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# Collaborative Geomatics for Innovation in Health Research and Policy

**Don Cowan[1], Paulo Alencar[1], Fred McGarry[2], and Daniel McCarthy[3]**

[1] David R. Cheriton School of Computer Science, University of Waterloo, Canada
[2] The Centre for Community Mapping, Waterloo, Canada
[3] Social Innovation Generation/Department of Environment and Resources Studies, University of Waterloo, Canada

*Abstract*
*Inter-agency collaboration in health research, health policy development, planning, decision-making and outcomes-tracking is required to enhance governance and adaptive capacity within complex health and socio-economic systems. Collaborative information infrastructures are emerging that support such collaboration and serve to increase the resilience of health and social systems through the development of social capital, fostering innovation, the inclusion of a diversity of perspectives and redundancy in governance systems. World leading web-based collaborative structures and services are being developed in Ontario that enable government and society to foster the emergence of collaboration and governance networks. These technologies although not yet applied in the health sector have been widely applied in environment and community economic development. The authors hope that by presenting this paper containing examples in many sectors and showing some extrapolation to the health sector, the health community will see the benefits of adopting these approaches in health research, public and population health, and health policy development.*

***Keywords: Health research and policy; collaborative geomatics; social media***

## 1 Introduction

The Geo-web, more popular than any other Web 2.0 application, represents an opportunity for new forms of communication and collaborative innovation [1]. The geo-web can be viewed as the merging of the abstract information usually found on the web with location based information that is almost always contained in such documents. This paper describes efforts at the Centre for Community Mapping (COMAP) and the Computer Systems Group (UWCSG) at the University of Waterloo, both in Waterloo, Ontario, Canada to leverage both geo-web social media technologies and their user-base for progressive purposes that could have significant benefits for the health, socio-economic and environmental communities.

Collaborative geomatics, social media and application services can enable Web platforms to support consultative contribution and interaction, in which the collective interests of grass-roots and authoritative participants can be negotiated and resolved in planning health research and policy. These technologies are designed to foster what we refer to as collaborative innovation (see next section) by fostering an interactive, participatory, democratic context where individual agents can share and synthesize data, information and knowledge to generate new knowledge about a complex system in order to identify opportunities to innovate and change the system. Leading edge strategies are being deployed by COMAP and UWCSG to meet technological and operational challenges to implementation and wide-spread adoption of such information infrastructures.

They are building shared information infrastructures for applications in which data, text and media content are authored and managed by communities of interest, practice and geography. This paper will discuss known

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and anticipated challenges and cite projects as case studies. These strategies include tools and processes that are responses to conditions that became apparent through extensive research as COMAP and UWCSG engage with user-groups to meet their needs. The strategies discussed and illustrated in this paper are: (i) declarative application development; (ii) collaborative geomatics; (iii) community engagement through dynamic asset-mapping processes; (iv) community-based asset mapping for landscape identity values; (v) social media services for social innovation and content maintenance; (vi) custodial distribution of authority to publish using the social media paradigm; (vii) web-based collaboration services for multi-party spatial planning and transactional decision making; and (viii) an inclusive service framework for authoritative and volunteered content. The phrases social media and online community [2] rather than social network [3] are used in this paper as these expressions indicate groups cooperating using the web as a collaboration medium with any product that has been created belonging to the group rather than an individual. In contrast a social network is focused on the individual and ownership and sharing by the individual.

Based on broad experience in applying the approach presented in the paper in complex areas such as environment and community economic development, we believe that the same techniques can be used to explore many issues in health research and policy, and related areas. The research team, based at UWCSG and COMAP, has worked with public and population health personnel to apply some of the approaches presented in this paper in the areas of smoking cessation management, health system management and healthcare network management. However, the authors believe that these applications, though interesting, have only scratched the surface of what can be accomplished. We hope that the reader can perform "gedanken" or thought experiments, some of which are presented later in the paper, to extrapolate the technologies and techniques to the health area in general. The discussion that follows the presentation of examples is intended to assist these thought experiments by providing a framework relevant to health-related examples.

