VISUALIZATION FOR DEVELOPMENT OF CITIES IN NORTHERN CANADA

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Abstract

Increasing economic development activities in the northern regions of Canada require large amounts of geo-spatial information. Various types of visualizations need to be developed, not only for management of natural resources, but also for ensuring protection of a fragile northern environment, for ensuring national safety and security, and for initiation of new economic activities. Visualization, digital mapping and geographic information systems are becoming basic tools used by local communities for the effective economic, social and cultural development of the northern territories.

This paper will present results obtained in projects carried out to effectively visualize issues related to the sustainable economic, social and cultural development of northern cities of Canada. Visualization techniques to depict the development of the capital city of Nunavut, Iqaluit, focus on representation of change. The visualization of Whitehorse, the capital city of the Yukon Territory, serves as example of web-based visualization for communication of residential energy and Greenhouse Gas (GHG) information for urban development. These visualizations were based on the Google Earth environment and an in-house Dynamic Visualization System, which uses Scalable Vector Graphics format suitable for web-based on-demand mapping and analysis of the geo-spatial information. These projects were conducted in collaboration with the local government of Nunavut, and between the two sectors of Natural Resources Canada, namely the Earth Sciences Sector responsible for mapping and visualization and the Innovation and Energy Technology Sector responsible for research and development of energy technologies.

1.0 Background information

Natural Resources Canada, a department of the federal government, is responsible for policies, science and technology that support the sustainable development of natural resources. It aims to reduce the environmental impacts of emissions and waste; to find longer-term solutions that will protect the environment for future generations; and to ensure regulatory regimes are effective and efficient. The Natural Resources department plays a pivotal role in helping shape the important contributions of the natural resources sector to the Canadian economy, society and environment. Its sectors—forests, energy, minerals and metals, as well as related industries—are one of the most productive, “high-technology” sectors in the global economy. The projects presented in this paper have been conducted in partnership - the visualization of Iqaluit, with the Territorial Government of Nunavut [http://www.gov.nu.ca/cley], Department of Culture, Language, Elders and Youth and the visualization of energy use within neighborhoods in the City of Whitehorse, in collaboration with the CanmetENERGY division of the Innovation and Energy Technology Sector [http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca], and the Earth Sciences Sector [http://ess.nrcan.gc.ca] of Natural Resources Canada.

Northern communities use traditional knowledge while adapting to the global economy and modern technologies (Alekseyev, 1997). Economic development has brought new occupations and with that change in wealth, income distribution, community and family patterns. The economic future of this region is firmly linked to the sustainable development of its renewable and non-renewable natural resources: mining, petroleum development, commercial fishing, hunting, and eco-tourism.

2.0 Cartographic visualization of spatial change

The visualization of change could benefit from the use of dynamic cartographic representations (Armenakis and Siekierska 2009), enabling the user to reconstruct the temporal changes of geographical phenomena, events and spaces by creating an illusion of the spatio-temporal transformation and evolution. The effective portrayal of spatial changes on maps requires special attention to overcome the static properties of printed maps. The current methodologies for change visualization need to take advantage of opportunities provided by modern computer technologies (Andrienko and Andrienko, 2007) but at the same time should incorporate the legacy of classical cartography.

The involvement of the users in the visualization process must also be considered. Interactive systems based on predefined processes provide quick response to user queries. Proactive approaches allow users to decide their own exploratory paths, and to access, retrieve, and process various sources of information during the analysis. One approach to build an active cartographic environment is to integrate motion - animated maps - and various multiple types of data - images, text, sound, numerical data - with conventional and innovative cartographic representations. The concept of hypermedia can provide the tool for exploration, while the visualization of spatio-temporal data will facilitate dynamic representations (Siekierska and Armenakis, 1999).

