Collaborative mapping and dissemination of spatio-temporal data through a web-based virtual globe application

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by

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Disclaimer

To the most amazing people I know:
Tzveti, Ivan and Adi

Abstract

The need to coordinate efforts in environmental sciences has always been strong. This is even more relevant (and complex) at present when dispersed teams of researchers struggle to extract and communicate useful information from an increasing amount of spatio-temporal data. Recent updates in Google Earth, providing the possibility to couple cartographic animation with rapid real-time information dissemination, seem to make this software a suitable solution. As this and similar web-based applications mature, however, the challenge is no longer the technology, but rather to make such tools more useful and usable. This means that we need to place users and interactions, instead of processes and tools, at the centre of design. Unfortunately, the current focus of development of geo-collaborative tools is directed mainly towards a broad range of non-expert users. In contrast, significantly less attention is given to domain expert users who work with spatio-temporal data on distributed research projects where visualization can serve as a mediator for presenting results and coordinating actions. In parallel, user-centered design and empirical evaluations of web-based virtual globes are still very rare, which often leads to developed functionality which is neither used, nor suitable for its intended purpose. To fill this gap, a user-centered design approach was adopted in the development of a geo-collaborative web-based virtual globe prototype, designed for environmental researchers working with spatio-temporal data in dispersed teams of researchers.

Several methodological issues had to be solved throughout this study before gaining knowledge on user requirements. Relevant user characteristics influencing user requirements were explored through a dedicated on-line survey. A user profile was compiled where the main differences were in the data used for analysis, the resulting products to be communicated further as well as the frequency and the nature of communication with team-members. These user attributes served to extend a hypothetical use case scenario and identify a set of concrete usability goals which the conceptual design of the application strived to satisfy through specific design elements.

Consequently, a low-fidelity prototype, a set of questions in a trial interview and focused group discussion generated a list of additional user requirements. The obtained results served to observe user reactions to the interface and planned functionality, as well as to identify possible barriers for collaborative activities. This allowed preparing the prototype for the next stage of this research, specifically directed towards evaluating its real use with representative users.

After re-design, a high-fidelity prototype was developed through the Google Earth API and Ruby on Rails. It was further tested in a number of dedicated usability tests in controlled laboratory settings. The outcome reveals the main advantages and disadvantages of such novel environment to support group work with animated maps. In terms of presentation of spatio-temporal data in a collaborative environment, the main limitation of the Google Earth API is the lack of possibility to synchronize fully the visual displays among users.

Acknowledgements

The next paragraphs are dedicated to the people that made this M.Sc. research possible and enjoyable.

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I dedicate this thesis to my parents and my twin sister even though I owe them much more than this. More than words can ever describe.

Table of contents

List of figures

List of tables

List of acronyms

AJAX	Asynchronous JavaScript and XML
API	Application Programming Interface
AVI	Audio Video Interleave
CSCW	Computer Supported Cooperative Work
GE	Google Earth
GIF	Graphics Interchange Format
GML	Geography Markup Language
HFP	High-Fidelity Prototype
HTML	Hyper Text Markup Language
JSON	JavaScript Object Notation
KML	Keyhole Markup Language
LFP	Low-Fidelity Prototype
MOV	Apple Quicktime movie
MPEG	Moving Pictures Experts Group
OGC	Open Geospatial Consortium
RoR	Ruby on Rails
SVG	Scalable Vector Graphics
SWF	ShockWave Format
UCD	User-Centred Design
UML	Unified Modelling Language
URL	Uniform Resource Locator
XML	eXtensible Markup Language

1. Introduction

In science, "interesting and unpublished" is equivalent to "non-existing"
Whitesides, 2004

1.1. Background

The need to coordinate efforts in environmental sciences through knowledge and data dissemination and exchange has always been strong. This is even more relevant at present when current environmental projects involve dispersed world-wide teams of researchers. However, this effort is also very demanding for two reasons.

On one hand, the gradual shift from only working with spatial to spatio-temporal data (i.e. time-referenced geographic data) allowed scientists to understand better how systems function (Harrower, 2002). This, however, increased the complexity in cartographic representations. *On the other hand*, current technology is still incapable of providing fully adequate support for people working with geo-spatial information at the same time, but at different locations (Hardisty, 2009). As a result, scientists struggle to communicate effectively and on time their findings. Recent developments in web-based virtual globe technology, however, seem to provide some solutions to these challenges.

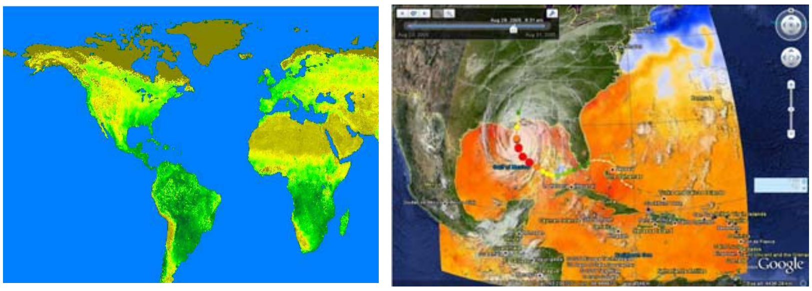
Also known as 3D geobrowsers (Foresman, 2004) a virtual globe is a digital three-dimensional and highly interactive representation of the planet Earth (Blower et al., 2007; Köbben and Graham, 2009). Such geobrowsers allow adjustment of the display and navigation through vast amounts of online geospatial data at any scale (for review see Tuttle et al., 2008; URL_1.1). Without a doubt, the most developed and widely accepted application is Google Earth (Blower et al., 2007; Tuttle et al., 2008). Its biggest advantages in the context of the outlined problem, however, are connected with two recent updates. The first is the upgrade of the Keyhole Markup Language, used for dissemination of data in Google Earth, to support dissemination and visualization of spatio-temporal data. The implications of this development are discussed in Section 1.1.1. The second, and more recent one, is connected with the official release of the Google Earth Application Programming Interface and plug-in, discussed in Section 1.1.2., which gives us the opportunity to bring not only distributed data, but also people together.

1.1.1. Advantages of Google Earth and the Keyhole Markup Language for spatio-temporal data dissemination

In 2006 the Keyhole Markup Language (KML), originally used for dissemination of geo-spatial data in Google Earth, and now in many other virtual globes, was expanded to allow visualization of temporal data (URL_1.2). The introduction of two additional elements for description of geo-spatial data (also known as tags, and written between <> brackets), <TimeStamp> and <TimeSpan> (URL_1.2), allowed animating raster or vector georeferenced features on a virtual globe.

This upgrade presents a good opportunity, because a number of authors identify *cartographic animation* as one of the most effective means to communicate temporal patterns and dynamics (DiBiase, 1990; Peterson, 1995; Harrower, 2002). Often referred to as *dynamic,* or simply *animation*, an animated map is a series of individual maps that are shown in quick succession, creating the illusion of a change (Peterson, 1995). The advantages of animation are often connected with gathered evidence that the human eye-brain system is adept at perceiving change through motion (Peterson, 1995).

In the last few years, the amount of animated maps on the Web increased. Apart from KML, a number of formats offer various ways to visualize environmental spatio-temporal data. However, to a large extent most products end up with representing only one type of data (e.g. movie files such as AVI[1], MOV and MPEG), while interfaces lack basic controls and provide no navigation (e.g. GIF, Figure 1.1.A) or require special skills to produce (e.g. SVG, SWF or GML) – aspects which will ultimately determine the effective use of animated maps in a collaborative environment for presentation and exchange of spatio-temporal data.



A **B**

Figure 1.1 Example of animated maps on the Web: A. A GIF showing global NDVI animation product (URL_1.3). B. KML animated maps combining raster and vector datasets to represent sea surface temperature and hurricane Katrina's storm tracks (URL_1.8)

Alternatively, KML animations can be utilized for different types of spatio-temporal data (e.g. URL_1.4, URL_1.5, and URL_1.6) and provide interactive temporal legends. What is more, the KML syntax can be used for dynamic real-time acquisition of data (e.g. URL_1.7), or to combine and visualize datasets from different sources and providers for the purpose of comparison (e.g. URL_1.8, Figure 1.1.B).

Supported by a number of virtual globes and GIS applications, Blower et al. (2007, p. 103) recognized that KML "is already becoming a *de facto* standard", even before

[1] For description of each abbreviation, please refer to the List of acronyms in the beginning of this document

being adopted as an OGC[2] standard in 2008. Export to KML is offered, for instance, by ESRI's ArcGIS, Arc2Earth (extension to ArcGIS), KML Export (extension of MediaWiki), Link Utility (extension to MapInfo), etc.

Although the same authors (Blower et al., 2007) argue that KML is not yet a fully-featured, general-purpose exchange format, they also recognize its advantages: 1) it is easy for users to visualize data with KML; 2) fills the gap between simple (GeoRSS) and more complex (GML) standards; and 3) serves as an interface to related information since it allows inclusion of hyperlinks to full data archives.

1.1.2. Advantages of the Google Earth Application Programming Interface and plug-in for collaborative visualization and mapping

Moving on to the second challenge, another more recent update in Google Earth allows the opportunity to bring distributed people, working with animated spatio-temporal data, together. Before explaining the implications of this update for this study, first we will have a look at the essence of geo-collaborative work.

Distributed collaborative use of geo-spatial information (also referred to as geo-collaborative visualization or collaborative mapping) is defined as a committed effort to use visual displays by multiple participants to frame and address a task (Brewer et al., 2000).

Group activities may be situated differently in time and space. Considering the temporal dimension, collaboration can happen in two distinct ways: synchronous and asynchronous (Slocum et al., 2001; MacEachren, 2001). Synchronous collaborative activities involve people working on a geospatial problem at the same time, either at the same place (same time/same place geo-collaboration) or at different places (same time/different place geo-collaboration). Asynchronous activities, on the other hand, are distributed in time. In this respect, realizing same time/different place collaboration has been identified as a particularly challenging effort (Slocum et al., 2001).

Irrespective of the collaborative situation at hand, visual displays have a fundamental role in supporting group work. Firstly, they serve as objects to talk about, secondly, they are shared objects to think with and lastly, they may be used as shared objects to coordinate perspectives and actions (MacEachren and Brewer, 2004).

Designing and implementing geo-collaborative applications is still a grand challenge (MacEachren and Cai, 2006; Hardisty, 2009) connected with a number of technical problems. Probably the most relevant research efforts to this study, where such problems are discussed, are reported in Brewer et al. (2000) and MacEachren et al. (2001). The authors developed two prototypes to facilitate environmental scientists to explore spatio-temporal data at distant locations (Figure 1.2).

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[2] The Open Geospatial Consortium (OGC) is a non-profit, international, voluntary consensus standards organization that is leading the development of standards for geospatial and location based services.

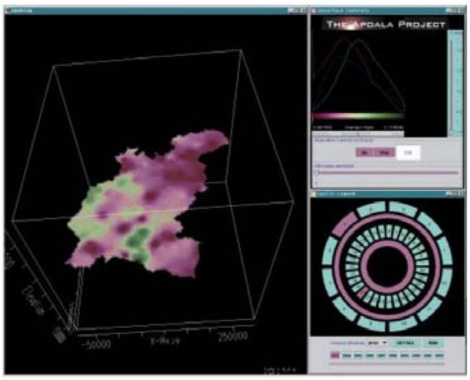


Figure 1.2 A collaborative environment for exploration of spatio-temporal data (Source: Brewer et al., 2000)

The tools were implemented in Java/Java3D as part of the HERO/HEROINE project (Brewer et al., 2000). While limited in functionality, the prototype (shown in Figure 1.2) served as a tool in a series of interviews to identify important system characteristics in satisfying different place collaborative activities, including:

1) Facilitating dialogue – ability to talk/chat while viewing and interacting with tools

2) Group member behaviours – ability to know what others were doing

3) Drawing the group's attention – ability to indicate objects, places, and regions and to alert others to the indications

4) Private work – ability to work ideas out individually before sharing them with others

5) Asynchronous collaboration – ability to save and share sessions and to initiate new analysis from any point.

The authors (Brewer et al., 2000) concluded their report identifying three challenges that need further research: 1) supporting joint control over displays of multiple users; 2) represent users and their behavior; and 3) integrating verbal with visual communication.

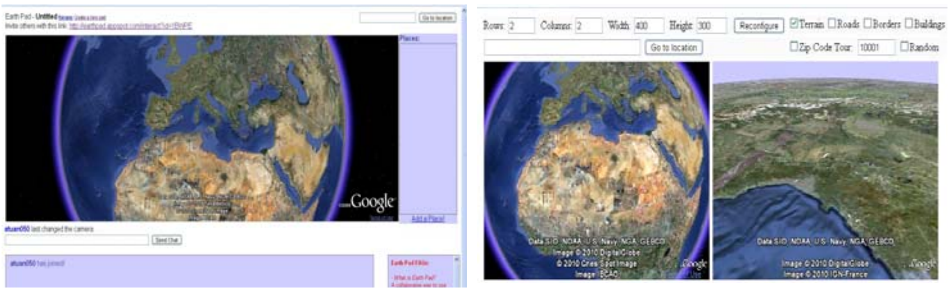
A series of geo-collaborative prototypes and applications developed in the last couple of years address to some extent such problems. Research efforts to facilitate dialogue between experts who explore and analyze multivariate spatially referenced data are part of ongoing work reported by Hardisty (2009). The author extended the capabilities of the GeoViz Toolkit (Hardisty, 2009) through the Jabber open standard for instant messaging in order to support collaborative activities through peer-to-peer instant messages. Fuhrmann et al. (2008) developed three collaborative geo-information prototypes to support collaborative emergency management. A good contribution to the matter is reported by Cai (2005), where the GCCM_Connect is described as a proof-of-concept architecture to support geocollaborative crisis management by teams.

Although a number of other geo-collaborative applications exist, including Toucan Navigate, RIJAN, GATIR, GeoChat and NeoCITIES (described in more detail in Friedenberg (2006)), they were mainly developed to handle spatial data. From those, Toucan Navigate is probably the most popular application at present. It is, however, proprietary software while the accent in this research project will be on developing an application which will be widely accessible to a number of researchers through a simple web browser.

In this context, the *Google Earth plug-in* and *Google Earth Application Programming Interface*, officially released in 2008 (Taylor, 2008) are already showing a potential to satisfy same time/different place collaborative activities and satisfy some of the system requirements identified in Brewer et al. (2000) and MacEachren et al. (2001). An Application Programming Interface (API) is “a set of code libraries made available by the developers of an application to allow others access to the services provided by this application” (Roth and Ross, 2009, p.2). The power of published APIs has already been recognized as one of the two groups of technologies having profound contribution to the development of web mapping (the other one being AJAX) (Haklay et al., 2008).

The Google Earth API and plug-in allow users to embed a virtual globe within a website and customize it according to their needs (URL_1.9). Also released in 2008, the application by Carl Nygaard - EarthPad (URL_1.9, Figure 1.3.A), allows multiple users to synchronize their displays so that all see the applied changes. Additionally, a text-based chat is provided at the bottom of the page to facilitate dialogue between users. The latter can also mark places on the globe through a pin placemark.

A



A B

Figure 1.3 Examples of customized applications using the Google Earth API: A. EarthPad, a collaborative mapping platform (URL_1.9[3]); B. Two Google Earth plug-in instances with additional options to change width/height of each instance

[3] This reference is for the Google Earth API Gallery of examples which contains a link to EarthPad. The application requires a Google, or G-mail account to log in.

A number of other examples in the Google Earth API gallery show how several Google Earth instances (i.e. displays) can be embedded in a web page (Figure 1.3.B), or how the contents of KML can be changed interactively (URL_1.9). The latter is a good example how access to underlying code can be allowed without the need for special scripting skills. Further, another application, The KML Factbook (URL_1.10), shows the potential to develop a web-based tool for interactive conversion of CSV files to KML (Figure 1.4).

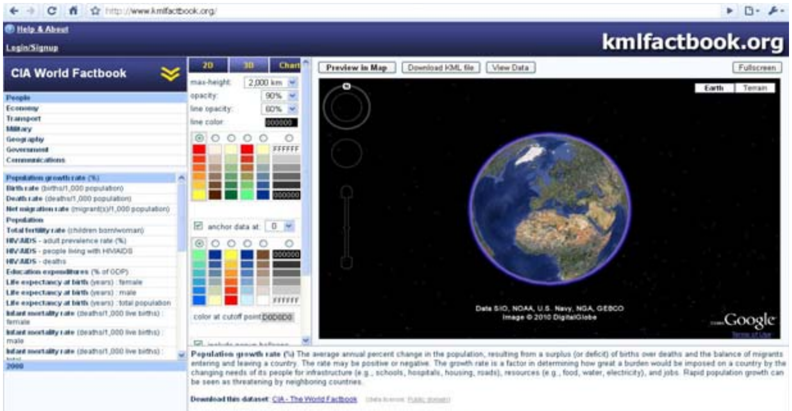


Figure 1.4 The KML Factbook, developed by David Tryse, allows users to create KML files from their custom data (URL_1.10)

Brought together, such elements provide the opportunity to combine interactive cartographic animation with rapid real-time dissemination of information in a multi-user environment. A web-based collaborative virtual globe application used to visualize animated spatio-temporal data may serve as a two-way communication channel between researchers working on distributed projects.

