EMERGENCY RESPONSE GEO-MEETING SYSTEM (ERGMS): A REAL-TIME PARTICIPATORY SPATIAL DECISION SUPPORT TOOL IN DISASTER MANAGEMENT

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ABSTRACT

An occurrence of disaster requires accurate, effective and prompt response to tackle the situation. Emergency Response Geo-Meeting System (ERGMS), a Web-based real-time application is designed to support live meetings, effective decision making, response planning, discussions and many other tasks related to emergency response in a synchronous manner. Several organizations, departments and experts are required to collaborate in all phases of Disaster Management particularly realizing good decision making and efficient information management thus controlling damage, saving lives and resources, and minimizing consequences of a crisis.

The application of ERGMS will provide a platform to a variety of actors from different fields such as police, fire brigade, municipality, disaster management authorities etc to acquire, process and analyze data judiciously, alleviate the effects of crises, coordinate the response and thus reduce suffering. The paper focuses on public participation and geo-collaboration facilitated with information sharing, interactive geo-conferencing, real-time map and data sharing with tools to draw features or add text to the map while discussions, uploading files and live chatting. Through utilizing geospatial ERGMS application, relevant personnel can locate damaged buildings, injured residents aiding prompt response, especially during the critical period immediately after the catastrophe when there is the greatest possibility of saving lives.

Keywords**:** Emergency response system, Effective decision making, Public participation, Real-time data, Disaster management, Efficient geospatial system.

1. INTRODUCTION

Emergency response is basically the intended participation of concerned departments after a disastrous incidence either caused by nature or resulting from human conflict. Geospatial processing activities supporting emergency response range from the provision of relevant available map to data processing providing thematic inputs into the different phases of emergency response, e.g., situation assessment, logistical planning, detailed damage assessment and post disaster reconstruction (Brunner et al. 2009).

In emergency circumstances, multiple agencies need to collaborate and coordinate, sharing data and information about actions / steps to be taken. However, many emergency related resources are not available on the network and interactions among agencies or emergency response organizations usually occur on a personal basis. The resulting interaction is therefore limited in scope and slower in response time, contrary to the nature of the need for information access in an emergency situation (Tanasescu et al. 2006)

In responding to emergency situations, information regarding location of medical facilities, relief shelters, sources of food supply in spatial format is crucial. Further the amount of data to be organized is quite extensive and is difficult to collect physically from various sources and convert to the required format for organizing into database. Hence it is proposed to use Web-based application interface for data collection and organisation wherever applicable.

The primary information such as the extent of the area affected, location specific details, population affected, availability of resources for evacuation of the people & relief and quick assessment of damages. Hence, there is a need to make available the required information to the key persons in the disaster management activity with appropriate tools to support the decision making process based on scientific inputs. Early warning, risk prediction, situational analysis, damage assessment, thematic hazard maps etc. are some of the major activities of the data management system of emergency data and information system configuration (Bhanumurthy et al. 2008).

The research presents the development of a prototype of an integrated synchronous Geo-Meeting system by assimilating the OSGIS, Web GIS, OSS-based tools and open mapping Application Programming Interface (APIs). The purpose behind introducing a GIS based GeoMeeting e-collaboration system is to allow the concerned departments, personnel and organizations dealing with emergency management to interact over the web; viewing/sharing maps and spatial images in real-time and making better decisions promptly. Emergency management activities are grouped into five phases i.e. planning, mitigation, preparedness, response and recovery. These phases are inter-linked, and it is highly crucial to have the right data at the right time, displayed logically and to respond promptly throughout the emergency scenario.

Moreover, the study also aims to test the usability of the prototype by providing a case study relevant to emergency response which is an essential component of Disaster management. In the researcher's view, real-time collaboration application requires steady usability evaluation to ensure its workability for real emergency situations. The idea behind testing this prototype is to come up with results targeting synchronous real-time collaboration when integrated and developed with internet-based GIS and open source technologies. In short, it is an effective way in enhancing real-time participation as well as improving the decision making process in any emergency state.

2. OBJECTIVES OF STUDY:

The aims &objectives of the study are described as under:

a) To design and develop a Geo-meeting system for facilitating real-time participation in emergency response and disaster management activities;
b) Both Synchronous and Asynchronous collaboration between stakeholders/participants/planners for better understanding, communication and decision making to handle Disaster conditions thus saving lives and assets of people.

3. ERGMS STUDY METHODOLOGY

The methodology adopted to undertake this study was based on reviewing the system design and evaluating the usability of the Web-based application (ERGMS).

- System design study
- Usability evaluation

The figure below depicts the series of development stages of Web-based application prototype. The present paper is about Emergency response as one of the crucial phases of disaster management that provides quick synchronous (Real-Time) decisions to relevant governmental departments in all emergency scenarios. It also highlights the usability of this real-time system which can be equally beneficial for general public, Government departments, etc who can participate and take prudent decisions. ERGMS web-based application is highly beneficial for every type of emergency situation occurring in our country Pakistan and will be applicable in all disaster scenarios thus aiding in quick and timely decisions & actions pertaining to preparation and relief provision.

4. SYSTEM DESIGN STUDY

4.1 Description/Features of the Prototype (ERGMS)

Emergency Response Geo-Meeting System (ERGMS) or real-time collaboration is a Web-based application which has been designed and developed to support coordination between concerned government departments dealing in emergency response and management and for public in general. ERGMS facilitates these entities for effortless discussions and support in better decision making process without being physically present at the meeting and especially for public who can play a participative role in responding to such emergency situations.