## 2 Collaborative Innovation as a Context for Geomatics and Decision-Making

Collaborative geomatics technologies can be usefully set in the context of broad notions of collaboration, participatory democracy and social innovation. It has been argued that these technologies can foster the adaptive capacity of communities while working in the context of linked, complex social-ecological systems [4]. Collaborative geomatics technologies, in this sense, have been designed and are being used to foster a virtual collaborative planning space to foster interaction and consensus-building between a diversity of perspectives. Collaborative planning is a critical response to more conventional, rational comprehensive planning and its assumption of full information on the subject environment, alternatives, and values of citizens [5], and acceptance of the political and economic status quo [6]. This more collaborative, participatory approach to collective decision-making is informed by the work of Habermas and his theory of communicative action [7] and the search for undistorted communication that will allow for consensus and action. As well, collaborative planning is based on Anthony Giddens' [8] structuration theory, specifically "the continual interaction between, and mutual constitution of 'structure and agency' . . . " [9]. From this perspective, decision-making and planning is seen as involving "some interactive relation and some kind of governance process" [9]. It has been defined as, "an interactive partnership among government, interest groups, major sectors of the community and the public, all identified as stakeholders that work toward consensus on three main phases of any planning issue - problem setting, direction setting and implementation" [10]. The tools of collaborative geomatics described herein can foster this form of interactive, consensus-based, democratic decision-making.

In addition to fostering collaboration these disruptive technologies may also create the conditions for innovations within decision-making and planning processes. That is, collaborative geomatics technologies are designed to foster social innovation which refers to, "an initiative, product, process or program that profoundly changes the basic routines, resource and authority flows or beliefs of any social system. Successful social innovations have durability and broad impact" [11]. The capacity of any society to create a steady flow of social innovations, particularly those which engage a diversity of perspectives, is an important contributor to the overall resilience of a social system to change [11],[12]. It is argued herein that collaborative geomatics technologies can do so by providing diverse communities of practice with the tools to collaborate with reference to place and time-based issues by bringing together a diversity of knowledge, information and data to synthesize and create new ideas, new knowledge by setting the context for individual agents to create a vision collaboratively and also to identify opportunities to catalyze their vision within a broader system context. Westley [11] argues that for any social innovation to achieve durability and scale there needs to be an understanding of the emergence of opportunities within the system of interest and deliberate agency, and a connection between the two. The tools of collaborative geomatics are designed to allow individual agents to participate democratically in a place and time-based decision-making process while also contributing to a collective understanding of the state of the broader social-ecological system, its dynamics, and opportunities for emergence and change. Therefore, we argue that the tools of collaborative geomatics are designed to create a context for collaborative innovation which we define as, an interactive, consensus-based, democratic/transparent process of integrating and synthesizing a variety of perspectives, knowledge, information and data in order to develop a collective of understanding of a complex system to identify opportunities for emergence.

# 3 Methods

## 3.1 Declarative application development

COMAP and UWCSG use an iterative approach to create complex web-based systems where the users are engaged during the entire specification, design and implementation cycle. Once users operate a version of the system, they may quickly refine the specification and the corresponding design and implementation. This method contrasts with the waterfall [13] model where specifications are gathered and then realized without much subsequent input from the user or client. Because part of the approach supports ease of change, COMAP/UWCSG developed systems are much easier to maintain than those created using traditional methods.

This iterative approach is based on the Web Informatics Development Environment (WIDE) toolkit developed by UWCSG. In the WIDE context, "programming" has been replaced with a wizard or forms-based approach to building Web-based systems. This approach allows the technical team to create systems about 10 times faster than more traditional methods. COMAP in partnership with UWCSG has created over 70 operational Web 2.0 systems, many using collaborative geomatics and social media.

## 3.2 Collaborative Geomatics – the Stewardship Tracking System (STS)

A common mapping framework can provide a "place" where constituencies can collaboratively sustain discussions and communications relating to evolving health policy issues and also use applications based on standard protocols for data capture, analysis and reporting. Collaborative geomatics service initiatives were created as a result of a web-based environmental project known as the Stewardship Tracking System (STS). The geomatics framework developed under STS has been applied and extended in other systems developed by COMAP/UWCSG.

STS was devised by the Ontario Ministry of Natural Resources (OMNR), the Ontario Federation of Anglers and Hunters (OFAH), COMAP and UWCSG to address the need for conservation planning of ecosystem functions in the Southern Ontario landscape. The STS enables the tracking of restoration projects (e.g. landscape elements: woodlots, streams, wetlands, prairie) and provides for adaptive management amongst the conservation community of practice. A project technical committee comprised of over a dozen non-government and government organizations oversaw the development of the STS as a concurrent iterative design process through province-wide workshops and web-forums. The STS was operational for all of the Southern Ontario landscape in November of 2007.