1.2. Motivation and problem statement

Designing and implementing geo-collaborative applications is still a grand challenge (MacEachren and Cai, 2006; Hardisty, 2009), hindered by a number of technical problems. In the last couple of years, however, the focus was placed so much on the technical end, that researchers recognize that the challenge is no more to show that an idea can be implemented (MacEachren, 2005), but rather to make tools more usable and useful which brings us to a user-centered design approach (van Elzakker and Wealands, 2007). The primary goal of user-centered design (UCD) is to develop a deeper understanding of how single users, and more specifically to the context of this study, groups of users work with geospatial information, and only afterwards develop functionalities that enhance, rather than hinder their work (MacEachren, 2005).

In this direction, MacEachren (2005) advocates two initial steps: 1) to conduct formal user task analysis and 2) to design and conduct formal empirical studies that focus on specific user-task-tool combinations. The latter will be a particular focus of this study.

Although rarely, the UCD approach is already being attempted and reported by some authors who design and implement geo-collaborative applications. Unfortunately, the current focus is mainly directed towards the needs of a broad range of non-expert users (Koua et al, *in press*) within the fields of disaster and emergency response (Friedenberg, 2006; Fuhrman et al., 2008), crisis management (Cai, 2005; Cai et al., 2005; MacEachren and Cai, 2006; Tomaszewski and MacEachren, 2006), or other fields, including cancer control and surveillance (Robinson et al., 2007).

In contrast, significantly less attention is directed towards domain-expert users who work with spatio-temporal data on distributed research projects, where visualization can serve as a mediator for presenting results and coordinating actions. Google Earth provides the grounds for group work with animated maps through a number of already developed tools. The problem, however, is that the accent of development of such functionality is often placed on "cool", rather than "useful". Having this in mind, we do not know to what extent gathered tools would impede, rather than facilitate, presentation of spatio-temporal data in a multi-user environment.

Taking this into consideration, the essence of this research is to outline key user requirements for collaborative work with animated maps of a specific group of domain-expert users and look for effective ways to satisfy them through already existing web-based virtual globe functionality.

1.3. Research identification

1.3.1. General objective

The main aim of this study is to look for ways to improve current collaborative mapping and dissemination of spatio-temporal data for domain experts involved in distributed research projects through a web-based virtual globe application.

1.3.2. Specific objectives

- To gain knowledge on the use and user requirements for collaborative dissemination of spatio-temporal data
- To develop a web-based virtual globe prototype which allows viewing and sharing of animated spatio-temporal data and supports collaborative mapping
- To evaluate the usability of the design and give recommendations for further work

1.3.3. Research questions

- What are the relevant user characteristics that affect user requirements?
- What are the preferences of potential users for collaborative map use?

- What are the specific usability goals that need to be met in a collaborative web-based virtual globe environment to support dissemination of spatio-temporal data?
- What are the general usability guidelines that have to be followed in a web-based virtual globe environment to support dissemination of spatio-temporal data?
- What further insights can we gain from obtained user feedback in terms of effective dissemination of spatio-temporal data in a collaborative environment?
- Which technical solutions can be used to satisfy user requirements for dissemination of animated maps in a collaborative environment?
- What are the advantages of the selected technical solutions for domain experts who work with spatio-temporal data on distributed research projects?
- What insights can we gain through usability testing of the developed high-fidelity prototype with respect to effective collaborative work and dissemination of spatio-temporal data?

1.4. Thesis structure

Reaching the aim of this study requires ensuring that all design efforts are firmly grounded in the needs and characteristics of domain expert users who work with spatio-temporal data on distributed research projects. For this reason, a User-Centred Design (UCD) approach was undertaken.

Placing the users at the centre of design in order to increase the usefulness of (geo-) collaborative tools is a very demanding effort and the beginning of Chapter 2 reveals the challenges behind such an endeavor. The main focus here is on usability and utility of single-user and groupware applications, followed by a more detailed description of the User-Centered Design cycle and a breakdown of its phases. The description of each phase is supplemented by a review of the range of instruments and methods for data collection. Finally, the most suitable methods for the purpose of this study are selected and justified.

The rest of the chapters take a quite different approach in order to answer the posed research questions. Chapter 3 deals with the first three research questions: *What are the relevant user characteristics that affect user requirements? What are the preferences of potential users for collaborative map use? What are the specific usability goals that need to be met in a collaborative web-based virtual globe environment to support dissemination of spatio-temporal data?* The beginning of this chapter identifies generic high-level goals and tasks related to presentation of spatio-temporal data in a collaborative environment. Afterwards, the data collection techniques and methods to obtain data on user characteristics and preferences which influence user tasks and requirements are described. The obtained results allow setting the usability goals that the conceptual design should satisfy.

Chapter 4 concentrates on the conceptual design of a collaborative web-based virtual globe prototype used for dissemination of animated spatio-temporal data. It starts with a review of general design recommendations for on-line single user and groupware applications, as well as principles for design of interfaces that supply interaction to animated spatio-temporal data. The design and re-design activities, guided by these principles are further described. Translating usability goals in concrete design elements allowed exposing a number of domain experts to the interface of the prototype. Hence, this chapter deals with two research questions: *What are the general usability guidelines that have to be followed in a web-based virtual globe environment to support dissemination of spatio-temporal data? What further insights can be gained from obtained user feedback in terms of effective dissemination of spatio-temporal data in a collaborative environment?*

Chapter 5 focuses on the third, and final, stage in this research – implementation and empirical evaluation of a collaborative web-based virtual globe application which supports dissemination of spatio-temporal data. The beginning of this chapter deals with: *Which technical solutions can be used to satisfy user requirements for dissemination of animated maps in a collaborative environment?* Further, overcoming several challenges connected with usability evaluation of groupware applications, the end of Chapter 5 describes six collaborative usability tests, aiming to answer the final two research questions: *What are the advantages of the selected technical solutions for domain experts who work with spatio-temporal data on distributed research projects? What insights can we gain through usability testing of the developed prototype with respect to effective collaborative work and dissemination of spatio-temporal data?*

2. User-Centered Design and selected methodology

"With exception of games and instant messaging, most real-time groupware is not widely used. One reason is that groupware has serious usability problems in how they support group work - collaborative systems are, at best, awkward to use"

Baker et al., 2002

2.1. Introduction

A criticism to current geo-collaborative tools is that the main focus is on the technical end, while the users are often neglected, making such applications inadequate in supporting effective group work (MacEachren, 2005). This is mainly due to the fact that placing the users at the centre of design in order to increase the *usefulness* of (geo-)collaborative tools, also known as groupware, is a very challenging endeavour.

The last decade witnessed impressive progress in Computer Supported Cooperative Work, and the number of available collaborative tools increased rapidly. However, while software vendors are increasingly enhancing single-user applications with collaborative elements, literature still provides a limited number of reports for formative or summative user evaluation of collaborative or geo-collaborative applications. What is more, none of those is particularly directed towards group work with animated representations.

This chapter begins with a brief explanation why this is the case (Section 2.2). Concepts such as usefulness, utility and usability for single-user and multi-user applications, are explained. Following (Section 2.3), a more detailed description of the User-Centered Design cycle and a breakdown of its phases are presented, together with the possible instruments and methods for data collection. In summary, it should be noted that all of the presented methods have their own advantages, as well as limitations. To address such limitations, prior work suggests to combine multiple techniques in order to leverage their individual weaknesses and strenghts. In this context, Section 2.4 provides a summary and justification of the combination of techniques and methods selected for the purpose of this study.

Even though related efforts in geo-visualization are presented, this chapter draws heavily upon related research within the fields of Human-Computer Interaction (e.g. Zaphiris and Ang, 2009), Usability Engineering (Nielsen, 1993), and Computer Supported Cooperative Work (e.g. Haynes et al., 2009). Research in such domains provides a substantial body of knowledge about human factors that may influence design and the methods and techniques that can be adopted for implementing and assessing collaborative tools. Much of this information, however, is not yet extensively applied in the design of geo-collaborative applications. One of the reasons is that, when it comes to work with geo-spatial information, identified design principles with standard software applications may no longer be valid when it comes to individual and group work with spatial and temporally referenced data.

2.2. Software and groupware usability and utility

Assessing the usefulness of a product means to investigate whether it can be used to achieve some desired goal (Nielsen, 1993). To this end, two main attributes of a system come into play: its utility and usability. *Utility*, also referred to as functionality, addresses the issue whether a system can do what it was designed for irrespective of other factors (Nielsen, 1993). On the other hand, *usability* is a measure of "the extent to which a product can be used by specified *users* to achieve specified *goals* with effectiveness, efficiency and satisfaction in a specified *context of use*" (ISO 9421-11).

Effectiveness measures whether an activity is easy to perform through, for example, the errors that users make during the use of the product, and the severity of those errors. *Efficiency* measures the resources utilized in achieving a goal, such as time and effort, while *satisfaction* measures whether the users are subjectively happy in achieving their goals through the product. Nielsen (1993), added three other qualities relevant to system design: *learnability* – how easy it is for the user to learn how to work with the product; *memorability* – does the user remember how to work with the system after some time; *errors* – the user should not make a lot of errors in trying to achieve his/her goals.

User requirements towards a system may be directed towards the utility (functionality) or its usability. As Maguire (1998) explains, when the focus is on the former, they are called *functional requirements*, i.e. what functionality users need to get their job done. On the other hand, *non-functional* requirements are those related to how efficient, effective and satisfactory a current system is from a user perspective. Historically, requirements gathering in software engineering concentrated on functional requirements only, however, experience shows that, from a user perspective, non-functional requirements may be critical in determining the successful use of an application (Maguire, 1998). The same principle applies for GIS and visualization applications and is even more relevant when it comes to collaborative geovisualization tools (MacEachren, 2005). Increasing the usability of end-products is especially essential when working with spatially referenced or temporal geographical representations. It reduces the risk that a map will fail in delivering what it was designed for – to communicate geospatial (or spatio-temporal) information effectively. What is important to realize, however, is that the measure of usability is dependent on *who* the users of the product are, what their *goals* are, and in what *context* they use the product. In this sense, measuring usability in general, is not plausible.

Let us imagine, for instance, that a particular GIS application is optimized to satisfy all single user functional requirements to a particular English-speaking user who wants to produce land use maps (Figure 2.1). Further, he would also like to send over the maps exported in JPEG format to his colleagues through his PC in the office. All of this functionality is supported by the application and is clear and obvious in the interface so that: 1) the user makes no mistakes (increased effectiveness); 2) completes his work with minimum effort and time (increased efficiency), and 3) is satisfied when using the product (increased satisfaction).

However, any variability in the parameters above causes the usability of a product to decrease (Figure 2.1). This would be the case for a user who has a different operating system, speaks another language, prefers to export his products into different file formats and would like to study the temporal evolution of land cover, rather than spatial patterns in land use. Even if the system offers the necessary functionality, it may be rather impossible for this fictional second user to complete his work in the same way the first one does. Hence, in terms of increasing the usefulness of an application for single users, it has to be fine-tuned to difference in context of use, individual characteristics, preferences and the tasks at hand.

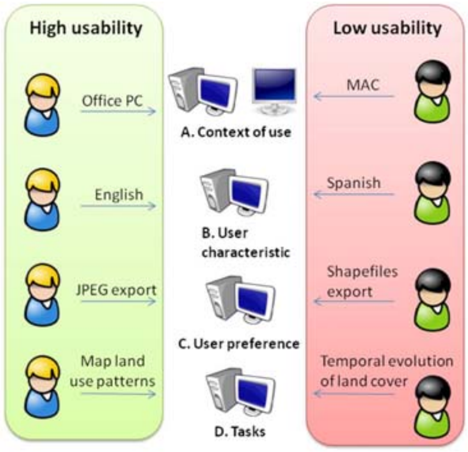


Figure 2.1 Some factors affecting the usability of a single-user application

When it comes to groupware, usability is “the degree to which a groupware system supports the mechanics of collaboration for a particular set of users and a particular set of tasks” (Gutwin and Greenberg, 2000, p.100). According to the same authors, adequate support of collaborative tasks is achieved through several processes, also called “the mechanics of collaboration”:

- **Explicit communication** – group members intentionally provide each other with information; this may happen through verbal and written communication, or through pointing at artifacts in the workspace
- **Consequential communication** – opposite to explicit communication, this is the support of picking up information from others as they go about their activities
- **Coordination of action –** actions in shared workspaces and manipulation of shared resources needs to happen in such a way so that no conflict arises when people work with them

- **Planning** – help users to plan their activities through, for example, an option to divide and re-divide their workspace into public or private, or consider various courses of action
- **Assistance** – people need to be able to help each other through either opportunistic assistance (one person helps another through a particular situation) or informal assistance (when help is explicitly requested)
- **Protection** – prevent other people from destroying work that someone else has carried out.

Assessing the usability of multi-user systems, therefore, means to measure how effective, efficient and satisfactory a system is in supporting all of these activities (Gutwin and Greenberg, 2000).

Figure 2.2 Factors affecting the usability of groupware (multi-user applications)

The above stated definitions reveal why assessing and increasing the usability of groupware is a significant challenge. More attention on the definition of groupware usability reveals that it relies on the assumption that a system is already usable from a single-user perspective. This makes early focus on individual users essential and brings us to one of the main concepts behind a user-centered design approach.

2.3. User-Centered Design

2.3.1. Definition

User-Centered Design (UCD) is a broad term describing design processes in which end-users influence and shape out the design of a system under development (Abras et al., 2004). The purpose behind placing users in the center of design is mainly to increase the *utility and usability* of a system under development (Maguire, 1998). The basic concept behind UCD is to achieve a more in-depth and thorough understanding of the users of a product, their tasks, preferences and the environment in which the product will be used (Nivala et al., 2005). Irrespective of whether the system is designed for single or multiple users, there are several key activities that underpin different stages in UCD cycles. These are described in the following section.

2.3.2. Stages in User-Centered Design and data gathering techniques

In general, there is a lack of a single unified framework for conducting UCD (Gulliksen et al., 2003). A common starting point, however, is identifying and describing all types of users that will be affected by the product under development. These may be 1) primary users (who use the application), 2) secondary users (who use it occasionally) and 3) tertiary users (who will be affected by its use) (Abras et al., 2004). The needs of these three groups, however, may vary to a great extent, and be in conflict. This is why it is generally recommended that focus is placed early on a particular user group which will facilitate understanding and analysis of its specific needs (Maguire, 1998; Wealands, 2007). Subsequently, what follows is an iterative process, whereby three main stages may be identified: Analyze Requirements, Produce Design Solutions and Evaluate Design (Figure 2.3).

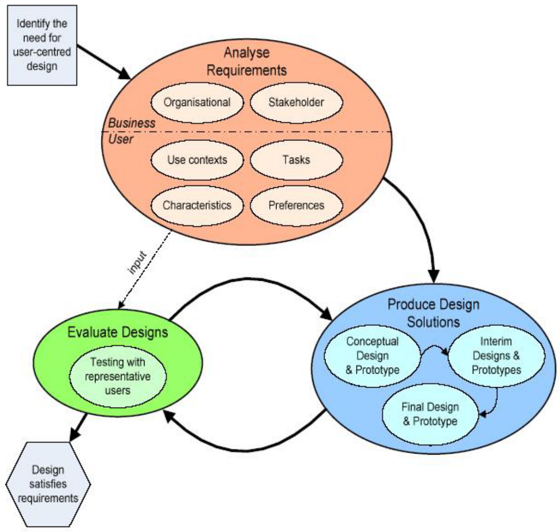


Figure 2.3 Diagram of the stages involved in a user-centered design (Source: van Elzakker and Wealands, 2007)

There is a great variety of methods that can be applied at each stage of design, each having its own advantages and disadvantages, discussed in more detail in Zaphiris and Ang (2009). The final choice of methods will eventually depend on the nature of the system being designed, the available resources and time (Nivala et al., 2005), as well as the objectives of the usability evaluations (Koua and Kraak, 2004). The common trait between instruments to gather data at all stages is the aim of gathering user feedback and user-related information, which afterwards is used directly as an input in design and re-design activities.

This principle is also followed by recent design efforts within the field of collaborative visualization and cartography which span application domains including cancer control and surveillance (Robinson et al., 2007), crisis management (MacEachren and Cai, 2006), and water-balance (Slocum et al., 2003). All of these try to follow the iterative design process for geovisualization tools, suggested by Robinson et al. (2005) and illustrated in Figure 2.4.

