# DESIGN AND IMPLEMENTATION OF A COASTAL COLLABORATIVE GIS TO SUPPORT SEA LEVEL RISE AND STORM SURGE ADAPTATION STRATEGIES

**TITUS TIENAAH**

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Titus Tienaah

Department of Geodesy and Geomatics Engineering
University of New Brunswick
P.O. Box 4400
Fredericton, N.B.
Canada
E3B 5A3

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# PREFACE

This technical report is a reproduction of a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Engineering in the Department of Geodesy and Geomatics Engineering, March 2011. The research was supervised by Dr. Sue Nichols, and support was provided by International Community University Research Alliance.

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# DEDICATION

I dedicate this research to my parents Mr. and Mrs. Tienaah, for their encouragements and interest in my education.

# ABSTRACT

The ICURA C-Change is a collaboration of universities and eight communities in Canada and the Caribbean to develop adaptation strategies for the effects of sea level rise and storm surges. These vulnerable communities have topographic and sea level data, ranging from high to low precision for developing scientific scenarios of coastal threats. Scientific scenarios without precise data lead to gaps in quantifying the extent of threats in coastal communities, which is vital in developing adaptation strategies. This research develops an online Coastal Collaborative GIS (CCGIS) using local knowledge as input in threat mapping to supplement existing data.

The CCGIS developed using the *Zend Framework*, *OpenLayers* and *ExtJS* provide both server-side and client-side programming to embed Google and Bing Maps as base layers to capture spatial input described with multimedia. The purpose was to develop a low cost, user-friendly system, which could be used in any community. Local knowledge acquired in a coastal community is digitized as point, line, and polygons representing a location, linear and area features respectively. Descriptions of spatial objects with rich attributes such as video, audio, pictures, and text captured in a local environment compliment the CCGIS spatial abstraction. A prototype review mechanism and a peer review process to maintain a degree of trust in contributors and their contributions was implemented.

This research evaluated the developed CCGIS prototype based on user and system requirements. User tests indicated functional requirements were achieved with more improvements required in some areas.

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# List of Abbreviations

| | |
|---|---|
| Ajax | Asynchronous JavaScript and XML |
| APF | Adaptation Policy Frameworks |
| API | Application Programming Interface |
| CAGIS | Community Action Geographic Information System |
| CCGIS | Coastal Collaborative GIS |
| CDED1 | Canadian Digital Elevation Data (1: 50,000) Level 1 |
| CERN | European Laboratory for Particle Physics |
| CGIS | Collaborative GIS |
| CMS | Content Management System |
| CR | Collaborative Reputation |
| CRUD | Create, Read, Update, and Delete |
| CSS | Cascading Style Sheets |
| DEM | Digital Elevation Model |
| DOM | Document Object Model |
| ExtJS | JavaScript Library |
| FDL | Free Documentation License |
| FLV | Flash Video (movie file format) |
| GDAL/OGR | Geospatial Data Abstraction Library |
| GeoJSON | Geographic JavaScript Object Notation (encoding format) |
| GIF | Graphics Interchange Format (image file format) |
| GIS | Geographic Information Systems |
| GML | Geography Markup Language |
| GPL | General Public License |
| GSDSS | Group Spatial Decision Support Systems |
| HTTP | Hypertext Transfer Protocol |
| ICURA | International Community University Research Alliance |
| IIS | Internet Information Services (web server) |
| IP | Internet Protocol (address) |
| IPCC | Intergovernmental Panel on Climate Change |
| ISO | International Organization for Standardization |
| JPEG/JPG | Joint Photographic Experts Group (image file format) |
| JS | JavaScript |
| JSON | JavaScript Object Notation |
| KML | Keyhole Markup Language |
| LEK | Local Ecological Knowledge |
| LiDAR | Light Detection and Ranging |
| LMAS | Linear Map Accuracy Standards for National Topographic Data Base) |
| MP3 | Moving Picture Expert Group Audio Layer 3 (audio file format) |
| MP4 | Moving Picture Expert Group Layer 4 (movie file format) |
| MPAs | Marine Protected Areas |
| MVC | Model View Controller |
| OGC | Open Geospatial Consortium |
| OSGeo | Open Source Geospatial Foundation |

| | |
|---|---|
| OSM | Open Street Map |
| OWS | OGC Web Services |
| PAR | Participatory Action Research |
| PGIS | Participatory GIS |
| PHP | Hypertext Preprocessor |
| PNG | Portable Network Graphics (image file format) |
| PPGIS | Public Participatory GIS |
| PRA | Participatory Rural Appraisal |
| SOA | Service Oriented Architecture |
| SOAP | Simple Object Access Protocol |
| SVG | Scalable Vector Graphics |
| TEK | Traditional Ecological Knowledge |
| UI | User Interface |
| UML | Unified Model Language |
| WCS | Web Coverage Service |
| WFS | Web Feature Service |
| WGI | First Working Group of the IPCC |
| WKT | Well-Known Text format |
| WMS | Web Map Service |
| WSDL | Web Services Description Language |
| XHTML | eXtensible HyperText Markup Language |
| XML | Extensible Markup Language |

# Chapter One: Introduction

*Climate change poses clear, catastrophic threats.*
*We may not agree on the extent, but we certainly can't*
*afford the risk of inaction* ~ Rupert Murdoch, 2007.

Most low-lying coastal communities around the globe experience the effects of climate change, translated as sea level rise and other storm events. These effects lead directly or indirectly to flooding, damage to infrastructure, socio-economic impacts, water pollution, and health hazards. It is natural for a coastal region, a community, a household, an economic sector or a population group to respond to these external forces by developing an approach or method to cope with these consequences. "Adaption" to these events refers to the ongoing process by which strategies to moderate, cope with, and take advantage of the consequences of climate events are developed, enhanced, and implemented to reduce their negative impacts [Ebi et al., 2005].

Universities, governments, and organisations mostly conduct and publish research on climate change in the scientific domain. However, to implement scientific knowledge in an adaptation process requires local interaction and co-operation with the people, groups, or local governments experiencing the effects. It is agreed by many authors that implementing a sustainable plan requires involvement of all stakeholders to address diverse interests before a crucial decision is made to reflect the community interest [Rantanen and Kahila, 2009, Aswani and Lauer, 2006; Tang, 2006; Sieber, 2006; Cinderby and Forrester, 2005; Al-Kodmany, 1999; etc.].

The participation of local people in a geographic context usually involves the use of maps, physical models, forums, and interviews to exchange implicit or explicit spatial knowledge. In many sea level rise adaptation projects, relatively precise scientific maps and scenarios have been used to identify and predict threats to engage the public in discussion forums. Less attention has been paid to the area where people can express their views and opinions to threat mapping digitally with local knowledge and experience of their own environment. This leads to missing rich details captured at the time of historic events in the form of spatial objects described by pictures, audio, video, or text. In addition, collection of local experiential knowledge at large public meetings is usually limited since only one person or a group can articulate their views at a time. It is also important to keep the stakeholders engaged in a dialogue that has a geographic context after an interview or public meeting to keep monitoring and modifying adaptation strategies to changing local issues due to sea level rise and storms. This research will provide a means to overcome the above limitations in a coastal sea level rise and storms surge adaptation process.

This chapter sets the stage with the research problem: how can local knowledge be spatially captured to supplement communities with the best available data in developing coastal adaption strategies to the effects of sea level rise and storm surges? The chapter sets out the research objectives, scope, concludes with research contributions and the overall organisation of this thesis.

## 1.1 Research Problem

Four Canadian coastal communities (Charlottetown, Prince Edward Island; Gibsons, British Columbia; Isle Madame, Nova Scotia; and Iqaluit, Nunavut) and four in the Caribbean (Georgetown, Guyana; Grand' Riviere, Trinidad and Tobago; Belize Barrier Reef, Belize; and Island of Bequia, Grenadines) are in a collaborative process with universities in developing adaptation strategies to overcome the effects of sea level rise and storm surges. Funding to develop adaptation strategies is being provided by two Canadian agencies: Social Science and Humanities Research Council (SSHRC) and the International Development Research Centre (IDRC) through their joint International Community University Research Alliance (ICURA) program. This project, known as C-Change, will run from 2009 through to 2014 [C-Change, 2010]. The research reported here is one part of that project.

With growing migration of populations to coastal areas for economic and aesthetic reasons, human society is becoming increasingly vulnerable to rising mean sea level, increased frequency of storm-surge flooding, and changing rates of coastal erosion [McCulloch et al., 2002]. Inherent in the cultural fabric of North Americans is the desire for owners and developers to have waterfront properties (scenic view of the sea, river, beach, etc.). These coastal developments, acquisitions and settlements in low-lying areas are prone to flooding due to sea level rise coupled with storm surges.

The effects of climate change have drawn the attention of world organizations and the Intergovernmental Panel on Climate Change (IPCC) was formed in 1988 [IPCC, 2007]. The estimated budget for the global mean sea level rise calculated by the first working group (WG I) of the IPCC [2007] showed that sea level rise observed from tide gauges from 1961 to 2003 was 1.8 ± 0.5mm per year. With advancements in satellite altimetry, the observed global mean of sea level rise between 1993 and 2003 was estimated to be 3.1 ± 0.7mm per year. This global mean varies from local and regional values due to local ground subsidence or uplift (described further in Chapter 2). Local sea level rise coupled with storms can raise water levels by a few metres.

Why are these estimates important to the C-Change project? Storms and floods because of climate change have direct and indirect impacts on property (residential, commercial public properties), historical and heritage resources (tourism, heritage, recreational values), coastal infrastructure (urban and rural infrastructure), health, ground and surface water pollution, habitat destruction, education, and employment. To avoid the "*...risk of inaction*" as stated by Murdock [2007], it is very important to identify vulnerable coastal areas using the best available data (information) and technologies to help communities adapt to or mitigate these effects.

Predicting flood zones requires quantification of small changes in water level (vertical) with respect to coastal topography; usually, vertical estimates range from decimetres to a few metres. Precise modelling of these small height differences requires a Digital Elevation Model (DEM). Today, this is often achieved with precise Light Detection and Ranging (LiDAR). Most LiDAR platforms can provide height, with uncertainties of ±30 cm or better. For example, the “first and most comprehensive” economic impacts assessment of storms and sea level rise in Canada conducted in Charlottetown used LiDAR [McCulloch et al., 2002]. In this study, a Digital Elevation Model (DEM) covering Charlottetown determined that seawater begins to flood waterfronts at a level of 3.6 metres above chart datum. Presently, this water level is reached every seven (7) years, and the frequency of this happening will increase with increasing sea level rise [McCulloch et al., 2002; Environment Canada, 2006].

While very accurate, LiDAR data usually have an initial high cost to acquire. Many communities have less precise or unavailable data and will have to use other data sources to determine impacts. Alternative elevation data from most national topographic maps are much less precise and therefore not as useful. For example, Canadian Digital Elevation Data (1: 50,000) Level 1 (CDED1) for the City of Charlottetown has a vertical accuracy of ±10m for the region *011L06* and ±20m for region *011L03* (Linear Map Accuracy Standards (LMAS) for National Topographic Data Base) [CDED1, 1987]. This amount of vertical height uncertainty is greater than historic storm events in the City of Charlottetown. Uncertainties from most national elevation maps make them unreliable when used for predicting flood zones caused by sea level rise and storm events, which must account for decimetres to a few metres. Other data sources (e.g. provincial mapping) also may not have sufficient precision.

In summary, many communities may not be able to afford the benefits of LiDAR to improve the accuracy of flood mapping and prediction; therefore, coastal communities are faced with the cost of collecting new data in places where available data is inadequate or non-existent. The C-Change project includes a variety of conditions from data rich (e.g., Charlottetown) to “data-poor” (e.g., Isle Madame). The challenge for this research is to design and implement a platform where the best available data can be augmented by local knowledge in assessing the effects of sea level rise and storm surges.

## 1.2 Research Goal

The aim of this research is to improve local participation in a coastal collaborative process. To improve collaboration, this research designs an on-line collaborative system to capture local knowledge as a means of assessing the effects of sea level rise and storm surges. The system includes a digital interface for map content creation and visualization, multiple interfaces for participant interactions, and a digital database to provide and store new information. The system brings together scientific maps, spatial local knowledge, comments and participatory forums to facilitate the process of threat mapping [Bodorkós and Pataki, 2009]. Outputs of this research will help bridge the information gap that exists in many communities to threat identification using local knowledge and to provide a means of feedback on scientific scenarios of threats generated with existing topographic data.

This thesis reviewed a wide range of local, indigenous, public participation and collaborative research to establish a collaborative process of local knowledge acquisition (see Chapter 2). The relative term “local” will refer to all forms of coastal settlements (urban, peri-urban, and rural) or a local decision making group (local government, city planners, etc.). This helps fulfil a key mandate of the C-Change project, which is to establish a coastal collaboration between researchers, policy makers and the various local communities.

### 1.2.1 Research Objectives

To achieve the goal of this research, the following objectives are defined to:

- identify and classify commonly used and supported publicly available web mapping tools and to identify at least three (3) web tools useful for project design based on classification,
- design a local knowledge platform for spatial identification of coastal threats as a result sea level rise and storm surges,
- link the designed web GIS platform and local knowledge in a collaborative process that can be applied in the eight (8) communities of the C-Change project, and
- test and evaluate the designed system based on requirements and project objectives.

### 1.2.2 Research Scope

A prototype for demonstration was developed based on the following assumptions:

- this research will not create a template for a general purpose adaption strategy for various communities, since each community issues are uniquely different and must be studied, planned, and implemented differently;

- the prototype will not attempt to replace physical interaction with coastal communities; it will only serve as a facilitating tool to enhance such collaborations;
- this research assumes local users have basic knowledge of computers and have access to the internet; and
- all tools used in this research design are publicly available with free right to use, modify, redistribute and redistribute modified copies at no cost.

## 1.3 Proposed Methodology

Generic user requirements obtained and cited are from published literature in Participatory GIS (PGIS), Participatory Action Research (PAR), Collaborative GIS (CGIS), Public Participatory GIS (PPGIS), Local Ecological Knowledge (LEK), and Traditional Ecological Knowledge (TEK). System requirements (functional and non-functional) derived from a review of online mapping tools provided a generic functional requirement base. Spatial cognitive knowledge abstracted and captured by digitizing simple vector objects on a mapping platform are used to indentify threats. Threats described by adding attribute information such as text, video, audio and images complimented details lost in spatial abstraction. A prototype forum discussion then facilitates collaboration towards developing adaptation strategies. A generic flow of various tasks is as shown in Figure 1.1.

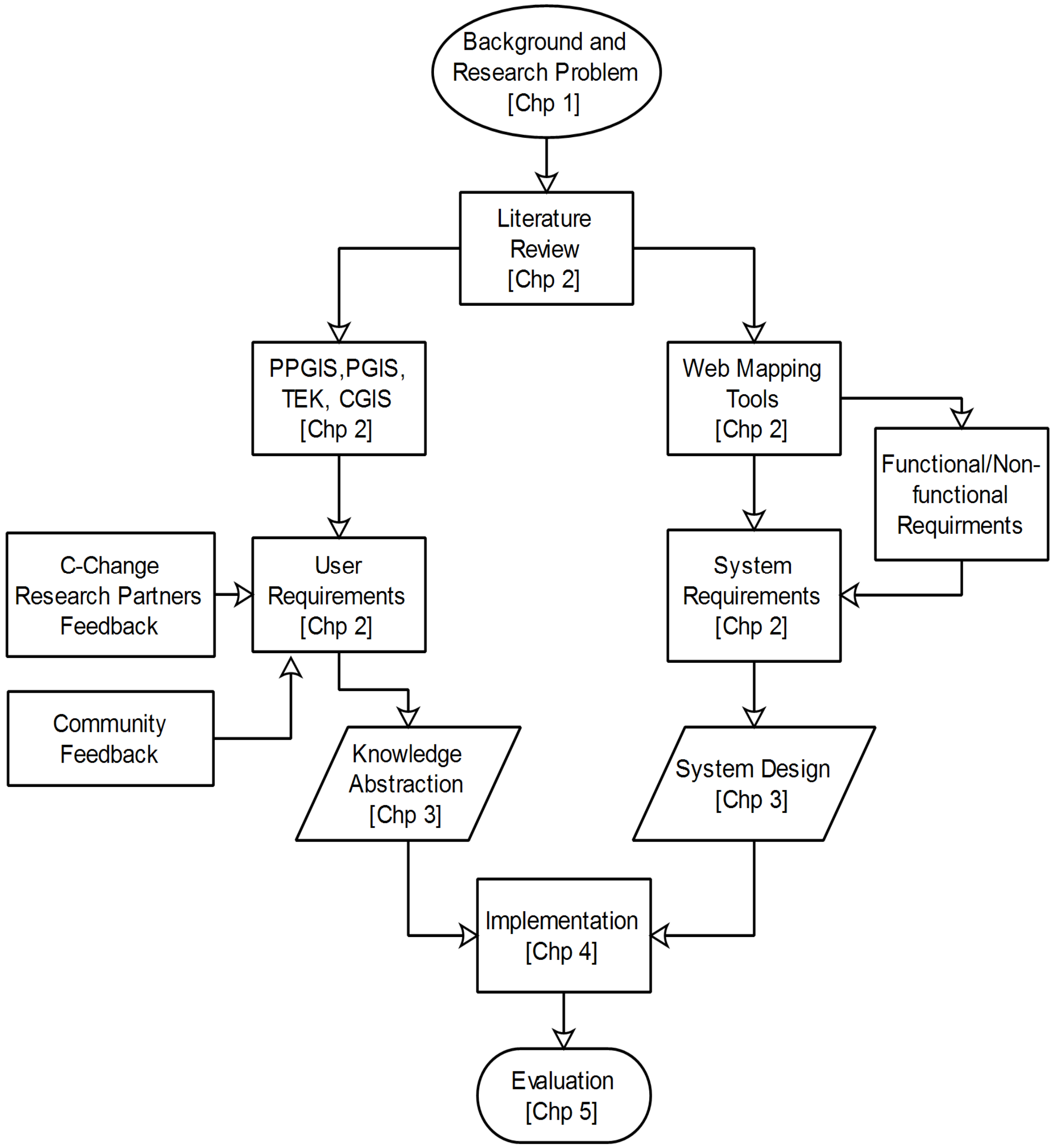



Figure 1.1 Research Method.

### 1.4 Research Contribution

The main contribution to the body of knowledge is the design, development and testing of a low cost Coastal Collaborative Web GIS tool to facilitate collaboration between scientific researchers, vulnerable coastal communities, and policy makers in identifying coastal threats related to sea level rise across varied community profiles. This significant contribution provides spatial local knowledge as a supplement to the best available scientific data in a coastal collaborative process. In the C-Change project, the designed system will serve as a feedback mechanism to scientific outputs while also helping to close the loop in community-university communications in a coastal adaptation process.

### 1.5 Thesis Organization

This research is organised into five chapters. Chapter One sets the stage with a research problem with set objectives within a research scope. A proposed methodology is presented as an alternative to precise mapping. The chapter ends with research contributions to the body of knowledge and an overall organisation of this thesis.

Chapter Two contains a literature review on participatory and collaborative knowledge and its relation to science. The chapter presents a review of relevant case studies with lessons learned from local knowledge research. User and system requirements are derived from the literature on local knowledge processes and publicly available web mapping platforms.

Chapter Three constitutes knowledge and knowledge abstraction. The chapter presents a system design created with user requirements, functional requirements, and non-functional requirements from Chapter 2. The use of publicly available mapping platforms is discussed to illustrate its strengths and limitations. Details on data storage, how data is accessed from the client interface is discussed through Model View Controller (MVC) pattern. The functions of each MVC pattern conclude this chapter.

Chapter Four in this research involves system implementation based on functional and non-functional requirements and thesis objectives. The Zend Model View Controller pattern discussed in Chapter 3, serves as the overall architecture for laying out the CCGIS. Implementation of components and communication between the client, server, and database are discussed. The chapter also discusses output formats of this research and its possible conversion formats to be used on other interoperable GIS platforms.

Chapter Five concludes this research by discussing issues associated with a coastal collaborative system design and implementation. The chapter concludes with the role of the platform in an adaptation process, system evaluation, and lessons learned.

Chapter Six concludes this research. The chapter presents concluding remarks and recommendations for future research.

### 1.6 Summary

This chapter presented a brief overview of this research as a platform to support threat identification in coastal environments pursuant to sea level rise and storm surges. This research design and implementation is to help the C-Change project engage stakeholders in the process of developing adaptation strategies. The research problem is identified with research objectives and scope to achieve a research goal. A proposed methodology extracts user requirements from participatory processes and system requirements from mapping platforms to design a Coastal Collaborative GIS. The chapter lays out the research contribution and the organisation of this write-up. The next chapter discusses climate change, GIS participatory processes as a means to derive functional and non-functional requirement for the CCGIS.

# Chapter Two: Climate Change, Collaborative Processes, GIS and Requirements

*In the long history of humankind (and animal kind, too) those*
*who learned to collaborate and improvise most effectively*
*have prevailed* ~ Charles Darwin (1809-1882).

This chapter discusses climate change and its associative impacts as a precursor to how local knowledge can play a role in a sea level rise and storm surge adaption planning. The chapter goes on to review various collaborative and participatory GIS processes and web mapping platforms as a means of deriving functional and non-functional requirements. The chapter concludes with derived requirements for the coastal collaborative GIS.

## 2.1 Climate Change

Climate change, as defined by the IPCC, refers to any change in climate over time, whether due to natural variability or because of human activity [IPCC, 2007]. Changes in climate are considered to persist over an extended time period, typically decades or longer. Decadal climate changes are associated with the systematic variations in global patterns of atmospheric pressure, temperature, and sea surface temperature that persist from a year or two to multiple decades [Inman and Jenkins, 2005]. This research will focus on specific effects of climate change: coastal flooding caused by sea level rise and storm surges.

Sea level rise, as well as sea level fall, and storm surges are being experienced and recorded in all coastal countries. Irrespective of the primary causes of sea-level rise (for example, climate change, natural or human-induced, subsidence, dynamic ocean effects), natural coastal systems can be affected in a variety of ways. The effects include, displacement of ecosystems, alteration of geomorphologic forms, and the vulnerability of social and physical infrastructure [Chappell, 1990; IPCC, 1996; Crooks and Turner, 1999; Inman and Jenkins, 2005]. From a societal perspective, some of the most important geophysical effects are: increasing flood frequency probabilities, erosion, inundation, rising water tables, saltwater intrusion, and habitat changes [Klein and Nicholls, 1999].

Sea level change cannot be translated to a single global measurement. Changes in regional relative sea level can be large or small based on coastal geomorphologic configuration, which may be affected by local subsidence, tectonic uplift or changes in ocean currents, such as the El Niño-Southern Oscillation event [Bijlsma, 1997; Vellinga and Klein, 1993]. Taking a broad perspective, coastal landform morphology responds to external forces, such as those imposed by sea level rise and storm events [Bijlsma, 1997; Bird, 1993].

Sea level rise and storm events occur in a geographic context. Understanding broader ramifications of sea level rise requires maps of lands that could be inundated or eroded [Titus and Richman, 2001]. As part of the steps in developing adaptation strategies, one must answer questions such as where are the impacts, who or what is being affected? To be able to answer these questions, people require geographic information. Creation of scientific maps includes, but is not limited to, the use of: elevation data, models of shoreline erosion and wetland accretion, topographic maps, tidal records, bathymetry and other coastal processes to provide a scientific basis for where these impacts may occur, who or what may be affected. Public geographic knowledge (acquired through observation and experience) in coastal communities also serves as a great resource in identifying threats related to storm events and flooding. Therefore, local inhabitants can also provide answers to where the impacts may occur, who or what are affected during historic coastal storm events.

## 2.2 Adaptation and Stakeholder Involvement

*Adaptation* is a process by which strategies to moderate, cope with and take advantage of the consequences of climatic events are enhanced, developed and implemented [Conde and Lonsdale, 2005]. Conde and Lonsdale [2005] recognized that relevant stakeholders need to be brought together to identify the most appropriate forms of adaptation. It is also recognized that adaptation strategies generally address current challenges, rather than future impacts and opportunities [Field et al., 2007]. The participation of stakeholders in the decision-making process assists in the implementation of adaptation policies. In effect, it is important to develop strategies with the local people and not for the local people, stakeholders are central to the adaptation process.

The Adaptation Policy Frameworks (APF) for Climate Change developed by the United Nations Development Programme – Global Environment Facility (UNDP - GEF) outline strategies, policies and measures to provide a structured approach to formulating and implementing adaptation [Burton et al., 2005]. The components of the APF are as shown in Figure 2.1. The diagram indicates that assessing risks and engaging the stakeholders are vital components to an adaptation process. The process of adaptation requires a long term, interdisciplinary dialogue between researchers and stakeholders. Supporting this dialog can also serve as a link between local knowledge and science. Since these adaptations occur in a local geographic context, a Geographic Information System (GIS) can be an important tool to facilitate engagement and to help assess current and future risks. Specific local participatory processes employed GIS and local knowledge as a means of complementing science; local knowledge and science and how local knowledge can play a key role are discussed in the next section.

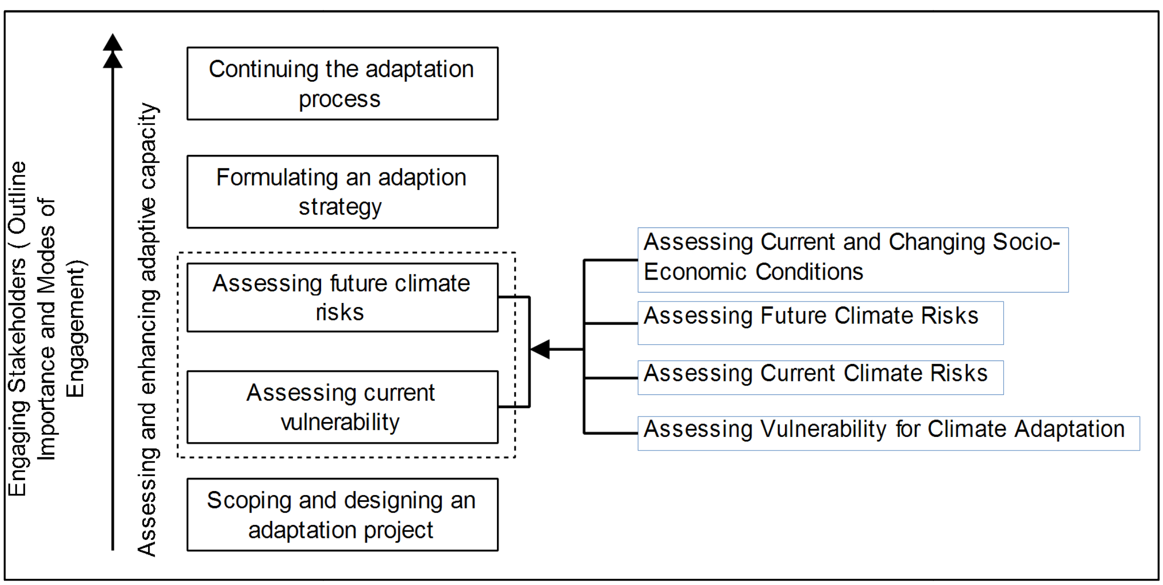



Figure 2.1 Adaptation Policy Framework (after [Burton et al., 2005]).

### 2.3 Local Knowledge and Science

Local knowledge in management plans is often not considered due to the belief by some researchers that it is fragmented, subjective, and thus lacks scientific merit. This view is currently undergoing re-evaluation and the importance of local knowledge is being increasingly recognized, especially in light of the failures of management policies derived solely from scientific knowledge [Close and Hall, 2006; Sieber, 2006]. Local ecological knowledge is fallible and does have certain limitations. Its fine-grained perspective, while adding value to coarse-grained studies, can also be a disadvantage as local knowledge is often only locally relevant [Gadgil et al., 2003]. Therefore, local inhabitants often have a weaker understanding of processes taking place at greater spatial and temporal scales that are not obvious to them.

In addition, other authors raise the caution that local knowledge has rationality and origins different from that of formal science [Chalmers et al., 2007]. Certain local customs such "fire" or the "sea" considered sacred in some communities do not fall in the “rational” context of modern science. Chalmers et al., [2007] advices scientists should be cautious and sensitive to differences in worldviews when attempting to bridge the gap between local knowledge and science.

Some researchers have argued that public or stakeholder involvement will assist effective design, implementation, and monitoring because stakeholder views were involved in the process [Aswani and Lauer, 2006]. Others also claim that, in democratic societies, people simply have a right to participate. Finally, across disciplines, cultures, and varied communities local people may have access to knowledge that is unknown to experts; local people may themselves count as experts about their own localities [Cinderby and Forrester, 2005].

## 2.4 GIS: Link between Local Knowledge and Science

Geographic Information Systems for local participation started as a process of using locally acquired knowledge to map an area for planning purposes [Cinderby and Forrester, 2005]. The benefit of capturing information using local participation in GIS helps in the comparison of local knowledge about land use against other forms of spatial data to assist in answering questions posed by the locals themselves and by other local policy stakeholders [Cinderby, 1999]. The term Participatory GIS (PGIS) developed in the mid-1990s in conjunction with a shift in focus from GIS technology and applications towards a critical evaluation of the uses of GIS [Harris, 1995]. PGIS originated from Public Participatory GIS (PPGIS) (to indicate grassroots involvement) with its methodologies originally developed in the United States [Cinderby and Forrester, 2005]. Cinderby and Forrester [2005] also suggest that PGIS had its roots in Participatory Rural Appraisal (PRA) and rural livelihoods development.

A literature review shows that at least six terms are used to indicate local participation in a geographic context: Participatory GIS (PGIS) [Tang, 2006], Participatory Action Research [PAR], Collaborative GIS (CGIS) [Balram et al., 2009; Bodorkós and Pataki, 2009], Public Participatory GIS (PPGIS), Local Ecological Knowledge (LEK), Traditional Ecological Knowledge (TEK) [Huntington 2000; Inglis 1993; Johnson 1992]. These concepts of local knowledge are qualitative or value-based and acquired as a result constant observation and interaction in a local environment. Researchers are making efforts to quantify and spatially represent local knowledge in a computer environment for easy access and querying. The next section discusses case studies undertaken in these fields of research.

### 2.4.1 Selected Case Studies

GIS was used to engage community members in developing alternative design solutions in the Pilsen neighbourhood of Chicago, United States [Al-Kodmany, 1999]. Al-Kodmany [1999] found that freehand sketching in conjunction with GIS and photomontage was the most effective way of identifying problems and expressing ideas with a non-technical participatory group during a town planning design exercise. In other planning case studies in the United Kingdom (UK), Kingston et al [2000] discuss the use of traditional methods of public participation and web-based GIS. In this article, the authors argue that new Internet-based technologies have the potential to widen participation in the UK planning system.

In another urban planning project, a demonstration prototype called *SoftGIS* was developed to support urban planning processes and decision-making. *SoftGIS* enabled mapping local knowledge and integrating it into urban planning practices [Rantanen and

Kahila, 2009]. Rantanen and Kahila[2009] utilized internet based map applications in collecting local knowledge from local actors about their living environment. The authors concluded that when the residents are involved in the urban planning process, they are more committed to its outcome.