The STS project accesses spatial data and information in real-time from distributed sources over the Internet. The STS permits the Southern Ontario conservation community participants to work in collaboration to:

- enter spatial (polygon) and tabular data, photos and documents about their ecological restoration projects as well as exporting entered data to external geographic information systems;
- query the database to meet their needs for tracking success of specific restoration projects;
- report and summarize monitoring data about numerous restoration projects with many relevant parameters (e.g., jurisdiction, implementation year, restoration type, planting stock type); and
- implement adaptive management of ecological restoration practices based on an ever-expanding base of knowledge about the factors that contribute to successful ecological restoration projects.

The following STS technical objectives were achieved:

- a common map with airphoto, satellite and thematic data available in Ontario;
- an ability to enter spatial (polygon) and tabular data about stewardship and restoration projects;
- the provision of stewardship tracking protocol, data model and web service;

- the export/import spatial data to/from external GIS; and
- querying, reporting and summarizing of the database to track success of specific projects.

The STS, an on-going project, is acknowledged to be the leading effort in shared information infrastructure for cross-scalar provincial reporting on stewardship in Canada. The STS infrastructure co-exists with agency-supported geographic information systems (GISs).

### 3.3 Community engagement through dynamic asset mapping processes

Based on Clay Shirky's concepts for an available "cognitive surplus" [14], COMAP and UWCSG believe that community of practice participants such as those in health policy will take the time to populate maps, using collaborative geomatics with text, data and media to organize and share community perspectives, reporting and analyses, when they see value in the result. The process of creating a community inventory often termed "Asset Mapping" [15], now widely used in North America, is an appropriate engine to encourage widespread adoption.

Family Service Toronto (FST), a city-wide charity offering community development services, COMAP and UWCSG have formed a partnership to build a web-based system to support the FST Building Inclusive Communities Division, Community and Neighbourhood Development Unit (CND). CND is funded to facilitate a community development planning process in a large area of the City that includes established social service agencies, grassroots groups, businesses, faith groups, residents and other interested community groups that live or work in the area. The goal of this project is to create and implement a collaborative community planning process, which is fully inclusive and rooted in best practices of community development and empowerment. FST believes that one of the best tools to assist in this process is the development of an "open" and accessible web-based asset map that puts mapping tools into the hands of all involved stakeholders, especially the groups who have the least resources in the community.

The evolution of grassroots groups, which range from community circles to coherent organizations with capacity to collaborate with external resources, is seen by professional Toronto community developers as an evolution to viable community governance [16]. Community inventories (i.e., asset maps), in trying to improve assets and capabilities through collaboration, fall short in situations where governance is weak. In the absence of a coherent system of governance, access by grass-root groups to external resources, by default, falls under the control of the external organizations (that do not necessarily reflect the values of community residents). The objective is to develop capable and effective neighbourhood collaborative approaches to which resources could be devolved by external agencies.

FST has agreed to work with COMAP's NewsAtlas proposal to proceed toward accomplishing its objectives. COMAP recommended the newspaper metaphor, NewsAtlas, as a mechanism that would encourage maintenance of current community information. The NewsAtlas architecture will have three components: (i) a public view with organized news pages, map-layer based search facilities, calendars, classifieds and a service directory; (ii) a secure online community service for participants who publish NewsAtlas content; and (iii) an underlying database for content and application services.

NewsAtlas will start as a community asset mapping initiative and be maintained as a community news source with departments and sections providing: entertainment, arts, sports and recreation content, lifestyle and spiritual content with mapping and event calendars. At the outset COMAP envisions a Toronto-wide service with a list of neighbourhood "front" pages, which will mimic a city-wide newspaper with neighbourhood sections. As neighbourhoods join NewsAtlas, their front-page will be activated and linked at neighbourhood participant sites. All activated neighbourhood front-pages will be portals for local neighbourhood content. All content will be searchable city-wide by map area in combination with powerful temporal and content search tools. The NewsAtlas media services will contribute to building viable community governance. Specifically, the NewsAtlas is intended to bring on-going service sustainability in terms of content and community participation, all to address the main project objective: to increase the amount of community planning that is done collaboratively, inclusively and intentionally.