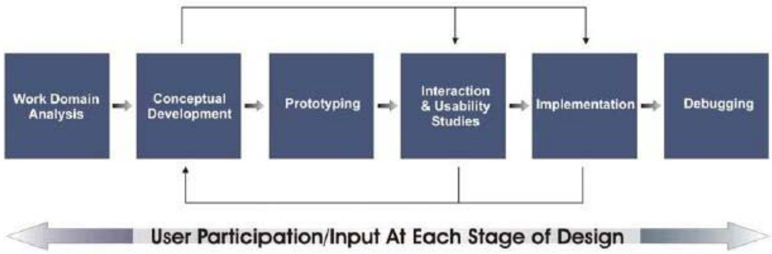


Figure 2.4 Iterative user-centered design process for geo-visualization tools (Source: Robinson et al., 2005)

In Figure 2.4 *work domain analysis* stands for initial communication and elicitation of requirements between the clients and developers (Robinson et al., 2005). *Conceptual development* represents the outline of desired features and architecture of the application under development, while *prototyping* involves implementation of working models. *Interaction and usability studies* are actual formal evaluations with users, followed by implementation which includes "feedback loops between both assessment and implementation stages as they work backward into conceptual development and initial design" (Robinson et al., 2005, p. 250). The same workflow (with slight differences in the names and numbers of stages) was suggested by Fuhrmann and Pike (2005) for designing and evaluation of geo-collaborative tools. All of these frameworks rely on the three main principles in UCD (Maguire, 1998):

- Early focus on users, tasks and environments
- Active involvement of users and incorporation of user-derived feedback into system design
- Iterative design, whereby a prototype is designed, tested and modified.

For instance, Slocum et al. (2003) emphasize the importance of placing focus on the users as early as possible, prior to implementation of key functionality. Accordingly, after identifying the users, a second step is to perform a thorough investigation on their characteristics, preferences, tasks and the environment in which they will use the product (also referred to sometimes as "context of use"). These and related activities are unified at the first stage of UCD – Analyze User Requirements.

2.3.2.1. Analyze user requirements

This stage often includes a description of what users do currently to achieve their goals, as well as their wishes for future products. The gathered information serves to perform a detailed task analysis later (Nivala et al., 2005).

There are a number of methods to collect data at this early stage, including background interviews and questionnaires, brainstorming, focus groups, observations and ethnographic case studies (Maguire, 1998; Abras et al., 2004; Nivala et al., 2005). *Observations* and *ethnographic case studies* generate rich amount of data, however, they are also exclusively time consuming (Robinson et al., 2005). For this reason, interviews are often used for detailed task analysis (e.g. Brewer et al., 2000). However, they are very similar to questionnaires and surveys, which take much less time to compile and conduct.

The advantages of on-line user surveys for requirements elicitation is further discussed in Belani et al., 2005. As noted by the authors, in an early stage of design, requirements elicitation is highly prone to errors, but user surveys may help in acquiring focused data on attitudes, facts and behaviours.

The gathered information at this stage can be used later to specify user requirements, which can be unified in use case scenarios (Nivala et al., 2005). Use cases, or scenarios, are “a description of a possible set of events that might reasonably take place” (Jakobsson, 2003). Scenarios may be real or fictional and describe how users perform their tasks in specified contexts. Further, a scenario may be used at early design stages to guide design alternatives, new functionality, tasks and needs analysis (Van Helvert and Folwer, 2003). The number of scenarios may range from several to more than 20, but a general recommendation is to focus not on the number, but on the depth of the scenario (Gulliksen et al., 2003). The main disadvantage of use case scenarios to drive design, as noted by Pruitt and Grudin (2003), is that often they are not engaging enough. In this case, personas, or fictional characters are used. One of the advantages of personas is that the designer may decide who to design for.

In Computer Supported Cooperative Work, cooperative scenarios are one of the preferred methods to stimulate new functionality and to generate ideas (Stiemerling and Cremers, 1998). What is more, they can also be used in later evaluation stages with representative users. Within the field of geo-collaborative visualization, scenarios were used by MacEachren and Cai (2006) as part of their *GeoDialogue* approach which aims at facilitating same time/same place human-GIS-human dialogue through visual displays. The same approach was used by Wealands (2007) as basis for design of user interfaces for a mobile location-based service.

After initial compilation, scenarios can be further validated according to their importance, at which point a decision must be taken on which representative tasks the system will be tested. The most significant aspects of the scenario can be selected later to evaluate the usability of the system (Nivala et al., 2005). Usability metrics need to be defined for each usability criterion, but setting criteria for new systems is hard (Nielsen, 1993).

2.3.2.2. Produce design solutions

After specifying preliminary user requirements and usability goals, the next step is to make the first design implementations (Nivala et al., 2005). Such efforts are based on a number of assumptions. When the first design alternatives are ready, storyboards, a set of scenarios or limited versions of the product, also called prototypes (Maguire, 1998; Abras et al., 2004), are used to generate user feedback. One of the disadvantages of scenarios are that they do not consider the details of interface design and layout (Maguire, 1998). To address this drawback, users are often exposed to the interface of a planned system through a prototype. Prototypes can be horizontal, where features of the interface are incorporated but are non-functional, or vertical, which do not have a lot of features but support some kind of functionality (Nielsen, 1993). They can also be fully non-functional, also called low-fidelity prototypes or mock-ups. When the prototype supports some kind of functionality, it is referred to as a high-fidelity prototype (Nielsen, 1993; Abras et al., 2004). If time is a constraint, low-fidelity prototypes are often a preferred method to gather user feedback (Nielsen, 2001). Prototypes save time and cost, since they can be used to gather early user feedback before the whole (or part of the) system is implemented. Additionally, they facilitate the dialogue between the designer and the users, as they make abstract ideas and specifications explicit and concrete (Nielsen, 1993; Helvert and Fowler, 2003).

Prototypes are particularly suitable to use in workshops or focus groups. *Workshops* are often organized with representative users in several consecutive sessions, where design alternatives are presented and evaluated. For instance, Stiemerling and Cremers (1998) organized several workshops to introduce a prototype to a set of representative users and discussed user goals and interface through a representative scenario. In this sense, workshops are quite similar to focus groups.

Focus groups are an informal technique that can be used to assess user needs and feelings both before the interface has been designed and after it has been used for some time. In a focus group, about six to ten users are brought together to discuss new concepts and identify issues over a period of about two hours (Nielsen, 1993). Representative users are also often encouraged to “work” with the system and further speak about their work and evaluate the design of a product. A similar approach was adopted used by Harrower et al. (2000) to identify “unintended variables or distracting interface flaws”. One of the disadvantages of focus groups, as reported in Maguire (1998), is that peer pressure among the members of the group may lead to inaccurate reports. When this is the case, the author suggests using the Delphi groups method. This technique allows designers and usability experts to explore group thought asynchronously over the Web (Fuhrmann and Pike, 2005). This method has been identified by Fuhrmann and Pike (2005) as a suitable tool to gather user feedback for geo-collaborative applications, however, it also tends to be very time-consuming.

2.3.2.3. Evaluation of the design

Iteratively throughout the UCD cycle, usability tests, expert evaluations or on-site observations allow designers to obtain data related to user interaction and performance with the product. Such data are needed to reveal whether the design fulfills user requirements and usability goals established from the previous design stages (Nivala et al., 2005). *Usability tests* or *on-site observations* are carried out with actual representative users of the system, as opposed to *expert evaluations*, which require special personnel as they are performed by usability experts (Rosenbaum, 1989).

There are a variety of methods to evaluate multi-user environments, similar to and originally adapted from the methods used for single-user applications evaluation. However, the research community is yet to reach a consensus on a framework for conducting groupware evaluations. Some of the most common methods used by researchers to evaluate groupware are described in a comprehensive overview article by Pinelle and Gutwin (2000). Among others, these include: case and field studies, heuristic evaluation, walkthroughs, observations, discussions, and follow-up user questionnaires (Pinelle and Gutwin, 2000; Araujo et al., 2004).

One of the most widely used approaches is to actually observe the users and how they interact with the product in their natural environment (also referred to as on-site observation). This type of evaluation, however, may take considerable amount of time. For instance, Steves et al. (2001) conducted a field experiment to evaluate the usability of a collabotative software for a welding research team which took approximately 10 months to conduct and analyse. Such experiments are rare since they are very time- and resource-consuming. As Araujo et al. (2004) argue, groupware applications are difficult to asses because:

- They are adopted very slowly by the final users
- The group members that use them differ in personality and behaviour
- Social, political, economical and motivational dynamics have a huge effect on their use
- Their use changes in time and this has to be considered as a factor to understand the influence of the system.

Fuhrmann and Pike (2005) discuss *video conferencing* and *desktop sharing* as a way to test and evaluate geo-collaborative tools. Both of these methods, however, require installing special equipment or software packages in order to monitor remotely all participants in the tests. Alternatively, usability testing is often conducted in usability laboratories where experts assess the performance of representative users based on a preliminary set of quantifiable or qualitative usability measures. Techniques to complement such usability testing (for single-users and groupware applications) often include (Abras et al., 2004):

1) **The “think aloud” protocol** – users are asked to articulate their thoughts while working with the prototype

2) **Videotaping** – users are recorded with a video camera which allows a follow-up analysis of the tests

3) **Follow-up interviews and questionnaires** – users are interrogated after the tests which allows to gain a deeper understanding of user likes and dislikes towards the design and experienced difficulties

4) **Screen logging** – allows analysis of user interactions with the interface and is often synchronized with the video recordings and the “think aloud” recordings.

A preferred method to use during usability testing is a scenario-based evaluation. Collaborative scenarios can help in capturing the context of collaboration (Stiemerling and Cremers, 1998), while think aloud sessions and video logging can record user reactions to the interface and their work in the groupware environment. Usability problems revealed at this stage can be used to further improve the product and its interface, or redefine gathered information relating to user requirements (Nivala et al., 2005).

2.3.3. Qualitative and quantitative approach

There are two methods to obtain and analyse data with UCD: qualitative and quantitative. They differ substantially in the approach, the way data are gathered and the way they are analysed. The main difference between the two is that qualitative research methods are not directed towards revealing *how much* is there of something, but *why*. Hence, in qualitative research the researcher is not concerned with numbers and quantities, but rather with studying in-depth a particular phenomenon.

Prior to gathering data, the most suitable approach must be selected, where the ultimate decision will depend on the *purpose* of the study. Normally, during the first stages of UCD qualitative methods are often preferred (Gulliksen, 2003; van Elzakker and Wealands, 2007). In this context, Wealands (2007) notes that qualitative exploratory data collection methods, and their associated interpretative analytical techniques, produce outcomes grounded firmly in the experience and perspectives of the user population. Being also exploratory in nature, a qualitative approach was the preferred method used in this MSc study.

2.4. Selected research methodology

Deciding between methods and techniques in UCD is difficult, because very few studies examine and compare how different methods perform. In an overview article, Haynes et al. (2009, p.333) suggest that "the different perspectives gained from multiple evaluation may be better equipped to address the inherent complexity of collaborative systems". However, when time and resources are a constraint, each method needs to be chosen and considered carefully. The final choice of methods and techniques used in this study is illustrated in Figure 2.5.

As can be seen on Figure 2.5, the output from each stage affects the steps that follow and is used in all other stages of research. In order to increase the output from each individual stage and keep the research focus, a preliminary hypothetical use case scenario was developed (Stage 1, Chapter 3), which captured basic user activities of environmental researchers who work in a real-time collaborative environment to present their spatio-temporal data. This was later extended and used in all stages of development.

As described earlier, it is very important to think carefully who the final users of an application are and how individual differences will affect their tasks. The activities undertaken in this study rely heavily on this principle. In order to look for a way to improve current spatio-temporal data dissemination in a collaborative environment, the first issue to explore was difference in user needs (functional and non-functional) from a single-user perspective.

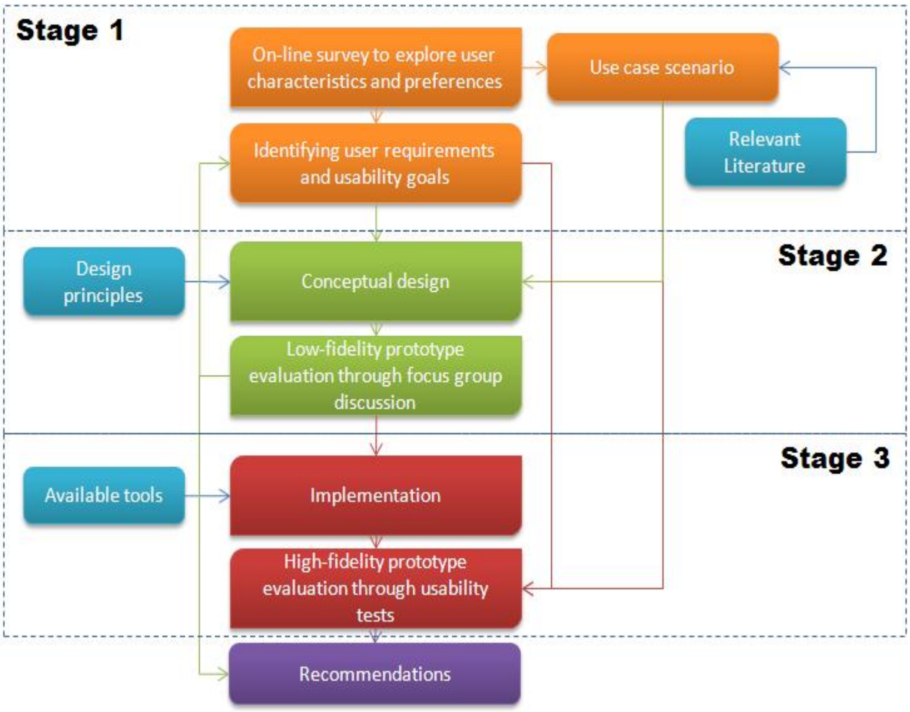


Figure 2.5 Research methodology

At the first stage of research, a user survey was the selected instrument to gather individual user-related data, because of several advantages:

- It may be exploratory in nature
- It is inexpensive
- It takes little time to compile and conduct.

The deployed user survey served to explore individual user characteristics and preferences and set the initial usability goals that design should aim for. Even though a survey gives a limited amount of data for full requirements elicitation, apart from the already identified advantages, an on-line survey was used for several other reasons:

- It could guide a follow-up choice of users in user evaluation
- It provided breadth and depth of input data in the initial stages of this research.

After analysis of the gathered data, user differences affecting the tasks that the system has to support were captured in two fictional characters (personas) and helped extending the use case scenario. A standard practice is to model use case scenarios through the Unified Modeling Language (UML). Nonetheless, Gulliksen et al. (2003) emphasize the difficulties users have in understanding the language and its notations, which is also illustrated with examples from their experience on the Swedish National Tax Board project with real users. Since use cases had to be compiled and presented to users for a relatively short time, a simple text based method was preferred. A similar approach was also used by Stiemerling and Cremers (1998) to facilitate the dialogue between designers and users.

Afterwards (Stage 2, Chapter 4), a number of design recommendations for animated maps interfaces, general and groupware usability heuristics were translated into specific design elements. These guided the design and re-design of a low-fidelity prototype, centered around the extended scenario and usability goals. In addition to its other advantages, the low-fidelity prototype developed in this study served to:

- Translate abstract specifications and principles into specific design elements
- Make assumptions clear and explicit
- Gather early user feedback in a focus group discussion before implementation took place.

Combining a range of ideas and concepts into a low-fidelity prototype was followed by evaluation in order to assess whether those are sufficiently good for further development. Being collaborative in nature, a focus group discussion allowed to:

- Explore in-depth where user requirements differ the most
- Observe how users react to planned functionality
- Identify flaws in the interface with respect to utilized language and organization
- Encourage reasoning about possible conflict situations
- Generate ideas for further improvement.

Considering the limitations of the low-fidelity prototype where actual collaborative work with animated maps was not possible, it was decided that a high-fidelity prototype should be developed (Stage 3, Chapter 5). This was of absolute necessity in order to test how representative users perform with the Google Earth plug-in. During the final empirical user tests, a synergy of a number of methods was used in order to increase the output of the evaluations. In this context, the scenario-based evaluation was qualitative in nature and coupled the “think-aloud” method, together with video/voice recording, screen logging, and follow up interviews which facilitated further analysis. The conducted evaluation was based on a set of qualitative usability goals, and allowed to:

- Identify potential difficulties that users experience with the interface of the developed prototype
- Observe actual group work with animated representations

- Reveal individual and collaborative usability problems.

Problems during the implementation phase, as well as the empirical evaluations allowed addressing the final set of research questions and exposing the advantages and disadvantages of the developed prototype to support real-time group work with animated maps and give recommendations for further development.

2.5. Summary

This chapter started with a review of general terminology within the fields of Usability Engineering, Human-Computer Interaction and Computer Supported Cooperative Work. The most important concepts, including functional and non-functional user requirements, single-user and groupware usability and utility were described and explained.

Next, the main stages in User-Centered Design were presented, together with the range of data gathering methods and instruments available to designers and developers. Their advantages and disadvantages were discussed, allowing later to identify the most suitable combination of techniques for the purpose of this study. The first stage of the selected research methodology is further implemented and described in Chapter 3.

