10% of the historic range (Aldridge and Brigham 2002). Since sage-grouse was listed as an endangered species in Canada in 1998, recovery teams have been active at the international, national, and provincial levels.

The Alberta recovery plan (Alberta Sage Grouse Recovery Action Group 2005) makes reference to specific limitations to land use activities within the remaining sage-grouse range, including the type of activity, its distance from the habitat of interest, noise levels and the temporal use of surrounding lands. What trends will emerge between sage-grouse activity in relation to human development of the sagebrush steppe environment in Alberta? Will these trends help outline the path to recovery for sage-grouse? The primary purpose of this study is to analyze the relationship between sage-grouse dynamics and the temporal and spatial changes of development footprints in southeastern Alberta. We hypothesized that the decrease in sage-grouse lek persistence from 1968 to 2008 would correlate directly with increase in human footprint within sage-grouse habitat.

Methods and Data

The study area of this project is located in southeastern Alberta near the Milk River valley. The available data included the locations of active and inactive sage-grouse leks, male activity levels from 1968 to the present, air photos from 1968 to the present, and the distribution of current human footprints across the study area. All data was provided courtesy Alberta Sustainable Resource Development (ASRD) and Southern Alberta Landscapes.

We created a current Human Development Footprint (HDF) layer showing the distribution of current human development are around each lek in the study area. The HDF layer consists of a collection of human development in the study area including urban areas, agriculture, water wells, oil and gas facilities, wells, and pipelines, power lines, telecommunications infrastructure, roads, and gravel pits. We then used historical air photos to backdate the HDF layer to show changes in those features through time. We used regression analysis to analyze the influence of human disturbances (footprint and zones of influence) on trends in lek persistence and lek activity over time.

Results

Forthcoming results will show (I) definition of the areas where sage-grouse have been most affected by human development, (II) characterizations of trends between different kinds of human development and sage-grouse lek dynamics and activity levels, and (III) recommendations to improve the effectiveness of Alberta land use guidelines based on the trends identified.

Conclusions

This investigation will reveal correlations between specific human development types and sage-grouse lek activity levels. By highlighting correlations between development types and lek activity declines, recommendations can be made to limit harmful developments and allow the restoration and recovery of the sage-grouse in southeastern Alberta.

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Web-Based Participatory Mapping for Parole Boundary Deliberation

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Abstract

This paper describes a Correctional Service Canada (CSC) project conducted in the summer of 2010, using web-based participatory mapping to compile, analyse, and deliberate jurisdictional boundaries for Canada's 84 federal parole offices, utilising input from CSC officials across the country. The Google Maps API was selected for its ease-of-use, extensibility, and large developer community. Participants were able to toggle regional boundaries, create markers, and submit comments spatially referenced to the markers' coordinate pairs, which were then uploaded into a GIS for analysis and adjustment. Participation rates were assessed, finding that 75% of participants used the web-based tool, while the remaining 25% preferred to submit comments via email or telephone (n=64), and regional variations in participation rates were noted. Lessons learned are reflected upon and a pilot framework for assessing such web-based participatory tools is presented.

Background and Relevance

Correctional Service Canada (CSC) operates 84 parole offices nationwide (as of August, 2010), each of which handles parolees within its respective catchment area. These catchment areas cover the entire country, ranging in size from under 10 km^2 in some urban areas over 2 000 000 km^2 in the North. In order to more efficiently service these spaces, regional parole offices have independently designed and implemented boundaries without the knowledge of the central administrative body, National Headquarters (NHQ), posing significant concerns for incident response planning. In order to more efficiently coordinate inter- and intra-departmental actions, the development of a comprehensive nationwide spatial database of parole office locations and catchment areas became a priority.

Utilisation of Web 2.0 technologies for participatory data collection and mitigation is an increasingly prominent topic in the literature, facilitated by the growing community of amateur developers who are continually discovering novel applications for web mapping (O'Reilly 2005; Lévy 1997). Leveraging web technologies can both empower and restrict user groups in participatory processes, yet this particular case study is unique in that its 'public' is within an hierarchical organisation, thus the motivating factors for volunteering geographic information come from within that structure (Bussi 2001; Goodchild 2007).

Methods and Data

A three-phase plan of action was developed and implemented to address the problem. The first phase began with the consolidation of spatial information about parole office jurisdictional boundaries; a request was made to the regional offices to submit written descriptions of their parole offices' jurisdictional boundaries. These descriptions were received, interpreted, and digitised in a GIS to produce polygons corresponding to the catchment areas. A GIS was selected for its ability to quickly identify gaps, overlaps, and underserviced areas, which were subsequently identified, necessitating deliberation and mitigation. A bilingual participatory web-based mapping tool was developed to allow users to submit spatially-referenced comments regarding the boundaries. Utilising the Google Maps API, this tool allows users to overlay boundaries and submit comments spatially referenced to points (appearing as markers on the map) in a familiar and easy-to-use Graphical User Interface (GUI), although functionality was limited by the inability for users to create polygons. Comments were received as text strings with metadata and a coordinate pair corresponding to the user-created marker, arranged into a tabular format, and geocoded in MapInfo.

The second phase involved the dissemination of access to this tool and collection of submitted comments addressing boundary gaps, overlaps, conflicts, and other relevant qualitative spatial information from the regions and parole offices. Once user-generated comments were submitted, NHQ received and uploaded these comments into a GIS and used them to evaluate the original boundaries, as collected in the first phase. Changes to the catchment area polygons were made according to the user submissions, group evaluations of an area's spatial characteristics, and consultation with regional parole administrators. The second phase results were then disseminated back to the regions and parole offices, inviting users to make another round of comments before the jurisdictional boundaries were finalised.

The third phase comprised a more detailed GIS-assisted gap/overlap analysis of the boundary dataset, followed by the production of a parole atlas, which was disseminated to CSC offices and partner police organisations across Canada. The participation results were also analysed to determine ways in which the tool could be improved for future use.

Results

Of the 64 comments received, exactly 75 per cent were submitted using the tool; the remaining 16 comments were made via email or telephone, suggesting room for improvement in the tool design and accompanying instructions. All of the submissions from Ontario were made using the tool, while the Atlantic Region did not submit a single comment using it. The greatest proportion of submissions (33%) came from the Prairies Region, many of which referenced remote areas. Interpretation of the results was difficult in many cases, as users could only submit written descriptions referenced to a point. Discussions with users identified that the addition of line and polygon feature creation would significantly improve usability and encourage more participation through the tool, rather than the alternative methods (email and telephone).

Conclusions

While effective in consolidating parole office boundaries across six regions, this Google-based tool lacked some of the features that would facilitate more participation. These findings highlight the importance of user-centred design in participatory tool development (Abras, et al. 2004). Google Maps API provides an easy-to-use toolset with which many users are already familiar, and a growing 'crowdsourcing' community for ideas and support.

While such tools are useful for gathering input, much of the onus in their effective implementation lies in the ways in which information gathered is implemented in the decision-making process. In this instance, the GIS operator had control over how comments were interpreted and changes to boundaries made. A novel '3E' framework (engagement, empowerment, and enactment) is proposed for structured evaluation of participatory web-based tools, designed to analyse how a project engages its target users, empowers them with the tools and information required to participate, and enacts the data collected in a spatial decision-making process.

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Geolive: Participatory mapping on the Web

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Abstract

Geolive is an online participatory mapping application that combines the Google Maps API and Joomla an open source content management system. Using the example of a food system mapping project developed at the University of British Columbia Okanagan, this paper discusses the usability, design and implementation of Geolive, as well as explores the broader possibilities and limitations of participatory mapping using web 2.0/3.0 and open source software.

Background and Relevance

The recent and ongoing development of web-based social networking and Geoweb applications has had a significant impact in the way people access and share location-based information (Haklay et al., 2008; Hudson-Smith et al., 2009; Elwood, 2010). The new ability to allow any Internet user to author content and then communicate this content with a global audience has changed the flow of knowledge between individuals, organizations and government (Goodchild, 2007; Nuojua, 2010).

In this new era of multiple-authored interactive web content, the design and implementation of Geoweb applications requires new considerations, and must overcome novel and emerging hurdles not found in legacy web-based geoinformatic applications (Rouse et al., 2007; Coleman et al, 2009). Considerations in the development of geoweb tools include:

- Security and user management
- Expandability and concurrency
- Reusability, ease of distribution and durability
- Data management and privacy
- Data dependability, and content filtering
- Data analysis and decision making

Geolive is a web-based participatory mapping tool developed at University of British Columbia Okanagan. The application allows users to create and share their own spatial information using a single dynamic map-based interface. The original goal for Geolive was to create an application where many users can view and author spatial data content simultaneously, while allowing the software to be open-sourced, reused and distributed. Although there are numerous requirements in supporting public participation using Geoweb applications, the main focus of our research, and concomitantly this presentation, is design-centric. In other words how, from a usability perspective, can an online mapping tool be designed and developed to best support the active participation of users in the contribution of location-based content and in doing so promote community involvement in geographically bounded issues.

Methods and Data

To take Geolive from concept to deployment, we used a modular architecture that allowed Geolive to take advantage of existing open source software. These software blocks were used to solve many of the complex problems encountered in developing a Geoweb application from the ground up. This meant that instead of re-inventing the software development protocols required in typical website management and administration, Geolive's development could focus on integrating our participatory mapping application with existing blocks, or modules, of website functionality. This freed up efforts to focus specifically on developing the mapping component of the tool.

The design of Geolive as a Content Management System module has provided us with many advantages over standalone applications (Goodrich and Tamassia, 2006; Stallings, 2005). Geolive's user management is simply an abstract connector to the system that Joomla provides (for examples see http://docs.joomla.org/JFactory and http://docs.joomla.org/Framework). Additionally user management plugins can be applied directly to Joomla and work with Geolive immediately, these include for example user profile pages, avatars, and access control. The Joomla framework also provides platform independence, allowing Geolive to be easily distributable. However, allowing multiple Geolive instances to exist makes it difficult to maintain software. To help keep versions consistent, Geolive instances have the ability to upgrade themselves to match the highest released software version that is released on the Geolive project server. The ease of distribution of Geolive may provide solutions to future issues involving large volumes of data (currently large datasets have not been encountered).

The Geolive client application is built using the Google API as well as a number of 3rd party JavaScript Libraries, such as Mootools, CKEditor, and the Simile Timeline. Using asynchronous communication between the client and server, users can actively manipulate and contribute to the map. One of the key concerns with using the Google API is how client information and map data are stored. Although the API is used to render content, Geolive's data are stored on the local server, and is protected using existing Joomla security. Unlike cloud-based storage, managing user contributed data this way adds the ability for it to be analyzed and filtered by administrators. However security issues such as SQL injection and cross-domain script attacks must also be considered (Connolly & Begg, 2005). Building an Ajax framework can also be prone to security flaws, as it exposes sensitive methods that could be exploited if not properly secured (see http://www.symantec.com/connect/articles/ajax-security-basics).

Development considerations

Each of the six considerations for Geoweb application design identified above have had a major bearing on design and usability of Geolive as well as the trust that users can place in the tool in regard to security and privacy of their sensitive information and data.

Security and user management include the ability to protect user accounts using Joomla's authentication framework and user connectors, as well as securing asynchronous communication; Expandability and concurrency allow administrators to design for, and adapt to, large and growing users and datasets with simultaneous manipulation; Reusability, ease of distribution and durability enable the provision of an installable package that can be customized and used on different hardware and software platform; Data management and privacy, ensure that user contributed content is stored locally and used ethically); Data dependability, and content filtering mean that information is accurate and can be managed efficiently and; Data analysis and decision making help provide statistical information and tools to find trends and patterns in user contributed information. Each of these considerations will be discussed during this presentation.

Conclusions

The Geolive application is a participatory mapping tool built using a number of open source software libraries. Its integration with the Joomla CMS has allowed it to meet complex security requirements for web applications, while allowing it to be distributable. Geolive has been implemented into a number of different web sites, and demonstrates strong potential to share spatial knowledge.

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Mapping and modeling local food capacity in British Columbia

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Abstract

Interest in local food security has increased in the last decade, stemming from concerns surrounding environmental sustainability, small scale agriculture, community food security, and disaster preparedness. Promotions for consumption of locally produced foods have come from activists, non-governmental organizations, as well as some academic and government research and policy. The goal of this paper is to develop a predictive model for the agricultural self-sufficiency index in the province of British Columbia. To meet this goal, we develop a self-sufficiency index for each Local Health Area in the province, and create a predictive model based on capital investment in regional agriculture. Our predictive model allows for estimation of regional scale self-sufficiency without reliance on regional landuse or nutrition data; however, residual spatial autocorrelation must be accounted for through alternative spatial regression models. The methods developed will be a useful tool for researchers and government officials interested in agriculture, nutrition, and food security, as well as a first step towards more advanced modeling of current local food capacity and future potential.

Background and Relevance

Agriculture is a globally significant land use, and has considerable impact on economic systems, the natural environment, and human health (Rounsevell et al., 2003). Scientists and planners are increasingly required to consider and predict agricultural output based on local variation agricultural practices, ecological variables, climate change, and disaster management scenarios (Basso, Ritchie, Pierce, Braga, & Jones, 2001; Chakir, 2009; Feenstra, 1997; Lobell & Christopher, 2007). Methods to empirically assess local food production and consumption (i.e., local food capacity) are under-developed, hindering the ability of policy makers to effect innovative local food security policy (Rideout, Seed, & Ostry, 2006; Rounsevell, Annetts, Audsley, Mayr, & Reginster, 2003). There is demand for regional agricultural production estimates that allow for mapping of the spatial variation in agricultural productivity. While assessing local-scale agricultural capacity directly is possible, this requires the development and integration of multiple databases that can be time-consuming and costly to develop. The goal of this paper is to use more readily available data to develop a predictive model for the theoretical capacity of local scale agricultural in British Columbia. To meet this goal, we integrate previously developed map-based data on local scale food production and population-level food consumption estimates to estimate the theoretical ability for a local region to meet local food needs (Morrison, Nelson, & Ostry, 2011a, 2011b). We refer to this ratio as the self-sufficiency index. We create a predictive model using capital investment in regional agriculture and amount of cropland as covariates.

Methods and Data

The relationship between food production to food consumption provides us with a theoretical estimate the local food capacity of a region (Duxbury & Welch, 1999; Peters, 2009; Vancouver Food Policy Council, 2009). The SSI can also be used as a proxy to assess import-reliance, as regions must be importing at least *1-SSI%* of their foods. This information allows us to assess noteworthy spatial patterns in food capacity.

