A Web-based Framework for Collaborative Innovation

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ABSTRACT

Twenty-first century global change in most sectors is challenging us and our communities in the management and use of resources. The World Economic Forum has recognized the need for new approaches to enable collective action among both the leadership and concerned members of communities. We call this approach of working together to produce societal solutions *collaborative innovation (CI)*. CI is part of Web Science as it brings together information networks of people and communities who use and augment the digital records related to common problems mediated by the Web.

This paper outlines an approach to CI based on dynamic asset-mapping and how it has been supported through a web-based framework that requires both communication and operations on a knowledge base or asset map. Based on the experience using the framework in designing and deploying over 70 systems that incorporate dynamic asset-mapping as a foundation for CI, it is clear that CI takes many forms. We illustrate some of these forms through specific examples in environment, socio-economic development and planning. We conclude that it is not possible to build a single set of tools to support CI and that the users need access to meta-tools and frameworks to implement tailored systems supporting CI directly rather than relying on people with in-depth knowledge of the technologies. We then outline some of the properties of a set of software meta-tools that have been be used to implement these systems.

Categories and Subject Descriptors

H.1 [**Information Systems Models and Principles**]: General; H.4 [**Information Systems Applications**]: Miscellaneous; D.2.0 [**Software Engineering**]: General

General Terms

Web Science Applications

Keywords

collaborative innovation; Web Science; asset-mapping; web-based framework; meta-tools

1. INTRODUCTION

Twenty-first century systemic global change in health, water, environment, energy, business, governance and socio-economic structures is challenging our communities and us as individuals. For a community to be resilient and adaptable in the face of these disruptive transformations, while maintaining and even enhancing our economy and quality of life, new creative approaches are needed to enable intelligent collaborative innovation (CI) and related action. Such collaboration must occur within and among all sectors of society including government, non-governmental organizations (NGOs), business, community leadership and community members. Although we are talking about people collaborating to supply solutions as in the "wisdom of the crowds" [16], there has to be an underlying social and information infrastructure that turns the information supplied by the "crowd" into knowledge and action.

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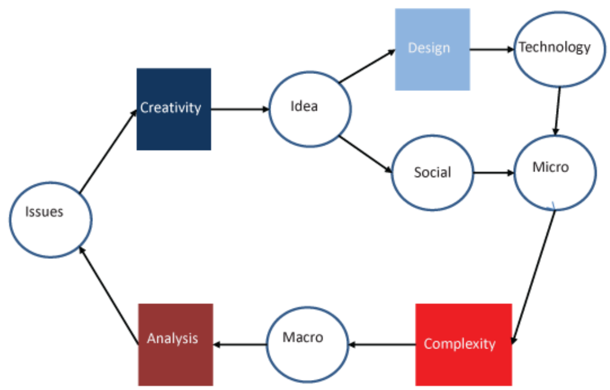

Figure 1: CI and Software Engineering for the Web

The World Economic Forum (WEF) [5] has recognized the need for an effective approach to CI in the ongoing global economic crisis as local and international communities are becoming more and more interdependent. The WEF has recommended that communities both geographic and virtual re-examine their strategies based on new evolving networks and forms of collaboration. Thus public-private partnerships and smaller-scale region or city-driven initiatives must move away from the "one-size fits all" arrangements and re-design and rebuild their structures and processes related to both local and global community interactions, resource exploitation and governance. Tapscott and Williams have written extensively about collaborative innovation [17], [18] and conclude that we can cling to the old industrial paradigms or use collaborative innovation to revolutionize the way we work, live, learn, create, govern and care for one another.

CI is a part of Web Science from two points of view: [1] CI embraces the use of the Web as a vast information network of people and communities; and [2] the software engineering approach envisioned for the Web is the same approach used in creating CI systems as depicted in Figure 1 [7].

CI systems based on the Web start as a micro system and as the user base evolves, a viral effect comes into play and emergent properties arise. CI changes the way we think about problems or to quote McLuhan [13], "We shape our tools,and then our tools shape us." The Web provides the connectivity to support CI, but how do we support the emergent needs that arise as a virtual or geographic community works toward a common understanding and solution of a problem? We need to extract the general architectural principles and interactions that occur and then look at the tools and meta-tools that are needed for CI. The authors of this paper and their research teams have constructed over 70 web-based systems in multiple fields and have devised an initial model for collaborative innovation. This paper describes the model, outlines a supporting web-based framework by discussing the processes involved and describes the behaviour of a related set of software assets.