3. Analyzing user requirements

"Qualitative analysis transforms data into findings. No formula exists for that transformation"
Patton, 2002

3.1. Introduction

As indicated in Chapter 2, initial activities in User-Centered Design (UCD) are directed towards achieving accurate, if not yet thorough, understanding of the potential users of a system. This is also tightly connected to the first specific objective in this study and the related research questions: to gain knowledge on relevant user requirements. In this context, the latter, as well as the utility and usability of a system will be mainly influenced by difference in user characteristics, preferences, use contexts and tasks (Maguire and Bevan, 2002; Nivala et al., 2005; van Elzakker and Wealands, 2007). It is noteworthy that identifying individual user needs and requirements is not a straightforward, but rather an iterative activity, which may expand all cycles of UCD. This chapter gives a brief overview of relevant literature and the activities undertaken to obtain initial understanding in this direction.

The beginning of this chapter (Section 3.2) identifies high-level goals and tasks related to the particular topic addressed in this study – presentation of spatio-temporal data in a collaborative environment. Prior to data gathering of key user attributes, it is recommended to develop a preliminary description of potential users in order to control subsequent analysis and to enable identification of a suitable user group (Wealands, 2007). Accordingly, Section 3.3 contains a preliminary description of the target user group, which also influenced the selected range of user characteristics to gather data on. The data collection techniques and methods to obtain an accurate user profile are covered in more details in the following section (3.4), while Section 3.5 describes the acquired results. Finally, key user requirements, design implications and usability criteria relevant to differences in user characteristics and preferences are discussed in Section 3.6.

3.2. Specifying collaborative user tasks in a use case scenario

The tools, tasks and user strategies in a visualization environment differ with respect to the four main map use goals (MacEachren and Kraak, 1997): exploration, analysis, synthesis and presentation. For instance, Blok (2005) discusses two main tasks, and the associated user activities and tools, in the exploration of spatio-temporal data: identify and compare. Conversely, in this study the main concern is visualization for presentation purposes, also referred to as cartographic or visual communication (DiBiase, 1990). This requires different (and far less) interactivity and visualization operations than discussed in exploratory studies such as the ones reported by Blok (2005), Ogao (2002), and Ogao and Kraak (2002). Nonetheless, the number of tasks in a collaborative environment, and the ways users interact with it, may be unlimited. This is why this study started with a review of relevant literature in order to identify key user tasks for presentation of animated spatio-temporal data in a collaborative environment. These are presented in the following sections and served to compile a hypothetical use case scenario.

As described earlier, use case scenarios are a very successful technique in early design (Helvert and Fowler, 2003) or later in usability evaluations, and are often a preferred mean to stimulate ideas for new functionality and increased usability, especially with collaborative systems (Stiemerling and Cremers, 1998). A use case scenario can record either actual uses of the system (elicited through interviews, focus groups, etc.), or a hypothetical situation (also called *envisioned scenario* by Haynes et al., 2009), and specifies the sequence of actions that the users and the system will perform (Wealands, 2007). The following paragraphs present the steps in which an envisioned (hypothetical) use case scenario was developed.

As discussed by MacEachren and Kraak (1997), presentation involves transfer of known facts and information through a visual display. The “message” contained in the visual display (map) is known to the “information designer” and unknown to the “user” of that presentation. In this sense, a collaborative same time/different place environment will be utilized by a person who is aware of the information communicated by the visual display, and one who is not. In order for the “user” to make sense of the transferred message, interaction, even though not of absolute necessity, is preferred (MacEachren and Kraak, 1997). The latter is even more relevant for animation. For instance, in an empirical study with 35 users, Ogao (2006) concluded that interaction plays a key role in animation for generating insights and formulating hypotheses. This is also confirmed by recent evidence in other fields that users feel much less confident of knowledge gained through animated displays, rather than when working with static representations (e.g. Tversky et al., 2002). Similarly to Ogao (2006), Tversky et al. (2002) argue that interactivity plays a key role in facilitating learning through animation. Hence, we can imagine a situation in which the “map producer” presents spatio-temporal data to the “map user”, who is able to interact with it (e.g. stop, pause, and rewind) in order to understand it:

> *“Person A displays an animated map. Person B views and interacts with the animated map to understand what it stands for.”*

This generic situation does not include on-line real-time communication between two or more users. In other words, it is yet lacking a specific description of verbal or written interaction, which is standard for real-time collaborative systems (Gutwin and Greenberg, 2000). In terms of specific group map use tasks, MacEachren (2001) reflected on an earlier proposed conceptual framework by Brewer et al. (2000), extending single-user map use goals into collaborative tasks which include: generate-explore, negotiate-analyze, choose-synthesize, and execute-present. There is, however, no indication of the low-level tasks that underpin the latter. The gist of the problem is tackled by Pinelle and Gutwin (2001, p.103) who pose that the difficulty to capture collaboration tasks in task descriptions is mainly connected with the fact that “in a group, a user might start without clear goals and decide their own actions by reacting to the actions of other users”. To overcome this problem, the authors propose a structured framework for defining a group task model, which comprises of: *scenarios* (high-level description of activities), *tasks* (basic components of a scenario), individual and collaborative *subtasks* (work that is carried out in a task, either tightly, or loosely-coupled), and *actions* (common ways to perform a collaborative subtask). Following this approach, the generic use case scenario presented above was extended to include specific collaborative tasks:

> *“Person A uploads and displays an animated map which Person B is able to view and interact with. Person A is able to focus attention (show) on a particular area or temporal period and explain (communicate) what his results are. Person B is able to zoom in/out to view the territory; play/pause the animation; look at individual frames and ask questions. ”*

Finally, in terms of functionality, it is unreasonable to expect that one application will provide all necessary tools to support all of the map use goals and their associated visualization operations. However, Robinson (2008a, p.10) argues how important it is that geovisualization tools are engineered to “easily coordinate with one another”. In this sense, the information discovered through one visualization application should be transferable to another. With this in mind, the main implication here is that a user should be able to upload and display (execute), but also download already created animated representations. Taking this argument under consideration, the scenario takes the following shape:

> *“Person A uploads and displays an animated map which Person B is able to view. Person A is able to focus attention (show) on a particular area or temporal period and explain (communicate) what his results are. Person B is able to zoom in/out to view the territory; play/pause the animation; look at individual frames and ask questions. Person B is able to download the animation to explore and view it further.”*

Using the framework proposed by Pinelle and Gutwin (2001), it is possible now, based on this generic scenario, to define the preliminary suite of user tasks that the prototype has to support.

Scenario: Present animated spatio-temporal representations to another researcher

- **Subtask A.INDIVIDUAL**: Upload animated maps
  - **Action 1**: click on upload button
  - **Action 2**: fill in the name of the map, etc.
- **Subtask B. INDIVIDUAL**: Display animated maps
- **Subtask C. INDIVIDUAL**: View animated maps
- **Subtask D. COLLABORATIVE**: Show spatial patterns
- **Subtask E. COLLABORATIVE**: Show spatio-temporal patterns
- **Subtask F. COLLABORATIVE**: Explain/communicate information

Subtask G. INDIVIDUAL: Change representation

Subtask H. INDIVIDUAL: Download animated maps

With the list of generic user tasks at hand, the next step was to identify key individual user attributes (characteristics) that may ultimately influence the use of such an environment.

3.3. Primary user group and selected range of user characteristics

3.3.1. Primary user group

The *primary user group* this research is concerned with consists of domain specialists with expertise in various environmental fields, including hydrology, geology, geography, ecology, etc. Potential users of the platform are involved with processing, analyzing and/or visually exploring spatio-temporal data to derive useful information within their field of expertise. Further, a typical *representative user* is a participant in a multi-disciplinary project conducted by dispersed teams of researchers who need to keep in touch for progress reporting. This effort requires and/or may be facilitated by collaborative work in a multi-user environment which supports visualization and dissemination of spatially referenced temporal data where scientists will be able to exchange knowledge and contextualize their work. Hence, representative users are identified based on three preliminary criteria:

- Have application domain within environmental sciences
- Work with spatio-temporal data
- Participate /or have participated in distributed research projects.

Accordingly, the use and usability of the system will be mostly influenced by knowledge and experience with: 1) Information technology and web-based technology; 2) Google Earth and similar virtual globes; 3) Geo-information in general and 4) Animated representations in particular.

3.3.2. Range of user characteristics

Key user attributes that influence the use of a product include (van Elzakker and Wealands, 2007; Nielsen, 1993): age, gender and spoken languages (*demographic characteristics*), sight problems, disabilities (*physical characteristics*), attitudes, motivation, preferences (*psychological characteristics*), relevant knowledge in the application domain, education, profession (*skills and abilities*). All of these will affect user requirements to some extent. However, they may not be indicative of user differences that design should accommodate when it comes to collaborative use of spatio-temporal data.

Unfortunately, the characteristics of the selected users have not been studied and reported extensively in literature. In order to collect such user-related data, a dedicated questionnaire was designed (Appendix 1.B). Its main aim was to collect qualitative information about the primary users on key demographic, physical and psychological characteristics, their work with spatio-temporal data, current ways and needs for collaboration. These items were selected in order to facilitate the process of compiling a user profile. In view of that, it was decided that gathered information had to pertain to several categories of attributes.

3.3.2.1. Basic user characteristics related to experience with information technology and web-based virtual globes: experience with virtual globes (or other immersive virtual environments) has an effect on the ability for orientation, spatial visualization and spatial memory (Gabbard, 1997). Further, experience with computers (e.g. speed of typing on a computer keyboard), the frequency and purpose of use of the Web and web-based virtual globes, ultimately influences the choice of design elements and language (e.g. placemark) that the interface utilizes. For the purpose of this study, other demographic data such as age, together with nationality and spoken languages, was considered irrelevant.

3.3.2.2. Current work with spatio-temporal data, problems with dissemination of (animated) maps: The goal here was to identify what type of spatio-temporal data users work with when analysing and formulating hypotheses or when presenting their results. The data used in all stages of analysis is a potential product to be used in the web application.

3.3.2.3. Collaborative work, frequency and purpose of communication on research projects: Difference in purpose, means and frequency of communication with fellow colleagues will influence organization, functionality, and ultimately, the usability criteria a future design should satisfy.

3.3.2.4. User preferences towards collaboration and dissemination of spatio-temporal data: It is generally accepted that users cannot predict how they would interact with a potential future system with which they have no experience (Nielsen, 1993). However, it was decided that several questions should address preferences towards functionality and design of the system in order to explore not only generated ideas, but also the users' attitude towards a collaborative environment for dissemination of spatio-temporal data.

3.3.2.5. Further contact: Since one of the main problems with UCD is finding and contacting representative users, here we sought an additional advantage of the questionnaire. In this context, the final set of questions served to identify users who are willing to participate in later stages of design and evaluation. As noted by Morgan (1998), willingness to participate in focus groups (or later evaluations), is crucial for successful completion of a project.

3.4. On-line survey design and implementation

A dedicated on-line survey was used as an instrument to collect data and administer the questionnaire. Apart from its other advantages (see also Chapter 2), this was the preferred choice in this study because of a consistent low-response rate associated with written and posted questionnaires, which is normally around 10% (Nielsen, 1993). For this, as well as a number of other reasons (summarized in Table 3.1), the questionnaire was distributed to potential users through a hyper-link generated by SurveyMonkey (URL_3.1). The hyper-link was sent through an invitation letter (Appendix 1.A) to researchers in four Departments (Water Resources, Earth System Analysis, Natural Resources, and Earth Observation Science) currently employed at the International Institute for Geo-information Science and Earth Observation (ITC), Enschede, the Netherlands. A number of additional actions were undertaken, advocated by Taylor-Powell (1998), Kumar (2005) and Nielsen, (1993), to deal with other limitations often associated with questionnaires and surveys, reported by Nielsen (1993), Kumar (2005), and Wealands (2007). These are described in Table 3.1, while the final wording and set of questions can be found in Appendix 1.B.

Table 3.1 Limitations of questionnaires and on-line surveys and activities undertaken to minimize them

Limitation	Action to minimize effect
Low-response rate	• On-line delivered through a link in an invitation letter • Limit the length of questions and answers
Participants may not understand the questions	• The questions were designed to be simple and self-explanatory in nature • Additional explanations were added for specific terms, which may cause ambiguity, e.g. “temporal”, “static maps”, and “animation” • An animated map was included in order to make sure that all participants perceive the term “animation” in the same way
Participants may give confusing responses	• Most questions were closed with a predefined range of possible answers
Bias in responses	• Include category “other” where a participant may explain his answer or provide a different answer from the pre-determined set of possible answers
The results cannot be generalized for the whole population	• No action – common with qualitative research and considered appropriate for this study (see Chapter 2)

The period for completion of the on-line survey was one week. Thereafter, the collector in SurveyMonkey was closed, preventing late participants to answer and influence the gathered data. Consequently, the results were downloaded in an Excel style sheet for further analysis.

3.5. Results

3.5.1. Response rate and omission of “junk” answers

In total, 43 researchers took part in the survey. From them, 14 (32.6%) were PhD-candidates, while the rest 29 (67.4%) were senior researchers, lecturers, assistant and associate professors or professors. In general, the response rate was higher than expected, which showed the interest in the topic and the need for implementation and development in this area.

Two respondents had skipped most of the questions regarding the nature of their work with temporal data and collaborative aspects of their work. This information was considered critical and, therefore, all of their other answers were excluded from analysis. The same procedure was performed for 2 other participants who have specified a background and current work (field of expertise) in a field different from environmental sciences. In total, the results of 39 participants who completed the survey (answered all questions) were taken into consideration. Thirty-one of them work with temporal data and participate in distributed research projects. Based on these characteristics, these respondents fit into the primary user profile (see also Section 3.3.1).

3.5.2. Range of user characteristics that affect interface design and functionality

3.5.2.1. Basic user characteristics

All of the participants in the on-line survey are experienced computer users (more than 3 years); make use of the Internet every day (with their main activities being research and communication); and type on a computer keyboard with moderate to very fast speed. Ninety percent of the users specify that they currently use Google Earth, half of which make use of the application at least once a week. Another three users indicated that they have used Google Earth before or have it installed on their computer. There were no indications for use or preference towards another virtual globe. Consistency of basic user characteristics poses several implications for interface design:

- The interface can employ standard website organization (e.g. navigation path and sign out link in upper right corner)
- The interface can employ standard Google Earth terminology (e.g. placemark, KML) and organization.

3.5.2.2. Data used in analysis and resulting products

The data input (used in analysis) is most of the time two or more remotely-sensed images or two or more maps (see Figure 3.1). In 87% of the cases, however, analysis is supported by complementary data, including vector or statistical data. Hence, when analysing their data, three main categories of users were identified: 1) use satellite images and/or maps; 2) use satellite images and/or maps, together with complementary data, such as vector, statistical or ground measurement data and 3) use only vector, statistical or ground measurements data. As each of these may become an intermediate product in order to confirm hypotheses and generate discussion, functionality should support creating animations from raster and vector maps. Those should be combined with (animated) vector, statistical or ground measurement data.

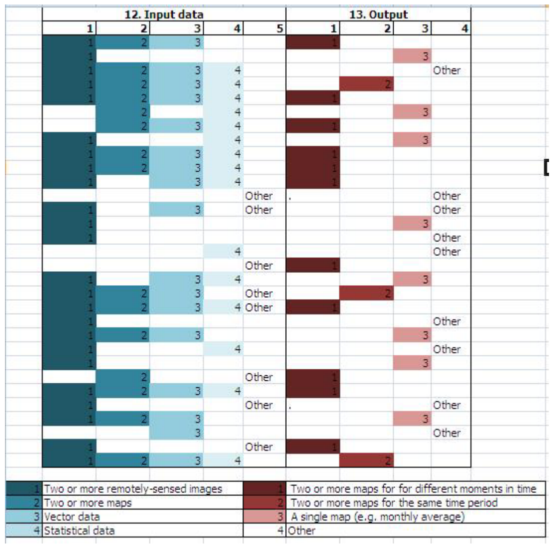


Figure 3.1 Results of the dedicated on-line survey with respect to data used for analysis and the resulting products to be communicated further

In general, the output from the users' analysis varies much more between users (Figure 3.1). For instance, only in 35% of the cases the result is two or more maps. Another 35% specify that the output from work with spatio-temporal data is most of the time spatial averages. The rest of the participants note down various outputs, including "graphs", "3D data", "subsurface models", "statistical data" and a "mix of textual, quantitative and qualitative spatio-temporal information". The main implication here is that a virtual meeting may not be specifically directed towards work with animated representations.

3.5.2.3. Collaborative activities on distributed projects

It was considered equally important to identify what is the purpose of collaboration, as well as how and how often communication is realized between domain experts. Results show that respondents can be divided into three main groups (A, B and C, described in Table 3.2) with respect to the nature of collaboration, means and frequency of communication.

When work is dependent on someone else (Group A), users indicate various means for communication and sharing of information, including personal meetings, voice chat, e-mail, dedicated web sites or software. The frequency of communication is most regular in this group of users and varies from every day to several times a month. Users in this group, where work is dependent of someone else, would benefit mainly from an exploratory environment where they can formulate hypotheses and analyse spatio-temporal data. Additionally, design for Group A may include more functionality and diverse design elements, since these users will use the application more frequently. Here, the main usability criteria would be effectiveness and efficiency.

