Visualization and Sustainable Development Decision Making

Eva Siekierska, Peter Williams and Anita Mueller
Earth Sciences Sector
Natural Resources Canada
Ottawa, Canada
siekiers@NRCan.gc.ca

Abstract

Visualization has emerged as a technique for searching through large volumes of data communicating complex patterns, and providing a formal framework for data presentation and exploratory analysis. Combining the power of multimedia dynamic representation of spatial information with interactive engagement of users, visualization allows both experts and non-experts to perform exploratory analysis and to communicate spatial information in graphical form. Geospatial information relevant for sustainable development often tends to be heterogeneous, complex, not directly comparable, and correlated in ways that may not be apparent without the use of visualization techniques. Furthermore, visualization is a component of geographic information systems as a tool to display multiple sustainable development scenarios, and thus, decision support techniques.

Visualization of geospatial information refers to the visual perception of various types of graphic representation of data ranging from static to dynamic presentation (cartographic visualization) to exploratory data analysis (scientific visualization). A number of visualization projects are carried out in the Mapping Services Branch in collaboration with the Canada Centre for Remote Sensing of the Earth Science Sector, Natural Resources Canada. The projects focus primarily on web-based, interactive, dynamic representation of information, suitable for effective communication of geospatial concepts in support of sustainable development decision making. The general objective of the visualization projects is to explore, develop and implement visualization techniques capable of translating complex scientific information into a form that readily communicates sustainable development to various user groups, in particular to policy and decision makers within the government of Canada.

This paper summarizes the sustainable development policy of Natural Resources Canada, discusses the impact of new technologies on cartographic visualization, and presents selected examples of new multimedia and multimodal techniques used for effective communication to decision makers.

The Sustainable Development Policy of Natural Resources Canada

Sustainable development was originally defined by the World Commission on Environment and Development, the Brundtland Commission, in a document entitled “Our Common Future”, as “development that meets the needs of the present without compromising the ability of the future generations to meet their own needs”. In 1989, Natural Resources Canada was the first department within the Canadian federal government to adopt a sustainable development strategy, as tabled in the document "Safeguarding our Assets, Securing our Future". In the natural resources sector, sustainable development requires the integration of social, environmental and economic considerations into resource development decisions. The responsible use of natural resources enables the protection of the health of Canadians, as well as Canada's environment and landmass, while continuing to meet human needs for energy, forest and mineral-based products.

In 2001, Natural Resources Canada tabled a follow-up sustainable development strategy entitled "Now and for the Future", which provided an optimistic vision of the country for the new century, while reminding Canadians that the implementation of sustainable development requires ideas, determination, and action on everyone's part, across all sectors of society. A third sustainable development strategy tabled in February 2004 and entitled "Moving Forward", formulated a results-based action plan guided by a unified, forward thinking vision, and an organizational commitment to sustainable development that encompasses the Department's diverse activities. The Department thus enables the Government of Canada to address the management of natural resources in a comprehensive manner.

The Sustainable Development through Knowledge Integration Program

Within the Earth Sciences Sector of Natural Resources Canada, the Sustainable Development through Knowledge Integration (SKDI) program was initiated in September 2003. This program focuses on a number of issues related to natural resources requirements for sustainable development, and builds on the concept that geospatial information can and should be used to support decision and policy making. The program will move the Earth Sciences Sector information and knowledge assets into the decision support environment of government, industry and the public. Within this program, innovative technologies and methodologies are being developed that facilitate the integration and visualization of geospatial information. These technologies enhance the Natural Resources Department's capacity to implement sustainable development and help promote the responsible use of Canada's mineral, energy and forest resources.

The "Visualization of Integrated Knowledge for Sustainable Development Decision Making" project addresses the visualization component of the Knowledge Integration program. The objective of the project is to assess and develop visualization techniques that effectively translate complex scientific information into a form that readily communicates sustainable development forecasting scenarios to selected user groups, in particular to policy/decision makers. The SDKI-Visualization project, through graphic and cartographic visualization on the Web, is bridging the gap between complex, quantitative data supplied by scientists and the decision makers who develop policies related to sustainable development of natural resources of Canada.