The SSI exhibits spatial heterogeneity, and we begin by performing descriptive mapping and cluster analysis to assess spatial patterns. We develop a simple regression model with two covariates; while additional covariates may potentially improve model fit, they increase the data requirements to utilize the model. Minimizing covariates is useful as long as a reasonable model fit can be achieved. Ordinary least squares regression (OLS) requires data to be independent with normally distributed zero-mean errors. The self-sufficiency index and the residuals from a linear regression both have significant spatial correlation in their data structure. To address this, we develop a conditional autoregressive (CAR) model to explore the relationship between the SSI and regional agricultural capital investments. This model incorporates the residual spatial dependence and avoids biased parameter estimates. We operate in a Bayesian framework, which benefits from a fully random effects model, treating all model parameters as random variables with distributions, rather than estimating a single fixed value (Banerjee, Carlin, & Gelfand, 2004). We investigate the impacts of neighbourhood definitions (as defined within the autoregressive model) on our model.

Results and Conclusions

Our conditional autogressive model accounts for residual spatial autocorrelation and allows for unbiased parameter estimation. Model assessment suggests good model fit with two covariates, suggesting that local scale capacity is highly influenced by regional capital investment and amount of regional cropland.

Our descriptive mapping of the SSI informs us on the high level of regionalization in the local food systems, as well as a strong provincial focus on the production of meat and dairy over fruits and vegetables. Regionalization on a food group basis is a negative finding for local food security, as no one region has sufficient variety in nutrients to make up a complete local diet.

The development of self-sufficiency models that are not based on agriculture or nutrition data, but rather on easily accessible farm financial statistics, may allow for estimates of local food capacity while bypassing the labour-intensive process of estimating local scale food production and consumption. The significant correlated relationship between invested farm capital and agricultural self-sufficiency suggests that local investment in agricultural could translate to increased food security at the local scale.

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A Field Based Depth Correction Algorithm for Submerged Aquatic Vegetation Spectra

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Abstract

Anthropogenic sources of nutrients in aquatic systems are known to degrade ecosystem health. Aquatic managers are reliant on intensive and destructive methods to understand the abundance of primary producers, which is one component of assessing ecosystem health. Remote sensing has the potential to provide non-destructive and efficient sampling of aquatic biomass, however, the effects of the water column on spectral signatures must be corrected. This study seeks to apply a water column depth correction for spectra in a field setting. A white panel and a black panel were submerged at incremental depths, with the spectra signature recorded using a spectroradiometer at each increment. Using model inversion the spectral signatures of the panels were used to correct the spectra of submerged aquatic vegetation, significantly clarifying the spectral signature. More work is required to assess the ability of the algorithm to improve the results of biomass estimation and classification.

Background and Relevance

Nutrient inputs in aquatic systems such as rivers, lakes and streams are known to increase primary productivity of submerged aquatic vegetation and biomass in-turn (Askey et al 2007). As the increased biomass respires, anoxic or more commonly hypoxic conditions can result in fish kills and unhealthy ecosystems. To understand, model and predict the health of aquatic ecosystems, managers are reliant on few discrete point samples of submerged aquatic vegetation using intensive and destructive sampling methods. The Bow River in Alberta, Canada has few nutrient inputs above the City of Calgary. However, wastewater treatment plants in the city release substantial volumes of nutrient rich effluent that alters aquatic ecosystems downstream (Askey et al 2007).

Remote sensing has proven effective for the delineation of submerged aquatic vegetation and to a lesser extent, the classification and estimation of biomass (Yuan and Zhang 2007, Cho et al 2008, Armstrong 1993, Dillabaugh and King 2008, Diersen et al 2008). Compared to terrestrial applications, the effectiveness of remote sensing of submerged aquatic vegetation has been limited owing to the degradation of spectral signal by the water column (Cho et al 2008). Depth-correction algorithms have been developed and applied to ocean and coral based studies since the 1980’s, most notably the Lyzenga method and modifications there of (Yang et al 2010, Tassan 1996). These corrections are well established and effective. However, water depths beyond light penetration are required for their creation, a characteristic which is not found in shallow inland water bodies including rivers, lakes and streams. Recently, shallow water corrections have been presented and proven effective in controlled experiments (Cho and Lu 2010, Yang et al 2010). However, these techniques have not been tested in applied field settings. This study seeks to apply a modified version and Cho and Lu's (2010) depth correction in a field application of biomass estimation and vegetation classification using a spectroradiometer.

Methods and Data

Data collection occurred during the fall of 2010 at three study plots in a reach of the Bow River in Calgary, Alberta. The study plots were located downstream of the Bonny Brook waste water treatment plant, the most substantial point source of nutrients to the Bow River within Calgary.

Following an adaptation of Cho and Lu's (2010) methods for water correction, at each plot a white panel and a black panel were submerged incrementally from the water surface to the maximum depth which could be safely sampled (governed by water depth and flow). At each 6.5 cm increment, a spectroradiometer was used to record the spectral signal of the white panel and the black panel respectively through a range of wavelengths from 330 nm - 1100 nm in 1 nm increments. Following a systematic sampling design, the spectral signatures of submerged aquatic vegetation were recorded. The vegetation which corresponded to the instantaneous field of view of the instrument was then harvested, identified, dried, and weighted to obtain dry weight, an estimate of biomass. The absorbance (white panel) and reflectance (black panel) values of the water column were modeled by fitting a least-squares function to the measurements, in the form of spectra as a function of depth. This was repeated for every wavelength recorded, storing the slope and intercept of the functions. The spectral samples of vegetation were then corrected for the effects of the water column by model inversion using the slope and intercept parameters.

Results

The depth correction algorithm has shown to significantly clarify the signal of submerged aquatic vegetation. Identification of the plant species and refinement of the algorithm are ongoing, therefore the effectiveness of the algorithm for biomass estimation and species classification is still forthcoming. However, owing to the significant improvement in signal following the correction, a significant improvement is anticipated. The complete results, including the effectiveness of the algorithm for biomass estimation and submerged vegetation classification will be completed shortly.

Conclusions

The current work seeks to share the progress to date on the development and application of a shallow-water depth correction algorithm in a field setting. This study is valuable as inefficient and destructive sampling methods are the only means currently used to assess the biomass and extent of submerged aquatic vegetation. Remote sensing has the potential to provide an efficient, non-destructive sampling method, however, corrections for the effects of the water column must be developed. The algorithm presented here, and applied in a field setting has shown a significant improvement in the spectral signal of submerged aquatic biomass.

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Remote Sensing-based Landcover Classification to Support Northern Woodland Caribou Conservation

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Abstract

In order to establish associations with vital landcover and plan conservation efforts, caribou recovery plans require standardized information on forest inventory and landcover classification over their entire range. Medium-spatial resolution satellite sensors provide an important supply of vegetation and landcover information over large areas, for a minimal cost. A nine-class landcover classification was produced using variables derived from Landsat TM data and DEM data. A classification tree approach using data mining software produce a map product with an overall classification accuracy of 83% and a KHAT statistic of 0.83, compared to an historical forest inventory product that has an accuracy of 33% and a KHAT statistic of 0.25. This new lancover classification containing vital caribou classes can now be used to derive landcover associations that will feed into wildlife recovery plans and conservation efforts.

Background and Relevance

Woodland caribou (*Rangifer tarandus caribou*) occupy a diverse range of ecological conditions and human disturbance levels in Canada. Recent extinctions of several mountain caribou herds (eg. Wittmer et al., 2005a, Hebblewhite et al., 2010) have sparked concern for proactive habitat-conservation measures, and have prompted federal managers to list the northern mountain caribou as a species of special concern under the Species at Risk Act (SARA) (Kinley and Apps, 2001; Thomas and Gray, 2002; Seip et al., 2007). Because of the remote nature of much of the range of northern mountain caribou, combined with complex jurisdictional and political issues, few efforts to standardize information on forest inventory over large areas have been initiated. The development of these inventories and classifications are an important step in developing wildlife recovery plans (Johnson et al., 2003; McDermid et al., 2009), which will be needed in order to establish well executed conservation efforts.

Medium-resolution satellite sensors such as those on board the Landsat, SPOT, and IRS platforms provide an important supply of vegetation and landcover information with several key advantages over traditional sources (e.g. aerial photography, that is often focused over only commercially viable areas) (McDermid et al. 2009). A mounting number of researchers have reported on the use of satellite-derived landcover maps to document important caribou-habitat relationships (e.g. Poole et al. 2000, Johnson et al. 2003, Bechtel et al. 2004). However, detailed descriptions of the *methods* required to process satellite data reliably over large, diverse study areas are largely absent from the wildlife literature. As a result, the goal of our research was to develop a strategy for performing remote sensing-based landcover classification in a manner capable of supporting detailed caribou habitat conservation planning.

Methods and Data

This study occurred within the 48,000 km^2 traditional territory of the TRTFN in the Skeena region of northwest BC near the town of Atlin (59° 35' N, 133° 40' W). Following a stratified random sampling design, we visited 617 sites between 2003 and 2008 and recorded spatial location using handheld GPS, landcover type and detailed species composition in each layer of the vegetation structure. In addition, we supplemented this data with 356 locations from a similar inventory of alpine environments and 151 additional locations collected from Landsat TM imagery for broad, non-vegetated classes, which were cumulatively used to define landcover information classes that are important for caribou.

A study area-wide set of geospatial predictor variables was assembled to generate the final classification product, derived from two Landsat TM images, (path/row) 57/18 and 57/19, acquired on July 26, 2006 and September 15, 2006, respectively, as well as a digital elevation model (DEM). Orthorectification was performed using ground control points from existing geographic information system (GIS) layers. Brightness, Greeness, and Wetness variables from tasseled cap transformation (Crist and Cicone, 1984) were derived, following a conversion to top-of-atmosphere reflectance. Wetness difference was calculated from wetness information for each acquisition date. Slope and aspect were both calculated using the Spatial Analyst extension in ArcGIS (Redlands, California). Compound topographic index (CTI), which is well known for its surrogate ability for soil attributes, was also derived.

A classification-tree approach for determining landcover was performed using See5 datas mining software (Rulequest Research, St. Ives Australia). A training dataset, consisting of 1124 locations with one of 9 landcover classes and values from each geospatial predictor variable, was processed to create a set of decision rules defining the occurrence of each class on the landscape. Validation of the final landcover model was performed using a k-fold cross validation, with a k-value of 10 (eg. Friedl et al., 2000) to produce confusion matrices. User's, producer's, and overall accuracies were calculated, along with a KHAT statistic as a measure of agreement between the observed and predicted classes. In addition, validation of a pre-existing forest inventory from the same area using historical methods was performed and the results were compared.

Results

The overall accuracy of the land cover classification model is 83%, with producer's accuracies ranging from a low of 36% for the mixed tree class to a high of 100% for the water class. User's accuracies range from a low of 48% for the mixed tree class to a high of 100% for the snow and ice class. The KHAT statistic is 0.80, indicating that the classification is 80% better than one resulting from chance. Conversely, the historic forest inventory has an overall accuracy of just 33%, with producer's accuracies ranging from a low of 0% for the tall shrub and low shrub classes, to 100% for the snow and ice, rock/rubble/bare soil, and water classes. User's accuracies range from 0% for the tall shrub and low shrub classes to 95% fpr the rock/rubble/bare soil classes. The KHAT statistic for the historic classification is 0.33, indicating that the classification is 33% better than one resulting from chance.

Conclusions

Using medium-spatial resolution satellite imagery and a classification tree approach, we successfully performed a remote sensing-based landcover classification in a manner capable of supporting detailed caribou habitat conservation planning. With accuracies far exceeding that of a pre-existing historical forest and landcover inventory, the classification we produced now provides an accurate and reliable inventory that includes classes that are relevant to caribou habitat use. This inventory will be used in future investigations to assess caribou landcover associations, which will feed into wildlife recovery plans and conservation efforts.

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Change Detection Using Historical Aerial Photography in Bighorn Sheep Habitat of the Sierra Nevada

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Abstract

This research project evaluates the changes in Sierra-Nevada bighorn sheep habitat over the past 75 years using historical aerial photography.

Background and Relevance

The bighorn sheep population in the Sierra Nevada (*Ovis canadensis sierrae*) was listed endangered in 2000 (65 FR 20, 2000). The causes of the population decline have been attributed to illegal hunting (Advisory Group 1997, Wehausen and Hansen 1988), disease (Buechner 1960), and the direct and indirect effects of predation (Wehausen 1996). The vulnerability of the population may be exasperated by low nutrition, environmental stochasticity, and anthropogenic disturbance (65 FR 20, 2000). The recovery effort on behalf of the California Department of Fish and Game and the Sierra Nevada Bighorn Sheep Recovery Program (SNBSRP) may be further impeded by changes in the landscape over the last century. Bighorn sheep tend to prefer open terrain allowing for better visibility of predators (65 FR 20, 2000), and tree encroachment, specifically by single-leaf piñon (*Pinus monophylla*), has been documented in the Sierra Nevada (Burwell 1999, Miller and Rose 1999, Gruell 2001, Romme et al. 2009). The scale of tree encroachment in bighorn sheep habitat has not been directly investigated

The principal goal of this research project was to evaluate the changes in Sierra-Nevada bighorn sheep habitat over the past 75 years using historical aerial photography. We hypothesized that changes in bighorn sheep habitat could be characterized by spatial and terrain-related variables such as low elevations, northern aspects, and north latitudes. Our analysis specifically focused on winter habitat ranges with substantial low elevation forest. The application of geographic information science and remote sensing will be useful for managers of the SNBSRP in restoring lost or vulnerable habitat to further aid the recovery of the subspecies.

Methods and Data

The study area is based in the Sierra Nevada mountain range of California, and is focused on four of the bighorn sheep herd units that have been identified as priorities for recovery (Figure 1). A total of 92 historical aerial photographs of the study area from 1929 and 1944 were found in hard-copy archives. Approximately 36000 hectares of sheep habitat were covered by the historical imagery, although the extent of the imagery was limited to the eastern front of the sheep's range. The imagery was scanned, orthorectified, and made available by the SNBSRP. True-colour and colour-infrared aerial photographs from 2005 with 1-meter spatial resolution were collected as digital orthophoto quadrangles from the online Cal-Atlas database (http://atlas.ca.gov/). A 10-meter digital elevation model (DEM) and shape files of the herd units were also provided by the SNBSRP.