Online map-based discussion forums enable internet users to submit place-based comments, threaded discussions, annotations, and respond to contributions from other participants [Tang, 2006]. Tang [2006] implemented a GIS-enabled online discussion forum for participatory planning. Her thesis added a spatial GIS context in a structured forum discussion. The application was based on ArcIMS, Java applets, MySQL and other scripting languages such as JavaScript (JS) and Hypertext Preprocessor (PHP). The internet is an efficient medium for a two-way communication between the public, planners and decision makers [Rinner et al., 2008]. Rinner et al. [2008] also developed a Web 2 online argumentation map using Java, *ArgooMap* (open source), and Google Maps API.

The integration of GIS and multi-media gives new possibilities for public participation [Hansen and Prosperi, 2005]. Zeiner et al. [2005] developed a geo-multimedia service infrastructure enabling users to store, retrieve, and share geo-referenced video. The GIS based multimedia content can provide its users with the advantage of getting additional audio-visual information for areas of interest. Barton et al. [2005] developed a public participatory system for the New South Wales Department of Housing. The authors implemented non-proprietary international standards using XML, SVG, GML, and X3D. The system did not support advanced urban design functionality, but rather simple user interface for input of points, lines and polygons as well as comments [Hansen and Prosperi, 2005].

In tourism, Stewart et al. [2008] explored responses to current and future local tourism development offered by a sample of residents using a modified Public Participatory GIS approach called “Community Action Geographic Information System” (CAGIS). Wu et al. [2010] developed a Web-2 virtual globe 3D visualization (like Google Earth) for publicizing urban planning information, using Web Services and Service Oriented Architecture (SOA) to support visual planning, model sharing, and interoperability. The authors implemented a standard descriptive language for 3D city models based on CityGML, open and standardised technologies such as XML, HTTP, SOAP, and WSDL (Web Service Definition Language). End users of this system can select any available urban planning solution for visual investigation and comparison in a virtual 3D visualization environment [Wu et al., 2010].

In marine research, Aswani and Lauer [2006] explored how a GIS database can used to incorporate indigenous ecological knowledge, artisanal fishing data, biophysical data and other information to assist in the design of marine protected areas (MPAs) [Hinkel and Klein, 2009]. In fisheries management, Close and Hall [2006] present a GIS-based protocol for the collection of local knowledge. In this research, the authors examined local knowledge in resource management and issues associated with the incorporation of qualitative data into a quantitative environment.

To keep to the scope of this thesis, readers can find other local knowledge and science research case studies that include but is not limited to: fishing, marine governance and marine resource management by Anuchiracheeva et al. [2003], Steyaert et al. [2007], Gerhardinger et al. [2009], and Evans [2010]. Soil science, forest resource management, environmental health and agriculture examples include works by Blaikie et al.[1997], Birmingham [2003], Davis and Wagner [2003], Oudwater and Martin [2003], Payton et al. [2003], Robertson and McGee [2003], Ryder [2003], Barrios et al. [2006], Lambert et al. [2006], Corburn [2007], Failing et al. [2007], Parrotta and Agnoletti [2007], Mulyoutami et al., [2009],Giordano et al. [2010], Raymond et al. [2010], and Reyes-García et al. [2010].

### 2.4.2 Lessons from Existing Research

From the reviewed literature, participatory platforms concentrate on enhancing public forum discussion, image visualization, audio, audio-visual, video, email and text support in an online environment. Using the World Wide Web as a means of increasing public participation has great potential in these fields. However, in communities where internet access is an issue, participatory web based platforms become unusable. Furthermore, large file sizes are not favourable for web application users with low internet bandwidth; this reduces user interactivity with mapping interfaces.

Possibly the most important challenge in Public Participatory GIS (PPGIS) is the ability to derive and represent the following on a map: soft, user-defined, fuzzy, and possibly non-spatial information that exist in the mind provided by the public [Kingston et al., 2000; Angelides and Xenidis, 2007]. Most often, people talk about everyday issues in vague terms [Kingston et al., 2000]. These may include imprecise qualitative data as well as processes that require the incorporation of subjective opinion and intuition to assess risks and plan for adaptation or mitigation measures [Angelides and Xenidis, 2007]. Developing an appropriate integrated approach for coastal risk assessment requires confronting these limitations with concurrent use of probability and fuzzy techniques. One lesson that emerges is that, PPGIS must first overcome a considerable amount of anti-technology prejudice and misconceptions on the part of local/traditional people before it is accepted [Ball, 2002].

### 2.5 Coastal Collaborative GIS (CCGIS)

This research will refer to all forms of local, indigenous, or public participation in a spatial context as *Coastal Collaborative GIS* (or *CCGIS*). The term "Coastal" attached to CGIS highlights this research as a derived entity sharing all the characteristics of the base parent collaborative GIS. "Coastal" in CCGIS indicates the collaborative process for settlements and developments bordering water bodies susceptible to the effects of climate change. In this dynamic environment, the collaborative process should be active in engaging stakeholder views captured in time as local knowledge. Therefore, CCGIS consists of tools and practices to directly support multiple stakeholder participation in the identification and mapping of current and future risks in a coastal adaptation process. It is in a broader disciplinary area of Group Spatial Decision Support Systems (GSDSS) and can be defined as an integration of spatially enabled tools, and technologies for structuring human participation and articulating issues of concern in local and distributed spatial planning process [Balram and Dragicevic, 2006; Bodorkós and Pataki, 2009].

The CCGIS, such as that developed by this research will include a digital workspace for map-based content generation and visualization, multiple interfaces for participant interactions, and digital databases to provide and store new information. The literature review of local ecological knowledge also suggested a need to spatially represent qualitative (local knowledge) and quantitative information through the use of fuzzy soft computing methods [Kingston et al., 2000; Ball, 2002; Angelides and Xenidis,2007].

A detailed treatment of fuzzy computing requires in-depth research into fuzzy spatial systems using fuzzy logic of which are beyond the scope of this research. Nevertheless, the CCGIS attempts to quantify local knowledge in simple vector objects in the form of points, lines, and polygons as a precursor to future fuzzy computing. In order to preserve the richness of cognitive local knowledge without losing detail in processes of abstraction, these simple vector objects are extended to add rich media content such as audio, video, pictures and text. Furthermore, it is important to address user interface complexity (user friendliness) to serve the scientist or researcher and the coastal stakeholder with little computer or GIS knowledge. Based on these propositions, this research seeks to answer the following questions:

- What publicly available tools can be customised for developing a user-friendly internet based participatory GIS?
- How can a scalable platform be established without licensing cost to vulnerable communities, scientific researchers, and policy makers?

- How can fuzzy and subjective local knowledge be spatially abstracted for coastal communities with or without precise scientific geographic data?
- What are the technical, policy issues in implementing such a coastal collaborative GIS?
- What are the specific user, and system requirements?

To answer the questions raised above, a review of GIS, its components, and services are discussed in Section 2.6. Differentiations of the CCGIS from other public available platforms are highlighted in the next section.

### 2.5.1 Uniqueness of the CCGIS

The CCGIS uses a purely open source and free software design to web collaborative GIS. This approach enables the C-Change project to adapt the CCGIS to each community issues being addressed in an adaptation process. For example, a software adaptation interface and queries for flooding will be different from that of habitat protection, or erosion. Therefore, to customize software to meet each community needs require either the source code or a programmable interface for extensions. An open source design gives the free right to modify, redistribute, and redistribute modified copies.

A non-proprietary and light spatial data format GeoJSON was used to communicate between the client and server. GeoJSON is a geospatial data interchange format based on

JavaScript Object Notation (JSON). This lightweight format improves transferring messages from the client to the server as compared to verbose xml formats.

The CCGIS uses a Model View Controller (MVC) pattern in its implementation. This approach allows the implementation of different views (clients) in each C-Change community to suite community needs with little or no change in the software backend implementation (Model and Controller).

Ease of use through public mapping and navigational tools shortens the learning curve for non-GIS users due to familiarity. The CCGIS uses Bing and Google Maps as base layers to serve as visual aids when capturing local knowledge in these environments.

Finally, the CCIGS incorporates moderators and peer review mechanisms to help structure or monitor what type of contributions as local knowledge become part of the system. This approach as opposed to wide-open public participation channels local knowledge towards achieving community goals to an adaptation process.

## 2.6 Geographic Information Systems (GIS)

The first documented geographic information system was the Canada Geographic Information System, designed by Roger Tomlinson in the mid-1960s as a computerized natural resource inventory system [Longley, 2008]. GIS are fundamentally concerned with building shared understandings of the world in ways that are robust, transparent, and, above all, usable in a range of real-world settings. There are many definitions of

GIS, most of which are in relation to a number of component elements: hardware, software, people, data, and procedures.

The term *geographic information system* incorporates all of the following [Longley 2008]:

- a software product, acquired to perform a set of well-defined functions (GIS software),
- digital representations of aspects of the world (GIS data),
- a community of people who use these tools for various purposes (the GIS community),
- the activity of using GIS to solve problems or advance science (geographic information science).

GIS is defined as a "system for capturing, storing, checking, integrating, manipulating, analyzing, and displaying data which are spatially referenced to the Earth" [Fazal, 2008]. A Geographic Information System goes beyond computer-based software; it involves organized activities that reflect institutions and cultures. The World Wide Web offers an opportunity to overcome challenges in map services, software distribution, and cost across multiple clients, and non-interoperability issues due to lack of standardised data exchange formats among traditional GIS users. It provides a universal platform for distributed computing with service architectures that designed for integration of diverse information systems [McKee, 2004].

### 2.6.1 Web GIS

Today millions of people around the world make daily use of the World Wide Web and its facilities. In 1991, the World Wide Web was born through the implementation of a large online hypertext database through the works of Tim Berners-Lee, based at the European Laboratory for Particle Physics (CERN 1), today, the World Wide Web is often referred to as the *Internet* [Lawrence et al., 2002; Sklar, 2009]. The internet now consists of billions of links and a plethora of web content is been generated daily on the World Wide Web. This has also lead to a many literature on the *Internet*, its concepts, technologies, design tools, and applications about the internet. For the purposes of this chapter, this research will consider the study of Web-based systems and Web technologies as consisting of three areas: technology, applications, and people [Tatnall, 2010].

Web GIS is the implementation of geographic information functionality through a web browser or other client programs, thus allowing a broader usage and analysis of a particular geographic database. Also referred to as *Internet GIS, distributed GIS*, and even *Internet mapping*; the implementation of online GIS systems has dominated the work of GIS professionals since the late 1990s [Peterson, 2008]. With increasing demand for web based GIS platforms, there comes the possibility of varied and fragmented formats and standards. As a result, the Open Geospatial Consortium (OGC) was formed to facilitate standardization of formats, products, and GIS services.

#### 2.6.1.2 OGC and Web Services

The Open Geospatial Consortium (OGC) is a member-driven, non-profit, international, voluntary, consensus standards organization. The mission of the OGC is to serve as a global forum for the collaboration of developers and users of geospatial data, products (content), and services and to advance the development of common standards that enable geospatial interoperability, the geospatial Web, and the integration of geospatial content and services into enterprise applications [Reed, 2008].

A *service* in a web context is a collection of operations (independent, well-defined, self-contained functions) that is accessible through an interface, and allows a user to invoke behaviour of value to the user (definition from ISO 19119) [Barry, 2003]. *Web services* therefore refer to a set of software applications or components developed using a specific set of application programming interface (API) standards and internet communication protocols. The objective is to enable these applications or components to invoke function calls and exchange data among themselves over the standard internet infrastructure [Ratnasingam, 2010].

*OGC Web Services* (OWS) represent an evolutionary, standards-based framework that enables seamless integration of a variety of online geoprocessing and location services. OWS allows distributed geoprocessing systems to communicate with each other across the Web using familiar technologies such as XML and HTTP. OGC Web Services provide a vendor-neutral, interoperable framework for web-based discovery, access, integration, analysis, exploitation, and visualization of multiple online geo data sources, sensor-derived information, and geoprocessing capabilities [Harrison and Reichardt, 2001]. The standard provides a web of geoprocessing services that are connectible in dynamic, open interoperable chains to create dynamic applications.

### 2.6.2 Web GIS Tools

To answer the second question in section 2.4, this research will focus on free and open source GIS Web tools to accommodate wide coastal community collaboration. The term free refers to free rights to use, modify, redistribute or redistribute modified copies. There are many web GIS tools for varied purposes; the Open Source Geospatial Foundation (OSGeo) supports some of these applications. OSGeo is a not-for-profit organization whose mission is to support and promote the collaborative development of open geospatial technologies and data [OSGeo, 2010]. The use of free or open source software as compared to proprietary software comes under the following categorizations of licences as shown in Figure 2.2.

A web GIS framework usually involves three application tiers: the data source, application servers, and the map client. The data source tier may involve spatial database server or a direct data source stored on disk. Application servers in the middle tier for communication between the client and the data source. This section involves spatial data servers and web application servers. The front-end or the client serves as the output and input interface to users. Discussed below is a review of selected applications in each tier.

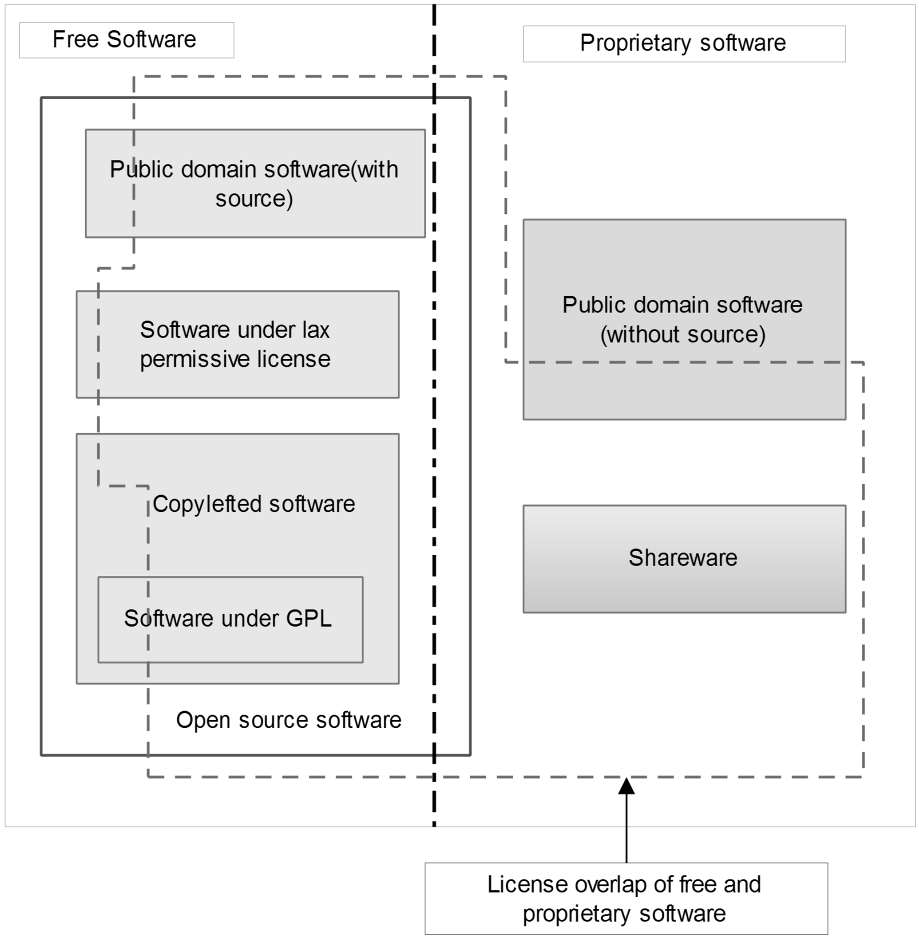



Figure 2.2 Types of Software Licences.

(*After Chao-Kuei and updated in 2010 by Ineiev - GPL*).

**2.6.2.1 Web Client Technologies**

A web client, often referred to as *thin client* (*thick client* for desktop applications) provides a front-end tier, which is often visible to the user. It serves as the interface through which users can interact with the map and all other provided services. Myriad open source software or free mapping tools are available in the public domain. Lists of some of the public available tools are available in Appendix I. To select a useful tool from the lot, one has to consider its Application Programming Interface (API), community support, data, or support services, standards (interoperability), functionality, flexibility, and licensing agreement.

A careful examination of each mapping platform shows that most are either dependent or independent on other mapping platforms. A general trend gives an indication of what could be the best client to use for the coastal collaborative GIS. In Figure 2.3, web-mapping client dependency relationships are established in relation to other clients and servers. The trend in Figure 2.3 shows an increased adoption of *OpenLayers* as a base platform for developing other web-mapping platforms or some mapping clients joined the *OpenLayers* project [Adams, 2009]. For example, the *Mapbuilder* team ends their mapping client platform at version 1.5. The team suggested theirs users and developers should join the *OpenLayers* project (*http://communitymapbuilder.osgeo.org/display/MAP/EndOfLife*).

Another key advantage of *OpenLayers* is that, it provides a means of imbedding publicly available map clients such as *Google*, *Bing,* and *Yahoo* maps. These map clients provide a wide public familiarity to map navigation and usage. A customised interface using OpenLayers and these tools will provide a means of shortening the learning curve for non-GIS users.

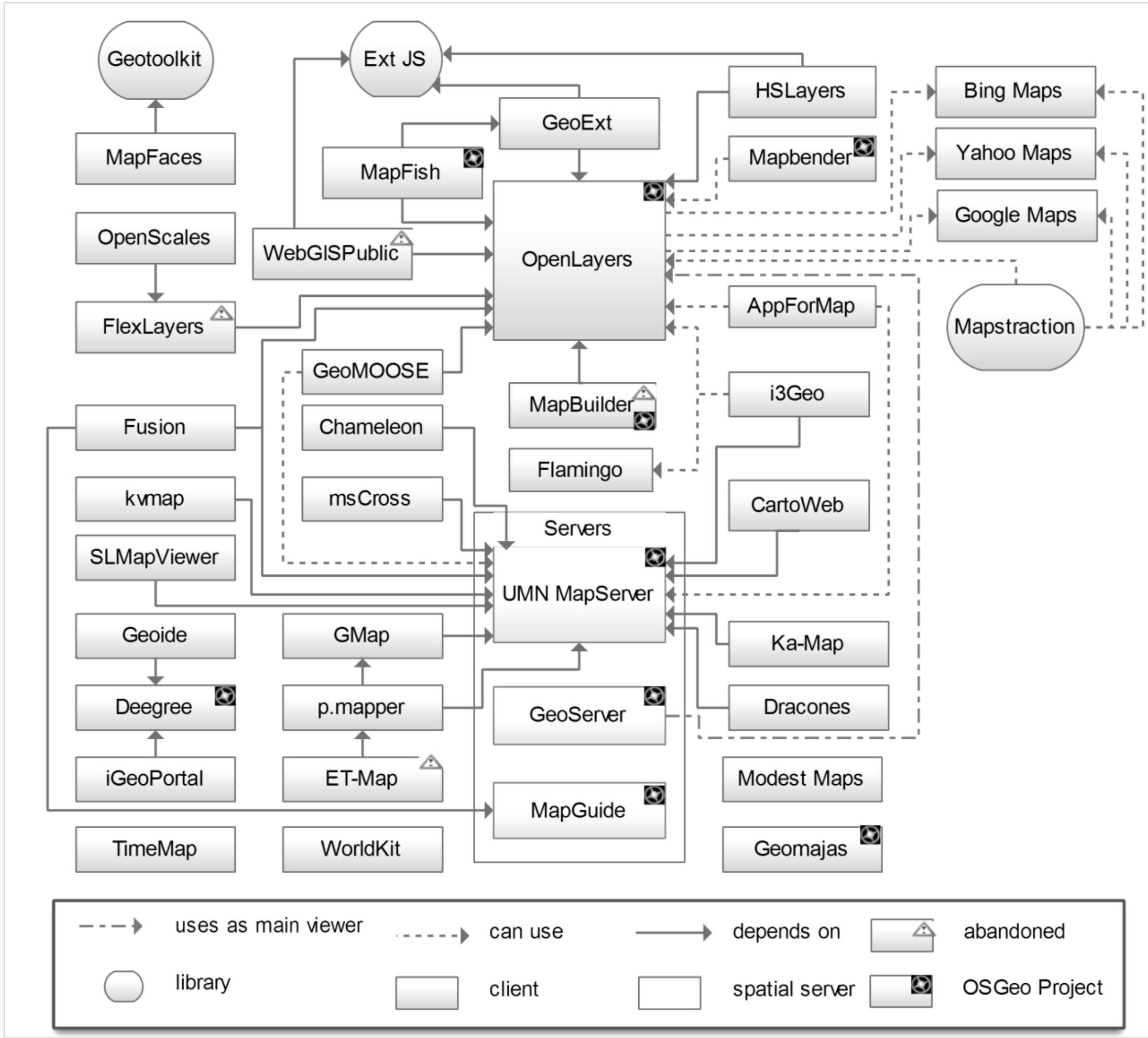



Figure 2.3 Web GIS Client Dependencies (*Improved Remix - After GeoTux [2010] License: Creative Commons Attribution-Share Alike*)

With increased adoption and development of other mapping clients based on *OpenLayers*, it is certain this project will continue to be supported until an alternative platform becomes necessary. An important support to the client interface is the backend spatial data server.

#### 2.6.2.2 Server Technologies

*MapServer* and *MapGuide* are not very favourable compared to *GeoServer* in selecting a long-term client. The lifetime of spatial data, servers are not erratic as web mapping clients. Client-side projects easily get abandoned as users and developers migrate to a better platform. *MapServer* is a widely used spatial data server on the web. As an Open Source platform, it provides an engine for publishing spatial data and interactive mapping applications. *MapServer* requires additional configurations to work with OpenLayers' Ajax framework hence not very favourable compared to *GeoServer*. *MapGuide* on the other hand features other rich interactive viewers other than *OpenLayers*, hence not an idle candidate.

*GeoServer* is Java-based software that allows users to view and edit geospatial data. Using open standards set forth by the Open Geospatial Consortium (OGC), GeoServer allows for great flexibility in map creation and data sharing. GeoServer is the reference implementation of the Open Geospatial Consortium (OGC) Web Feature Service (WFS) and Web Coverage Service (WCS) standards, as well as Web Map Service (WMS) [GeoServer 2010]. From Figure 2.3, *GeoServer* uses *OpenLayers* as its main Ajax map viewer. This creates a quick process of publishing maps on internet. With support for *GeoServer* and *OpenLayers* (both being OSGeo Projects) and their conformance to OGC standards, makes them good candidates for the CCGIS.

### 2.6.2.3 Database Technologies

Relational database management applications dominate the field of data storage and retrieval. In this research open source spatial databases are of interest to store spatial datasets. The following description is not an attempt to discuss all available free or open source spatial databases available, but gives a brief intro to a selected few that are widely used.

*PostgreSQL* is an open source object-relational database system [PostgreSQL, 2010]. It has more than 15 years of active development and a proven architecture that has earned it a strong reputation for reliability, data integrity, and correctness. The power of *PostgreSQL* is extended by *PostGIS* which "spatially enables" the *PostgreSQL* server, allowing it to be used as a backend spatial database for geographic information systems (GIS), much like ESRI's ArcSDE or Oracle's Spatial extension [Refractions Research, 2008]. *PostGIS* dominates in the open source spatial database extensions and currently in incubation as an OSGeo project. The CCGIS will take advantage *PostgreSQL* plus *PostGIS* as the spatial database tier given its wide user support base and functionality.

Other spatial extensions (not yet OSGeo projects) include:

- *SpatiaLite* extension enables *SQLite* to support spatial data [GEOMETRY], in a way conformant to *OpenGIS specifications* (*http://www.gaia-gis.it/spatialite/).*
- *MySQL* spatial extensions enable the generation, storage, and analysis of geographic features (*http://dev.mysql.com/doc/refman/5.0/en/spatial-extensions.html*).

- *Ingres* Database Object Model Extension (OME) supports Geospatial Data Abstraction Library (GDAL/OGR) *(http://www.ingres.com/kb/article/416990).*

## 2.7 CCGIS Requirements

Requirements are high-level, abstract statement of a service that the system should provide or a constraint on a system [Sommerville, 2001]. Requirements for the Coastal Collaborative Web GIS will include two major components: user requirements and system requirements. User requirements are statements, in a natural language plus diagrams, system services and the constraints under which it must operate. System requirements set out the system's functions, services, and operational constraints in detail.

### 2.7.1 User Requirements

In this research, requirement elicitations are accomplished using generic needs from published collaborative and participatory GIS research and feedback from project partners. An abstract high-level list of requirements includes the following:

- The system should allow local communities to identify coastal threats as a result of sea level rise and storm surges at a particular location, an area (residential, business etc.) and a linear event.
- The system should provide a means of describing and communicating threats with pictures, video, audio and text.
- The application should be user-friendly and cost effective.
- The system should provide a means of validating user contributions.
- The system should provide a means of commenting on scientific scenarios and local contributions.

### 2.7.2 System Requirements

The online collaborative GIS application herein called CCGIS should have the following system requirement:

*Functional requirements*

- The CCGIS should be an online collaborative application with
  a) client (public and administrator) interfaces,
  b) server (spatial application and web server) component, and
  c) database (relational and spatial database) server.

- The client interface should be user-friendly (using public mapping tools) that can be extended or customised using their Application Programming Interface (API).
- The client should provide digitizing and editing function for the creation of spatial content.
- Content generated should be simple vector objects such as:
    a) Points (to abstract a location or landmark)
    b) Lines (to abstract road, path, shoreline, etc.)
    c) Polygons ( to abstract and area or region)
- Client technologies should implement OGC compatible standards and should consume:
    a) Web Mapping Services (WMS),
    b) Web Coverage Services (WCS), and
    c) Web Feature Services (WFS).
- The system should provide administrative privileges of accepting or rejecting user contributions before it becomes public.
- Contributions should be stored in database that can provide object relational and spatial capabilities.
- Contributions made by users should be stored in a non-proprietary format.
- The system should provide administrator rights to restrict the area (extent) of contributions and contributors geographic location at the time of contribution.

- The system should provide a forum discussion with reference to spatial objects on the map.

*Non-functional Requirements*

- The CCGIS application should not provide services without internet connection.
- Only registered members can make spatial contributions to the system.

## 2.8 Summary

This chapter reviewed climate change and the importance of stakeholder involvement in the overall process of developing adaption strategies (policy framework). The chapter also identified the importance of tapping into community local knowledge in places with limited or imprecise data adequate for scientific scenarios. A review of selected case studies showed how local knowledge could compliment science in a participatory process. Lessons learned from existing case studies and a review of modern web GIS technologies were used as a basis for user and system requirements. In the end, the chapter identifies *OpenLayers* as the main client platform of which Google and Bing Maps can serve as base layers. Server-side tools such as *GeoServer* and *Apache* web server provides server-side services, including data stored in *PostgreSQL* database. The next chapter discusses how the web GIS tools identified in this chapter can be used to capture local knowledge through a platform design.

# Chapter Three: Local Knowledge and Conceptual Framework Design

*To us, science, art, ideology, law, religion, technology, mathematics, even nowadays ethics and epistemology, seem genuine enough genres of cultural expression to lead us to ask (and ask and ask) to what degree other peoples possess them and to the degree they do possess them, what form do they take, and given the form they take, what light has that to shed on our own versions of them.*
~ Clifford Geertz 1983.

In the first chapter, this research identified the need for coastal communities to develop a proactive adaptive approach to sea level rise and storm surges. A prerequisite for adaptation is to identify the spatial extent of this threat in a geographical context. In the field of science, datasets are required, which may include but are not limited to: elevation data, models of shoreline erosion, wetland accretion, topographic maps, tidal records, bathymetry and other coastal processes.

The availability of elevation data confronts anyone attempting to estimate the amount of land (horizontal) affected within a metre of sea level (vertical) with two unpleasant realities:

- the available vertical data are imprecise, and
- they do not necessarily tell us how far the land is above sea level.

These problems are commonly known as "poor vertical resolution" and "inconsistent benchmarks" [Titus and Richman, 2001]. Titus and Richman, [2001] showed that poor elevation data is not only limited to the United States, but also the United Kingdom and Canada. It is therefore expected to be worse in most developing coastal countries.

This research quantifies local knowledge as a supplement to scientific flood zone mapping. Local inhabitants interact with their environment and hence serve as human sensors in flood prone mapping. This runs across all levels of development: rural, peri-urban, and urban coastal communities. Tapping into this resource will not only provide a means of identifying risk areas but also provide an all-inclusive process of developing adaptation strategies. In view of this, this chapter will explore the meaning of knowledge in general, then local and scientific knowledge as specifics. The chapter will go on to identify how knowledge can be treated as data, information, and its spatial abstraction. A conceptual framework developed from the components of knowledge presents how local knowledge plays a role in an adaptation process. The chapter concludes with system designs using the requirements from Chapter 2 in each major system tier.

## 3.1 Knowledge

The Oxford Dictionary [2010a] defines knowledge as:

> 1. *Facts, information, and skills acquired through experience or education; the theoretical or practical understanding of a subject.*
> 2. *Awareness or familiarity gained by experience of a fact or situation.*

Epistemologists have distinguished some species of knowledge, including [Moser, 2005]:

- propositional knowledge (that something is so or declarative),
- nonpropositional knowledge of something (for instance, knowledge by acquaintance, or by direct awareness),
- empirical (a *posteriori*) propositional knowledge,
- nonempirical (a *priori*) propositional knowledge, and
- knowledge of how to do something (imperative or procedural)

To keep to the scope of this research, readers can refer to the Oxford Handbook of Epistemology [Moser, 2005]. To establish the means by which local knowledge is acquired, it is important to identify the sources knowledge. Moser [2005] identified the best candidates for the classical sources of knowledge as perception, memory, consciousness (sometimes called *introspection*), and reason (sometimes called *intuition*). Moser [2005] also suggests some writers have shortened the list under the heading, "experience, and reason."

Furthermore, how can one acquire knowledge from these acclaimed sources? Brazhnik, [2007] discusses in her paper that the process of acquiring knowledge is universal in nature. The way children explore the world and the steps of scientific method represent the same process, Figure 3.1 schematically depicts this claim. It starts with *observations* and *experiences* that stimulate us to generate hypotheses about various *phenomena* and the relationships between them. These observations and experiences constitute data. We interpret these data based on existing concepts to produce hypotheses and to predict outcomes, which we then test in experiments or further observations. If the outcome contradicts the predictions, the hypothesis needs to be revised. If the outcome is as expected, confirms the hypothesis. Supported hypotheses become models that we use to explain the world around us.

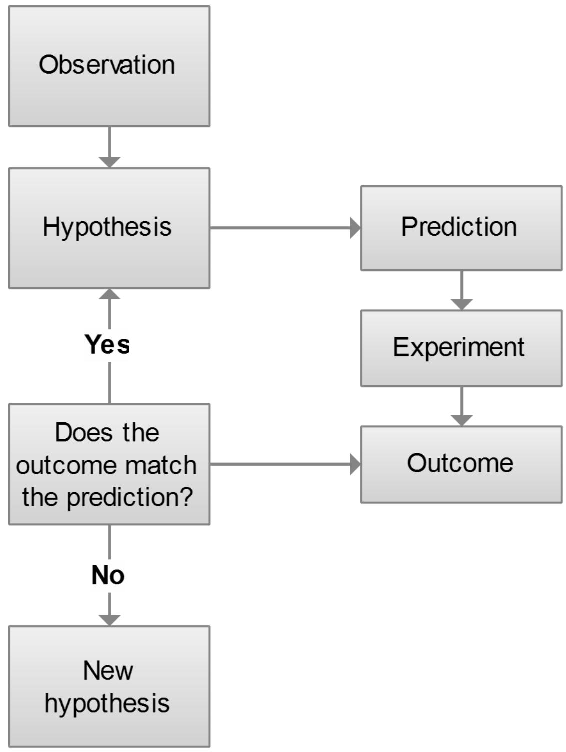



Figure 3.1 The Process of Acquiring Knowledge (after Brazhnik [2005]).