Visualization and Sustainable Development Decision Making

Visualization has been identified as one of the four main concepts for learning and decision-making in sustainable development. In this age of information revolution, the growing power of the visual image in human communication must be recognized. According to T. Wilbanks, the past president of the Association of American Geographers: "…across the world the creation and diffusion of visual images is displacing the printed word as a triggering mechanism for issue identification, constituency building and agenda setting. Visual images including computer mapping and aerial photography are increasingly used to identify threads to sustainability and to examine alternative paths. No other form of communication is as powerful among a variety of audiences, including scholars who are trying to associate creative thinking with empirical observations". [Wilbanks, 1994]. Wilbanks also stressed the importance of implementing innovative means of collaborative, technological and institutional change to foster greater inclusion of the geographical perspective in decision making for sustainable development.

As cartographic visualization is based increasingly on new technologies, there are concerns that the richness of human-to-human communication may be lost in virtual environments that can hamper spontaneous engagement. However, many researchers believe that the most dynamic and collaborative communication occurs when high and low technology do not replace traditional tools for decision making, but augment and enhance them.

Cartographic Perspective on Geospatial Visualization

Throughout the ages, various types of maps and images have been used to communicate information. The technological evolution and societal change have a huge impact on how maps and images are produced and distributed. Geospatial data representation has evolved from static representation of the world, to digital 2- or 3-dimensional and interactive presentations. In addition to graphical representation, maps have been enriched by multimedia, which expands the channels of information available to users through the addition of animation, sound and touch. These "new era" maps and graphics often become a medium for data exploration and analysis, and new distribution systems such as the Internet are being increasingly used.

One of the most fundamental issues in cartographic and graphic communication involves the suitability of the method used to represent data, since technology offers a variety of choices, including graphs, charts, tables, maps, 3-dimensional representation and animation, and selection of the appropriate methods is crucial. For example, cartographers warn against using choropleth maps that distribute a risk evenly over a surface when in fact the risk is not homogeneous to the degree that it follows the choropleth boundaries. Another issue is the use of visual variables, namely hue, size shape, value, texture and orientation of data symbolized [Bertin, 1983]. Web-based visualization is no longer limited to 2-dimensional static maps but includes dynamic and

3-dimensional representations. In this case the visual variables, as defined by J. Bertin, are further extended to encompass dynamic representation and VRML (Virtual Reality Modeling Language) which are dynamically linked to databases. Once the data is represented, the means of interaction that allow the user to manipulate variables to create different scenarios must be considered. The key to effective data exploration and analysis is the process by which users interact with data through functional and user friendly interfaces.

Multimedia Techniques Developed within the Mapping Service Branch

Selected examples of multimedia visualizations developed by the Mapping Services Branch that illustrate innovative multimedia and multimodal techniques are presented in the second part of this paper. These techniques include voice and sound integration, interactive cartography, representation of temporal dependant data, and information integration methods. Some of these techniques have been implemented in one of the northern territories of Canada, Nunavut, for sustainable development decision making and the promotion of eco-tourism.

Multimedia and hypermedia, with the integration of text, graphics, drawings, still and video, animation, audio, and other forms of media, have transformed cartography. The capability to explore and interact with data both spatially and conceptually has changed the way we learn and conceive relationships. The development and evolution of the World Wide Web has necessitated the development of techniques that allow a greater degree of user collaboration and immersion.

Multimedia Maps with Voice and Sound

The multimedia and multimodal technologies that engage hearing and touching are more effective in communicating information to users than simple graphics. The use of sound lends itself well to the map of Nunavut, the newest territory of Canada. When the user clicks on a place name, the name of the place is spoken in Inuktituk, the main native language of this territory. Figure 1 shows the audio-visual map of settlements in Nunavut [http://maps.nrcan.gc.ca/visualization].

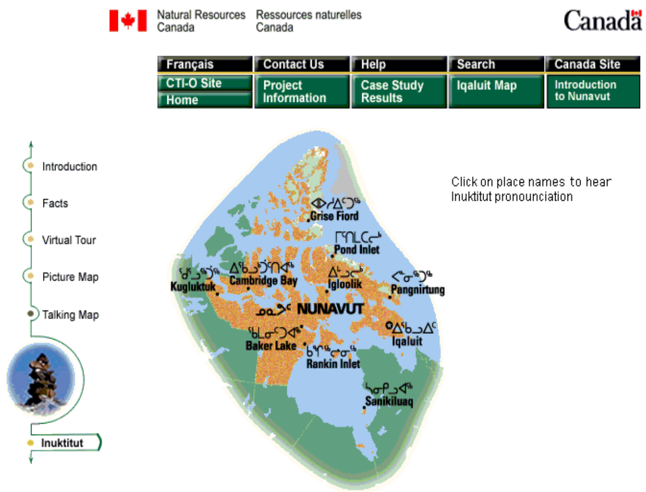

Figure 1. Audio-visual Place Name Map of Nunavut.

