A Web tool for Geographic Information Systems (GIS) (CS03-18-00)

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ABSTRACT

Geographic information system (GIS) users are growing in numbers everyday. The need for GIS systems is on an increase. This requires that information be made available on a large scale.

This is a major problem that many GIS users are faced with. They require a tool that will allow them to supply the dataset and rapidly generate a resulting geographic web map that will be accessible by virtually anyone.

Having been approached by the Marine & Coastal Management (MCM) services of Western Cape as well as the Cape Metropolitan Council (CMC) with this exact dilemma, we felt that their was a real need to develop a system that could help these GIS users.

In essence, the system provides:

- Useful and informative interactive mapping capabilities
- A tool to dynamically generate these maps which can then be placed on the web for easy access

The maps need to provide basic browsing capabilities, such as zooming, panning and layering various themes for display. Ideally it should provide added functionality, such as providing unique symbols for various features on the map.

G-WIS, short for Geographic Web-tool Information System, is a tool that allows users to extract and publish these geographic web maps with relative ease.

G-WIS is a stand-alone tool that is based on solid interface design methods. It allows a user to define a dataset that can be used to generate a web page, which embeds a Java Applet that reads the data and maps this in the form of a geographical map.

The key findings that were found after testing the G-WIS application are:

1. Supports long term and efficient management of data.
2. Promotes rapid generation of web maps.
3. Implements an "attractive and easy to use" interface.
4. Further development or improvements can be due to the use of XML.
5. Has the ability to solve real world problems.
6. Is cost effective.

Generating web maps with G-WIS is easy, fast and cost effective.

After testing the interactive maps, it was found that:

1. The maps were easy to use
2. It provided the basic needs for web mapping.
3. It was informative and useful

Implementing the maps using GeoTools caused a huge setback in the progress of the project, since GeoTools is poorly documented and only a few experts exist. Advanced functionality was thus not provided. Even though the maps only provided the basic functionality, it met the needs for functional interactive web map browsing.

Categories and Subject Descriptors

[**Computer Science**]: Geographic Information Systems– *data management, web maps.*

General Terms
Management, Measurement, Documentation, Performance, Design, Reliability, Human Factors, Theory.

Keywords
Web page generation, Specification, System usability, ArcView.

1. INTRODUCTION
This project aims to design and develop middleware that extracts and publishes geographical data from Geographical Information Systems (GIS).

It aims to facilitate basic GIS functionalities on the web, providing the most relevant and useful data to regular GIS users. The project will focus on solving some of the problems that the Marine and Coastal Management (MCM) face and will include functionality that the Cape Metropolitan Council can use to conduct town planning activities. The final product will not be limited to these users.

These are the two test cases that will provide us with a point of reference that will allow us to solve the set of problems that these test cases contain.

Currently the most popular geo-scientific tool to gather and display data is called ArcView. The problems of using this program will be discussed and I will draw on other methods to solve some of these shortcomings.

After outlining the difficulties that geoscientists face, we formulate an approach to solve some of these problems. From here we develop our own set of tools. After the design of this tool we look at the functionality the prototype provides.

Evaluating the tool becomes critical at this stage. To build and improve the prototype according to the needs of the users, continuous involvement is required. They can then give feedback so that these can be documented and can be used as a platform for future developments.

Testing the application based on various criteria is also documented and formulates conclusion based on the results of these tests. A note on the projects outcomes is then made. This section highlights the important findings that we have made throughout the project. A last note is made on possible future developments that should be implemented before being implemented into a commercial framework. Finally we draw clear conclusions about all aspects of the project.

The entire system developed takes the form of two separate sub systems – an application and a web mapping toolkit.

2. Background & Motivation
Associate Professor Sonia Berman from the Computer Science department of UCT initiated this project. Building a GIS web tool focuses on solving the problems that two organizations face. These organizations are the Marine and Coastal Management (MCM) and the Cape Metropolitan Council (CMC). Both of these users suffer similar problems – they are required to give simple and wide access to their GIS data.

2.1 Geographic Information Systems (GIS)
GIS allows one to capture, store, analyze, query and display geographical information.

A GIS stores spatial as well as temporal data. Spatial data is data containing the geographic location of a feature on the earth's surface as well as attribute information describing this data. Temporal data refers to data which changes over time.

A GIS combines layers of information for a better understanding of a particular place. The layers chosen, is dependent on the purpose of the user and what information is required.

The difference between conventional paper maps and digital maps is that digital maps display data, which is stored in a database. This provides the user with the ability to query and analyze the maps and results are displayed visually for a better understanding of raw data.

2.2. GIS terminology
View: - the map displayed on any GIS system. There can be many views.

Theme: - the layers of the map, such as roads, species, crime areas, rivers, etc.