The use of models in learning about the world, calls for a learners' attentiveness and ability to conceptualize (a cognitive pursuit). Experience in the world engages a learner's senses of touch, sight, and feeling – both as tactility and as emotion (an effective response) [Lutz, 2008]. These two processes, interwoven in experience are common and unique across rural, peri-urban, and urban coastal communities as shown in the Figure 3.2

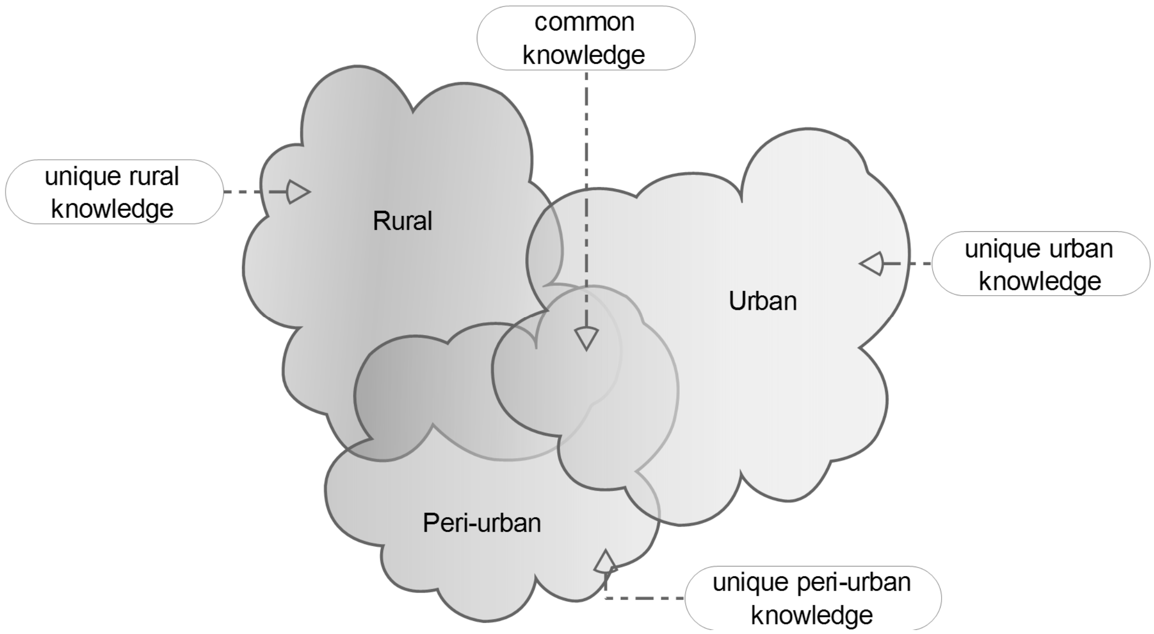



Figure 3.2 Local Knowledge Across Communities.

### 3.1.1 Local and Scientific Knowledge

To establish the scope of local knowledge, it is important to clarify what is counted "local" in the term "local knowledge"? In this research, the relative term "local" at least represents two distinct things. On one hand, local refers to the public, for example, the coastal property owner, the tenant by the coast, business owners, farmers, fishers, indigenous peoples and so on. The second category is a group of elected local experts: this can be in the form of experienced coastal action teams or the local government (including planners, emergency services and so on).

The anthropologist Clifford Geertz, defines local knowledge as "practical, collective and strongly rooted in a particular place" that forms an "organized body of thought based on immediacy of experience" [Geertz 1973; Geertz 1983; Corburn 2005]. Geertz [1983] suggests that local knowledge can be described as simply as "to know a city is to know its streets." This goes to strengthen the view that local knowledge often has a geographic context.

In the field of science, scientific knowledge is an intellectual and practical activity encompassing the systematic study of the structure and behaviour of the physical and natural world through observation and experimentation [Oxford Dictionary, 2010]. Knowledge acquired through the scientific process is also local and geographic in context. Although local in nature, scientific knowledge has the ability to move and apply the knowledge it produces beyond the site of its production (local environment) [Turnbull, 2000]. Scientific knowledge allows for comparison and testing in different environment from which it originated. This heterogeneous application of scientific knowledge is a buttress to its universal power.

### 3.1.2 Data, Information, Models, and Knowledge

The process of acquiring knowledge originates in data and undergoes steps of collection, organization, storing and processing. Integrating findings into a functioning unified whole produces knowledge [Brazhnik, 2007]. To gain knowledge is to acquire data: *datum* from Latin means "what is given or admitted as bases of reasoning or inference or a reference for measurement" [Merriam Webster Dictionary, 2010]. It is what we can perceive, experience or register with our senses, for example: windy weather, flooded lands, high fever, bad mood; a measurement or a reading of a device such as: tape measure, thermometer or tidal gauge. Data therefore, can be quantitative or qualitative and can be expressed as [Fazal, 2008]:

- linguistic expressions (e.g., name, age, address, date, ownership),
- symbolic expressions (e.g., traffic signs),
- mathematical expressions (e.g., $E = mc^2$ ), and
- signals (e.g., electromagnetic waves).

Data usually in its raw form require processing into information.

Information serves as value added data or the outcome of processed data from which decisions can be made. It is important to note that, information can also be data in a different domain. For example, take projections of sea level rise for the next three decades by the IPCC: to the coastal planner, it is information to help develop coastal policies while to the coastal geographic engineer it is data to help identify potential flood zones through geographic processing. Information collected about a phenomenon that supports observation and prediction can be consolidated into a model.

A model is an abstraction of reality. It can be developed from data or information and serves as the collection of interrelated concepts in describing entities. In this research, the spatial local experiences, or intuition sensed in the coastal environment are expressed in simple spatial data models. This thesis assumes that since information can be data and data can be information, depending on the universe of discourse, a model can be derived from data (data model) or information (information model). A conceptual model of local knowledge acquisition to the implementation of adaptation is described in Figure 3.3.

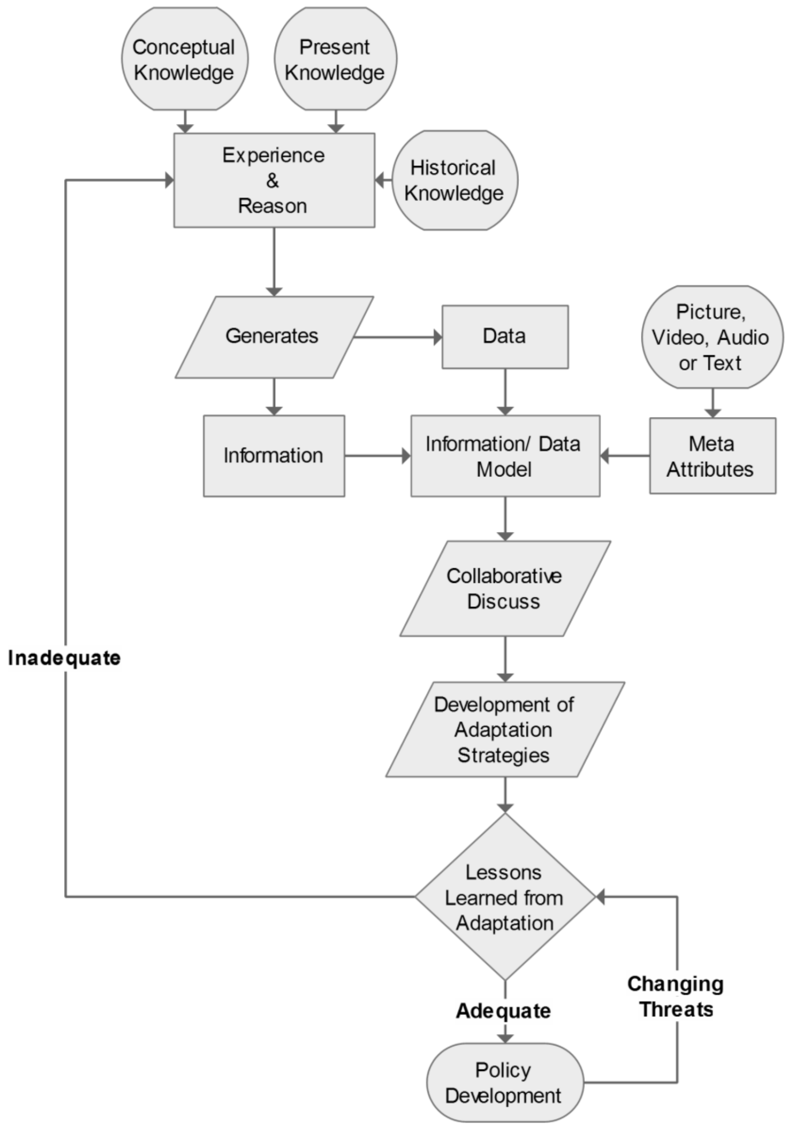



Figure 3.3 Models of knowledge in a Coastal Adaptation Process.

### 3.2 Spatial Abstraction of Knowledge

Spatially sensed phenomena in the environment usually occur in the form of a landmark, road, path, coastline, region, space, or an area. Experiences and observations discussed in the preceding sections leads to the development of mental models that exist in a spatial framework. Data abstraction is important to help quantify or graphically represent coastal events and their extents. To be consistent with spatial data abstraction in scientific spatial representation, this research adopts local knowledge as simple geometric vector objects: points, lines, and polygons. These spatial objects describe real world features such as a point to represent a spatial location or landmark, a line to describe a linear feature, and a polygon to quantify an area.

Abstraction leads to simplification of the knowledge recorded which is good for easy graphical representation but comes with loss of detail, expression, and values. To make up for the loss, this research includes rich attribute information (such multimedia: pictures, video, audio and text) as metadata to describe the spatial geometric objects. This process of geo referenced data collection, storage, processing, retrieval and visualisation for various spatial analyses is part of a GIS.

### 3.3 System Architecture

In Section 2.6.2, web-mapping tools for each system tier were indentified. The following subsections expand the description of the server, client, and database architecture. Figure 3.4 shows the overall system architecture, connections between each tier, and between system components. Of the three tiers, the client is the input and output interface for user interaction (front-end) and provided web and database services hidden from the user (back-end). This provides the flexibility of changing back-end components without affecting the client interface.

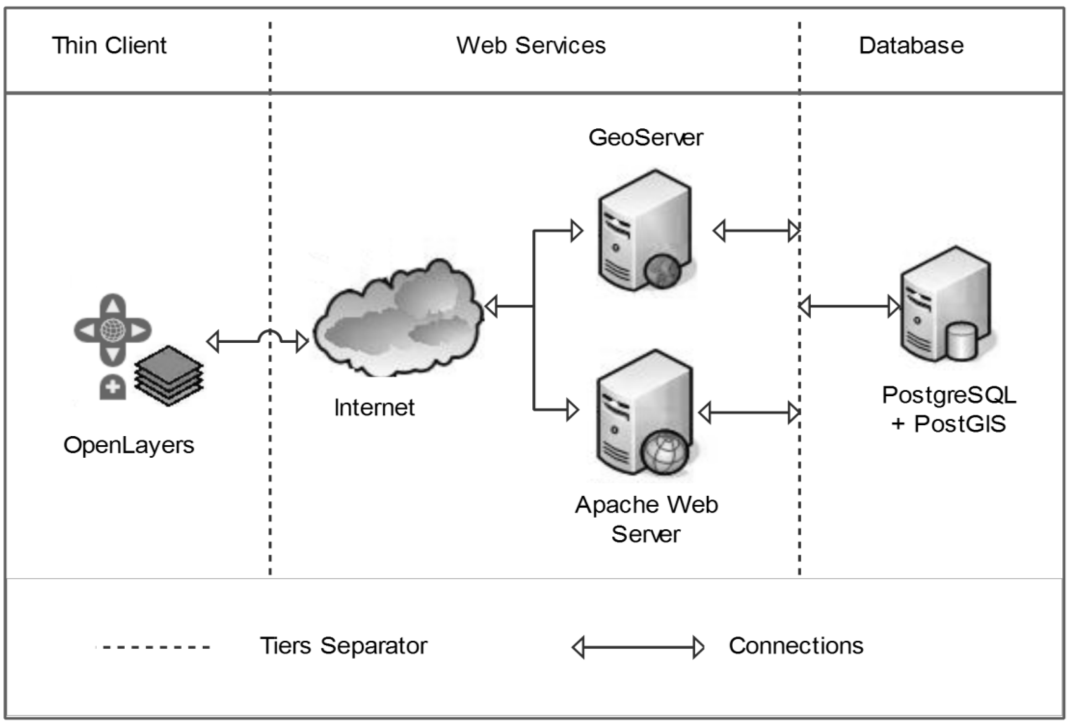



Figure 3.4 CCGIS System Tiers.

### 3.3.1 Client Architecture

The client serves as the interactive interface to the user of the CCGIS. Using *OpenLayers* (mapping API) and *ExtJS* (JavaScript plus graphics library), public available mapping platforms, such as Google and Bing Maps are embedded into the application to provide satellite base maps. Other map layers are added using the OGC services provided via *OpenLayers*. A vertical layout of client components is as described in Figure 3.5.

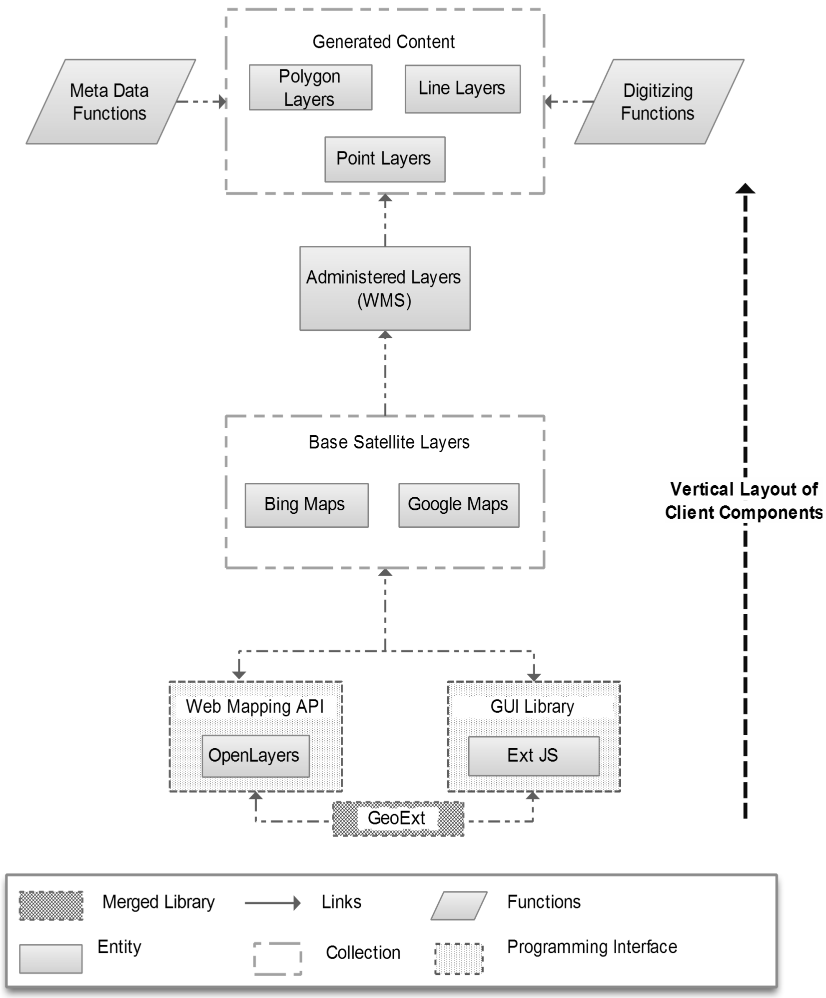



Figure 3.5 Client-side Tier.

### 3.3.2 Spatial Server and Web Server Framework

The spatial data server (*GeoServer*) and the web application server (*Apache*) communicate to the client architecture (as shown in Figure 3.6) through *Ajax* (Asynchronous JavaScript and XML) calls. The administrator can also manage content on the web server and configure map resources on the spatial data server using the RESTful interface (PHP cURL HTTP protocol) provided by *GeoServer*.

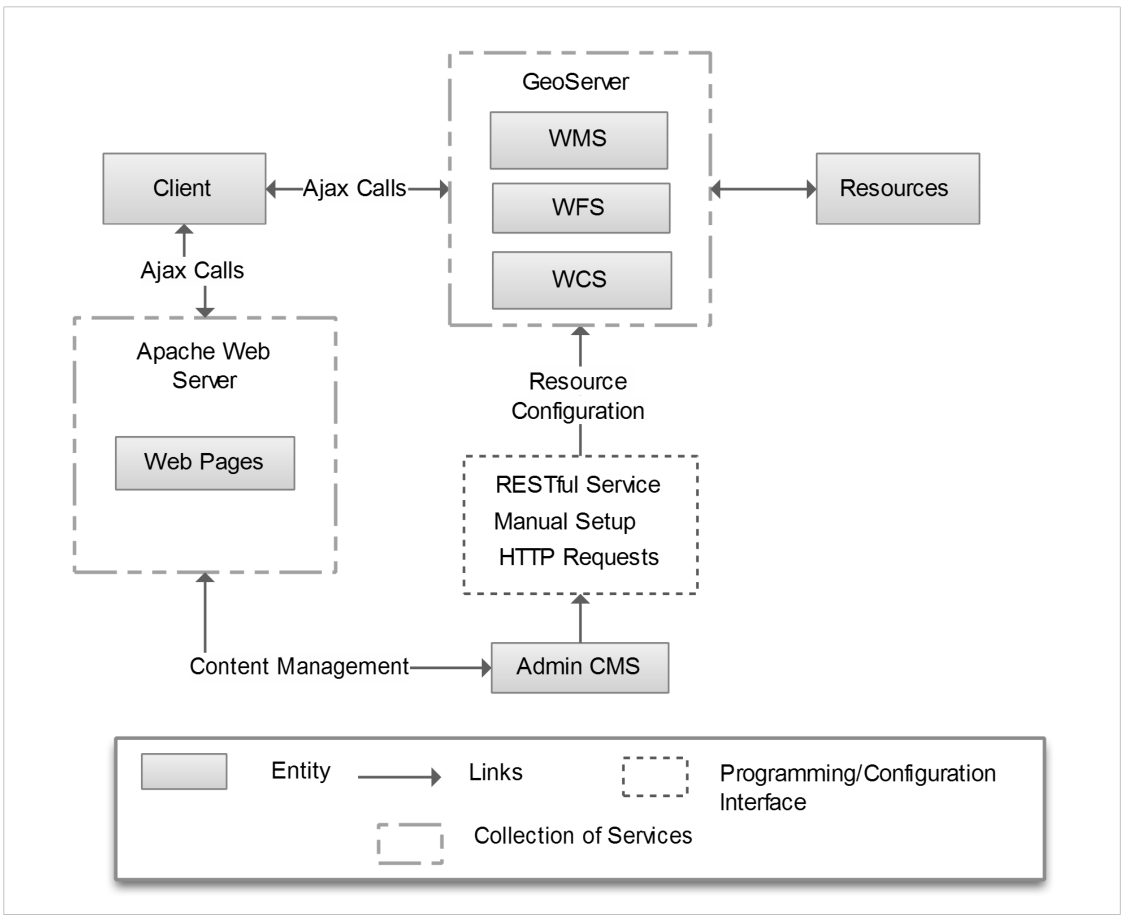



Figure 3.6 Web and Spatial Services Tier

### 3.3.3 Database Model

The CCGIS database model consists of five main inter related tables (*cc_user, cc_user_address, temp_spatial_contribution, spatial_contribution and spatial_forum*). *cc_user* table shares a one to one cardinality with *cc_user_address*. Relationship between *cc_user, temp_spatial_contribution, spatial_contribution and spatial_forum* tables may have a one to zero or more cardinality (may be one to zero or more). A UML (Unified Model Language) diagram expressing these relationships is as shown in the database model in Figure 3.7.

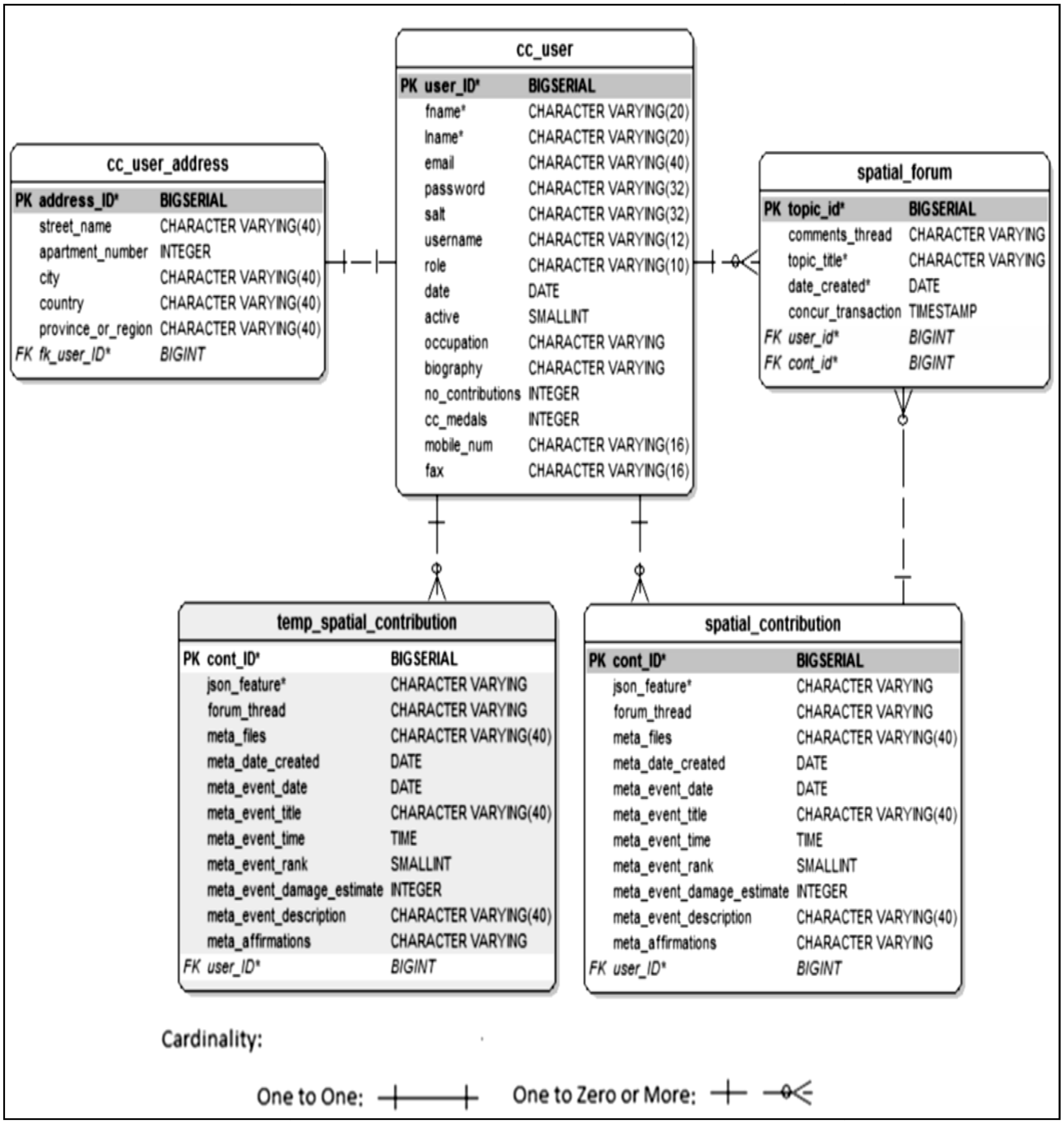



Figure 3.7 Database Model Diagram.

### 3.4 System Architecture Pattern

Systems that allow a high degree of user interaction usually have a Graphical User Interfaces (GUI). To enhance the usability of the CCGIS application in different local communities with different user interface requirements, it is important to adopt an architecture that keeps the core functional application to be independent of the user interface. The core of interactive systems based on the functional requirements usually remains stable; user interfaces, however, are often subject to change and adaptation [Buschmann et al., 1996]. A good architecture should support adaptation of user interface parts without causing major effects to application-specific functionality or the data model. The Model View Controller (MVC) architecture pattern provides this capability.

The MVC architectural approach keeps the application component of the software independent from the interface, and a general mechanism binds the user interface to the data model without introducing interface knowledge into the data model [Jézéquel et al., 1999]. MVC, as the name suggests, consist of three tiers: Model (data and application logic), View (interactive interface), and the Controller (binder). Each layer handles specific tasks and has specific responsibilities to the other layers [Singh et al., 2002]. This separates the user input, modelling of the external world and visual feedback to the user [Helman, 1998]. Figure 3.8 graphically depicts the association between the MVC components.

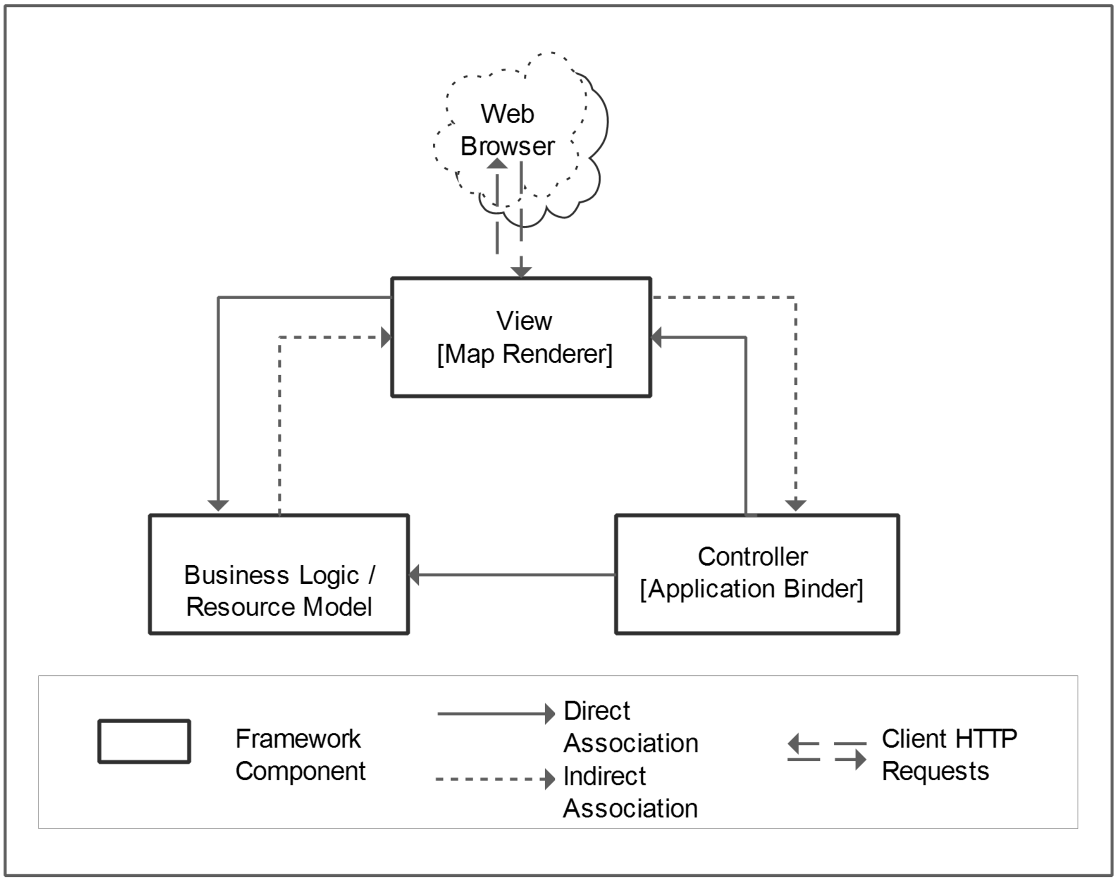



Figure 3.8 The Zend MVC Architecture.

The *Controller* binds the model and view. Using the observer pattern, the model communicates with the *View* (main output window). Input requests are routed to the controller, which then directs it to the model or view. The model abstracts the data resource and contains the application specific functions. This approach to decoupling allows for changes to the view with little effect to the application logic.

According to Buschmann et al. [1996] responsibilities of each MVC component are described as follows:

- the Model (data abstraction and application logic):

    a) provides the functional core of the application,
    b) registers dependent view and controllers, and
    c) notifies dependent components about data changes;
- the View (graphical component of the interface):
    a) creates and initializes its controllers,
    b) displays information to the user,
    c) implements the model update produced to keep itself accurate, and
    d) retrieves data from the model; and
- the Controller (the decision-making part of the application):
    a) accepts user inputs as events,
    b) translates events to service requests for the model or display requests for the view, and
    c) implements indirect graphical update procedures if required.

### 3.5 Summary

This chapter defined the meaning of local and scientific knowledge and how they are acquired. The chapter then discussed how data, information, models and knowledge are linked into a conceptual policy framework towards developing coastal adaptation policies. Data and information represented as spatial models in the minds of people exist as local knowledge and can be abstracted into simple vector objects such as points, lines, and polygons to represent a location, linear and area features respectively.

System components designs consisting of the client, server, and database model were developed as components of the Zend Model View Controller (MVC) architectural pattern. This approach separates data, application, and rendering logic into three components (model, view, and controller) that can be modified independently. The controller ties the model and view together. The chapter concludes with the roles of each component in the MVC architecture. The next chapter puts the system design into a functioning system that can be applied in each C-Change community to supplement best available data.

# Chapter Four: CCGIS Implementation

*Design is not just what it looks like and feels like.*
*Design is how it works*
~ Steve Jobs - [Walker,2003]

In Chapters 1 and 2, this research articulated some of the problems facing most coastal communities due to sea level rise and storm surge events. Since many coastal communities lack precise scientific data for flood mapping, this research identified the use of local knowledge as a supplement to the best available data when assessing threats or vulnerabilities in a coastal adaptation process. Local knowledge is a common resource in coastal communities acquired through experience and intuition in their own environment. To help quantify local knowledge, the author identified web-mapping tools to be used in developing a Coastal Collaborative GIS based on initial user and system requirements.

This chapter discusses design execution using publicly available web mapping tools for a Coastal Collaborative GIS. The MVC pattern discussed in Chapter 3 serves as the overall architecture for laying out the CCGIS. Implementation of components and communication between the client, server, and database are discussed. The chapter concludes with how to use outputs of this research on other interoperable GIS formats.

## 4.1 Choice of Framework

The MVC design in Section 3.5 can be rolled out using most server-side scripting languages with varied frameworks libraries. Popular server-side scripting languages (framework) include, but are not limited to:

- ASP.NET (*ASP.NET MVC, Vici MVC, MonoRail* etc.),
- Perl (*Catalyst, Mason, Maypole* etc.),
- PHP (*CakePHP, CodeIgniter, Qcodo, Symphony, Zend Framework* etc.),
- Java (*Spring Framework, Java Server Pages, Google Web Toolkit* etc.),
- Python (*Pylons, Django, TurboGears* etc.),
- Ruby (*Rails, Ramaze, Sinatra, Camping* etc.),
- ColdFusion (*ColdFusion on Wheels, ColdSpring, Model-Glue* etc.) etc.