In addition, main map view provides with the following common functionalities (options) which are embedded into all three components’ interfaces discussed in the following sections:

- A **base layer switcher** (see the panel window below) is provided, allowing users to switch between different base maps, including maps provided by OpenLayer, maps provided by any Web Map Services (WMS) and the OpenStreet map.
- A **standard toolbar** is provided with map zoom-in, zoom-out and pan functions. This is the default control, which allows you to scroll mouse wheel for zooming, left click+drag or double click the left mouse button to pan/re-centre the map image (as noted below) to the place you double click on the map.
- The **textual/graphical annotation** may be added onto a transparent map layer, acting as a shared whiteboard. The annotations can be in the form of texts, lines and polygons. These annotations shall be geo-referenced; meaning that they will be scaled as the map display is zoomed in and out resulting in no “distortion” of the annotation. The geo-referencing toolbar is designed and developed in order to depict the real-time supportive geo-referenced-based annotation on the map, further enhancement for this feature will be available in the Phase II of the system redesign and development.
- To **use the annotation tools**, click on the appropriate icon on the toolbar and then click on a location on the map or map feature. Add text, draw a line or draw a polygon. The following screen shot illustrates a map with point, line and polygon annotations.
- **Real-time chatting** allows any participant in the session to exchange textual information. Chat window panel is used for sending and receiving messages to other people that are viewing the same map as you, and for choosing which user-drawn features to display in the map. The closing features (arrow) apply for this window frame to increase/maximize the map view.
- The **list of participants** attending the meeting session is provided through an embedded window panel, shown as below. The big down-side blue arrow is used to hide/display the real-time chatting and participants list interface. Click on it to hide this part of the interface. The arrow becomes an up-side arrow. Click on it to display the real-time chatting and participants list interface again.

The **three interface components of ERGMS** and their key features are briefly discussed below.

i) Collaborative Map Sharing

Map-based displays can be highly useful for emergency response and planning discussion between participants. Therefore, a collaborative map-sharing component was developed to allow participants to collaboratively explore geographic context of the projects while discussing some issues. Figure 2 shows the main web interface of this component.

The component integrates a number of features, including shared map, chatting, video conferencing and white boarding, into a single interface that can be invoked and run in a new window. It is intended to be used by a group of participants who have a common topic to discussion, which requires access to map displays to make their points clearer. Any participant can initiate a collaboration session and invite others to join. All participants who join the session are given the right to use whiteboard tools.

ii) Virtual Public Meeting Interface

The virtual public meeting is a supplement to the real public meetings in order to give those who cannot physically attend the meetings a chance to participate. The idea is to stream real public meetings online and provides facilitating tools to enable online participants to question and interact, and to allow presenters to integrate their electronic presentations and maps into the virtual meeting environment. Figure 3 shows a view of the virtual public meeting interface.

By incorporating the collaborative map sharing components, the interface allows the presenters to share map displays in the same way as PowerPoint slides are shared on screens in many other web conferencing systems. The presenters can also use the built-in whiteboard tools to select features, add annotations, and draw graphics. However, during the virtual meetings, only the presenters can initiate the tools and control how the map data should be displayed to facilitate their presentations.

iii) *Geo-Meeting system*

Geo-Meeting is a Web-based system and can be accessed using a typical web Brower. The current version of the system supports any Internet browser e.g., Internet Explorer and Firefox, etc.

After entering screen name and joining a session, the map-sharing component will load its default interface as shown in Figure 4.

There are a number of ways to interact with the initial map view: 1) Click and hold the left mouse button and move the mouse to drag the map view to show a different part of the study area from the initial view; 2) Move the cursor to another location on the map and double-click the left mouse button to re-centre on that location; and 3) Move the mouse wheel up/down (or move the slider in the top-left corner of the map view) to zoom in (show less area in more detail) or zoom out (show more area and less detail) on the map view.

5. Architecture of Prototype (ERGMS)

ERGMS is a web-based geospatially-enabled conferencing system that integrates real-time and synchronous map sharing, chatting, audio/video conferencing, geo-referenced map annotation, and user and meeting management for supporting discussions between multiple users geographically located at different places towards consensus building on a decision-making problem. The system supports real-time integration of data from different sources through web map services APIs, and encourages the integration of local knowledge expressed by meeting participants.

The system design proposed for ERGMS consist of three main components:

- The Stakeholders access the database server to synchronously interact using variety of its functions i.e. live chatting, document uploading, comment box, real-time map sharing etc.;
- The central database server contain geospatial layers, reports and departmental data;
- The information attained from stakeholders is verified and disseminated through central database server in real-time.

  Figure 5 illustrates a conceptual architecture of the ERGMS prototype web-application system.

It was valuable to study how ERGMS prototype was understood and used by university students enrolled in different programs. The following sections describe the role of usability in Web-based applications, as well as the result analysis.

6. USABILITY EVALUATION

According to the well-known usability expert Jakob Nielsen (Nielsen 2000) usability evaluation is a component which is mandatory for a Web-based application to make its place for the target users / concerned departments involved in emergency response planning. Usability is defined in the ISO 9241 standard as "the effectiveness, competence and contentment with which specific users achieve specified goals in particular environments". By visualizing the above definitions author can say that usability can be measured by different attributes like learnability, effortless use, understanding, competence and contentment.

Sullivan et al. (2005) also defines usability evaluation as a procedure of investigating users/participants working together on a single platform through a Web-based application to determine how easily participants interact with the application interface. Significant progress takes place when testing is incorporated in the design and development phase resulting in recurring features of usability testing. The components that usability testing is generally comprised of are: 1) The usability evaluation has particular objectives during the test of designing; 2) The participants are representative of stakeholders / general public; 3) participants work on real tasks; 4) participants movements and computer interaction is recorded and observed; 5) the data thus collected from the usability testing will be examined to identify problems or difficulty and suggest suitable recommendations for the improvement of better interaction of system with stakeholders.

