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Volume 1

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This is the proceedings of the 2009 conference of Spatial Knowledge and Information Canada, held February 19-22 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 research, geomatics, remote sensing, geospatial web 2.0, and spatial statistics and 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 would stimulate additional avenues of exploration.

The 2009 conference was held in partnership with the GEOIDE Network Center of Excellence. Over 60 researchers, university faculty, students and interested parties from across Canada registered and attended. While the focus of the organization and conference is to bring together the Canadian Geographic Information community we also invited a small number of international attendees. The conference was composed of 43 scientific papers. We were delighted to have as our keynote speaker, Marie Josée Fortin, who wowed the audience with her lucid explanations of geostatistics. The conference concluded with a conference planning meeting on the final day, where we decided to skip a year due to the Winter Olympics to be held in British Columbia and resume our conference in 2011.

A substantial focus of the conference continues to be the promotion of Canadian student research on Geographic Information. We were excited to have 29 presentations by undergraduate, Master's, PhD students and postdoctoral fellows. We awarded seven outstanding students substantial awards for their research and presentation quality. First prize went to Jonathan Cinnamon, Simon Fraser University, for his presentation "Injury data collection and analysis in low-resource settings Using Web 2.0 and the Geospatial Web". Three people tied for second prize: Cyrille Médard de Chardon, Simon Fraser University, for his presentation "Real-time Interactive Groundwater Visualization using 3D Cellular Automata", Stine Barlindhaug, UBC Okanagan, for her presentation "Cultural sites, traditional knowledge and participatory mapping; Long-time landscape use in Sápmi" and Gregory Mc Quat, Queens University, for his presentation "3D Cellular Automata and Mobile Terrestrial Lidar: Simple rules for urban geography." Honourary mentions went to Jake Wall, UBC, for his presentation "Elephants Avoid Costly Mountaineering", Andrew Cuff, Memorial University, for his presentation "Improving seabed classification through the use of multiple acoustic frequencies" and Krista Jones, Memorial University, for her presentation "Relationships between Cold-water Corals off Newfoundland and Labrador and their Environment". Congratulations, prize winners and to all our student presenters!

Please enjoy the extended abstracts of student and faculty talks in these 2 volumes, visit the SKI-Canada site and attend the 2011 conference.

Volume 1

Volume 2

Is the Development of Environmental Knowledge in Human Wayfinding Sequential or Simultaneous?

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Abstract

The purpose of this study is to understand the steps of human wayfinder develop environmental knowledge and associating factors. Understanding how humans acquire environmental knowledge contributes to designing and improving navigational aids. The knowledge we use to solve wayfinding problems—environmental knowledge—is classified into landmark-, route-, and survey-based categories. Different from the traditional and dominant framework which suggests the acquisition of these types of knowledge takes place sequentially, growing efforts have been made to investigate an alternative framework that argues the simultaneous acquisition of environmental knowledge. After being trained in an unfamiliar environment through active exploration on an indoor route, participants in this experiment performed spatial tasks including wayfinding in one of three different navigational landmark scenarios (landmarks with directions, landmarks without direction, and no landmarks). Results support the hypothesis that knowledge acquisition does not follow the dominant framework but the alternative framework. Furthermore, landmarks served promisingly for recognition of locations but weakly for the development of survey knowledge. Furthermore, sense of direction had a positive effect on development of survey knowledge in the scenario where landmarks were unavailable.

Background and Relevance

Wayfinding in large-scale unfamiliar spaces requires the development of a mental representation to support spatial decision making (Golledge, 1999). Research on human wayfinding behavior contributes to our understanding of environmental acquisition and related applications, such as navigational systems and mapping services. Environmental knowledge has been studied extensively; one outcome of this research is a traditional classification framework for that knowledge. The accepted and traditional framework consists of three categories: landmark-, route- and survey-knowledge (Siegel & White, 1975). However, the strict sequencing of the three categories (landmark, then route, then survey) and the transition of the knowledge from non-metric to metric has intrigued researchers who search for a clearer understanding of how we acquire knowledge from the environment and correspondingly the navigation strategies for which this knowledge is used. In contrast to the traditional framework, an alternative framework proposes that knowledge at all levels is acquired simultaneously and refined quantitatively through experience (Montello, 1998). Therefore, the primary goal of this study is to investigate whether metric survey knowledge is developed during the earliest stages of acquisition. If so, the next consideration is how the characteristics of an environment, especially landmarks, contribute to the development of environmental knowledge.

Methods and Data

An experimental route was planned on the first floor of a campus building at the University of Saskatchewan. Except one group which consisted of 9 male and 11 female students, 31 female and 29 male students were randomly divided into three groups with equal number of males and females. None of them had previous experience in this building before the experiment.

All of the experimental sessions were carried out on a one-on-one basis in the following order: route training, directional estimation, route retracing, and directional estimation. Each participant was in one of three unique conditions:

1. Learning and retracing with navigational landmarks indicating right and left turns at decision points;
2. Landmarks indicating left and right were present during training but replaced with generic landmarks during retracing;
3. Landmarks indicating left and right were present during learning but completely removed before retracing started.

Directional estimation consistent with a validated procedure (Bell & Saucier, 2004) was conducted at the arrival of both destination and origin. Each participant's estimations were compared to the actual angle; hence the resulting absolute errors were recorded in the range between 0 ^{o} and 180^{o}.

Results

The absolute pointing errors are compared in two different ways. Fist comparison is between the two directional estimations by the same group. Group 3 ($F(1,19)=2.742$, $p=0.008$) showed significant pointing improvement on accuracy in the estimation, while there was no improvement in pointing accuracy in groups 1 ($F(1,19)=-0.198$, $p=0.845$) and 2 ($F(1,19)=-0.766$, $p=0.448$). This was followed by the comparison between groups on the first pointing task. Since each participant learned the route in the same way, there were no difference among the groups in the first pointing task ($F(2, 57) = 0.087$, $p = 0.916$). In addition, all angular estimations were better than chance performance (90^{o}).

The main purpose of the second comparison was to examine the contribution of different environmental characteristics to the development of survey knowledge. Among all three pairs there was a significant difference between group 2 and 3 (($F(1,38)=4.634$, $p=0.038$). No significant difference was found between group 1 and 2 (($F(1,38)=0.001$, $p=0.978$) but a marginal significance was found between group 1 and 3 (($F(1,38)=3.361$, $p=0.075$). The presence or absence of landmarks appears to be important to the development of survey knowledge.

First of all, the initial knowledge people obtain when they travel into a new environment is not limited to landmark knowledge as suggested in traditional framework. Instead,

the process of acquiring metric and non-metric environmental knowledge starts simultaneously at the earliest stages. In particular, survey knowledge is acquired along with more primitive forms of spatial and non-spatial knowledge, although its improvement depends on the experiences with the environment.

Conclusions

The alternative framework is supported by these experimental results. Even though different levels of knowledge develop simultaneously at a wayfinder's initial exposure to an unknown environment, the refinement of environmental knowledge is influenced by the nature of the environment in which learning occurs as well as the type of navigational assistance available in that environment. Additionally, the contribution of landmarks to the improvement of survey knowledge is very weak. Based on the experimental results it actually inhibits the development of some survey knowledge.

It was suggested that the sequence we acquire environment knowledge appeared to be the same order that we utilize the acquired knowledge (Lawton, 1996). The assessment of the alternative framework establishes the basis for further examination on utilization of wayfinding strategies and their sequence of use.

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Elephants Avoid Costly Mountaineering

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Save the Elephants[2]

Abstract

We collected and analyzed high resolution data on the whereabouts and movements of African elephants giving us, for the first time, a look at elephant 'negative' space (i.e., the areas elephants don't go).

Background and Relevance

Understanding the spatial behaviour of African elephants (*Loxodonta Africana*) is vital to successful conservation and management of this unique species throughout Africa. Only recently has high resolution data been collected on the whereabouts and movements of African elephants giving us, for the first time, a look at elephant 'negative' space (i.e., the areas elephants don't go). What becomes immediately apparent is their avoidance of sloping terrain and by extension, hill climbing. In this study we looked at this observation from the elephant's point of view, and found that the energetics of moving up gradients is likely the main deterrent from doing so. Terrain, or more appropriately the energy landscape, influences elephant movements to a large degree and must be a factor in any spatial modeling.

Methods and Data

Global Positioning System (GPS) tracking data was collected from 54 elephants within Samburu National Reserve (SNR) in Kenya over a period of several years (1998 – 2004), giving a total of 137,000 recorded locations. Elephant positions were collected at hourly intervals and the 54 individuals are considered a representative sample of the ~900 elephants who frequent the reserve. A Digital Elevation Model (DEM) was derived from contours from a 1962 Aerial Survey map of the region which represents the most accurate elevation data available. A subset of 20,000 randomly selected positions were chosen and slope values extracted for each position. An elephant fix density (fixes/km^2) was calculated for each unit slope of terrain (degrees) found within the reserve.

Results

An exponentially decreasing elephant fix density was found with increasing hill slope (R^2=0.90). This was attributed to the allometric scaling with body mass of the energy required to move up hilly terrain. An energy landscape was created based on the energy requirements for movement against gravity for both a 100

Kg and 5000 Kg individual. It was found that the energy to move vertically one meter for an elephant was 2500% the cost of it to move horizontally 1 meter and given that the base metabolic intake for an elephant requires up to 17 hours of foraging a day, this puts severe constraints on the amount of hill climbing that an elephant can do.

Conclusion

Owing to allometric scale relationships elephants are the least energetically efficient land mammals at climbing hills. Terrain puts severe energetic restraints on movement and it is very useful for modeling purposes to consider movement around a landscape in energetic terms. This is likely the reason for the exponential decline in elephant incidence with increasing hill slope. This study represents a key step in understanding how these mega-fauna perceive the world around them and the factors/drivers affecting their decisions.

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Spatial exploration of the relationship between grizzly bear health and environmental conditions in Alberta

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Abstract

McLellan (1998) documents how human activities since European settlement in North America have caused the large-scale reduction of grizzly bear range and decline in numbers. Increasing human activity in the Rockies may prevent bears from accessing sufficient and key food resources and cause stress through human-bear conflict and hunting. This can decrease the bears' health in the long term and potentially reduce their ability reproduce successfully (Cattet et al., 2003). To ensure the population can remain viable into the future, landscape managers must understand the key environmental factors critical for grizzly bear health. It is necessary to go beyond measurement and prediction of grizzly bear occurrence and abundance as these can be poor indicators of demographic performance (Van Horne, 1983; Hobbs and Hanley, 1990; Tyre et al., 2001, cited in Nielsen et al., 2006, p.218). It is therefore the aim of this study to uncover non-spatial and spatial relationships between grizzly bear health and environmental factors, including human disturbance features such as roads and well-sites.

Various environmental datasets, grizzly bear health measurements and GPS locations of grizzlies were provided by the Foothills Model Forest Grizzly Bear Research Program. Health data is comprised of several variables for body growth and condition, immunity and stress and are combined into a single indicator of health or health score using expert opinion (Saaty, 1977) and fuzzy logic (Zadeh, 1965). This process was found to normalize differences between bears of different reproductive classes making it possible to use all bear data in a single analysis.

The units of analysis are the core home ranges of the bears computed from GPS locations using a kernel density estimator (Silverman, 1986). Environmental variables are assessed over the core home range of each bear. Categorical variables are computed as a percentage area of the core home range and numerical variables as an average. Exploratory analysis is carried out to uncover relationships among dependent and independent variables, discover spatial trends and detect if spatial autocorrelation is present.

Spatial autocorrelation is frequently found in spatial datasets and causes the usual assumptions of conventional statistics to be invalid (Anselin, 1990). Spatial autoregressive models are a means to overcome the limitations of conventional statistical models when spatial autocorrelation is found (Anselin & Bera, 1998). Based on the exploratory analysis results various statistical models are developed to link the health score with environmental variables and then compared. The results and limitations encountered will be presented.

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Spatially Evaluating Resource Selection Functions using Conditional Randomization

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Abstract

Resource selection function (RSF) models are increasingly being used to predict maps of the relative probability of wildlife occurrence. Current methods evaluating a RSF's accuracy are reported as singular values, representing the overall ability of the model to correctly determine species occurrence. These methods do not indicate the spatial location or variation in accuracy. The spatial dependence in error values may relate to ecological processes unaccounted for in the original RSF. The purpose of this research is to explore spatial methods of evaluating RSF models using a conditional randomization approach. A case study on adult female grizzly bears (*Ursus arctos*) is used to demonstrate our approach. Local test statistics computed from bear telemetry locations are used to identify RSF scores that are statistically lower than expected. Through examining landscape characteristics associated with significant areas, factors that may contribute to the unexpected RSF values can be identified.

Background and Relevance

A resource selection function (RSF) is a model that determines the probability of use of a particular resource unit (Manly et al. 2002). They are often used as a quantification tool in ecology since resource location determines the distribution and abundance of organisms (Boyce and McDonald, 1999). RSF models statistically correlate field observations to a set of habitat variables with the intention of reflecting essential elements of the organism's ecological requirements, such as climate, land-cover, and geology.

The predictive capacity of a RSF is commonly reported as a singular accuracy value (Fielding and Bell, 1997) that measures the overall ability of the model to predict species occurrence. Common metrics used are: sensitivity, specificity, the Kappa statistic, receiver operating characteristics (ROC) and area under the curve (AUC) (Fielding and Bell, 1997; Raes and ter Steege, 2007). By reporting only a single value, differences in the spatial distribution of model errors are ignored. The spatial distribution of model errors may indicate ecological processes that have not been accounted for in the RSF model (Fielding and Bell, 1997). By characterizing the spatial distribution of model errors, areas that under perform can be identified and supplementary data evaluated to determine source of errors and, when included in the model, the level of improved predictive success.

Methods and Data

Randomization tests assess statistical significance based on empirical distributions generated from the observed sample (Nelson and Boots, 2005). Randomizations are appropriate for ecological data since many traditional methods of statistical analysis are based on probability and distribution theories that may not be known (Fortin and Jacquez, 2000). A reference distribution through randomization, by contrast, is derived from the observed data by randomization and is used to determine the significance of a statistic calculated from the actual observed data (Fortin and Jacquez, 2000). The common randomization tests, based on the complete spatial randomization (CSR) of observations, are not appropriate for ecological data (Fortin and Jacquez, 2000) since they are inherently spatially autocorrelated (Legendre, 1993) and therefore data independence is violated. To avoid such dependence and to take into account spatial structure in data, some researchers have employed a restricted randomization process (e.g., Fortin et al. 1996).