2. UNDERSTANDING CI

CI refers to a process that involves assembling a team of people to explore and act upon change in an idea or situation [4]. The span of collaboration is a virtual community of practice or interest, or a geographic community [21]. The individuals that compose the team can represent themselves, different departments in a single organization or different organizations. A team often works in a mediated environment where responsibility for actions can be devolved to specific team members. These responsibilities can be specified through one or more contracts among individuals and organizations.

CI teams have a collective vision and wish to work together by sharing ideas, information and work. Team members share directly rather than through a hierarchy, although each member may represent the views of the hierarchy to which he/she belongs. Organized CI has been recognized as early as Benjamin Franklin's "Junto" organization [6]. However, today most work of this type, relies on modern information and communications technology (ICT) such as the Internet, e-mail, the Web and more recently online communities and social networks. A collaboration must have four essential elements: [1] sound ethical principles and trust; [2] self-organization; [3] universally accessible knowledge; and [4] honest and transparent operation.

Although this provides a high-level view of CI it does not really provide a road map to implementing CI. The following examples illustrate most of the basic concepts.

All types of geographic and virtual communities both large and small have serious problems trying to manage and make the best use of a community's varied assets or resources in order to meet community challenges. In larger geographic communities there are often many agencies with overlapping services and catchment areas. The goal in this case could be to rationalize those services making them more effective from the viewpoint of both cost and delivery, but the information about the related assets is usually distributed and thus not easily accessible. In a virtual community such as one involved in ecological restoration, the information about the progress of restoration projects and their impact on the environment are not easily quantified; again because the knowledge is widely distributed within the community.

The concept of creating an asset inventory is called "asset mapping" [10] and the new value and assets produced from the collaboration are often called emergent properties. Most work in this field to date has focused on "static" asset mapping and has only begun to investigate the methodology to keep the asset inventory current or "dynamic" and take action over the growing asset base. To illustrate the entire process, consider a simple example, where a community group may list assets such as garden tools, vacant land, seeds, and may discover a hidden asset; a group of people interested in gardening. The innovation or new value created could be the planting, successful cultivation and harvesting of the vegetables. Of course this new value yields assets such as vegetables, procedures for successfully planting, cultivating and harvesting a garden and some of the garden product may yield seeds or cuttings for the future.

The same CI concepts are applicable to problems in business as well as societal communities. Goldcorp, one of the world's largest gold producers shared all its geological information (assets) with the world through the "Goldcorp Challenge" [17]. The company quickly reaped the benefits of this asset sharing by receiving many ideas on where and how they might find more gold (hidden and new value) on their existing properties. The Open Source movement is another example of CI. Here software is shared (assets) and then improved (hidden assets) or augmented (new value) with the new artifacts becoming part of the asset base.

Any collaboration where innovation is involved must have two essential elements, which are:

1. produce an inventory of assets and share this data across one or more communities; and
2. collaborate and act on that asset knowledge to:
   (a) recognize additional "hidden" assets;
   (b) produce value and change; and
   (c) create new assets related to the change.

The participants share knowledge and add value to that knowledge through collaborative tools that operate under various constraints such as access, time and mobility. Controls must be in place to manage access to the asset information so as to ensure that it is shared with appropriate parties and that the new value has credibility. Our research team has labeled this specific process "Collaborative Innovation (CI)" and the steps "Dynamic Asset-Mapping."

During the last two decades there has been a rich collection of web-based technologies developed such as shared databases, mapping, wikis, blogs, on-line communities and social networks to support connection and communication among disparate groups and individuals. Can we harness the power of the web, these new technologies and this collaboration paradigm to augment our intelligence as a new form of creativity machine [20], which will allow society and business to address the problems arising from the systemic changes that are having significant impact?

The Web has the potential to become a new medium of collaboration and to impact society and business similar in scope to the profound changes caused by writing, the printing press, the telephone, the automobile, the airplane, the computer and the Internet. However, Web-based CI involves operations over a dynamic repository of assets. Such tools are specific to the CI domain and therefore must be created for each Web-based CI system. The generation of the tools and their integration must be handled by the participants so as not to impede the CI. If the collaborators have to involve technologists such as programmers and GIS experts then the spontaneity of the collaboration may be impacted negatively causing the participants to lose interest and direct their efforts toward projects with more "psychic" benefits.