A manual interpretation of the imagery was performed using a multi-stage sampling design. Semivariogram analysis was initially performed on a 2005 classified air photograph of tree cover to aid in determining the coarse level of analysis. The study area for each herd unit was then stratified by the results of the semivariogram analysis to 600 meter by 600 meter (0.36-km^2) grids, and was sub-sampled systematically by eight 50-meter plots (2500 m^2). The sampling design needed to be non-biased in evaluating tree encroachment across bighorn sheep habitat, but it also required sampling flexibility in order to avoid major distortions and shadows in both the old and new imagery sets. The sampling design allowed for discretion in choosing alternate plots based on major distortions or shadows in the grid. The DEM was resampled to 50 meters using window averaging, and slope, cosine aspect, and elevation were recorded at each plot after resampling. Sampling also occurred across a range of elevations, but due to the variation of seasonal habitat use by the herd units and the extent of the historical imagery, only winter habitat is included in the analysis. The 2005 colour-infrared imagery was initially classified in the object-based software, Definiens Developer 7.0, and change was calculated as a difference of vegetation cover between the historical and current dataset by area (m^2). Overall, 58- 600-meter grids were identified in the four study area units resulting in 421 50-meter interpreted plots

Linear mixed model regression in R was used to predict change with the terrain variables of slope, aspect, and elevation. The authors chose not to model the loss of vegetation or negative change because it was assumed that the variables affecting vegetation loss would be different than tree encroachment. Due to zero-inflation of the data, we initially modeled change as a binary categorical response in a generalized mixed model under the binomial family, and then proceeded to model positive change as a linear mixed model. Models were evaluated based on residual plots, and significance values were used to evaluate the predictor variables. A validation assessment was also performed on the change areas.

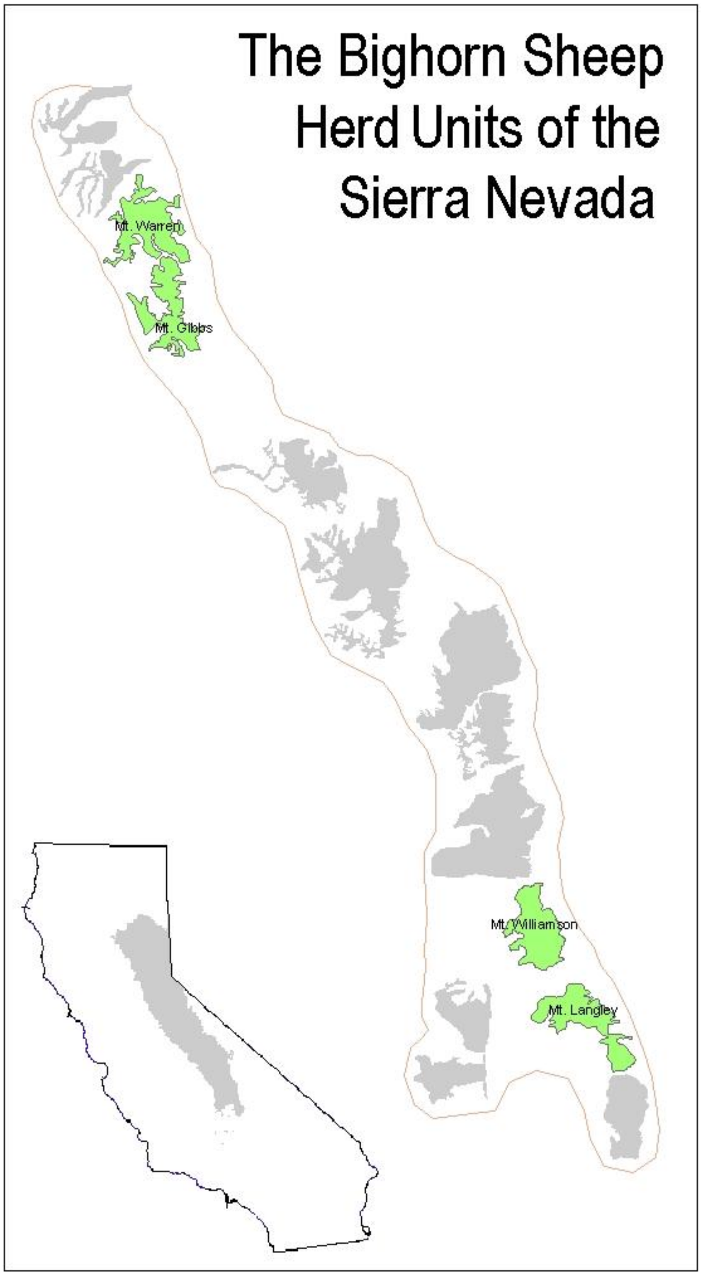

Figure 1. The four primary herd units of the Sierra Nevada include, from north to south, Warren, Gibbs, Williamson and Langley.

Results

Change was less than +4% on average for each of the herd units. One of the north herd units, Mt. Gibbs, had the most amount of change, and Mt. Langley in the south had the least. The results of the mixed model analysis indicated that the herd units were not significantly different from each other. Positive change was associated most with north aspects, low elevations, and steep slopes. More change rather than less change was also associated with low elevations and north aspects.

Our study indicates that tree encroachment in bighorn sheep range of the Sierra Nevada is not prevalent, but that local change may still be impacting the individual herd units in their winter and summer ranges.

Conclusions

Tree encroachment in the bighorn sheep herd units of the Sierra Nevada was found to be <+4%. The increase in tree cover may be attributed to external variables not explored in this analysis. The recovery of bighorn sheep however has benefited from viewing the historical landscape prior to major eras of settlement and anthropogenic change during the late 1800s and early 1900s. The methods employed for the interpretation of historical imagery were found to be robust to the shortcomings of the data, and further studies should seek to incorporate and extend the historical reach in time by using such methods.

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Characterizing Whitebark and limber pine Habitat in Alberta: Mapping highly localized tree species across a large study area

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Abstract

The endangered white pines, whitebark pine (*Pinus albicaulis)* and limber pine *(Pinus flexilis),* are crucial for Alberta alpine ecosystems. A province-wide species distribution map for whitebark and limber pine does not exist and will be important for future management strategies. An initial attempt to model whitebark and limber pine using the pre-existing dataset found that an insufficient density of presence data for the province resulted in an oversimplified, overabundant estimation of whitebark and limber pine presence. To address this, our study conducted ground surveys and acquired high resolution aerial imagery throughout the foothills and mountain ranges of Alberta. This data was analyzed and filtered to produce a large, high-precision inventory of whitebark and limber pine locations in Alberta. Through field observations, aerial photo analysis and extensive literature review, whitebark and limber pine habitat was characterized as having a multivariate dependency on elevation, hillslope profile, hydrologic regime, natural disturbance regime, and the relative abundance of lodgepole pine *(Pinus contorta),* alpine larch *(Larix lyallii),* alpine fir *(Abies lasiocarpa),* and Engelmann spruce *(Picea engelmannii).*

Background and Relevance

Whitebark pine (*Pinus albicaulis)* and limber pine *(Pinus flexilis)* have an important role in the alpine ecosystems of Alberta for watershed protection, shelter for both plants and animals, and as a food source for squirrels, grizzly bears, and nutcrackers (Tomback & Achuff, 2010). Both species have been severely impacted by the introduction of an exotic fungus that has infected whitebark pine across its entire range in Alberta (field observations, 2010). As a result, whitebark and limber pine are expected to decline throughout the province and have been listed as endangered species since 2008 (Wilson, 2007). Currently, initiatives are being outlined with the intention to conserve and restore the health of Alberta whitebark and limber pine communities, starting with a detailed inventory of both species (Wilson, 2007). To date, the only maps that exist for whitebark and limber pine distribution in Alberta are either imprecise or restricted to small regions for which there is an exhaustive collection of ground-truth data (McDermid & Smith, 2008). A complete province-wide inventory of high-precision ground-truth data for whitebark and limber pine is unrealistic due to the high cost and difficulty of accessing the high alpine regions that these trees inhabit. Yet it may be possible to acquire enough reliable data to permit a precise characterization of whitebark and limber pine habitat in terms of several key explanatory variables. Such controls are likely to include topographic factors that contribute to undeveloped soil, drought conditions and cyclic disturbance by rockslides and avalanches (Tomback & Achuff, 2010; Callaway, 1998). This study presents the methods and results of data collection and analysis for the purpose of characterizing whitebark and limber pine habitat in Alberta.

Methods and Data

The study area is comprised of the full range of the Rocky Mountains and foothills of Alberta. This includes Waterton, Banff, and Jasper National Parks and the surrounding wilderness areas.

At the outset of this study, we performed a rough decision tree classification of whitebark pine presence using Landsat TM imagery and digital elevation data. The classifier was trained with ground observation data that consisted of 520 whitebark pine and 210 limber pine presence polygons collected by various agencies from 1950 to 2010. The centroids of these polygons were assumed to be points of whitebark and limber pine presence. Absence points were generated programmatically at random locations outside the natural elevation range of whitebark pine. The model was run on a total of 20 explanatory variables, which included 15 spectral variables from Landsat-TM imagery and 5 topographic variables from a digital elevation model. Using IDL programming, the final output was a binary raster image of presence and absence.

From mid-June to late August of 2010, a field campaign aimed at obtaining whitebark and limber pine presence points was conducted over the entire study area.[1] The field methods in this study had to address the logistics of difficult access, an extensive study area, and a limited budget. A cluster sampling design was used accommodate both the data requirements and the fiscal limitations of the survey. To reduce the probability of travelling long distances on foot without finding whitebark and limber pine trees, the data used in the preliminary classification (above) was used as a guide for planning access. Two crews were dispatched on 40 day-trips to take pictures and record a few key properties of whitebark and limber pines and their surrounding environment. The location, landform classification, species composition, crown closure, cone count, and tree heights were recorded for a 30 metre radius sample plot. In addition, observations were made with respect to the characteristics and variability of habitat variables associated with whitebark and limber pine occurrence. Distance samples were also obtained by identifying trees on adjacent slopes using binoculars and employing optical-rangefinders and inclinometers to pin down the location.

Beginning on July 24 (2010), 300 kilometres of aerial transects were flown to collect 5-10 cm resolution RGB imagery in remote parts of the province. These images were viewed stereoscopically and visually scanned for whitebark and limber pine presence and absence. The sample locations were entered into the database along with a cropped image of the sample and an estimation of species composition and crown closure.

Finally, a comprehensive review of field observations and literature was carried out in order to develop a working hypothesis with respect to whitebark and limber pine habitat characterization. This review was aimed at identifying the characteristics of whitebark and limber pine habitat that can be reconstructed from transformations on digital elevation data and spectral analysis of data from Landsat TM. In particular these characteristics included species composition and abiotic conditions that could be defined in terms of reflectance or terrain.

[1] Except for Waterton National Park, for which sufficient ground-truth data already exists.

Results

The results of the preliminary decision tree classification indicated that the sparse and largely inaccurate data set had the effect of reducing the usable explanatory variables to a single elevation variable. Thus, the final output was no better than a truncated digital elevation model. Upon visiting these data sites in the field, it was found that many of the samples were not located over whitebark and limber pine stands. In some cases, the sample locations seemed to be the result of misidentification of lodgepole pine, alpine fir, and spruce as whitebark and limber pine.

The 2010 field season yielded 350 ground-truth points in roughly 70 clusters scattered about the province. In combination with points collected in 2007 and 2009, the new dataset spans the province from Waterton National Park to the Willmore Wilderness Area north of Jasper National Park.

Aerial photo analysis is increasing the sampling density throughout the study region. Based on the results so far, it seems that many stands of non-characteristic trees can not be identified as whitebark pine with certainty. These are being classified as "possible presence" and will be re-examined as additional means of interpretation is developed to distinguish these trees. However, the aerial dataset in proving useful for sampling a large area of remote whitebark pine habitat in the Willmore Wilderness Area as well as improving the sampling density in the Crowsnest Pass and southern Kananaskis regions.

Discussion

Observations that were made during the 2010 field season have resulted in several key considerations related to the characterization of whitebark and limber pine habitat. First, both whitebark and limber pines occur in three distinct phenotypes. The large-form type is typically 10-20 metres tall with a large fanning crown. The mid-form type ranges from 3-9 metres tall, with a full and bushy branch structure that tapers outward from top to bottom. The final form is stunted trees that range in height from 0-2 metres. These trees do not have a well defined trunk and usually appear as a clustered series of branches arching out of the ground. Although elevation is a strong factor in which form of tree is expected, it is not an exclusive predictor and it is likely that each of these phenotypes will have to be modeled separately.

Another important issue for habitat modeling is that whitebark and limber pines rarely occur in pure stands. Over the course of the field season a completely pure stand of whitebark and limber pine trees was not observed in Alberta. In the case of whitebark pine there were very few stands in which whitebark and limber pine was the dominant tree species. As a result, any attempt to classify whitebark and limber pine trees from spectral data will be hampered by the inclusion of signatures from other trees.

The sampling density that is needed in order to successfully model whitebark pine across Alberta cannot be achieved by field operations alone. According to a 2008 study of the Greater Yellowstone Area, a successful model for whitebark pine habitat requires adequate training data and the use of highly-evolved computer learning methods (Landenburger *et al.*, 2008). Landenburger *et al.* (2008) used a similar approach to the preliminary model performed at the outset of this study, combining 16 spectral variables and 3 topographic variables in a decision tree classification model. However, the sampling density in the Yellowstone study was much greater than is fiscally possible for Alberta. In lieu of a high sampling density, the second phase of this study is aimed at using information on the habitat characteristics of whitebark and limber pine (from a combination of literature review and field observations) to reduce the area over which the classification is run. It is hypothesized that both reducing the model area and supplementing the existing number of samples with samples from aerial photos will increase the accuracy of prediction by the model.

Conclusions

The pre-existing whitebark and limber pine presence dataset was insufficient for modeling whitebark and limber pine distribution across the province. Cluster sampling and aerial photo interpretation is a cost-effective method of acquiring whitebark and limber pine presence data across large regions that are inaccessible by vehicle. Whitebark and limber pine presence is dependent on elevation, hillslope profile, hydrologic regime, natural disturbance regime, and the relative abundance of lodgepole pine, alpine larch, alpine fir and engelmann spruce. It is hypothesized that all of these variables are needed to characterize the habitat of whitebark and limber pine. Additionally, three separate combinations of these variables may be needed explain the occurrence of the three distinct whitebark and limber pine phenotypes.