Our goal is to show how conditional randomization methods can be used to quantify the spatial variability in the predictive success of a RSF. We outline methods and demonstrate them with a case study on patch-level selection (Johnson, 1980) for grizzly bears (*Ursus arctos*) in the Yellowhead Ecosystem in the Northeastern slopes of the Canadian Rockies. We use presence/available data to fit a RSF model. The RSF was developed as a 30 m by 30 m grid for each grizzly bear foraging season based on food availability and plant phenology (Munro et al., 2006; Nielsen et al., 2003).

The pattern of observed adult female grizzly bear radio telemetry data is quantified using spatially local statistics generated for 900 m by 900 m quadrats. The conditional randomization is based on the expected number of grizzly bear telemetry validation points that should fall within each RSF score bin (Johnson et al., 2006). Reference distributions are generated by applying the same local statistics to 99 permutations randomized conditionally on the RSF model (Edgington, 1995). Comparison of the observed data to reference distributions allows us to identify quadrats where the spatial pattern of habitat selection is unexpected given conditioned random use of the RSF model. A map showing unexpected locations is produced and compared with environmental data, such as elevation and land cover, in order to explore how the RSF model can be improved.

Results and Conclusions

We expect most of the bear telemetry locations will coincide with higher RSF values. Telemetry points that consistently coincide with lower RSF values indicate areas where the RSF is poorly predicting grizzly bear habitat selection. By quantifying the spatial distribution of RSF model errors we can identify regions where the RSF under performs. These areas can be linked to

supplementary data to evaluate variables that may be contributing to errors in the RSF model.

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Relationships between Cold-water Corals off Newfoundland and Labrador and their Environment

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Abstract

Cold-water corals inhabit deep-water environments in many parts of the world, but the factors governing their distribution remain unclear. Effective cold-water coral conservation strategies depend on knowledge of their distributions, their ecology, and the threats they face. The main objective of this study is to quantify relationships between corals occurrence/abundance and six environmental parameters to determine how these parameters may control the distribution of cold-water coral species in the Northwest Atlantic region. Data for six environmental parameters and two types of coral bycatch data were obtained. These datasets were processed to obtain regularly gridded data of each parameter which were subsequently sampled at each recorded coral location to build a sufficient database for analysis. The Geographically Weighted Regression (GWR) technique, along with correlation analysis, was used. This research approach is beneficial, as other similar studies have not accounted for local or spatial variation in the relationships between coral species and environmental parameters as using GWR allows this study to do. The strongest associations between environmental parameters and coral were used to determine which variables to use in the GWR analysis. Other strong associations between variables were used to determine where cases of collinearity may exist. When using the Fisheries Observer Program (FOP) coral data, it was found that the local regression performed significantly better than the global regression in explaining the variance in the dataset. Also, the range in current velocity was found to be significant in explaining some of the local variation without being significant on a global scale. Using the Scientific Survey (SS) coral data did not show much improvement in the local regression over the global regression as did the FOP data. As found in previous studies, slope, on a regional scale, was the most significant parameter, but locally, the most important factors governing distribution were range in velocity and mean bottom temperature. Interesting areas or 'hot spots' were also observed through the visual analysis of important residuals.

Background and Relevance

Corals have been studied in oceans around the world since the mid 19th century (Bellwood *et al.*, 2004), but most knowledge of corals is based upon warm water reef building coral species (Roberts *et al.*, 2006). Cold-water corals inhabit much deeper environments and are hence harder to observe and sample. As a consequence, they have been studied less and there is still little known about them (Buhl-Mortensen and Mortensen, 2005; Gass and Willison, 2005). Although the existence of cold-water corals has been recorded by fishermen since the late 19th century, it is only recently that there has been more systematic research done to better understand the factors governing their distributions (Leverette and Metaxas, 2005). There has been more interest and accessibility to information on these cold-water species due to activities like natural

resource exploration into deeper waters in recent years (Roberts *et al.*, 2006), as well as technological advances (e.g. Remotely Operated Vehicles).

Cold-water coral research is currently being performed in several regions of the world and with diverse research goals. Regions of study include the Northwest Atlantic (Bryan and Metaxas, 2007; Edinger *et al.*, 2007a; Wareham and Edinger, 2007; Mortensen and Buhl-Mortensen, 2005; Buhl-Mortensen and Mortensen, 2005; Reed *et al.*, 2005; Leverette and Metaxas, 2005), the Northeast Atlantic (Bryan and Metaxas, 2007; Entoyer and Morgan, 2005; Leverette and Metaxas, 2005), and the Northeast Pacific (Roberts *et al.*, 2005).

One of the goals of this research is to quantify the relationship between corals and fish habitats (Edinger *et al.*, 2007b; Etnoyer and Morgan, 2005; Buhl-Mortensen and Mortensen, 2005), as corals are thought to be an important habitat for fish and hence should deserve some level of protection. Another goal of these researchers is to monitor the vulnerability of marine life around cold-water corals using sensors and ocean floor photography (Roberts *et al.*, 2006). The distribution of cold-water corals is also being studied, as little is known about it (Gass and Willison, 2005).

One largely unknown fact about cold-water corals in the North West Atlantic region is how they relate to their environment. This involves the determination of which relationships deepwater corals share with individual environmental parameters (e.g. water temperature and salinity, substrate, current velocity), and which of these parameters most significantly influence corals occurrence and abundance. Generalisations about corals habitats have been made but few studies have quantified the relationships coral have with their environment.

Recently, a study which involved the prediction of the most suitable habitat parameters of two coral families (*Paragorgiidae* and *Primnoidae*) was conducted by Bryan and Metaxas (2005, 2007) on the Atlantic and Pacific Continental Margins in North America, using empirical and written data from interviews with local fishermen. This study used the program Biomapper[1] to produce habitat suitability maps. Biomapper uses the ecological niche factor analysis (ENFA) statistical technique (Bryan and Metaxas, 2007; Leverette and Metaxas, 2005). This technique is similar to a principal component analysis (PCA) except that the resulting components have direct ecological meaning (Bryan and Metaxas, 2007; Leverette and Metaxas, 2005). The study found that, on either side of the continent, corals lived within specific ranges of each of the environmental parameters used in the study (Bryan and Metaxas, 2007; Leverette and Metaxas, 2005). Slope and chlorophyll *a* concentration were reported to be the common factors in all of the top ranking combinations for each study area, and they report that temperature and currents were also present in many top ranking combinations (Bryan and Metaxas, 2007; Leverette and Metaxas, 2005).

As Bryan and Metaxas use a non-spatial method to determine which environmental parameters are of greatest importance in controlling the distribution of cold-water corals, the question of local spatial variation was ignored. The study presented in this paper uses non-spatial correlations along with Geographically Weighted Regression

[1] Further information pertaining to Biomapper can be found at: http://www2.unil.ch/biomapper/

(GWR), which enables the spatial drift of the regression parameters to be identified by looking at the data on a local level (Brunsdon *et al.*, 2001).

Methods and Data

Data have been collected from various sources. They include geological data about surficial sediments from digital and paper atlases, biological and environmental data provided by the Department of Fisheries and Oceans (DFO) Canada (Newfoundland and Labrador region) and bathymetric data from the General Bathymetric Chart of the Oceans (GEBCO). Each of the environmental parameters have been transformed into gridded datasets, if not originally in this format. The spatial extent of each of these datasets varied and played an important role in determining which of the coral data could be analysed with the appropriate environmental parameters.

The scientific survey (SS) data were obtained from the Department of Fisheries and Oceans (DFO). These surveys, which took place between 2003 and 2005, were conducted as part of a multispecies stock assessment and were sampled using a random-stratified technique. The corals found during these surveys were collected and later identified and recorded at Memorial University of Newfoundland (Edinger *et al.*, 2007). Two SS datasets were acquired for the purpose of this project. The first dataset only records presence/absence of corals while the second one also includes corals' biomass.

Fisheries Observer Program (FOP) data were also obtained from the Department of Fisheries and Oceans Canada. The FOP data, collected from 2004 to 2006, contain presence/absence records of coral caught accidentally (by-catch) during commercial fishing activities. These data were recorded by observers placed aboard vessels for the purpose of monitoring fishing activities and collecting biological scientific data. To obtain a quantitative measure, the data collected in 2004 to 2005 were normalized. The presence/absence data were converted to percentage of coral occurrence per cell of fishing effort.

Pairwise Pearsons' and Spearman's correlations have been performed using SPSS v.15 statistical software to quantify the relationship existing between (1) the environmental parameters and the coral abundance or presence/absence for both available datasets (SS and FOP), (2) corals and other coral species /groups and (3) environmental parameters and other environmental parameters. The coral datasets analysed consisted of FOP presence/absence, FOP percentages, SS presence/absence and SS biomass. The environmental parameters analysed were salinity (minimum, mean, maximum and standard deviation), temperature (minimum, mean, maximum and standard deviation), bottom velocity (mean and range), bathymetry, slope and surficial geology. These analyses were performed to identify the environmental parameters most strongly associated with coral occurrence/abundance that could be used in further analyses.

Analyses were then performed using Geographically Weighted Regressions (GWR) to establish relationship between corals and their environmental parameters. This technique also determines whether there is a locally significant explanation of the variation in the datasets that is greater than the variation explained by a global multivariate regression. The parameters selected as independent variables in the

analysis are mean bottom temperature, slope and the range in current velocity. For this project, a Gaussian model was the one showing a best fit with the data. An adaptive kernel was chosen. The optimal bandwidth, which defines how many data points should be included in each calculation, was found to be 15 by running several trial regressions. Due to the elongated distribution of the data, including more points would have increased significantly the region analysed locally. GWR produces several types of statistics. These help to assess whether or not the local regression model is of significant improvement upon the global regression model. There is also an output which is readily viewable in a GIS to examine individual results at each data point, such as residuals and predicted values.

Results

The pair-wise correlation analyses between environmental parameters and corals identified bathymetry as the most significant environmental parameter overall, followed by temperature and salinity. The five coral groups all had significant associations between each other for one or more of the datasets analysed. Since almost all these associations were positive, it suggests that certain types of environment are more suitable for corals in general and where any coral is found, other species are likely to be found as well. The analysis performed in GWR showed that the technique may be suitable for predicting occurrences of corals but not coral biomass. The Monte Carlo simulation in GWR identified slope as the variable which explains the most variability in the data at a global scale. This result generally indicates that corals mostly occur on the continental shelf edge and the upper continental slope, which may indicate a relationship with local surficial geology as both parameters are related. Mean bottom temperature and the range of current velocity were the parameters controlling most of the variability at a local scale, whereas slope was not as important. As corals are found mainly on the continental shelf in the Northwest Atlantic, slope is likely to be the parameter which changes the most over a large study area. Therefore, when looking at the study area as a whole (i.e. on a global scale), the parameter which would seem to account for the most variability in the locations of coral would be slope.

The standardised residuals from the GWR model identified interesting outliers in two specific areas, the southwest Grand Banks and north of the Grand Banks (near Tobin's Point). These two areas have been identified as coral hotspots in the Northwest Atlantic region (Edinger *et al.*, 2007a, Wareham and Edinger, 2007). They are areas which are known to have greater coral occurrences and diversity. This may make them more susceptible to being positive outliers, which was found as an interesting result.

In areas where there are significant positive standardised residuals in the analysis of the FOP percentages, data may indicate that the model is slightly underestimating coral occurrence. The locations of significant negative standardised residuals indicate that there was a considerably greater number of corals estimated than observed. One possibility is that some estimates are in waters too shallow to have corals, even if the other parameters (i.e. temperature and velocity) are optimal for corals. Another possible explanation of these negative residuals is that there should be a higher occurrence of corals at these points, but due to prior extensive bottom trawling of these areas corals were depleted in abundance prior to the data collection. It has been concluded in

studies, such as Gass and Willison (2005), that areas where bottom trawling has occurred on a regular basis have seen depletions in the amount of corals observed in those areas. Also, studies on the amount of by-catch of coral in commercial fishing activities have found that significant amounts of corals are disturbed by these activities (Krieger, 2001; Anderson *et al.*, 2003; Edinger *et al.*, 2007a). The amount of fishing effort documented in the FOP data used in this study can be seen in Edinger *et al.* (2007a) as maps of total fishing effort.

Conclusions

Few studies attempted to understand cold-water coral habitats using quantitative approaches. This study contributed by using pair-wise correlations and Geographically Weighted Regression (GWR) techniques to take into consideration spatial variation into the analysis. This study suggests that local spatial variability in environmental parameters seems to play a role in determining coral habitats while findings on the global scale coincide with previous studies.

When the data are analysed spatially on a local scale, slope is found to drop out as an important parameter. Range in bottom velocity and mean bottom temperature are important in explaining variation on a local scale, whereas previous works identified slope to be important parameter controlling corals' distribution (Metaxas & Bryan 2007). Interesting areas were identified through the analysis of standardised residuals. These areas coincided with previously identified coral hot spots in the study area region.

Although this study brings interesting results, several limitations should be raised. First, the analyses were performed using data spanning only two years in the FOP percentages dataset (2004 and 2005) and up to three years in the other datasets analysed. Unfortunately these are the only years available as corals have only recently been sampled. Also, due to the different spatial extents of the various datasets, the number of samples that could be used for statistics was limited. This resulted in a low number of samples used for calculation of the local statistics and results should hence be interpreted with caution. Finally, the FOP data are biased by fishing effort (Edinger *et al.*, 2007a; Wareham and Edinger, 2007) as their sampling is not random but is higher where commercial fishing is denser. It would be interesting to renew such a study in a number of years when the sampling of corals will allow a higher number of samples and increase the geographic coverage.

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Spatio-temporal mapping of vegetative types in the Canadian Mixed Prairie

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Abstract

Remote sensing of vegetation in the mixed prairie offers challenges due to their variable vegetative type and cover and high amount of non-photosynthetic vegetation and background noise. Canopy spectral reflectance and biophysical data of commonly occurring vegetative types were collected by intensive vegetation sampling in 41 randomly selected sites (minimum of 820 points) in the West block of Grasslands National Park of Canada during the summer of 2006 and 2007. A 3-endmember model (green vegetation, soil, shadow) spectral library was created. Images were subjected to spectral unmixing. We found that the spectral responses of vegetative types in the Canadian mixed prairie are unique but are often contaminated by high levels of background noise and reflectance from dead materials. This warrants noise-removal procedures on the spectral data.