The human brain perceives change as either movement or change in shape, texture, colour, sound or feel. Historically, maps were very limited in showing change through time because of their static nature and their two-dimensional representation of space. Maps were used with a single slice of time to show change phenomena. Most commonly, representation of change is demonstrated by several states at once through two of more maps, displayed side by side. For example, change in urban growth would have been represented by one map showing spatial extent of the city in a specific time period and a second map showing the city’s current boundaries. In this type of change visualization, users make visual comparison and interpretation of presented data.

With advances in computer technology, multimedia is used to represent a multitude of changes in a dynamic environment. Cartographic animation has become a very effective visualization technique to intuitively represent dynamic geographical phenomena (Buziek, 1999). Through cartographic animation one can show interrelations amongst geospatial data components, location, attribute and time and multi- dimensional representations. Spatio-temporal changes of dynamic phenomena are best visualized through dynamic maps, and images, enabled by computer technology (Oberholzer and Hurni, 2000; Siekierska et al. 2001).

3. Visualization of the city of Iqaluit, Nunavut

Nunavut is the newest northern territory of Canada. It was created in April 1999; the capital of the territory is Iqaluit, previously known as Frobisher Bay. To acknowledge the creation of this new territory, the Canada Centre for Topographic Information produced a special commemorative topographic map of Iqaluit and its environment. This map breaks with conventional portrayal of the country within the National Topographic Mapping System (NTS) and positions the capital of the territory in the centre of a new topographic map (Iqaluit - parts of the NTS maps 25N-9, -10, -15 and -16) [http://maps.nrcan.gc.ca/topo101/025n10_e.php]. Furthermore, several projects have been conducted to develop new methods of cartographic visualization and geographic information handling suitable for web-based communication of geospatial and historical information pertaining to northern communities [http://maps.nrcan.gc.ca/visual/index_e.php]. Within these projects experiments were conducted on how interactive hyper-linking techniques could be used to show the rapid urban development, which occurred in Iqaluit from its inception as a small fishing village, to the active port serving northern territories, to the capital of Nunavut [http://maps.nrcan.gc.ca/iqaluit/index_e.php].

3.1 Spatial and historical evolution of Iqaluit

The Canadian National Air Photo Library stores and provides access to a vast collection of aerial photographs. These photographs are good data sources for examining past distribution of land use and a realistic starting point for discussing potential future developments. A visualization of the evolution of Iqaluit was based on the historical and current aerial photographs, taken at approximately ten-year intervals [http://maps.nrcan.gc.ca/iqaluit/index_e.php]. The aerial photographs were assembled and continuous orthomosaics created to portray the rapid growth of the city over 50 years (1948-2000). They served as a basis for the creation of historical city maps. The historical photographs and records provided additional information to reconstruct the development of Iqaluit, to discover factors influencing change, explain patterns in development, and provide cultural and social context.

Figure 1 shows an interactive display of the aerial photo mosaics and historical maps of the city, and the animated fly-over terrain videos. The most effective way to portray the change in the evolution of the city is by use of animations. The techniques used to portray the change included interactive overlays of images with different opacity to illustrate the continuous change in the growth of the city based on aerial images. Another way to represent change is a discrete comparison between two consecutive periods based on historical maps (Siekierska et al., 2001). An innovative representation of change implemented in this project is a parallel flight over 3-dimensional historical landscapes using animation. Figure 2 shows the 'parallel fly-over' of the historical landscapes in two time periods.