### 3.4 Community-based cultural asset mapping for landscape identity values

The Mennonite Heritage Portrait (MHP - http://www.mennoniteheritageportrait.ca), which was developed by COMAP/UWCSG allows users to view and use services when they join the MHP online community and builds on social media, WIKI, and mapping concepts. The resulting system allows a community of interest to contribute, discuss, narrate and authenticate specialized content.

The MHP presents and inter-relates current heritage digital media and document collections (such as a photo-negative collection by Peter Etril Snyder, a Canadian Mennonite landscape artist), in a comprehensive portrait and narrative. Collections have been digitized and presented along with linked narratives to provide context. The MHP connects with other extensive collections, housed in various locations throughout Waterloo Region, and provides collaborative tools for:

- the development of narratives and learning materials that link to collection content;
- content searches that use combinations of a simple map, tags, text phrase and meta-data parameters to reveal, map and list content by themes and quality of provenance; and
- enabling online communities of formal and ad-hoc communities of practice to contribute, map and link content.

Novel social media services are provided for the broad engagement of the knowledgeable, professional and academic heritage communities of practice, youth and family, to encourage continuous improvement of the MHP. MHP will eventually be rolled out to the world-wide Mennonite community and MHP-derived services are also being made available to other heritage and cultural groups across Canada.

Cultural content without context provides only part of the picture. Local culture and heritage – the buildings and landscapes, community histories, stories, artefacts, paintings, sculpture, music, poetry, photographs, and much more – are among the most powerful tools for consolidating a sense of place and building social capital in communities. Yet, local culture and heritage organizations often lack the tools and capabilities to "take stock" of the full richness of their cultural asset base and communicate and share this richness with residents and visitors to their communities. MHP objectives and goals are to:

- present content and narratives previously unavailable online in a coherent, easy-to-navigate and useful manner;
- connect seamlessly with content from various collections and present the content in new and meaningful ways, within its proper context;
- engage Mennonite youth with their culture and history through an online community;
- support social media services to enable local conversations among practitioners, youth, and the community on cultural heritage topics of common interest; and
- provide a mechanism for grassroots generated content to be authenticated and moved into the authoritative collection.

### 3.5 Social media services for on-going social innovation and content maintenance

Social media prompt connection and communication to enhance opportunities for emergence and self-organization within virtual communities with shared goals. COMAP/UWCSG offer social media services to encourage social interaction and innovation within virtual communities of interest, practice and geography.

- communities of interest spring up around subject matter in searchable shared spaces such as forums and wikis rather than organizational hierarchies;
- social media helps people find and connect through user profiles, private messaging, groups, contributed content and WIKI linkage, notification, expert search and online communities; and
- tags, social bookmarks, and other social media tools help bring order to the avalanche of information [17].

COMAP and UWCSG built an online community service and have used it in the MHP. Features of this service include: My Profiles, My Contacts, My Groups, My Messages, My Recommended Content, My Groups with Forums, managed threads and posts, My Bookmarks, document development with content upload, writing, and WIKI linking.

COMAP and UWCSG are also working with the Muskoka Community Network to provide web support for the combined communities of Muskoka and Parry Sound in Ontario Canada. The Muskoka and Parry Sound Collaborative Atlas (MAPSCA) portal will provide quick access to up-to-date regional information from authoritative sources. MAPSCA will be truly community-driven in that the many groups and organizations in the area will be active participants, providing and maintaining the regional content. Muskoka organizational membership lists will be used by COMAP to populate its social media service and provide all participating organization leadership with userid and password access. Leadership participants will be enabled to:

- create and moderate group forums and invite their membership or participants from the COMAP online community to join and discuss their agenda, and participate in forum-based system applications;

- control who has access to their group forums, add/delete submitted threads and content and control/deny access to their application(s); and
- add/update system applications in which they participate, taking into account that applications will be tied to group forums that are managed by MAPSCA leadership to ensure that participation and submitted application content is representative of the organization that initiates a forum-based application.

Only members of the MAPSCA online community will be permitted to contribute content and such content will only be published with the permission of the organization that has been assigned the MAPSCA custodian with the right to author content.

### 3.6 Custodial distribution of authority to publish by assigning access controls using the online community paradigm

The NewsAtlas system, the MAPSCA system and all other collaborative geomatics systems developed by COMAP/UWCSG have similar access control challenges. The right to participate in the online community, contribute and report data and publish content is distributed to participating organizations and professional individuals belonging to communities of interest, practice and geography. In all cases, system security is or will be managed by the content custodian. The custodian distributes the right to publish and secures agreement (i.e., a contract) from rights recipients to conditions necessary for system security and integrity. In the NewsAtlas, for example, instead of a single publisher there will be Service Directories of participating neighbourhood individuals, formal and grass-roots groups, and agencies that have access, rights and tools to publish.