Our research team and our partners are working with several different types of geographic and virtual communities to improve the CI technologies and processes and to learn how to transfer the knowledge on using the Web to implement CI effectively in environment, health, social services, aboriginal affairs, cultural heritage and socio-economic development and in the intersection between business and society. Here we examine experiences with CI to propose new approaches to meta-tools, tools and frameworks that would bring substantive improvement to web-based CI. We use examples of web-based systems for CI in specific fields such as environment, socio-economic development and planning that have been developed and deployed to demonstrate our current thinking. The goal of the ongoing research program briefly outlined in this paper is to:

1. develop operational software systems to support CI in multiple domains in order to understand how CI can be implemented effectively using the web;
2. to identify and develop web-based software approaches
   - for meta-tools or frameworks that significantly simplify the construction and evolution of CI systems; and
   - that can support the simple integration of existing tools into CI frameworks;
3. and to transfer the knowledge created in 1 and 2 to both geographic and virtual communities so that individuals and community groups can use the technology effectively in deriving and operating web-based information systems for CI.

3. CI EXAMPLES

Different forms of CI depend on factors such as community scope, degree of cohesion among community members, type of knowledge exchanged. Variations on these factors can lead to different types of communities [9]. Our research has examined software systems that have been used to support many different forms of CI with varying sizes of geographic and virtual communities and different degrees of community coherence based on common goals. A brief description of some actual projects are described in this section. At the end of each example, the assets and value provided through CI are summarized to show the examples relationship to the CI model. The examples show CI based on: [1] Geomatics (mapping); [2] Dynamic asset-mapping for communities; [3] Real-time synchronous web-based geomatics services; and [4] Citizen Science.

3.1 CI based Geomatics (Mapping)

CI-based geomatics consists of a common map where communities can collaboratively have discussions relating to evolving spatial issues and also use applications based on standard protocols for data capture, analysis and reporting. CI-based geomatics services were used extensively in an ecological stewardship project (ESP) across a large geographic area. The map consists of satellite and highly resolute airphotos with thematic data.

The ESP was devised to address the need for conservation planning in a large geographic area. The ESP is a system which enables the tracking of restoration projects based on landscape elements such as woodlots, streams, wetlands, and prairie, and provides for adaptive management by the conservation community as they observe the results both as individual projects and collectively over the entire area.

The ESP project is a web-based set of applications and databases that accesses spatial data and information in real-time from distributed sources over the Internet. The ESP was planned to permit the conservation community participants to work collaboratively by:

- entering spatial (polygon) and tabular data, photos and documents about their ecological restoration projects using a mapping engine;
- querying an underlying database to track specific restoration projects;
- reporting/summarizing monitoring data about restoration projects by parameters (e.g., jurisdiction, implementation year, restoration type, planting stock type);
- implementing adaptive management of ecological restoration practices based on an ever-expanding base of knowledge about the factors that contribute to successful ecological restoration projects; and
- capturing fine-scale data using the map and standard protocols, so that the data can be exported to geographic information systems (GIS) to augment existing GIS data and permit landscape GIS analyses.

ESP needs to report on individual projects and also roll up information to obtain an overall picture of ecological restoration. These two processes were necessary so that project funders could determine effectiveness of funding. Security of the data was a critical factor in the design of ESP. Land owners, particularly those working the land for income may not want to share information with competitors or with government agencies.

A project technical committee comprised of over a dozen non-government and government organizations worked iteratively with the design team through numerous workshops and web-forums to enure that ESP met the needs of the user community. The ESP was operational in November of 2007 and a version can be seen on an Adobe Captivate Video [14]. The ESP is acknowledged by the conservation community to be the leading effort in shared information infrastructure for wide area reporting on ecological stewardship.

The dynamic asset base, which can be modified with new projects added over time, consists of: maps; a database of projects; attribute data related to ecological restoration projects including geographic shapes, text, pictures, audio and video; users and funding agencies.

3.1.1 ESP - Assets and Added Value

The ESP creates many assets and resulting value for the ecological restoration community. The assets considered here are only those related to sharing of information. The assets and derived values are listed including comments on items.

Assets - A desire to improve the ecology of a region; interested public - a group of people interested in ecological restoration; and funding agencies - organizations and governments interested in supporting ecological restoration.

Added value - Knowledge repository structure; knowledge content about ecological restoration projects; controlled access to content about ecological restoration projects; formation of online communities for discussion about classes of ecological restoration projects; and summary of the content related to the ecological restoration projects.