On the other hand, users in group B and C work independently and only share progress at regular intervals of time or when their work on the project is finished (Table 3.2). The means of communication are mainly personal meetings and e-mails for both groups. Respectively, contact is not realized more regularly than once a month. The main implication with respect to this result is that the interface for Group B and C should be simple. Here, memorability and learnability would be the main aspects that will determine usability.

Table 3.2 Emerging sub-groups of users with respect to nature, means and frequency of collaborative activities

Group	Nature of collaboration	Means of communication	Frequency of communication
A	Work is dependent on someone else	Means range from personal meetings to dedicated software	Every day – several times a month
B	Work is independent; share progress	Mainly e-mail, personal meetings and voice chat	Irregularly; once a month to several times a month
C	Work is independent; present results at the end of a project	Mainly e-mail and personal meetings	Irregularly; once a month to once every three months

3.5.2.4. User preferences

As expected, the vast majority of domain experts prefer a fast website rendered with GIS functionality. In this context, one of the users indicated that "*both the local and the distant user* [should] *have the possibility to make changes*". Two participants express the need for customization of the whole application, as well as with respect to the maps themselves, with one participant noting down "*it can be updated in the way of the thinking process*". To sum up, the main themes emerging from the responses are:

- Fast access and a lot of space
- Tools to comment and add text
- Restricted access to collaborators (security)
- Should be able to display vector and raster maps and download the maps
- Gives the other party a possibility to upload their own results in exactly the same location
- GIS functionality.

3.5.2.5. Context of use

The particular context of use of a product may vary in several aspects. In this context, variation in the physical environment (desktop versus mobile use; on-line versus off-line), as well as social and cultural dynamics, will ultimately determine different aspects of usability (Wealands, 2007; Araujo et al., 2004). For instance, design of a desktop application needs to take under consideration the variety in hardware and operating system configurations, while on-line use has to accommodate different broadband speed and web-browser configurations (Haklay et al., 2005). Identifying these aspects with all potential users was considered inappropriate for the given time-frame and this is why an assumption was made that the system's context of use will stay constant.

3.6. Designing for the user

Supplying all the necessary functionality and arranging design elements to accommodate difference in all individual characteristics and satisfy all user goals would take much more time than available. Hence, it was decided that the conceptual design of the application should be directed towards a particular "cross-section" of users, or a particular class of respondents. As indicated by Belani et al. (2005), users in cross-sections have: 1) different subset of features; 2) different frequencies of product usage; 3) varying experience and skill levels.

As the results from the on-line survey show, a number of users would benefit from an exploratory collaborative environment, where progress on research projects depends on someone else and is discussed every day (Sub-group A). Finally, however, it was decided that design organization and elements will be directed towards users who work independently and only share progress at regular intervals of time (Group B and C). Identified differences between users formed the initial user requirements towards the application under development and allowed to determine a specific set of usability goals that further design and implementation should aim to satisfy.

3.6.1. Usability goals

Usability goal setting is generally recommended prior to design activities and implementation since it gives designers: 1) a concrete goal to aim for and 2) concrete assessment criteria (Nielsen, 1993). Usability goals can be further differentiated into *qualitative* (general, non-quantifiable), and *quantitative* (specific and objective, quantifiable). In general, defining measurable (quantitative) usability criteria at the early stages of design is quite hard (Nielsen, 1993). This is why usually efforts are directed towards satisfying a set of qualitative usability goals (Wealands, 2007).

Qualitative usability goals to guide initial design were set based on the user profile and identified user requirements towards the application. It was decided that users from Group B and C would benefit the most from a collaborative environment for presentation of spatio-temporal data. Preliminary usability goals (UG), hence, are:

1. **UG1 - Easy-to-learn and easy-to-use interface** - collaborators from Group B and C communicate less often on research projects where frequency of communication varies from once to several times a month. For these users, memorability and learnability would play a major role. In this sense, the general organization of the interface, as well as all other elements should be self-explanatory.

2. **UG2 - Conversion of different types of data** – when presenting research results, users need an interactive tool to convert different types of temporal data into animated representations, which may vary from satellite imagery and/or maps, to vector, and ground measurement data, but may also include non-temporal data, including 3D and subsurface models.
3. **UG3 - Visualization and dissemination of location-specific non-spatial temporal data** – when presenting research results, except animation, the platform should support dissemination and visualization of different types of data, which may be location-specific temporal data and/or representations which are not spatial in nature (e.g. graphs and charts).
4. **UG4 - Support of synchronous and asynchronous collaborative activities** – one of the implications for design from identified groups of researchers working on distributed projects is that frequency of communication will vary between team members and will be relatively less frequent. In support of such collaborative work, all activities relating to communication (e.g. chat messages), and applied changes in the map display need to be tracked and saved.
5. **UG5 - Access to current and previous work on projects –** a number of users have participated previously in distributed research projects. Hence, it was considered that the interface of the application should provide access to information relating to previous activities on projects.
6. **UG6 – Security** – a number of users indicated the necessity for security and restricted access for people outside a research project.

3.6.2. Modelling user behaviour: scenario and personas

Modelling users' behaviour and needs helps in task performance analysis and is useful to predict the efficiency of the user interface. Modelling can relate to two key aspects: the users and their characteristics (persona development) and specifying how they achieve their goals in terms of activities (use case scenarios). Both of these techniques are widely used in UCD for single-user and multi-user interfaces and have proved successful in a number of studies (e.g. van Elzakker and Wealands, 2007; Stiemerling and Cremers, 1998; MacEachren and Cai, 2006) to guide further design. In this sense, personas are also used to identify users whose particular needs and requirements will not be addressed (Gulliksen et al., 2003).

3.6.2.1. Extending the initial use case scenarios

The information gathered through the survey and subsequent identification of several cross-sections of users, allowed extending the composed scenario (Section 3.2) to make it more specific:

> "*Every three months, Person A enters the application to upload his animated raster maps. He sends notification to Person B to check the maps…*"

Presented in this form, however, it was yet not clear which sub-section of users the use case scenario is addressing. In order to deal with this, user characteristics were gathered in two fictional characters, also called personas.

3.6.2.2. Personas and the extended use case scenario

In general, persona development requires more user input than a questionnaire may provide. However, as Wealands (2007) notes, the main purpose of developing personas is not to give a precise definition of a theoretical model of a user, but rather to produce a simple description of the user in order to make it possible to design the system. Thus, it was considered best if at least a preliminary set of personas was developed. In doing so, any assumptions made for the users become clear and transparent and can further be confirmed or dispersed through direct contact in interviews or focus groups. As noted earlier (Chapter 2), it was decided that a simple text-based form was selected, as opposed to the UML notations often used by designers. Hence, the final outlook of the scenario and the description of the personas were developed in simple text.

The two personas, where user differences were gathered, are described in more detail below. Personas 1 and 2 (Simon and Bert) combine different aspects of characteristics related to data and collaborative activities in sub-groups B and C.

Persona 1: Simon
Background education: M.Sc. in Physical Geography
Current position: PhD student
Field of expertise: vegetation modeling; land cover/land use mapping;

Simon is currently working on a big scale European project involving different researchers at various European institutions. Even though he works independently when processing his data, he needs to share his progress at regular intervals of time to keep the other researchers on the project updated. The input data Simon uses for analysis is temporal satellite images. Simon’s output is mainly maps for the same area, but for different periods of time. As one of the few vegetation experts on the project, when presenting results, he needs to make sure that all participants understand what his results and input for the project are.
Simon’s purpose: to present his research results to Bert in order to exchange knowledge and coordinate efforts.

Persona 2: Bert
Background education: PhD in Hydrology
Current position: Assistant professor
Field of expertise: water resources management; remote sensing and GIS;

Bert is working on the same big scale European project as Simon. His research is mainly concerned with temporal aspects of precipitation. The input data Bert uses for analysis is vector data. Bert’s output is mainly maps for the same area, but for a single period of time, mixed with textual information.

Bert's purpose: to understand how Simon is progressing and help him get a more accurate idea about other environmental processes in the study area.

After making the fictional users of the system more concrete, the use case scenario was extended to include individual user differences and is based on the characteristics of the two main personas that design was directed towards. The scenario was broken down in two sections (Asynchronous collaboration and Synchronous collaboration). In essence, it describes how two representative users could make use of the system to realize same time/different place and different time/different place collaborative activities.

Asynchronous collaboration

"*Every three months, Simon enters a web-based platform and selects the project he and Bert are working on. Afterwards, he creates a user room for their meeting and enters it. He uploads his data there in the form of animated raster maps.*

Next, he sends a notification through the web site to Bert, together with a suggestion to discuss at 15.00 o'clock the next day. On the other hand, while checking his mail, Bert notes the message from Simon containing a link to the posted earlier animation.

By clicking the received link, Bert is able to log into the platform, view and interact with the uploaded animated maps. He thinks it would be better if they discuss the precipitation maps for the study area, together with the vegetation maps, and this is why he goes to a separate module where he can create his KML files.

After his animated maps are ready, he uploads them in the room where he and Simon discuss. He leaves a message for Simon, and is also able to upload location-specific information for the study area in the form of text, charts, or photos."

Synchronous collaboration

Simon logs on to the platform the next day and together with his colleague they are able to look at the animation, comment and discuss on possible reasons for the anomalies. Initially, Simon takes the lead. He is able to show to Bert a particular area he is interested in, or a specific temporal pattern.

Afterwards, Bert is able to zoom in/out, interact with the animation to explore and view it further. Finally, Bert is able to download the animated maps and send a notification to another team member about the discussion with Simon"

3.7. Discussion and summary

This chapter was dedicated to gaining initial understanding of user tasks, characteristics and preferences towards collaborative mapping and dissemination of spatio-temporal data.

The beginning of this chapter presented the development of a hypothetical use-case scenario. This generic scenario specifies low-level individual and collaborative user tasks in a multi-user environment for presentation of spatio-temporal data.

As part of the requirement analysis, user characteristics and preferences were further explored through the deployment of an on-line survey. Results show consistency of basic user characteristics, related to the use of information technology and web-based virtual globes. This finding implies that the application under development should employ standard web and virtual-globe terminology and organization of the interface. However, looking at the results from the on-line survey, it becomes clear that the most relevant user characteristics are defined by the differences in used data, and purpose and frequency of communication on research projects.

To expand on this, the spatio-temporal data used by domain-experts in the exploratory and analysis phases of research are mostly satellite images and/or maps, but these are complemented by additional statistical, ground measurement or vector data. As each of these may become an intermediate product to confirm ideas and generate discussion, functionality should support conversion and combination of different types of data into KML format.

Further, the initial hypothesis was that the final output would be presented as data series, considering that the input data are of the same nature. Results show, however, that the products that need to be presented vary much more than expected and include spatial averages, 3D and subsurface models, but also non-spatial data representations such as graphs and text. As each of these would require implementing different functionality, the main implication here is that visualization operations towards animated maps have to be complemented by other options, specific for the data at hand. Such results cannot be further compared with previous research, as they are specific for the user group and its characteristics explored in this study. However, a major repercussion for future development was to separate functionality specifically directed towards creating animated representations and changing their settings in a separate module.

The frequency of communication varies among users, depending on the purpose of collaborative activities carried out during a research project. This finding influences both the design, as well as the usability criteria that the prototype should meet. Irregular and less frequent communication on distributed research projects defines learnability and memorability as main criteria which will determine effective use of the application under development.

In terms of preferences, environmental researchers express their desire for fast access, GIS functionality, tools to comment their work and restricted access for non-members in a research project.

In summary, when domain expert users are considered, basic user characteristics such as exposure to and experience with technology and web-based virtual globes are not indicative of differences that the design should accommodate. As opposed to age, skills and abilities which are often advocated as most influential upon design in usability engineering literature, of main concern here is the variety in data among users, purpose and frequency of collaboration. These findings allowed extending the generic scenario and setting initial usability goals that design and implementation should be directed towards. The conceptual design of the application is further described in Chapter 4.

4. Conceptual design and user feedback

"Designing user interfaces is a complex and highly creative process that blends intuition, experience and careful consideration of numerous technical issues"

Maguire, 1998

4.1. Introduction

The literature presented in the previous chapter, together with the results from the on-line survey, provided a general overview of the potential users, their tasks, characteristics and preferences to be accommodated by the interface of the application under development. Designing user interfaces, however, is not a straightforward activity and is highly prone to inappropriate decisions and inadequate choice of design elements in the early stages of a project.

Despite the general lack of principles to guide the design of a collaborative environment for the dissemination of animated spatio-temporal data representations, a number of principles for single-user applications may be adopted. Accordingly, Section 4.2.1 contains a review of general design recommendations and guidelines for interfaces that supply interaction to animated spatio-temporal data. Next, Section 4.2.2 provides a synthesis of more general principles towards web page design and collaborative applications through single-user and groupware usability heuristics.

Guided by these guidelines, the next step was to satisfy the identified usability goals through specific design elements. In parallel to this, an investigation of already developed functionality through the Google Earth API was performed. In addition, although not considered particularly optimal, a number of other on-line applications were inspected. Accordingly, Section 4.3 includes a report on the design and re-designs activities undertaken to select and combine available tools, which resulted in a low-fidelity prototype. The latter served as an artefact to make ideas and concepts concrete and was used in a focus group discussion, the organization of which is reported in Section 4.4. This is followed by a synthesis of the key findings in Section 4.5, which are further discussed at the end of this chapter.

4.2. Preparing for design

4.2.1. Guidelines for interfaces of animated maps

A number of studies and empirical evaluations directed towards the design of animated maps and their interfaces address "the cognitive limits" of animated maps (Harrower, 2007). For instance, the challenges that animations pose to map-readers are discussed in Harrower (2003), Blok (2005) and Harrower (2007). In a comprehensive overview, Harrower (2003) describes the main difficulties related to the design and use of animated maps. For the purpose of this study, a number of ways to deal with these challenges, some of them proposed by the same author, were investigated. Later some of these strategies were translated into design rules and coded. Each challenge is explained in Table 4.1, together with the adopted strategy (design rule) to deal with it.

Table 4.1 Challenges connected with animated maps and strategies to overcome them (after Harrower, 2003)

Challenge	Description	Design rule	IP*
Disappearance	Because of dramatic changes from frame to frame, or rapid eye movements, the map reader may miss important information	Cluster design elements and related functionality together	1
Attention	The user does not know where to look	Synchronize the displays for two or more users	2
Complexity	Too much information in each frame may overload short-term memory	Provide an option to smooth or filter the data when creating animated maps	3
Confidence	People have less experience with animation and are less confident in knowledge acquired through animated maps	Provide a guided introduction to the interface	4

** The code "IP" comes from "interface principle".*

Disappearance may cause the map reader to fail to notice large changes in the display. As discussed by Blok (2005) and Harrower (2007), this is either because these changes occur too slowly or too fast, or during rapid eye movements. The temporal legend (also called "time slider", URL_4.1) in Google Earth provides all the interactivity recommended by Harrower (2003) to deal with this challenge (Figure 4.1).

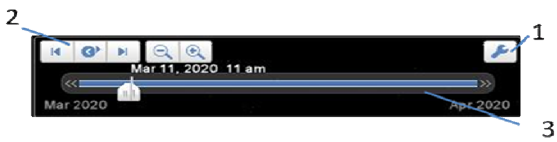


Figure 4.1 The temporal legend (time slider) in Google Earth, providing interactivity to animated maps: 1) settings to change the speed of an animation; 2) basic controls (play, pause, step forward/backward) and 3) the time slider can be used to jump to a particular frame

On the other hand, missing information because of rapid eye movements may occur when the user is required to look simultaneously at the display and the temporal legend of a map. Accordingly, a number of studies address the design and position of the temporal legends of animated maps (e.g. see Kraak et al., 1997; Buziek, 2000; Midtbø et al., 2007). In the case of Google Earth this variable could not be influenced, since the temporal legend in the plug-in is pre-set and appears in the upper left corner. However, this design recommendation had an important implication in terms of clustering related elements together in the prototype (**IP1**).

Moving on to the second challenge (*attention*), Harrower (2003) suggests that it may be overcome through voice-overs and dynamic map symbols at critical moments. On inspection of the KML and API documentation, however, none of these could be implemented at this stage. Therefore, an alternative solution was sought to overcome this problem partially through synchronized displays. In a recent study, Hardisty (2009) describes the "persistent settings" strategy where each user can be either a "leader" or a "follower" in a map. Utilizing this strategy in our case, the "leader", being also the map producer, can guide the map user (or the "follower") to the most relevant patterns both in the spatial and temporal domain (**IP2**).

Regarding *complexity*, Harrower (2003) recommends that the user is provided with options to smooth and filter the data (**IP3**). Finally, increasing the *confidence* in knowledge learnt from animation can be achieved through a guided introduction to the interface (**IP4**). Additionally, other suggestions in Harrower (2003) for better interface design relevant for this study were adopted. These were also coded and explained below:

- **IP5**. Minimize the footprint of the interface – the controls and menus of the interface should not take more space than the map display
- **IP6**. Make the interface less intrusive and demanding – the interface should look simple and explicit, not distracting the user from the main content in the map display
- **IP7**. Use popular interface metaphors – using menus and buttons that users are already familiar with and know how to control (e.g. pull-down menus) minimizes the time the user spends on learning what the interface does, and maximizes the time he/she is spending on the actual content of the map display (also called "effort-to-reward ratio").