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The Effects of Edges on Grizzly Bear Habitat Selection

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Abstract

Understanding grizzly bear (Ursus arctos) habitat selection is critical for managing threatened populations. The goal of this paper is to develop a better understanding of grizzly bear habitat use through a comparison of grizzly bear location data with landscape edge inventories. We utilized GPS telemetry data from 26 grizzly bears from 2005-2009 in the foothills of the Rocky Mountains in west-central Alberta. The locations were compared to a series of landscape transitions extracted from landcover data, and linear features, such as streams, roads, and pipelines. Results show variation between seasons and sexes in edge distance, selection, and density. Wetland edges comprise a small proportion of the study area (< 2%) but females select edges of this type up to 7% of the time, with little variation between seasons. Roads are selected for by females, but avoided by males, and hydrocarbon pipelines show similar results to roads, indicating these are also important grizzly bear edges. Seasonal differences indicate that females and males select for edges more in the fall, due to changes in feeding and security, or as a result of contracting home range following the mating season. These results indicate that while managing for anthropogenic disturbances in grizzly bear habitat is of utmost concern, understanding bears' reactions to natural transitions can provide new management opportunities not related to resource extraction activities. Specific focus should be paid to maintaining wetlands, as these areas are selected by grizzly bears, but they comprise a very small part of the study area.

Background

Grizzly bears require diverse habitats due to their seasonal diets (Nielsen et al. 2004a), and their diurnal feeding patterns (Klinka and Reimchen 2002). Much of this food can be found at transitions between homogenous landcover types. Natural and anthropogenic transitions provide important food sources not always available in either adjacent patch (Fortin et al. 2001). As such, grizzly bear habitat selection can be viewed as the selection for, and avoidance of edges, where edges are the boundaries separating distinct habitat patches (Ries et al., 2004), and can be either natural landscape features or anthropogenic disturbances.

Edges play an important role in ecosystem dynamics as they alter the flow of energy, materials, and organisms, which, in turn, alters the community structure at edges (Ries et al. 2004). Edge community structure can increase mortality, when it exposes species to increased predation (Gardner, 1998) or parasitism (Murcis, 1995), or improve conditions when it provides access to complimentary habitat patches in close proximity (Nielsen 2004a; 2004b). Edges can come in many forms, such as natural transitions between a forest and meadow, or as anthropogenic disturbances, such as roads and hydrocarbon developments.

The goal of this project is to quantify grizzly bear use of edge habitat; both natural and anthropogenic. There are three main objectives for accomplishing this goal. 1) To quantify edge density in available grizzly bear habitat (available being defined as area inside a bear's home range). 2) To quantify the frequency of bear edge use, and the distance of that use. 3) To statistically evaluate if the frequency and distance of observed bear locations to nearest edge types is unexpected relative to random (where random is conditionalized on factors known to impact grizzly bear habitat selection). These goals will be evaluated based on seasons and sex.

Methods and Data

Numerous edges were extracted for comparison to grizzly bear telemetry data. Landcover transitions were extracted following Wulder et al. (2010). The final transitions used were shrub-conifer, shrub-broadleaf, shrub-mixed, and wetland-forest (all three forest classes were grouped together for wetland edges). As well, vector datasets for roads, streams, and pipelines were obtained from the Foohills Research Institute (http://foothillsresearchinstitute.ca).

A 95% by volume isopleth of a kernel density estimation was used for home range deliniation, as this is a method widely used in habitat analysis (Seaman and Powell 1996). For each season, individual grizzly bear home ranges were calculated. Bandwidths were calculated using direct least-squares cross validation, with a Gaussian kernel (Ruppert, Sheather, and Wand 1995). Total length of each edge type in each home range was compared to the area of the home range to create an edge density in m / km2. These densities were tabulated for season and sex, and boxplots were created to compare edge density.

For all telemetry data, distance to nearest edge was calculated, and the edge type was stored. The nearest edge was considered 'used', and frequency of use, and average distance to nearest edge was calculated for each edge type. The values were compared to randomized points created though a conditionalized randomization, based on a resource selection function (RSF). The RSF evaluates third-order habitat selection for grizzly bears based on a series of underlying landcover datasets. The RSF explicitly removes edges from its calculation, so it accounts for all non-edge biological phenomena. The observed distance to edge and frequency of selection was compared to the expected (from the randomized points) to determine significant differences between sexes and between seasons.

Results

Females use habitats with a higher density of pipelines and roads than males. The difference between genders is significant at $\alpha = 0.05$ for spring and fall for pipelines, and spring and summer for roads. Anthropogenic edges less common in grizzly bear home ranges than shrub-conifer edges, which are the most common in every season for both sexes, with females having significantly higher density in the spring. The wetland transitions appear to be much less common than any of the other transitions in bear home ranges, but this reflects the relative frequency of wetlands in the study area (~2%). Females are also found significantly closer to streams in the spring than males.

The analysis of distance to edge and frequency of edge selection shows a number of interesting results. Females select for wetlands more than expected, selecting edges 5.38%, 6.71%, and 3.93% for spring, summer, and fall respectively, where as wetland edges makeup only 0.74% of edges in their habitat. Males select for shrub-conifer transitions more than expected in the fall, using these edges 46.41% of the time, while the edge makes up only 34.5% of the habitat; conversely females use this transition approximately as expected throughout the year. Males select for the shrub-mixed transition more than available in every season at 10.53%, 11.16%, and 10.16% in the spring, summer, and fall compared to an availability of 6.65%. Males are found close to the shrub-broad transition often in the spring (21.48%), but that selection decreases throughout the year (11.48% in the summer, and 8.3% in the fall). Males select for streams only in the summer (36.38% versus 27.82% availability). Females appear to select for anthropogenic edges (pipelines and roads), whereas males avoid them in all seasons.

Discussion and Conclusion

Our results follow recent studies in this area that show females select for roads more than males (Roever, 2008a), as females are found closer to roads, more frequently than expected, and in areas with higher road density. A corollary to this is the selection of pipelines by female grizzly bears. Nielsen et al. (2006) used pipelines in an analysis of grizzly bear habitat and defined these as low impact human-access corridors; lower impact than either established roads or logging roads. Our results indicate that pipelines follow similar trends as roads, with females being closer than males and closer than expected.

The identification of edges as key grizzly bear habitat extends beyond anthropogenic disturbances. Whereas many studies have focused on grizzly bear attraction to anthropogenic disturbances, our work highlights natural edges as well. It is established in other species that there is variation in edge effects between natural and anthropogenic edges, but this has not been well investigated in grizzly bears. Our results show that natural transitions have substantial variation in selection by season. Females select for wetland edges much more than available. Despite the fact that these edges are uncommon in our study area (<2% of landcover), females use them up to 7% of the time in the spring. This could be due to important food resources, such as Heracleum lanatum, which grows in low lying, wet areas (Servheen, 1983). The importance of these wetland areas for females compared to their frequency makes these important areas for management considerations. Males are found near broadleaf edges more than females, and more than expected; however this selection decreases significantly from spring to fall. This could be due to variation in diet, as males feed more on ungulate than females, or it could be due to mate selection, as males travel widely in search of females in the spring.

Current forest management regimes in the foothills of the Rocky Mountains focus on limiting road density (Roever 2008a; 2008b) and maintaining consistency in forest harvest industries, with small cuts in a patchwork of forest and harvest (Nielsen 2004a; 2004b). While both of these are essential to managing grizzly bear habitat, maintaining a balance of natural landcover, and natural landcover transitions should also be considered when designing management plans. Forest harvests create important edges for grizzly bear habitat, as these clearings are surrogates for natural clearings containing important food stuffs (Nielsen 2004b). Anthropogenic edges cannot, however, replace the resources derived from natural transitions. Maintaining a balance between natural and anthropogenic edges, and focusing on retaining equal percentages of all landcover should be priorities in managing grizzly bear habitat in this area.

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Digital Globes Gone Mobile:
LBS, VGI and their Potential Implications for Spatial Cognition and Environmental Learning

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Abstract

As technology is evolving, so too are the demands, trends and requirements of cartographic production and distribution. Compelling new ways of distributing spatial information and interacting with geographic space are being rapidly adopted in everyday activities. In this paper we explore the nature of 'digital globes,' in an era of Location-Based Services (LBS) and Volunteered Geographic Information (VGI), from the perspective of spatial cognition and environmental learning. We discuss these concepts in the context of a popular LBS application (Yelp). We identify empirical research from the literature that suggests popular LBS applications may have a negative influence on spatial cognition. We consider some of the potential negative and positive implications of using such applications. Research suggests that dividing users' attention reduces their ability to retain environmental information. We then offer recommendations for further research.

Background and Relevance

Contemporary mobile geographic computing has evolved considerably from the tools and methods available to us a decade ago. Current mobile geographic computing integrates four key technologies that were previously separate systems. Widely available mobile devices now include Global Positioning System (GPS), basic Geographic Information System (GIS) software, wireless communication, and access to the Internet - all in a handheld or tablet computer (Armstrong and Bennett, 2005). Furthermore, newer devices contain accelerometers and other sensors, enabling devices to also sense orientation, movement and acceleration in three dimensions.

These integrated mobile platforms provide incredible opportunities for people to move through space and interact with real world phenomena while simultaneously having access to information repositories in the palm of their hand. As more people gain access to ubiquitous computing devices such as smart phones, a new world of possibilities opens up – for us to interact with many types of spatially organized digital representations of geographic space – all parts of 'digital globes'.

The use of digital globes is increasingly being integrated into location-based services (LBS) and applications. Some LBS provide large quantities of varied information to users through the integration of Volunteered Geographic Information (VGI). These services paired with the use of digital globes in new spaces have considerable implications for spatial cognition and environmental learning. For us to consider possible implications we must identify, situate and describe key terms such as LBS, VGI, and digital globes. Our emphasis in this paper is to focus on spatial cognitive mechanisms that may operate during LBS and VGI use. In particular, we focus on how they may impact human development of mental models of geographic space as part of mobile and in situ environmental learning. By doing so, we aim to develop a new conceptual framework through which to encourage productive dialogue between GIScientists, Neogeographers, and broader communities of LBS and VGI researchers.

Situating our discussion: defining Digital Globes, LBS and VGI

Digital globes[1] are web-enabled digital representations of the Earth's surface. Digital globes allow us to tap into vast repositories of spatially indexed information. As a result, they are changing the way we interact with and display geographic information, and may enhance our ability to visualize geographic information (Miller, 2007; Haklay, 2008; Goodchild, 2007). These developments may have the potential to modify spatial understanding of geographic phenomena. Digital globes provide the user the ability to shift between scales swiftly and seamlessly, move quickly to any location on the globe, and view the world in two or three dimensions (Rouse *et al.,* 2007; Zhang, 2007). Digital globes often act as base maps for web-based spatially enabled applications delivering place-based information.

LBS offer information about where a mobile location-aware device user is situated (Gartner et. al., 2007 a, b; Jiang and Yao, 2006). Raper described LBS as "…distributed, componentized and dependent on a range of associated services," and as "examples of scalable ubiquitous computing applications designed for use in environments ranging from individual buildings to cities and even whole regions" (Raper, 2007). For LBS to be relevant to a wide range of users, a commensurate range of information needs to be available.

[1] Digital globes are sometimes referred to as digital earths. We prefer the term digital globe because much like a physical globe, they are a **representation** of the Earth's surface.

Goodchild (2007) introduced the term VGI to describe location-based information that people record on the web to share with others. Tulloch notes that VGI applications "...are those in which people, either individually or collectively, voluntarily collect, organize and/or disseminate geographic information and data in such a manner that the information can be used by many others" (Tulloch, 2008: 161). VGI is a unique method of collecting and recording local knowledge. The concept is broadly understood and widely used by GIScientists and Neographers, yet more work needs to be done to identify and classify various forms of VGI – including an investigation of the influence of each on geographic sense-making or distributed intelligence.

Considering the cognitive dimensions of LBS and VGI

We learn about place either by navigating the landscape freely, using a map or mobile device to give us directions. There has been much debate over the form of representations of spatial objects and relationships in the brain. Cognitive maps may be mental representations of a geographic space (Stea and Blaut, 1973), or the cognitive processes associated with encoding and retrieving the spatial knowledge (Kitchin and Blades, 2002), or feelings and attitudes associated with places (Gould and White, 1974). Unlike fixed cartographic representations of space, cognitive maps are developed in a piecemeal fashion over time (Davies *et al.,* 2010; Montello, 1992).

Spatial cognition or mental maps comprise both hard information (routes, landmarks, configuration, wayfinding, spatial distribution) as well as soft information (feelings, perceptions, attitudes, memories) – all of which are subject to variable internalization by humans. Spatial cognition is influenced by psychological factors associated with soft information (Downs and Stea, 1973) and the spatial layout of landmarks. Each individual may view and feel extremely different about the same place based on their unique experiences in that place. As people navigate through space their feelings and memories of that place are tightly intertwined with their spatial understanding of place.

These factors must surely have a powerful influence on various aspects of LBS and VGI information dissemination, and the similarly wide range of user transaction types. While objects and phenomena in geographic space may have 'hard' coordinates, the form of their internalization by user networks – mediated by information systems – may vary considerably.

Exploring these issues in a popular mobile application

There are several popular LBS applications that are populated by VGI. A recent report issued by the Pew Research Center indicated that 4% of Americans report using LBS (Zickuhr and Smith, 2010) while another study by Microsoft reported 51% of people in the United Kingdom, Germany, Japan, United States and Canada use LBS (Microsoft, 2011). These reports suggest that substantial numbers of citizens actively use LBS on a daily basis – as part of everyday behaviour. As GIScientists, we must not stop there. We feel that it is important to deconstruct one of these popular mobile applications, identify some of the possible cognitive mechanisms operating during citizen use of LBS/VGI, and discuss potential implications for geographic sense-making. We will consider Yelp -

a web-based application that has over 5 million users on both desktop and mobile applications (Yelp, 2011).

Yelp allows users to perform geographic searches by entering the name of a business or other location-based information. The application will then reveal relevant location-based results from that search. The user (Yelper) can choose from three different user interfaces (UI) to view the results from the search (map, list or mobile augmented reality view).

In the next section, we will describe connections between these LBS and VGI functions and identify some results from empirical research from the academic literature testing some of the components shared with Yelp.