To choose from this list, it is important to consider the architecture implementation of the framework (flexibility), licensing, and community support. From the list of server-side scripting languages itemized above, PHP (Hypertext Preprocessor) is the most widely used server-side scripting language on the World Wide Web. Given the popularity of PHP and its community support, it is a good start. PHP as a language has varied framework flavours (*CakePHP, CodeIgniter, Qcodo, Symphony, Zend Framework* etc.).

One of the most promising technologies is the Zend Framework. The Zend Company is the main leader in support of the most widely used open source server-side scripting language on the web (PHP). The Zend MVC provides a plethora of loosely coupled libraries for dynamic web programming. This research implements PHP using the Zend

Framework MVC architecture given the fact that it is loosely coupled (fragments of the framework can be used without using the whole bulk) and there is a high degree of long-term support by its community of developers to changing web technologies.

## 4.2 Zend MVC Project Structure

The MVC pattern implemented by the Zend Framework consists of three main components:

- the model, (*Zend_Db_Table* or any data source),
- the view (*Zend_View*), and
- the controller(*Zend_Controller*).

At its simplest, *Zend_Controller* processes the request, fetches data from *Zend_Db*, and then passes this data to *Zend_View* to render dynamic XHTML (eXtensible HyperText Markup Language). The Zend MVC project layout consist architecture of directories and file hierarchies. This hierarchy allows for a well-organised project as shown in Figure 4.1. The *Application* directory contains the CCGIS application and houses the MVC system, as well as configurations, and the *bootstrap* file. The subdirectories: *Controllers, Models,* and *Views* provide and serve as the default controller, model and view directories respectively. These three directories inside the application directory provide the best layout for starting a simple Zend MVC project. One important file in the application folder is the *bootstrap* file. Its purpose is to bootstrap the application and make components available to the application by initializing them.

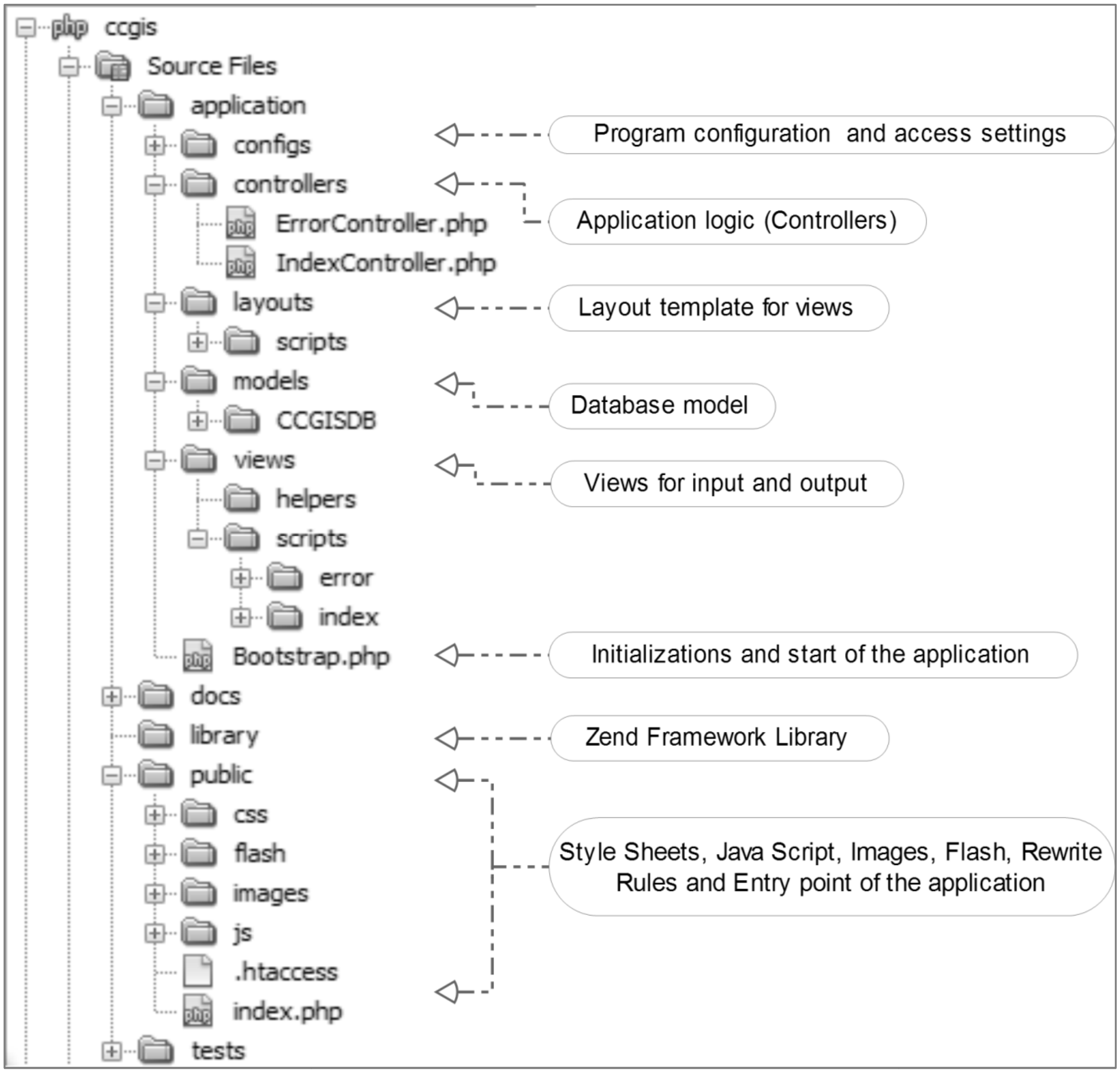



Figure 4.1 Zend MVC Project Structure for the CCGIS.

## 4.3 Client Layout Structure

From the Zend MVC project structure as shown in Figure 4.1, the view folder in the application directory consists of files that represent each client interface. Each view has an associated layout that combines JavaScript (JS), Cascading Style Sheets (CSS), Flash objects (*.swf*), and Images (Portable Network Graphics: *.PNG*, Joint Photographic Experts Group: *.JPEG/JPG*, Graphics Interchange Format: *.GIF* etc.) to render and present the view. It is through the view that a user can interact with the MVC application. As identified in section 3.3.1, the client combines *OpenLayers*, *ExtJS,* and *GeoExt* (combination of *OpenLayers* and *ExtJS*) for page rendering and interactive scripting.

Google and Bing Maps are used as base layers for the CCGIS. A generic layout of the view showing some of its resources is as shown in Figure 4.2. Different pages may have more or less of the list in the diagram based on whether it is a mapping page or web form page or a combination of both. The document type for each view uses "*XHTML1_STRICT*"; this is specified in the configuration file *application.ini* (*resources.view.doctype= "XHTML1_STRICT";*). In the CCGIS, there are five layouts connected to corresponding views. Their relationships are as shown in Figure 4.3.

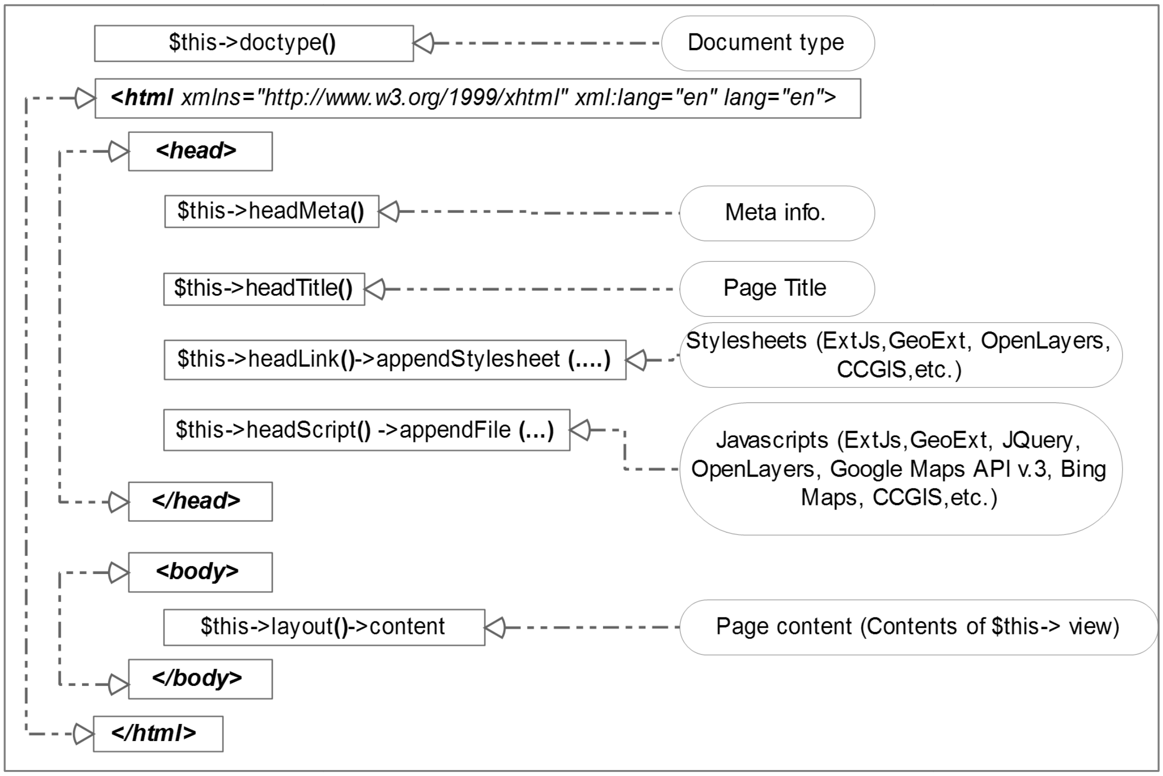



Figure 4.2 Generic CCGIS Layout.

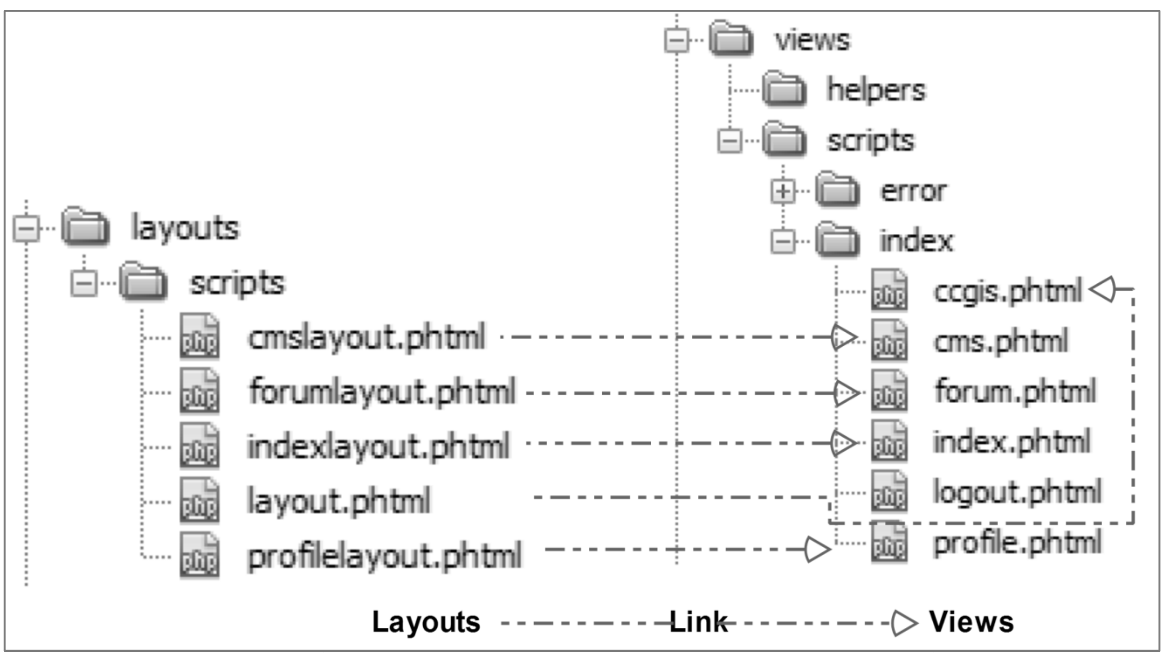



Figure 4.3 Relationship Between Layouts and Views in the CCGIS.

## 4.4 Views, Controller and Model Relationships

In the preceding Sections 4.2 and 4.3, the MVC project structure and the client interface layout were previewed. There is an internal relationship between each view and the controller and their relationship with the model. In the CCGIS, there are six views as shown in Figure 4.3 linked to one controller (*indexController.php*). These views are controlled by *actions* in the *IndexController*. The *IndexController* inherits from the *Zend_Controller_Action.* The hierarchy and relationship between *actions* and *views* are as shown in Figure 4.4. The *indexAction* is the default *action* for the *IndexController* and has a corresponding view *index.phtml.* The *index.phtml* also has a rendering template *indexlayout.phtml* as shown in Figure 4.3. Each *action*, *view* and *layout* follow a similar pattern.

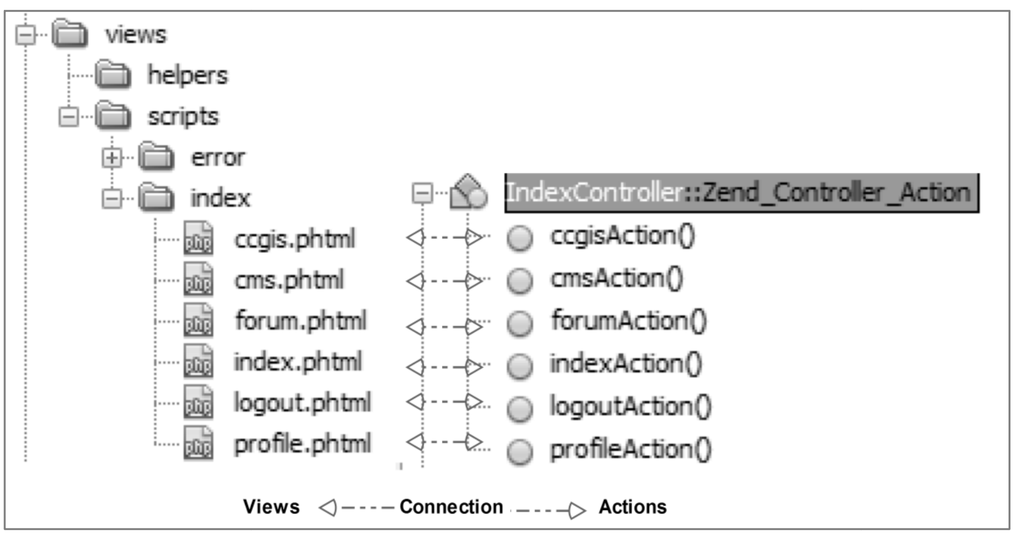



Figure 4.4 Views and Their Actions in *IndexController.php*

The *IndexController* communicates requests and receives data from the *model.* It then directs results to the corresponding *view* that made the request. The CCGIS database model consists of nine (9) database tables. Seven of these tables relate directly to the functions of the CCGIS platform and two (*geometry_columns and spatial_ref_sys*) relates to *PostGIS* spatial extension. Access to the database tables are implemented using the *Zend_Db_Table* class. This class provides an object-oriented interface to database tables with methods for many common database table operations. The *Zend_Db_Table* is an implementation of the *Table Data Gateway* pattern. This allows an object to serve as the access point to a database table. As shown in Figure 4.5, each PHP class extends the *Zend_Db_Table_Abstract* as a definition of a database table class. The name of the actual table is passed into the protected property *$_name.* New instances of the table class definition provide access to CREAT, READ, UPDATE, and DELETE (CRUD) functions for interacting with a database table.

The CCGIS data access implementation links all the tables into *protected* properties of a database service class *Application_Model_CCGISDB_CCGISDBService.* With this approach, a single instance of the service class gives access to all its public methods that can interact with its protected properties (table data gateway objects). This approach is described in the Figure 4.6. The model also contains utility classes:

- *Application_Model_CCGISDB_Uploads* (*uploads.php*), and
- *Application_Model_CCGISDB_ImageUtil* (*ImageUtil.php*)

that handle user uploads and image methods (resizing and compression) respectively.

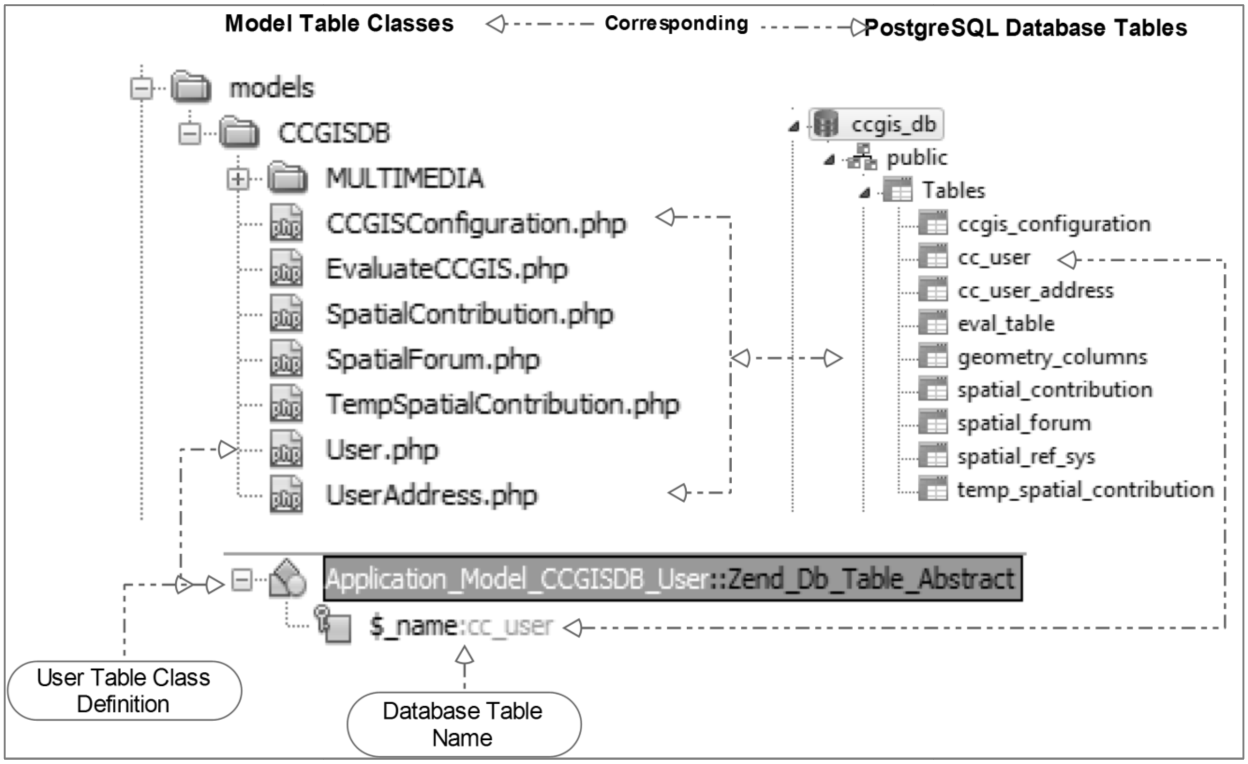



Figure 4.5 CCGIS Data Model.

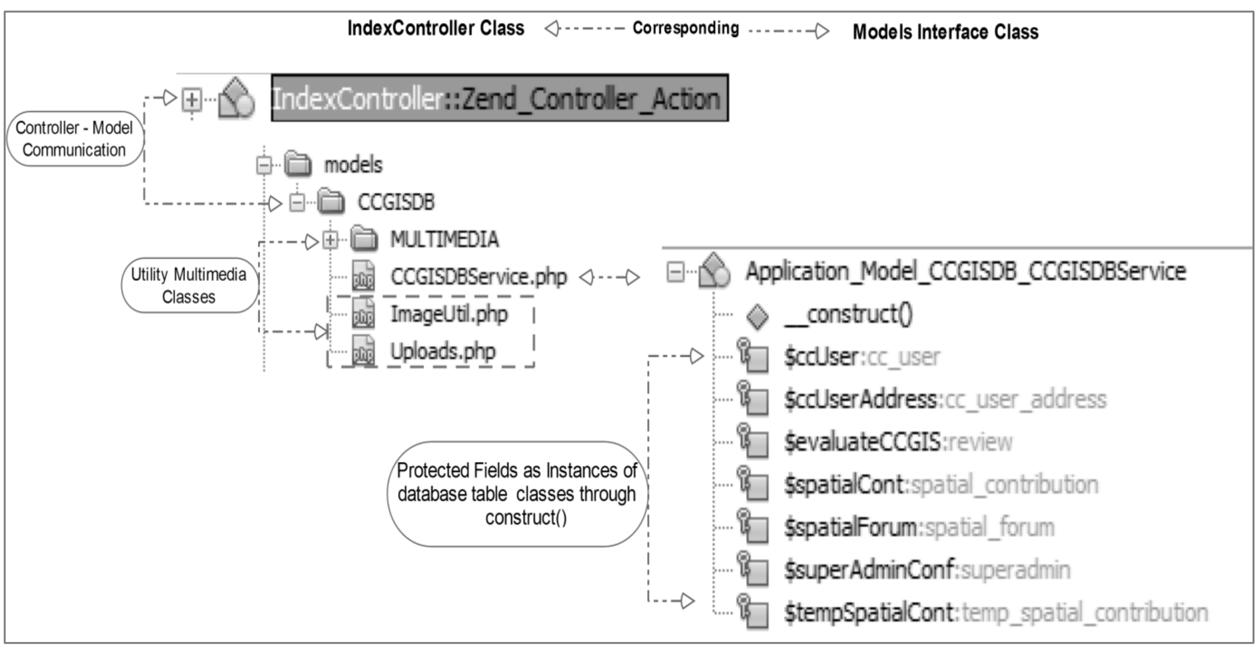



Figure 4.6 Controller Access to the Model Interface

### 4.5 Client Side Implementation

The client side implementation uses *OpenLayers* web GIS platform and *ExtJS* for interface design. The combined (*OpenLayers* and *ExtJS*) library *GeoExt* was also used given its useful user extensions (*UX Extensions*). The client interface implementation consists of four visible views. The function of each view is described in the Figure 4.7.

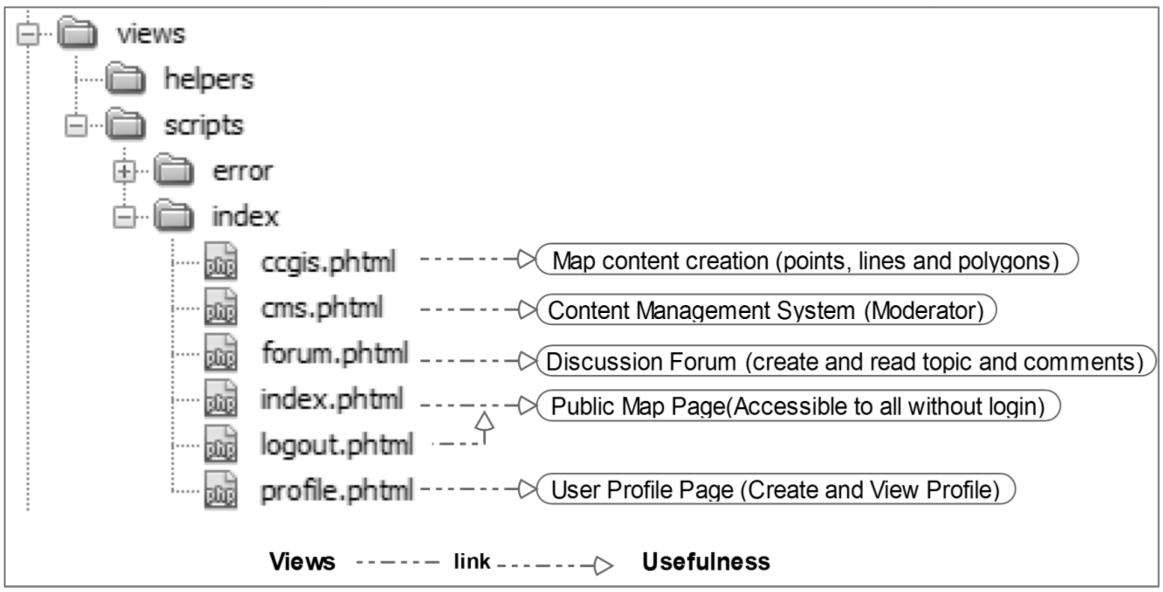



Figure 4.7 Views and Their Utility.

Each mapping or map view page defines five layers; these include three vector layers:

- points : *new OpenLayers.Layer.Vector("Points",...)*,
- lines : *new OpenLayers.Layer.Vector("Lines",...)*,
- polygons : *new OpenLayers.Layer.Vector("Polygons",...)*,

and two satellite base layers :

- Google Maps :*new OpenLayers.Layer.Google("Google BaseMap",...)*
- Bing Maps :*new OpenLayers.Layer.VirtualEarth("Bing BaseMap",...)*

The satellite base layers serve as a background for which users can draw or sketch simple vector objects that are editable in the layers: *points*, *lines,* and *polygons.* The drawing of a vector object can be initiated using *OpenLayers* controls with specific handlers. Code snippets of how to draw in the three vector layers are:

Points : *new OpenLayers.Control.DrawFeature(layerName,OpenLayers.Handler.Point,...),*

Lines :*new OpenLayers.Control.DrawFeature(layerName, OpenLayers.Handler.Path,...)*,and

Polygon: *new OpenLayers.Control.DrawFeature (layerName, OpenLayers.Handler.Polygon,...)*.

Additional controls include:

- *Snapping* (for snapping the mouse cursor to features and vertices),
- *ModifyFeature* (when active, a clicked line or polygon vertices can be modified by adding more vertices to change shape),
- *DragFeature* (used for dragging features: points, lines or polygons from one position to another),
- *Split* (for splitting lines, when active a line drawn across any given line splits the line at the point of intersect),
- *LayerSwitcher* (for switching between layers. A non base layer can be switched on or off irrespective of the state of other overlays whiles only one base layer can be on at a time),
- *Permalink* (permalink provides additional URL parameters that describe the map state: location coordinates and zoom level),
- *ScaleLine* (scale of the map at a given zoom level displayed on a line bar),
- *SelectFeature* (when active, a clicked feature is selected, CCGIS uses select to display object attributes),

- *PanZoomBar* (this control displays a vertical bar for zooming in and out and a four cardinal control for panning),
- *MousePosition* (displays map position in latitude, and longitude coordinates as the map receives focus),
- *Pan* (control for panning map),
- *NavigationHistory* (this control keeps track of map navigation history),
- *Click* (control for registering map click event. This is implemented in showing pop ups at the clicked location).

Detailed implementation of these controls and other functions can be reviewed in the documentation files (Appendix III) or source code of the CCGIS.

### 4.5.1 Interface Implementation

The various interfaces of the views implement a multi panel User Interface (UI) layout that supports multiple nested panels, automatic split bars between regions and built-in expanding and collapsing regions. The five regions consist of the *north, south, east, west and centre* with the following functions:

- the *north region* of the main base border layout contains the toolbar with clickable buttons;
- the *west region* serves as a table of content for map layers or a nested accordion search and link panels;

- the *east region* contains accordions for spatial object properties or map search fields;
- the *south region* for users geo-location and copyright notice; and
- the *centre region* is used for imbedding other panels or used as the map panel.

In instances where there are nested border layouts, the *centre region* is always required plus any of the other four regions. Sample implementation of a single border layout with nested components is as shown in Figure 4.8.

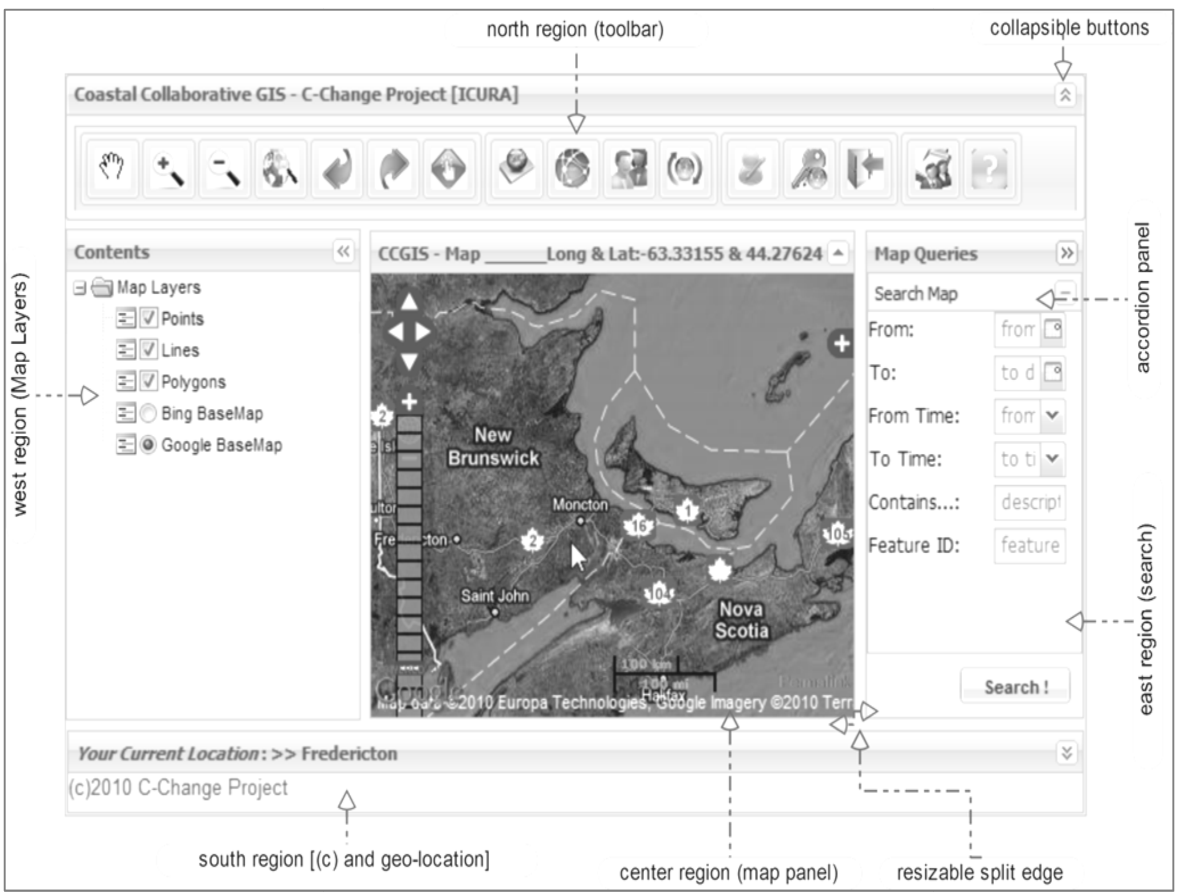



Figure 4.8 Index View.