Background and Relevance

Remote sensing has been found effective to monitor vegetation dynamics in ecosystems at multiple- spatial and temporal scales. This monitoring is critical especially in Canadian mixed prairie ecosystems which are affected by various natural and human-induced disturbance regimes. However, remote sensing of vegetation in the mixed prairie offers challenges due to their variable vegetative type and cover and high amount of non-photosynthetic vegetation and background noise. Sensors having moderate to coarse spatial resolution are limited in their ability to capture sub-pixel variations. Spectral unmixing strategies such as multiple endmember spectral mixture analysis (MESMA) of captured reflectance are effective for retrieving sub-pixel information of vegetation endmembers on the landscape and detecting spatio-temporal changes.

Methods and Data

Canopy spectral reflectance and biophysical data of commonly occurring vegetative types were collected by intensive vegetation sampling in 41 randomly selected sites (minimum of 820 points) in the West block of Grasslands National Park of Canada during the summer of 2006 and 2007. Spectral reflectance of endmember types (field endmembers) were collected using a field spectroradiometer (FieldSpec®, ASD Inc.) under optimum sky and atmospheric conditions. The spectral reflectance measurements were taken at a spectral resolution of 3 nm in the 350-1000 nm and 10 nm in the 1000-2500 nm. Biophysical data such as Leaf Area Index (LAI-2000 Plant Canopy Analyzer®, LI-COR Inc.), foliar cover, plant height, vertical structure, and above-ground biomass were also collected.

Using the field and image endmembers, a 3-endmember model (green vegetation, soil, shadow) spectral library was created using software, ENVI (ITTVIS Inc.) and VIPER Tools (www.vipertools.org). The image endmembers were identified using the Pixel Purity Index (PPI;

Boardman et al., 1995) method from a SPOT-5 image after minimum noise fraction (MNF; Green et al., 1988) procedure. Orthorectified images, which were geometrically and atmospherically corrected, from Landsat-5 TM, SPOT-4, and SPOT-5 for 1998, 2006, and 2007 respectively. These images were subjected to spectral unmixing through multiple endmember spectral mixture analysis (MESMA; Roberts et al., 1998). MESMA was performed on the images using the model spectral library to derive fractions of various endmembers in each pixel. MESMA resulted in vegetation distribution maps for the different years, and these maps were used for change-detection analysis over the years. The vegetation maps were validated for accuracy of classification using landcover classes identified through field observations, archived field data, and other maps reported in the literature.

Results and Conclusions

We found that the spectral responses of vegetative types in the Canadian mixed prairie are unique but are often contaminated by high levels of background noise and reflectance from dead materials. Thus, the inherent noise in the canopy reflectance data makes it difficult to separate many vegetative types at the landscape-level merely based on vegetative indices. This warrants the essentiality of noise-removal procedures on the spectral data.

Mapping and management of vegetation are the best strategies for conserving biodiversity and maintaining ecological integrity of the Canadian mixed prairie (COSEWIC, 2004; Grasslands National Park of Canada Management Plan, 2001). Spectral unmixing through MESMA can be successfully employed for landscape-level mapping of vegetation types and for studying vegetation dynamics in the mixed prairie at various spatial and temporal scales. MESMA was found to perform better than simple SMA with an accuracy of over 60%, however, the accuracy of MESMA was highly dependent on the selection of best and optimum number of endmembers. Vegetation distribution maps produced by MESMA can be used for monitoring ecosystem or vegetation dynamics in the Canadian mixed prairie. We believe that our results can also aid in developing newer algorithms for spectral unmixing in semi-arid ecosystems, specifically such as the mixed prairie.

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Unravelling the Mysterious Phenomenon of Yellow-Cedar Decline

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Abstract

In this presentation we will report on our research investigating the decline of yellow-cedar. The focus will be on the use of GIS in characterizing the forest decline and investigating the role of abiotic factors. Particular attention will be given to the possible connections between the underlying biophysical factors and the hypothesized climatic mechanism. The use of GIS in interpreting causal factors to predict sites susceptible in the long term will also be discussed.

Background and Relevance

For over two decades, the phenomenon of yellow cedar decline has perplexed researchers. Yellow cedar (*Chamaecyparis nootkatensis* (D. Don) Spach), which ranges from Southern Oregon to Prince William Sound, Alaska, was known to be declining on over 200,000 ha of undisturbed forest in southeast Alaska (Snyder *et al.* 2008). During an aerial survey in 2004, numerous large areas of dead and dying yellow-cedar were identified in coastal locations in B.C. and the nature of the dieback was found to be consistent with the phenomenon in southeast Alaska (Hennon *et al.* 2005).

According to the current leading hypothesis, saturated soils create open, exposed canopies that experience soil warming early in the spring. This warming triggers the yellow-cedars to deharden prematurely, making them more susceptible to freezing injury, which may ultimately lead to fine root mortality and subsequent crown death (Hennon *et al.* 2006). Snow appears to protect yellow-cedar against this potential freezing injury by preventing soil warming (Hennon *et al.* 2006). However, there has been a reduction in the snowpack at lower elevations since the end of the Little Ice Age, which coincided with the onset of decline (Hennon *et al.* 2006). The involvement of a climatic mechanism suggests that cedar dieback may expand if warming trends continue (Beier *et al.* 2008, Hennon *et al.* 2006).

In order to successfully manage this ecologically, culturally and economically important tree species, a more thorough understanding of the mechanisms of decline and the contributing role of climate is needed. The current hypothesis is based primarily on observed associations and research is required to determine whether these relations occur throughout the range of the decline (Hennon *et al.* 2006). Quantifying the distribution and density of the yellow-cedar decline and predicting where the decline will occur in the next few centuries will provide critical information to decision makers. The high value of yellow-cedar wood and the importance of this species in First Nations culture mean that a management strategy incorporating the influence of a warming climate is required. Ultimately, this research may provide insight into the devastating effects that climate change can have on a forest ecosystem.

Methods and Data

The major aims of this research project are to quantify the distribution and density of the yellow-cedar decline in British Columbia, and to evaluate the role of various biophysical factors (e.g., elevation, slope, aspect) implicated in the hypothesis. The project will use a combination of remote sensing and GIS analysis. Forest inventory and forest health datasets, containing known areas of yellow cedar decline, and air photos taken during 2006 and 2007 of the Mid- and North-Coast Forest Districts, have been collected from the Integrated Land Management Bureau. This data will be used to delineate areas of healthy and declining yellow-cedar stands and the biophysical factors will be derived from a Digital Elevation Model of the province. A predictive model will then be developed on the basis of these results to attempt to forecast sites susceptible to decline in the long term. Cross-validation will be performed to evaluate model fitness.

Results

The results of the initial exploratory analysis will be presented, with an emphasis on characterizing the spatial structure of the decline and highlighting any early findings regarding links to biophysical factors. A discussion of the role of the hypothesized climatic mechanism and expected results will be made. Plans for future research will also be shared.

Conclusions

This research focuses on characterizing the density and distribution of declining stands and analysing biophysical associations through the use of remote sensing and GIS. Investigating the underlying abiotic factors and their relationship to the proposed climatic mechanism will lead to a more thorough understanding of the decline of yellow cedars and how this species should be managed in the context of a warming climate. This research is being conducted at University of British Columbia in conjunction with the Ministry of Forests and Range.

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The effect of landscape pattern on mountain pine beetle spread.

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Abstract

Landscape patterns of forested ecosystems influence the operation of ecological processes. The extent to which landscape patterns influence the spread of forest insects across a landscape is thought to vary for different insect species. This study investigates the effect of landscape patterns on the spread of the mountain pine beetle (Dendroctonus ponderosae). Using two years of mountain pine beetle survey data from British Columbia, Canada, we calculated the average rate of spread by associating nearest neighbour infestations from consecutive years. We define landscapes of 1 km and approximately 30 km resolution for computing landscape metrics measuring forest patchiness and forest edge. Spread clusters were identified using local indicators of spatial association (LISA) and significance was determined by randomization. Preliminary results indicate an epicentral spread pattern at 30 km resolution and more variable spread patterns at 1 km resolution. Furthermore, spread of mountain pine beetles may be facilitated by edge habitats at the 1 km landscape size.

Background and Relevance

Forest ecosystems experience frequent changes to spatial patterns and therefore often exhibit substantial spatial heterogeneity (Riiters et al. 2002). Harvesting removes habitat and increases fragmentation (Mladenoff et al. 1993). Natural disturbances such as insect infestation, windthrow, fire, and landslides impact the configuration of forest landcover. Within this dynamic environment, species respond to landscape patterns and pattern changes. Landscape pattern indices (LPIs) offer a useful way of capturing the spatial pattern of a forested landscape in order to assess the impact of pattern on a particular species or process (Gustufson 1998).

The impact of landscape patterns on populations in forest ecosystems has primarily focused on the habitat requirements and responses of species in order to understand spatial ecological relationships and ultimately plan for species conservation (e.g., Hargis et al. 1999). While the role of insects as disturbance agents, changing forest patterns, is the subject of extensive research, the impact of landscape pattern on insect population processes is not. The general effects of forest fragmentation on forest ecosystems include changes in solar radiation, wind exposure, and hydrologic cycles (Saunders et al. 1991).

Our objectives in this research are two fold. Firstly, we aim to establish empirically the rate of spread for mountain pine beetles during outbreak populations. Estimates of

average dispersal distance from field-based mark recapture experiments (i.e., 30 m in Safranyik et al. 1989) suggest that beetles typically disperse locally within stand, with environmentally-driven stochastic long distance dispersal events. We aim to establish the average rate of spread over a two year period in order to identify the approximate spatial scale at which beetle spread is occurring. The rate of spread will then be used to help identify the size of landscapes at which to assess pattern effects on spread, our second objective. In order to use LPIs to address the impact of pattern on spread, they must be calculated relative to the process under investigation (Wiens 1989), and assessed at multiple scales to determine the stability of such effects (Wu 2004). Understanding if and how landscape pattern influences spread of mountain pine beetles will yield information regarding both dispersal ecology and strategies designed to mitigate and manage rapidly spreading beetle populations (see Carroll et al. 2006).

Methods and Data

Locations of mountain pine beetle presence in the years 2000 and 2001 were differenced to create a new dataset indicating the locations of newly colonized habitat in 2001. The shortest distances between newly infested locations in 2001 and locations of beetle presence in 2000 were then d0etermined. The distribution of shortest distances were used to assess the nature of mountain pine beetle spread over one year, and infer the spatial scale at which spread was occurring

We selected LPIs that characterize two aspects of spatial pattern that describe the nature of forest fragmentation: the amount of forest edge and the 'patchiness' of the forest landscape. For each spatial scale, our goal was to characterize the spread of mountain pine beetles between 2000 and 2001. To isolate spatial variability in spread, we computed a bivariate local indicator of spatial association (LISA) on landscapes which summarize the number of pixels with infestation in 2000 and new infestations in 2001. The bivariate LISA is based on the local Moran's I statistic, which is a local version of the Moran's I spatial autocorrelation index (Anselin 1995).

The bivariate local Moran's I values can be categorized into one of four classes based on the Moran scatterplot. The high-high category indicates a landscape had a large number of infested cells in 2000 and a high level of spread to neighboring cells in 2001, low-low indicates relatively few cells infested in 2000 and little spread to neighboring cells in 2001, low-high indicates a small number of infested cells in 2000 and spread to a large number of cells in 2001 and high-low indicates a large number of infested cells in 2000 and little spread to neighbouring cells in 2001. For ease of interpretation, we refer to these as classes of spread clusters: intense, incipient, diffuse, and focal.

Landscapes were partitioned based on four categories of spread clusters: intense, incipient, diffuse and focal. LPIs were computed for each landscape and their distributions were compared by plotting the mean for each of the spatial association categories. Examining changes in the mean of each LPIs across categories and between spatial scales relative to changes in proportion (PF), allowed us to draw some general conclusions about the nature of pattern effects on spread.

Results

The overall pattern of spread in British Columbia varied from epicentral at the 30km scale, to much more variable at the 1km scale. For 30km landscapes, landscape pattern indices appear to be driven primarily by forest proportion. For 1km landscapes, spatial patterns indicating rapid spread were associated with higher edge density and total forest edge, and higher indices representative of forest patchiness. This suggests that forest fragmentation may enhance the spread of mountain pine beetles at a local scale.

Conclusions

The relationship between forest fragmentation and mountain pine beetle spread has important consequences for forest management. In western Canada, the ongoing outbreak is expanding the mountain pine beetle's geographic range as climate change redefines the historic boundaries delineated by latitude and elevation (see Carroll et al. 2006). Further, there is interest in managing for spread into the boreal forest where jack pine (Pinus banksiana) is considered a susceptible host species for mountain pine beetle. Our results suggest that increasing forest fragmentation at small scales through patch harvesting may actually facilitate the spread of mountain pine beetles across the landscape. At larger scales, the effects of fragmentation appear to be no greater than what occurs due to loss of habitat. Identifying a scale at which landscapes are not crossable by mountain pine beetles remains an elusive, if not impossible task.

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National Forest Fire Susceptibility Assessment using the EOSD

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Abstract

Fire is the main natural disturbance of the boreal forest and an important driver of ecosystem dynamics. Increased fire activity of both natural and anthropogenic origin is expected with changing climate scenarios. The focus of this research is to create a fire susceptibility assessment for Canada that will identify areas of risk based on fire history and landscape composition. Earth observation for sustainable development (EOSD) data will be used as a baseline representation of landscape structure in the year 2000. Forest fire information from 1970 to 2008 will be used to identify fire event areas. We will develop fire expectations by Canadian ecozone with respect to specific aspatial and spatial fire characteristics such as size, frequency, and spatial pattern. These results will provide Canada with a nationwide fire risk assessment to be used by forest fire managers. Preventative efforts can then be focused on anticipated problem areas.