The interface is based upon guidelines mandatory for all government of Canada websites. The interface consists of a primary navigational bar located at the top of the page, which provides standardized access to the main sections of the project information structure. The secondary navigational bar provides access to subsections of the web site. Such interfaces give users the assurance of consistent access to information across all Canadian government web sites.

Research on the use of sound as cartographic information has other applications than spoken place names. Topography can be thought of as an auditory form. By modulating pitch, hills and slopes can be expressed by sound. Water cover might be given a splashing sound different than solid land. This concept has been successfully applied in another project carried out in Earth Sciences Sector of Natural Resources Canada directed towards blind and visually impaired people [http://tactile.nrcan.gc.ca/maps-4-all]. In this case, multimodal maps have been created based on an upcoming web-suitable format called Scalable Vector Graphics. This format facilitates the addition of sounds and haptic (forced-feedback) effects to audio-tactile-haptic maps. This technique is useful in providing feedback during information exploration.

Interactive Map Interface

The research undertaken within the visualization project focused on development of an effective interface that could facilitate integration of geospatial information. Using interactive cartographic tools, users can create their own displays by selecting information to be included on the map.

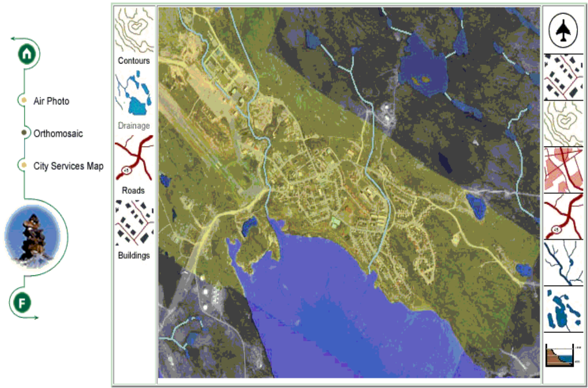

Figure 2. Data Integration Interface for Selection of Map Layers.

One of the information integration techniques is the interactive layer selection method. Using *JavaScript*, a function was created to allow users to attach layers of information to the background image by clicking the icons on the left. Moving the cursor to the right permits the user to temporarily superimpose other layers to the map background. Clicking on the central image displays all the data at a higher resolution. Figure 2 shows the results obtained by attaching the roads and then superimposing the buildings on the background image. This information integration technique could be further enhanced by accessing individual features based on the SVG methodology, creating a useful range of options and scenarios for decision making.

Representation of Temporal Data

A clear advantage of portraying geospatial data using electronic media is the ability to effectively display the past and present distribution of various geographic phenomena in order to analyze patterns of change and to model possible future scenarios. Historical maps and aerial photographs are good sources of data to examine the previous distribution of land use, and are a realistic starting point in discussing potential future developments.

The application selected for representation of temporal change is the historical and spatial evolution of Iqaluit, the capital of Nunavut. Historical aerial photographs taken at approximately ten-year intervals were assembled to portray the rapid growth of the city over 50 years (1948-2000) and served as a base for the creation of historical city maps. The historical photographs and records provided additional information to reconstruct the development of Iqaluit, discover the factors influencing change, explain patterns in development of the city, and provide a cultural and social background. Figure 3 shows the user interface created to display historical orthomosaics, maps, photographs and 3-dimensional renderings of the terrain in the form of animations [http://maps.nrcan.gc.ca/Iqaluit].