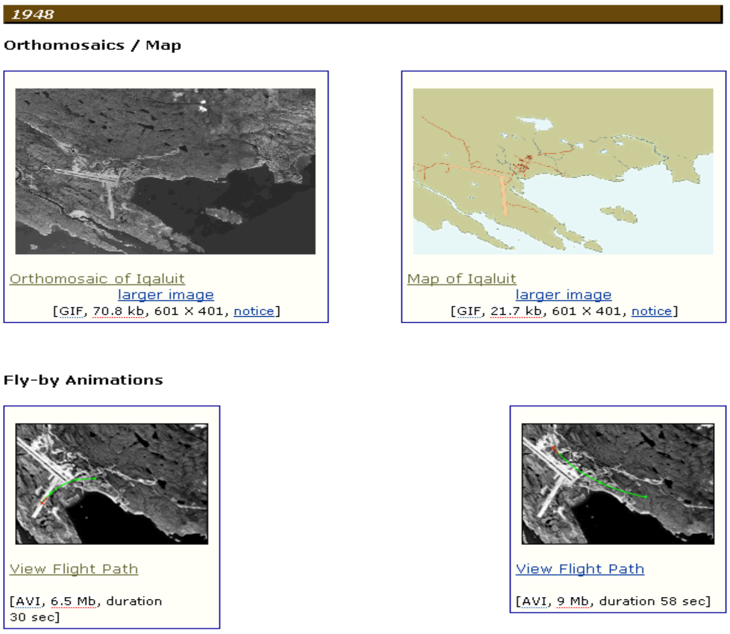

Figure 1. Orthomosaic and map of Iqaluit (Frobisher Bay) in 1948

Figure 2. Animation of 3-dimensional historical landscapes - comparison between years 2000 and 1969.

The 3-dimensional animated visualizations have broad range of applications. Passive or interactive animations such as the Canada Rover system portray an interactive 'fly-over' of a given area for more effective visual interpretation. (Baulch, et al. 2005). The simulated landscapes have been extensively used tourism and in urban planning (Al-Kodmany, 2002). The "fly-over" using historical data (figure 2) is a useful tool for analyzing change and planning the development of cities.

3.2 Historical evolution of Iqaluit web site – multilingual version

The web site depicting the historical and spatial evolution of Iqaluit was created to explain the background of the development of the city and to provide basic information for planning and sustainable development activities The site was created in collaboration with the Government of Nunavut, Department of Culture, Language, Elders and Youth (CLEY- Nunavut), the City of Iqaluit, and the Nunatta Sunakkutaangit Museum. To facilitate the use of the web site in Nunavut, the site has been translated into the native languages of the region, *Inuinnaqtun*, written in the Roman orthography, and *Inuktitut* written in syllabics. This site uses standardized, syllabic font called *Pigiarniq*, developed for the Government of Nunavut. To use the multilingual version of this web site, users need to download the *Pigiarniq* font package from the Government of Nunavut web site. Figure 3 shows an example of the implementation of the web site in *Inuktitut*.

Figure 3. Historical and spatial evolution of Iqaluit in Inuktitut – historical commentary.

The development in the field of informatics and specifically electronic communications via Internet offers much flexibility in the design and distribution of versatile cartographic products in multilingual versions.

4. Visualization of neighbourhoods within the City of Whitehorse

Visualizations of residential energy and GreenHouse Gases (GHG) use were developed for application in a sustainable community design charette in the City of Whitehorse, capital of the Yukon Territory. They were developed in conjunction with the Urban Archetypes Project, which investigated 31 neighbourhoods in 8 communities to explore the linkages between urban form, lifestyle patterns of residents and energy consumption. Although only one northern community, Whitehorse, participated in the project, this research contributes to climate change mitigation by developing information to inform decision making for energy efficiency in residential neighbourhoods.

The Urban Archetypes Project was carried out by the Sustainable Communities and Buildings group within the Innovation and Energy Technology Centre (formerly the Canmet Energy Technology Centre) [http://www.sbc.nrcan.gc.ca]. To effectively communicate preliminary project results for the Porter Creek Bench Charette, a mapping pilot project was initiated. Several visualization methods were developed in collaboration with the Visualization Team of the Canada Centre for Topographic Information - Ottawa, Earth Sciences Sector [http://ess.nrcan.gc.ca/2002_2006/sdki/visual/index_e.php], and the Laboratory of Applied Geomatics and GIS Science (LAGGIS) research centre of the University of Ottawa [http://www.geomatics.uottawa.ca/index_e.html]. Visualization systems evaluation and preliminary user feedback provide a basis for recommending appropriate visualization methods for effective communication of findings to urban planners and the general public.