Background and Relevance

Fire is the dominant natural disturbance in Canadian forests (Johnson, 1992). It is a critical factor in driving many ecological processes in addition to shaping the landscape composition and carbon cycling. Forest fire activity is expected to increase under changing climate (Flannigan *et al.* 2005) and while number of fire ignitions have decreased in recent years, three of the top four seasons for largest area burned have occurred within the 1990s (Stocks *et al.* 2002). Continuation of these trends will cause changes in natural forest regimes and increase the ~2 million ha of forest burned annually (Stocks *et al.* 2002). Future forest management requires expectation estimates of which ecozones, habitats, and landscapes will be at highest risk for fire ignition and spread. Additionally, the spatial nature of fire size, pattern, and convergence needs to be characterized for prospective model input (Wimberly 2004). The goal of this research is to create a national forest fire susceptibility assessment to identify areas of risk based on fire trends from 1970 to 2008.

Methods and Data

Landscape characteristics for Canada are represented circa 2000 by the EOSD. This cover map is based upon a compilation of over 480 Landsat scenes focusing on the forested area of Canada (Wood *et al.* 2002; Wulder *et al.* 2003). Land cover is classified similar to the hierarchical NFI land cover classification system and differentiates by vegetation type and vegetation density (Wulder and Nelson, 2001). Forest fire event polygons will be used to represent area burned by fire from 1970 until 2008. Fires are identified using satellite detected hotspot data from two sensors, the Moderate Resolution Imaging Spectroradiometer (MODIS) and the Advanced Very High Resolution Radiometer (AVHRR) (De Groot *et al.* 2007).

We will develop fire expectations and distributions by Canadian ecozone with respect to specific local aspatial and spatiotemporal fire characteristics such as size, frequency, and spatial pattern. This may be used as a baseline for an early warning system of uncommon fire years. Spatiotemporal pattern will be quantified for use in fire risk models. We will also compare these spatial and aspatial characteristics to land cover to determine how topography and forest fragmentation affect forest fire. Pre fire landscape conditions will be examined to summarize fire-susceptible topography whereas post fire landscape will describe successive growth.

Results and Conclusions

A national fire susceptibility assessment will be created to identify areas of wildfire risk in Canada's forest. Forest fire managers may use this product as a means to anticipate problematic locations and work to prevent or mitigate detrimental effects with increasing fire activity. Climate change and carbon flux modelers may use this assessment to add fire expectation into their spatial models.

This is the first step towards spatial-temporal analysis of fire ignition and spread patterns. It is important to obtain current measurements of fire size, pattern, spread rate, and convergence by ecozone for comparison with future datasets. Expected evolution of fire dynamics can eventually be incorporated into the fire susceptibility assessment.

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Automated labelling of remotely sensed disturbances: Framework and example

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Abstract

Canadian forests are managed to meet a myriad of aims, including ecological, biological, social, and economic. Forest disturbances can be planned, through urbanization, harvesting or other development activities, or unplanned through insect infestations or fire. As such, it is imperative that forest managers have complete and current information to aid with decision making. Detection of disturbances and identification of disturbance type are equally important, as different disturbances lead to different managerial responses and / or ecological effects. Further, for habitat specific applications, insights on animal response may be gained by correlating land cover disturbances and animal activity data. In this study, we are developing a methodology for automatically labelling change classes derived from Landsat-based disturbance products, based upon a spectral differencing method (from two dates of Tasselled Cap wetness), and labelled through manual interpretation of imagery and field data. By incorporating available spectral information with derived composite band values (including Tasselled Cap transformations), spatial and contextual information, and secondary datasets, we have developed a framework for automatically labelling disturbance features. Preliminary results show successful differentiation of changes, using classification tree analysis (CTA) and general linear models (GLM). For areal changes (cut-blocks, well-sites, mines and fire-scars), CTA successfully identified 81% of the features, while GLM increased that to 91%. Linear features (roads and pipelines) showed an even greater success rate, with 92% of the features being properly identified using a classification tree analysis. For both types of changes, differentiation occurred without any manual intervention. By incorporating automatic disturbance labelling with automatic change detection, it may be possible to update land-cover databases with only minimal human intervention; leading to quicker integration of data, and better managerial responses.

Improving seabed classification through the use of multiple acoustic frequencies

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Abstract

Existing acoustic technologies used for seabed mapping typically use only one acoustic frequency. There is a growing interest in the scientific community to combine various acoustic frequencies to improve the accuracy of seabed habitat maps produced using these technologies, as it is typically done in satellite remote sensing. Classifying and mapping seabed sediment types can be achieved using acoustic echo sounders as different sediment types absorb, reflect or scatter varying amounts of acoustic energy, which allow them to be differentiated. Such maps can indirectly be used to delineate the distribution of marine benthic habitats of demersal (bottom dwelling) fish species as these habitats are believed to be primarily determined by substrate type. Using multiple frequencies should improve seabed sediment classification, and therefore seabed habitat maps, because backscatter intensity, a measure of the intensity of acoustic energy scattered back towards the source, varies with frequency. Hence, the use of multiple frequencies is expected to add information, as lower acoustic frequencies penetrate the seafloor deeper and higher frequencies will detect smaller spatial features. This research investigates the benefit of combining multiple acoustic frequencies from a single beam echo sounder to directly improve the mapping of seabed sediments, and indirectly improve seabed habitat maps. Raw acoustic data from 38 kHz and 120 kHz frequencies have been processed to extract backscatter strength data from the returned acoustic energy received by the transducer. These processed data have then been used to derive information about seafloor sediment characteristics. GIS techniques were used to classify the backscatter data and the resulting classes are compared to existing interpreted surficial geological classes of the area. This paper presents preliminary results of the classification done using the two frequencies, compares it to the individual classifications performed by each frequency, and relates it to interpreted surficial geological classes.

Background and Relevance

Mapping of the seafloor is almost entirely performed using acoustic systems, as optical systems are limited by the fact that light does not propagate in waters deeper than 10-50 meters, depending on water clarity (Guenther *et al.*, 2000). Sound is emitted at a given frequency, propagates through the water column, interacts with the seafloor or other objects (e.g. fish, vegetation), and part of it (i.e. the backscatter) is returned to and recorded by the transceiver.

Most systems used today for seabed mapping make use of only one acoustic frequency (Kostylev *et al.*, 2001, Anderson *et al.*, 2002, Courtney *et al.*, 2005). The frequency selected depends on the application and the water depth. Backscatter data are used to map and classify seabed types based on the theory that different sediment types reflect and absorb varying amounts of acoustic energy. This theory is based on models which

quantify the relationship between sediment types and backscatter intensity, based on certain frequencies and geophysical parameters (APL94, 1994). Some researchers have explored the use of multiple acoustic frequencies for applications such as mapping corals (Fossa *et al.*, 2005), detecting fish (Korneliussen and Ona, 2002), and differentiating limestone reef and sediment flat mesohabitats (Kloser *et al.*, 2002).

However, the utility of combining multiple acoustic frequencies to acquire information about seafloor sediment characteristics remains largely unexplored. The combination of multiple frequencies is expected to provide more information about sediment structure and surficial geological classes. This assumption is based on the theory of the physical response of acoustic energy from different sediment types. Hence, combining multiple frequencies should improve sediment classification because both surface and volume backscatter vary with frequency (Anderson *et al.*, 2008). An object must be larger than the acoustic wavelength to be detected. Therefore, higher frequencies will detect smaller features while lower frequencies will penetrate the seafloor deeper (Anderson, 2007). Hence, lower frequencies should detect seafloor features that higher frequencies should not and *vice versa*. Varying amounts of surface and volume backscatter are primarily a result of two geophysical properties, grain size and porosity, which allow normal incidence echo sounders to differentiate between sediment types (Anderson, 2007). The use of multiple frequencies should be most effective when the seabed sediment distribution is heterogeneous, as a mixture of sediments should best be detected with more than one frequency. Finally, this potential for improvements in sediment classification can indirectly improve efforts to define the distribution of marine benthic habitats of demersal (bottom dwelling) fish species as these habitats are believed to be primarily determined by substrate type (Kostylev *et al.*, 2001).

The main objective of this study is to determine if and how the combination of multiple frequencies will directly improve seabed sediment classification, as well to indirectly improve seabed habitat maps. A secondary objective is to determine which sediment types are best detected by one frequency, or the other, or the combination of the two frequencies.

The International Council for the Exploration of the Sea (ICES) has recently listed the use of multiple acoustic frequencies as one of the main future issues for acoustic seabed classification (Anderson *et al.*, 2008). Furthermore, investigating the usefulness of combining multiple acoustic frequencies to improve seabed classification is important and necessary research for fisheries science and marine geology.

Methods and Data

Data were collected on ship surveys conducted by the Department of Fisheries and Oceans Canada (DFO) on the Scotian Shelf, in the North Atlantic Ocean, in September 2002 and October 2003. The study area is composed of two 100 km^2 study sites on Western Bank, which each have a 5km^2 detailed study site within its boundaries. The detailed study sites have higher resolution data from the normal incidence echo sounder, as well as interpreted surficial geological classes. Data were collected using a

BioSonics DTX normal incidence echo sounder system at both 38 kHz and 120 kHz frequencies.

The current geological setting of Western bank has been shaped by events following the last glaciation. Marine transgressions have placed pre-existing glacial deposits of well-rounded gravels and fine to coarse-grained sands into the area. This process has replaced fine-grained silts and clays which have been deposited into deeper water. There are presence of boulders, and the sediments are generally reworked by waves and currents moving from the northeast to southwest (Courtney *et al.*, 2005). Recent sonar surveys have revealed that the seabed contains evidence of glacial processes, as evident by moraines, and fluvial erosion and there is a high degree of sediment patchiness and small scale roughness. There is a full range of sediment bedforms which include ripples, megaripples, sand ribbons, and ridges (Anderson & Gordon, 2007, p.14).

This particular study area on the Scotian shelf was chosen for a number of reasons. First of all, there has been a lot of work done in this area by DFO and therefore the area is generally well known. It hence lends itself well for testing a new method for seafloor mapping where ground truthing is important. Previous work has included geological and habitat mapping using sidescan, multibeam, and single beam sonar systems (Anderson *et al.*, 2005, Courtney *et al.*, 2005). There also has been a lot of ground truthing done through the use of video transects and underwater photography. Finally, there exist multiple frequency normal incidence echo sounder data of the study area which is required for this project.

Acoustic data from the surveys were processed in order to compensate for radiometric and geometric biases (i.e. remove the effects induced by the sonar system and the transducer's varying range, or distance, from the seafloor) so that meaningful backscatter data can be extracted. Raster surfaces of both depth and backscatter intensity were interpolated from these data. Surfaces for each frequency were then classified, using both supervised and unsupervised classification techniques, in order to delineate different seafloor types or surficial geological classes. Following this step, another classified map of seafloor types was created using the combination of the two acoustic frequencies (38 kHz and 120 kHz). The combined frequency classes were compared to the classes derived from each individual frequency. Then, the classification results were compared to existing interpreted surficial geological classes of the detailed study areas in order to examine and quantify the differences and similarities between the single frequency and multi-frequency results.

Results

This paper presents preliminary results of this research project. It highlights the different classifications of seafloor types based on acoustic backscatter from two frequencies individually and then from the combination of both frequencies. It looks at the similarities and differences of each classification in relation to the different surficial geological classes and will come with recommendations regarding the best frequency to use for detecting specific types of sediments.

Conclusions

This research demonstrates how backscatter information obtained from multiple acoustic frequencies, as opposed to one, provides further insight into the physical characteristics of seafloor sediments. This was achieved using normal incidence echo sounder data from two frequencies using specific classification algorithms in order to effectively delineate seabed sediment classes. An important result is that improved classification of seafloor types based on the combination of acoustic backscatter from several frequencies can be achieved. Such an approach is expected to be very useful to marine habitat mapping, fisheries and resource management, and geological studies. This research can be expanded to examine the effectiveness of such methods in a different study area with varying physical characteristics. It would also be interesting to incorporate multibeam data. Such a dataset would provide higher frequency data with wider spatial coverage and should add useful information about the study area and therefore impact the results of the classification.

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Temperature Mapping in Nova Scotia's Annapolis Valley

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Abstract

The Applied Geomatics Research Group (AGRG) has been monitoring the weather conditions of the Annapolis Valley region for more than five years. Temperature and other meteorological parameters have been monitored via AGRG's sensor network. Many of the monitoring locations are on existing vineyard locations owned by members of the Grape Growers Association of Nova Scotia (GGANS). In addition to understanding the temperature regime in existing vineyards, there is also interest in knowing the temperature potential of other areas in the Valley where no sensors have been deployed. This information is of specific interest to those involved in expanding the Valley's vineyard footprint. The AGRG set out to create a temperature map for the entire Valley area, based on five years (2004-2008) of temperature data and a collection of GIS data layers including elevation, slope, aspect, solar radiation, and coastal proximity. This presentation will highlight the data layers, interpolation methods, and results that have been generated to date in this on-going project.

Background and Relevance

Nova Scotia's Annapolis Valley is well known for its agricultural production and is home to a burgeoning grape growing industry. In 2002 the Applied Geomatics Research Group (AGRG) began deploying environmental instrumentation throughout the Valley region (approximately 150km x 25km in size) to better understand the meteorological regime of the area. Today the AGRG has a sensor network (i.e., 15 Campbell Scientific weather stations and 75 Onset temperature data loggers) used to monitor temperatures and other meteorological parameters. Many of the monitoring locations are on existing vineyards; other are located to sample the temperature extremes (i.e., shoreline, hill tops, etc.). To share project results the AGRG provides web-based geospatial temperature summaries to members of the Grape Growers Association of Nova Scotia (GGANS). These summaries provide growers with valuable information (i.e., duration of the growing season, heat unit accumulation, and minimum winter temperatures) which is used to assist in the selection of grape varieties suitable for growing in the Valley area.

In addition to understanding the temperature regime in existing vineyards, there is also interest in knowing the temperature potential of other areas in the Valley where no sensors have been deployed. This information is of specific interest to those involved in expanding the Valley's vineyard footprint. Thus the AGRG has been working to create a temperature map for the entire Valley area. Temperature has a strong co-variation with topological characteristics, and thus the temperature data that has been collected over the past five years has been modeled with a collection of GIS data layers including elevation, slope, aspect, solar radiation, and coastal proximity.

Certainly the use of GIS in climatology and meteorology studies is increasing (Hartwig et al., 2007). There are numerous spatial interpolation techniques that have been used to model temperature (Shen, et al., 2001). Based on the results of a comparative study of various techniques (Bater 2005), this study used multiple regression analysis (Ninyerola, et al., 2000; Daly, et al., 2002; Joly et al., 2003) to derive temperature maps.