The interface of the Web-based application should be simple enough for the common user / public whether having experience in GIS applications or not to understand and operate its functions easily. The users are only satisfied when they can achieve their goals in a successful and efficient way.

Koua et al. (2006) proposed usability evaluation criteria for GIS applications that helps to assess the ability of GIS applications regarding user performance and satisfaction. This evaluation of Web-based GIS application is very important because many usability issues can be taken care of through usability testing.

According to the Usability Engineering approach, an effective way for increasing usability of a web-based prototype is to address it in the early phases of the application development. In order to realize this goal, some criteria or standard needs to be defined e.g., general usability principles, suggesting how the application must be organized to conform to usability requirements (Matera et al. 2005).

7. USABILITY EVALUATION CRITERIA OF ERGMS

The perspective of the case study is to assess and evaluate a system prototype that is planned to be developed for responding to various emergency situations. This system will be designed in such a way that participants/attendees working in different departments associated with emergency response, planning and management shall participate and play their respective roles. The following factor elucidates the steps necessary for prototype’s usability assessment and implementation as a mock case study using emergency management planning to authenticate the proposed approach.

The only way to ensure that a Web-based application designed for the stakeholders is really usable is through extensive testing of the usability before launching this application. Thus, the usability criteria have to be carefully selected and another critical factor is to include the user’s requirements and needs for the development of an application.

This section deals with assessment of the real-time ERGMS prototype that is being developed. The criterion factors include: effortless use of the real-time collaboration, competence, the initial and monitoring cost of the prototype, and intercommunication or Human Computer Interaction (HCI) of the prototype in the long run. Different investigators such as Butt (2012), Chang (2010), Tang (2006) & Zhao (2006) also proposed somewhat similar methods of evaluation for assessing the implementation of prototype.

7.1 Effortless use

The prototype will have the ability to be effortlessly utilized by stakeholders related to emergency response planning and share maps and other information in real-time. This will be monitored through number of clicks done to perform a single task during the testing period.

7.2 Competence / Understanding

Effective participation deals with application’s functionality, observation of user performance and experience of tasks. The public involvement requirements should be addressed in more efficient manner. The user performance can be judged by its efficient completion of the given assignments within the allotted time frame.

7.3 System cost

The system cost is the one which would be invested for the designing and development of prototype. In this ERGMS, the prototype is proposed to be developed using open source software and GIS technologies and therefore renders no charges.

7.4 User contentment

ERGMS prototype will provide user friendly, efficient, accurate and interactive interface, so that a participant can quickly communicate / request and get response from other participants about their inquiry. The quicker response a participant can get, more will be its interactivity and contentment.

The figure below gives an overview of the usability indicators that were chosen to assess participant’s ease in interaction with the prototype application.

8. STATISTICAL ANALYSIS

Statistical analysis was performed on the user performance data collected from both software and post questionnaire were fed into SPSS (statistical package for social sciences) for statistical analysis. The result detail is explained in the subsequent sections.

Nielsen (1993) suggests that efficiency, learnability, fewer errors, understanding and contentment are the main components of usability. Whereas, in this paper usability has been evaluated by recording number of clicks for a given task (calculating user competence), number of tasks performed within the given time (measuring user understanding of the system), time to perform a single given task (Effortless use of the Web-application) and contentment (measured through these variables i.e. relevance of content, innovative, communicative and participatory). All these four indicators were measured through Userfly and Clicktale software and post questionnaire.

The Statistical analysis section covers the following components:

8.1 Participant’s Characteristics

The sample size was selected to be 25, taking 5 users/participants from each university program group. The selected five groups for the testing experiment consisted of Urban planning, Environmental engineering, GIS, Management studies and English literature. The gender ratio of male to female of the selected users was 9:16. It was found that the number of graduate and post graduate students were the same (48%) while a single doctorate student (4%) was present in the sampled population. Judging the IT and GIS skills of the students from the pre-questionnaire, it was observed that 60% had good level of computer (IT) knowledge while 36 % had beginner level skills in GIS.

The graphs (Figure 6) presented below depict the user characteristics in percentages. IT and GIS knowledge was marked on the scale of 0-4 thus showing 0 as nil, 1= beginner, 2= moderate, 3- good and 4 as very good levels.

8.2 Usability Indicators

The results collected from the software and feedback questionnaire after the end of the testing session are graphically presented below (Figure 7).

Graph 1 of figure 8 represents **understanding** of the Web-based application by the participants on the basis of tasks performed. Each group consisting of five participants performed varied number of tasks of whose average was taken. **Competence** of users was measured through number of clicks done to carry out a single task. Graphs 2 depicts the average number of clicks taken by each group to perform the task. While **Effortless use** was determined through average time taken to complete a single task by the group members; Graph 3 represents time in minutes to complete a task showing ease of use for the user.

These results clearly display that the GIS group of university had an edge over the other groups as they have better GIS knowledge and computer skills. The graphs displayed in Figure 9 clearly depicts that the GIS group took less time to complete the given tasks as compared with the rest of the students. Simultaneously, urban planning, environmental engineering and management studies group also performed well in the tasks. Whereas English literature group was a little behind the others and took comparatively more time and clicks to understand and accomplish the tasks.

8.3 Spearman Rank Correlation Interpretation

Spearman's correlation helps to identify whether the correlation is positive or negative. Spearman rank correlation works by converting each variable to ranks. Once the two variables are converted to ranks, it is easy to perform a correlation analysis on the ranks.