4.2.2. Single-user and groupware usability heuristics

Usability heuristics are widely accepted methods for preventing and discovering potential conflicts in application development. Probably the most widely accepted heuristics for single-user web page interfaces are the ten usability heuristics introduced by Jakob Nielsen (Abras et al., 2004). These were improved later to be more concrete for designers (Nielsen, 1994) and also to address groupware-specific problems (Baker et al., 2002).

The heuristics are normally used as discount usability methods for evaluation of design alternatives early in the UCD process (Nielsen, 1993; Gutwin and Greenberg, 2000; Baker et al., 2002). However, they can also be used to guide design, provided they are translated into specific design rules. The main limitation is that such general principles are often hard to translate into concrete design decisions (van Welie et al., 1999).

The ten usability heuristics introduced in Nielsen (1994) and their revised version for groupware applications (Baker et al., 2002) are further described and coded so that a design decision can be tracked to the appropriate guideline.

4.2.2.1. Nielsen's usability heuristics

- **UH1 – Visibility of system status –** the system should always keep the users informed of what is going on through appropriate feedback. In terms of web page design, this means that the user should be able to know immediately "where" in the web site he/she is. Links to content from different parts of the web site should be provided.
- **UH2 – Match between system and real world** – The system should speak the user's language with words, phrases and concepts familiar to him/her.
- **UH3 – User control and freedom –** Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.
- **UH4 – Consistency and standards –** Users should not have to wonder whether different words, situations, or actions mean the same thing.
- **UH5 – Error prevention –** Even better than good error messages is a careful design which prevents a problem from occurring.
- **UH6** – **Recognition rather than recall** – Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another.
- **UH7** – **Flexibility and efficiency of use** – Accelerators, unseen by the novice user, may often speed up the interaction of the expert user.
- **UH8** – **Aesthetic and minimalist design** – Dialogues should not contain information which is irrelevant or rarely needed.
- **UH9 – Help users recognize, diagnose and recover from errors –** Error messages should be expressed in plain language and precisely indicate the problem.
- **UH10 – Help and documentation –** even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation.

4.2.2.2. Groupware specific heuristics

- **GH1 - Provide the means for intentional and appropriate verbal communication** – Users should be provided with a mechanism by which they can exchange verbal and/or written information.

- **GH2 - Provide the means for intentional and appropriate gestural communication** – Provide options for explicit gestural communication as a mean to directly support the conversation and convey task information.
- **GH3 - Provide consequential communication of an individual's embodiment –** Provide conversational awareness that helps the users maintain sense of what is happening. Unintentional body language can be in the form of: 1) action coupled with the workspace, e.g. gaze awareness, movements, etc.; 2) actions coupled to conversation, e.g. facial expressions, intonation, pause, etc.
- **GH4 - Provide consequential communication of shared artefacts (i.e. artefact feedthrough) -** Consequential communication also involves information unintentionally given off by physical artifacts as they are manipulated. This information is called *feedback* when it informs the person manipulating the artifact, and *feedthrough* when it informs others who are watching.
- **GH5 - Provide protection -** Concurrent access to artifacts in a workspace is beneficial but it can also be a source of conflict. People should be protected from inadvertently interfering with work that others are doing, or altering or destroying work that others have done.
- **GH6 - Manage the transitions between tightly and loosely-coupled collaboration -** People continually shift back and forth between loosely- and tightly-coupled collaboration where they move fluidly between individual and group work. For this reason, they have to maintain awareness of others: where they are in the workspace, where they are working and what they are doing.
- **GH7 - Support people with the coordination of their actions -** Coordinating actions involves making some tasks happen in the right order and at the right time while meeting the task's constraints. On a small scale, awareness helps people work effectively while on a larger scale, groups regularly reorganize their labor division based on what the other participants are doing and have done, what they are still going to do, and what is left to do in the task.
- **GH8 - Facilitate finding collaborators and establishing contact -** Most meetings are informal: unscheduled, spontaneous or one-person initiated. Add mechanism to support awareness and informal encounters (similar to bumping into each other in the hallway and exchanging information).

4.3. Conceptual design and low-fidelity prototype

One of the main objectives of this study was to design and implement a prototype which enables researchers to present spatio-temporal data in the form of animated maps, while allowing them to modify and discuss these in real-time with fellow colleagues. As described in Chapter 2, a usable groupware system needs to satisfy, first of all, individual requirements. For this reason, prior to implementation, a Low-Fidelity Prototype (LFP) was preferred since this is considered a suitable instrument for gathering individual user feedback early in design (Nielsen, 1993). Figure 4.2 illustrates the early design, directed towards an environment which supports the generic scenario presented in Chapter 3.

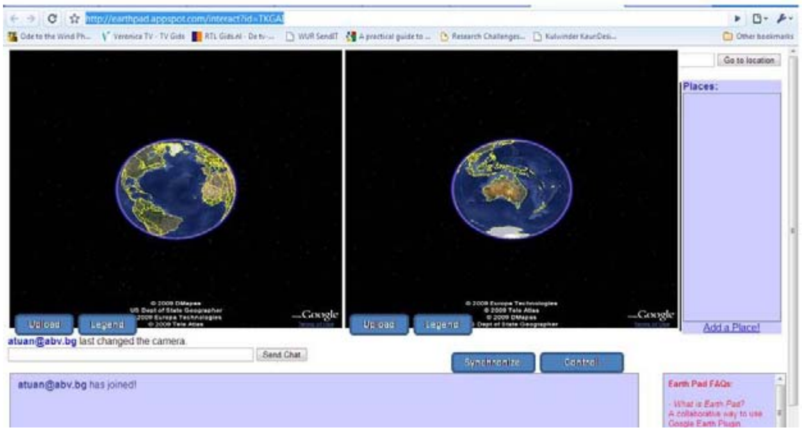


Figure 4.2 Early design, prior to usability goals, personas and scenario development

The design and re-design of the LFP, described in the following section (4.3.1), was guided by:

1) The usability goals (**UG1-6**), described in Section 3.6

2) Personas and use case scenario, described in Section 3.6.2.1

3) Design principles for animated maps interfaces (**IP1-7**), described in Section 4.2.1

4) Single-user (**UH1-10**) and groupware (**GH1-8**) usability heuristics, described in Section 4.2.2.

4.3.1. Design overview

The LFP developed for the purpose of this study (called "Geo Puzzle") served as an artefact where abstract design rules and user requirements were translated into specific design elements. It was developed through the Axure RP Pro 5.5 (URL_4.2) and Adobe Dreamweaver CS3 (URL_4.3) software packages and can be found on URL: http://geoserver.itc.nl/zorni/LFP/Home_page.html.

4.3.1.1. "Geo Puzzle" home page and Projects panel

On accessing its URL by a web browser, the user can log into the system through the Home page (Figure 4.3) by specifying his/her user name and password (**UG6**). Thereupon, the user enters the Projects page (Figure 4.4) which contains links to current or past projects that he/she is or has been involved in (**UG5**). This information is contained in the Projects panel (Figure 4.4) on the left side of the page. A user can create a new project and invite members (collaborators) (**GH8**). In accordance to so-called “gestalt” rules (**UH4, UG1**), the Projects were grouped together with headings similar in shape, size and font.

The information that is available to the user on the right side of the page is controlled by the Projects panel. For each research project, a user can select a link, situated under the name of the project, in order to “enter” several modules: Description, Team members, Datasets, Rooms and Action points. This is illustrated in Figure 4.4 which shows the Projects panel and the above mentioned links (left side of the figure), and the Rooms module (right side of the figure).

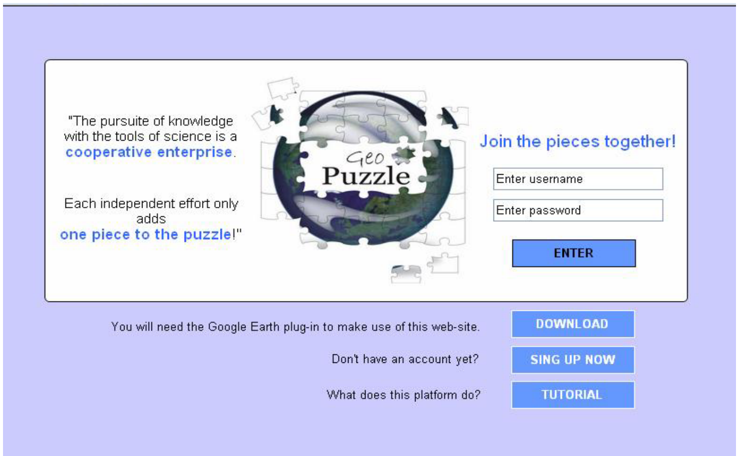


Figure 4.3 Home page of the prototype “Geo Puzzle”

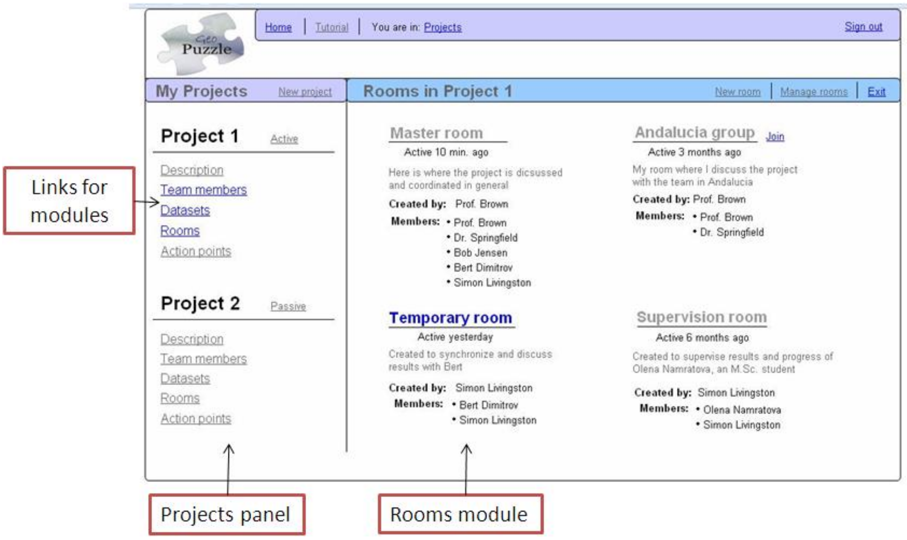


Figure 4.4 The Projects page and Rooms module

The modules Description (containing information, links and other relevant data for each project), Team members (containing name/pseudonym of each user, description of his/her work, contact details and a list of rooms he/she is a member of) and Action points (where the general plan for the project is updated) were based on hypothetical user needs and are in line with **UG1** and **UG4** (Figure 4.4).

Following the scenario, it was considered that a user will first enter the Projects page, and choose one of two options afterwards: 1) either generate and prepare his/her own maps (high level task *execute*) in the Datasets module or 2) choose and enter a user room in the Rooms module where he/she can upload his/her ready-made (e.g. exported from another application) KML files (high-level task *present*). These two modules are further explained.

4.3.1.2. Datasets module

The Datasets module (Figure 4.5) is where the user can create his/her KML animated maps from different data sources (**UG2**). The name was chosen in line with **UH2**. The purpose of the Datasets module is to provide the user with an option to choose a working dataset (satellite imagery, vector layers and maps, or ground measurements) and create and export animated maps in KML format. After choosing a dataset, the user can specify additionally the time unit (temporal resolution) and period (**IP3**) for the animation, and preview the latter in a display on the right hand side of the window. Ideally, this combination of options should change according to the selected dataset.

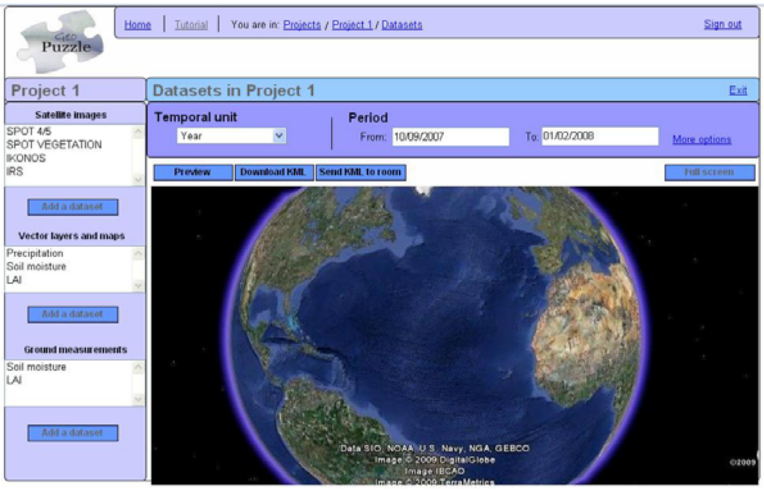


Figure 4.5 The Datasets module

4.3.1.3. Rooms module and virtual rooms

On clicking the Rooms link in the Projects panel, the user enters the Rooms module (Figure 4.4) where he/she can see the virtual rooms in a project where discussion and presentation of animated maps takes place. The information for each room consists of: 1) when was the room last active, 2) a general description why it was created, 3) the name of the creator, and 4) the members that have access to the room (**UG1**). The user can either create a new room, or enter an already existing one. If the user is not a member of a room, he can decide to request access to it, by clicking on the “Join” link next to its name (**GH8**).

A virtual room is the place where two or more users can discuss their spatio-temporal data in the form of animated maps. The general outlook of a virtual room is shown in Figure 4.6. The contents of a virtual room can be roughly separated into two main parts: the Google Earth display, on the left side of the web page, and three tabs: Chat tab, Maps and places tab and Users tab.

Figure 4.6 General outlook of a virtual room, showing the Google Earth display on the left side of the web page, and the Chat, Maps and places and Users tabs on the right

In order to maximize the footprint of the map display (**IP5**), the Google Earth display has a central position in each room and is visible in all sub-pages of a user room (irrespective of which tab a user chooses to “open”, see also the final part of this section). Several options to control and customize the display window are provided below the Google Earth display. These include:

- Full screen button – if the situation requires, the user may switch from small display window to visualizing the GE plug-in on the whole screen
- Overview map button – on clicking this button, an overview map appears in the bottom right corner of the GE plug-in

- Control button – on clicking this button, the user can synchronize his/her display with all other users (this option is further explained in the text that follows).

A low-level collaborative task, identified in Chapter 3, is to show a particular pattern to another user, either in the spatial or the temporal domain. This can be achieved through a joint display between the users in a virtual room. The original code of EarthPad (the collaborative application designed and implemented by Carl Nygaard through the Google Earth API, also described in Chapter 1) offers the possibility for two, or more, users to change simultaneously the display and view the applied changes. However, as Hardisty (2009) notes, this option can be rather unsuitable if two users try to zoom in simultaneously on a location. To overcome this limitation, the author describes two strategies for joint display during a collaborative analysis session: 1) persistent settings and 2) selectable history of map extents. The former implies that there is one "leader", who coordinates the activities in the display, while all other users are "followers". In this sense, their map displays reflect all changes applied in the display of the "leader". Alternatively, the selectable history method provides all users with a clickable list of map extents.

In the design of the system, both strategies were selected. A selectable history of map extents would be beneficent for users who use the system less regularly and try to recollect previous virtual meetings (**UG4**). This is why it was decided that feedback would be generated in the Chat tab whenever a user moves the Google Earth display. Each member of a virtual room can click on the generated feedback and review previously applied changes in the maps display. This approach allowed to satisfy another design guideline related to the mechanics of collaboration: **GH4**.

Furthermore, apart from avoiding awkward situations (like the one described above where two users would like to zoom in simultaneously on different locations), the *persistent settings* approach allowed to address **GH2** and **GH7**, as well as a way to overcome another disadvantage connected with animated maps. As discussed in Section4.2.1, a problem with animated representations is that the user often does not know where to look. A solution for this problem, however, could be introduced through the option for one of the users (who has created the animated maps) to control the display and focus attention of the other person to a particular area or frame of the animated map (**IP2**). This is the function of the "Control" button situated under the map display. On pressing the "Control" button, only one participant has control over the display, which is synchronized with the display of all other members that are currently on-line.

In order to keep the interface simple (**IP6, UG1**), but still include all the information that users require to work in a collaborative environment, it was considered that similar functionality should be separated in three distinct, but related tabs (**IP1, IP7**): Chat tab, Maps and places tab and Users tab.

- Chat tab (Figure 4.7): The Chat tab is where the user can send on-line text messages to another member that has access to the room (**GH1**). Inside the chat window the messages that both users send to each other are saved (**UG4**). The chat window is a focal point where general feedback for the activities in a room is generated (**GH4**). For instance, the system provides feedback who last changed the display, who uploaded new files or created placemarks in a chronological order (displaying the date and time of the interaction with the platform). Additionally, a “Send file” button was added next to the “Send message” button in looking for a way to reach the third usability goal (**UG3**).