#### 4.5.1.1 Index View

The index *view* serves as the main entry point of the CCGIS application. The *front controller* initialises the index view as the default view of the index controller. The purpose of this page is to serve an interface for all users (registered and non-registered alike). A non-registered user has access to search contributions in the system, browse the map and the opportunity to file a new registration. An administrator moderates all registration requests. Accepted users are active to login and can proceed to access other pages such as profile page, map creation page, forum page, and the Content Management System (CMS) with administrative privileges. The basic layout of the index page is as shown in Figure 4.8.

#### 4.5.1.2 Profile View

The profile view is a non-mapping page that provides a registered user with access to manage their profile while having read only access to their Collaborative Reputation (CR). Through the profile page, a user can make changes and commit their contact details, and biography. All of a user's accepted contributions could be accessed, showing active and deactivated spatial objects. Pending contributions are also listed to allow users to know the state of their new spatial contributions. The CR system implemented by the author of this research serves as a peer-reviewed system that quantifies an index (collaborative medal) to represent a user's reputation in the CCGIS. The number of medals is calculated as the sum of all affirmations (thumbs-up) to a particular user's spatial contribution minus the sum of all negations (thumbs-down) or counter opinions, divided by three (3 – the next odd number after one). Hence, a CR of one (1) means either a user has three thumbs-ups to all his/her contributions and no thumbs-down or six thumbs-ups and three counter opinions. The facets in the profile view are shown in Figure 4.9.

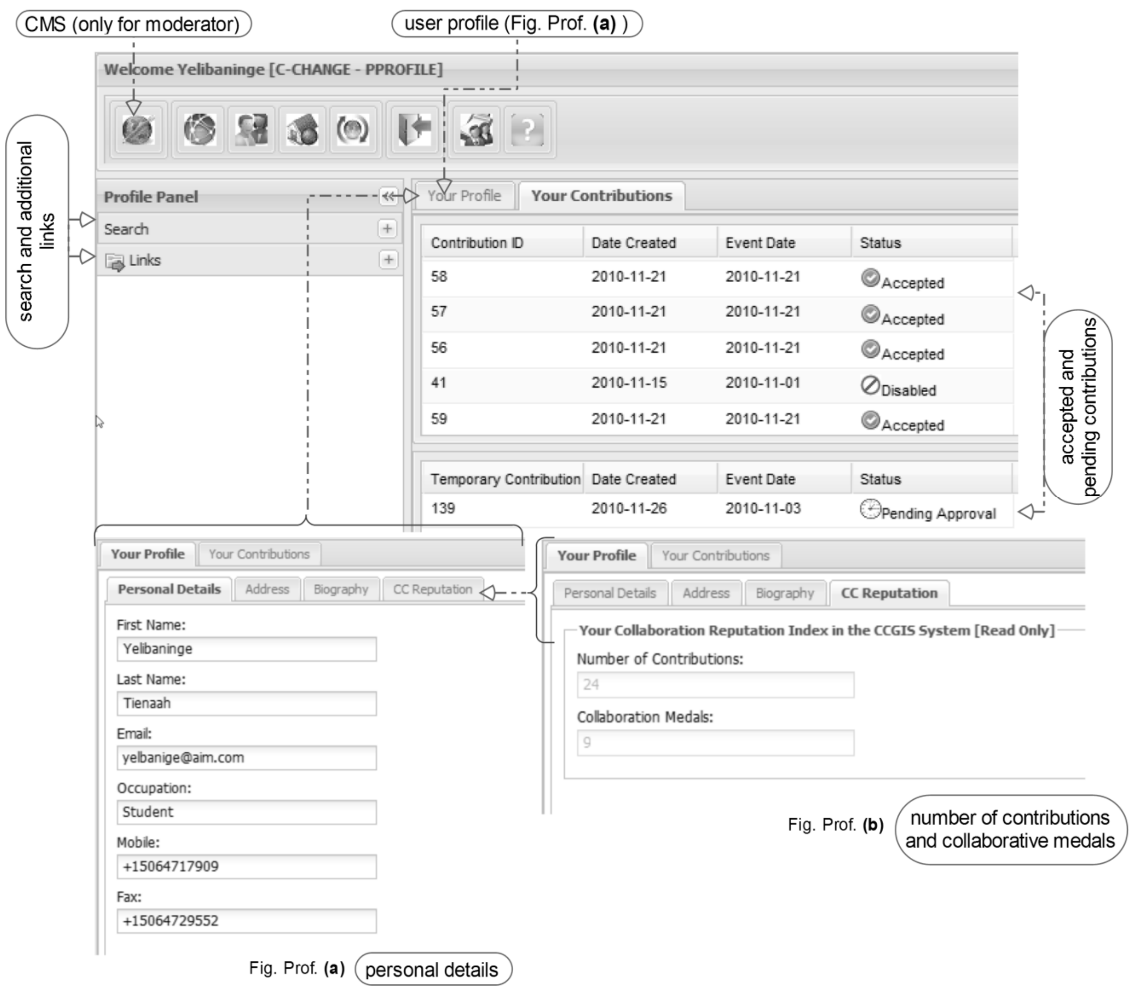



Figure 4.9 Profile View.

#### 4.5.1.3 Forum View

The forum view serves as the interface for collaborative dialog between users of the CCGIS. It is in this interface that users can search, engage in a spatial context dialog, and peer review accepted contributions. Users can create topics for dialog concerning a spatial object (point, line, or polygon) and comment on topics created by others. Forum interfaces implemented are described in Figure 4.10.

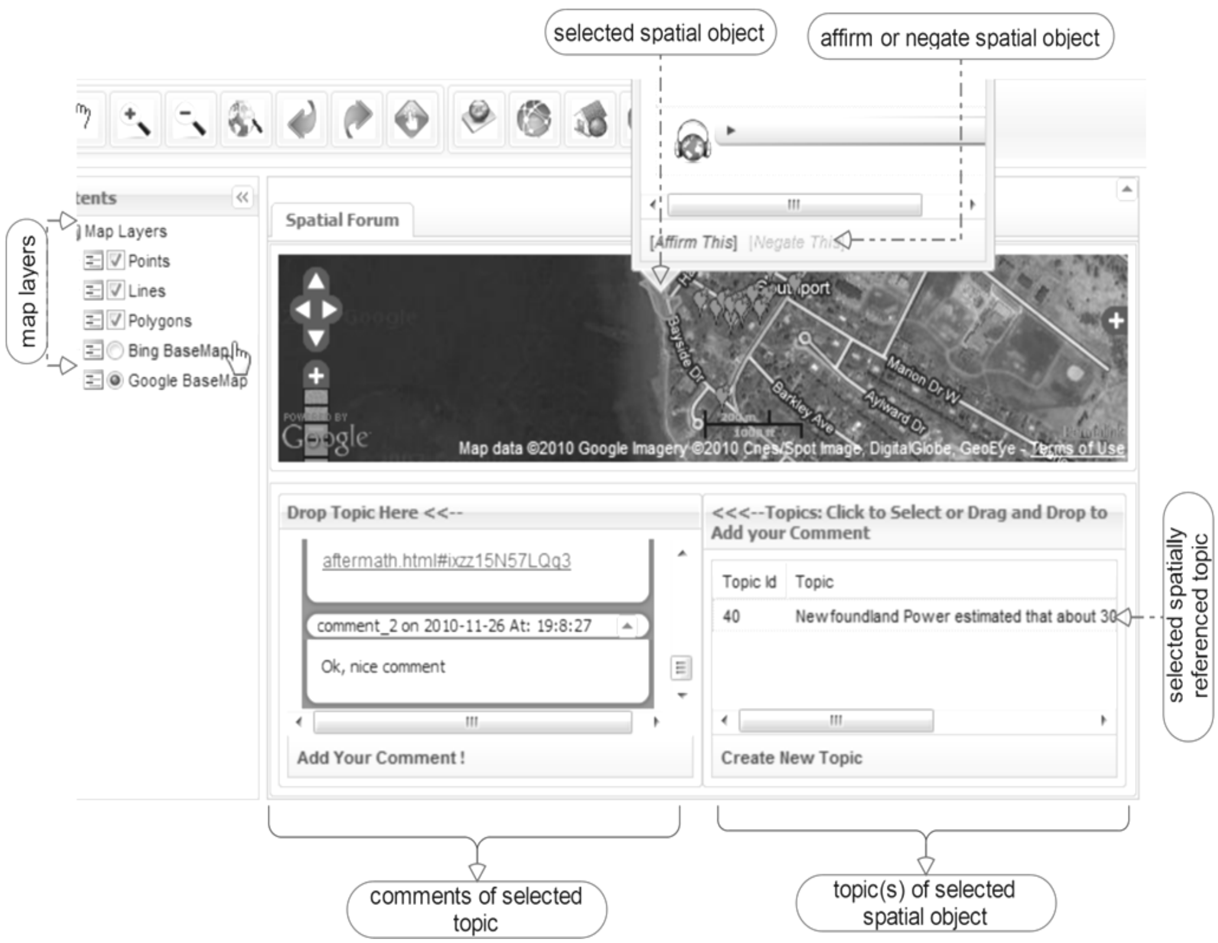



Figure 4.10 Forum View.

#### 4.5.1.4 Map Creation and Updates Page

To digitize simple vector objects such as points, lines and polygons, a visit to the map creation and updates page is required. This page provides the basic functions for sketching a polygon, line, or point against a satellite image background. Spatial content created can be cartographically edited (colours, opacity, line weight, line style) and can be described with text, pictures (*.png*, *.jpeg/jpg* and *.gif*), video (Flash Video: *.flv* and Moving Picture Expert Group-4:*.mp4*) and audio (Moving Picture Expert Group Audio Layer 3: *.mp3*) as attribute information. Contents generated can also be modified by shape (vertices of lines and polygons) or moved (points, lines and polygons) from one spatial location to the other. Other functions include delete feature, measure distance, area, point location, add GeoJSON feature, and navigation controls. A section of the map creation and update page is as shown in Figure 4.11.

#### 4.5.1.5 Content Management System

A Content Management System (CMS) is an interface for the administrator or moderator of the CCGIS. Through this interface, an administrator can accept or reject user registration requests and temporary spatial contributions. A Layer Management tab intends for future spatial management of layers (WMS, WCS, and WFS) to the CCGIS. In addition, reports on activity in the system can be implemented in the reports generation tab; this will be based on the intended use in a coastal collaborative process. Sections of the CMS are described in the Figure 4.12.

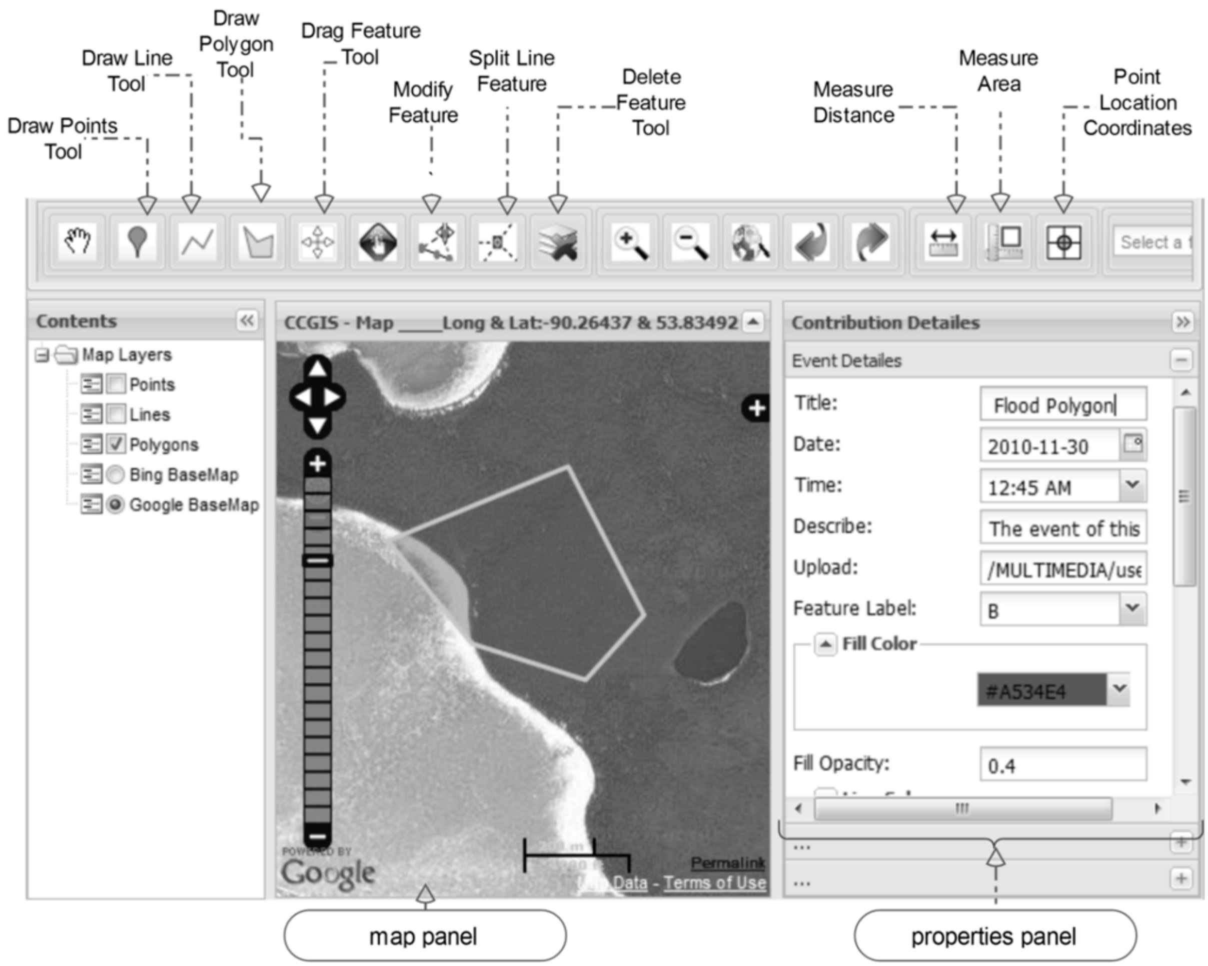



Figure 4.11 Map Creation and Updates View.

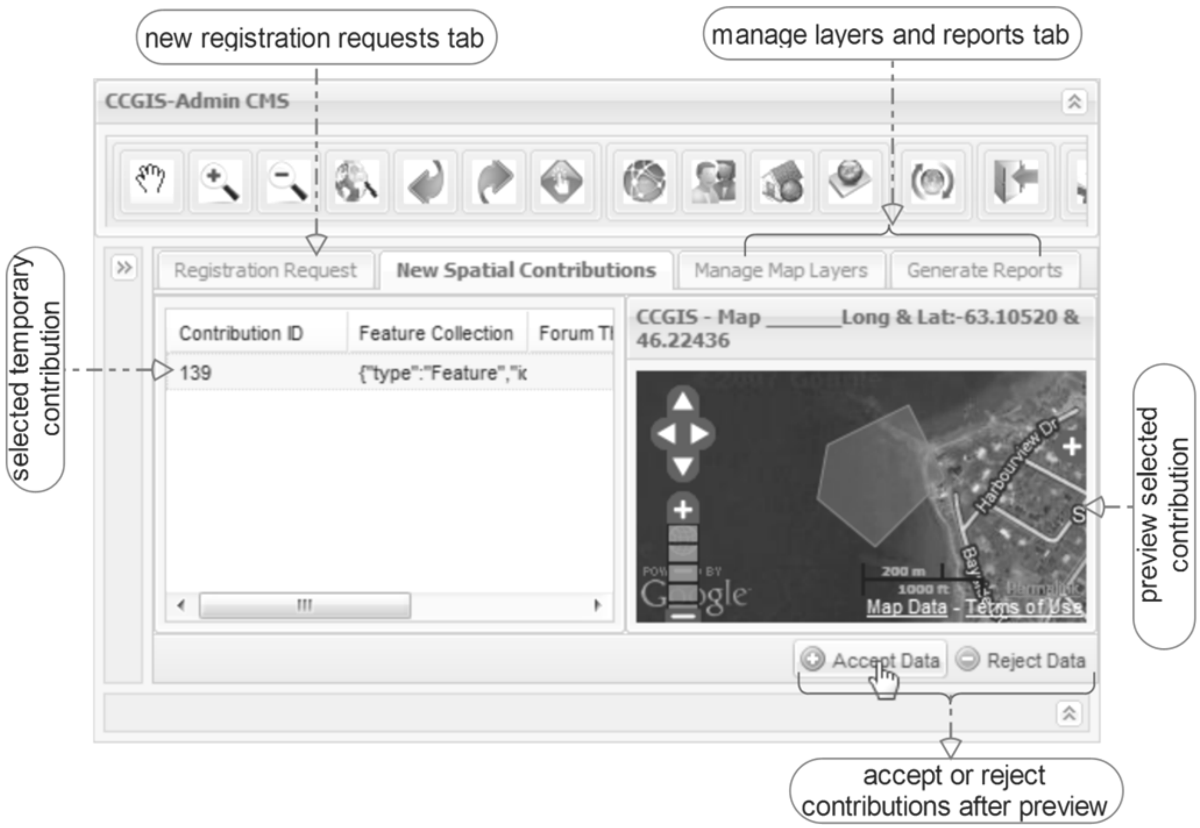



Figure 4.12 CMS View.

### 4.6 Visualizing Spatial Attributes

A popup window shows up when a feature (point, line, or polygon) is selected. A popup retrieves multimedia content from the MVC model that referenced to a selected feature for a rich description of a particular event or phenomena. An example of a popup window and its contents are as shown in Figure 4.13.

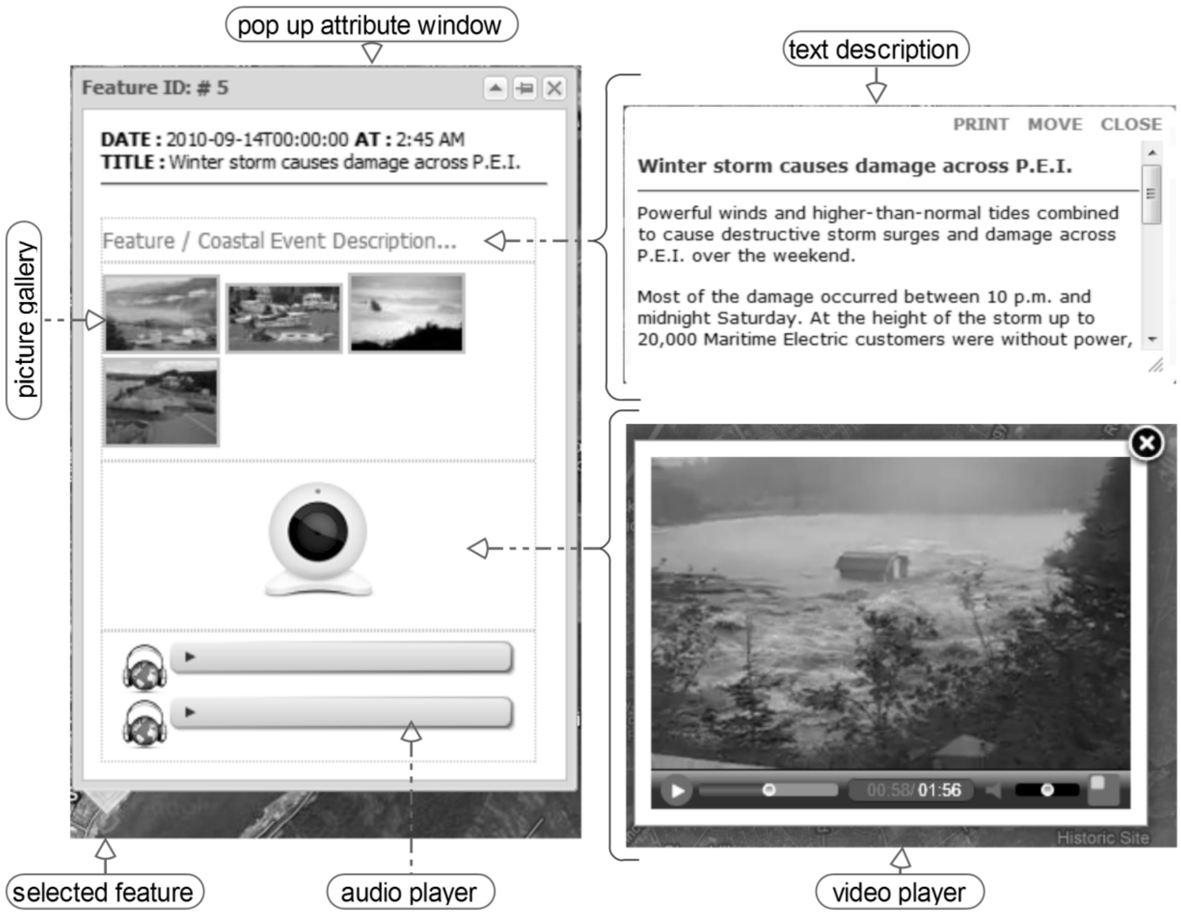



Figure 4.13 Feature Attribute Popup Window.

## 4.7 Visualizing Overlapping and Clustered Map Features

It is not uncommon for features to overlap or get clustered within a region of the map. Multiple contributors can give their opinions on an event covering the same spatial region spanned over date and time. The CCGIS does not attempt to edit and store only the best available spatial contribution (as done on most collaborative mapping platforms: Open

Street Map, Wikimapia, etc.) but tries to visualize all contributions. This rich cluster of spatial objects can be filtered by the search functionality. Filtered data by search can further be visualized by date and time using in-bounds functions of features. A bound is a box having a lower left corner and an upper right corner. By using the *SHIFT KEY + Mouse Drag*, features within the bounds (as shown in Figure 4.14) or the dragged bounds within a feature bound are selected for browsing by date and time (shown in Figure 4.15).

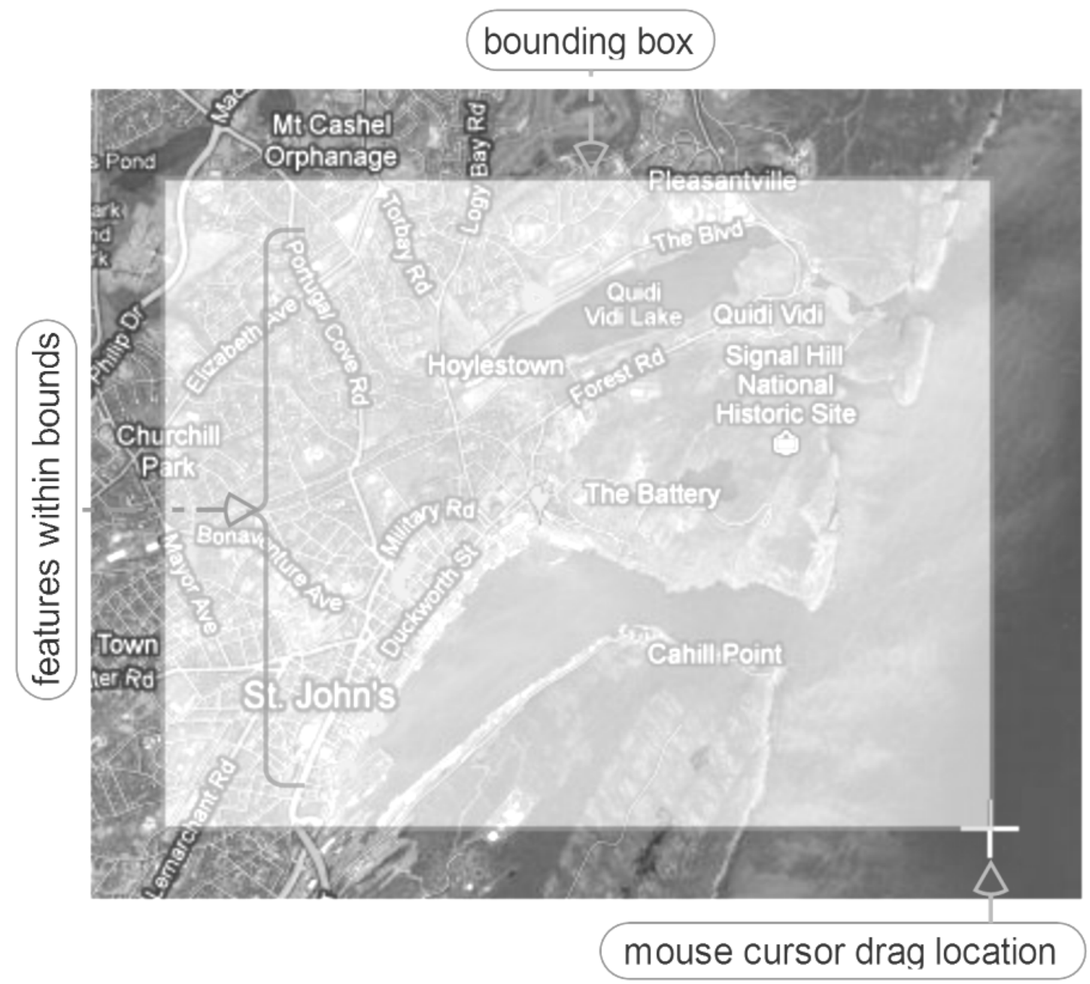



Figure 4.14 Bound Selection (*SHIFT-KEY + Mouse Drag*).

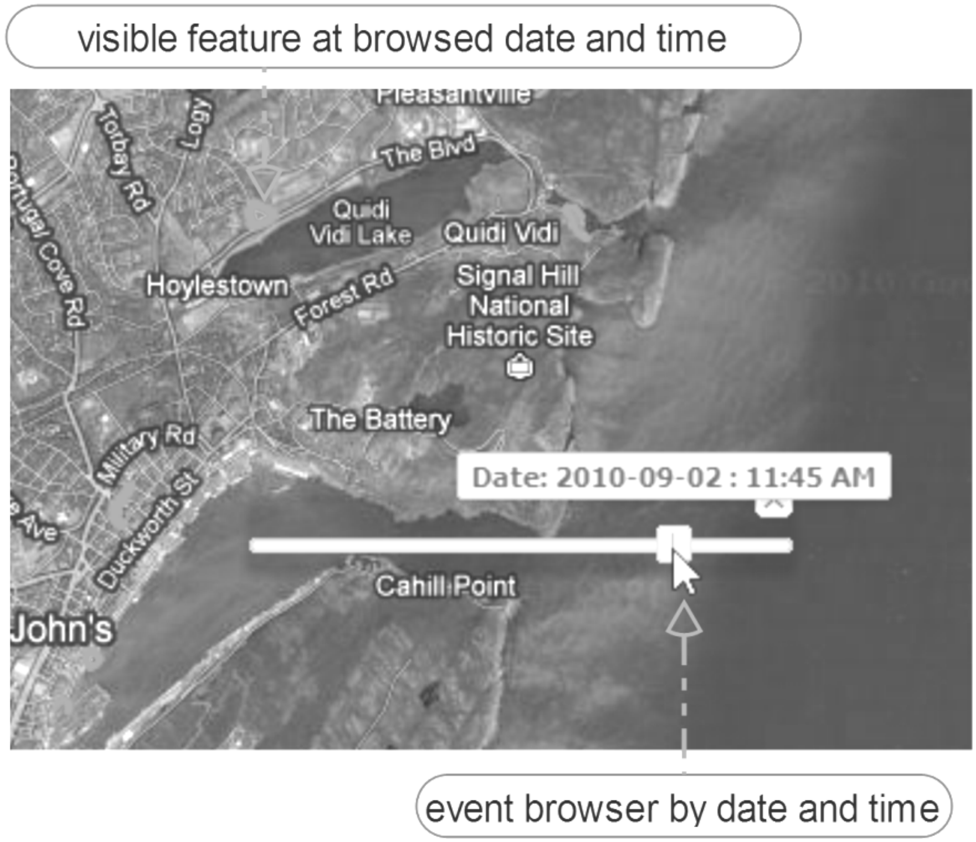



Figure 4.15 Bound Selection Browser (Date and Time)

## 4.7 Spatial Data Format

A non-proprietary spatial data format GeoJSON serves as the default format for storing spatial content. GeoJSON is a new interchange format derived from JSON (JavaScript Object Notation). JSON provides a lightweight data-interchange format that is easy for humans to read and write; it is also easy for machines to parse and generate

[JSON, 2010]. The format is completely independent and has been implemented in C, C++, C#, Python, Java, Pearl, PHP, and so on. This format is built on two structures:

- a collection of name/value pairs (also called members: object, record, *struct*, dictionary, hash table, keyed list, or associative array); and
- an ordered list of values (array, vector, list, or sequence).

The simplest representation of a JSON object is:

*ObjectName = {string: value};*

where a pair is equivalent to *string: value*. Each name/value pair is separated by commas (,) and the name (*string*) from the value (*value*) by a colon (:).

GeoJSON is a new geographic format (now at version 1.0 since June 2008) for encoding a variety of geographic data structures. A GeoJSON object may represent geometry, a feature, or a collection of features. In GeoJSON, a geometry object is that which supports the following geometry types: *Point, LineString, Polygon, MultiPoint, MultiLineString, MultiPolygon, and GeometryCollection*. Geometry objects support additional properties, and a feature collection represents a list of features [Butler et al., 2008]. According to the format specification, a GeoJSON geometry object of any type other than "*GeometryCollection*" must have a member with the name "coordinates." A coordinate reference system (*crs*) and bounding box (*bbox*) members are optional.

### 4.7.1 Geometry Objects Representation

A position is the fundamental geometry object (must be *x, y, z* or *easting, northing, altitude*, or *longitude, latitude, altitude*). The "*coordinates*" member of a geometry object is made up of one position (in the case of a *Point geometry*), an array of positions (*LineString* or *MultiPoint* geometries), an array of arrays of positions (*Polygons*, *MultiLineString*), or a multidimensional array of positions (*MultiPolygon*). An example from the specification v1.0 of GeoJSON further explains as follows:

Point => must be a single position

```
{"type": "Point", "coordinates": [100.0, 0.0]}
```

MultiPoint => must be an array of positions

```
{"type": "MultiPoint", "coordinates": [ [100.0, 0.0], [101.0, 1.0] ] }
```

LineString => must be two or more positions

```
{"type": "LineString", "coordinates": [[100.0, 0.0], [101.0, 1.0]]}
```

LinearRing => is closed LineString with 4 or more positions

MultiLineString => must be an array of *LineString* coordinate arrays

```
{ "type": "MultiLineString", "coordinates": [
     [ [100.0, 0.0], [101.0, 1.0] ],
 [ [102.0, 2.0], [103.0, 3.0] ]
]}
```

Polygon => must be an array of *LinearRing* coordinate arrays

```
{"type": "Polygon", "coordinates": [
   [ [100.0, 0.0], [101.0, 0.0],
    [101.0, 1.0], [100.0, 1.0],
   [100.0, 0.0] ]
  ] }
```

MultiPolygon => must be an array of polygon coordinate arrays

```
{"type": "MultiPolygon","coordinates": [
   [[[102.0, 2.0], [103.0, 2.0],
 [103.0, 3.0], [102.0, 3.0],
[102.0, 2.0]]],
   [[[100.0, 0.0], [101.0, 0.0],
 [101.0, 1.0], [100.0, 1.0],
[100.0, 0.0]],
    [[100.2, 0.2], [100.8, 0.2],
 [100.8, 0.8], [100.2, 0.8],
[100.2, 0.2]]]
]}
```

GeometryCollection => collection of geometry objects. It must have member name "geometries" with a value array with each member in the array GeoJSON geometry object.