Potential Implications of LBS and VGI Applications for Cognitive Maps

Combining LBS, VGI and digital globes all together in one application may be overwhelming, confusing and frustrating for a user, (especially a new user) to understand. In some cases, perhaps users are completely unaware of these components. Despite the promises held by the use of LBS and VGI applications, studies have shown that using mobile maps or mobile devices divert attention away from the task of navigating and impose other cognitive demands on users. When attention is divided, speed and accuracy of the task diminishes (Spence and Feng, 2010; Montello and Freundschuh, 2005). This may have negative implications for effective spatial cognition. Willis *et al.* (2009) found that mobile map users performed worse than static map users on route distance estimation as well as Euclidean distance (*ibid.*). These findings suggest that users do not understand the hard information associated with spatial cognition.

Some researchers (such as Ishikawa *et al.*, 2008) have conducted studies measuring the effectiveness of Google Map-like GPS-based interfaces versus paper-based maps to test users' wayfinding behaviour and spatial knowledge acquisition. These studies have found that: users of GPS devices traveled more slowly and made larger direction errors than those who used paper maps; GPS users did not have to update their position manually, and their position was updated automatically on the device much like the use of LBS on smartphones. Some researchers suggest that this could be due to the fact that "mobile map learning took place concurrently with information being delivered incrementally, so that it was never learned as a single stable schema" (Willis *et al.*2009: 109). This suggests that novel mobile device-based geographic interfaces do not necessarily result in improved geographic learning.

A new framework for approaching LBS and VGI

More needs to be done to understand the powerful role that LBS and VGI play in mediating and influencing human perception of geographic space, and the mental models that result. As a community, GIScience and Neogeography need to develop more than just detailed specifications of the technological and UI features of LBS and VGI systems. We need to situate each and every type of work within a comprehensive conceptual framework that incorporates both the tangible and amorphous features and transactions of LBS and VGI system. These should be pursued both quantitatively and qualitatively. The results of these studies could likely influence LBS and VGI application design to enhance spatial understanding.

We propose a new conceptual architecture that may provide new inroads into understanding the mechanisms that operate in LBS and VGI. We suggest that different geographic topologies result from LBS and VGI- and from different forms and uses of them. These variations may substantially modify 'live' geographic sense-making as mediated by mobile geographic computing platforms and user behaviour. We present the first iteration of this new conceptual framework, and attempt to situate existing examples of LBS, VGI, cognitive mechanisms and empirical studies within it.

Recommendations for Future Research

New research needs to be done to reveal the effects and affects of LBS and VGI people's perceptions of place and topology in geographic space. Does reading about other peoples' experience in places you are currently visiting influence your feelings and experience in the same place? Does the act of contributing VGI differ from the act of reading others contributed VGI through LBS?

Further research is needed to investigate the synergistic relationship between LBS and VGI and the use of digital globes for mobile applications. Research in this area could reveal interesting unknowns for GIScience and pervasive computing.

Conclusion

In this paper we identify popular definitions of LBS and VGI. We situate them within the context of 'digital globes', and consider spatial cognitive mechanisms that may influence human mental models of space in freeform or structured geographic sense-making activities. We use the application Yelp to illustrate a selection of these mechanisms, and the implications they raise. We propose a new conceptual framework to distinguish different types and combinations of LBS and VGI which may mediate representations of geographic phenomena and topology in different ways. In turn, they may influence mental models that result from the use and exchanges of LBS and VGI. We offer recommendations for further research.

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Indoor localization method comparison: Fingerprinting and Trilateration algorithm

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Abstract

Enhanced Positioning Systems (EPS) are able to supplement Global Positioning Systems (GPS) in indoor environments where GPS cannot work because of disrupted or weak signals. Most EPS are Wifi-based because Wifi is a common technology available in many indoor environments and is deployed in cost effective manner. Fingerprinting and Trilateration are the two general methods used for calculating position with Wifi-based EPS. This paper will briefly introduce these two methods, summarize their common ground and differences, and compare the strengths and weaknesses of each.

Background and Relevance

As GPS becomes a routine tool for navigation and wayfinding more and more mobile handled devices (smartphones and PDAs) are integrating GPS. However, an important and well-known limitation of GPS is that it cannot work inside buildings because of the weak signal's inability to penetrate building material. EPS is an important supplement for GPS in indoor environments where GPS cannot work. Most EPS are Wifi-based because Wifi is a common and accessible technology that provides the basic information necessary for indoor positioning without requiring additional hardware. In the case of Wifi-based indoor localization, the fingerprinting method based on Wifi singnal strength observations is often employed (Mok & Retscher, 2007). An alternate method is the trilateration algorithm which is also implemented in GPS; trilateration uses distance to surrounding Access Points which, in the case of Wifi routers, is derived from signal strength values.

Methods Comparison

Fingerprinting can be generally divided into two phases: an offline phase and an online phase. The offline phase involves building the signal strength database and creating the signal strength map. After creating an accurate database of Access Point (AP) locations, reference points are chosen. Evenly spreading these reference points in the experimental area improves the accuracy and reliability of the locations derived from fingerprinting. The received signal strength from every visible AP is included in the database for each reference point. After measuring the received signal strength from each visible AP, the mean value of the signal strength and the distribution of signal strength of each reference point will be calculated and stored in the database. During the online phase, both deterministic and probabilistic methods can be employed as a positioning algorithm (Zhou, 2006). The former chooses the reference point in the database whose signal strength has the minimum difference from the received signal strength of the device as the most probable location; the latter chooses the most likely location of the device in database as the most probable location.

The trilateration algorithm does not need an offline phase like fingerprinting. However, trilateration still needs an accurate AP location database, including accurate Access Point coordinates and the unique Media Access Control (MAC) address for each AP. During active measurement, after calculating average signal strength for each visible AP, the system uses this value as an approximation for distance to trilaterate the device's location. It is of considerable importance that the general relationship between signal strength and distance may vary from different networks of APs, so it is practical and necessary to recalculate the general relationship when the network of Access Points change. This also suggests that trilateration benefits from the use of a common or small set of AP models. The common ground of the two methods is the need for an accurate database of AP locations and the dense and consistent wireless signal.

The differences between the two methods lead to some strengths and weaknesses. From a cost perspective, compared with trilateration algorithm, using fingerprinting consumes more time and labor during the collection of signal strength data and a huge volume of data needs to be stored as fingerprinting depends on a pre-existing signal strength database for all reference points. For a reasonably sized building, the offline phase of fingerprinting could take over 100 hours (Bahl & Padmanabhan, 2000). Positional accuracy with a fingerprinting algorithm is positively associated with the density of reference points in the database. The trilateration technique, on the other hand, includes as a database creation process but without collecting signal strength data.

From the perspective of adaptability, the trilateration technique performs better than fingerprinting. When a router is installed or removed in the environment, the trilateration technique only needs to add that new record to the database (with its accurate location and MAC address) or delete the existing record in the database; the fingerprinting technique, on the other hand, signal strength data needs to be recollected for every reference point within range of that new or removed router.

From the perspective of signal strength, fingerprinting takes into account the attenuation because the actual signal strength at each reference point is collected (which integrates the presence of obstructions between device and routers). Trilateration, on the other hand, collects signal strength values in real time and converts them to distances, taking no account of possible obstructions. The distance used for trilateration will be same for common received signal strength whether a signal is passing through walls or travelling through an obstruction-free space. To reduce this effect, a correction factor should be added to revise the average of the signal strengths for the non-line-of-sight router signals, if it can distinguish occluded from non-occluded signals.

From the perspective of accuracy, the calculating accuracy of fingerprinting will be greatly affected by the density of the reference points. When the database granularity achieves 5 feet, the corresponding average distance error could be 21.7 feet (6.62 meters) (Prasithsangaree, Krishnamurthy, & Chrysanthis, 2002). In Wireless indoor tracking system, a history-based tracking algorithm helps improving the accuracy to 3.89 meters for quickly moving device (Zhou, 2006). When calculating position with trilateration algorithm, distance conversion error becomes the largest error source, usually Kalman

Filter and Particle Filter are applied to trilateration algorithm to improve the accuracy, which ranges from 2 to 6 meters depending on various kinds of systems.

Conclusions

Both fingerprinting and trilateration use estimated wireless signal strength to determining the location. However, each determines position in different ways. Fingerprinting requires a detailed signal strength database for each reference point that can be compared with received signal strength in the field; the use of this method needs to balance the accuracy and time-commitment for collecting data when creating signal strength database. The trilateration technique is more flexible as the system calculates device location in real-time and the system is more adaptable to environmental change than fingerprinting. In real-world use, trilateration needs a correction factor to reduce the effect of attenuation; fingerprinting, on the other hand, already considers attenuation in the database creation process, which leads to a better accuracy in the signal strength data for calculation.

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What Makes Difference in WiFi-based Positioning Services: The Importance of Establishing a Reliable Database

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Abstract

WiFi-based positioning systems (WPS) are designed to support the acquisition of accurate location information with technology other than Global Positioning System (GPS). These systems have the potential to supplement GPS where GPS is unreliable, specifically, indoor environments. Recently, Location Based Services (LBS) have become increasingly popular for many mobile device users. These new mobile devices incorporate various wireless technologies, such as WiFi, A-GPS, Bluetooth, and GSM. While each of these technologies contributes to the integration and development of LBS, WiFi has been most widely employed as an alternative positioning service. Indoor location uncertainty with WiFi stems from utilizing an unreliable database for wireless router locations and not fully utilizing and correcting received signal strength. Furthermore, database information is often collected using unreliable and unsecure methods. The purpose of this study is to validate the advantages of using a reliable database for SaskEPS (a small area WPS) from indoor environments. This research has been implemented within two multi-floor buildings in the University of Saskatchewan. The results of the location finding service test with WPS show that using a reliable database for WPS significantly increased location certainty from indoors.

Background and Relevance

After the removal of selective availability in 1996, the use of personal GPS dramatically increased due to its ability to provide accurate location information to the user (Clinton, 2000). GPS is capable of providing location information with high certainty (within 10 metres) and consistency in almost all outdoor environments. However, GPS has some significant weaknesses in isolated spaces which contain urban canyons, natural canyons, and most indoor environments where its service is generally unreliable and unavailable.

Although the GPS-based positioning system has problems in several specific environments (specifically indoors), these can be replaced or supported with an increased array of available radio technology (Ishikawa, Fujiwara, Imai, & Okabe, 2008). Many other fixed radio signals, including WiFi, are available in many places and those radio signals can be easily used for positioning without employing new infrastructure (LaMarca, Hightower, Smith, & Consolvo, 2005). Recently, wireless Internet services have become available in many indoor spaces; therefore, existing WiFi service can be used to develop indoor positioning systems as an alternative, or supplement, to GPS. WiFi can be a very efficient and cost effective indoor navigation system because it provides very dense wireless coverage in different types of indoor spaces such as universities, airports, and shopping centres. Once a proper positioning algorithm is developed, WiFi-based location services can be easily established providing an indoor positioning solution without building additional infrastructure.

Many WiFi-based location finding services fail to provide sufficient accuracy or clear communication with location uncertainty (Bell & Jung, 2010). This failure could be caused by an unreliable database as most WiFi-based location services collect required database information using unreliable and unsecure methods (unreliable wireless Access Points (APs) information collection methods include: wardriving, third party sources and volunteered Geographic Information). If a WiFi-based location finding service employs a reliable and valid database which includes the accurate x-y coordinates of all APs in the area of coverage, the level of location certainty can be improved. With a goal of increasing location certainty in indoor environments, the University of Saskatchewan Enhanced Positioning System (SaskEPS) has created such a database and an accompanying positioning algorithm that returns GPS-like accuracy for indoor spaces.

Methods and Data

This research validates SaskEPS (with a well-structured database) with the hopes of providing efficient indoor positioning service in campus buildings at the U of Saskatchewan. WiFi signal strength mapping is required for validation of the WiFi signal as it helps to identify WiFi availability in each building. The SaskEPS database contains accurate geographic coordinates, floor information, router type information, and each AP's Media Access Control (MAC) address as an unique identifier. This optimized database for SaskEPS provides GPS-like positioning in indoor environments. Below we will compare this accuracy with currently available WiFi based systems (Skyhook and Loki).

This positioning comparison test took place in two multi-floor buildings (Kirk Hall and the Engineering building) where dense WiFi APs are available. Furthermore, these two study areas can be used to study the impact of building structure on indoor positioning services (Kirk Hall is a relatively simply structured building whereas the Engineering Building is a relatively complex structured indoor setting). Our test is also capable of showing position certainty based on indoor structure and composition. 25 random points on each floor were generated using ArcGIS™ for the comparison test. Skyhook running on a 3Gs iPhone and Loki running on a laptop were used for data comparison. SaskEPS ran on two laptops with/without an 802.11 N capable wireless modem that provide positioning service with a reliable database.

Results

SaskEPS successfully provided sub-10m positioning accuracy for both Kirk Hall and the Engineering Building; Skyhook and Loki positions were consistently returning locations over 20 meters of error. Positioning in all systems was somewhat more accurate in Kirk Hall, a building which has a relatively straight forward (orthogonal) indoor layout (SaskEPS: average 5m, Skyhook and Loki: over 15m). Both Skyhook and Loki were egregiously inaccurate as positioning services in the Engineering building (over 50 meters of error). Although SaskEPS's location certainty also decreased at Engineering Building, it still provided sub-10m accuracy positioning service (average 8 meters of error).

Conclusions

In this test SaskEPS provides better location services than other WiFi-based positioning services. Although SaskEPS is primarily designed for providing WiFi-based location service indoors, SaskEPS can also support seamless positioning service from indoor to outdoor environments (and vice versa) when its service is integrated with a GPS-based positioning service. In addition, in the past, the use of GPS usually required a specific device. Currently many mobile devices have integrated A-GPS and WiFi modems. SaskEPS is a software-based positioning system, so any mobile device user can have seamless positioning services if their devices have integrated A-GPS and WiFi modems: GPS (outdoors) and SaskEPS (indoors). SaskEPS is distinguished from other WiFi-based positioning systems due to the combination of the trilateration with an accurate and reliable database. SaskEPS can maintain a GPS-like positioning system in indoor environments as long as the database provides up-to-date APs data in support of the location finding algorithm. Updating the database must include nominal changes in wireless routers, technology changes in WiFi services, as well as accurate location for new and relocated routers. For this reason, the availability of a reliable database is the most critical criteria for SaskEPS in terms of providing GPS-like positioning services in many environments where a dense WiFi network exists. If SaskEPS were to employ a larger database an extended indoor environment, it could easily expand its service coverage to such spaces.