Orientation Data: - Information that appears on a web map that gives the user a feel for direction. Examples are roads, suburbs, and schools.

Attribute Data: - Information that appears on a web map that offers up information about the data. Examples of attribute data are themes that show an income distribution for a province or data showing the gender spread.

Pan: - Moving a geographic web map,

Zoom: - Increasing the level of detail available on geographic web map.

2.3. Overview of web GIS

Having GIS available on the web for any user, from novice users to advanced users, will provide more functionality and efficiency to the value of GIS technology.
Web-GIS provides the user with basic GIS functionalities to create maps together with viewing and interacting with it. There is the ability of spatial analysis functionality and querying.

GIS on the web allows for a larger audience to benefit from it and avoids the need for non-geoscientists to purchase expensive GIS software. Web GIS enables the use of spatial data and map browsing becomes easier due to there only being one window providing all the necessary functionalities.

Since web GIS allows a larger audience to benefit from the information, more value is added to GIS technology.

Web GIS provides the advantage of not needing any training or experience with GIS, which is usually a requirement with commercial GIS software.

2.2 The MCM

The Marine and Coastal Management is an organisation that monitors and manages South Africa's shores and fishing industry. They work with spatial and temporal data on a daily bases. Marine sciences deal with information obtained from various disciplines, such as ecology, oceanography and biology. It thus consists of the most spatially extensive data compared to other sciences. The type of data they normally would look at is fishing hauls over a certain period of time or temperature changes along with movement of a particular species of animal or fish.

2.3 The CMC

The Cape Metropolitan Council manages the activities required to maintain and develop Cape Town. We are responding mainly to the needs of the town planners of the CMC. The CMC similarly deals with large amounts of data. This department deals primarily with census data and crime statistics. This can become an extremely large dataset to work with.

2.4 Related Work

Two existing applications in the field of Web GIS are:

2.4.1 Alov Map

Alov Map is a free, portable Java application for publication of raster maps to the Internet and interactive mapping on the web browser. It supports stand-alone and client-server approaches to interactive mapping.

2.4.2 MapObjects Internet Map Server (MOIMS)

MOIMS is an ESRI-developed piece of software that allows GIS developers to create and publish their applications on a local Intranet or on the Internet. It allows web authors to add map capabilities to their current websites.

2.5 Motivation

There is a great and increasing demand for GIS data. The data only becomes useful if end users are able to use it to make informed decisions as a result of viewing it.

Making this data available to end users on a wide scale is just one of the many issues facing GIS at this moment. Making GIS information accessible on such wide scale definitely enhances the value of GIS technology.

This paper focuses on the tools developed to tackle this problem.

3. Methodology & Approach

The system has been designed as two sub sections. The system architecture can be viewed in figure 1. It shows how the two sub systems interact with each other.

The two separate modules was developed separately and then recompiled into one complete solution. The project was broken up into two main segments as follows:

1. *Interactive web maps*

The result of this section is to provide a geographic map with simple interactive functionality. To do this we researched various mapping toolkits. Further explanations can be found in section 3.3 about the various tools that could be used as well as the various different formats that relate to GIS web applications.

2 *General system for web GIS*

The second part of this project was to provide a general application to generate a GIS website. The user will be able to define a set of data and maps and also provide various themes that they want the generated web page to have.

3.1 Design Model

A prototype design model was used to develop the system. Due to the graphical nature of the system and the amount of user interaction required we decided it best to use a user centered design methodology.

A top down approach was used as a problem solving technique. The fundamental aspect top using approach when designing and implementing a solution is partitioning problems into sub problems. This process is recursive and is repeated until "tractable sub problems are identified."

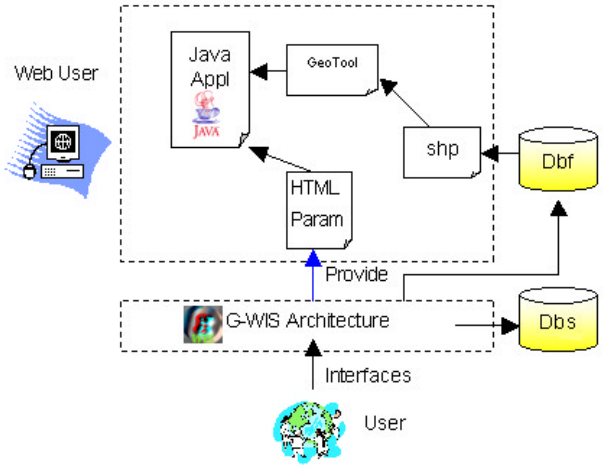
Due to a prototype design constant meetings were held throughout the project lifecycle in order to acquire a clear understanding of the problem definition. This is essentially making geographic information accessible on a wide scale to general users

Once the problem definition and user requirements were identified, we developed a system that would extract and publish the geographic information.