The data collected through usability software (Userfly & Clicktale) and the post questionnaire were given ranks ranging on a scale of 1 to 5. The following table displays positive and negative correlation between the usability indicators (obtained through user e-monitoring) and user’s characteristic variables (obtained through questionnaires).

i) Competence:

The correlation results (Table 1) showed that there was a negative relation between GIS (-0.675) & IT (-0.587) knowledge of the users and average clicks to perform a single task. This value depicts that there is an inverse relationship between the two indicators, meaning thereby the group that has good GIS and computer knowledge, s/he would do less number of clicks to accomplish a single assigned task. Whereas, there is a weak positive correlation (direct relationship) between education (0.256) of users and average clicks to perform a task, meaning thereby that even an educated user can get confused regarding the application usage and randomly start clicking the wrong tabs of the site.

ii) Understanding:

Similarly, there is a strong positive (direct) relationship among the variables GIS (0.714), IT knowledge (0.626) and number of tasks performed. On the contrary, a weak negative (inverse relationship) (-0.143) exists between educational level and number of tasks performed depicting that the less education of a user (even a graduate) can perform the given Web-application usability tasks.

iii) Effortless / Easy Use:

In case of time consumed by the users / participants on the tasks, we see its strong negative correlation with the user characteristics GIS knowledge (-0.695), IT (-0.541), education (-0.054) showing that those having a good level of computer know how can finish the given tasks in less time.

iv) User Contentment:

Table 2 shows user contentment indicator which was correlated separately with the four indicators that were extracted from the post questionnaire, which are innovative, relevance of content, communicative and participatory.

There is a positive strong correlation between gender (0.178), group of users (0.241), and education (0.335) showing that all the participants found the web-based application quite innovative. Similarly, there is a strong correlation (0.083) between group of user and the attribute of communication. A positive strong correlation exists between the gender (0.393) and attribute of participation illustrating that they all found the prototype quite participative.

9. DISCUSSION

Since usability is primarily a user oriented concept, therefore the term ‘user contentment’ has been included. This term implies that the user is able to satisfactorily perform the task which he/ she wanted to perform. During the study, it was observed that a few users were sitting idle and just clicking the mouse. The reason can be that they got stuck which was confusing them and they couldn’t complete the given assignment within given time period.

The majority of the respondents were familiar with computer (IT) knowledge having internet navigating proficiency and basics of using participatory GIS skills. Four of the 25 participants had expert level computer skills and were familiar with web applications and basics of using GIS as well. Five of the 6 respondents from the GIS program had expert level web surfing and usage skills. The educational level of this sector was that 90% were post graduate degree holders (M.Phil, MS).

The Management studies department had graduates who had done web and GIS courses and therefore were good at exploring the web application prototype. Urban planning sector respondents had an intermediate level of web and GIS experience. The task completion output was an average 4. Environmental engineering program had less know-how of web applications and though respondents were able to carry out the given task but not within the specified timelines. English Literature program had graduates with one doctoral degree holder respondent. The responses were positive with one student who accomplished four of the five given tasks.

10. CONCLUSION

In a nutshell, usability results show that participants found Emergency Response Geo-Meeting System ERGMS quite easy-to-use, useful for communication, and that it may support participatory Emergency response planning and monitoring activities effectively. Comments were relevant to emergency planning issues and users did not have substantial problems in using the different tools. Users from the English literature program who were not much familiar with knowledge of GIS applications and had little know how of computer operating system, found it’s functioning easy and interesting. It was a good learning experience for all the participants. Thus, it can be safely said that ERGMS prototype will bring a revolutionary change in Emergency response and disaster management planning and decision making activities at the higher level and for stakeholders, consequently reducing human life and asset losses in the future.

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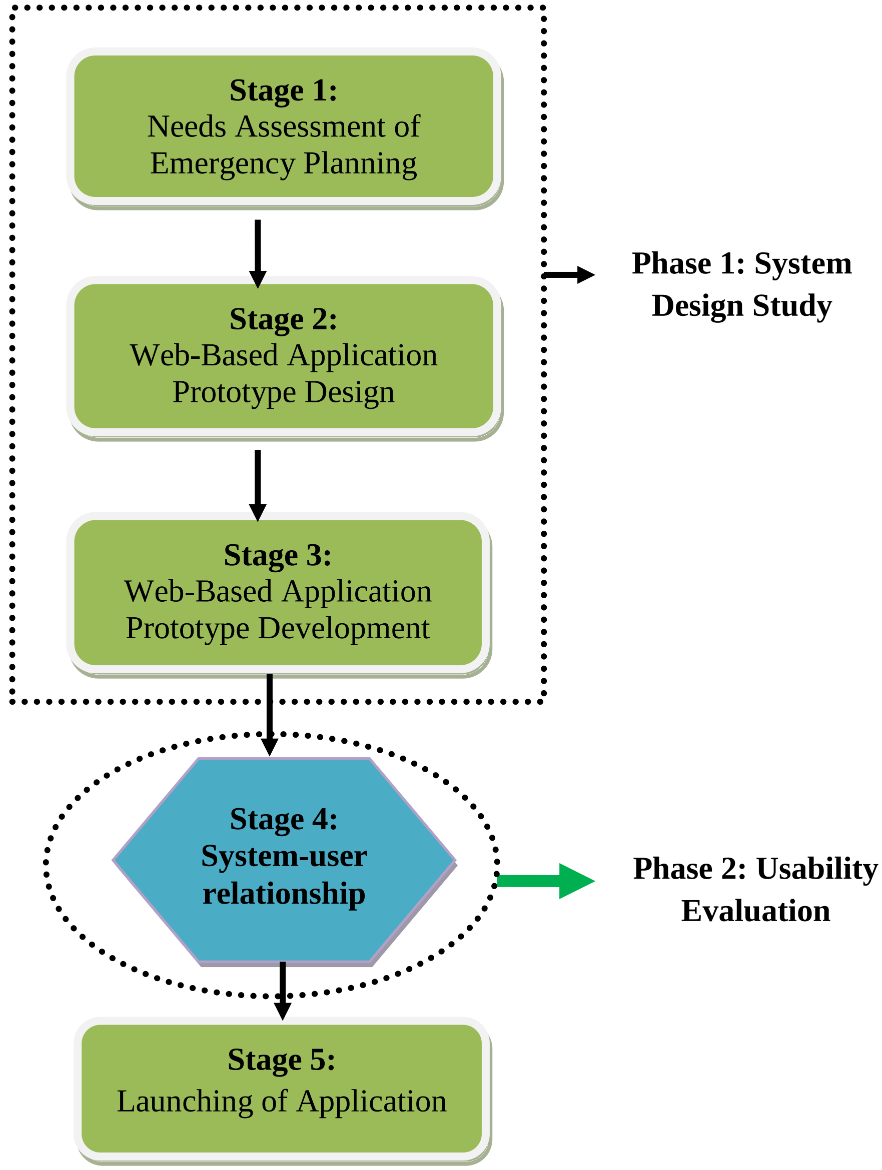