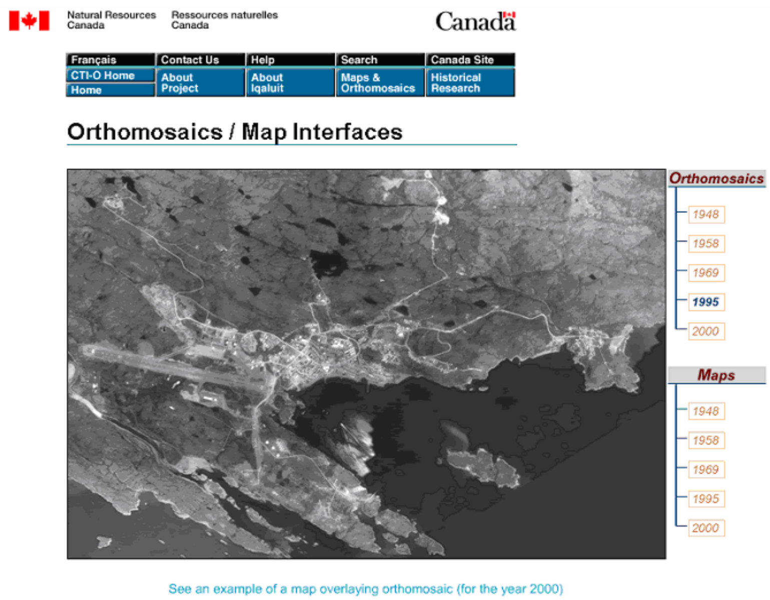

Figure 3. Historical and Spatial Evolution of Iqaluit.

Aerial photographs are also being used to examine the history of land use changes and their relationship to change in the transportation modes, which have occurred in response to changing city needs. Transitions in the downtown regions of the capital city of Ottawa over a span of 82 years (1920-2002), have been analyzed using historic aerial photographs (see figure 4). The transitions can be visualized using the SVG (Scalable Vector Graphics) format, which permits interactive display, manipulation and linking to ancillary information in a Web environment.

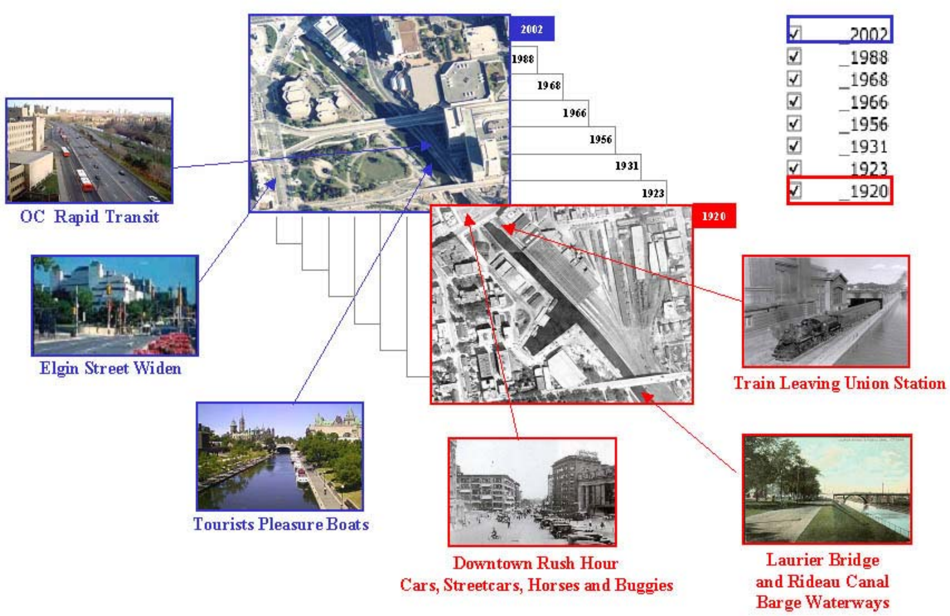

Figure 4. Ottawa Center Transportation Transition.

Such interactive visualization may serve many purposes including city planning, resource development, tourism, culture and education. Understanding the development of cities over time is not only valuable for the education of youth, but also of interest to visitors and tourists.

Dynamic Interactive Scaleable Information Representation

Information from multiple geospatial data sources, such as remote sensing and digital elevation models, are being integrated to examine current and potential land use as well as create multiple scenarios for the future. Visualization tools facilitate the use of integrated information for transportation planning, as well as the promotion of tourism and urban planning.