3.2 NewsAtlas - Community Dynamic Asset-mapping

Community participants will take the time to organize and share community perspectives, reporting and analyses using collaborative geomatics to populate maps with text, data and media, if the members of the community see value returning to their community through their participation. This process known as "dynamic community asset-mapping" is an extension of "community asset mapping" as initially defined by John McKnight and John Kretzmann [10] and now practiced by communities in North America.

A city-wide social service agency in a major North American city offers family counseling and community development services, and engaged the research team in a partnership to build a web-based system to facilitate a community development planning project in an area of the city that includes established social service agencies, grassroots groups, businesses, faith groups, residents and other interested parties.

The goal is to create and implement a community planning process, which is inclusive and rooted in best practices of community development and empowerment. The main objective is to increase the amount of community planning that is done collaboratively, inclusively and intentionally. The social service agency, the driving force behind the project believes that one of the best tools to assist in this process is the development of an "open" and accessible web-based asset-mapping process that puts mapping tools into the hands of the groups who have the least resources in the community.

The evolution of grassroots groups from (horizontal) community circles to coherent organizations with capacity to collaborate with (vertically oriented) external resources is seen, by some professional community developers, as an evolution to viable community governance. Community asset mapping in the pursuit of improving assets and capabilities through collaboration, falls short of viability 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 input of community residents. The objective here is to develop capable and effective innovative neighbourhood collaboratives to which resources could be devolved by external agencies.

In order to create a forum for collaboration and dynamic asset mapping, we are adapting a web-based system we have named NewsAtlas^{TM} with the social service agency as system operator. We use the newspaper-map metaphor as a mechanism that would encourage maintenance of current community information. NewsAtlas^{TM} will pilot community development work in four large neighbourhoods in conjunction with service organizations that participate in the social service agency. A sample NewsAtlas^{TM} interface is shown in Figure 2. The NewsAtlas^{TM} service architecture

Figure 2: A NewsAtlas^{TM} Viewer Interface

Figure 3: A NewsAtlas^{TM} Presentation Interface

has three components:

1. a public view with organized news pages, map-layer based search facilities, calendars, classifieds and a service directory;
2. a secure social network service for participants who develop and publish NewsAtlas^{TM} content; and
3. an underlying database that holds content and application services.

NewsAtlas^{TM} begins as a community asset-mapping initiative consisting of information about services and their catchment areas. In addition, there is a community news source with departments and sections for local news, entertainment, arts, sports and recreation content, lifestyle, and spiritual content with mapping and event calendars. The process is available to community groups and social service agencies at no charge which levels the playing field for groups with little or no resources. At the outset we envision a city-wide service with a list of neighbourhood "front" pages, which mimics a newspaper. All content is searchable by drawn map area in combination with powerful search tools that support searches by content, space and time. Figure 3 illustrates another presentation interface.

The NewsAtlas^{TM} media services will contribute to building viable community governance. NewsAtlas^{TM} is intended to bring on-going service sustainability in terms of content, community participation and social enterprise revenues, all to address the main project objective: to increase the amount of community planning that is done collaboratively, inclusively and intentionally.

The asset base just described consists of:

- maps and databases of community and neighbourhood assets ranging from service agencies to gardens, sports facilities and events; and
- the content supported by NewsAtlas.^{TM}

The asset base is dynamic and supports CI as various community members can contribute to the databases and the content represented by the NewsAtlas^{TM} publications.

3.2.1 Assets, added value and tools

Assets - Knowledge repository structure; interested NGO contributors; online NGO community; and knowledge of social services.

Value - Complete "map" of social services; gap and redundancy analysis; and action plan to rationalize social services.

3.3 Real-time synchronous CI - MAPS

A Community Planning, Land Management, Infrastructure and Environmental Resource Management application service has been developed for the aboriginal communities under the Indigenous Cooperative on the Environment (ICE) [8]. One component of this mapping and planning service (MAPS) allows real-time synchronous collaboration over the Web among multiple parties involved in land use planning.

Using MAPS, a moderator who initiates a session, can create and pass a link to other parties in a teleconference. The link gives access to view the moderator's web page. The moderator can "pass the chalk" to each of the teleconference participants so that each one can 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 each party. 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.