Methods and Data

The three initial data layers employed in this study were: temperature, elevation, and coastline mapping. The temperature data was harvested from the AGRG sensor network (~90 sensors). Temperature sampled every 15 minutes was used to compute the annual heat accumulation units (i.e., Growing Degree Day values using base 10^{o} Celsius) between the months of April and November for five years (i.e., 2004-2008). The elevation data was acquired from the Nova Scotia Geomatics Centre (NSGC) provincial mapping. This was a 20m resolution raster dataset that was used in ArcGIS v9.2 to generate slope, aspect, and solar radiation layers with the same resolution. A heat load index (McCune & Grace, 2002) was calculated from the aspect layer to circumvent the difficulties of modeling aspect data (where 1^{o} is essentially the same as 359^{o}). The coastline mapping was also from the NSGC; it is 1:10,000 scale vector data derived from aerial photography. This layer was used to compute a 20m resolution raster layer depicting the proximity to the coast.

The sensor sites were each mapped using a Real Time Kinematic Global Positioning System (RTK GPS). The resulting locations were used to sample the elevation, slope, aspect, solar radiation, and coastal proximity layers. The sampled measures from these associated landscape layers were then copied into an Excel spreadsheet. The heat accumulation units for each year were copied to the same spreadsheet and multiple regression calculations were conducted on various combinations of the temperature (the dependent variable) and associated landscape attributes (the independent geographical variables). The resulting regression coefficients were used in the ArcGIS raster calculator to create a new 20m resolution layer representing predicted temperature values throughout the study area. This process was carried out using temperature data for each of the five years, and once using an average of the five years of temperature data.

A subset of the temperature data (withheld from the above calculation) was then used to conduct a validation exercise on each of the six resulting temperature layers.

Results

Six temperature maps have been created, one representing each of the five years (i.e., 2004 to 2008) and one representing an average of the five years. These represent draft results in our ongoing investigation. Most of the maps exhibit similar overall patterns. The coastal proximity and solar radiation layers have been found to have the best fit to the temperature data; the slope and elevation layers had the weakest fit. Final results complete with validation information will be delivered during the presentation.

Conclusions

Similar patterns exist in most of the resulting temperature maps. Thus the results should prove useful to those interested in better understanding the April to November temperatures of the Annapolis Valley region. Grape growers will now be better able to identify areas within the Valley area that have a temperature regime that will support the production of grapes.

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A dynamic self-adapting recommendation engine for the sensor web

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Abstract

Web-enabled sensor networks are growing rapidly, mirroring the exponential growth of the World Wide Web (WWW). The complexity of these networks necessitates mechanisms to enable users to gain quick access to relevant and reliable information. We are proposing a self-correcting recommendation engine that would suggest new sensors to the web using a set of metrics, including user behaviour and collaborative filtering.

Background and Relevance

The next generation web-enabled sensor networks (sensor webs)(Botts et al. 2008)are anticipated to mimic the growth of the WWW. They are expected to grow exponentially in terms of complexity, with millions of heterogeneous nodes and billions of users connected at any given time. Moreover, the traditional model where sensors could be considered experts is being broken down as practically any individual with a mobile phone being able to function as a sensor (Kansal et al. 2007).

In common with the WWW, the proliferation of sources of varying degrees of quality would lead to sensor networks that are data rich and information poor. Some users of such networks would be faced by information overload, while others would have to deal with information poverty as they would not be aware what sensors exist where.

Therefore, users would start requiring recommendation services to help them identify which sensors could be useful and/or interesting to them. There are recommendation engines already available for the traditional web, but there has been no research done on extending these to the sensor web. Catalogue Services are already available for the sensor web (Nebert & Whiteside 2004) and there are nascent research efforts to develop search engines for it (Reddy et al. 2007). It is envisaged that advancements made with recommendation engines may be used to enhance the capabilities of the search engines.

There are a number of recommendation engines available for different applications (e.g. Amazon for books and other merchandise, StumbleUpon[1] and reddit[2] for websites), and they incorporate elements of both user behaviour analysis and collaborative filtering. However, they only deal with content matching, but a sensor recommendation engine would also have to deal with the spatial aspects.

[1]http://stumbleupon.com
[2] http://reddit.com

Methods and Data

Methods

The recommendation engine will be built by harnessing the collective intelligence of the users by enabling a folksonomy (Mathes 2004) and a rating system. A self-correcting weighting algorithm, based on neural networks, is proposed to train the engine.

The proposed content recommendation engine would have a graphical front end that allows users to tags nodes (analogous to del.ici.ous[3] in the WWW world) and rate nodes (analogous to the Web2.0 sites Digg[4] and reddit). There will be search/browse function that would enable the users to access content as the system is trained.

The proposed recommendation algorithm uses five metrics which have been successfully used in WWW systems, some of which are mentioned above:

1. User behaviour analysis
2. Collaborative filtering
4. Submitter Reputation
3. Sensor Reputation
4. Popularity
5. Freshness

User behaviour analysis

The user behaviour analysis will consist of both spatial closeness matching and tag similarity matching. Spatial interpolation methods, such as Kriging and Inverse Distance Weighting, will be used to calculate the score based on distance. Methods proposed by Cattuto et al. (2008) will be used to assess tag similarity.

Collaborative filtering

Collaborative filtering will be achieved using the weighted Slope One predictor proposed by (Lemire & Maclachlan 2005). Slope One algorithm is considered to be one of the simplest algorithms to predict a user's opinion based on the said user's opinion and other users' opinions. The predictor is of the form $f(x) = x + b$ which precomputes the average difference ratings given to an item by two users. For example, if user A likes items X and Y, and users B likes items X,Y and Z, then there's a high probability that user A would also like item Z.

Submitter Reputation

One successful strategy adopted by community driven websites is the concept of user karma, i.e., a score assigned to users on the basis of the quality of their participation. It was popularized by the pioneering collaborative news aggregation portal Slashdot[5]. It is envisaged that the recommendation engine will use the reputation of the submitter, based on the submitter's karma, to initially assign a score to a sensor. However, given that there's a significant number of sensors provided by experts (e.g. WMO, NASA, Environment Canada, USGS), these experts can be assigned a high karma score by default.

[3] http://delicious.com
[4] http://digg.com
[5] http://slashdot.org

Sensor Reputation, Popularity and Freshness

Reputation will be based on the weighted sum of user ratings. Popularity will be a function of the number of users who tag/rate a node, and Freshness will depend on the time of the last update of a sensor.

Self-adopting weighting algorithm

The system will be a learning system, adopting weights given to different scores based on a neural network.

System Design Considerations

The system will be of a very high computational complexity. For example, for a system of m nodes and n users, the size of the Slope One matrix will be mn^2. Therefore, a series of optimizations is proposed to reduce computational complexity of the engine.

Moreover, any wisdom-of-the-crowds system is open to gaming, *i.e.*, a segment of users (often a tiny fraction), who try to skew the results by manipulating algorithm to promote certain nodes. For example, Google bombing (Judit Bar-Ilan 2007) is a classical example of people gaming the Google Pagerank algorithm. We will design anti-gaming mechanisms in order to prevent a small amount of users manipulate the algorithm and skew the recommendation results.

Data

The data will consist of the sensor metadata, and user generated data. The sensor metadata would include sensor location, the data the sensor is providing (temperature, ground-level O_3 concentrations, road traffic images) and information about the sensor operator. The user generated data would include tagging (using both controlled vocabularies and free-text) and ratings.

Results

The results will be evaluated by measuring the average scores users assign to recommended nodes after they have used the system for a reasonable period of time, and a critical mass of users have signed up to the system.

The expected results are that as the user numbers increase and user-hours spent using the system (thereby passively training it) increase, the average score assigned to recommended nodes will go up.

Conclusions

We have proposed a recommendation engine that harnesses the collective intelligence from sensor web users and helps them to discover sensors that maybe of utility or interest to them. The recommendation engine uses a neural network to aggregate a set of metrics. The expected results are that as more user-hours are spent on the system, the performance of the engine will increase.

Future work will add temporal aspects to the recommendation engine.

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An Object-based Spatial Data Search Engine

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Abstract

It is now nearly 40 years since the Internet was first established. During the last 15 years many Internet users have been exposed to increasing amounts of information. Most of the information consists of text or images. As such, most search engines use text criteria to find web-pages containing relevant information. Therefore, in order to find spatial data one can only search web-pages using keywords, as there are few spatial concepts that have been readily adapted to enable the identification of spatial data on the Internet; But most spatial data users prefer to use spatial concepts rather than simple keywords to find spatial datasets. Concepts such as within, adjacent, near are vague further confounding one's ability to search spatial features and datasets. These concepts demand a basic understanding of geometric space and spatial data model rules in order to be implemented within an Internet framework. Besides, representation of spatial data requires data models that maintain coordinate systems and other relevant spatial data characteristics.

New Internet technologies such as SVG, VML and Java applets make it possible to represent spatial data in an object-based or object-oriented way. But representing spatial data is not the only benefit. These technologies can be used to design interfaces that can apply spatial relationships during the process of searching for spatial data. SVG is a vector-based mark-up language for describing images and maps on the Internet so that they can be stored, managed and displayed as object-based spatial data. Objects can be represented independently; which can improve the quality of visualization when compared with raster-based images and maps. The ability of SVG to describe object data is an advantage for designers in that they can apply various spatial relationships and / or concepts to the objects. SVG maps differ greatly from simple image maps on the Internet, as they contain spatial coordinate systems and can store and display features with various spatial, non-spatial and cartographic characteristics. They can also contain interactive or animated content that make use of script programming languages such as JavaScript or ECMAscript for improved visualization.

This paper is the result of using such a technology for development of a spatial data search engine. The search engine consists of four components: an interface for users to register spatial data sets via their metadata; a DBMS to store and manage registered data; a server that extracts data from database and makes all components compatible, and an interface that allows users to search for appropriate data sets.

This implementation allows spatial data user's to search and retrieve spatial datasets that meet their needs from different sources using spatial tools, and provides prospective users with both a producer and consumer view of the data in an attempt to simplify the selection of the most appropriate data for a given problem. Future improvements to this system will include enhancements to collect metadata directly from a range of data formats, and additional spatial operators that can be used to narrow the spatial search domain.

Prairie Shelterbelt Inventory: Using High Resolution Imagery and Object-based Classification

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Abstract

The Shelterbelt Program established by the Prairie Farm Rehabilitation Administration (PFRA) has had several benefits to farmers and the prairie landscape. The effective planting of shelterbelts can mitigate the effects of soil erosion, provide a means to control snow drifting over highways and roads, provide wildlife habitat and control the odor around large intensive livestock operations. Due to growing concerns of about rising levels of Carbon Dioxide in the atmosphere shelterbelts have also been seen an effective way to sequester carbon dioxide from the atmosphere. Despite the positive effect of the Shelterbelt Program on the prairie landscape PFRA has limited channels to judge the success of the program. The current number of trees that exists and their exact location on the landscape is not known.

In this paper we use Definiens eCognition software along with SPOT-5 2.5m panchromatic image to produce an accurate inventory of Prairie shelterbelts which will be used in future research to create an inventory of carbon sequestration in Prairie Shelterbelts.

Background and Relevance

The Prairie Shelterbelt Program has distributed trees throughout the prairies for many years. Records have been kept on the number and location trees that have been distributed but no ground inventory has been done due to the large resources that would be needed. An earlier study was done to identify shelterbelts using high resolution aerial photography, along with Definiens Imaging, eCognition software (Wiseman et al., 2007) but was found to be expensive and time consuming due to the nature of acquiring aerial images. SPOT-5 2.5m panchromatic images were looked at as a more economical and time efficient source of data.

Methods and Data

The data used in this study is a, SPOT-5 2.5m panchromatic mosaic image, 34.5 by 28 kilometers, taken between July 1 and August 11 2006, in the area around Biggar, Saskatchewan. Other spatial data was used in the classification; Building, Roads and Limited Use Road shape layers from the National Topographic Database.

The classification of shelterbelts is a three step process; segmentation, classification, and classification refinement. Segmentation process involved the creation of shelterbelt-like objects on the image. Classification required the classification of three types of shelterbelts; field shelterbelts, roadside shelterbelts and farmyard shelterbelts. The classification refinement

incorporated other spatial data to separate field and roadside shelterbelts also to increase the accuracy of the farmyard shelterbelt classification.

Results

The results of the classification show that it is possible to provide an accurate inventory of shelterbelts using SPOT-5 panchromatic images.

The classification procedure that was used provided a positive classification of over 80% for all three types of shelterbelts found in a previous manual classification. The number of falsely classified shelterbelts objects was found to be acceptable rate for both field and farmyard shelterbelt, while roadside shelterbelts were falsely classified at a high rate.

Conclusions

It is evident that the Spot 2.5 m panchromatic images have a great potential to create an inventory of shelterbelts on the Prairie Provinces. In future research the shelterbelt inventory that is created by this methodology will be applied to carbon sequestration data to create an inventory of carbon sequestration by Prairie shelterbelts. Tree planting has great potential to reduce carbon emissions, noted in research done by Brandle (1992) and Kort and Turnock (1999). The expansiveness of the prairie landscape is an ideal location to develop such a program of tree planting. (Agriculture & Agri-Food Canada n.d.) The potential of a mass tree planting program on the prairies is substantial due to the over 61 million hectares of agriculture land that can be used for planting of shelterbelts. The creation of an inventory will hopefully demonstrate the impact that current shelterbelts have had in impacting the environment and show what future gains can be made in mitigating Co^2 emissions.

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GEOgraphic Object Based Image Analysis (GEOBIA): Developing a New Sub-Discipline in GIScience

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Abstract

We introduce to the SKI-Canada community a recently proposed and rapidly evolving sub-discipline in GIScience referred to as *GEOgraphic Object Based Image Analysis* (GEOBIA). We further provide a background on its development, report on the first International GEOBIA Conference (held in Calgary Alberta August 05-08, 2008 - in partnership with the CSA, ASPRS and ISPRS), and outline a plausible path ahead.

Background and Relevance

From Global Climate Change to natural disaster response and National Defense, Remote Sensing has provided critical information on vast areas of the Earth's surface for over 30 years, and continues to do so today. Daily, terabytes of data are acquired from space- and air-borne platforms, resulting in massive archives with incredible information potential; however we have only just begun to mine the wealth of these archives. Essentially we are data rich, but information poor. In most cases, data/image access is constrained by technological, institutional, and political barriers. Additionally tools for analyzing, visualizing, comparing, and sharing these data and their extracted information are still in their infancy. Furthermore, policy, legal and remuneration issues related to who owns (and are responsible for) value-added products resulting from either the original data sources, or from products that represent the culmination of many different users input (i.e., the web) are not well understood and still developing.