3.2 System Architecture

A stand-alone application was developed called G-WIS (Geographic Web tool for Information Systems). It publishes the geographic information in the form of an html file. Embedded in this html file is a Java applet that extracts the graphic information stored in a file called a shape file. The raw data and attribute information as well as the mapping coordinates are stored in another file called a dbf file.

The applet uses a geographic mapping toolkit called Geotools [5]. Geotools is an open source set of classes that allows developers to read in and display the shape files as geographic map. These shape files are created using a complex and costly GIS package called ArcView, developed by the Environmental Systems Research Institute (ESRI).



3.3 Interface Design Approach

Using a top down design methodology to solve problems, the interface design followed the more common prototyping model. High fidelity interfaces were built and communicated to the user. By means of the users' feedback, the interfaces were refined and tweaked until the user was happy with the result.

Whilst designing the interface, great care was taken to insure that the use of widgets within the system followed the usual acquired affordance given to any windows based interface.

The interface also takes advantage of the user's skill level when delivering information and messages. For the most part the users will have a background in geographical maps, so the terms used like 'themes' and 'views' will be familiar. However the interface does not rely on the user understanding these terms.

Considering that most users tend to move passed the novice stage quite easily and then become experienced users, it is essential that the interface provide faster functionality. This is accomplished through the use of short cuts to all functions that support the main system functions.

Testing the G-WIS application was undertaken twice. This conforms to the prototype design methodology. Both of these tests were complete by Mr. Henk Eichhorn from the MCM. It was decided that the usability aspects be addressed very early to clarify the user requirements as soon as possible. High fidelity interfaces where developed. They included mock-ups of various interfaces that the user would work with.

The feedback from this early stage of testing would be used to refine and modify the interfaces to resolve the earlier problems. The second test was conducted on the final implementation. This testing would look at the usability of the system and its ability to function correctly.

We used a naturalistic observation technique, to evaluate the system's usability. This observation method was chosen instead of a "think aloud" approach because it is faster and the user feels less intimidated. Using think aloud approach is not a natural process for anyone and therefore will not reflect the true actions of the user as they operate the system.

Before the user sat down to operate the software he was given a short user guide that explained the interface and functions.

For designing the interactive web map interface, research was done on similar web maps on the Internet together with meeting the clients' needs. An interface was needed that was easy to use, informative and correct. The map should be intuitive to use for any web user, but still provide the functionality required by the geoscientists. Similar usability tests were performed on the web maps as with the G-WIS tool. Post-enquiry was done on users to gain more insight on their experience with using the tool.

4. Results

Testing the system was done to ensure that the system is usable and meets the needs of the users. The criteria that were tested were:

- Interface usability
- Expected result vs. Actual result and
- Ability to interact with the map.

A discussion of the results follows:

The user was presented with a scenario to solve using the G-WIS tool. At each stage of the user was able to navigate through the interface and entered the information required. The user was able to generate the web page with relative ease. When asked to comment on the overall usability, the user responded with the following: *" It's attractive and easy to use"*.

Before the user generated the map, they were asked to visualize the result. After the viewing the generated map the user's response was: "It's *pretty much what I was thinking of.*"

The web map that is generated was tested and the results were fairly similar for all the users tested. The users were satisfied with the overall usability. In terms of correctness, the users found the

map to be a reliable source of orientation. There were some suggestions on advancing the functionality of the maps.

5. CONCLUSION

Managing large amounts of data and making these datasets available on a wide scale is not an easy task.

This work was completed in an attempt to solve this difficulty by using sound design methodologies and developing an efficient tool to manage the data, so that it can be published as lightweight web application.

After researching various GIS frameworks and other related material I was able to design a system that would be able to embark upon this problem. Using a prototype design methodology and running periodic tests with the user, we were able to develop a system that is both usable and will "*meet the need*" of the users. This system was called G-WIS: Geographic Web tool Information System.

Testing the G-WIS system showed that it:

1) Supports long term and efficient management of data.
2) Promotes rapid generation of web maps.
3) Implements an "attractive and easy to use" interface.
4) Further development or improvements can be due to the use of XML.
5) Has the ability to solve real world problems.
6) Is cost effective.

The results show that it meets the requirements and objectives that were set out at the very beginning. The results also reflect that the G-WIS tool is a viable solutions provider for GIS users looking to publish web maps.

Developing interactive maps with GeoTools, caused a stunt in progress with the maps and thus real issues concerning GIS mapping were not tackled. The maps created thus lacks advanced functionality. Nevertheless, the maps developed, provided the basic functionality required for interactive web maps and thus met the needs of both the geoscientists and general web users. GeoTools has great potential for web mapping and more research and documentation is required.

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