An audit trail is kept for all system interactions during the multiparty collaboration session with information such as when parties joined and left, what content was entered, when and by whom. The collaborative web session service can be a re-playable file for use when arbitration is required. A text chat feature allows minute taking during a session.

In addition to the real-time collaboration the MAPS will offer a secure community-driven collaborative geomatics and social-innovation software service for First Nations developed, managed and maintained by the aboriginal community. MAPS contains databases and web and mobile interfaces that helps to capture data and information to:

- support jurisdiction of First Nations peoples with respect to their lands, ecosystems, resources, culture, traditions and citizenship; and
- rebuild and restore an authentic aboriginal identity (culture, values, symbols, ceremonies and languages).

3.3.1 MAPS - Assets, added value and tools

Assets - Tools to manage consultation; traditional knowledge repository structure; interested community contributors; online community; and secure access control - sharing limited by contributor.

Value - Complete history and culture details; free input; consultation database; and income generation through consultation.

3.4 ITS - Citizen Science

The Invasives Tracking System (ITS) is an example of citizen science where members of the public collaborate with scientists to detect and record the presence of so-called invasive species. The annual bird count is a similar activity. Specifically, ITS is used to allow:

- agencies and experts to enter species, photographs and content for invasive aquatic and terrestrial species; and
- the general public to specify the location of such species with content related to the sighting, such as time.

The ITS can be used to track invasive species across jurisdictions such as a municipality, province or state.

ITS uses a social network system consisting of groups, forums and authoring services that the agencies' experts can use to author and publish collaboratively official and authoritative information used to help identify and then control invasive species. The data on sightings entered by members of the public acting as citizen scientists are "accepted" before being used to update an area-wide database. The agencies involved in ITS wanted a social network that is only open to the experts and related agencies, even though the resulting "public" network effects would have increased the utility of the system. They reasoned that users may be confused and misconstrue volunteered content with official content.

The benefits of organizing the chaos of social network services for community intentions are legion. Clay Shirky's [15] comments on "cognitive surplus" suggest a huge unused capacity that could be channeled for social benefit by new social media frameworks. However, academics, professionals and other authorities resist this "wisdom of the crowd" for many and often good reasons. We have implemented systems that provide for both authoritative and volunteered content in a manner that maintains clear distinctions.

3.4.1 ITS - Assets, added value and tools

Assets - Expert field guide; experts; interested public contributors; and online community.

Value - Sightings - location, progress over time; remediation projects; and sharing of information (sightings and projects).

4. CI AND THE WEB

There are many facets to CI using the Web and a dynamic asset-mapping approach. In this section we analyze this phenomenon and try to understand its constituents and related properties in order to create a model for a CI framework. Basically the participants share knowledge and add value to that shared knowledge through a set of collaborative tools that are operated under various constraints.

4.1 Constituents of CI

4.1.1 Shared knowledge

There must be a collection of shared information or knowledge, often called a database, knowledge base, inventory or asset map, to support collaboration. This shared information may be distributed and should be accessible within the collaborating community. It may also be necessary to import or export data from other asset bases such as maps.

For example, an environmental group interested in tracking and eliminating invasive species in a region would likely start with a database of all such known species in the area and the protocols associated with their identification and remediation. Similarly there would be a shared map of the area, which may have originally been imported from a geographic information system (GIS). Spatially related data such as sightings of invasives may be exported to a GIS for complex spatial analysis. As the processes around invasive species evolve this shared knowledge will be augmented with sightings of species classified by location and time as well as reports on effectiveness of remediation approaches.

4.1.2 The Collaborative Canvas

Information about these assets and input to and results of the collaboration can be presented through shared collaborative canvases or interfaces. The shared canvas can provide many different tools such as a data report, input to databases, e-mail, audio, video, pictures, text, maps (geomatics), short messages (Twitter tweets), blogs, and wikis to name some examples. Thus, a member of a collaborative can view the current state of the assets by reading a report, viewing a presentation on a map, analyzing a tweet log or reading a blog or wiki. These canvases can allow members to provide new information to the set of assets through an input form, by allowing a drawing on a map or diagram, or through commentary in a blog or wiki.

A report showing a list of sightings of invasive species can indicate the prevalence of the species, while a map showing the geographic location of the sightings is more valuable since it indicates the geographic extent of the unwanted species invasion. If time is included the speed at which the species is moving across the landscape can also be revealed. The map can also be used to allow anyone providing information about an invasive species sighting to provide its geographic location by placing an electronic pin in the map. Similarly someone attending a historical event re-enactment could take a video of a battle and attach it to a map where the location and extent of the real battle could be specified.