City planners in Whitehorse were the first to integrate Urban Archetypes Project information into a land use planning process. Information collected by the project was used in the city's Porter Creek Bench Design Charette. A charette is a short and intensive multi-stakeholder workshop to facilitate consensus-based planning and design [Smart Growth 2008]. In the case of Whitehorse, the charette pertained to the development of a new neighbourhood and was held in November, 2006.

A primary challenge associated with the communication of energy information in the context of neighbourhoods is the need to display both spatial and statistical information simultaneously. An approach that employs cartographic visualization is therefore appropriate as it facilitates the holistic communication of features of urban form and relevant statistical data on residential energy consumption.

Community planning process engages a wide variety of stakeholders with varying levels of experience in working with maps and geospatial data. Urban planners, for example, can be considered expert map and visualization systems users whereas the general public are more likely to be novice users. Because Urban Archetypes Project information should be communicated to both of these groups, different methods of visualization were investigated. Platforms explored in the context of the mapping pilot project described here include Google Earth and Dynamic Visualization System (DVS), a Scalable Vector Graphics (SVG)-based platform.

4.1 Google Earth based visualization of urban neighbourhoods

Google Earth is a freely available virtual globe program that uses streaming technology to deliver imagery, maps and ancillary information over the Internet. Users can import their own data, such as vector or raster data, real-time GPS data, movie sequences, or 3-dimensional buildings with photorealistic textures to complement base images or map information which exist within Google Earth. The system permits users to export their visualizations in an XML based file format called KML (Boulos, 2005). A characteristic feature of Google Earth is the ability to carry out an effective search based on place name or relevant annotations. Temporal data may also be portrayed in Google Earth for time based visualizations. Google Earth supports real-time links to Open GIS Consortium (OGC), Web Map Servers (WMS) or Web Feature Servers (WFS) - thus additional data may be integrated into the visualizations. Displaying information layers in Google Earth is relatively straightforward; however, Google Earth has limited analytic functions and is not designed to replace professional GIS software.

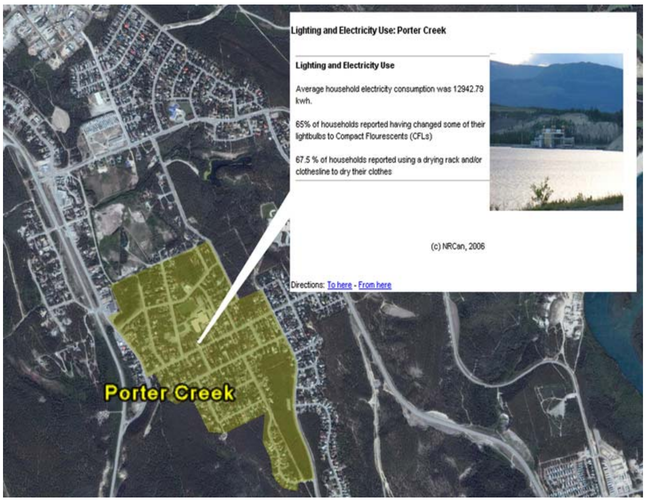

Figure 4. Whitehorse neighbourhood with display of energy related information.

A Google Earth environment was used to present research results at the Porter Creek Bench Design Charette. Figure 4 shows an image of Whitehorse and one of three neighbourhoods studied The information bubble displays household energy information. This information was then compared to the values obtained in the other neighbourhoods examined in the project by navigating to the other neighbourhoods.