Participation in the neighbourhood Directory will be managed by the custodian (e.g., FST in the Toronto NewAtlas) that acts as the neighbourhood moderator until local capacity has been established. Participation will have privileges and responsibilities. A contract between the neighbourhood moderator and each participating individual, group and agency will set out the terms of use. Registered Participants will be able to (or enable their membership or affiliates to) access NewsAtlas content publishing tools and content management services for depictions of their individual or organizational assets. Groups and agencies, in turn, will have responsibility for (i) granting access to their membership and affiliates to tools for publishing on their organization's behalf, and (ii) for maintaining the access rights of their membership. Minimum conditions for the right to publish include having an agreement to appoint an organization's group moderator, and maintaining, in good standing, an organization's membership information for those members that will publish on behalf of the organization.

### 3.7 Web-based collaboration services for multiparty spatial planning and transactional decision making

The Faculty of Environment (UWFE) at the University of Waterloo, in partnership with James Bay, Mushkegowuk First Nations and Mushkegowuk Tribal Council, UWCSG and COMAP are developing a pilot system for evaluation of a community or region-based land use planning process with the objectives to: (i) explore the empowering potential of community and regionally-based land use planning; (ii) determine what Mushkegowuk First Nations would want in community and regionally-based land use plans; and (iii) set out a process to develop community-based land use plans using collaborative geomatics.

COMAP and UWCSG have provided a basic system for the UWFE and Mushkegowuk research called First Nations Indigenous Knowledge Mapping and Planning Service, which replicates a service developed for the Mississaugas of the New Credit First Nation (MNCFN). The MNCFN Mapping and Planning Service (MAPS) system provides a novel technology to support application-based consultation services. MAPS offers multiparty services for collaborative synchronous web sessions, where a moderator, who initiates a session, can create and pass a link to other parties in a teleconference. The link provides access to a view of the moderator's web page. The moderator can "pass the chalk" to each of the teleconference participants so that they can each use services for spatial (map-based) feature and text entry on the moderator's page. In this way, commentary and spatial elements can be contributed by parties to a teleconference. This ability will be a valuable addition in many application contexts such as land use consultation, community arts and recreational event planning, and collaborative digital media content development.

A database record is kept of all system interaction during the multiparty collaboration session, which includes information such as when parties joined and left, what content was entered, and by whom and when. As a result, the multiparty collaborative web session service could be played back for use in judicial proceedings if needed.

### 3.8 An inclusive service framework for authoritative and volunteered content

The Ontario Invasives Species Tracking System, developed by COMAP/UWCSG, for the Ontario Federation of Anglers and Hunters and partnering organizations will use an online community to allow agencies and the general public to enter site, species, photographs and related content for invasive aquatic and terrestrial species. A field guide to invasive species is part of the system, so that an observer of an instance of a species can be confident that a correct identification has been made. The data entered will then be verified before it is used to update a provincial database. Once submitted and verified, the invasive species can be viewed on the map by one or more types of species, coverage within an area, and coverage by time within an area. Thus, the viewer can see how far a species has progressed and how fast it is moving.

Portability adds a new dimension to a system like the ITS. In the initial system, the citizen scientist must return to their home computer to record an invasive siting. However, the system is now available on some smart phones enabling a member of the public to photograph the instance of the species, record its position and report directly from the field. If a photo is not feasible, the observer can submit the picture in the field guide as a substitute.

The system provides groups, forums and authoring services that the agencies will use to author and publish collaboratively official and authoritative information used to help identify and, then control invasive species using mechanical or chemical methods. The agencies that oversee system development agreed with such a solution, although they have previously refused a public online community even though the resulting network effects [18] would have increased the utility of the system. They reasoned that users may be confused and misconstrue volunteered content with official "expert" content.

The benefits of organizing the chaos of social media services for community intentions are enormous. Clay Shirky's comments on "cognitive surplus" [19] suggest a huge unused capacity that could be channeled for social benefit by new social media frameworks. However, academics, professionals and other authorities strenuously resist the "wisdom of the crowd" for many and often good reasons. COMAP and UWCSG are planning to implement systems that provide for both authoritative and volunteered content in a manner that maintains clear distinctions.