The CCGIS implemented *MultiPoint, MultiLineString, and MultiPolygon* for storing spatial objects. Additional information such as attributes is stored in a feature (A GeoJSON object with *type: "Feature"*). A feature must have a member with name "geometry" and value of JSON or null, a member with name "properties" with value JSON object or null, and if a feature has an identity, the identity should be included with member name *"id"*. Further details on the GeoJSON specification for more details can be accessed at: *http://geojson.org/geojson-spec.html*.

OpenLayers support a parser: *OpenLayers.Format.GeoJSON.* This allows read/write functions to features created on a vector layer in the Document Object Model (DOM) of a web browser. On submission to the web server, all features on the map are bundled into a feature collection and then transferred to the server via *Ajax*. At the server, the feature collection is converted to a PHP JSON object and then saved as individual features. Any data transmitted to the server in the form of a spatial contribution goes through a review by the administrator or moderator before it becomes public. Data flow in the CCGIS is described in the Section 4.8.

## 4.8 Spatial Data Flow

The rich spatial content (spatial polygon, line, and points plus video, audio, pictures and text) flow through a cycle and the content is examined and moderated by a system administrator. New contributions can be previewed and rejected or already accepted contributions can be disabled from public view. This cycle is described in Figure 4.16.

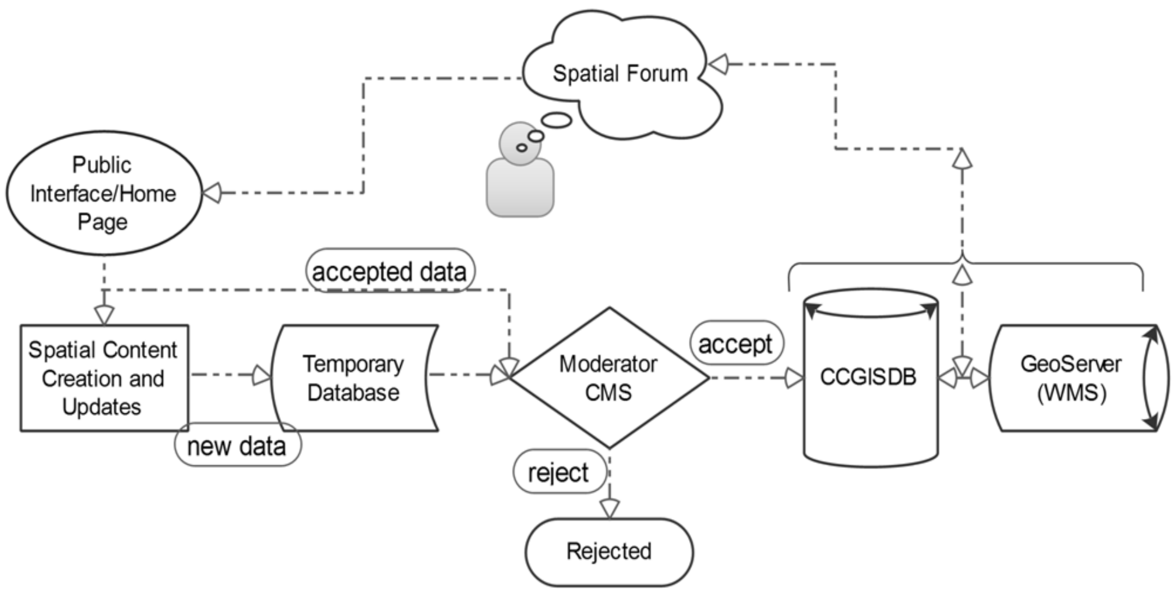



Figure 4.16 Spatial Data Flow Through the CCGIS

### 4.9 GeoJSON on other platforms

Now, most platforms (GDAL/OGR GeoJSON driver, GeoServer) can output other spatial data formats in GeoJSON as a lightweight medium of communication and not the reverse. However, OpenLayers support conversion from GeoJSON to other formats:

- GeoRSS (a lightweight, format for extending existing feeds with geographic information. It supports basic geometries: point, line, box, and polygon),
- GML (Geography Markup Language (v2. and v3.) is an XML grammar for expressing geographical features),
- WKT (Well-Known Text format. The format stores objects that can be transmitted between interoperating computer programs),
- KML (Keyhole Markup Language commonly used on Google Map, Google Earth etc.),
- Atom (XML format used for web feeds),
- OSM ( Open Street Map format),
- ArcXML (ArcXML is the protocol for communicating with the ArcIMS Spatial Server),
- GPX (GPS Exchange Format: format for exchanging GPS Data), and so on.

At this point, further development is required to convert CCGIS GeoJSON to specific formats. This will be a future implementation based on demonstrated needs to change GeoJSON into a different format or formats that may be used on other platforms.

### 4.10 Summary

This chapter detailed the implementation of the designed CCGIS using the Zend MVC architectural pattern. The client (view) and database (model) are linked using one index controller. The view consists of five views: *index*, *forum*, *profile*, *map creation*, and *content management*. Each view has a corresponding *action* in the *index* controller while rendered by its XHTML layout. The various actions communicate with the model service interface, which has access to all the data gateway objects that can access each corresponding database table. The Zend data gateway allows access to table records using objects to represent tables in a database.

The model stores data in a non-proprietary GeoJSON format. This format provides a lightweight spatial object notation than can be converted into objects at the client and server. GeoJSON also provides a simple human readable data format that is supported by *OpenLayers* and *GeoServer*. The chapter concluded with conversions from GeoJSON to other data formats. The next chapter discusses system evaluation based requirements, lessons learned and other issues when implementing the CCGIS in a community setting.

# Chapter Five: Evaluation of and Issues with the CCGIS

*Everything that can be counted does not necessarily count;*
*everything that counts cannot necessarily be counted.*
Albert Einstein ~ (1879-1955).

From the preceding chapters, this research formulated a design and implementation of a Coastal Collaborative GIS to help identify the coastal threats of sea level rise and storm surges. The implementation of the CCGIS platform aimed at wide public involvement in the adaptation process. The research also highlighted the importance community engagement using a web GIS application (CCGIS) to record and present their local knowledge as part of the participatory process of developing adaptations. The CCGIS provides a means through which stakeholders can participate in a spatial context from their community experience (local knowledge).

This chapter discusses system evaluation and issues associated with the CCGIS. The chapter highlights user-friendliness, the role of the CCGIS in a collaborative process, system limitations, and satisfaction of user requirements.

## 5.1 Collaborative Design and Implementations Issues

The CCGIS at this stage of development accepts reviewed contributions from only registered users. Registered users have their profile details linked to their contribution(s).

This means a contribution can be traced to the user's name, address and other details provided. There are issues to the extent of stakeholder involvement and restrictions as to what and where contributions can be accepted. The following issues have been identified:

- ***Validating Contributions – Public vs. Focus Groups***: Stakeholder involvement at wide public involvement can provide a wide user base but comes with the responsibility of checking each contribution before acceptance. An alternative is automatically accepting all contributions and letting the public act in a peer review context. The public can report damaging or irrelevant contributions that are not geared towards the collaborative adaptation goals. In the public review scenario, there are instances where content may be damaging to people's reputation or sensitive information may be made public. In these instances, the collaborative process should be ready deal with legal and privacy issues. Participation can also be limited to focus groups (experienced individuals) in the community. In this instance, the level of trust may allow all contributions without validation or moderation by an administrator.
- ***Validating Users' Location***: It is unavoidable in an online system to have spatial contributions from users in different geographic locations. The question that surfaces quickly is the following: should users outside a coastal community share their knowledge on the effects of storms and sea level rise in a community they do not live in (or live in anymore)? If this is answered in the affirmative, then it goes to negate the concept that local knowledge is local and unique or limited in a geographic context. The

CCGIS has been based on the fact that individuals experience and best know their environments, hence they should be the only participants. However, it is possible to miss historic data collected by someone who lived in the community some time past but has now relocated to a different city or country. The CCGIS has implemented but not enforced a geo-location tool that identifies the user's city at the time of usage. Its enforcement is open to future requirements.

- ***Validation of Geographic Extent:*** Another issue is the geographic extent of contributions. If the system administrator sets a geographic boundary within which the system should accept contributions, contributions outside the region, which may be useful or may have an indirect impact on the study area may be automatically rejected or flagged for rejection. This type of implementation depends on the intended strict adherence to the geographic region for adaptation. A containment test for all contributions could be implemented to know which features are outside the accepted geographic region.
- ***Accepted contributions***: In a moderated collaborative process, a system administrator is always required to review contributions before they are made public. This approach is to make sure contributions satisfy some basic requirements such as title or theme of contribution, date of the event, time of the event, description, and any additional supported multimedia data attached to the spatial object. Contributions that do not support the goals of a collaborative process may be rejected; this decision is entirely

based on the discretion of the moderator(s). As contributions pile up due to a coastal storm event, extra effort is needed by the moderator(s) to review each single contribution before it can be made public.

## 5.2 System Evaluation

At the beginning of this research, a set of objectives where defined within a scope to meet user and system (functional and non-functional) requirements. These sections discuss how sufficient these requirements have been met by the CCGIS and other possible alternatives of implementation.

### 5.2.1 Research Objectives

The following objectives were achieved by the CCGIS in varying degrees:

- *To identify and classify commonly used and supported publicly available web mapping tools and to identify at least three (3) web tools useful for project design based on classification*: Section 2.6.2.1 and Appendix I summarize a review of 32 different web client and server technology platforms. The review included factors such as Open Geospatial Consortium standards, platform customization, platform dependency, community of users and flexible licensing. These thirty two (32) platforms do not constitute the entire range of technology, but the list is representative of most of the public available web mapping platforms.

- *To design a local knowledge platform for spatial identification of coastal threats as a result sea level rise and storm surges:* This research discussed the process of knowledge acquisition and how it relates to threat identification through a platform design (Chapter 3) and implementation (Chapter 4) of the Coastal Collaborative GIS. The research also identified how it could be implemented using varied platforms for the server-side scripting. Model View Controller architecture was implemented to separate the viewer from the application and business logic of the CCGIS.
- *To link a designed web GIS platform and local knowledge in a collaborative process that can be applied in the eight (8) communities of the C-Change project*: The implemented CCGIS serves as a platform for local knowledge abstraction using vector objects plus rich multimedia content. Online access to the CCGIS is replicable in eight C-Change communities.
- *To test and evaluate the designed system based on requirements and project objectives*: The system provides the functionalities detailed in the user requirements and system requirements (functional and nonfunctional). These functionalities have been tested by users, with different degrees of success. User test and feedback are discussed in Section 5.2.5. The evaluation details of how user and system requirements are satisfied by the CCGIS are discussed in the next sections.

### 5.2.2 User Requirements

User requirements obtained from published literature and the C-Change research team itemized high-level requirements of what the CCGIS should fulfil:

- *The system should allow local communities to identify coastal threats as a result of sea level rise and storm surges at a particular location, an area (residential, business, etc.) and a linear event:* The CCGIS met this requirement by providing digitizing functions that can be used to identify threats represented in a spatial context. A location is digitized as a point, an area is digitized as a polygon, and a line digitized as a linear event.
- *The system should provide a means of describing and communicating threats with pictures, video, audio and text*: Spatial objects digitized from the first requirement can be described by text using an html text editor. Images (.png, .jpg/jpeg and .gif), video (.flv and .mp4), audio (.mp3) can also be uploaded as attribute information to describe the spatial representation of a coastal event.
- *The application should be user-friendly and cost effective*: Familiar user-friendly mapping and navigation tools are used (Google and Bing Maps). Map navigation and system functionality are accessed with simple icons and tool tips to describe how to use them. The CCGIS implemented tools that are free (at no cost and free rights to redistribute) for public non-commercial use. There may be cost of management and site hosting,

which may depend how the system is implemented at the local community.

- *The system should provide a means of validating user contributions:* The CCGIS uses a peer review mechanism on accepted contributions. Users can affirm or negate a public spatial contribution in a forum session. With time, the moderator can turn some spatial objects off based on public review responses. Added validation restriction include the geo-location function, which may be used to filter who can contribute and where.
- *The system should provide a means of commenting on scientific scenarios and local contributions*: Now, the CCGIS cannot support other formats of spatial data – it can only save data in the GeoJSON format. To satisfy this requirement, scientific scenarios can serve as base layers on which user comments and feedback can be overlaid. This approached preserves scenario layers as a separate entity and community comments as another layer.

### 5.2.3 Functional Requirements

The following functional requirements satisfy what the system is supposed to support and do at a low system level:

- *The CCGIS should be an online collaborative application with a. client (public and administrator) interfaces, b. server (spatial application and web server) component, c. database (relational and spatial database) server.* The CCGIS satisfies this requirement based on:
    a) Interfaces: A Content Management System is used by the administrator to moderate collaborations. In addition, a home page (accessible to non registered users), profile page, forum page and map creation page serve as interfaces where users can interact with the CCGIS;
    b) The CCGIS implements a spatial data server called GeoServer that supports Open Geospatial Consortium standards such as Web Mapping Service (WMS), Web Feature Service (WFS) and Web Coverage Service (WCS). These services allow serving spatial data to clients who can be online (web) or on a local host (offline). In addition, web pages are served using Apache web server, which supports Hypertext Preprocessor (PHP) for server-side scripting; and
    c) All data flow in the CCGIS are persisted and retrieved from an object relational database called PostgreSQL (version 8.4). The database is further extended using PostGIS (version 1.5) to provide spatial extensions.
- *The client interface should be user-friendly (using public mapping tools) that can be extended or customised using their Application Programming*

*Interface (API)*: OpenLayers web mapping platform with embedded public user-friendly maps (Google and Bing Maps) provides a user friendly client mapping interface for the CCGIS. The *OpenLayers* API is further customized with a rich graphical user interface called *ExtJS*;

- *The client should provide digitizing and editing function for the creation of spatial content:* The CCGIS provides functions for digitizing simple vector objects such as points, lines, and polygons with a single click of a button. These vector objects represented as JavaScript objects can be moved, modified (lines and polygons), split (lines) and deleted;
- *Content generated should be simple vector objects such as: a. Points (to abstract a location or landmark) b. Lines (to abstract road, path, shore line etc.) and c. Polygons (to abstract and area or region):* Map creation page supports drawing simple vector objects: points, lines, and polygons that are stored as *GeoJSON* objects. This format allows a lightweight representation of spatial objects that can be converted into objects at runtime both at the client and server;
- *Client technologies should implement OGC compatible standards and should consume: a. Web Mapping Services (WMS), b. Web Coverage Services (WCS), and c. Web Feature Services (WFS):* OpenLayers supports industry-standard Web Mapping Service (WMS), and Web Feature Service (WFS) protocols. GeoServer also implements Web Feature Service (WFS), Web Coverage Service (WCS), and Web Map

Service (WMS) in OGC standards. These services can be implemented as and when needed to support any collaborative processes in the future;

- *The system should provide administrative privileges of accepting or rejecting user contributions before it becomes public:* The CCGIS Content Management (CMS) gives the administrator access to preview contributions. The administrator can accept or reject contributions based on content to support collaborative goals;
- *Contributions should be stored in a database that can provide object relational and spatial capabilities: PostgreSQL* (version 8.4) is an object relational database extended with *PostGIS* (version 1.5) to work as a spatial database (these are bundled installation from PostgreSQL and Refractions Research). The CCGIS uses PostgreSQL as a relational database of which based on future requirements, PostGIS spatial data formats can be implemented as when needed;
- *Contributions made by users should be stored in a non proprietary format:* Data created with CCGIS are stored in a light weight GeoJSON (JavaScript Object Notion) spatial format, which can be converted into an object both on the server and client in a human readable format;
- *The system should provide the administrator rights to restrict the area (extent) of contributions and contributors geographic location at the time of contribution:* CCGIS implements a geo-location service provided by *GeoPlugin* (see Appendix II) to locate a user's city at the time of contribution. A further investigation is required at this stage since IP

address geo-location can only give a rough estimate of user's location. A good alternative will be the upcoming W3C geolocation API standard (*http://dev.w3.org/geo/api/spec-source.html*) as part of HTML5 standards now supported in some new web browsers (Firefox 3.5+, Google Chrome 5+, Safari 5+,Internet explorer 9+); and

- *The system should provide a forum discussion with reference to spatial objects on the map:* CCGIS implements a forum discussion page, which gives the opportunity for users to search, create topics, and add comments to a spatial object. The forum discussion engages collaborators to discuss other spatially represented contributions whiles having access to attributes of the spatial object.

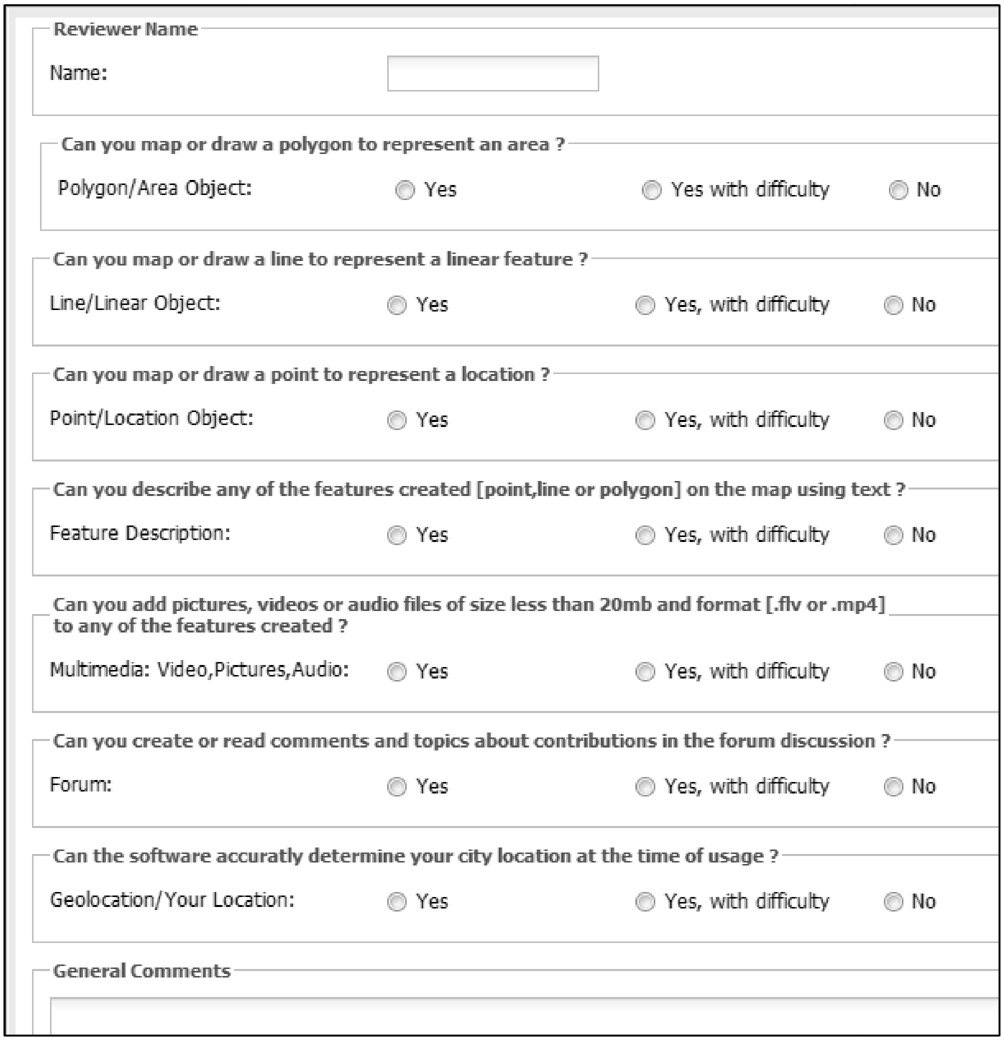
### 5.2.4 Non-functional Requirements

This is a generalised requirement, which spells out system constraints:

- *The CCGIS application should not provide services without internet connection:* CCGIS can only work with access to the internet. As an online application it provides access to multiple users at the same time.
- *Only registered members can make spatial contributions to the system:* A user is required to login to access the map creation page. This is protected by an encrypted password and user name to allow unique user accounts.

### 5.2.5 CCGIS Initial Usability Feedback Results

The period for this research did not provide the opportunity to perform an in-depth treatment of a usability test. However, a simple questionnaire was used to obtain initial usability feedback of this prototype. The questionnaire consisted of seven questions that required a reviewer to provide “Yes,” “Yes with Difficulty,” and “No” as answers to basic functionalities of the system. The reviewer also had the opportunity to add any general comments after the questionnaire and submit results online. Figure 5.1 shows details of the questionnaire.



**Reviewer Name**

Name:

**Can you map or draw a polygon to represent an area ?**

Polygon/Area Object: Yes | Yes with difficulty | No

**Can you map or draw a line to represent a linear feature ?**

Line/Linear Object: Yes | Yes, with difficulty | No

**Can you map or draw a point to represent a location ?**

Point/Location Object: Yes | Yes, with difficulty | No

**Can you describe any of the features created [point,line or polygon] on the map using text ?**

Feature Description: Yes | Yes, with difficulty | No

**Can you add pictures, videos or audio files of size less than 20mb and format [.flv or .mp4] to any of the features created ?**

Multimedia: Video,Pictures,Audio: Yes | Yes, with difficulty | No

**Can you create or read comments and topics about contributions in the forum discussion ?**

Forum: Yes | Yes, with difficulty | No

**Can the software accuratly determine your city location at the time of usage ?**

Geolocation/Your Location: Yes | Yes, with difficulty | No

**General Comments**

Figure 5.1 CCGIS Evaluation Questionnaire

This user feedback solicitation consisted of 17 randomly known participants to the author. This number (17) consists of participants that responded out of 60 people contacted. Some authors suggest the maximum ratio between benefit and cost in terms of time and effort for testing is achieved when using five to eight participants [Hwang and Salvendy, 2010; Zhao, 2007; Nielsen, 2000]. An appreciable number, between 5 and 20 participants, should provide preliminary limitations or strengths of the CCGIS for future improvements and controlled testing. Respondents for the test had varied backgrounds with 6 out of 17 from GIS and Geomatics. Range of user locations include: 9 participants from Canada, 2 from the United States, and 6 from Ghana (West Africa). This is an attempt to obtain feedback from different geographic locations. The system test results are displayed in Table 5.1.

Table 5.1 CCGIS Evaluation Results.

| Reviewer ID | Description Review | Forum Review | Geolocation Review | Line Review | Multimedia Review | Point Review | Polygon Review |
|---|---|---|---|---|---|---|---|
| 1 | Yes | No | Yes | Yes | No | Yes | Yes |
| 2 | Yes_With_ Difficulty | Yes | No | Yes | Yes_With_ Difficulty | Yes | Yes |
| 3 | Yes | Yes | No | Yes | No | Yes | Yes |
| 4 | Yes | Yes | No | Yes | Yes | Yes | Yes |
| 5 | Yes | Yes | No | Yes | Yes | Yes | Yes |
| 6 | No | Yes | No | Yes | Yes_With_ Difficulty | Yes | Yes |
| 7 | No | No | Yes | No | No | No | No |
| 8 | Yes_With_ Difficulty | No | Yes | Yes | No | Yes | Yes |
| 9 | Yes_With_ Difficulty | Yes | No | Yes | Yes_With_ Difficulty | Yes | Yes |
| 10 | Yes | Yes | No | Yes | Yes | Yes | Yes |
| 11 | Yes | Yes | No | Yes | Yes | Yes | Yes |
| 12 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 13 | Yes | Yes | No | Yes | Yes | Yes | Yes |
| 14 | No | Yes | Yes | Yes_With_ Difficulty | Yes | Yes | Yes |
| 15 | Yes | Yes | Yes | Yes | Yes_With_ Difficulty | Yes | Yes |
| 16 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 17 | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Summary | | | | | | | |
| Yes | 11 | 14 | 8 | 15 | 9 | 16 | 16 |
| Yes With Difficulty | 3 | 0 | 0 | 1 | 4 | 0 | 0 |
| No | 3 | 3 | 9 | 1 | 4 | 1 | 1 |

The summary of results from Table 5.1 shows a rough preliminary CCGIS functional ease of use. Functionality wise, work is required in the Geolocation and Multimedia upload implementation. Geolocation performed poorly with more numbers of “No” than “Yes”. Also, the multimedia upload showed that of those able to use the functionality of the system, approximately half were able to use it with difficulty or could not use it at all. However, other functionalities tested showed higher “Yes” compared to “Yes with Difficulty” and “No”. Participant comments are available at Appendix IV.

### 5.3 System Limitations and Lessons Learned

One of the strengths of the CCGIS is an online web mapping application, which is also its highest limitation. Communities with no access to the internet cannot have access to the CCGIS. Furthermore, users with poor internet access will have a long application response time when streaming multimedia content (pictures, video, and audio) which serves as attribute information to spatial objects.

The design and implementation did not take into consideration smaller computer screens less than 15 inches. Computers and cell phones with screens smaller than this will not have a full view of some of the page controls.

It is also important to define a user base and test the system for user friendliness in each community to be implemented. The term “user-friendly” meaning easy to use is ambiguous without a test group. The CCGIS adopted a public familiar platform and functions in its implementation. Since ease of use is relative to a user group, it is important to continue to improve interface interaction functions based on the community user's level of online application interaction and computer knowledge.

### 5.4 Role of CCGIS in an Adaptation Process

Spatial mapping based on local knowledge using the CCGIS will provide the ability to assess current and possible future vulnerability from a stakeholder perspective. The CCGIS online forum discussion will provide a means of engaging the public in a spatial context dialog long after any interview session, public community workshop, or forum. Web Mapping Service (WMS) of flood scenarios can provide overlays to identify community interest and feedback using community spatial mapping, comments, and opinions.

A very important role of the CCGIS is to facilitate threat and risk mapping in communities without precise spatial data. Local knowledge threat mapping will not only help identify risks but involve the people being affected by sea level rise and storm surges.

## 5.5 Summary

This chapter discussed issues associated with the implementation of the CCGIS, limitations and evaluation based on objectives, functional and non-functional requirements. The chapter goes further to discuss evaluation of the CCGIS based on objectives, user, and system requirements. The evaluation shows that most requirements were satisfied but further improvements require future user requirements. These include a full use of object relational spatial database representation using PostGIS and improvements in geolocation using W3C standards. Furthermore, future spatial data formats (*Shapefile*, etc.) can be published using the services of *GeoServer*.

The system is limited to users with internet access possessing a basic level of computer knowledge and can navigate on public mapping platforms such as Google and Bing maps. Functions added with OpenLayers are activated with a single click. In summary, the author recognises that varied community implementation will require a test to make it suitable to their use and to support a specific (issue based) collaborative process. The next chapter summarizes this research with conclusions and recommendations.

# Chapter Six: Conclusions and Recommendation

*This is not the end. It is not even the beginning of the end.*
*But it is, perhaps, the end of the beginning*
~ Winston Churchill ~ (1874-1965).

This chapter concludes the preliminary prototype of the CCGIS design and implementation. The chapter hightlights conclusions and recommendations based on system evaluation and testing.

## 6.1 Conclusions

This research designed a platform as means to supplement existing data in threat or risk mapping caused by sea level rise and storm-surges using local community knowledge. This functioning system called the *Coastal Collaborative GIS (CCGIS)* is to help eight coastal communities engage with the *C-Change* research team in developing adaptation strategies. The CCGIS allows coastal communities to participate spatially by creating vector objects (with multimedia attributes) based on their local environmental knowledge. The platform also allows a spatial context forum discussion based on map features as a way of engaging stakeholders in the adaptation process.

Despite the implementation of a web-based collaborative platform, the author agrees with Tang [2006] that the best designed collaborative process intended to be fully inclusive cannot guarantee everyone is willing to take part in the process. The CCGIS is not a solution but a tool to facilitate engagement in the collaborative process.

Furthermore, online implementation of the CCGIS aimed at a wide public involvement in the process of adaptation. In communities without internet service, the platform cannot be used. Communities that have access to the World Wide Web should in the future implement the CCGIS to support varied input devices and technologies. These include location-based devices such as mobile phones, PDAs and GPS enabled devices to extend the range of participants.

Issues raised with respect to system implementation, can be solved on a local basis to address unique local community concerns and adaptation issues. The generic requirements used in developing the CCGIS serve as a template for local customization to meet local needs. This prototype and its future improvements will go a long way to support the C-Change research team in community spatial context engagement during the process of developing adaptation strategies to the effects of sea level rise and storm surges.

## 6.2 Recommendations for Future Research

The CCGIS was developed without requirements for mobile devices (mobile phones, smart phones, PDAs, GPS, etc.). Most mobile devices now have location-based services with multipurpose functions such as an audio recorder, a camera for both pictures and videos. Future implementation should consider the support for mobile platforms instant uploads as users are exposed to coastal events. A mobile support will also help adopt a different design, which will accommodate limited screen space less than 15 inches.

Internet based mapping provides a good opportunity for multiple user interactions. This also presents a limitation where users with limited internet bandwidth or no internet access cannot use the service or may have poor application response time in the case of low bandwidth. A future research into hybrid (desktop and internet) mapping is recommended where some layers can be made available to allow a user to create and view some datasets without internet connection whiles having access to other datasets when online. A hybrid platform will help users to create data using application functions without being online and share their local knowledge when they have internet access.

Further research to support W3C geolocation now implemented in new browsers (*Firefox 3.5+, Google Chrome 5+, Safari 5+,Internet explorer 9+* etc.) supporting HTML5 is recommended. The CCGIS implemented an IP address geolocation to identify a user's city location at the time of a page request. IP geolocation databases are known to have a few wrong city identifications, but they do work most of the time. Accurately knowing the user's location at the time of contribution will provide a way of filtering contributors from a local region if need be. In addition, in-bounds validation tests should be implemented on the side server to identify if a contribution is within a specific region delineated by the moderator as a way of further filtering inputs outside a local domain.

Further software implementation is also required for automation of data resources on *GeoServer* to its eventual publishing. This functionality will allow research teams to quickly test their scenarios against community provided spatial objects in other supported formats such as a compressed *Shapefile* archive. This will provide an easy to use interface for the C-Change research team to publish scenario outputs without having knowledge of *GeoServer*. This automation process is possible through *cURL* scripting or any other *http/ftp* protocol language.

In addition, further investigation of future user and system requirements are required to customise the CMS. Based on local issues, the administrator may want to do different queries in one community compared to the other. For example, database and content management of spatial datasets relating to the protection of sea turtle habitat will be different from flood mapping. Future improvements on the CCGIS should include coastal themes based on specific issues (e.g. flood, habitat, erosion, water pollution, etc.) that can serve as customised templates to address unique local conditions rather than being generic.

Finally, the implementation of the CCGIS employed already familiar public mapping tools to reduce the learning curve for users. A user-friendly approach is used by registering events such as click, double-click, drag, hover, and focus to interact with users. As the term user friendly may be ambiguous without a specific user group, it is recommended to test the platform in the community to assess their level of user friendliness. This was not possible in the scope of this project now. Creation of video demonstrations may provide further help to shorten the learning curve of using the CCGIS.