Overall feedback obtained from the Porter Creek Bench Design Charette indicated that while visualization methods enhanced the communication of energy information for planning by situating the energy information in a spatial context, seeing the results in a format that enabled comparison of results between neighbourhoods in a side-by-side basis would be more useful. Participants also commented on variability in housing types within neighbourhoods and associated differences in energy performance that might not be properly reflected in an average value. As the charette pertained to the design and development of a new neighbourhood, the ability to compare current performance of houses against projected future energy demand of certain housing types was also mentioned as being of interest. Lastly, the ability to correlate urban form variables with transportation energy consumption was stated as being important for associating energy information with spatial land use information.

Subsequent to the charette, other Google Earth-based displays developed included a 3-dimensional mock up of a local high school created in Sketch-up showing the school's electricity consumption (figure 5).

Figure 5. Whitehorse Porter Creek high school showing its electricity consumption.

4.2 Dynamic Visualization System (DVS) – web based visualization created on-demand

Another Internet-based system used in the visualization of Urban Archetype data for the City of Whitehorse was the Dynamic Visualization System (DVS). This system is based on the Scalable Vector Graphics (SVG) format, a promising technology for real time interactive mapping. It has the potential to provide a web-based spatial decision support within an on-demand mapping environment. Using this system, geospatial information available at remote locations may be accessed and selectively downloaded by feature type or by attribute.[1] The implementation of DVS system is based on GeoClient open source SVG mapping environment. This capability optimizes web mapping by permitting users to integrate information most relevant to their particular application online, thus avoiding excessive data processing and reducing the reliance on the speed of the Internet. The system could provide researchers, planners and decision makers, real time access and on-demand display of geospatial information, from distributed, web-enabled, data sources (Williams et al., 2006).

[1] Services for web based real-time exploratory data analysis are currently being developed. See http://www.galdosinc.com

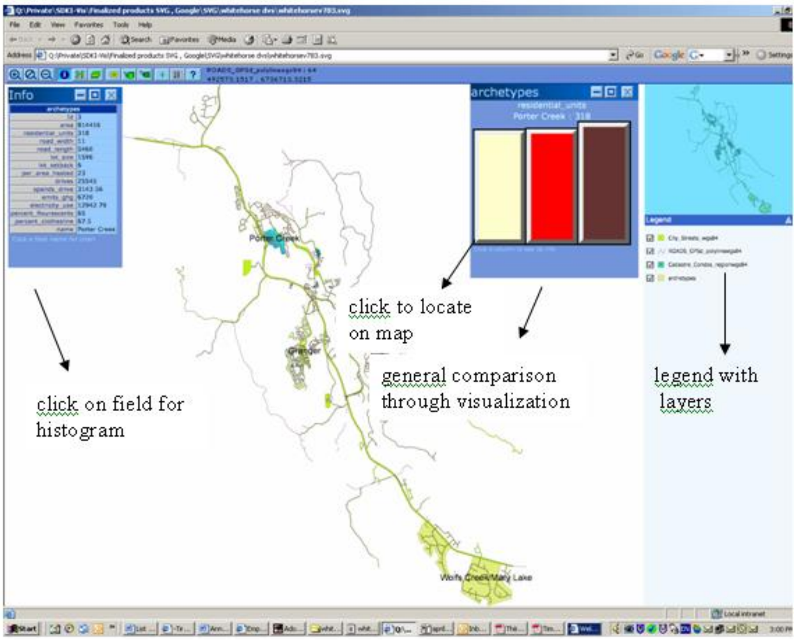

Figure 7. On-demand web based mapping using dynamic visualization system.

Figure 7 illustrates the functionality of the system: the interactive bar graph on the right shows size of sampled neighbourhoods studied in Whitehorse linked to their location, while the table on the left shows user-selected values of energy variables.

The SVG technology has been used by the Earth Sciences Sector, Geomatics for Northern Development program, to develop visualizations for demonstrating the use of Earth Observation data and geo-spatial technologies for portraying the environmental change [http://maps.nrcan.gc.ca/svg_prototype/index_e.php].
Although the DVS-SVG system was in development and thus not presented in Whitehorse, subsequent presentations given to decision and policy makers of the Mining and Minerals Sector at Natural Resources Canada indicated a interest in this upcoming technology.