Over the last decade a quiet paradigm shift in remote sensing image processing has been taking place that promises to change the way we think about, analyze and use remote sensing imagery. With it we will have moved from more than 20 years of a predominantly pixel-spectra based model to a dynamic multiscale object-based contextual model that attempts to emulate the way humans interpret images. However, along this new path from pixels, to objects, to intelligence and the consolidation of this new paradigm, there are numerous challenges still to be addressed. In an effort to identify these challenges and potential solutions the international conference titled *GEOBIA, 2008 - Pixels, Objects, Intelligence: Geographic Object Based Image Analysis for the 21St Century* was held at the University of Calgary, Alberta, Canada August, 5-8, 2008. A key objective of this event was to facilitate a forum for this growing international community to share in the latest developments of GEOBIA theory, methods and applications so as to more intelligently exploit remote sensing imagery.

GEOBIA (pronounced *ge-o-be-uh*) is a sub-discipline of GIScience devoted to developing automated methods to partition remote sensing imagery (of our planets surface) into meaningful image-objects, and assessing their characteristics through scale. Its primary objective is the generation of geographic information (in GIS-ready format) from which new *geo-intelligence* can be obtained (Hay and Castilla, 2008). Interest in GEOBIA is world wide. Based on Google statistics for the GEOBIA website

(April 12 2007- August 05, 2008) it shows 58,623 page views - representing 17,209 visits from 5865 unique visitors originating in 111 different countries/territories and 1647 individual city locations throughout the planet. Furthermore, a total of 137 participants from 19 different countries attended this conference and workshops over the 4-day period that featured three keynote addresses, more than 63 regular oral presentations in three concurrent sessions, poster sessions and a student prize award for best paper (provided by the Canadian Remote Sensing Society). Eight industry workshops were held along with a special session entitled *'GEOBIA in Support of Government of Canada Needs*'. GEOBIA 2008 was co-organized in partnership with the Canadian Space Agency, the American Society for Photogrammetry and Remote Sensing (ASPRS) and the International Society for Photogrammetry and Remote Sensing (ISPRS). Conference proceedings will be linked with ISPRS Commission IV – Geodatabases and Digital Mapping to provide literary/scientific standards and online access. A GEOBIA special issue of the ASPRS Journal *Photogrammetric Engineering and Remote Sensing* (*PE&RS*) featuring selected full papers from GEOBIA 2008 will be published in 2009, and a GEOBIA wiki (with over 6000 views) can be found at (http//wiki.ucalgary.ca/page/GEOBIA).

Discussion

In his concluding keynote remarks G.J. Hay noted that while the "I" in GEOBIA currently represents the word 'image', it could also be used to represent other key components of this evolving discipline that need to be met in order to truly realize its potential; namely (i) *Intelligence Acquisition* – in this case 'geo-spatial content in context'; (ii) *Identification* – of scene features based on shared user-defined feature libraries; (iii) *Interpretation* – based on shared semantic and network models; (iv) *Integration* – a common ontology is required allowing for its diverse members to communicate across different geo-data-base architectures; (v) *Innovation* – a Transdisciplinary approach to tool/method development, drawing upon numerous innovations in other fields including computer vision, biomedical imaging etc; (vi) *Images* rather that 'Image', indicating the need for multiscale image analysis (in time, space, spectra, etc) and the hierarchical mechanisms to support and exploit them.

Conclusions

GEOBIA is a recent sub-discipline of GIScience devoted to developing automated methods to partition remote sensing imagery into meaningful image-objects, and assessing their characteristics through scale. Its primary objective is the generation of geographic information (in GIS-ready format) from which new *geo-intelligence* can be obtained. In this presentation, we report on the first International GEOIBA conference tilted: *GEOBIA, 2008 – Pixels, Objects, Intelligence. Geographic Object-Based Image Analysis for the 21st Century* and outline key components to meet its potential.

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An Ontology-Based Spatial Clustering Reasoning System

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Abstract

Spatial clustering, which groups similar spatial objects into classes, is an important research topic in spatial data mining. Many spatial clustering methods have been developed recently. However, common users may not know how to choose the most suitable spatial clustering method for their applications due to lack of expertise in the area. In this paper, we develop an ontology-based spatial clustering reasoning system. Using the system, the most suitable clustering method can be chosen for the target dataset with the support of the users' goal and a spatial clustering ontology. The system consists of the following parts: a spatial clustering ontology, an ontology reasoner, a web server and a user interface.

Background and Relevance

With the rapid growth of volume of spatial datasets, spatial clustering becomes an important topic in knowledge discovery research. It aims to group similar spatial objects into classes and is useful in exploratory pattern-analysis, grouping, decision-making, and machine-learning(Han et al., 2001). However, most existing clustering algorithms do not consider semantic information during the clustering process. Thus, a spatial clustering user needs to be familiar with the features of spatial clustering methods in order to choose a most suitable spatial clustering method for the dataset. In addition, users need to specify the parameters for the clustering algorithm, such as the number of clusters k for the k-Means method, which is also quite challenging for common users. Thus, providing knowledge support in clustering will be helpful for common users.

An *ontology* is a formal explicit specification of a shared conceptualization(Gruber, 1993). It provides domain knowledge relevant to the conceptualization and axioms(Wang & Hamilton, 2005). An clustering ontology can help us represent the knowledge in the spatial clustering domain.

In this paper, we propose an ontology-based reasoning system for spatial clustering. The purpose of the system is to guide a user to select an appropriate spatial clustering algorithm. The main contributions of the system are summarized below:

● The users' clustering goal is given at the semantic level. With the assist from a friendly user interface, users can easily find and use an appropriate clustering algorithm without knowing details about the algorithm.

● The ontology is represented in Web Ontology Language (OWL)(Owl Web Ontology Language Overview), the standard web ontology language and the system is built closely with the web service platform, so the system can be used to find clusters in web environments.

The Structure of System

Fig. 1 shows the structure of the system.

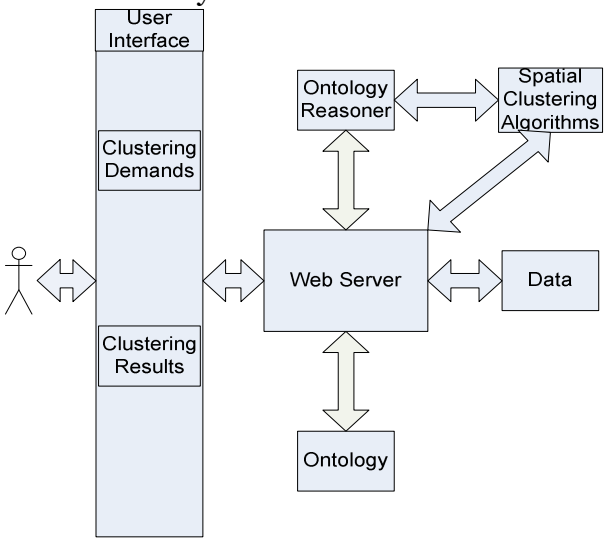

Fig. 1 The Structure of Ontology-Based Spatial Clustering System

The system performs spatial clustering reasoning under the following steps. First, the spatial clustering ontology is generated in a web ontology language and is posted on the Internet. Secondly, the users' goal is translated into queries that can perform reasoning on the ontology by Ontology Reasoner component. Then, the appropriate spatial clustering algorithms and spatial data sets are selected from the reasoning results. Thirdly, the selected clustering algorithm performs clustering on the datasets and clustering results are returned to the user.

A. *Clustering Ontology*

The ontology in the system is a formal representation of a set of concepts within the spatial clustering domain and the relationships between those concepts. The ontology can be used to explicitly represent the meaning of terms in vocabularies and make the information be easily accessed by computers. In the system, the spatial clustering knowledge in the ontology is organized by clustering techniques and clustering characteristics.

[5] provides a hierarchical classification of spatial clustering algorithms in terms of clustering techniques, shown in the Fig. 2. Every spatial clustering algorithm would be stored under a right node in the tree structure shown in the Fig. 2. For

example, K-Means algorithm is a partitioning clustering method based on distance, so it can be stored under the Node3.

Other ways to classify spatial clustering algorithms are based on the following characteristics: *Assignment Way, Attributes Type, Constraint, Dataset, Dataset Size, Dimensionality, Distance Measure, Measure Way, Noise Points Influence, and Search Way*. This approach tries to describe a spatial clustering algorithm from different aspects and extract algorithms' features. The ontology is developed using protégé-OWL. The snapshot is shown in Fig. 3.

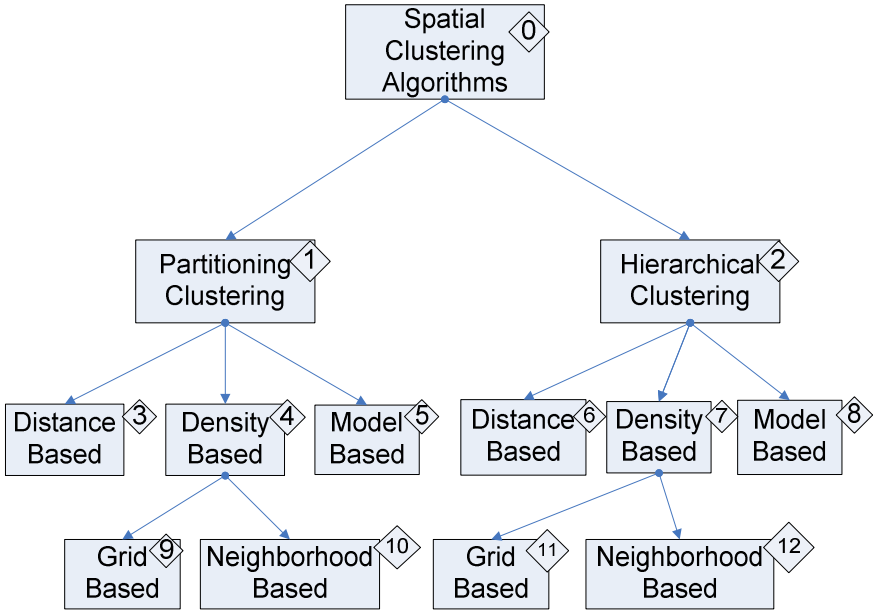

Fig.2 A Hierarchical Classification of Spatial Clustering Algorithms(Berkhin, 2002)

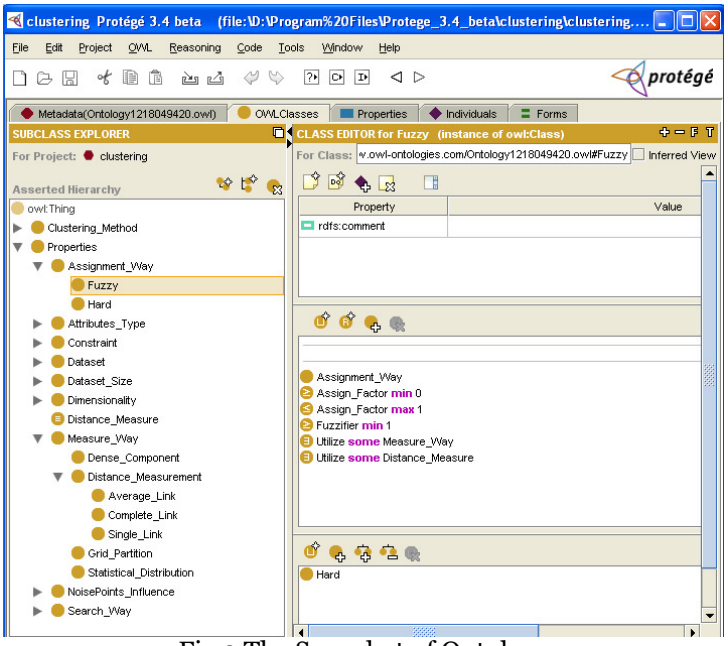

Fig.3 The Snapshot of Ontology

B. *Ontology Reasoner*

The ontology reasoner is used to reason the knowledge in the ontology. The input of the reasoner is the semantics information given by users, and the output is a set of appropriate spatial clustering algorithms. We use Pellet (Pellet website) as the reasoner for the system. Pellet is an open-source Java based OWL-DL reasoner. It provides functionality to validate ontology species, check consistency of ontologies, classify the taxonomy, check entailments and answer SPARQL queries.

C. *User Interface and Web Server*

User interface is used to receive the semantics requirements from users, transfer the information to web server and return clustering results to users. The users' requirements are described by type of attributes, scalability requirement, dimensionality of data, assignment method, outliers handling, defined parameters and constraints. Users can select the characteristics from the interface. The snapshots of user interface are shown in Fig.4.