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Positioning using Signal Distribution Patterns

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Abstract

Location determination of moving objects is a fundamental task of a location based service since the current location of mobile users is used to provide better services. GPS and GLONASS technologies are useful for outdoor positioning, as they generally provide good quality real-time position data for users 24/7/365, anywhere on the earth. However, these technologies are not as suitable for indoor environments. As such, indoor positioning of users is the foremost objective of this research. In addition to positioning, indoor route-finding based on users routing preferences is also a challenging problem for location based services, and forms a concomitant component of this work. In this research, a new fingerprinting method of indoor positioning is proposed, also three main location models including: geometrical, hierarchical and graph-based are integrated together to form the base for positioning solution.

Background

In recent years, indoor positioning based on Wi-Fi signals has received attention from numerous researchers from different disciplines (Yeung & Ng, 2007). A Wi-Fi network is characterized by a number of access points (AP) that are distributed throughout an environment for the purpose of transmitting and receiving signals from mobile devices. Because AP signal strengths varies as the radio waves travel through obstacles and space, researchers have taken advantage of this variation and have proposed numerous methods for determining the location of mobile user. The majority of methods can be classified as either based on radio propagation models or based on location fingerprinting.

Methods and Data

In this research we investigate the use of the Bhattacharyya distance to determine the location of a user in an indoor environment by comparing statistically a user's real-time signal with calibration points at nodes in an indoor pedestrian network. The primary advantage of this method, when compared to other fingerprinting methods like K-nearest neighbour, Artificial Neural Network (ANN) and Support Vector Machine (SVM) (Brunato M. and Battiti R, 2005) is the reduced calibration set necessary for determining a user's location. In this method the geometrical structure of building are considered as part of a user's contextual information, and a matching algorithm based on the Bhattacharyya distance used to estimate the real-time position of a user on a predesigned pedestrian network.

Environmental conditions affect signal strength in an indoor environment. Wall thickness, wall material, distance between transmitter and receiver, the geometrical structure of buildings, and the presence of people or other moving objects traversing the local environment contribute to signal strength variation. Therefore, signal strength is rarely constant over time and varies even when a user is stationary.

The Bhattacharyya distance measures the similarity of two discrete or continuous probability distributions. The statistic determines the relative closeness of two distributions by considering their distribution parameters: their mean and Covariance matrix, and is similar to the Kullback-Leibler divergence (Kullback & Leibler, 1951; Kullbac, 1987).

Conclusion

The study area for this work was the first three floors of the Science Theatre building at the University of Calgary. A ground truth campaign was undertaken to determine signal strength, signal variation, and the service set identifier of unique media access control (MAC) addresses within the study area. For calibration, a small number of points were identified, with the vertices at intersections and bends in the pedestrian network for the study area. A combination of the Bhattacharyya distance and filtering, to reduce the initial candidate set, was used to determine the user's position, which produced high precision in position matching.

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Sports, Time Geography, and Mobility Data

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Abstract

This research investigates the usefulness of concepts from time geography for studying in-game movements of athletes. Mobility data, collected using sport-specific GPS devices is used to highlight this approach. A simple training-ground drill is conducted on members of the University of Victoria Ultimate Frisbee Club (*UVictim*) to investigate differences in players' ability to cover space. Results are discussed with respect to defensive tactics in team sports. Future directions for mobility data applications in sports are presented.

Background and Relevance

Hagerstrand's (1970) time geography develops conceptual limits on spatial bounds of objects moving in a space-time continuum. Time geography uses volumes, such as the space-time cone and space-time prism (Miller 2005), to delineate these limits. The reach of time geography volumes into space is controlled by an object's movement capability, for example it's maximum velocity. In general, time geography has been applied to problems concerned with broad spatial and temporal extents (e.g., the daily activities of humans, Kwan 1998), but also in the context of agent-based systems (Boman & Holm 2005).

Time geography presents a unique angle for investigating player movement in team sports (Moore et al. 2003), relating to a player's ability to cover space. Traditionally, time geography volumes are symmetrical, however with fine-grained athletic movement, an athlete's current direction of motion will influence the shape of these volumes. Consider in football, when attempting a pass the quarterback subconsciously performs intersections of the space-time cones of the receivers and defenders on the field. A defender that moves in the wrong direction, or shifts their momentum, becomes out-of-position, opening up an opportunity for the offensive team.

New developments in GPS and video-analysis now facilitate generation of extremely detailed records of athlete movement (Randers et al. 2010). The study of player movement in team sports represents an ideal arena for investigating novel methods in mobility data analysis because of explicit spatial and temporal bounds placed on movement (Moore et al. 2001) and the fine temporal scale of processes. Moreover, given the competitive nature of sports, analysis methods that can be related to in-game tactics have increased value. Here, I present necessary modifications to Hagerstrand's time geography for use with fine-grain movement, such as that performed by an athlete in a team sport. Specifically, I calculate space-time *isochrones* (O'Sullivan et al. 2000) for athletes, that incorporate player momentum. Space-time isochrones can be used to delineate the area that a player is able cover. The size and shape of athlete isochones depends not only on physical abilities, but on their current direction of movement.

Methods and Data

Impacts of object momentum on time geography volumes, specifically space-time isochrones, are demonstrated using a micro-study on the types of movements common in thrower-receiver sports (e.g., football and ultimate Frisbee). Athletes participating in this study are drawn from the 2010-2011 University of Victoria Ultimate Frisbee Club (*UVictim*). Athletes will first be measured for physical attributes (i.e., height, weight, resting heart rate), and a timed 40-yard dash trial to derive a relative measure of speed. Athletes will be affixed with a 5 Hz sport specific GPS device (GPSports – Fyshwick, Australia, http://www.gpsports.com). The athletes will navigate an agility drill, specifically designed for deriving estimates of the space-time isochrones for each athlete. The GPS mobility data for each athlete will than be analyzed in a geographic information system (GIS) to investigate the geometric properties (e.g., size, shape, symmetry) of each individual isochrone.

Results and Conclusions

Results are discussed in relation to the concept of defensive coverage in team sports. Players with larger isochone areas at given intervals (e.g., 2 sec.) are therefore capable of covering more space. As well, the positional and mental aspects of defensive coverage (such as not responding to fake movements) will be discussed. Results will be related to tactical options available to coaches, and how such analysis could improve team management. Further discussion will identify future opportunities for mobility data and sports analysis.

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Loading Architecture for a Sensor Web Browser on Digital Earth

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Abstract

The world-wide sensor web observes real world phenomena at a particular moment in time with a large number of geo-referenced sensors. Sensor web needs a sensor web browser for accessing distributed and heterogeneous sensor networks in a coherent frontend. The Digital Earth provides a geo-referenced three-dimensional environment for intuitively browsing and displaying sensor observations. However, the major challenge is to load the vast amount of sensor observations from servers to a sensor web browser while minimizing the delay that a user experiences. This research uses two techniques to address the challenge. First, the browser caches transmitted data onto the local hard drive to reduce redundant internet bandwidth consumption. Second, this work designs a loading architecture to decouple sensor data loading, rendering, and browsing. The proposed scheme is implemented in the GeoCENS sensor web browser. To the best of our knowledge, with the proposed loading architecture, GeoCENS is the first Digital Earth-based sensor web browser.

Background and Relevance

The Digital Earth was envisioned in Gore's 1998 speech[1]. The Digital Earth is a three-dimensional visualization model of the physical Earth, which contains high resolution imagery and digital elevation models. Users are able to intuitively interact with Digital Earth by navigation features such as flying to places or floating above the surface. In recent years more and more publicly-available Digital Earths are revealed, such as ESRI's ArcGIS Explorer[2], NASA's World Wind[3], Microsoft's Bing Map[4], and Google Earth[5]. One of the visions that Gore described is that people can access vast amount of scientific information through the Digital Earth to help them understand real world. Therefore, at the same time that Digital Earths were being developed, the deployments of the world-wide sensor web were also put into practice for observing heterogeneous, environmental phenomena. The sensor web concept originated at the NASA/Jet Propulsion Laboratory in 1997 (Delin *et al.* 2005; Liang *et al.* 2005) for acquiring environmental information by integrating massive spatially distributed consumer-market sensors. The world-wide sensor web has been applied in a range of applications, including: large-scale monitoring of the environment (Hart and Martinez 2006), civil structures (Xu *et al.* 2004), roadways (Hsieh 2004), and animal habitats (Mainwaring *et al.* 2002). Ranging from video camera networks that monitor real-time traffic, matchbox-sized wireless sensor networks embedded in the environment for monitoring habitats, sensor webs generate tremendous volumes of valuable observations, enabling scientists to observe previously unobservable phenomena. Similar to how the World

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[1] http://www.isde5.org/al_gore_speech.htm
[2] http://www.esri.com/software/arcgis/explorer/index.html
[3] http://worldwind.arc.nasa.gov/java/
[4] http://www.bing.com/maps/
[5] http://www.google.com/earth/index.html

Wide Web needs an Internet browser for viewing web pages, the sensor web needs a coherent frontend for accessing the distributed and heterogeneous sensor networks. This kind of coherent frontend is called sensor web browser.

In order to achieve Gore's Digital Earth and sensor web visions, an online Digital Earth-based sensor web browser for users to browse, search, manage, and exchange sensor data is needed. However, transmitting the vast amount of sensor readings from servers to a sensor web browser with minimum delay is very challenging. Therefore, the goal of this paper is to present a sensor web data loading architecture for addressing the following two issues: (1) transmitting vast amount of sensor data and (2) minimizing the delay time that user might experience. To address the first issue, efficient data loading management utilizing a local cache is applied. To address the second issue, a loading architecture that decouples loading and browsing, a speculation mechanism, and a dynamic priority queue (Xhafa & Tonguz 2001) are applied. With the proposed scheme, efficient sensor web data loading and good user experience are attained. The sensor data used in this work are historical and can be represented as points on the Digital Earth.

Methodology

Issue 1: Transmitting Vast Amount of Sensor Data

To mitigate this issue, we can adopt strategies from Web browsers and how they are able to minimize redundant transmissions. Web browsers cache data, which means they store web page requests and associated responses as key-value pairs on the local disk in order to reduce unnecessary and redundant transmissions, and to improve end-to-end latency. Similarly, this work implements a caching strategy to reduce the unnecessary transmission of sensor data in the sensor web. However, sensor web browsers' requests and sensor observations are different from web browsers' requests and web pages. We cannot simply manage sensor web requests and responses as key-value pairs in web caches. A sensor web request can be interpreted as asking for sensor observations of a certain phenomenon in a set of spatio-temporal cubes. The spatio-temporal cubes can be distributed irregularly in space and time. An effective sensor web caching strategy requires efficient management of these spatio-temporal cube requests. Therefore, we develop a new spatio-temporal indexing structure, LOST-Tree (LOading Spatio-Temporal indexing tree) to manage sensor data loading with a local cache.

A LOST-Tree manages sensor data loading of one phenomenon. A LOST-Tree consists of two techniques. First, instead of indexing massive amounts of raw sensor data, a LOST-Tree will index requests (*i.e.*, spatio-temporal cubes). Because no actual data stored in LOST-Tree, it is small and able to fit into memory for efficient processing. Second, a LOST-Tree applies any two regular and aggregatable structures onto the spatial and temporal domains for transforming irregular spatio-temporal cubes into regular cubes. For instance, this work implements with a Quadtree (Finkel & Bentley 1974) and the Gregorian calendar. These two structures are integrated by using temporal structure (*i.e.*, the Gregorian calendar in this work) as main structure and embedding spatial structure (*i.e.*, Quadtree in this work) in nodes of temporal structure. In this way, a record in LOST-Tree represents a spatio-temporal cube, which allows simple look-up searches (rather than range query) for determining unloaded cubes. Records are inserted into LOST-Tree only if the corresponding cubes have been loaded. Since both structures are aggregatable, the more cubes are loaded, the fewer records remain. Therefore, a LOST-Tree is scalable, light weight, and able to efficiently identify unloaded potions in sensor web browser. By incorporating LOST-Trees into a sensor web browser, previously loaded sensor data can be retrieved from the local cache. The end-to-end latency can be reduced and the Internet bandwidth can be efficiently utilized on transmitting the data that has not been loaded.

Issue 2: Minimizing the delay time that users experience
In order to minimize the delay users might experience when loading sensor web data, we need to decouple data loading, rendering, and browsing. We implemented the following performance improvement strategies in the GeoCENS sensor web browser (Liang *et al.* 2010). (1) *Checker*: In order to reduce the requesting frequency, instead of executing loading processes whenever the Digital Earth is moving, loading processes start when the earth has stopped moving for more than a defined period of time (e.g., 500 milliseconds). This follows the assumption that a user's area of interest corresponds to where the user stops moving the Digital Earth. (2) *Wrapper*: After a user requests a spatio-temporal cube, a thread is trigged to determine the portions that are not available in the local cache (by using a LOST-Tree). The *wrapper* also filters out the requests that have been issued, and composes new loading tasks. (3) *Loader*: After the loading tasks are created, these tasks are stored into a queue waiting for being sent to the servers. A thread-pool with pre-defined number of threads polls these loading tasks from the queue and issues requests based on the loading tasks to the servers. After the data are transmitted to the browser, a thread is trigged to parse the data and store them in local cache. (4) *Poller*: The *checker*, *wrapper*, and *loader* are for the data loading, and the *poller* is for rendering. A timer runs periodically to check if user moves the Digital Earth. If not, a thread will then be trigged to retrieve data from the local cache and render the data on Digital Earth.

Besides applying the decoupling architecture, two additional mechanisms are implemented for improving a user's experience. They are speculation and dynamic priority queue. Firstly, speculation means the system issues requests before a user issues the requests. For instance, we expect users will browse the nearby regions around their initial area of interest. Therefore, when a user requests a spatio-temporal cube, the spatial component (e.g., bounding box) of the cube is then expanded. Secondly, users are allowed to navigate freely within the Digital Earth environment. A user may decide to move to other places before the previous loading tasks are digested. As a result, it is important to prioritize the loading tasks dynamically. For example, if we manage the loading tasks with a first-in-first-out (FIFO) strategy, new requests will not be executed until the old requests are finished. In this case, users may feel slower system performance because the system is background loading data they aren't expecting. Therefore, instead of following a FIFO queue, we apply a dynamic priority queue (Xhafa & Tonguz 2001) to prioritize the loading tasks. Whenever a user moves the Digital Earth, the priorities of loading tasks in the queue will be re-assigned with the distance between the current area of interest and the tasks' loading area. By using a dynamic priority queue, loading tasks that are close to the current area of interest will be requested from server first.