Fig 1. Development Stages of Emergency Response Geo-Meeting System Application

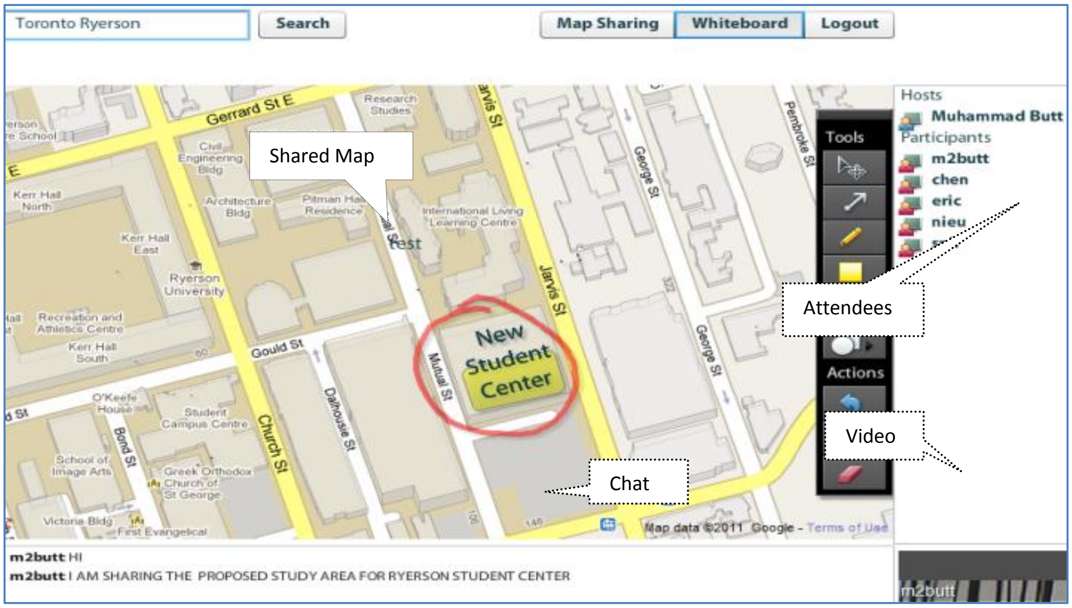


Fig 2. Main interface of ERGMS

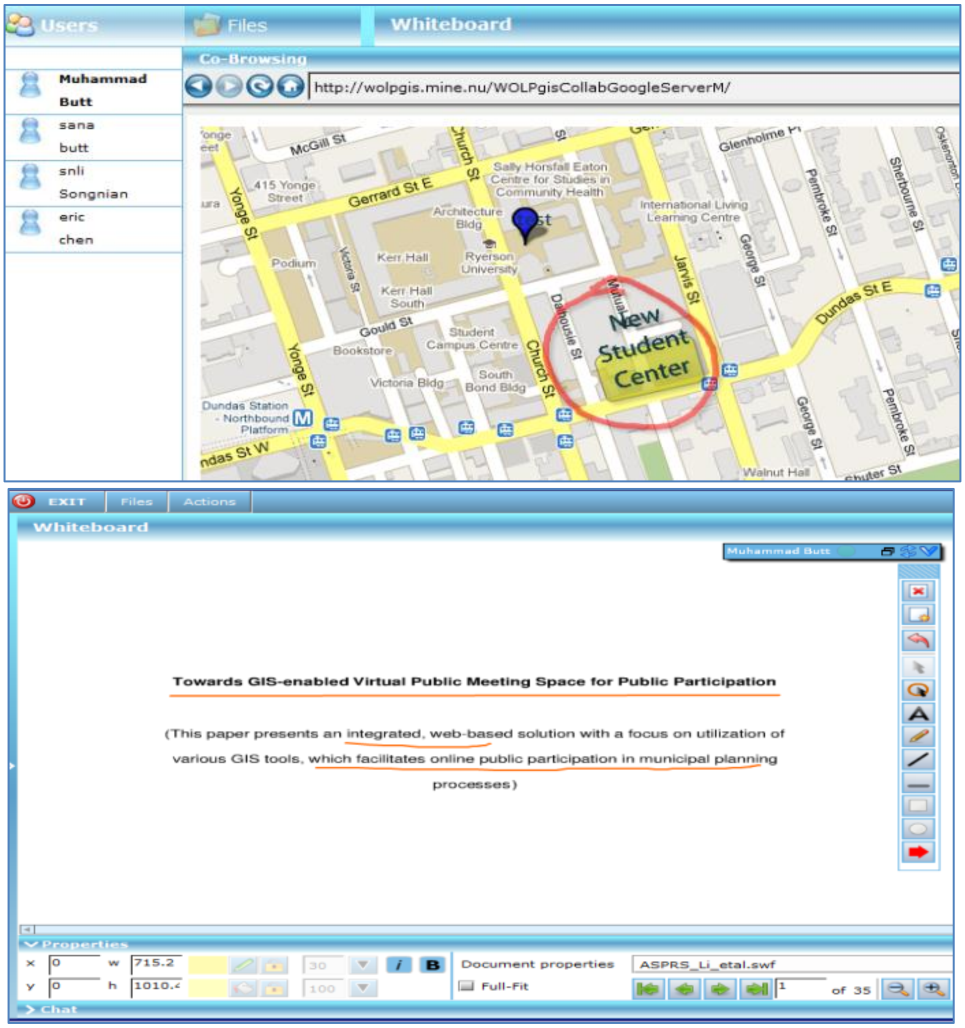


Fig 3. Virtual public meeting interface with real public meeting streams

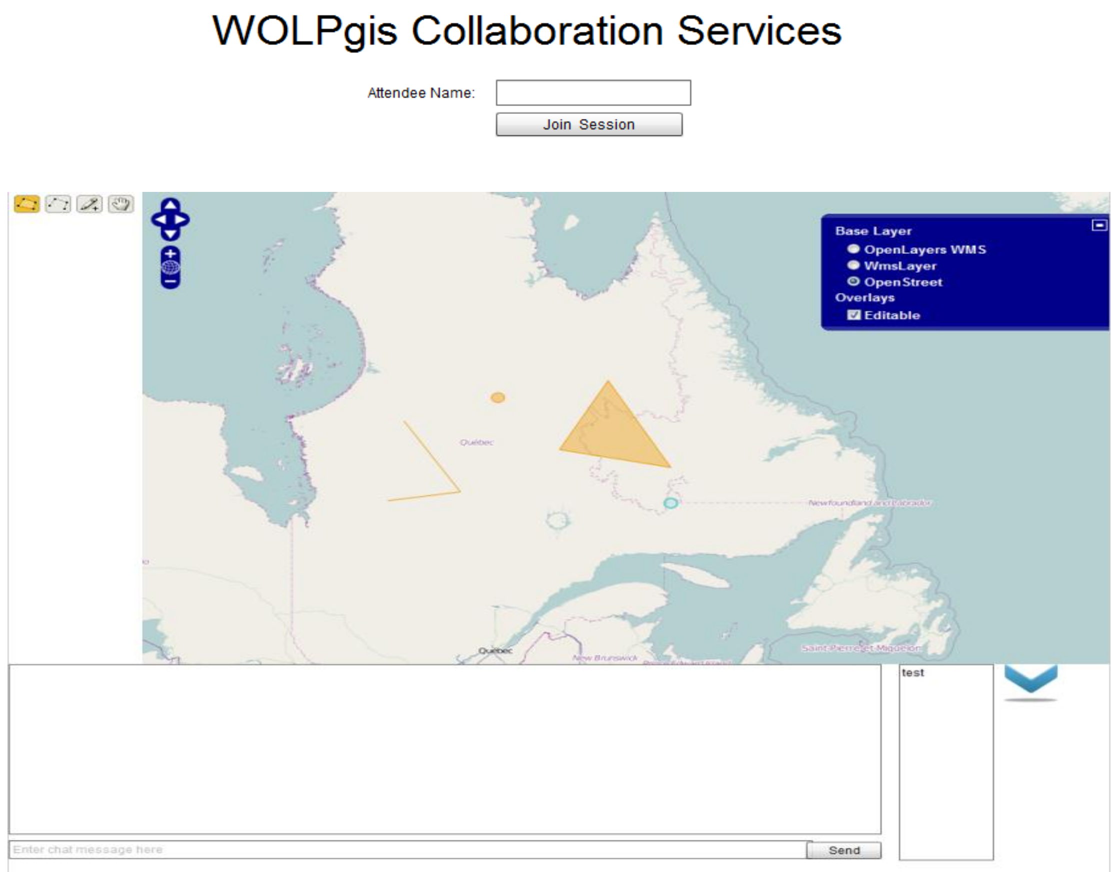


Fig 4. Geo-Meeting Interface

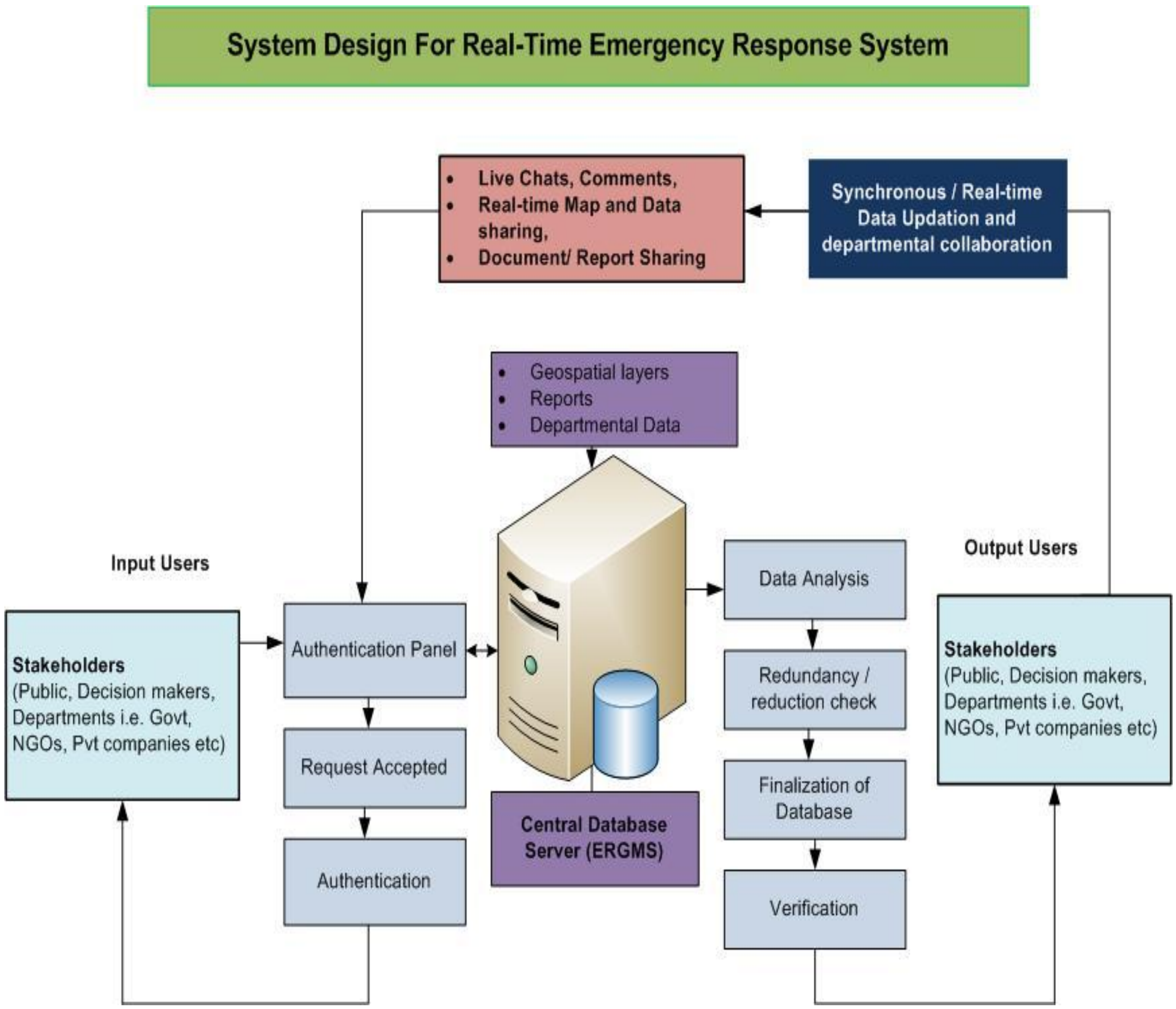


Fig 5. Architecture of the ERGMS Prototype