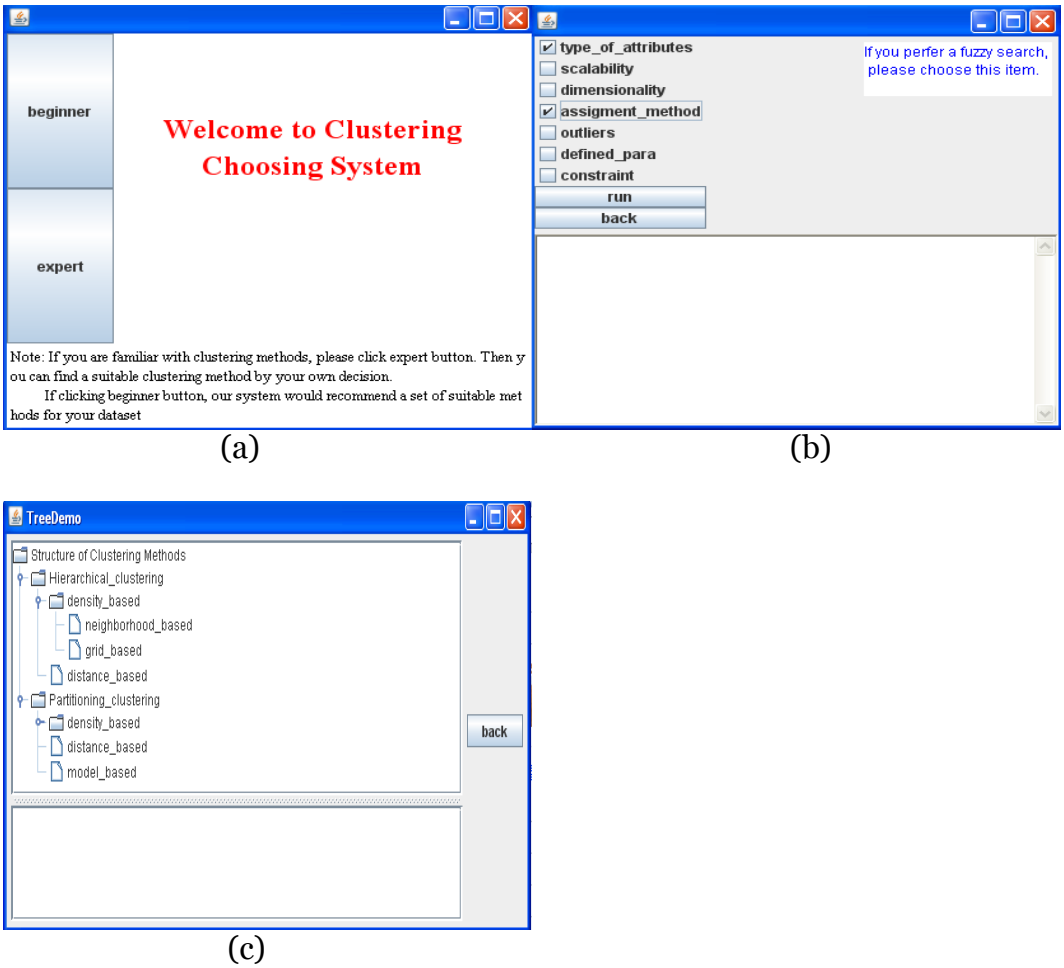

Fig. 4 The Snapshot of Use Interface (a) Main Page of the System, (b) Information Input Interface in Checkbox, (c) Information Input Interface in TreeView.

The web server built on Apache Tomcat (The Apache Software Foundation website) (which is an implementation of the Java Servlet and JavaServer Pages technologies) is responsible for searching an appropriate ontology on the Internet and sending the ontology to the ontology reasoner and return the clustering results to the user interface. Currently, only one spatial clustering ontology written by us is on the Internet for testing.

Conclusion

The major contribution of our work is to develop an ontology-based spatial clustering reasoning system. By reasoning the spatial clustering ontology, the system can automatically translate the semantics information into queries, then let user easily choose the most suitable spatial clustering algorithm without mastering the knowledge in spatial clustering domain.

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Integrating ontologies and schema for biographic and geographic databases

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Abstract

This paper describes a key set of ingredients to sharing biographical and geographic information that is stored in separate databases. These ingredients include the concepts of geospatial ontologies as well as database schema. A proof-of-concept system was developed with three databases of Chinese history and geography.

Background and Relevance

Ontologies have been a dominant theme in GIScience for 10 years. The goal is to work with a higher level of semantic abstraction than the individual variables or database schema of databases. Ontologies can serve to create semantic interoperability among heterogeneous databases, that is databases of various data structures and formats and in various physical locations. We argue that application of ontologies should maintain the distinctive way of modeling concepts in each database and not enforce a single way of modeling a concept, for example, the variables comprising where a historical person lived. This is especially important for the social sciences and humanities, where there should be support for multiple, competing categorizations of concepts (Bowers and Ludascher 2004, Friedlander et al 2009). Kintigh (2006) emphasized that archeologists used numerous systems to classify, for instance, stone tools. There may be contradictory indications of where and how a person lived. Because historical geographies are often contested and researchers view their data through diverse theoretical frames, these contestations need to be preserved.

Questions remain on how the geospatial ontologies are realized. For instance, how high a level of abstraction before that abstraction becomes meaningless? How many levels of abstraction are necessary or useful? How can we operationalize what's been up till now in GIScience (at least) conceptual and logical ontologies?

Even though geospatial ontologies enjoy broad usage, at least in the academy, they are still poorly understood. This is probably because ontologies are often confused with database schema and relations among data tables. Instead, ontologies are defined as an abstraction of concepts not relations among data tables or field names (e.g., entity relation model). Ontologies comprise a set of entities, attributes, axioms and relations (Gruber, 1993). These relations in an ontology can be more descriptive than join or "is a type of". Ontologies provide the concepts behind the data. Developing ontologies also provides the opportunity for a shared conversation about what the semantics should be.

Methods and Data

We sought to integrate three databases. They are the Chinese Historical GIS, hosted at Harvard University, the Chinese Biographical Database (CBDB), hosted at Academia Sinica, Taiwan, and the Ming-Qing Women's Writers database, hosted at McGill University. The first two constitute the most significant (i.e., in number of records and completeness) databases of Chinese history and geography in the world. The third, although physically smaller compared to the others, is also the largest database of its kind.

Our approach was to build a multi tiered ontology. We follow Bowers and Ludascher (2004), who argue that ontologies should occur in multiple tiers, or levels of specificity. We chose three tiers – application ontologies (AOs), domain ontology (DO), and upper level ontology (ULO) (Figure 1). The level closest to the database is the AO, which is a mapping of each database schema; in a relational database, schemas are basically the structure of tables. A DO, shared by all databases, is a mapping between the logical objects in the dataset (specific fields in a table for instance) and objects in the conceptual schema (classes and properties). It should represent concepts as they are explicated by the domain experts, in this case Chinese history and geography. The ULO is the highest level of abstraction and should be independent of the knowledge domain. It represented categories such as place and person and was used generally to guide a standard creation of concepts in the DO.

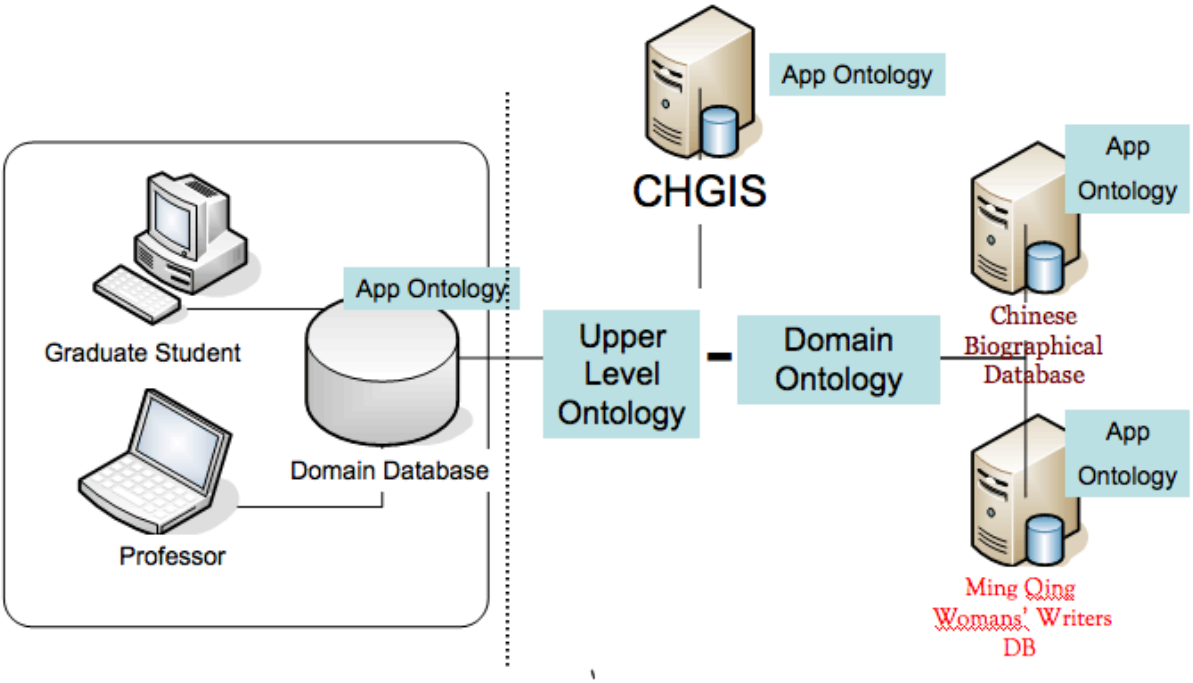

Figure 1. System Diagram, showing databases and their ontologies.

Geography present its own problems to ontologies (Egenhofer 2002) because many geographic features are determined not by single records in a geographic database but by topological relations among records as well as multiple and nested ways to represent

place. We were guided by our previous work (Wellen 2008) in development of ethnographic geospatial ontologies.

We used primarily open source or freely available software because we operated in a knowledge domain where developers did not have extensive computing resources. Much open source software is supported by large software user communities so it is conceivable that humanities resources could be extended by this support. These open source/free components included D2R and Protégé. A companion piece of software, D2RQ, converted the database schema into the application ontologies. We were guided by Zhao et al. (2008), who pioneered the work in the use of D2R and D2RQ for geospatial ontologies. Zhao et al. (*ibid*.) worked with only geospatial data; ours combined geospatial and nonspatial data. SPARQL and RDF were used to represent the semantics. D2R utilizes SPARQL and RDF.

Results

Figures 2 and 3 show the actual integration of the ontologies/schema. The figures illustrate the ULO and how it connected to the more specific ontologies and then to the database schema. The ULO was designed to operate at a high level of abstraction, in that it represents place as a feature, with properties such as feature type. To develop the ULO, we relied on existing ontology standards such as GeoOWL (for space) and Friend of a Friend (FOAF, for people).

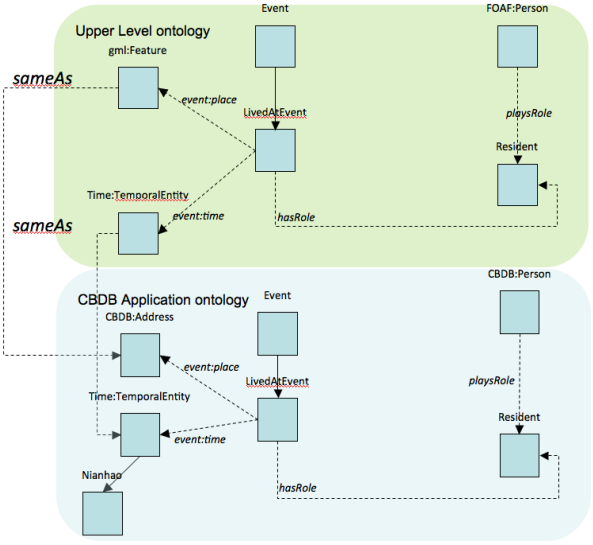

Figure 2. Upper level ontology/application ontology integration

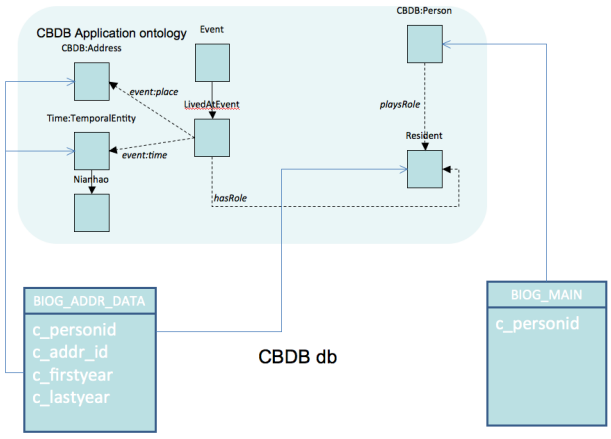

Figure 3. Application ontology/database schema integration

Figures 2 and 3 demonstrate that proposed methods do not necessarily translate into actuality. This was due to our choice of open source software. D2R was useful because it has a strong user community that could support developers from the social science and humanities. More importantly D2R handled the query brokerage (e.g., "where does famous woman poet x live?" requires a division of the questions into subquestions appropriate to each databases and a prioritization of the order in which the subquestions are asked of the databases). Query brokerage undergirds the functioning of the system architecture. Instead of being separate, the DO was collapsed into the ULO. It functions as a subset of the ULO. Like the ULO, the DO is shared across all databases. The two figures trace the integration of the abstract and generalized concept of geographic feature to greater specificity about how location are represented in the CBDB. What is not shown is the same abstraction of feature is linked to geographic locations in the CHGIS.

Using D2R required us to make use of D2RQ, which automates the translation of database schema into AOs. D2RQ generated separate files where D2R demanded only one database. The AO in Figure 3 represents the CBDB concept of "lived at". But each database had a different way to represent "lived at". So there was considerable manual modification to get the AOs to link to the ULO/DO.

Some final points on geography: We modeled geospatial data mostly as attributional—names and point features instead of features composed of multiple x, y's. This was dictated by the way the geospatial data was modeled in the three databases. Our relations were mostly mereotopoligical and places were disambiguated by dates, so we created relationships like preceeded_by. The geography in our case study is simple relative to other geospatial ontologies but did provide us with interesting challenges, nonetheless.

Conclusions

We were able to develop a proof-of-concept tiered ontology for our domain, which is Chinese historical biography and geography. We are left with numerous research questions for using ontologies for integrating databases, many of which are non-technical. How do we handle varying institutional issues, such as who maintains the ontology? How do we manage open/closed source systems? Lastly, how do we attend to the uneven institutional resources for computing in the social sciences and humanities? These questions and others provide a substantial domain for geospatial ontology research.

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3D Cellular Automata and Mobile Terrestrial Lidar: Simple rules for urban geography

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Abstract

Advances in LiDAR acquisition are providing high-resolution data of urban environments from the street perspective. In contrast to lidar acquisition from an aerial platform, mobile terrestrial lidar (MTL) captures the richness of urban space as it relates to social, economic and transportation uses and behavior at larger scales. However, with high resolution comes large data volumes and there are relatively few automated or even semi-automated methods for efficiently extracting surfaces and features into a usable and representative form.

In this study, data acquired using Terrapoint's TITAN system is resampled into a gridded three-dimensional virtual environment consisting of sampled and non-sampled space. Cellular automata are then used to build agglomerative surface structures using simple path-finding rule sets. Practically, this technique provides an abstract representation of space useful for describing and visualizing crude urban geometry at a high level of detail. Fundamentally, this work presents an interesting and novel paradigm for the exploration of sampled environments and demonstrates how simple decision rules can be used to build complex structures.