Conclusions

This paper presents a sensor web data loading architecture for constructing a sensor web browser. This work applies a caching mechanism that eliminates redundant transmissions and reduces end-to-end latency. Figure 1 depicts the end-to-end latency before and after implementing local caching. The cache mechanism significantly improves system performance. In addition, this work presents a loading architecture that decouples data loading, rendering, and browsing in order to minimizing the delay time that a user might experience while loading data from servers. Two additional mechanisms also improve user experiences: speculation and dynamic priority queue. With these mechanisms, users can efficiently and smoothly interact with a sensor web browser while transmitting vast amount of sensor web data in the background. We implemented the loading architecture in the GeoCENS sensor web browser (Liang *et al.* 2010). The GeoCENS sensor web browser can be accessed at http://www.geocens.ca. Based on our testing experience, the proposed loading architecture successfully addresses the challenges of integrating the Digital Earth and the world-wide sensor web. To our best knowledge, GeoCENS is the first Digital Earth-based sensor web browser.

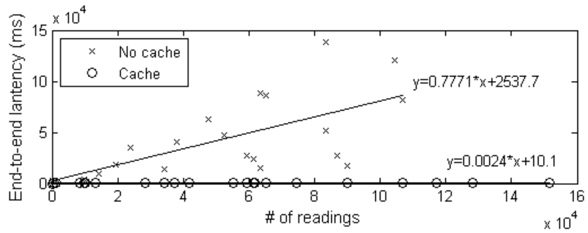

Figure 1. End-to-end latency before and after applying local cache

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A Hybrid Peer-to-Peer Architecture for Global Geospatial Web Service Discovery

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Abstract

For any large-scale distributed system, both communication and data management distill down to the problem of resource discovery. Similarly, the geoweb needs a resource discovery service for users to find the relevant web services that providing data of interest. The Open GIS Consortium (OGC) recommends tackling the question by using Web Catalog Service (CS/W). However, the system provides only local knowledge. In this work we propose and implement a locality-aware peer-to-peer (P2P) based system for global geospatial web service discovery. The system is scalable because it operates on a cooperative model and has no single point of failure. We use spatial hash indexing to preserve spatial locality information while retaining the load balancing properties of the underlay P2P networks. We evaluate our implementation with both simulated and real world data sets. Our experiments show promising potential of the architecture in both performing spatial and keyword query for discovering geoweb services.

Background and Relevance

Efficient methods for geospatial data discovery and exchange still pose a major challenge for scientists. It is not unusual that scientists working on multidisciplinary Earth Science research have to spend more than 50% time and resources on locating and acquiring data and information, pre-processing and assembling them into analysis-ready form (Di & McDonald, 1999). The technology for information extraction and knowledge discovery is accordingly considered far behind the technology for data collection (Di et al., 2008). Open Geospatial Consortium (OGC) recommended the Web Catalog Service (CS/W) to tackle the issue (OGC, 2007). However, existing OGC architectures and implementations have the following issues:

1) **Single points of failure**: CS/W becomes a system performance bottleneck. When a CS/W portal ceases to function, users are not able to search for services in interest even though the services are functioning;
2) ***A priori* knowledge of CS/W locations**: users have to know the location of existing CS/W servers *a priori* to search for OGC web services (OWS).
3) **Difficult to maintain and manage**: data publishers have to find one or multiple CS/W portals to publish their resources. Without proper tools, management and maintenance can be difficult and challenging.

We argue that using a peer-to-peer (P2P) approach can address the above-mentioned problems and enhance the existing CS/W systems. However, building a P2P system for geospatial web service discovery needs to consider the following unique settings:

1) An OGC server (mostly hosted by large organizations, e.g., Natural Resource Canada, NOAA, and NASA) is a *stable peer* in the system that would not join and leave randomly; in most cases these servers are made accessible 24-7.
2) The volume of data served by OGC servers is huge in general while the number of servers is considerably smaller.
3) There are a greater number of dynamic and transient users (compared to the number of servers). In other words, users are *dynamic peers* in the system that join and leave frequently.

P2P systems normally implement an abstract overlay network built on top of the psychical network. Such overlays are for peer indexing and discovery. According to how peers are organized, generally P2P overlay network is categorized into two paradigms:

1) Structured system: In the system peers are organized and optimized by algorithms and specific criteria such as CAN (Ratnasamy et al., 2001), Pastry (Rowstron & Druschel, 2001), Chord (Stoica et al., 2001). As a result, peers are connected with specific topologies and properties. It offers a scalable solution for exact-match queries.
2) Un-structured system: Peer connections are randomly created so that the overlay network is not optimized by any specific algorithm. Such a system (e.g. Gnutella (Doyle et al., 2001)) is generally more appropriate for accommodating highly transient peer populations (Androutsellis-Theotokis & Spinellis, 2004).

In a geospatial web service discovery context, extension and customization are required for existing architectures to enhance the system stability and reliability. Considering the above-described settings (i.e., a mixture of stable and dynamic peers), the unnecessary overhead required to maintain the structured overlay network makes use of a structured design impractical. On the other hand, an unstructured design diminishes the system stability from stable peers.

As a result, we propose a hybrid P2P approach for geospatial web services discovery. The goal is to build a dynamic, scalable, and decentralized OGC CS/W with flexible spatial and keyword querying capabilities. The proposed system is also unique in that it is a locality-aware system, that is the system is able to exploit the locality information between peers in order to deliver the query results quickly and efficiently.

Methods and Data

Figure 1 depicts the core elements of this distributed geospatial service discovery system. A quadkey (i.e., a quadtree key) is a unique geographical identifier adopted in the system. A geographical location (i.e., latitude and longitude) can be converted from two-dimensional coordinates into a one-dimensional string (i.e., quadkey) using Peano Space-Filling Curves a particular level of detail. Instance here refers to the application running on the local machine. Specifically, in the system only the Hybrid P2P instance runs on machine of a dynamic peer while both instances are executed on a stable peer (i.e., an OGC server). The Hybrid P2P instance is composed of two engines:

1) The **communication manager** provides the interface to users and peers (i.e., neighbors in Figure 1). It is responsible for following tasks:

   i. Determining a physical location of the peer (through IP geolocator) and its location quadkey based on Peano SFC.

   ii. Network setup and cooperative discovery.

   iii. Receiving queries from users. It further resolves the queries by using the local query engine. If no local match found, it sends requests to other peers and merges the received responses as response to the original query.

   iv. Receiving queries from peers in the system. Similar to task iii, it first resolves the local query. Then it sends the response to the requester peer if a local match found. Otherwise, it forwards the query to other peers if the query is still alive (i.e., Time To Life (TTL)>0), merges received responses from forwarded peers as the response to the requester peer.

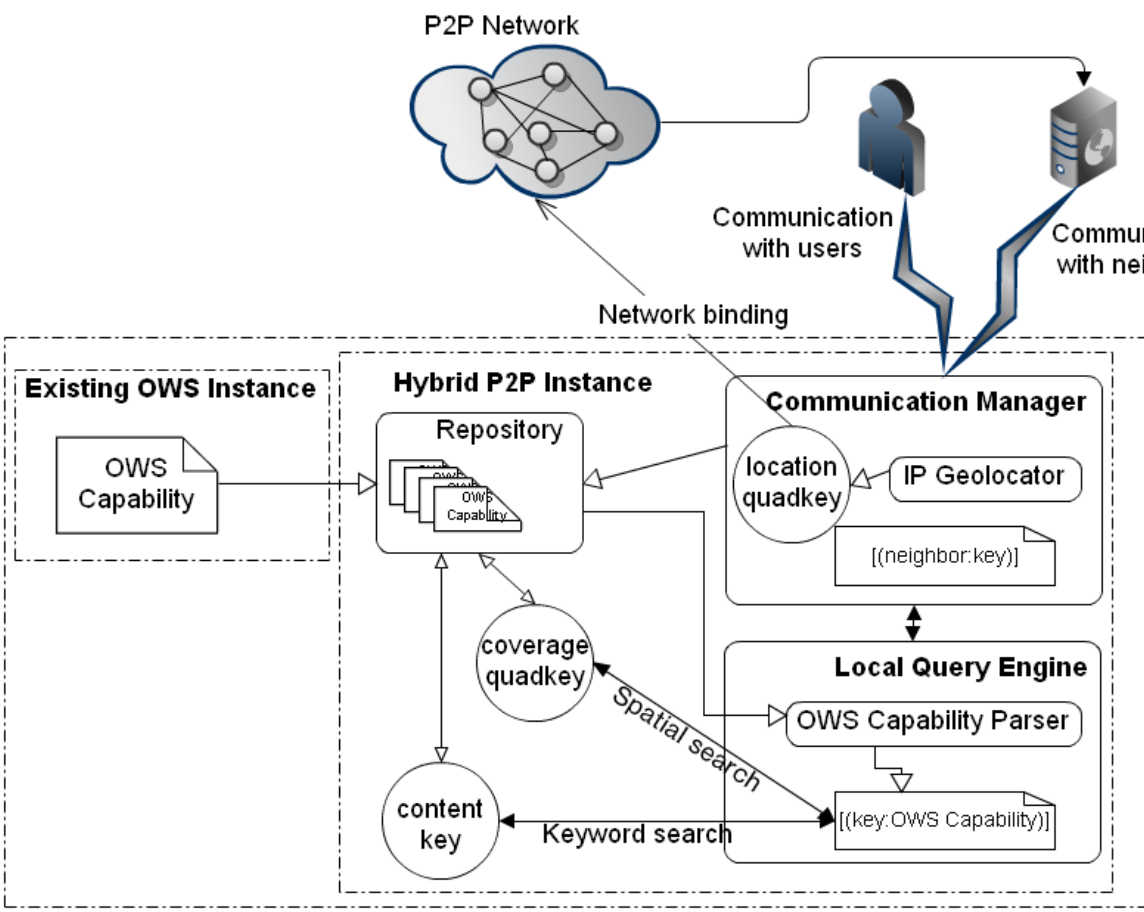

Figure 1 System Architecture (existing OWS is an optional component)

2) The **local query** engine handles following operations:
    i. Spatial indexing OWS capabilities XML document by determining its coverage quadkey.
    ii. Receiving queries from communication manager, searching the local repository for matching services and sending a response to the communication manager.

Results

In this work we present emulation results by using the following settings:

1) Network topology: a Bittorrent swarm replica
2) Search mechanism: *Random Walks* (Lv et al., 2002) and proposed *Locality-Aware Walks*. The former approach is essentially a blind search that a peer forwarding queries randomly chosen neighbors. On the contrary, a locality-aware walks directs queries based on the geographical location that a query is looking for.
3) Query: A Nearby Region-of-Interest (ROI) query is a query looking for services geographically closed to the requester peer. Remote ROI query refers to a query looking for services geographically far from the requester peer.

As shown in Figure 2, *Locality-Aware Walks* design creates higher search hits than *Random Walks* with both types of query. Moreover, in the case that a user querying for dataset in his neighborhood, search hit rate of *Locality-Aware Walks* (0.919 in Table 1) is three times higher than *Random Walks* (0.296 in Table 1).

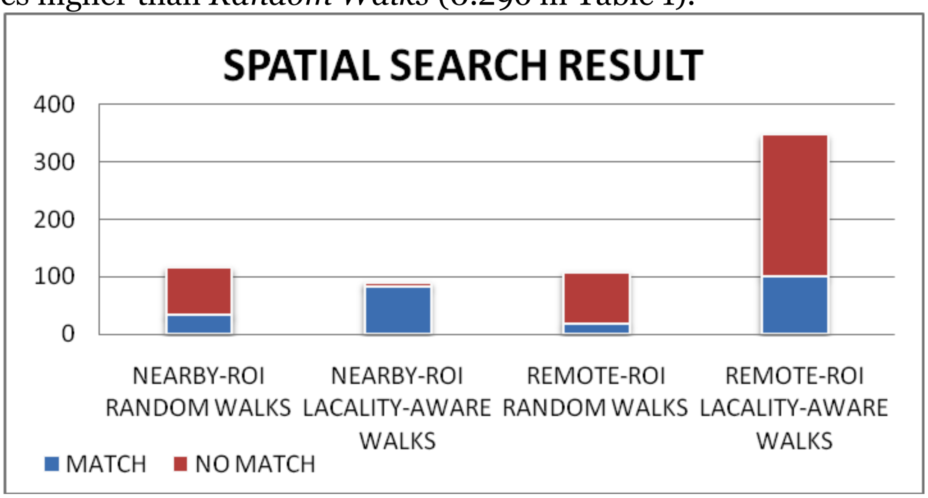

Figure 2 Average Message Productions

From Table 1 we notice that the number of hops is similar for two designs. This happens because, with small network size, a dynamic peer (i.e., a user) is easily neighbored to a stable peer (i.e., an OWS server). One interesting observation is how transmission delay is affected by geophysical distance. *Random Walks* design connects peers regardless of their geographical location and as a result tends to induce larger transmission delay.

Table 1 Statistics of Emulation Result

	Nearby-ROI Random Walks	Nearby-ROI Locality-Aware Walks	Remote-ROI Random Walks	Remote-ROI Locality-Aware Walks
Search Hit	0.296	0.919	0.203	0.290
Maximum Hops	2	3	3	4
Average Hops	0.935	0.739	1.223	1.830
Maximum Transmission Delay	1200	840	1400	1240
Average Transmission Delay	402.533	220.118	632.9577	322.994

Conclusions

We have presented and implemented new hybrid P2P architecture to enhance OGC CS/W for global geospatial web service discovery. The system provides two functions: (1) service discovery and (2) service publishing. That is, if a user decides not to publish to an OGC CS/W server, the service can still be accessible and discoverable with the proposed system.

Our preliminary experiments focus on three metrics, namely accuracy, the number of exchanged messages and the number of the discovered services. *Locality-Aware Walks* produce much higher accuracy results with less network transmission delay than *Random Walks*, but it may incur higher network traffic in extreme cases.

We are currently improving the primitive implementation to emulate a larger scale of network.

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Mesoscale Temperature Patterns in Southern Alberta

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Abstract

Near-surface air temperatures were monitored from May 2005 to the present in a landscape scale network of 280 sites in the foothills of the Rocky Mountains in southwestern Alberta, Canada. The monitoring network covers a range of elevations, topographic conditions, and surface environments and provides a high-density array that is uncommon in meteorological observations, allowing for detailed analysis of surface influences. Here we report on the seasonal structure of temperature patterns and near-surface lapse rates in the region for the period 2005-2009. Regression models identified the influence of synoptic weather systems on regional temperature patterns and prevailing lapse rates. To explore this further, we examined daily temperature patterns when the region is under the influence of two common weather systems that impact the region: cold (continental polar) air masses and chinooks.