4.1.3 Online Communities and Social Networks

An on-line community can be viewed as a group of individuals seated around a real or virtual conference room table collectively working on tasks that support CI. The group and its set of purposes form around a geographic community or community of interest and the group may break into sub-groups to divide the tasks and make them more manageable. The assets and the value created from them are held and controlled by the group. The group may appoint mediators to manage the composition of the group and sub-groups, to assign tasks, and manage and control the group's assets and derived value. In contrast a social network is focused on the individual rather than the group. The individual controls what can be seen and shared and ownership of assets and derived value belong to the individual.

Online communities/social networks are primarily designed to share without being concerned about the nature of the content. Both types of networks can use tools from the collaborative canvas that allow sharing and collaboration over the asset base with responsibilities usually delegated through control over access. There can be many different types of tools that are used as components of both types of social networks as already described including maps (geomatics), input forms, reports, text, video, pictures, audio, wikis, blogs, and asset repositories.

Online communities/social networks prompt connection and communication to enhance opportunities for self-organization with shared goals, protocols and applications. Such communities can gel around subject matter in searchable shared spaces such as forums, wikis and geography (maps) rather than organizational hierarchies. They can also form around groups where individual members find and connect with each other through shared background or knowledge based on user profiles, private messaging, groups, contributed content and Wiki linkage, notification, expert search and other linking concepts.

Tags, social bookmarks, and other social networking tools can help bring order to the avalanche of information that is involved in forming a creative network and managing the output from the collaboration.

4.1.4 Access control model

Collaboration requires that a group forms around an idea or situation with the objective of working together. The group is self-limiting by expertise or interest although it may grow or change in composition as the collaboration forms and changes. By its nature collaboration is not completely open. Therefore there must be moderators who manage the group composition and delegate authority to members of the group related to responsibilities. These moderators must be given a set of tools not only to enable the collaboration but to admit participants with responsibilities, so-called transactional access controls. Such access controls can be role-based [2] or use other confidentially models [11]. Participants could be allowed a subset of operations on the asset base such as read, write, update, or write/update with history log. These same participants could also be limited in the collaborative canvas tools that they can use or the portion of the asset base they can see through an interface such as a map. For example, experts in invasive species could use a wiki or blog to discuss issues around protocols for identification and remediation, whereas laymen could read the content of the wiki or blog, but could not offer an expert opinion.

4.2 Properties of Dynamic Asset-Mapping CI

4.2.1 Collaboration in Time

Collaboration can occur asynchronously or synchronously (real-time). Asynchronous collaboration is more common because contributors do not have to agree on a time to meet. The collaborators can contribute through e-mail, maps, wikis, blogs, Web forms and similar mechanisms. Posting sightings of invasive species on a map is an asynchronous independent action. It does not require the participation of anyone else.

Synchronous or real-time collaboration requires the presence of two or more parties to the collaboration. For example if a land developer, local government and concerned citizen's group are negotiating (collaborating) over the site and extent of a commercial mall, then they could share a common map for the discussion. Of course all the collaborators could use the map and communication channels over the Web.

4.2.2 Mobility

Mobility adds a new dimension to collaboration as the collaboration and the creation of value can happen while participants are on the move. When locating an invasive species with a smart phone and its global-positioning system (GPS) the location and a photo can be recorded on a map where the map might also be shown on the phone. Thus mobility can provide more accuracy and immediacy as the the data can be captured and reported upon in real-time.

4.2.3 Adding Value

Once the collaboration begins,the active collaborators using the shared assets and collaborative canvas add value since they create more information and knowledge or assets, which are usually added to the asset base. These additions are called emergent properties. Rich emergent properties often arise when diverse groups form communities of practice. Returning to the environmental group that is interested in invasive species, individuals could join the collaboration and pinpoint the location of sightings of invasive species thereby adding emergent properties to the asset base by giving an indication of a species' progress across the landscape.

4.2.4 Redundancy

Some shared knowledge is often a partial copy of a primary source. For example, original invasive species data may include property ownership as well as geographic coordinates. The property ownership data should not be made widely available as revealing this information may impact property values. The easiest way to do this is to make a partial copy. Now there are two copies that must be kept synchronized. Harmonization of two or more copies can use intelligent software agents to manage the need for redundancy [1].