## 4 Gedanken Experiments in Applications to Public and Population Health

A number of the systems described in this paper can easily have their functionality related to applications in population and public health. In this section we describe how the Invasives Tracking System (ITS) and the Stewardship Tracking System (STS) might be modified to handle problems in health planning and health policy. We then address the issues of security and privacy and indicate that the requirements for these can be just as stringent in areas such as environmental management as in health. Finally, we introduce social media, specifically online communities, to illustrate how these may be used in support of the health sector.

### 4.1 The ITS and Health

The Invasives Tracking System (ITS), which is the last application described in this paper has many applications in health. The words "invasive species" can easily be replaced by one or more diseases that can be tracked both spatially and temporally. The spatial tracking (e.g., location of residence or location of last restaurant meal) might be used to determine the likely cause of a disease. The temporal tracking mode combined with the spatial can be used to determine how fast the disease is spreading and can help with effective isolation or quarantine measures.

Of course the ITS is not limited to disease monitoring. Invasive species could be translated into topics such as fast food outlets in a specific area of a city. A map overlay could be created that is colored red and the depth of the color could be related to the number of fast food outlets per person in the area. One could also map the number of occurrences of conditions such as cancer or obesity and produce a similar overlay, only colour it blue. Once these two layers were overlaid, for example, the colour purple would be produced and the depth of the purple would indicate a possible correlation between the outlets and the disease thus leading researchers to look for a probable cause.

One could apply the same concepts to cancer screening clinics, where the layers could represent the number of clinics in an area and the outcomes. Similar ideas could be used in examining the effects of public policy such as a no-smoking policy on the occurrence of certain diseases such as cancer.

Portability in conjunction with a field guide could be used in disease identification by "citizen" health workers. Further, the field guide could show symptoms and the health worker could photograph the "patient" and these could be posted for examination and triage by experts.

### 4.2 The STS and Health Policy

The Stewardship Tracking System (STS) was designed to collect information about ecological restoration projects and to summarize or roll-up the information to develop a province-wide view. Such a system could be modified for planning related to infrastructure for healthcare delivery. In this case, each healthcare district could create an asset map showing the facilities that are currently available for delivering services, their catchment areas, the number of people being served and the needs. This asset map could then be used to perform both gap and overlap analysis, thus providing a view of each district's requirements. The results could be then summarized to indicate the overall needs for the province or state, thus giving the background information for budget purposes.

### 4.3 Security and privacy

When collecting information about individuals related to health, there is significant and justifiable concern about security and privacy of the data. Although perhaps difficult to believe, the same concerns arise in dealing with ecological restoration. For example, farmers do not want it widely known that they are "improving" their land as this could have several adverse effects such as an increase in taxes or the provision of a competitive advantage to another farm business. Similarly, conservation authorities are often competing for the same funding and may not want to cede a competitive advantage to a neighboring authority. For these types of reasons, access to data is often just as tightly controlled as it would be in health applications.

### 4.4 Social media

Many of the applications described in this paper use forms of social media to work collaboratively on a set of related issues or problems. The type of social media specifically addressed is the mediated online community, where participants are not anonymous and access is controlled by a mediator appointed by the group of participants. A social media system can support many different online discussions among different participants.

The social media can support secure communication and knowledge sharing among health researchers or health workers who need to collaborate but are not able to meet because of geographic dispersion or size of group. The interaction can be synchronous or asynchronous. For example, while monitoring the outbreak of a disease, public health workers could post known outbreaks and related commentary about their observations, which can be seen as an asynchronous form of communication. This information would be above and beyond the normal recording in a database, as shown in the ITS example. This material could then be accessed by a panel of "experts," that could mine the recorded commentary to come to conclusions about the outbreak.

Similarly, a group could be discussing the extent of a quarantine area for a specific disease outbreak and could use the synchronous mapping tools described earlier to consult and make decisions. Any inquiry later into the decisions would be able to consult the record.

## 5 Discussion

In this paper we have presented a number of examples of Web-based systems that use databases, collaborative geomatics and social media tools for the purpose of communication and collaborative innovation. Collaborative innovation is an interactive, consensus-based, democratic/transparent process of integrating and synthesizing a variety of perspectives, knowledge, information and data in order to develop a collective understanding of a complex system to identify opportunities for emergence. Collaborative innovation is therefore a process that involves providing a context or a virtual space for individual agents to explore and act upon improvement in an idea or situation, which can be related to a domain such as health or health research. The span of collaboration is usually a community of practice in the case of research or a geographic community in the case of public health.