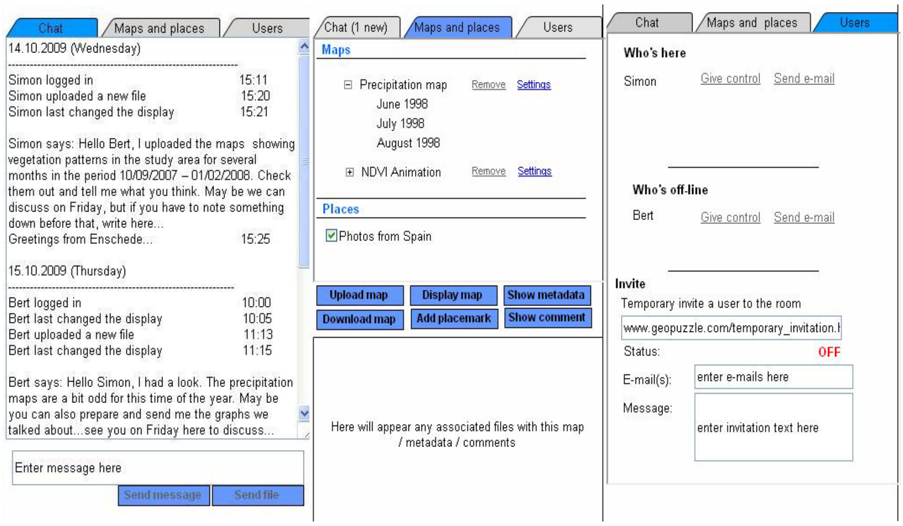


Figure 4.7 The Chat, Maps and places and Users tab

- Maps and places (Figure 4.7): The Maps and places tab is where the user can upload maps and create placemarks. The user may choose to upload/remove a map specifying additional comments or metadata related to the file; display/hide a map; or adjust its settings – functionality available for each file. On clicking the “Settings” link, an additional pop-up dialogue box appears where the user has the possibility to change the file name, set the transparency of the animated maps or the number of frames. Although the information which an animated map can contain is practically unlimited, too much information can overload short-term memory (Harrower, 2007). For this reason, a general recommendation is that animated maps are kept simple and short (Harrower, 2007; Tversky et al., 2002) and this is why providing access to the number of frames in each animation was considered appropriate. This is also a function which the original Google Earth browser provides. Finally, in addition to maps, a user may create a placemark to display location-specific non-spatial data (**UG3**), such as pictures, videos, or text.
- Users tab (Figure 4.7): The Users tab provides control and overview over the users in the room (**GH6**). The panel is split into three parts: on-line users, off-line users and a temporary invitation option. The idea behind this tab is to

provide at least partial awareness for users. Further, since access is allowed only to people invited into a room, it was considered appropriate that an additional option should be created to allow temporary access to other members of the project (**GH8**). Therefore, an additional panel ("Temporary invite user to the room") was added which can have an ON or OFF status. When the panel is ON, the members of a room can send a link to an outside user who will be able to enter the room. When the panel is OFF, this user will lose access to the room (**UG6**).

4.3.2. Design revision

Throughout design, "playing out" the scenario from the perspectives of both fictional users of the platform: Bert and Simon (see Chapter 3), proved very helpful. Several times, for instance, where options were available for one of the fictional characters, the interface did not provide enough feedback or functionality for the other user. For instance, initially the Control button was placed in the Chat tab, and lost its visibility when Bert switches to the Maps and places panel. Consequently the position of this button was re-considered and placed under the Google Earth display, so that it can be visible irrespective of "where" the user is in a virtual room.

Upon completing organization in one module, or sub-page, the interface was inspected with respect to the usability heuristics and interface design principles described in Section 4.2.1 and 4.2.2.

- All the text in the prototype is the same font (Arial), with different weight and size to indicate importance of the elements (and hierarchy) (**UH4, UH6**). Although different variations of blue were used, the colours were limited to four main colours (white, black, blue, and grey) (**UH4**). Adding more hues and tones would have been potentially distracting when working with animated representations.
- Clearly marked exits were added to all dialogue windows (Cancel or Exit button) (**UH3**) in order to increase the users' feeling of being in control of the system.
- Explicit navigation options were added to allow the user recognize where they are currently located (**UH1**) and to jump to different places in the web page ("Path" in the upper part of the web page) (**UH1**, **UH7**). Providing shortcuts to different parts of a system decreases the time and effort to work with elements that are likely to be used together or interchangeably (as may be the case with the Datasets module and the virtual rooms).
- All inactive elements (buttons, links) in the prototype, which were included to make planned functions and operations explicit, were in grey colour or activated a message that this option is not available (**UH5, UH9**).
- A "Tutorial" link was included in the upper right part of the interface. Although non-functional in the LFP, here a user would be able to find either a guided introduction to the interface (**IP4**), or further help and documentation about the application (**UH10**).

4.3.3. Low-fidelity prototype constraints

As discussed in Chapter 2, one of the main benefits of a LFP, as opposed to abstract specifications, is that it makes ideas concrete. Therefore, it can be used for evaluation with representative users. There are, however, some limitations connected with low-fidelity prototyping.

Of major concern was the fact that the Google Earth display is represented by an image, preventing actual experience and work with animated maps. This is the most significant limitation that has an effect on the results from early evaluation, described in the following sections. Nevertheless, the LFP helped identifying critical and valid problems, which were addressed further in the implementation stage.

4.4. User feedback

Obtaining early user feedback is one of the main principles in UCD. Once the LFP was ready, the next stage was to evaluate the extent to which the overall approach and the conceptual design fit user needs. The main goal was to introduce the scenario and the prototype to a set of representative users and give them the opportunity to describe in more detail their own work. This was achieved through a focus group discussion.

Being collaborative in nature, focus groups are a research instrument for collecting qualitative data in early design stages (Morgan, 1998). The same approach has proved successful in a number of previous studies, including Robinson et al. (2005) and Harrower et al. (2000) to identify “unintended variables or distracting interface flaws” (Harrower et al., 2000, p.11). In this sense, a focus group discussion allows observing how users react to planned functionality, organization and language of the interface and encourages reasoning for possible problems and conflict situations.

A number of methodological issues and challenges had to be addressed before conducting the discussion. Firstly, of major concern was the recruitment of participants. An invitation letter to an hour-and-a-half discussion was sent out to key representative users (see also Section 4.4.1 and Appendix 2.A), who participated in the on-line survey and were identified through analysis of its results. This resulted in a negative (or no) response. Several actions, respectively, had to be undertaken: 1) recruit participants personally and 2) shorten the time of the discussion. Even when these actions were undertaken, one of the key representative users could not participate in the discussion. Since this user was identified as a valuable source of information, it was considered that an individual exploratory interview should be scheduled. Trial exploratory interviews are a common method to adjust scripts and procedures later used in focus groups (Harrower et al., 2000). The interview provided a good opportunity to address other limitations connected with focus groups in general, also described by Morgan (1998), as well as the resulting drawbacks connected with the low-response rate. These are described in Table 4.2, including actions undertaken to minimize their effect.

The interview took place approximately a week before the focus group. It lasted little more than 40 minutes and was recorded with a voice recorder. Afterwards, the recording was transcribed for further analysis. When the interview started, the participant (a professor in Natural Resources, employed at ITC, Enschede, The Netherlands) was introduced to the interface of the prototype "Geo Puzzle". Later he was provided with the mouse and encouraged to click his way through the prototype. Throughout this activity the user was actively questioning and commenting on possible improvements. Several problems were observed, which were adjusted in the prototype later used for the focus group discussion. These are reported in Table 4.3.

Table 4.2 Limitations of focus group discussions and undertaken actions to minimize their effect

Limitation	Action to minimize effect
No time to let participants "play around" with the prototype	• Send the link for the prototype through e-mail and encourage users to have a look before the discussion; • Trial interview where the user is encouraged to work with the prototype
Individual feedback in focus groups is limited	• Trial interview to explore individual reactions and obtain feedback
Several focus groups to evaluate design	• Not relevant – focus group discussion was organized with key representative users • Maximize diversity in the focus group
Focus groups are difficult to handle	• Focus group script adjusted after trial interview

Table 4.3 Observed problems in trial interview and re-design activities regarding the low-fidelity prototype

Observed problem	Re-design activity
Confusion because of the blue colour used for the description of the rooms	Colour changed to grey
Could not find the Exit button in the Datasets module	Exit button position changed for all modules and situated in the upper right part of the module
The participant was not aware that he is in the Rooms module when he enters his account and the Projects page	Initial page that loads after log in changed to show a hint "Please, select one of the links from the panel on the left for further options"
Suggestion to add an option to specify user e-mail and message in the Temporary invitation bar	E-mail and message fields added under the Temporary invitation link

After correcting these problems, the prototype was working well enough to be distributed as a stand-alone link to the participants from the focus group. Next to this, after analysis of the transcript of the interview, several topics emerged: 1) tasks during a virtual meeting; 2) privacy issues; and 3) conflict situations. These were added to the script for the focus group discussion, as described in the following section. The remaining suggestions that emerged in the course of the interview are presented in Section 4.5.

4.4.1. Participants

One of the methodological issues that had to be addressed was the choice of participants in the focus group discussion. A general recommendation for recruiting participants in a focus group is to do a *purposive sampling*, as a way to increase the results and gained knowledge (Morgan, 1998). Various qualitative sample strategies, described in more detail by Miles and Huberman (1994), were considered, including *maximum variation, confirming and discomfirming cases* sampling schemes. Finally, a *homogenous purposive sampling* strategy was considered best in line with the recommendations given by Morgan (1998). Thus, selected key users for the focus group discussion had similar characteristics, satisfied all preliminary criteria (see Section 3.3.1) and were considered valuable source of information if they have indicated in the on-line survey: 1) that they work independently on distributed research projects (group B and C); 2) create and work with animated maps; 3) use and share animated maps in all stages of research (see also Appendix 1.B, questions 14-19).

An invitation letter (Appendix 2.A) was distributed amongst a number of selected participants. The low-response rate (see Section 4.4) triggered approaching available representative users in person, even though they differed slightly from the originally targeted list of participants. Fortunately, recruiting users who differed in backgrounds and characteristics (see Table 4.4) provided more comprehensive input to interface design, confirmed by the results but also in previous studies by Robinson et al. (2005).

Table 4.4 Description of participants in the focus group discussion

User	Occupation	Research expertise	Work with animated maps
1	PhD-candidate	Natural resource management	Creates animated maps
2	PhD-candidate	Hydrogeology	Works with ready-made animated maps
3	Assistant professor	Natural resource management, climate change, forestry	Works with ready-made animated maps
4	PhD-candidate	Landslide hazards and hill-slope processes	Creates animated maps
5	PhD-candidate	Soil erosion and remote sensing	Does not work with animated maps
6	PhD-candidate	Soil erosion modelling	Does not work with animated maps

Regarding the number of participants, literature identifies a minimum of 5 and a maximum of 12 users (Nielsen, 1993; Morgan, 1998) with 8 being the perfect number (Morgan, 1998). In total, six users accepted the invitation for a focus group discussion, which was considered appropriate for the purpose of this study. The profile of the final focus group is presented in Table 4.4.

4.4.2. Materials and procedure

The focus group discussion took place in the International Institute for Geo-information Science and Earth Observation (ITC), Enschede, the Netherlands. For the purpose of the meeting, a specially prepared room, where several tables and chairs were situated in front of a wall-screen, was used (Figure 4.8).

Figure 4.8 View of the focus group discussion set-up

The focus group was organized in line with the following general recommendations, found in URL_4.4, URL_4.5, Nielsen, (1993), Harrower et al. (2000) and Morgan (1998):

1. The questions in the script should progress from general to specific with an optimal number of 8 questions.
2. The questions should be open-ended, objective and neutral to stimulate discussion.
3. The moderator's role is only to stir the discussion in the "right" direction.
4. A video or short demonstration may be used to start the discussion.
5. The moderator should encourage each participant to express his/her opinion.

According to these recommendations, the meeting began with a short presentation[4], describing the objectives of the study, the schedule, and the purpose and ground rules of the discussion. Additionally, each user had a document containing key points from the presentation (Appendix 2.B) and purpose and description of the

[4] The slide-show can be found at http://geoserver.itc.nl/zorni/Geo_Puzzle/Home.html

meeting. Afterwards, the experts were exposed to the design through the personas and scenario. Thereafter, the meeting transformed naturally into a discussion. Participants were prompted and encouraged to ask questions and discuss key elements of design in six categories: 1) work with spatio-temporal data /during a virtual meeting/; 2) creating animated maps /Datasets module/; 3) tasks during a virtual meeting; 4) privacy issues; 5) conflict situations; and 6) overall impression of the LFP. Finally, after the discussion, each participant was presented with an opportunity to evaluate and grade each category.

4.5. Results

The focus group discussion and interview generated more suggestions towards the collaborative aspects of the application under development. This was an expected result due to the nature and constraints of the LFP (Section 4.3.3). In general, all participants were intrigued by the application, and expressed their desire for a follow-up evaluation session after re-design. An overview of the results is presented in the following sub-sections, summarizing the key suggestions outlined by the users. A summary of all suggestions, considered improvements of the prototype and their status can be found in Appendix 3.

4.5.1. General suggestions

A suggestion given both during the focus group session and the interview was to provide data exchange, video tutorials, privacy policy and help documentation. Several minor adjustments of different elements of the interface were suggested: remove “active” and “passive” link next to the name of each project and change the name of the “Action points” module. The rest of the suggestions are separated in five main sections.

4.5.2. Management of information

- **History of a virtual room**: Participants in the focus group found the idea that the meeting will be saved in the chat window very useful. They suggested that one of the settings of the room should include setting a time-span of the history so that the user is not overwhelmed by presented information.
- **Organization of virtual rooms**: Participants suggested that there should be a way to organize the rooms in a project to prevent confusion if their number is too large.

4.5.3. Accuracy and scale

- **Accuracy** - Several participants voiced concern about accuracy. As two users noticed, when converting files to display them in Google Earth, you lose accuracy, especially if you are working on a local scale.
- **Scale** - One of the discussed issues was regarding work with large scale maps. One of the participants inquired, “*What if you are working in a very small area? In this case, Google Earth is not very useful.*”

4.5.4. Setting privacy level

- **Access to datasets**: Explaining the Datasets module, all participants agreed with the comment of one of the domain experts that "*The people in a project should all have access to the same datasets and should all be able to work with them*". In contrast, the interviewee expressed his desire to be able to set the access to the datasets himself.

- **Access to and visibility of rooms**: The visibility and privacy of the virtual rooms was also discussed. In general, the interviewee placed much more importance on privacy issues than the users in the focus group. He expressed his desire to be able to attach different levels to invitees in a room. Similarly, a suggestion during the focus group discussion was to provide the user with an option to set different access levels to the rooms in a project: either visible to all (public rooms) or only to members (private rooms).

- **Access to visual display**: The interviewee suggested that the maps on display should have different access level.

- **Access to a project**: the participants in the focus group discussion also suggested that temporary access should be provided to virtual rooms for people who are not part of a research project.

- **Private work**: The interviewee suggested also to provide an option for a private chat in a virtual room, provided more team members are on-line and present at a virtual meeting.

4.5.5. Control of display and display settings

- **Control of display –** Participants in the focus group found the option to handle over the control very useful. On the other hand, the interviewee voiced out his concern that "*you can also end up in a dead-end situation when you, let's say, give control to somebody who either forgets to give the control to somebody else, or simply walks away from the computer or maybe he is just not there, or maybe there is some kind of an emergency and the chat is hung.*"

- **Display settings –** An additional suggestion in the focus group discussion was to "*have the settings of the project…and these include study area…and then when someone logs in it just automatically zooms in to the place*". Most of the participants agreed with this point.

4.5.6. Visualization operations

- **Analysis operations**: All participants in the focus group discussion expressed their desire to be able to "*change the colors and other user options*" in an uploaded map. Additionally, interviewee and some of the focus group participants added that they would prefer to have the chance to perform at least limited analysis operations and access to attribute tables and actual values.

The suggestions and problems observed during the focus group and the interview were further examined prior to implementation, described in the following chapter.

4.6. Discussion and summary

This chapter started with a literature review where basic principles for dissemination and visualization of animated spatio-temporal data were discussed. Coupled with general single-user and groupware heuristics, these were later coded and used during the design stage, together with the scenario and the usability goals presented in Chapter 3. Such activities were complemented by iterative investigations of available web-based virtual globe functionality and tools. Several revisions of the conceptual design resulted in a low-fidelity prototype. It is noteworthy that some of the groupware specific heuristics were not considered during the evolution of the LFP (**GH3** and **GH5**). This is not because they are not relevant, but rather due to the nature of the developed tool and its constraints.

The LFP served to translate abstract ideas, goals and principles into specific design elements. As such, it became an instrument for further development and implementation, discussed in Chapter 5. Furthermore, it was also used in a focus group discussion to attain early user feedback. Instead of simply evaluating the outlook and the organization of the interface, as in previous studies (e.g. Harrower et al., 2000), here we made use of this collaborative discussion in order to identify the most relevant and controversial user needs regarding the functionality of the prototype from an individual point of view. In this manner, the organized meeting generated a number of suggestions towards the outlook of the interface as well as some additional user requirements, considered further during the implementation stage, described in Chapter 5.