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# Appendix I: Open Source Tools

| **No. #** | **1** |
|---|---|
| Client Name | OpenScales |
| Application Focus | Rich Internet Mapping Applications |
| OSGeo Project | |
| Scripting Language | ActionScript 3, Flex |
| Software license | LGPL |
| Dependency | FlexLayers (abondoned), OpenLayers |
| Layers | OGC protocols : WMS/WMS-C 1.1.1, WFS 1.0, |
| Demo(s) | http://openscales.org/openscales.swf |
| URL | http://openscales.org/ |
| Wiki/Community | http://groups.google.com/group/openscales-dev |
| | |
| **No. #** | **2** |
| Client Name | MapFish |
| Application Focus | RIA, querying and editing geographic objects. |
| OSGeo Project | Yes (incubation) |
| Scripting Language | Pylons, JavaScript |
| Software license | GPLv3 |
| Dependency | GeoExt >> OpenLayers |
| Layers | OGC norms, like WMS, WFS, WMC, KML, GML etc.. |
| Demo(s) | http://demo.mapfish.org/mapfishsample/1.2/ |
| URL | http://mapfish.org/ |
| Wiki/Community | http://trac.mapfish.org/trac/mapfish |
| | |
| **No. #** | **3** |
| Client Name | WebGISPublic |
| Application Focus | RIA, Rich JS Tools |
| OSGeo Project | |
| Scripting Language | JavaScript |
| Software license | GPLv3 |
| Dependency | ExtJS and OpenLayers |
| Layers | OGC(Open Layers) |
| Demo(s) | http://www.wololo.org/webgispublic/example.html |
| URL | http://code.google.com/p/webgispublic/ |
| Wiki/Community | http://code.google.com/p/webgispublic/w/list |
| | |
| **No. #** | **4** |
| Client Name | HSLayers |
| Application Focus | mapping framework |
| OSGeo Project | |
| Scripting Language | JavaScript |
| Software license | GNU/GPL |
| Dependency | ExtJS and OpenLayers |
| Layers | OGC (Open Layers) |
| Demo(s) | |
| URL | http://dev.bnhelp.cz/trac/hslayers |
| Wiki/Community | http://dev.bnhelp.cz/trac/hslayers/wiki/community |

| | |
|---|---|
| **No. #** | **5** |
| Client Name | Mapbender |
| Application Focus | Client Framework for SDI |
| OSGeo Project | Yes |
| Scripting Language | PHP, JavaScript and XML |
| Software license | GNU GPL and Simplified BSD |
| Dependency | |
| Layers | WMS specifications 1.0.0, 1.1.0 and 1.1.1 |
| Demo(s) | http://www.mapbender.org/Demo |
| URL | http://www.mapbender.org/Main_Page |
| Wiki/Community | |
| | |
| **No. #** | **6** |
| Client Name | MapBuilder |
| Application Focus | Rich IDE Mashup of Google and Yahoo Maps |
| OSGeo Project | Yes |
| Scripting Language | JavaScript |
| Software license | Proprietary (Google Maps and Yahoo Maps) but Free except |
| Dependency | Google & Yahoo Maps API |
| Layers | |
| Demo(s) | http://www.mapbuilder.net/realestate/index.php |
| URL | http://www.mapbuilder.net/index.php |
| Wiki/Community | |
| | |
| **No. #** | **7** |
| Client Name | GeoMoose |
| Application Focus | Web Client Javascript Framework |
| OSGeo Project | |
| Scripting Language | JavaScript |
| Software license | MIT |
| Dependency | Mapserver and OpenLayers |
| Layers | WMS , Google, Bing, Yahoo, ArcGIS Server Cache Layers |
| Demo(s) | http://www.geomoose.org/info/demo.html |
| URL | http://www.geomoose.org/index.html |
| Wiki/Community | http://www.geomoose.org/trac |
| | |
| **No. #** | **8** |
| Client Name | GeoExt |
| Application Focus | Desktop style GIS apps on the web |
| OSGeo Project | |
| Scripting Language | JavaScript |
| Software license | Sencha dual License (GPL v3) |
| Dependency | ExtJS and OpenLayers |
| Layers | OGC (OpenLayers) |

| | |
|---|---|
| Demo(s) | http://www.geoext.org/examples.html |
| URL | http://www.geoext.org/ |
| Wiki/Community | |
| **No. #** | **9** |
| Client Name | OpenLayers |
| Application Focus | Dynamic map in any web page |
| OSGeo Project | Yes |
| Scripting Language | JavaScript |
| Software license | BSD-style License |
| Dependency | |
| Layers | OGC WMS and WFS |
| Demo(s) | http://openlayers.org/dev/examples/ |
| URL | http://openlayers.org/ |
| Wiki/Community | http://trac.openlayers.org/ |
| | |
| **No. #** | **10** |
| Client Name | MapFaces |
| Application Focus | Presentation, manipulation, and analysis |
| OSGeo Project | |
| Scripting Language | Java Server Faces (JSF) and JavaScript |
| Software license | GNU LGPL |
| Dependency | Enhanced Geotoolkit library |
| Layers | ISO, OGC (WMS , WCS, SOS) |
| Demo(s) | http://mapfaces.codehaus.org/examples.html |
| URL | http://mapfaces.codehaus.org/ |
| Wiki/Community | http://docs.codehaus.org/display/MAPFACES/home |
| | |
| **No. #** | **11** |
| Client Name | Fusion |
| Application Focus | application development framework |
| OSGeo Project | No |
| Scripting Language | JavaScript |
| Software license | MIT license |
| Dependency | Mapguide, MapServer and Openlayers, |
| Layers | OGC |
| Demo(s) | http://trac.osgeo.org/fusion/wiki/Gallery |
| URL | http://trac.osgeo.org/fusion/ |
| Wiki/Community | http://trac.osgeo.org/fusion/wiki/DevelopersCorner |
| | |
| **No. #** | **12** |
| Client Name | Flamingo |
| Application Focus | interactive map viewer |
| OSGeo Project | |
| Scripting Language | ActionScript (Flash) |
| Software license | GPL2 license |
| Dependency | |
| Layers | WMS, WFS and ESRI ArcXML, ESRI ArcGIS Server |
| Demo(s) | |

| | |
|---|---|
| URL | |
| Wiki/Community | |
| **No.#** | **13** |
| Client Name | I3geo |
| Application Focus | access and analyze spatial data |
| OSGeo Project | |
| Scripting Language | PHP5 |
| Software license | GPL |
| Dependency | MapServer |
| Layers | |
| Demo(s) | http://www.mma.gov.br/sitio/index.php?ido=conteudo.monta&idEstrutura=41 |
| URL | http://pt.wikibooks.org/wiki/I3geo |
| Wiki/Community | http://pt.wikibooks.org/wiki/I3geo |
| | |
| **No.#** | **14** |
| Client Name | Chameleon |
| Application Focus | Distributed, highly configurable |
| OSGeo Project | |
| Scripting Language | JavaScript |
| Software license | OpenSource |
| Dependency | MapServer |
| Layers | WMS and WMT |
| Demo(s) | |
| URL | http://chameleon.maptools.org/index.phtml?page=home.html |
| Wiki/Community | http://chameleon.maptools.org/index.phtml?page=mailinglist.html |
| | |
| **No.#** | **15** |
| Client Name | msCross |
| Application Focus | Namically display geographical information |
| OSGeo Project | |
| Scripting Language | Javascript |
| Software license | |
| Dependency | UMN Mapserver |
| Layers | OGC WMS WFS |
| Demo(s) | |
| URL | http://datacrossing.crs4.it/en_Documentation_mscross.html |
| Wiki/Community | |
| | |
| **No.#** | **16** |
| Client Name | CartoWeb |
| Application Focus | Web-GIS and Customization |
| OSGeo Project | |
| Scripting Language | PHP5 |
| Software license | GPL |
| Dependency | UMN MapServer |
| Layers | OGC WMS WFS |
| Demo(s) | http://www.cartoweb.org/demo.html |
| URL | http://www.cartoweb.org/ |

| | |
|---|---|
| Wiki/Community | http://www.cartoweb.org/cwiki/ |
| **No.#** | **17** |
| Client Name | kvmap |
| Application Focus | eGovernment-purposes |
| OSGeo Project | |
| Scripting Language | PHP |
| Software license | GPL |
| Dependency | UMN - Mapserver, PostgreSQL/PostGIS-databases |
| Layers | WMS, WFS Support |
| Demo(s) | http://sourceforge.net/dbimage.php?id=48703 |
| URL | http://sourceforge.net/projects/kvwmap/ |
| Wiki/Community | |
| | |
| **No.#** | **18** |
| Client Name | ka-map |
| Application Focus | Highly interactive web-mapping interfaces |
| OSGeo Project | |
| Scripting Language | JavaScript |
| Software license | open source |
| Dependency | UMN-MapServer |
| Layers | OGC (MapServer) |
| Demo(s) | |
| URL | http://ka-map.maptools.org/ |
| Wiki/Community | http://ka-map.ominiverdi.org/wiki/index.php/Links_to_some_ka-Map_applications |
| | |
| **No.#** | **19** |
| Client Name | Dracones |
| Application Focus | Public health surveillance |
| OSGeo Project | |
| Scripting Language | Python, PHP and JavaScript |
| Software license | BSD license |
| Dependency | UMN-Mapserver |
| Layers | OGC (MapServer |
| Demo(s) | http://surveillance.mcgill.ca/dracones/examples/index.php |
| URL | |
| Wiki/Community | |
| | |
| **No.#** | **20** |
| Client Name | Gmap |
| Application Focus | Cross-platform map application |
| OSGeo Project | No |
| Scripting Language | C# |
| Software license | GPL |
| Dependency | SQL Lite |
| Layers | Open Street Map |
| Demo(s) | http://sourceforge.net/apps/mediawiki/gmap/index.php?title=File:Screenshot.png |
| URL | http://sourceforge.net/apps/mediawiki/gmap/index.php?title=Main_Page |
| Wiki/Community | http://sourceforge.net/apps/mediawiki/gmap/index.php?title=gmap:Community_Portal |

| | |
|---|---|
| **No.#** | **21** |
| Client Name | p.mapper |
| Application Focus | Broad functionality and multiple configurations |
| OSGeo Project | |
| Scripting Language | PHP/MapScript/ Javascript |
| Software license | GPL |
| Dependency | UMN-Mapserver |
| Layers | |
| Demo(s) | http://www.pmapper.net/demo.shtml |
| URL | http://www.pmapper.net/ |
| Wiki/Community | http://svn.pmapper.net/trac/wiki |
| | |
| **No.#** | **22** |
| Client Name | Geomajas |
| Application Focus | Solutions for businesses and government |
| OSGeo Project | Yes (incubation) |
| Scripting Language | |
| Software license | AGPL v3 |
| Dependency | |
| Layers | |
| Demo(s) | http://apps.geomajas.org/showcase/ |
| URL | http://geomajas.org/ |
| Wiki/Community | http://geomajas.org/forum |
| | |
| **No.#** | **23** |
| Client Name | deegree |
| Application Focus | Professional spatial data infrastructures |
| OSGeo Project | Yes |
| Scripting Language | Java |
| Software license | LGPL |
| Dependency | |
| Layers | OGC (CSW, SOS and WPS) |
| Demo(s) | http://wiki.deegree.org/deegreeWiki/ProductInformation |
| URL | http://wiki.deegree.org/deegreeWiki/FrontPage |
| Wiki/Community | http://wiki.deegree.org/deegreeWiki/iGeoPortal |
| | |
| **No.#** | **24** |
| Client Name | Geoide |
| Application Focus | Web-viewer and web-service |
| OSGeo Project | |
| Scripting Language | ActionScript and Java |
| Software license | LGPL |
| Dependency | degree |
| Layers | WFS, WMS and WCS |
| Demo(s) | |
| URL | http://www.idgis.nl/index.php?option=com_content&task=view&id=42&Itemid=91 |
| Wiki/Community | |
| **No.#** | **25** |

| | |
|---|---|
| Client Name | deegree's iGeoPortal |
| Application Focus | Portals for geodata and services |
| OSGeo Project | No |
| Scripting Language | Java |
| Software license | |
| Dependency | degree |
| Layers | OGC Web Services WFS, WCS, WTS and Gazetteer |
| Demo(s) | http://demo.deegree.org/igeoportal-std/ |
| URL | http://wiki.deegree.org/deegreeWiki/iGeoPortal |
| Wiki/Community | |
| | |
| **No.#** | **26** |
| Client Name | GeoServer |
| Application Focus | Interoperability (any major geospatial data source) |
| OSGeo Project | Yes (incubation) |
| Scripting Language | Java |
| Software license | GPL |
| Dependency | |
| Layers | OGC WMS , WFS/ WFS-T, WCS, KML |
| Demo(s) | |
| URL | http://geoserver.org/display/GEOS/Welcome |
| Wiki/Community | |
| | |
| **No.#** | **27** |
| Client Name | MapGuide |
| Application Focus | Platform for development and deployment |
| OSGeo Project | Yes |
| Scripting Language | PHP, .NET, Java, and JavaScript |
| Software license | LGPL |
| Dependency | |
| Layers | OGC WMS and WFS, ESRI ArcSDE, CAD etc. |
| Demo(s) | http://mapguide.osgeo.org/livegallery.html |
| URL | http://mapguide.osgeo.org/ |
| Wiki/Community | |
| | |
| **No.#** | **28** |
| Client Name | MapServer |
| Application Focus | Server Engine |
| OSGeo Project | Yes |
| Scripting Language | Python, PHP, Java, C# , C and C++ |
| Software license | MIT-style license |
| Dependency | |
| Layers | OGC |
| Demo(s) | |
| URL | http://mapserver.org/ |
| Wiki/Community | |
| **No.#** | **29** |
| Client Name | TimeMap |

| | |
|---|---|
| Application Focus | Interactive Maps |
| OSGeo Project | No |
| Scripting Language | XML and JavaScript, TMJava |
| Software license | Open Source |
| Dependency | |
| Layers | WMS, Time-Stamped Maps,Flash etc. |
| Demo(s) | http://www.timemap.net/index.php?option=com_content&task=view&id=163&Itemid=128 |
| URL | http://www.timemap.net/index.php?option=com_content&task=view&id=51&Itemid=144 |
| Wiki/Community | http://www.timemap.net/index.php?option=com_content&task=view&id=119&Itemid=67 |
| | |
| **No.#** | **30** |
| Client Name | Worldkit |
| Application Focus | Flexible mapping application |
| OSGeo Project | No |
| Scripting Language | SWF based app, configured by XML |
| Software license | GPL v.2 |
| Dependency | |
| Layers | WMS, RSS, etc. |
| Demo(s) | http://worldkit.org/examples.php |
| URL | http://worldkit.org/ |
| Wiki/Community | |
| | |
| **No.#** | **31** |
| Client Name | SLMapViewer |
| Application Focus | map viewer for MapServer |
| OSGeo Project | No |
| Scripting Language | ASP.NET and C# |
| Software license | GPL |
| Dependency | MapServer |
| Layers | MapServer and ESRI's ArcIMS services |
| Demo(s) | http://www.mapoholic.com/slmapview/ |
| URL | http://slmapviewer.codeplex.com/ |
| Wiki/Community | http://slmapviewer.codeplex.com/discussions |
| | |
| **No.#** | **32** |
| Client Name | Modest Maps |
| Application Focus | minimal, extensible, customizable, and free viewer |
| OSGeo Project | No |
| Scripting Language | Action Script |
| Software license | BSD |
| Dependency | |
| Layers | Tile-based maps e.g. NASA Blue Mapple, Yahoo, Bing |
| Demo(s) | http://www.modestmaps.com/example.html |
| URL | http://www.modestmaps.com/ |
| Wiki/Community | |

# Appendix II: Acknowledged Open Source Libraries

**Ext JS Library 3.3.0**

Copyright(c) 2006-2010 Ext JS, Inc.

licensing@extjs.com please see http://www.extjs.com/license

for the full text of the license.

**Ext.ux.form.FileUploadField**

Ext JS Library 3.2.1

Copyright(c) 2006-2010 Ext JS, Inc.

licensing@extjs.com

http://www.extjs.com/license

**Ext.ux.layout.ColumnFitLayout**

author  Ing. Jozef Sakáloš

copyright (c) 2008, Ing. Jozef Sakáloš

version 1.0

revision $Id: Ext.ux.layout.ColumnFitLayout.js 707 2009-05-12 07:03:31Z jozo $

license *Ext.ux.layout.ColumnFitLayout* is licensed under the terms of

License details: <a href="http://www.gnu.org/licenses/lgpl.html"

**FancyBox - simple and fancy jQuery plugin**

Examples and documentation at: http://fancy.klade.lv/

Version: 1.2.1 (13/03/2009)



Requires: jQuery v1.3+

**Flowplayer.js 3.1.1. The Flowplayer API**



Date: 2009-02-25 16:24:29 -0500 (Wed, 25 Feb 2009)

Revision: 166

**GeoExt**



**GeoExt.ux.GoogleEarthClick, GeoExt.ux.Measure, GeoExt.ux.MeasureArea, and GeoExt.ux.MeasureLength**

See http://svn.geoext.org/core/trunk/geoext/license.txt for the full text of the license.

**GeoPlugin**

Author GeoPlugin (gp_support@geoplugin.com)

Copyright geoPlugin (gp_support@geoplugin.com)

GeoPlugin class to geolocate IP addresses using the free PHP Web services of http://www.geoplugin.com/

**Highslide JS**

Version: 4.1.9 (2010-07-05)

Author: Torstein Hønsi

Support: www.highslide.com/support

License: www.highslide.com/#license

**JSON**

http://www.JSON.org/json2.js

2010-08-25

Public Domain. No warranty expressed or implied. Use at your own risk.

See http://www.JSON.org/js.html

**jQuery JavaScript Library v1.3.2**

http://jquery.com/

http://docs.jquery.com/License

Date: 2009-02-19 17:34:21 -0500 (Thu, 19 Feb 2009)

Revision: 6246

**jQuery Easing v1.3**

http://gsgd.co.uk/sandbox/jquery/easing/

Uses the built in easing capabilities added In jQuery 1.1

to offer multiple easing options

TERMS OF USE - jQuery Easing



**MP3 Player**



For commercial use, script at a fee of 15 Euros.

UPDATES 2.0

www.jeroenwijering.com

mail@jeroenwijering.com

**OpenLayers Map Viewer Library**



**Zend Framework**

# Appendix III: CCGIS Documentation

## Package CCGIS Server-Side Classes

### *Class Application_Model_CCGISDB_CCGISConfiguration*

Super Admin CCGIS Configuration Class: Zend_Db Table Data Gateway

### *Class Application_Model_CCGISDB_CCGISDBService*

Coastal Collaborative GIS: DataBase Table Gateway Service Class C-CHANGE Project

**<u>Constructor:</u>**

> *void function*
> *Application_Model_CCGISDB_CCGISDBService::__construct()*

Initialises all CCGISDB Tables, each instance of the Zend table data gateway is stored in the corresponding table class

**<u>acceptTempContribution:</u>**

Accepts temporary contribution [Admin privilege required]

> *boolean function Application_Model_CCGISDB_CCGISDBService::*
> *acceptTempContribution ($tempContId, $fkUserId)*

*Function Parameters:*

> *integer $**tempContId***
> *integer $**fkUserId***

**<u>activateUser:</u>**

Activate a user (admin privilege required) *boolean function Application_Model_CCGISDB_CCGISDBService:: activateUser ($regId, $regSig)*

*Function Parameters:*

*integer **$regId***
*integer **$regSig***

**createNewForumTopic**

Create new forum topic

*boolean function Application_Model_CCGISDB_CCGISDBService:: createNewForumTopic ($newTopicData,$fk_user_id)*

*Function Parameters:*

*array **$newTopicData***
*integer **$fk_user_id***

**deactivateUser:**

Deactivate a user (admin privilege required)

*boolean function Application_Model_CCGISDB_CCGISDBService:: deactivateUser ($regId, $regSig)*

*Function Parameters:*

*integer **$regId***
*string **$regSig***

**deleteCCUser:**

Delete ccUser [Administrator privilege required]

*integer function Application_Model_CCGISDB_CCGISDBService:: deleteCCUser ($user_id)*

*Function Parameters:*

*integer **$user_id***

**deleteCCUserAddress:**

Delete ccUser Profile

> *integer function Application_Model_CCGISDB_CCGISDBService:: deleteCCUserAddress ($address_id)*

*Function Parameters:*

> *integer **$address_id***

**deleteSpatialContribution:**

Delete spatial contribution

> *integer function Application_Model_CCGISDB_CCGISDBService:: deleteSpatialContribution ($cont_id)*

*Function Parameters:*

> *integer **$cont_id***

**deleteTempSpatialContribution:**

Delete temporary spatial contribution

> *boolean function Application_Model_CCGISDB_CCGISDBService:: deleteTempSpatialContribution ($temp_cont_id)*

*Function Parameters:*

> *integer **$temp_cont_id***

**evaluateCCGIS:**

Evaluate CCGIS

> *boolean function Application_Model_CCGISDB_CCGISDBService:: evaluateCCGIS ($data)*

*Function Parameters:*

> *array $**data***

**getAllCCUsers:**

Fetch all users order by first name

*array function Application_Model_CCGISDB_CCGISDBService:: getAllCCUsers ($condition)*

*Function Parameters:*

*string* ***$condition***

**getAllCCUsersAddress:**

Fetch all user addresses order by city

*array function Application_Model_CCGISDB_CCGISDBService:: getAllCCUsersAddress ()*

**getAllSpatialContributions:**

Get all  public available spatial data

*array function Application_Model_CCGISDB_CCGISDBService:: getAllSpatialContributions ($columnNames)*

*Function Parameters:*

*string* ***$columnNames***

**getAllTempSpatialContributions:**

Fetch all temporary spatial contributions order by temp contribution id

*array function Application_Model_CCGISDB_CCGISDBService:: getAllTempSpatialContributions ()*

**getCCUser:**

Find a user by id

*array function Application_Model_CCGISDB_CCGISDBService::*

*getCCUser ($user_id)*

*Function Parameters:*

*integer **$user_id***

**<u>getCCUserAddress:</u>**

Find record by user id

*array function Application_Model_CCGISDB_CCGISDBService:: getCCUserAddress ($fk_user_id)*

*Function Parameters:*

*integer **$fk_user_id***

**<u>getCCUserByName:</u>**

Find *ccUser* by *firstName*

*array function Application_Model_CCGISDB_CCGISDBService:: getCCUserByName ($fname)*

*Function Parameters:*

*string **$fname***

**<u>getCMSSpatialQuery:</u>**

Get Spatial Query [CMS - Admin] Throws Exception date range not set

*array function Application_Model_CCGISDB_CCGISDBService:: getCMSSpatialQuery ($columnNames,$queryParams)*

*Function Parameters:*

*string **$columnNames***
*array **$queryParams***

**<u>getFeatureReputation:</u>**

Get feature reputation

*string function Application_Model_CCGISDB_CCGISDBService::*
*getFeatureReputation ($rep_data, $columnNames)*

*Function Parameters:*

*array* ***$rep_data***
*string* ***$columnNames***

**<u>getForumRecord:</u>**

Get forum data by id

*array function Application_Model_CCGISDB_CCGISDBService::*
*getForumRecord ($forum_id)*

*Function Parameters:*

*Integer* ***$forum_id***

**<u>getForumRecordsQuery:</u>**

Get forum data by query

*array function Application_Model_CCGISDB_CCGISDBService::*
*getForumRecordsQuery ($columnNames, $queryParams)*

*Function Parameters:*

*string* ***$columnNames***
*array* ***$queryParams***

**<u>getIndexSpatialQuery:</u>**

Get Spatial Query [Index - Main Page] Throws Exception date range not set

*array function Application_Model_CCGISDB_CCGISDBService::*
*getIndexSpatialQuery ($columnNames,*
*$queryParams)*

*Function Parameters:*

> *string* ***$columnNames***
> *array* ***$queryParams***

**getProfileSpatialContributionByUserID:**

Get user spatial contribution profile by id

> *array function Application_Model_CCGISDB_CCGISDBService::*
> *getProfileSpatialContributionByUserID ($fk_user_id)*

*Function Parameters:*

> *integer $**fk_user_id***

**getSpatialContribution:**

Find record by contribution id and column names

> *array function Application_Model_CCGISDB_CCGISDBService::*
> *getSpatialContribution ($cont_id, [$columnNames = 'notset'])*

*Function Parameters:*

> *integer $**cont_id***
> *string* ***$columnNames***

**getTempSpatialContribution:**

Find record by temporary contribution id

> *array function Application_Model_CCGISDB_CCGISDBService::*
> *getTempSpatialContribution ($temp_cont_id)*

*Function Parameters:*

> *integer* ***$temp_cont_id***

**getWhereForumFieldIsEqualTo:**

Quote into SQL id value for *where* clause

> *string function Application_Model_CCGISDB_CCGISDBService::*
> *getWhereForumFieldIsEqualTo ($forumField, $filedValue)*

*Function Parameters:*

> *string **$forumField***
> *dynamic $**filedValue***

**getWhereIdIsEqualto:**

Quote into SQL id value for where clause function (user table)

> *string function Application_Model_CCGISDB_CCGISDBService::*
> *getWhereIdIsEqualto ($idField, $idValue*

*Function Parameters:*

> *string **$idField***
> *integer $**idValue***

**getWhereSpatialFieldIsEqualTo:**

Quote into SQL query string: id value for where clause

> *void function Application_Model_CCGISDB_CCGISDBService::*
> *getWhereSpatialFieldIsEqualTo ($spatialField,$filedValue)*

*Function Parameters:*

> *integer **$spatialField***
> *string **$filedValue***

**newCCUser:**

Create new *ccUser* (admin privilege is required to Commit Registration)

> *integer function Application_Model_CCGISDB_CCGISDBService::*

*newCCUser ($fname, $lname, $username, $password, $salt, $role, $date, $active, $email)*

*Function Parameters:*

*string **$fname***
*string $**lname***
*string $**username***
*string $**password***
*string $**salt***
*string $**role***
*date $**date***
*integer $**active***
*string **$email***

**<u>newccUserAddress:</u>**

Create new user address (foreign key constraint - user id)

*integer function Application_Model_CCGISDB_CCGISDBService:: newccUserAddress ($street_name, $apartment_number, $city, $province_or_region, $country, $fk_user_id)*

*Function Parameters:*

*string **$street_name***
*integer **$apartment_number***
*string $**city***
*string **$province_or_region***
*string $**country***
*integer $**fk_user_id***

**<u>newSpatialContribution:</u>**

Create a new spatial contribution

*boolean function Application_Model_CCGISDB_CCGISDBService:: newSpatialContribution ($json_feature, $forum_thread, $fk_user_id, $meta_files, $meta_date_created, $meta_time_created, $meta_event_date, $meta_event_title, $meta_event_time, $meta_event_rank, $meta_event_damage_estimate, $meta_event_description, $meta_affirmations, $meta_rep_concur , $meta_rep_concur)*

*Function Parameters:*

> *json* ***$json_feature  string***
> *string* ***$forum_thread***
> *integer $**fk_user_id***
> *string $**meta_files***
> *date* ***$meta_date_created***
> *time* ***$meta_time_created***
> *date* ***$meta_event_date***
> *string* ***$meta_event_title***
> *time* ***$meta_event_time***
> *integer* ***$meta_event_rank***
> *integer* ***$meta_event_damage_estimate***
> *string* ***$meta_event_description***
> *string* ***$meta_affirmations***
> *timestamp* ***$meta_rep_concur***

**<u>newTempSpatialContribution:</u>**

Create new temporary spatial contribution

> *boolean function Application_Model_CCGISDB_CCGISDBService:: newTempSpatialContribution ($json_feature, $forum_thread, $fk_user_id)*

*Function Parameters:*

> *string* ***$json_feature***
> *string* ***$forum_thread***
> *integer $**fk_user_id***

**<u>rejectTempContribution:</u>**

Reject temporary contributions. Throws Exception *id* is not set

> *boolean function Application_Model_CCGISDB_CCGISDBService:: rejectTempContribution ($tempContId, $fkUserId)*

*Function Parameters:*

> *integer $**tempContId***
> *integer $**fkUserId***

**<u>saveCCUserAddress:</u>**

Update or Save *ccUser* Address

> *integer function Application_Model_CCGISDB_CCGISDBService::*
> *saveCCUserAddress ($address_id, $street_name, $apartment_number,*
> *$city, $province_or_region, $country, $fk_user_id)*

*Function Parameters:*

> *integer $**address_id***
> *string **$street_name***
> *integer **$apartment_number***
> *string $**city***
> *string **$province_or_region***
> *string $**country***
> *integer $**fk_user_id***

**<u>saveProfileCCUser:</u>**

Update or save user profile details

> *boolean function Application_Model_CCGISDB_CCGISDBService::*
> *saveProfileCCUser ($user_id, $fname, $lname, $email, $occupation,*
> *$mobile, $fax, $biography, $ProfAddress)*

*Function Parameters:*

> *integer $**user_id***
> *string $**fname***
> *string $**lname***
> *string $**email***
> *string **$occupation***
> *string $**mobile***
> *string $**fax***
> *string $**biography***
> *string **$ProfAddress***

**saveSpatialContribution:**

Save or Update spatial contribution [Administrator privilege required]

> *integer function Application_Model_CCGISDB_CCGISDBService:: saveSpatialContribution ($cont_id, $json_feature, $forum_thread, $fk_user_id)*

*Function Parameters:*

> *integer $**cont_id***
> *string **$json_feature***
> *string **$forum_thread***
> *integer $**fk_user_id***

**saveTempSpatialContribution:**

Save or Update temporary spatial contribution

> *integer function Application_Model_CCGISDB_CCGISDBService:: saveTempSpatialContribution ($temp_cont_id, $json_feature, $forum_thread, $fk_user_id)*

*Function Parameters:*

> *integer **$temp_cont_id***
> *string **$json_feature***
> *string **$forum_thread***
> *integer $**fk_user_id***

**setFeatureReputation:**

Set feature reputation

> *boolean function Application_Model_CCGISDB_CCGISDBService:: setFeatureReputation ($rep_data, $columnNames)*

*Function Parameters:*

> *array **$rep_data***
> *string **$columnNames***

**updateNewForumComment:**

Update forum comment

> *boolean function Application_Model_CCGISDB_CCGISDBService:: updateNewForumComment ($newCommentData, $forum_topic_id)*

*Function Parameters:*

> *array **$newCommentData***
> *integer **$forum_topic_id***

**updateUserContProfile**

Update the number of contribution of users

> *array function Application_Model_CCGISDB_CCGISDBService:: updateUserContProfile ($user_id, $cont_id)*

*Function Parameters:*

> *integer **$cont_id***
> *integer **$user_id***

**updateUserMedalsProfile:**

Update the medals for a user (reputation index)

> *integer function Application_Model_CCGISDB_CCGISDBService:: updateUserMedalsProfile ($user_id, $cont_id)*

*Function Parameters:*

> *integer $**cont_id***
> *integer **$user_id***

***Class Application_Model_CCGISDB_EvaluateCCGIS***

***Class Application_Model_CCGISDB_ImageUtil***

---

Image Utility Functions. Author: Titus Tienaah [2010] after Simon Jarvis [2006] GPL