Background and Relevance

LiDAR datasets are generally synonymous with large data volumes and this is only exacerbated in mobile-terrestrial LiDAR given the closer proximity of sampled surfaces to the sensor(s) and the slower acquisition speed relative to aerial LiDAR systems. Such large datasets are difficult to manage since they require exhaustive spatial search to define local point sets for statistical analysis or for computational geometry or computer vision algorithms. Therefore, there is a definite need for the point cloud to be "organized" into a structure that is conducive to rapid spatial query. Ideally this organization should support a variety of subsequent tasks such as segmentation, extraction, and compression.

Traditionally 3D city models are some combination of extruded 2D polygons and higher fidelity 3D geometric models reconstructed through photogrammetric methods or from surface models derived from aerial LiDAR data (Luo & Gavrilova 2006; Madhavan *et al.* 2006). Specific methods have been derived, for example, for reconstructing roof structure from point cloud data (Vosselman & Dijkman 2001). However, from the terrestrial point of view there has been very little focus on modeling "as-built" urban infrastructure for block scale urban

settings, despite the fact that terrestrial lidar scanners are built to operate at precisely this scale. Examples of innovative work in extracting and visualizing building facades can be seen in Zhao & Shibasaki (2001) and Früh & Zakhor (2001) . This work is extended by Früh (2002) to include both aerial and ground-based techniques for a full 3D city model. These methods rely on textured polygonal meshes for visualization purposes and do not make attempts to model architectural features or smaller urban objects such as benches or light poles. Other research has used static LiDAR systems to produce "as-built" cadastral and polygonal mesh objects for industrial and small-scale architectural applications (Stemberg *et al.* 2004) but involve substantial 3D modeling knowledge and manual processing time to produce the finished models.

There has been no research focused on creating representations and structures from ground-based LiDAR data that allow for further analysis and subsequent modeling. In other words, in most cases human processing of Lidar data produces geometric models for comparison to plans (as-built drawing) or for visualization and game uses (3D features) but not, in general, for spatial analysis and modeling. This study attempts to work in that relatively new domain – 3D spatial analysis situated in ultrahigh resolution worlds. In particular, we examine the use of cellular automata to analyze urban LiDAR data.

A cellular spatial representation can be used to model the sampled urban environment (see voxels) and cellular automata (CA) techniques can be used to segment space and to build models for further analysis.

CA are spatially situated, finite state, information processing software machines. That is, CA operate under locally constrained conditions and process information from their local neighborhood using state-transition functions. The central tenet behind modeling with CA is that global structure emerges from simple local interaction. CA can been used to simulate the growth of urban environments and have also been used in urban simulation using mobile CA, also known as "cellular agents" (Batty 2005; Batty *et al.* 2002).

We propose that geometric constraints can be introduced into a cellular agent system to segment distinct surfaces from terrestrial-based lidar point clouds. Tavakoli *et al.* (2008) outline a similar basic framework and path-planning algorithm for cellular agents in a geometrically bounded environment. Essentially, cellular agents are constrained by the *affordances* provided by the environmental structure where they exist and the affordance similarity correlation between adjacent spatial regions can be used to group sampled urban structure (Gibson 1979; Raubal & Moratz 2007).

Methods and Data

Data was collected using Terrapoint's TITAN mobile terrestrial LiDAR system. TITAN was mounted to a pickup truck platform and data was collected for large sections of the city of Kingston, ON, Canada. The terrestrial collection platform provides high-resolution range measurements of urban surfaces and objects.

Data points are stored in matrix format for fast access and to provide a structured spatial representation of the sampled environment. The downside to this "grid" representation is that non-sampled space must also be taken into account and thus increases the data volume. While it is possible that sparse-matrix methods could be used to compress such grids, the performance impact would be considerable.

We explore using a cellular agent approach for extracting and abstracting physical structure from TITAN point clouds. Our approach uses mobile cellular "agents" whose movement is constrained by physical structure of the environment. An example of a constraint would be to limit vertical movement to a specific angle from the currently approximated plane. In essence, this approach uses simulation to investigate the effects of spatially constrained transition functions. These transitions functions are constructed to mimic the natural transitions in the world.

We simulate the systems at multiple levels of detail in order to explore the efficacy of our algorithms across spatial scales. Furthermore, moving from low detail towards higher detail representations of space provides a framework for focusing computation to areas where data samples exist and thus helps to mitigate data volume and computation issues. As a result of this, it is likely that such algorithms, once refined, could be implemented in parallel, for example on a programmable GPU, in order to achieve higher performance.

Results

Initial results point to a need for a more flexible representation of space. Cellular partitioning of space predicates fixed spatial relationships to a grid or other tessellation of space. Furthermore, in order to represent the data accuracy in a matrix format requires trading off larger data volumes for search time. The larger data volumes result from the need to model not only points in space but also all non-sampled regions as well. Future work will take advantage of different spatial decomposition techniques in computer science and 3D graphics to help organize data into smaller and more flexible data structures.

Conclusions

From a GIScience perspective this work provides an investigation into the tools and methods needed to introduce dynamic simulation modeling with CA into the spatial analysis suite and as such can be considered to contribute to the developing science of geocomputation. In particular, we move CA and spatial analysis into the emerging field of 3d urban visualization, which marries computer graphics, GIScience, planning, and infrastructure studies. Although preliminary, this work points towards future tools to improve the state of knowledge about cities, and so to support urban decision support efforts across the board.

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A multi-agent system to simulate the decision process of stakeholders involved in a land residential project in the Calgary region

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Abstract

The objective of this project is to build a multi-agent system to simulate the decision making process of stakeholders in a residential land development project and the influence of such decisions on land-use resources. The environment over which decisions are made is the Town of Strathmore, Alberta, where competition for land-use resources is increasing as a result of its proximity to the City of Calgary. The stakeholders simulated as agents are the citizens, the town planner and the developer. Interviews were conducted with representatives of each group to gather information about their goals, decision making process and influence. Simulations were performed over 30 years with a one year interval to mimic different land development scenarios. The model generates a series of land-use maps showing the changes in the environment based on the goals and decisions of agents. This model represents a valuable tool to better understand the complex interactions among several stakeholders involved in a land redesignation process and forecast the cumulative impact of their decisions on the environment.

Background and Relevance

In Alberta, prior to the development of a parcel of land, the land-use designation must be legally changed to allow for the proposed development. Several stakeholders are involved in this process including but not limited to the land owners, the land developers, the citizens, the municipal planners, the utility companies, and the environmental organizations. These stakeholders make decisions by weighing the social need, environmental impact, economic advantages/disadvantages and political support/opposition of a proposed land development. The municipal planner also attempts to fit a proposed land development into future plans that have been developed for the community. Each stakeholder has different opinions on the land development and different goals that he attempts to meet. There is a structure of formal and informal communication between the stakeholders, and the outcome of this complex system is a decision which changes the land-use designation of the parcel. Municipal planners use various tools including historical data and past experiences, statistical analyses of census data, and community economic models to make decision. However, these decisions are still quite often made in the face of uncertainty. Planners do not have the ability to forecast the cumulative effect of many individual decisions made by stakeholders on the environment over which they make their decisions. They need a tool that can model how final environmental patterns and trends emerge from the cumulative effect of complex behaviors and interactions of several individual stakeholders who might have conflicting views. This project has been undertaken to fulfill these requirements through the development of a multi-agent system.

Methods and Data

A multi-agent system (MAS) simulates a community of agents making decisions and taking actions on an environment. These agents are autonomous, they control their own decisions and actions, they are social, they communicate to negotiate and cooperate with one another; they are able to perceive changes in the environment and react to them; they have goals and are able to take initiative to achieve them (Marceau, 2008). MAS are built from a bottom up approach, explicitly reproducing the actions of individual agents in attempts to understand how the properties of the system emerge from individuals perceiving and acting upon their environment. They are increasingly used for wildlife and natural resource management (Anwar et al., 2007; Feuillette et al., 2003), and land-use planning (Ligtenberg et al., 2001; Monticino et al., 2007). In this project, the environment, the Town of Strathmore, is represented by a series of raster-based maps at 4 m spatial resolution including the land-use designation, the cadastral base, and the land use. The stakeholders include the town planner (also representing the town council), the land developer and the citizens. Structured interviews with representatives of each agent type were performed and the information was compiled to determine their goals, how they make decisions, the factors that influence their decisions, and how they communicate with each other. A decision module was built to simulate the intricate process of negociation and decision of these interacting agents. The model was programmed in Java and simulates agent-environment interactions that occur when agents "see" the environment over which they make decisions, and agent-agent interactions that are defined as logical rules and communication between agents. The model involves three components: 1) a simulation module of the agent goals, interactions and decision making that creates the development scenarios, 2) a module that changes the land use based on development scenarios and neighbouring existing land use, and 3) the combination of the two modules that takes the agents' decisions in a development scenario and applies them to the environment. Simulations were run for a period of 30 years, which lies within the future plans of the Town, with a one year incremental step.

Results

The model allows the user to modify the parameter values of each agent type: the planner, the citizen, and the land developer. This is done through the use of a pairwise comparison matrix where the intensity of importance of one goal over another is recorded. The user can also modify the land-use bylaws and environmental regulations, the real estate market value and construction costs, and the population and housing properties. The Run-time Variables panel shows the values of the variables as the model runs such as the population statistics and the proposed development, the opinion and change of behavior of each agent, and the variables affecting their decisions. Several different development scenarios were performed using the model to visualize the impact on the development of Strathmore, including: increasing and decreasing residential density, allowing, forbidding, or compensating any impact on wetlands present in the proposed development area, and decreasing the average household size. The model generates a series of raster-based land-use maps showing the change of the environment based on the goals and decisions made by the agents.

Conclusions

The results generated by the model are being validated using two approaches: conceptual validation that consists in verifying if the underlying assumptions are appropriate for the purpose of the modeling exercise, and operational validation that will determine the extent to which the model produces outcomes that match the real system under investigation. Meetings with the stakeholders will be organized during the fall 2008 where they will be shown the results and asked if they accurately portray the intentions of the actual decisions made on the land development project. The stakeholders will be invited to suggest additional development scenarios to forecast the possible future town growth based on the carry-over of agent goals. This will allow further testing of the robustness and usefulness of the model in a range of conditions. This model could potentially lead the stakeholders to achieve a beneficial outcome in the best interest of everyone when facing the challenge of new urban development.

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Examining Access to Health Care at the Neighbourhood Level

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Abstract

The objective of this research is to measure physical access to primary health care at the neighbourhood level in Mississauga, Ontario to determine if inequities in health care distribution and access exist. This study will meet its primary objective using geographic information systems (GIS) mapping techniques.

Background and Relevance

There is a well established link between health care access, health care use, and the overall health of populations (Health-Canada, 1999). Health care is recognized as one of the main determinants of health. According to the Canada Health Act (CHA), all Canadians are entitled to receive access to medically necessary services, regardless of their ability to pay (Library of Parliament, 2003). However, with decreased federal funding of health care in the last two decades and a decentralization of services, Canadians are experiencing greater waiting times for physicians, and more Canadians are expressing dissatisfaction with the health care system (Sanmartin et al, 2000). In addition, approximately 4.1 million Canadians do not have a regular family doctor (Nabalamba & Millar, 2007).

Access to health care can be described in several ways, but the most elementary definition is based on physical accessibility. Physical access is described by the distribution of health care services within a geographic area. The distribution of primary health care facilities in Canada has been of interest to health geographers for some time, and there is little disagreement among researchers that the geographic distribution of physicians is unequal relative to the distribution of the Canadian population, creating inequities in access to health (Health-Canada, 1999). However, the traditional focus of literature has been the unequal distribution of physicians between rural and urban settings (Health-Canada, 1999), with fewer studies focused on intra-urban variation.

Recent research within health geography has begun to focus on intra-urban variations in health with a particular focus on the study of neighbourhood effects on health. Current research indicates that neighbourhood social and physical contexts are important in shaping individual health outcomes (Law et al, 2005; Sampson, 2003). Yet, we know little about variations in access to health care at the neighbourhood level. The objective of this research is to measure physical access to primary health care at the neighbourhood level in Mississauga, Ontario to determine if inequities in health care distribution and access exist. This study will add needed information on the distribution of and physical access to primary health care at the neighbourhood level.

Methods and Data

This study will meet its primary objective using geographic information systems (GIS) mapping techniques. Street addresses for health services will be obtained from the College of Physicians and Surgeons of Ontario. In the research, primary health care services include family physicians/general practitioners, walk-in-clinics, after-hours clinics, and community health centres. Primary health care facilities will be categorized into an SPSS database and entered into the GIS through geocoding, which will provide them with a discreet point location on a Mississauga city map. The city will be divided into neighbourhood boundaries based on grouping and cutting 2006 Census Dissemination Areas (DAs) where necessary to approximate municipal neighbourhood boundaries. We will then assess the total number of primary care locations in addition to the total number of primary care physicians in each neighbourhood to develop an index of availability in each neighbourhood. In addition, the location of health care facilities will be analyzed for spatial distribution patterns within and between neighbourhoods, such as spatial clustering. Finally, social contexts of neighbourhoods will be considered using available 2006 Census data to determine whether the spatial distribution and abundance of health care services is related to contextual variables such as average household income and educational attainment.

Results

This research will take place between October 2008 and January 2009, and therefore, results are potential rather than actual. Based on previous literature, there are several trends in health care distribution and access that may be seen in this analysis. It has been found in previous studies that the location of health care providers does show uneven spatial distributions within some Canadian cities (Health-Canada, 1999). As a result, we might see spatial clusters of primary care within some neighbourhoods and a lack of primary care providers in other neighbourhoods. We may also see significant differences in the ratio of persons-per-physicians between neighbourhoods. Additionally, previous literature has found an abundance of primary care facilities in census tracts with higher educational attainment (Krishnan, 2007). Our study may also find clusters of primary care in neighbourhoods with higher socioeconomic status indicators such as income and education. Finally, we may also see differences in the abundance of different types of primary care facilities depending on neighbourhood contextual attributes. This may occur, for example, because the population to frequent walk-in clinics may be dissimilar to the population to have a dedicated general practitioner.

Conclusions

This research project of mapping access to primary health care at the neighbourhood level will contribute knowledge to the field of health geography by helping to explain how and why health care distribution differs at local scales in Canada. This study will create opportunities for future research to study how health care distribution affects health care utilization and overall health outcomes within neighbourhoods.

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