5. A SOFTWARE FRAMEWORK FOR CI

Each example in this paper illustrates aspects of CI and uses many components of the CI model. This section isolates and describes components of a software framework for CI.

5.1 Shared Knowledge

A typical collaboration starts with an initial data model for the shared knowledge that changes over time as the collaboration proceeds and new requirements for data become evident. Thus, there must be tools to create and modify the underlying data structures (often databases) easily, as well as ones to support the unloading of the old data structures and re-loading of the new ones. Tools must also be available for connecting to new knowledge repositories and importing and exporting data from both open and partially closed data repositories and from systems such as a GIS when mapping data is needed for the collaboration. In the case of GIS, WMS [23] can be used to obtain a common map and WMF [22] can be used to exchange feature data between the CI environment and a GIS. Thus, the GIS can be used for complex analysis that would not be supported directly.

5.2 Collaborative Canvas

The collaborative canvas can provide many different tools such as a data reports, input forms for databases, e-mail, audio, video, pictures, text, maps (geomatics), short messages (Twitter tweets), blogs, and wikis. Here we focus on some of these features to show their use in the applications described in this paper. Table 1 shows how these components are used in each example.

Components	ESP	News-Atlas	MAPS	ITS
Geomatics (asynch)	X	X	X	X
Geomatics (synch)			X	
Document Mngement	X	X	X	
Input forms	X	X	X	X
Output reports	X	X	X	X
Searching by time		X		X

Table 1: The location of canvas components

5.2.1 Geomatics (asynchronous and synchronous)

Asynchronous geomatics provides maps or diagrams and allows one or more individuals to operate on that map. Operations proceed independently and can include zoom-in, zoom out, re-centering, spatial searching, specifying a point or shape feature and related attribute creation. Even when individuals are using the same map at the same time through distinct browsers, there is no direct interaction between users except through changes to the asset base.

Synchronous geomatics has the properties of the asynchronous case but has the extra structure to allow a group to work collaboratively with each member of the group using a browser usually in a different location. One individual, the moderator, can pass control to another member of the group to use the functionality of the mapping system, while others observe the results. In addition a transaction and chat audit trail is recorded, thus allowing playback of a session.

5.2.2 Document management

Documents with text and multimedia can be stored in the system. All text can be indexed and is fully searchable. Searches can performed on words or phrases, proximity of words and phrases in a document set or time. Documents added since the last search would be highlighted.

5.2.3 Input forms

Forms are available to allow modification of the asset information or to create new assets. The forms can allow both structured and textual information. The forms can work in conjunction with the map to qualify the attributes of a feature such as a location or shape that is drawn on a map. The input forms can support wikis, which allow users to collaborate in creating a database of content.

5.2.4 Output reports

Output reports can take many different forms. They can provide a listing of specific content in the asset base, show one or more documents or can be related to a geomatics-based search. In this case the report would be related to a point or area.

5.2.5 Searching by time

All information in the asset base can be time-stamped and thus can be searched by time. Such a feature is particularly valuable when presenting information about events or showing how an invasive species or disease is progressing across a landscape.

5.3 Collaborative Social Networks

Collaborative social networks are mediated, that is there is some form of management of the individuals who can participate in the network. People can apply or be invited to join based on expertise or interest, and the management group issues userids and passwords. Thus, some form of access control mechanism must be in place to allow construction, distribution and access management. The next subsections describe some of the ways in which a collaborative "social" network may be structured. Table 2 shows the different collaborative social networks and what applications use them.

5.3.1 Single Exclusive Network

A single exclusive network only contains one collaborative "social" network for a subset of the individuals involved in an application. The network usually focuses on a small number of topics. For example the ITS provides a network for individuals who are experts in classifying and identifying invasive species. Members of the public who become citizen

Networks	ESP	NewsAtlas	MAPS	ITS
Single Exclusive				X
Multiple Exclusive	X	X		
Multiple Dynamic			X	
Multiple Open			X	

Table 2: The type of online community

scientists to detect invasive species in the field are excluded from the network so their input is not misconstrued as expert opinion.

5.3.2 Multiple Exclusive Networks

An application containing multiple exclusive networks has multiple collaborative "social" networks but the membership in the network is restricted by some criteria. For example in the ESP, each network is associated with a project and membership is restricted to individuals that are related to a specific project. In the NewsAtlas application, contributors in a neighbourhood are restricted to those who have "signed" a contract to produce material. There is also one social network for readers with no restrictions on membership.