String image property

*Application_Model_CCGISDB_ImageUtil::**$image***

String const Image Type Constant

*Application_Model_CCGISDB_ImageUtil::**$image_type***

**getHeight:**

Get Image Height

*integer function Application_Model_CCGISDB_ImageUtil::*
*getHeight ()*

**getWidth:**

Get Image Width

*integer function Application_Model_CCGISDB_ImageUtil::*
*getWidth ()*

**load:**

Load image

*void function Application_Model_CCGISDB_ImageUtil::*
*load ($filename)*

*Function Parameters:*

*string $**filename***

**<u>output:</u>**

Image Output function

*void function Application_Model_CCGISDB_ImageUtil::*
*output ([$image_type = IMAGETYPE_JPEG])*

*Function Parameters:*

*const string **$image_type***

**<u>resize:</u>**

Resize image to a specified width and height

*void function Application_Model_CCGISDB_ImageUtil::resize*
*($width, $height)*

*Function Parameters:*

*integer $**width***
*integer $**height***

**<u>resizeToHeight:</u>**

Resize to a Height value keeping aspect ratio

*void function Application_Model_CCGISDB_ImageUtil::*
*resizeToHeight ($height)*

*Function Parameters:*

*integer $**height***

**<u>resizeToWidth:</u>**

Resize to a Width value keeping aspect ratio

*void function Application_Model_CCGISDB_ImageUtil::
resizeToWidth ($width)*

*Function Parameters:*

*integer $**width***

**save:**

Save image

*void function Application_Model_CCGISDB_ImageUtil::
save ($filename, [$image_type = IMAGETYPE_JPEG],[$compression = 75], [$permissions = null])*

*Function Parameters:*

*string $**filename***
*const **$image_type string***
*integer **$compression***
*object/string $**permissions***

**scale:**

Scale image

*void function Application_Model_CCGISDB_ImageUtil::scale ($scale)*

*Function Parameters:*

*integer/float **$scale***

***Class Application_Model_CCGISDB_SpatialContribution***

Spatial_Contribution Table Class: Zend_Db Table Data Gateway C-CHANGE Project [ICURA] 2010. Package CCGIS Author. Titus Tienaah

***Class Application_Model_CCGISDB_SpatialForum***

Spatial_Forum Table Class: Zend_Db Table Data Gateway C-CHANGE Project [ICURA]. Package CCGIS.Author Titus Tienaah

***Class Application_Model_CCGISDB_TempSpatialContribution***

Temp_Spatial_Contribution Table Class: Zend_Db Table Data Gateway C-CHANGE Project [ICURA] 2010.Package CCGIS. Author Titus Tienaah

***Class Application_Model_CCGISDB_Uploads***

Upload Utility Class and Functions ICURA - C-Change Project [2010].Package CCGIS Author Titus Tienaah

**__construct:**

Constructor:[no arguments] creates resources and initializes root directories

*Constructor void function Application_Model_CCGISDB_Uploads::__construct ()*

**copyFile:**

Copy file from target to destination

> *boolean function Application_Model_CCGISDB_Uploads::*
> *copyFile ($targetPath, $destinationPath)*

*Function Parameters:*

> *string* ***$targetPath***
> *string* ***$destinationPath***

**create_storage_space:**

Creation of resource directories for file management

> *void function Application_Model_CCGISDB_Uploads::*
> *create_storage_space ()*

**fileUpload:**

Upload function. Used after resource directories are created

> *array function Application_Model_CCGISDB_Uploads::*
> *fileUpload ()*

**mkdir_recursive:**

Make directory recursive function

> *boolean function Application_Model_CCGISDB_Uploads::*
> *mkdir_recursive ($pathname, $mode)*

*Function Parameters:*

> *string $****pathname***
> *integer $****mode***

***Class Application_Model_CCGISDB_User***

CCUser Table Class : Zend_Db Table Data Gateway. C-CHANGE Project [ICURA] 2010. Package CCGIS. Author Titus Tienaah

***Class Application_Model_CCGISDB_UserAddress***

CCUser Address Table Class : Zend_Db Table Data Gateway. C-CHANGE Project [ICURA].Package CCGIS. Author Titus Tienaah

***Class Bootstrap***

Coastal Collaborative GIS BootStrap :: Zend_Application_Bootstrap_Bootstrap C-CHANGE Project [ICURA] 2010. Package CCGIS. Author Titus Tienaah

**_initRoutes:**

Routes manager

*void function Bootstrap::_initRoutes ()*

***Class ccGeoLocation***

---

Package CCGIS. Author Titus Tienaah after GeoPlugin (gp_support@geoplugin.com)

Version 1.01. Copyright GeoPlugin (gp_support@geoplugin.com)

Area code

*ccGeoLocation::**$areaCode***
*mixed = null*

City name

*ccGeoLocation::$city*
*mixed = null*

Continent code

*ccGeoLocation::**$continentCode***
*mixed = null*

Country code

*ccGeoLocation::**$countryCode***
*mixed = null*

Country name

*ccGeoLocation::**$countryName***
*mixed = null*

Default base currency

*ccGeoLocation::**$currency***
*string = CAD*

Currencey Code

*ccGeoLocation::**$currencyCode***
*mixed = null*

Currency converter

*ccGeoLocation::$currencyConverter*
*mixed = null*

Currency symbol

*ccGeoLocation::**$currencySymbol***
*mixed = null [line 1452]*

DMA code

*ccGeoLocation::**$dmaCode***
*mixed = null*

GeoPlugin Server

*ccGeoLocation::**$host***
*string = http://www.geoplugin.net/php.gp?*
*ip={IP}&base_currency={CURRENCY}*

IP address

*ccGeoLocation::**$ip***
*mixed = null*

Latitide coordinates

*ccGeoLocation::**$latitute***
*mixed = null*

Longitude coordinates

*ccGeoLocation::**$longitude***
*mixed = null*

Region name

*ccGeoLocation::**$region***
*mixed = null*

**<u>convert:</u>**

Currency converter

*number function ccGeoLocation::convert ($amount, [$float = 2], [$symbol = true])*

*Function Parameters:*

*number $**amount***
*integer $**float***
*boolean $**symbol***

**<u>fetch:</u>**

Fetch host

*mixed function ccGeoLocation::fetch ($host)*

*Function Parameters:*

*string $**host***

**locate:**

Locate geographic location by IP address

*void function ccGeoLocation::locate ([$ip = null])*

*Function Parameters:*

*mixed $**ip***

**nearby:**

Nearby places

*array function ccGeoLocation::nearby ([$radius = 10], [$limit = null])*

*Function Parameters:*

*integer **$radius***
*number $**limit***

***Class ErrorController***

---

Error Controller : Zend_Controller_Action . C-CHANGE Project [ICURA] 2010. Package CCGIS. Author Titus Tienaah.

**errorAction:**

Error Action

*void function ErrorController::errorAction ()*

**getLog:**

Get error Log

*log function ErrorController::getLog ()*

***Class IndexController***

Package CCGIS.

**ccgisAction:**

CCGIS Action (Spatial Content Creation and Editing Action)

*json function IndexController::ccgisAction ()*

**cmsAction:**

Content Management Action [Used by only Administrator]

*json function IndexController::cmsAction ()*

**forumAction:**

Entrance into public interface of CCGIS forum page

*json function IndexController::forumAction ()*

**indexAction:**

Entrance into public interface of CCGIS Index Action controls public/home requests

*json function IndexController::indexAction ()*

**init:**

See Zend_Controller_Action::init()

*void function IndexController::init ()*

**logoutAction:**

User Logout Action (Clears user preferences)

*void function IndexController::logoutAction ()*

**preDispatch:**

See Zend_Zend_Controller_Action::preDispatch();

*void function IndexController::preDispatch ()*

**profileAction:**

User Profile Action (User Details)

*json function IndexController::profileAction ()*

**_acceptUserContribution**

Utility Function: Accept user contribution

*boolean function IndexController::_acceptUserContribution ($contId, $contSig)*

*Function Parameters:*

*integer $**contId***
*integer $**contSig***

**_activateRegisteredUser:**

Utility Function: Activate registered user

> *array function IndexController::_activateRegisteredUser ($regId, $regSig)*

*Function Parameters:*

> *integer $**regId***
> *integer $**regSig***

**_addUser:**

Utility Function: Add New User

> *boolean function IndexController::_addUser ($regData)*

*Function Parameters:*

> *array $regData*

**_ccContributionUpload:**

Utility Function: Upload user contribution

> *array function IndexController::*
> *_ccContributionUpload ($ccUploadSpatialData)*

*Function Parameters:*

> *array $ccUploadSpatialData*

**_checkRegistration:**

Utility Function: Validate registration entries

> *boolean function IndexController::_checkRegistration ($regvalue)*

*Function Parameters:*

> *array $**regvalue***

**_createNewForumComment:**

Utility Function: Create new forum comment

> *boolean function IndexController::*
> *_createNewForumComment ($commentData, $topicData)*

*Function Parameters:*

> *string $**topicData***
> *string **$commentData***

**_createNewForumTopic:**

Utility Function: Create new forum topic

> *boolean function IndexController::*
> *_createNewForumTopic ($topicData)*

*Function Parameters:*

> *string $**topicData***

**_deactivateRegisteredUser:**

Utility Function: Deactivate registered user

> *array function IndexController::_deactivateRegisteredUser($regId,*
> *$regSig)*

*Function Parameters:*

> *integer $**regId***
> *integer $**regSig***

**_deleteUser:**

Utility Function: Delete user

> *integer function IndexController::_deleteUser ()*

**_getAuthAdapter:**

Utility Function: Get authentication adapter

*auth function IndexController::_getAuthAdapter()*

**_getCmsSpatialQuery:**

Utility Function: Get CMS spatial query

*array function IndexController::_getCmsSpatialQuery ($queryParams, $columnNames)*

*Function Parameters:*

*array* ***$queryParams***
*string* ***$columnNames***

**_getFeatureReputation:**

Utility Function: Get Feature Reputation

*boolean function IndexController::_getFeatureReputation ($getReputeData)*

*Function Parameters:*

*string* ***$getReputeData***

**_getForumTopicsByContId:**

Utility Function: Get forum topic by contribution id

*boolean function IndexController::_getForumTopicsByContId ($queryData)*

*Function Parameters:*

*string **$queryData***

**_getIndexSpatialData:**

Utility Function: Get spatial data given list of columns

> *array function IndexController::_getIndexSpatialData ($columnNames)*

*Function Parameters:*

> *string **$columnNames***

**_getIndexSpatialQuery:**

Utility Function: Get spatial data : Get spatial data given list of columns

> *array function IndexController:: _getIndexSpatialQuery ($queryParams, $columnNames)*

*Function Parameters:*

> *array **$queryParams***
> *string **$columnNames***

**_getNewSpatialContributions:**

Utility Function: Get New all new spatial contributions

> *array function IndexController::_getNewSpatialContributions ()*

**_getNewUserRequests():**

Utility Function: Admin CMS: get new user requests

> *boolean function IndexController::_getNewUserRequests ()*

**_getProfileContributionsData:**

Utility Function: Get all contributions of the user (temp and accepted)

*array function IndexController::_getProfileContributionsData ()*

**_getProfileData:**

Utility Function: Get user profile data

*array function IndexController::_getProfileData()*

**_postReview:**

Utility Function : Post CCGIS Evaluation

*boolean function IndexController::_postReview($postReview)*

*Function Parameters:*

*array* ***$postReview***

**_processLogin:**

Utility Function: Process login

*boolean function IndexController::_processLogin($values)*

*Function Parameters:*

*array $**values***

**_rejectUserContribution:**

Utility Function: Reject user contribution

*boolean function IndexController::_rejectUserContribution ($contId, $contSig)*

*Function Parameters:*

*integer $**contId***
*integer $**contSig***

**_saltgen:**

Utility Function: Salt generator

*random function IndexController::_saltgen()*

**_setFeatureReputation**

Utility Function: Set feature reputation

*boolean function IndexController::_setFeatureReputation ($setReputeData)*

*Function Parameters:*

*string **$setReputeData***

**_updateProfile:**

Utility Function:  Update Profile Information

*boolean function IndexController::_updateProfile ($postData, $authId)*

*Function Parameters:*

*array $**postData***
*integer $**authId***

***Class Logging***

---

Package CCGIS.

**Lopen:**

Open Log File

*void function Logging::lopen ()*

**lwrite:**

Write to log file

*void function Logging::lwrite ($message)*

*Function Parameters:*

*string $**message***

**Client-Side Map Creation JavaScript Functions**

**<u>Properties</u>**

Static *Object* popup

*Global: pop up window { object } popup*

Static *Array* filesUploaded

*Global: files uploaded array { array } filesUploaded*

Static *Boolean* someFeaturesTimeDateNotSet

*Global: true/false upload test { boolean } filesUploaded*

Static *String* attributeMapping.attributeMapping

*Global: attribute mapping to the various Ext Cmponents { object } attributeMapping*

Static *String* attributeMapping.attributeMapping

*Global: attribute mapping to the various Ext Cmponents { object } attributeMapping*

Static *Object* fillColorCmp

*Global: fill color component { object } fillColorCmp*

Static *Object* lineColorCmp

*Global: line color component { object } fillColorCmp*

**<u>Functions</u>**

*ccMapControls(String layerName) : static json*

Creates and returns a JSON object of OpenLayers map controls

*String layerName*

*ccToggleControls(Object controlName) : static void*

Map control toggle: turns on/off a control (call-back function)

*Object controlName*

*featureSettings(String cc_layerName) : static void*

Creates output formats from features on the map. Post method is then called to deliver features to the server

*String cc_layerName*

*selectStyleFeature(Object feature) : static void*

Selected feature call-back function

*Object feature*

*unselectStyleFeature(Object feature) : static void*

Utility function when feature is unselected, manages style

*Object feature*

*updateRenderColorComponents() : static void*

Utility function update fill and line colour ext text field ux components

*styleEditor(Object featureStyle) : static void*

Used to set feature styles in editable text fields

| | |
|---|---|
| *Object* | *featureStyle* |

*propertyEditor(Object feature) : static void*

Assign properties to form elements for editing

| | |
|---|---|
| *Object* | *feature* |

*redrawLayer(Object featureName) : static void*

Redraw layer

| | |
|---|---|
| *Object* | *featureName* |

*cleanupObjSettings() : static void*

Reset text fields: garbage collection

*addFeatures(Object vectorLayersObject) : static void*

Add features to map window

| | |
|---|---|
| *Object* | *vectorLayersObject* |

*postccGISData(Object postData) : static void*

Post spatial data to server function

| | |
|---|---|
| *Object* | *postData* |

*postData(Object postType, Object formObj) : static void*

Post data to server function

| | |
|---|---|
| *Object* | *postType* |

*Object    formObj*

*attributeMonitoring(String featureType) : static void*

Monitoring function for feature attribute editing

*String    featureType*

*uploadWin() : static void*

Multimedia upload window

*refreshUploads(String refreshType) : static void*

Reset uploads function (new or clean)

*String    refreshType*

*ccToolbars() : static Array*

Creates and returns a toolbar collection

*ccViews() : static Array*

Creates and returns the page views (panels) and sub containers

**Client-Side Content Management System Functions**

**Properties**

Static *Object* popup

*Global: pop up window { object } popup*

Static *Array* popupList

*Global: popup list { array } popupList*

Static *Array* popupDescList

*Global: pop up description list { array } popupDescList*

Static *Object* myTpl

*Global: formating template { object } myTpl*

**Functions**

*cmsLayers () : static*

CMS layers generator

*ccMapControls (String layerName) : static json*

Creates and returns a JSON object of OpenLayers map controls

| | |
|---|---|
| *String* | *layerName* |

*featureSettings (String cc_layerName) : static void*

Creates output formats from features on the map. post method is then called to deliver features to the server

| | |
|---|---|
| *String* | *cc_layerName* |

*selectStyleFeature (Object feature) : static void*

Selected feature call back function, manages selection, unselect and selected feature popup window (attribute window)

```
Object    feature
```

*unselectStyleFeature (Object feature) : static void*

Utility function when feature is unselected, manages style and pop up window

```
Object    feature
```

*redrawLayer (String featureName) : static void*

Redraw layer function based on feature layer name

```
String    featureName
```

*addFeatures (json feature_collection, String cc_type) : static void*

Add features function to map, accepts a collection of layers (json) with open layers supported formats

```
json      feature_collection
String    cc_type
```

*postData (String postType, json formObj) : static void*

Post data to server function

```
String    postType
json      formObj
```

*queryMap (String section) : static*

Map query utility function

| | |
|---|---|
| *String* | *section* |

*createPopupWin (Object feature, Object vectorLayer) : static void*

Pop up window function, requires a selected feature and the layer name

| | |
|---|---|
| *Object* | *feature* |
| *Object* | *vectorLayer* |

*getCMSViews () : static Array*

Creates and returns the CMS page views (panels) and sub containers

*cmsToolbars () : static Array*

Creates and returns a toolbar collection

**Client-Side CCGIS Actions (Common Functions)**

**Properties**

Static *Object* cc_Formats

Global: formats for datatypes { object } cc_Formats

Static *Object* selStyle

Global: selected feature style { object } selStyle

Static *Object* unselStyle

Global: unselected feature style { object } unselStyle

Static *Object* curSelectedFeature

Global: current selected feature { object } curSelectedFeature

Static *Object* selFeatureID

Global: selected feature id { object } selFeatureID

Static *Array* formatTypes

Global : formatTypes [ "geojson","atom","kml","georss","gml2","gml3","wkt" ] { array } formatTypes

Static *Array* stokeLineStyles

*Global: stokeLineStyles [ "solid","dot","dash","dashdot", "longdash","longdashdot" ] { array } stokeLineStyles*

static *Object* cc_deafaultStyle

*Global: OpenLayers feature style { object } cc_deafaultStyle*

Static *json* Ext.feedback.feedback

*Feedback function*

**Functions**

*ccInit() : static Array*

Initialize function

*isEmpty (Object ob) : static Boolean*

Checks if an object is empty

| | |
|---|---|
| *Object* | *ob* |

*getTimeStamp (Object xDate) : static Date*

Get the time stamp of a given date

| | |
|---|---|
| *Object* | *xDate* |

*isArray (Object obj) : static Boolean*

Check if a feature is an array or object

| | |
|---|---|
| *Object* | *obj* |

*trim (String stringToTrim) : static String*

Trim string of white space (left and right)

| | |
|---|---|
| *String* | *stringToTrim* |

*ltrim (String stringToTrim) : static String*

Trim string of white space (left)

| | |
|---|---|
| *String* | *stringToTrim* |

*rtrim (String stringToTrim) : static String*

Trim string of white space (right)

| | |
|---|---|
| *String* | *stringToTrim* |

*timeStampToDate (Number unix_timestamp) : static Date*

Converts UNIX timestamp to date

| | |
|---|---|
| *Number* | *unix_timestamp* |

*convertFormat2Object*
*(Object pre_ccOutput, Object cc_type) : static jsonxml*

Converts a data (string output and type ) format (JSON and xml) to JavaScript object

| | |
|---|---|
| *Object* | *pre_ccOutput* |
| *Object* | *cc_type* |

*getFeatureStyle (Object feature) : static Object*

Get selected feature style

| | |
|---|---|
| *Object* | *feature* |

*setFeatureStyle (Object setStyle) : static void*

Set selected feature style

| | |
|---|---|
| *Object* | *setStyle* |

*ccLayers (String layerName) : static json*

Map Layers generating function

| | |
|---|---|
| *String* | *layerName* |

*waitFeedback (Object msg, Object title) : static*

Progress bar animation window

| | |
|---|---|
| *Object* | *msg* |
| *Object* | *title* |

*cleanFeaturePreviewGlobals () : static void*

Clean Global Variables

*sliderNavigator () : static void*

Slider Navigator

*featureAddRemoveNavigation (Number curThumbValue) : static void*

Feature cluster navigation add/remove given current index value

| | |
|---|---|
| *Number* | *curThumbValue* |

*removeTrailingFeatures () : static void*

Feature cluster remove trailing features add/remove given current index value

*featuresInBounds () : static void*

Feature cluster: features within the a given bounds

*addFeaturesToMap*
*(String layerNames, Array featureArray) : static void*

Feature cluster: add features to map

| | |
|---|---|
| *String* | *layerNames* |
| *Array* | *featureArray* |

*removeFeaturesFromMap*
*(String layerNames, Array featureArray) : static void*

Feature cluster: remove features from map

| | |
|---|---|
| *String* | *layerNames* |

| | |
|---|---|
| *Array* | *featureArray* |

*sliderIndex () : static void*

Feature cluster: slider index

*_12to24 (Object _12var) : static Number*

Feature cluster: converts 12hour time to 24 hour time

| | |
|---|---|
| *Object* | *_12var* |

*sortIndexOfObj (Object o) : static Array*

Feature cluster: sort the index of JavaScript object

| | |
|---|---|
| *Object* | *o* |

*quickSortedObjAccess (Array b) : static Object*

Feature cluster: quick object sort (input array to object) with additional info

| | |
|---|---|
| Array | b |

*ccToggleControls (String controlName) : static void*

Map control activator (on/off function)

| | |
|---|---|
| *String* | *controlName* |

*zoomToolbar (String arg, Object controlObj) : static void*

Zoom toolbar callback function

| | |
|---|---|
| *String* | *arg* |

| | |
|---|---|
| *Object* | *controlObj* |

*updateFormats (json proJ) : static void*

Update data format function

| | |
|---|---|
| *json* | *proJ* |

*ccNavigation (String pageName) : static void*

Page navigation function

| | |
|---|---|
| *String* | *pageName* |

*ReviewCCGIS (String varReview) : static void*

Evaluation window function

| | |
|---|---|
| String | varReview |

*helpWin (String argType) : static void*

Help function

| | |
|---|---|
| *String* | *argType* |

*Ext.feedback () : static json*

Feedback function

**Client-Side Forum JavaScript Documentation**

**Properties**

Static *Object* gridStoreNew

*Global: registration window { object } registerWindow*

Static *Array* popupList

*Global: popup list { array } popupList*

Static *Array* popupDescList

*Global: pop up description list { array } popupDescList*

Static *Boolean* boolAffirmRep

*Global: bool affirm contribution { bool } boolAffirmRep*

Static *Boolean* boolNegReg

*Global: bool negate contribution { bool } popupDescList*

Static *Object* commentsContainer

*Global: comments container { object } popupDescList*

**Functions**

*ccIndexMapControls (String layerName) : static json*

Creates and returns a JSON object of OpenLayers map controls

| | |
|---|---|
| *String* | *layerName* |

*selectStyleFeature (Object feature) : static void*

Selected feature call back function, manages selection, unselect and selected feature popup window (attribute window)

| | |
|---|---|
| *Object* | *feature* |

*unselectStyleFeature (Object feature) : static void*

Utility function when feature is unselected, manages style and pop up window

| | |
|---|---|
| *Object* | *feature* |

*redrawLayer (String featureName) : static void*

Redraw layer function based on feature layer name

| | |
|---|---|
| *String* | *featureName* |

*addFeatures (json feature_collection, String cc_type) : static void*

Add features to map, accepts a collection of layers (JSON) with open layers supported formats

| | |
|---|---|
| json | feature_collection |
| String | cc_type |

*postData (String postType, json formObj) : static void*

Post data to server function

| | |
|---|---|
| *String* | *postType* |
| *json* | *formObj* |

*createPopupWin (Object feature, Object vectorLayer) : static void*

Pop up window function, requires a selected feature and the layer name

| | |
|---|---|
| Object | feature |
| Object | vectorLayer |

*queryMap () : static void*

Map query utility function

*commentGen*
*(String title, String htmlContent, Number commentID) : static json*

Comments generator

| | |
|---|---|
| *String* | *title* |
| *String* | *htmlContent* |
| *Number* | *commentID* |

*topicTitleGen (String htmlContent) : static json*

Topic title generator

| | |
|---|---|
| *String* | *htmlContent* |

*postNewComment (json postnewComment) : static void*

Post new comment

| | |
|---|---|
| json | postnewComment |

*postNewTopic (json newTopic) : static void*

Post new topic

| | |
|---|---|
| *json* | *newTopic* |

*reconfigureForumGrid (json local_queryResult) : static*

Reconfigure forum grid

| | | |
|---|---|---|
| *json* | *local_queryResult* | *return { void }* |

*utilRepHadles (Object data) : static void*

Utility function (enable or disable affirm/negation)

| | |
|---|---|
| *Object* | *data* |

*topic_comment_Gen*
*(Object topicSelectedObject, Object commentsThreadObject):*
*static void*

Topic comment generator function

| | |
|---|---|
| *Object* | *topicSelectedObject* |
| *Object* | *commentsThreadObject* |

*ccIndexToolbars () : static Array*

Creates and returns a toolbar collection

*ccViews () : static Array*

Creates and returns the forum page views (panels) and sub containers

**Client Side Homepage JavaScript Documentation**

**Properties**

Static *Object* loginWindow

*Global : login window { object } loginWindow*

Static *Object* registerWindow

*Global: registration window { object } registerWindow*

static *Array* popupList

*Global : popup list { array } popupList*

Static *Array* popupDescList

*Global: pop up description list { array } popupDescList*

**Functions**

*ccIndexMapControls (String layerName) : static json*

Creates and returns a JSON object of OpenLayers map controls

| | |
|---|---|
| *String* | *layerName* |

*selectStyleFeature (Object feature) : static void*

Selected feature call back function, manages selection, unselect and selected feature popup window (attribute window)

| | |
|---|---|
| *Object* | *feature* |

*unselectStyleFeature (Object feature) : static void*

Utility function when feature is unselected, manages style and pop up window

| | |
|---|---|
| Object | feature |

*dialogFunc (String action) : static void*

Utility call back function for user login and registration window

| | |
|---|---|
| String | action |

*userLogin (Object logIn) : static void*

Login window function

| | |
|---|---|
| Object | logIn |

*userRegistration () : static*

Registration window function

*register: string*

*returns void*

*redrawLayer (String featureName) : static void*

Redraw layer function based on feature layer name

| | |
|---|---|
| String | featureName |

*addFeatures (json feature_collection, String cc_type) : static void*

Add features to map, accepts a collection of layers (JSON) with open layers supported formats

| | |
|---|---|
| *json* | *feature_collection* |

| | |
|---|---|
| *String* | *cc_type* |

*postData (String postType, json formObj) : static void*

Post data to server function

| | |
|---|---|
| *String* | *postType* |
| *json* | *formObj* |

*createPopupWin (Object feature, Object vectorLayer) : static void*

Pop up window function, requires a selected feature and the layer name

| | |
|---|---|
| Object | feature |
| *Object* | *vectorLayer* |

*queryMap () : static void*

Map query utility function

*ccIndexToolbars () : static Array*

Creates and returns a toolbar collection

*ccViews () : static Array*

Creates and returns the index page views (panels) and sub containers

**Client-Side Profile Page JavaScript Documentation**

**Functions**

*ccIndexMapControls (String layerName) : static json*

Creates and returns a JSON object of OpenLayers map controls

| | |
|---|---|
| *String* | *layerName* |

*ccIndexMapControls.ccIndexMapControls (String layerName) : static json*

Creates and returns a JSON object of OpenLayers map controls

| | |
|---|---|
| String | layerName |

*postData (String postType, json formObj) : static void*

Post data to server function

| | |
|---|---|
| *String* | *postType* |
| *json* | *formObj* |

*profileToolBar () : static void*

Creates CMS icon if administrator

*utilRepHadles (String handleType, Object util_data) : static void*

User profile fields handler

| | |
|---|---|
| *String* | *handleType* |
| *Object* | *util_data* |

*reconfigureSpatialProfileGrid(String fieldName, Object rootName, Object local_data) : static void*

Reconfigure spatial contributions profile grid

| | |
|---|---|
| *String* | *fieldName* |
| *Object* | *rootName* |
| *Object* | *local_data* |

*profileToolbars () : static Array*

Creates and returns a toolbar collection

*getProfileViews () : static Array*

Creates and returns the index page views (panels) and sub containers

# Appendix IV: Reviewer Comments

**Reviewer ID 1**

*I think this is great application and has a greater potential; what I could do easily is: Create a vector (polygon, line, point) and input all the required information and change colour without problem. What I could not do is:*

*1. I could not upload pictures with different format (jpg, png,bmp) with size less than 20mb. I haven't tested videos though.*

*2. I could not post a new topic on the forum because to post a topic, I had to choose a created feature. as soon as navigate out of the" content generation page" to go to the forum page, i lose the drawn feature. Therefore, I had difficulty to figure that out. i could not see any posted topic to read. One time, when I submitted the created feature through "submit map data", the features was gone from the map. That is my notices to the test results. I hope that is helpful. Thanks,*

**Reviewer ID 2**

*I think the application has a nice collection of tools, especially measure area tool which is very nice. However, I think the application should be more user friendly, some of the buttons I think are rather difficult to work with such as "add features" button.*

*I also think the contents tab has a room for improvement. If I draw a feature on the map I do not see it as sublayer in the contents tab.*

**Reviewer ID 3**

*Good one there! I think we need a help file to understand the menus. It not so straight forward what each menu does :) OK, I found out that the "?" is the help :)*

**Reviewer ID 4**

*This is awesome, but I guess you can do something about the start up loading of the page. It is a bit slow.*

**Reviewer ID 5**

*It seems to work as expected except that it gets my location wrong. In addition, from a user interface design point of view, there should not be a logout button if a user has not logged in yet.*

**Reviewer ID 6**

*1. Tooltips of top icons a little difficult to understand: needs some time and practice to understand what tooltip means and what it does.*

*2. All contribution details fields are mandatory - too many. Fields don't bear explanation of what information to give. Tooltip could be used to give extra detail/explanation*

*3. Couldn't delete a feature*

*4. If clicking on Select feature changes the Cursor icon it will help create a better visual effect in terms of navigation*

**Reviewer ID 7**

No Comment

**Reviewer ID 8**

No Comment

**Reviewer ID 9**

*I find it quite innovative and dynamic and user friendly. An amateur user like me finds it easy to use. I commend the genius behind this creation.*

**Reviewer ID 10**

*Pretty good:) Just one comment, is there any way to search a certain place to add a feature? I cannot find the option. For example if I took some pics in a rural area, but that place does not have internet, so I have to upload the information once I come back to the city. Even the software can determine the city; it is not the place where I want to add the feature.*

**Reviewer ID 11**

*Perfect idea. However, the files uploads, should the cumulative file size be less than 20 or less than 20 per upload. I had an error of too big a file size......greater than 2mb when uploading a second file.*

**Reviewer ID 12**

No Comment

**Reviewer ID 13**

*Nice interface created with tools well incorporated. My only issue was the identification of location at the time I was interacting with the software. It did not really identify my location as expected. Hope it helps.*

**Reviewer ID 14**

*I add a line as a road in Isle Madame but I tried to give a colour in the contribution details on right of the page but I could not select the feature to do that. Overall, you did a great job, thanks*

**Reviewer ID 15**

*For the Multimedia/video, pictures, Audio question, maybe it's not fast because of my computer*

**Reviewer ID 16**

*Yey, you did it :) Nice work*

**Reviewer ID 17**

*Nice! work. Have some browser issues though*

## Curriculum Vitae

| | |
|---|---|
| Candidate's full name: | Titus Tienaah |
| Universities attended: | Kwame Nkrumah University of Science and Technology, Bachelor of Science, Geomatics Engineering, June 2007. |
| Publications: | Ayer, J., and Tiennah [*sic*], T. (2007). "Datum Transformations by Iterative Solution of the Abridging Inverse Molodensky Formulae." *Journal of The Ghana Institution of Engineers* Vol. 5, No.1-2, pp. 21-24 |
| Conference Presentations: | NIL |