5. Conclusions

New tools capable of visualizing the development of cities can be used effectively to integrate and communicate diverse information and knowledge to provide a strong foundation for science-based decision making.

The mapping pilot project conducted by Natural Resources Canada for the Porter Creek Bench Design Charette in the City of Whitehorse endeavoured to effectively visualize energy use in selected neighbourhoods using interactive maps that portrayed spatial and thematic energy and GreenHouse Gas (GHG) information. In general, interactive web-based maps can be effective tools for the communication of energy information in the context of community planning as they facilitate the integration of geospatial information with relevant statistical data on resident behaviour, and energy consumption for multiple users. Two distinct user groups were identified during the course of the project: urban planners and the general public. To address the requirements of these two groups, experiments were conducted to test interactive web based maps and visualization methodologies showing various levels of detail and functionality. The results of tests indicated that Google Earth or a similar web-enabled system could be an effective platform for use by the general public, while GIS-based, analytical interactive mapping and visualization systems, such as, the SVG based Dynamic Visualization System, would be better suited for expert users such as urban planners.

Feedback obtained from design charette participants indicated a preference to view side by side results from different neighbourhoods. Furthermore, correlation analysis between variables of urban form and transportation energy consumption would have provided additional valuable information. Thus although the Google Earth application facilitated the presentation of project information at the charette, maps with additional analytically capabilities would have been appropriate. To provide additional functionality to deliver information for future planning charettes and possibly to meet ongoing energy and land use planning needs of municipal planning departments, the inclusion of energy and GHG information in a GIS platform should be considered a preferable methodology.

The mapping pilot project was valuable from a research perspective as experience was gained on integrating and communicating energy information in the design charette. Feedback informed the development of the Urban Archetypes Project Community Case Studies (CanmetENERGY, 2009) and subsequent energy mapping research being conducted in conjunction with the Smart Growth on the Ground process in Prince George, B.C., a project involving the integration of housing energy use information in the city's geodatabase (Webster, 2009).

Incorporation of energy and GHG information in land use planning processes particularly in the north will be important for facilitating the sustainable development of communities that are attempting to mitigate their contribution to climate change and become resilient and adaptive to its impacts. Further investigation is warranted of energy and GHG applications in a web mapping environment. In the future, when information on the energy performance and building characteristics of housing types are available on open-source servers, this type of visualization and exploratory data analysis of energy-related indicators can be performed in real-time. This functionality has potential for accessing information from distributed databases that exist, for example geodatabases developed by municipalities for land use planning. Such databases must conform however to standards of interoperability to create a fully integrated GIS environment and will be successful only in the context of collaborative institutional structures.

Visualization created for the City of Iqaluit focused on change representation. The clear advantage of portraying geospatial data using electronic media was the ability to display the change, to analyze the patterns of development, and to model the possible future scenarios. The integration of ancillary information such as historical commentaries that explained the stages in the evolution of the city facilitated the understanding of the evolution in development of urban regions. Spatio-temporal change representation is particularly important for decision making within the context of sustainable development, as it provides information and tools to measure the rate of change.

Progress in web based technology allows cartographers to create advanced geospatial information representations. As a result, geospatial data handling process and visualization has dramatically improved by moving from static to dynamic, from passive to interactive electronic mapping and visualizations. Consequently, more methods to support the establishment of a territorial management information infrastructure are being made available. With the end user able to interactively control map content and styles of information visualization, decisive steps forward have been achieved in dynamic participatory cartography, interactive mapping, and geospatial data exploration. Furthermore, for the effective use of visualization in northern regions, publication of information in native languages used by these communities is essential to enable all inclusive participation. The visualization of information, in the native languages that are used in the region will ensure the greater awareness and accessibility of geospatial data and information processing methods and will enable the participation of the local population in decision making concerning the future developments of northern regions.

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