Background and Relevance

Spatial-temporal patterns of temperature variability are relevant to a broad range of Earth surface processes, and many scientific disciplines confront the need to estimate local- or regional-scale surface temperatures based on point measurements or atmospheric models. Temperature is considered to be a relatively straightforward meteorological variable to interpolate on climatic scales, because temperature fields are continuous and horizontal temperature gradients are typically low when averaged over many years, over which time the effects of individual weather systems average out.

This generalization breaks down in regions with complex terrain, such as mountain environments, where varying topography can lead to processes such as cold air drainage and pooling in valley bottoms (Rolland, 2002), and variations in solar heating occur as a function of slope, aspect, and topographic shading (Barry, 2008). Contrasting surface conditions (e.g., snow vs. rock vs. forest environments) also lead to gradients in the surface energy balance processes that govern near-surface air temperature. These complications are rarely addressed, as meteorological data is generally unavailable to evaluate their importance. Instead, temperatures in complex terrain are typically estimated based on low-elevation (e.g., valley-bottom) data along with vertical temperature gradients based on typical values of the free-air atmospheric lapse rate, –6 to –7°C km^{-1} (e.g., Legates and Willmott, 1990; Walland and Simmonds, 1996; Dodson and Marks, 1997).

Standard atmospheric lapse rates may not represent near-surface temperature when interpolating temperature observations over shorter time periods or in areas of variable terrain. Surface environment, terrain features, and atmospheric conditions play a complicated role in dictating spatial and temporal patterns of surface temperature (McCutchan and Fox, 1986; Bolstad et al., 1998; Pepin et al., 1999). Large scale weather systems and local to regional air mass movements, such as the chinook winds that descend in the lee slope of the Rocky Mountains, also alter surface temperatures in ways that cannot be estimated as a simple function of elevation. Several studies have examined the seasonal and spatial variation in near-surface temperature patterns and lapse rates (*i.e.* Pepin et al., 1999; Pepin and Losleben, 2002). Many of these studies found influences of terrain variables, surface environment and synoptic weather systems; however, they have not been examined in detail.

Methods and Data

Data for this study were collected as part of the University of Calgary Foothills Climate Array (FCA), which has been in operation since the summer of 2004 and has a spatial coverage of approximately 24,000 km^2, with a station density of one station per 86 km^2. The weather stations that make up the FCA are deployed in a grid extending from the continental divide, across the eastern slopes of the Canadian Rocky Mountains to the agricultural prairie lands east of Calgary, Alberta. Stations were located 5 to 10 km apart along twelve west-east running transects located between 116°21'W and 113°21'W. North-south transect spacing was approximately 10 km, ranging from 51°32'N to 50°18'N. Stations collect and store instantaneous measurements of temperature and humidity at the top of every hour and are visited yearly to download the collected data.

Hourly station data was processed for daily mean, minimum and maximum temperatures. Initial quality control algorithms were developed to flag and omit suspect data, based on several known problems. Data that was retained were then compiled into daily, monthly, seasonal, and annual means. Seasonal means were calculated for each site based on the conventional meteorological seasons (DJF, MAM, JJA and SON). We then aggregated all available seasonal and annual data from each site to derive nominal five-year (2005-2009) mean values, although means were calculated from fewer years for sites with missing data.

36 multivariate statistical models of monthly temperature patterns were developed, with independent variables measured at each station location that were hypothesized to impact local temperature. These included elevation (measured with a GPS), aspect and slope (estimated), and surface vegetation (categorized in the field as urban, prairie, shrub, forest and rock). Daily temperature patterns were also explored for ensembles of two prominent weather systems that influence winter weather in the region: chinook and continental polar (cP) air mass incursions.

Results

We found an east-west gradient of mean seasonal temperatures in all seasons, reflecting the increase in elevation to the west. Temperature decrease with elevation (lapse rate) was –5.3°C km^{-1} and –4.8°C km^{-1}. Mean seasonal lapse rates were found to be steepest in spring and summer, ca. –6°C km^{-1}, with weakening in the fall and winter seasons as reported in previous studies (e.g., Shea et al., 2004). Winter lapse rate estimates differed markedly for the complete ensemble of FCA sites and the regression with stations aggregated into 100-m elevation bands. There was a large degree of variability in the winter season, giving a weak regression result with the complete set of data. Binning by elevation provided a stronger statistical result, so the associated winter lapse rate, ca. −4°C km^{-1}, may provide a good estimate.

The best temperature models were daytime and monthly models, with better explanatory power for the multivariate models observed in the summer months (April to September). There was high variation in the elevation coefficients, ranging from −1.0°C to −9.3°C km^{-1} with a mean of −4.3°C km^{-1}. Elevation coefficients could not be directly compared with the seasonal lapse rates calculated above, as other independent variables modified the predicted temperature in the multivariate model. They were nevertheless indicative of lapse rates, with diurnal and seasonal variability that is similar to what has been reported elsewhere (e.g., Shea et al., 2004; Pepin and Losleben, 2002).

One hundred and two chinook days and cP air mass days from 2005-2009 were compiled for this analysis. For the ensemble of chinook events, the mean temperature at all FCA sites was 0.0°C, with a between-site standard deviation of 2.6°C. Corresponding values under the influence of cP air masses were −16.9 ± 1.4°C. On chinook days, all sites were warmer than their mean DJF temperatures, with anomalies from 3.1 to 9.3°C. The mean site winter temperature anomaly was 7.1°C. The highest anomalies were in the eastern part of the study area. All sites were colder under the influence of cP air masses, with mean temperature anomalies from −13.0 to −3.9°C for the ensemble of cP days. The average temperature anomaly across all of the FCA sites was −9.8°C. Anomalies were again strongest in the eastern, prairie portion of the study area and were more muted in the foothills. Hence, both chinooks and cP air masses introduced high variability in the eastern part of the region.

Conclusions

The three phases to the analysis presented here paint a coherent picture of the patterns and controls of mesoscale temperature variability in the foothills region of southern Alberta. Our analysis shows the eastern, prairie sites within the study area experience more continental conditions, with a greater influence from cP air masses in winter and a greater degree of seasonal and annual temperature variability. The western edge of the study area has several high-elevation sites along or near to the continental divide. Both these sites and transitional sites in the foothills are colder overall but they experience less variability and less frequent influences from cP air masses; Pacific air masses are more influential here.

The chinook signal in the region introduces a notable exception to this. Anomalous seasonal warmth associated with chinooks is strongest at intermediate altitudes in the foothills region, with lesser warming along the western and eastern edges of the study area. This pattern explains some of the spatial and altitudinal temperature structure observed in the region in the winter season, but it largely opposes the spatial structure induced by cP air masses. The average winter temperature patterns are a complex composite that reflects the relative frequency of these two influences, amongst other weather systems.

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CGDI Operational Policies Facilitate the Access, Use, and Sharing of Canadian Geospatial Information

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Abstract

This paper presents the role that geospatial operational policies play in overcoming obstacles to accessing and using geospatial information via the Canadian Geospatial Data Infrastructure (CGDI). Geospatial operational policies are defined as analyses, guidelines, directives and policies that direct organizations in their day-to-day business. They relate to quality, consistency, accountability and requirements of geospatial information and address topics related to the life cycle of geospatial data (i.e., collection, management, dissemination and use). Over the past several years, GeoConnections has led research and consultations to identify and fill geospatial operational policies gaps across a range of issues. Key topics in geospatial operational policies will be described and resulting geospatial operational policy guidelines and best practices will be presented for several topics including sensitive information and privacy.

Background

Canadian Geospatial Data Infrastructure (CGDI)

The CGDI helps Canadians gain new perspectives into social, economic, and environmental issues, by providing an online network of resources that improves the sharing, use and integration of information tied to geographic locations in Canada. More specifically, the CGDI is the convergence of policies, standards, technologies, and framework data necessary to harmonize all of Canada's location-based information. Consequently, the CGDI reduces barriers to using geospatial information so that Canadians can discover, access, visualize, integrate, apply, and share quality location-based information and make effective decisions.

GeoConnections

The GeoConnections program is a national initiative, led by Natural Resources Canada, designed to facilitate access to and use of authoritative geospatial information in Canada. In its third mandate (2010-2015), GeoConnections will complete the CGDI by ensuring that the infrastructure is comprehensive, usable, high-performing, relevant and poised for future growth and development. GeoConnections supports the integration and use of the CGDI and is working to advance the geospatial operational policies needed to complete the CGDI.

Relevance

"More and more, geospatial information is becoming embedded in private and public sectors activities, as well as in the everyday lives of Canadians. Among the factors contributing to the growing use of geospatial data are a rapidly expanding world market for innovative geomatics products and services, and increasing evidence of the positive impact that geospatial data has on the economy and the quality of public services.

Although technology has removed many of the technical barriers to sharing geospatial data, gaps in geospatial operational policies were identified to address the demands of a changing environment. New geospatial operational policy guidelines and best practices on key topics (see below) are needed to promote data exchange and integration, and to ensure that social, economic, and environmental decisions are taken with the benefit of the best available information." (GCPedia, 2010).

Key topics that impact geospatial operational policies:

- Security
- Privacy/confidentiality/sensitive information
- Mobile & location-based services
- Volunteered geographic information/crowd-sourcing
- Intellectual property/copyright
- Digital rights management
- Licensing
- Archiving and preservation
- Open data
- Ethical legal practices
- Liability
- High resolution imagery
- Web 2.0/social networking
- Mass market geomatics
- Data integration
- Data quality

GeoConnections is working to advance the geospatial operational policies needed to complete the CGDI. The development of tools and resources such as guidelines and best practices will educate and help organizations integrate the CGDI into their business practices.

Methods and Data

GeoConnections contracted private firms to respond to these geospatial operational policy needs. Among others, AMEC Earth and Environmental was contracted to conduct research and stakeholder consultation (surveys and workshops) in supported of the development of best practices related to sensitive geospatial information (GeoConnections, 2010 a). Also, CanadaPrivacy Services Inc. was contracted to conduct research and consult with the Federal Government Geospatial Privacy Advisory Group to examine the interface between privacy and geospatial information in the federal public sector in Canada.

Results

"With advances in information communications technologies and associated geospatial capabilities, concerns arise in regards to the ease of sharing, layering of multiple geo-referenced datasets and viewing geospatial data and images." (GCPedia, 2010).

Sensitive Information:

Sensitive information is data and information products which contain confidential details. ***Challenge***: How to protect sensitive information while sharing geospatial data? ***Solution***: With geospatial operational policies.

Best Practices on Sharing Sensitive Environmental Geospatial Data

This guide highlights issues and concepts associated with the protecting, sharing and utilization of sensitive geospatial data related to the environment and sustainable development; provides frameworks for assessing data sensitivity; and describes potential mechanisms for facilitating the sharing of data, including online transactions (GeoConnections, 2010 a). These best practices provide the reader with sufficient insight and links to resources in order to assist them in implementing a consistent and documented approach to managing and sharing sensitive environmental geospatial data within their organization.

http://www.geoconnections.org/publications/Key_documents/Sensitive_Env_Geo_Data_Guide_EN_v1.pdf

How to categorize geospatial data as sensitive data

Data can generally be categorized as sensitive geospatial data if it meets any of the following criteria:

1. ***Legislation/Policies/Permits*** – the data is identified by legislation as requiring safeguarding;
2. ***Confidentiality*** – the data is considered confidential by an organization or its use can be economically detrimental to a commercial interest;
3. ***Natural Resource Protection*** – the use of the information can result in the degradation of an environmentally significant site or resource;
4. ***Cultural Protection*** – the use of the information can result in the degradation of an culturally significant site or resource; or
5. ***Safety and Security*** – the information can be used to endanger public health and safety.

Best Practices when working with sensitive data

The Best Practices identify basic principles that can be applied to assessing sensitive geospatial datasets in order to classify sensitivity consistently:

1. Unless the dataset is classified as sensitive it can be provided free of restrictions;
2. Information can not be considered sensitive if it is readily available through other sources or if it is not unique;
3. The Data Custodian of the information is the only agency that can determine whether a geospatial dataset is to be classified as sensitive;
4. Data Consumers of sensitive geospatial datasets must honour the restrictions accompanying the information in the form of an agreement, license and/or metadata; and
5. Organizations should document and openly publish their process, criteria and decisions.

Privacy

For the Office of the Privacy Commissioner of Canada (OPCC), privacy means "...the right to control access to one's person and information about one's self. The right to privacy means that individuals get to decide what and how much information to give up, to whom it is given, and for what uses." (GeoConnections, 2010 b). ***Challenge*** : How to protect the privacy of all individuals in Canada? ***Solution***: With geospatial operational policies.

Geospatial Privacy Awareness and Risk Management Guide for Federal Agencies (to be published in 2011)

This guide is intended to provide officials of federal government agencies with assistance in making decisions related to the collection, use, disclosure and retention/disposition of geospatial personal information (GeoConnections, 2010 b). While directed to the federal public sector, it is intended that the Guide be as general as possible so that it will be relevant to, and can be of utility to, the public, private, non-governmental organization ("NGO") and academic sectors.

Guidelines, including the *Seven "C's" of Geospatial Privacy*, for identifying and mitigating privacy-related risks and issues arising from the collection, use, retention, disclosure and disposition of personally identifiable geospatial information were developed. The Seven "Cs" include:

- **CHARACTERIZATION**: Data as personal or non-personal information.
- **CONTEXT**: A direct and important impact with privacy law and policy.
- **CONSULTATION**: When in doubt consult!

- **CONSISTENCY**: Each federal organization should make a concerted effort to ensure that it adopts a consistent approach to dealings with potentially identifiable geospatial information.
- **CUMULATIVE**: Geospatial data elements that are not identifiable when considered individually may become identifiable when combined with other data elements.
- **CAUTION**: "When in doubt, don't" is an appropriate initial approach to the issue of whether individual elements of geospatial data should be collected, used or released to third parties.
- **CONSTRAINT**: When disseminating either identifiable or de-identified information to third parties, be sure to consider the merits of restricting the data recipient's rights via contract.

Conclusions

Geospatial operational policy guidelines and best practices on key topics related to the life cycle of geospatial data (i.e., collection, management, dissemination and use) are needed to promote data exchange and integration, and to ensure that social, economic, and environmental decisions are taken with the benefit of the best available information. These geospatial operational policies are helping organizations in their day-to-day business to overcome obstacles to accessing and using geospatial information.

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