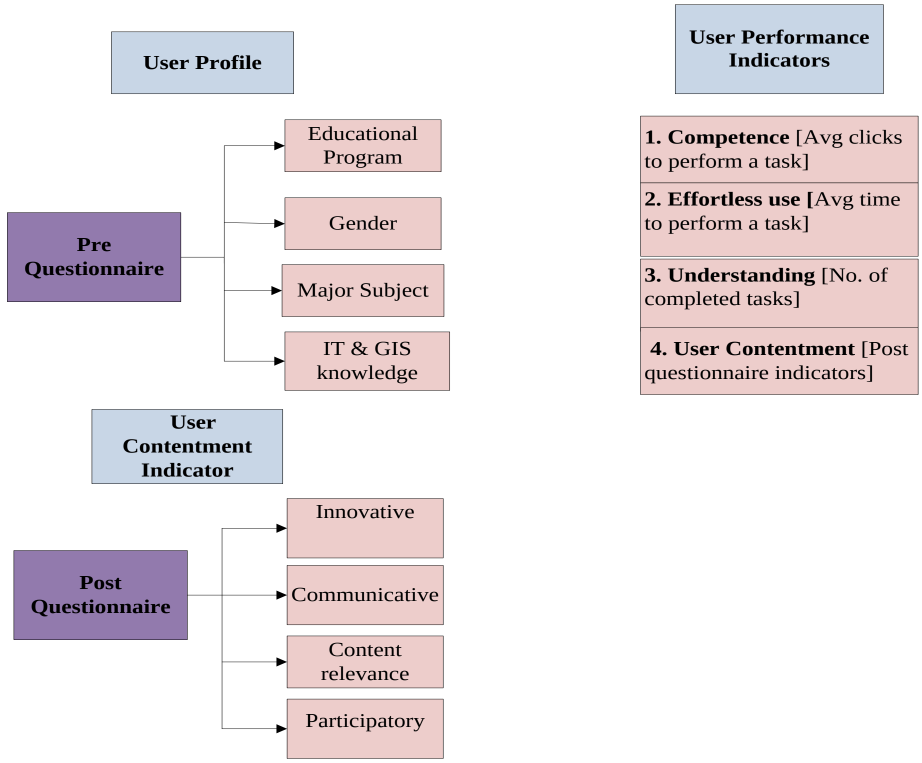


Fig 6. Measurement tools used in this study to determine Usability indicators

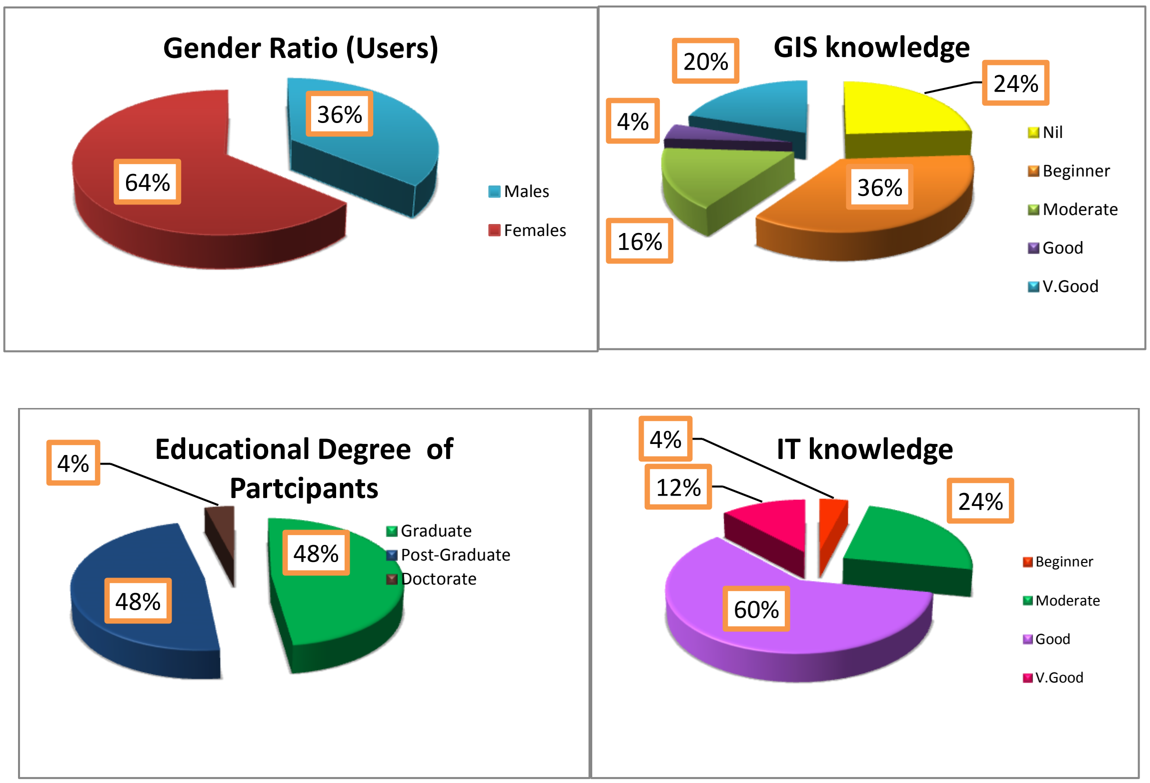
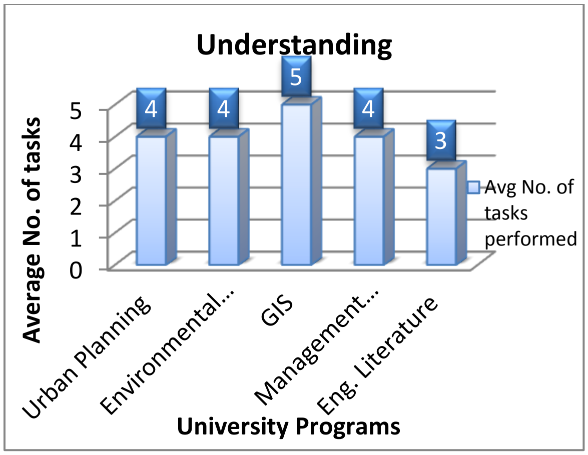
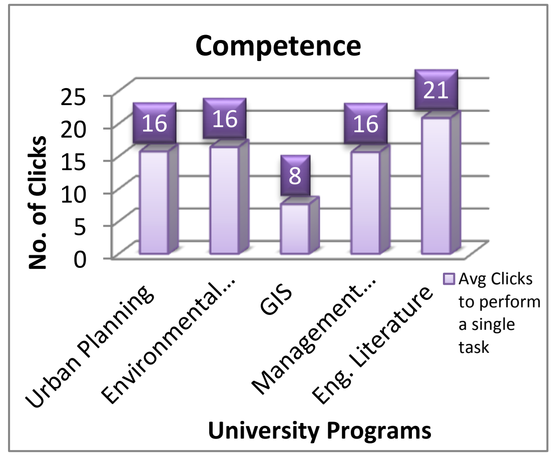


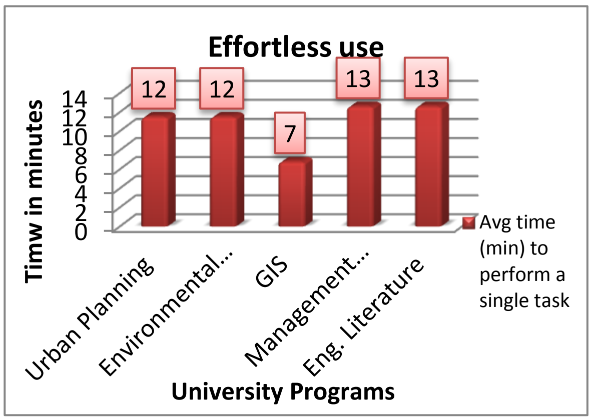
Fig 7. Graphical analysis of User characteristics



Graph 1



Graph 2



Graph 3

Fig 8. Graphical analysis of usability indicators derived from user performance

Fig 9. Graphical analysis of correlation results of user characteristics with usability indicators

Table 1. Spearman Correlation between Usability Indicators and User Characteristics

Sr no.	Usability Indicators	User Characteristics		
		GIS Knowledge	**IT knowledge**	**Education**
1	**Competence**: Avg Clicks to perform a single task	-0.675	-0.587	0.256
2	**Understanding:** No of tasks performed	0.714	0.626	-0.143
3	**Ease of Use:** Avg time (min) to perform a single task	-0.695	-0.541	-0.054

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 2. Spearman Rank Correlation between User Characteristics and Contentment Indicators

User Contentment Indicators	Gender	Group of users	Education
Innovative	0.178	0.241	0.335
Content Relevance	-0.368	0.445	0.006
Communicative	-0.326	0.083	-0.187
Participatory	0.393	-0.417	-0.127