Collaborative innovation teams have a collective vision and wish to work together by sharing ideas, information and work. Team members share directly with each other rather than through a hierarchy. Five essential elements are: (i) sound ethical principles; (ii) trust and self-organization; (iii) universally accessible knowledge; (iv) honest and transparent operation; and (v) communicating the value of the results. Most work of this type relies on modern information and communications technology (ICT) such as the Internet and e-mail, and more recently geomatics, online communities and social media.

Apart from these general properties, what is needed to make collaborative innovation effective? Collaborative innovation requires obtaining knowledge of the resources or assets that are available within an application domain or context and, then using that understanding to make and implement actions such as operational and structural decisions. Thus, collaborative innovation can be viewed as a two-step process consisting of:

1. taking an inventory of assets and sharing this data across one or more communities; and
2. collaborating and acting on that asset knowledge to (i) recognize additional "undiscovered" assets; (ii) produce value and identify opportunities for change within a system; and (iii) create new assets related to the change.

The intent of this paper is to make the health community aware of one view of collaborative innovation and what can be accomplished, in the hope that this concept will be applied to at least some of the problems that many communities confront. For example, concerning population health, the type of tools just described can be used to support a distributed network of health researchers working on common problems such as cancer, or to look at the effectiveness of public policy on rates of cancer in the population. Two of the authors of this paper are currently working with a population health team to apply these concepts in community public health.

The approaches described in this paper can be related to the work on Complex Adaptive Systems (CAS) by Zimmerman and others [20]. The tools and processes that have been created can be used to assist in the evolution of a multi-faceted organization such as found in health care by supporting communication among a disparate group of people and engaging them in the organization's change and growth. These methods can flatten the management structure providing an opportunity for those involved in the daily operations to contribute to solutions to organizational issues.

The paper also describes how individuals can be engaged in the discussion and interaction using social media without falling into the trap of crowd sourcing or mob rule. First, contributors are known to the system, although not necessarily to each other. Thus, the privilege of membership in the discussion group brings with it a responsibility to the group as a whole. Membership does have to be managed carefully and not abused. The paper implies a contractual arrangement between the organization and the manager of the specific social media system to ensure a legal obligation to behave in an appropriate manner. Information provided within the context of such social media is not just a one-shot effort. Everyone who provides material must be willing to engage in discussion, have their ideas challenged while contributing to the specific topic at hand.

The iterative approach to software design, development and deployment can also be viewed as providing feedback within a supportive infrastructure for CAS. Software systems need to adapt as organizations evolve. The excuse that the computer "will not let me do it" is not part of the CAS philosophy. The approaches related to software development, described in this paper although still the subject of research, are meant to (i) put more control in the hands of the users and (ii) allow organizations to react to changing circumstances not only up to the time an information system is deployed, but during its entire lifetime.

## 6 Conclusion

This paper has discussed some of the latest results in applying geomatics and social media to various fields and, then, through a number of thought experiments, has extrapolated these results to various areas of public and population health. For any social system to be resilient [12] to stresses (i.e. environmental/climate change, disempowerment within urban communities, loss of culture, pandemics/epidemics etc.) a steady flow of social innovations, especially those that engage a diversity of perspectives (i.e. different cultures, sectors, scientific disciplines etc.) is required. It has been argued that the tools of collaborative geomatics have been designed to foster a context of collaborative innovation where a diversity of individual agents can interact in a transparent and democratic virtual space to share and synthesize knowledge about their system of interest to generate new ideas and identify opportunities for change and emergence within the broader system. Whether it is tracking stewardship initiatives, building more inclusive communities, cultural mapping, empowering First Nations communities or tracking disease outbreaks or health promotion, the need to foster resilience and innovation by creating collaborative spaces that leverage a diversity of knowledge for developing new knowledge and fostering system change is apparent.

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## Correspondence


Donald Cowan, PhD
Distinguished Professor Emeritus,
David R. Cheriton School of Computer Science
University of Waterloo
Waterloo Ontario, Canada N2L 3G1
Phone: 519-888-4690
dcowan@csg.uwaterloo.ca