5.3.3 Multiple Dynamic Networks

Collaborative "social" networks can grow and shrink dynamically as sessions within an application begin or end. The MAPS application has this property. A network corresponds to a collaborative mapping session. Once the session is closed the network is no longer active and if a new session starts, a new network is opened with the participants in the new session being the members. There is an audit trail of transactions that occurred during the operation of the network, which can be replayed to show what happened during the life of the network. Even though the same group may join a network for subsequent interaction, this is viewed as a new network as the audit trails are distinct.

5.3.4 Multiple Open Networks

MAPS can also support ongoing networks that can be joined by invitation or request but are not closed to anyone. We call these open networks.

5.4 Mediation and Access in Collaborative Social Networks

All CI systems created by our research team have the same access control challenges. The right to participate in the collaborative social network, contribute and report on data and publish content is distributed to participating organizations and professional individuals, belonging to communities of interest 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 (a contract) from rights' recipients to conditions necessary for system security and integrity. In NewsAtlas,^{TM} 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.

For example in NewsAtlas,^{TM} participation in the neighbourhood Directory will be managed by the custodian, acting 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 terms of use. Registered participants will be able to (or enable their membership or affiliates to) access NewsAtlas^{TM} content publishing tools and content management services for depictions of their individual or organizational assets.

5.5 Mobility

Facets of CI can be provided through mobile devices such as smart phones and tablets. However, smart phones and tablets are often constrained by battery life, computing power, memory and screen size, and availability of communication, which significantly affects their use. Smart phones and tablets are usually equipped with a location mechanism such as a GPS, recording capability for stills, video, and audio, a limited database and a data connection that allows web browsing, e-mail and data transfer making the smart phone and tablet a context-aware device suitable for functions such as sensors or guides. We describe these two functions next.

5.5.1 Mobile devices as sensors

In the discussion in Section 3.4 individuals were described as citizen scientists as they located and reported on an invasives species collaboratively from the field. With a smart phone or tablet the citizen scientist can photograph or take a video of the species, record the exact location, complete the form and send the data to a central collaborative database. Such an approach provides immediacy and greater accuracy.

5.5.2 Mobile devices as guides

In Section 3.2 we show how to use the CI system to support community collaboration. A key notion is the concept of content related to a geographic point or area. A smart phone or tablet could be integrated into this CI application as a guide to community information sites such as the local mall or local historic buildings. In the mall the smart phone would be guiding the individual by providing information about the location of stores and sales. In the case of historic buildings the individual could be receiving information about the building or be contributing information such as uploading photographs similar to Section 5.5.1.

6. RELATED WORK

The asset-mapping CI approach proposed in this paper contrasts with closed community efforts, which involve limited interaction, and both restricted knowledge of community assets and their value chains [3]. In the context of service systems, it has been suggested that open service-oriented models could use novel paradigms based on innovation [12] and asset mapping.

Thinking frameworks have been proposed to help organizations focus their management attention, and enable users to participate in the innovation process [19]. In addition, modeling approaches have been defined to describe innovation networks from a services system perspective and to address inter-organizational interactions [9]. In comparison, our proposal focuses on a framework that supports the construction of web-based collaborative innovation systems based on dynamic asset-mapping that can address both inter-organizational and general community interactions and resource exploitation and production.

7. CONCLUSION

This paper outlines the concepts of collaborative innovation based on dynamic asset-mapping, a new and exciting branch of Web Science. Further the paper describes why CI is important to the functioning of modern society and how modern web-based tools could be used to support this activity. Based on the experience gained in designing and deploying over 70 systems that incorporate collaborative innovation, some of which are described in this paper, it is clear that collaborative innovation takes many forms. Thus, it is not possible to build a single set of tools to support collaborative innovation. Rather a set of meta-tools is needed which can be used by the participants in the CI to build tailored systems to fit specific situations that arise when web-based collaboration occurs. The authors of this paper and their research team have built a version of such meta-tools outlined in this paper under the name the Web Informatics Development Environment (WIDE). The meta-tools have been partially deployed to test their use in CI environments. Based on the experience gained, the meta-tools are currently being refined and improved.

In summary, the research described in this paper based on our experiences aims at defining dynamic asset-mapping approaches to the development of web-based CI systems that promote explicit knowledge sharing needs among cohesive and global-scope communities.

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