In this representation of integrated information for the city of Ottawa, Landsat-7 data is draped on a digital elevation model on which roads from the National Topographic Database have been superimposed. In the city centre, a 3-dimensional city model, visualized using VRML (Virtual Reality Modelling Language), is used. A series of images illustrate how the integrated information can be interactively manipulated using web-based visualization tools. Visualization through the integration of various types of data offers new perspectives, particularly for decision makers who are often new users of geospatial information.

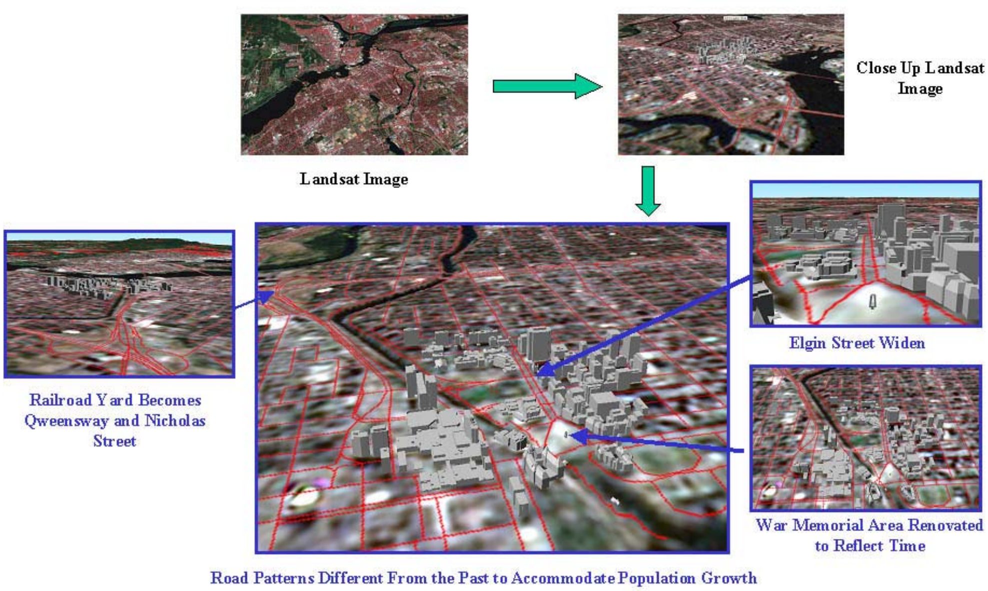

Figure 5. Dynamic Interactive Scaleable Information Representation .

Conclusions

The issues facing the integration of knowledge are not only technical (such as data and systems interoperability) but also primarily scientific, namely the clear communication of scientific results in the form of well designed graphics suitable for informed decision making. The results obtained so far within the visualization projects have resolved some of the main graphic communication issues, such as the overcrowding of images, lack of cartographic design principles, or even lack of awareness of the need to apply such principles. The greatest challenge is the articulation of user needs, since policy and decision makers are often not aware of the existence and importance of geospatial information.

The goal of visualization is to provide effective graphic representation of geospatial information. Visualization tools provide the means to move from static cartographic products, such as images, maps and aerial photographs, to interactive products that utilize geospatial data through dynamic, interactive graphics that employ multimedia and multi-modal technologies. By facilitating the exploration of multiple data sets, over both time and space, visualization tools can be used to develop sustainability scenarios that illustrate past or future landscape changes and to assist decision makers in understanding key spatial and temporal relationships.

References

Bertin, J., 1983. Semiology of Graphics: Diagrams, Networks, Maps. Madison University of Wisconsin Press.

Natural Resources Canada, 1998. Sustainable Development Strategy – Safeguarding our Assets, Securing our Future, internal report, 65p.

Natural Resources Canada. 2001. Sustainable Development Strategy - Now and for the Future, internal report, 90p.

Natural Resources Canada. 2004. Sustainable Development Strategy - Moving Forward, internal report, 65p.

United Nations. 1992. Report of the United Nations Conference on Environment and Development, Agenda 21. New York: United Nations http://www.un.org/esa/sustdev/documents/agenda21/english/agenda21toc.htm, accessed 31 March 2004.

Wilbanks, T.J., 1994. Sustainable Development in Geographic Perspective. Annals of the Association of American Geographers, 84(4), pp. 541-556.