The results from the interview and the focus group discussion can complement previously identified key system characteristics, such as private work and drawing the group's attention, also discussed in Brewer et al. (2000) and MacEachren and Brewer (2004). In addition to such system characteristics, in terms of presentation of spatio-temporal data in a web-based virtual globe environment, some of the key issues brought up during the discussion were related to scale and accuracy of the data once converted into KML format. Moreover, collaborative aspects that need to be satisfied include effective management of information and content within a project or a virtual room; setting and providing different access levels to datasets, rooms, projects and display content; and providing control overwrite and time-out options of the Google Earth display.

Comparing this list with previously identified system characteristics (Brewer et al., 2000), it becomes clear that user requirements are dictated not only by difference in individual characteristics, as discussed in Chapter 3, but are also task- and tool-specific. Even though not all suggestions from the interview and the focus group discussion could be addressed further due to the limited timeframe of this study, they allowed identify possible barriers to collaborative work prior to implementing key functionality in the high-fidelity prototype.

5. Implementation and evaluation

"*Once they understand user needs, context, and capabilities, developers must consider the technical solutions available to them*"
Haklay, 2005

5.1. Introduction

One of the primary objectives of this research was to evaluate the usability of the developed prototype to support same time/different place group work with animated maps and give recommendations for further work. More specifically, the investigation in the final stage of this research was directed towards support of environmental researchers in their effort to communicate spatio-temporal dynamics through animated maps in a collaborative environment. For this purpose, after re-design of the low-fidelity (non-functional) prototype described in chapter 4, a high-fidelity (functional) prototype was developed in order to gain insight related to the actual use of the application.

The specifics related to the implementation phase are discussed in Section 5.2. The choice of technical solutions used after the re-design of the system is presented in Section 5.2.1, followed by a description of its underlying architecture (Section 5.2.2), design revision (5.2.3) and constraints (Section 5.2.4). The second part of this chapter is dedicated to the evaluation of the usability of the prototype, which followed the implementation phase. A description of the selected method, the physical environment, participants and procedures undertaken to evaluate the web application are described in Section 5.3. Finally, a synthesized report of the obtained results is presented in Section 5.4 and further discussed in Section 5.5.

5.2. Implementation of a high-fidelity prototype

The purpose of this study was to look for ways to improve current collaborative mapping and dissemination of spatio-temporal data through web-based virtual globe technology. As opposed to the low-fidelity prototype (LFP), which allowed exploration of individual suggestions and preferences, the high-fidelity prototype (HFP) was built for a more practical reason – to test how users perform in a web-based virtual globe collaborative environment.

The implementation phase of the HFP started in mid November 2009 and was carried out by a software developer (Denitsa Belogusheva). Initially, a description of the prototype was sent to the software developer, which included only basic specifications of what the users should be able to do (high and low-level tasks) acquired from the generic scenario presented in Chapter 2 (Section 2.2). Later, implementation was based on the LFP and followed its re-design. The progress was closely monitored and discussed on a weekly basis through e-mail. For practical reasons, it was determined that most of the implementation process would take place after the results from the focus group were known, in case any substantial changes related to the interface were required. Nevertheless, some decisions for the type and nature of required technical solutions, which underpin the core of the HFP, had to be made well in advance. The final choice of elements and functionality is described in the next section.

5.2.1. The Google Earth Application Programming Interface and Ruby on Rails

The Google Earth Application Programming Interface is a free service provided by Google, which allows third party applications to query and send information to Google Earth (URL_5.1). Since its release, many custom applications have already been developed mainly as a prove-of-concept what the API libraries provide. In this context, as described earlier, the original code of the platform EarthPad, developed by Carl Nygaard in 2008 (see also Chapter 1), proved very useful as an example of how to synchronize the displays between two or more users. The code that became the foundation for development of the HFP can be found at URL_5.2.

Additionally, in the course of design and re-design activities, the sample code in the Google Earth API Gallery (URL_1.9) and Examples (URL_5.3) pages were examined to review the elements that would suit best identified user needs and requirements. The purpose of these inspections was twofold: firstly to help with design elements (described in Chapter 4) and secondly to make sure that the implementation is possible within the available time frame. Even though developing an interface, which supports functions in general, and testing these functions later, was out of the scope of this study, it is important to acknowledge that currently the Google Earth API examples gallery provides more than 30 samples with code. However, only a limited number of examples were identified as suitable to satisfy identified requirements towards the prototype. These are presented in Table 5.1.

Table 5.1 Used examples of code from the Google Earth API gallery (URL_5.3)

Name	Description	URL
Fetch KML (Interactive Checkboxes)	Used to toggle on/off and display KML files in the Google Earth plug-in	5.4
Placemark drag and drop	Used to allow users to put placemarks on the Google Earth display	5.5
Geocoder	Used for query operations within the Google Earth display	5.6
Setting Feature Opacity	Used to set the opacity of the KML files	5.7
Viewchange Event	Provides feedback whenever the current view of the display is changed and counts the number of times changes occurred	5.8

Further, several possibilities were discussed with the software developer with respect to various collaborative aspects of the application (e.g. text-based chat, saving the history of a virtual room, etc.). Initially, using Python and the Google Earth Apps Engine or PHP seemed most suitable. However, the final choice fell on the web application framework Ruby on Rails (RoR), created in 2003 by David

Hansson (URL_5.9). A web application *framework* alleviates the development of dynamic websites and web-based applications. Ruby on Rails was considered most appropriate for the purpose of this study because of the following advantages (Thomas and Hanson, 2005; Lewis et al., 2007):

- It is an open-source
- Allows fast development and re-design of web-applications
- Supports web services, AJAX, XML-code generation, JSON (JavaScript Object Notation)
- Has excellent libraries and provides support of collaborative processes (e.g. authorization)
- Can be extended to handle geometric data types, as well as various input and output data formats (KML, shapefile, GeoRSS) through the plug-in GeoRuby (URL_5.10).

Most importantly, RoR was built to suit the so-called Agile development methodology, where the focus of development is always placed on individuals and interactions, instead of processes and tools (Thomas and Hanson, 2005). This allows for producing working software early in the development cycle and quickly implementing changes as the web application develops.

5.2.2. System architecture

Ruby on Rails uses the Model-View-Controller architecture. The Model maintains the state, while the View is responsible for the interface. Finally, the Controller handles the interactions from the user (Figure 5.1). This architecture allowed the web browser to interpret and display the generated HTML code, fed to the interface, and the JavaScript and KML files fed to the Google Earth plug-in.

The high-fidelity prototype uses the open-source database management system PostgreSQL which can be upgraded with PostGIS and the GeoRuby plug-in to support spatial functions (processing and analysis of geographic data). For the purpose of the final evaluations, users were expected to work with pre-processed KML files. Since the evaluation was directed towards presentation, rather than analysis or exploration of spatio-temporal data, spatially enabling the web application was not necessary at this stage.

Several RoR plug-ins and gems (e.g. ruby_kml, paperclip, etc.) were used in the development of the HFP. Additionally, the RoR Juggernaut plug-in was used to achieve synchronization of the text-based chat and the displays of the users in a virtual room. The final architecture of the high-fidelity prototype is shown in Figure 5.1, while the actual prototype can be found on URL: http://deni.hostit.bg[5].

[5] The prototype will require a user name and password to log in. These can be generated when creating a new account or can be found in the individual instructions given to test subjects in Appendix 4.

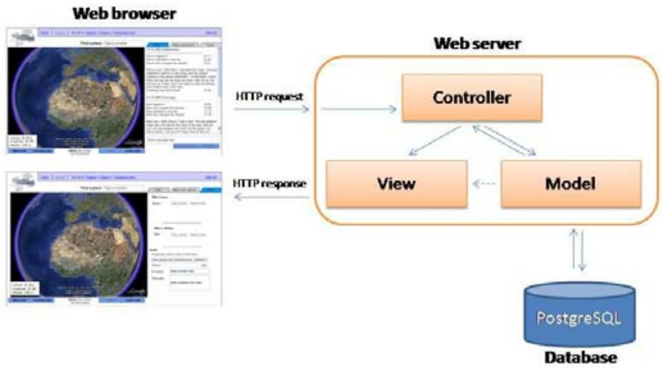


Figure 5.1 High-fidelity prototype architecture

5.2.3. Design revision

During implementation, all suggested functionalities resulting from the focus group discussion and the interview were discussed with the software developer. Implementation of all suggested improvements was not possible within the time-frame of this study and therefore the remaining suggestions have been listed as recommendations for improvement (Appendix 3). Of major priority from those suggestions was to provide a time-out option for control of the Google Earth display. This function was considered the most influential during same time/different place collaborative work as, after having finished his/her work, a user may forget to release the control and switch to other activities, leaving his/her partner not being able to work. Additionally, after initial implementation several other adjustments of the design were made, which did not interfere with the design principles, requirement analysis and user feedback, presented earlier. The reasons for these adjustments are described below:

- The user may not distinguish system messages from text messages sent from his/her partner. For this reason, the colour of the system messages was changed to blue.
- The user may not distinguish system messages from generated requests for taking/giving the control. For this reason, the colour of the system message when one user is requesting control was changed to orange.
- System messages may hinder normal communication in the text-based chat if they are too many. To overcome this, a link in the upper part of the Chat tab ("Show/Hide system messages") was added (Figure 5.2).
- System feedback for control over the display should be closer to the Control button. Therefore, an additional panel below the display was added, containing feedback on who has control over the display, and a button "Control" (Figure 5.2).

- “Maps and places” tab was renamed to “Maps and Places” to give equal weight to both elements.

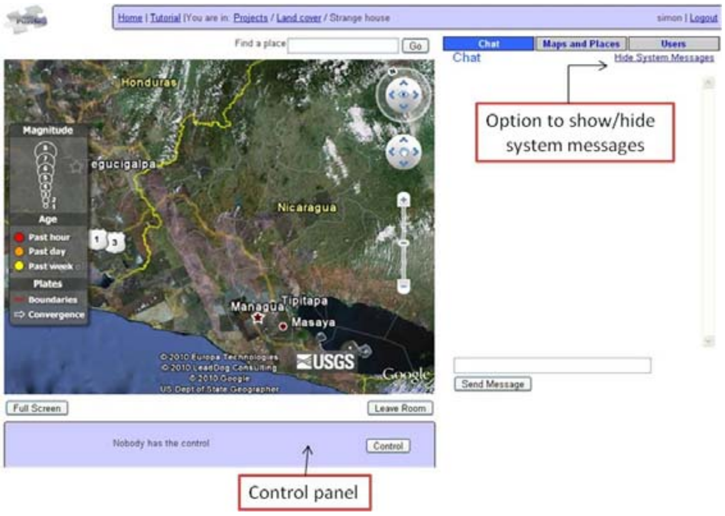


Figure 5.2 Control panel and Chat tab after re-design and implementation

- The display for maps and placemarks becomes too small when an additional comments field is added in the Maps and Places tab. Solving this problem was done through removing the comments field from the Maps and Places module and adding several links to each map, including a “Details” link where the user can see additional information for each uploaded KML file (Figure 5.3.A).

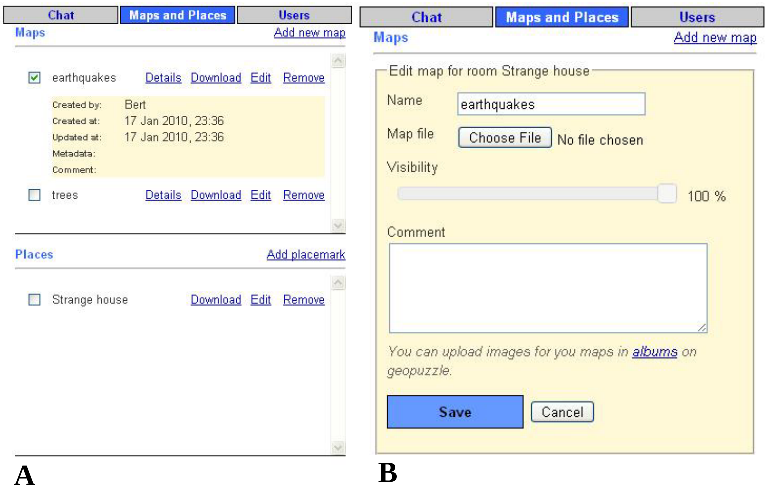


Figure 5.3 Maps and Places tab after re-design and implementation: A. Details about each map are provided directly below it. B. The form for uploading a new map

- Pop-up window when uploading a new animated map in the Maps and Places tab is not suitable since the user loses sight of the Google Earth display and the Chat tab. For this reason, a panel in the Maps and Places tab appears when the user is uploading a new map (Figure 5.3.B).

5.2.4. Reported bugs and constraints

Upon preliminary testing of the high-fidelity prototype, 17 bugs were reported to the software developer, out of which 12 were fixed. Some of the reported and fixed problems included:

- Chat does not notify that there is a message when the user is in another tab (Maps and Places or Users tab)
- While one user is typing in the Chat tab, the other one looses ability to type and send messages.

Unfortunately, several bugs could not be fixed in the available timeframe, including:

- Lack of full synchronization between the displays of two or more users
- Lack of synchronization between animations - animated maps are not synchronized for both users
- Placemarks – when a user wants to create a placemark, he/she has to drag it from a pre-set location; the application does not capture the current display coordinates (Figure 5.4).

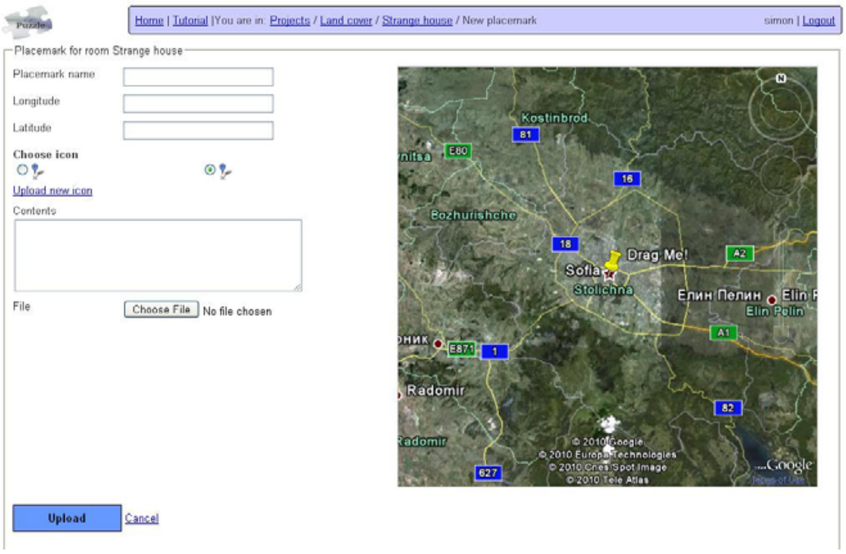


Figure 5.4 The form for uploading a new placemark

Upon discussion with the software developer it became clear that currently the Google Earth Application Programming Interface does not provide a way to fully synchronize animated maps for two or more users. A possible solution was discussed; however, the coding effort behind it would have taken much more time than available for completion of this study.

5.3. Usability evaluation

As described earlier (Chapter 2), to date very few efforts to test the usability of virtual globes with representative users are reported in the relevant literature. In parallel, only two studies (Jankowski and Nyerges, 2001; Robinson, 2008b) were found to document an empirical evaluation of maps as mediators for group work. Both of these experiments examined the use of maps in same time/same place collaborative activities. However, no reports were found of previously tested same time/different place group work with maps or animated maps. In fact, very few collaborative systems are being evaluated as such efforts remain a significant challenge within the field of Computer Supported Cooperative Work (Stiemerling and Cremers, 1998; Pinelle and Gutwin, 2000; Haynes et al., 2009). As a result, a number of challenges had to be addressed, mainly related to the final evaluation of the high-fidelity prototype. These are discussed in the following sections.

5.3.1. Aim and purpose

Much of the traditional methods to test usability in cartography rely on quantitative methods, also known as *functional map use research* (van Elzakker, 2004). Such tests include measures such as the time to perform a particular map use task as well as the number of completed tasks. Conversely, qualitative or *cognitive map use research* focuses on investigating “why maps and cartographic symbols work effectively” (van Elzakker, 2004, p. 24). In other words, quantitative methods can reveal “how” and “how fast” users perform with a given system, but not “why” they resort to particular actions. The overall goal of this study was to develop a prototype, where domain experts would be able to present research results in the form of animated spatio-temporal representations in a real-time multi-user environment. Therefore, a successful use of the prototype would lead to increased understanding and gained knowledge between two or more users. Taking into account that the main concern was whether users understand what is being reported and presented, the tests in this study were of qualitative nature. Since no comparison could be made with reported evaluation results in previous studies, the carried out investigation had an exploratory purpose.

Referring back to the usability goals in chapter 3, evaluation was directed mainly towards qualitative usability goal 1 (**UG1**): easy-to-use interface where memorability and learnability play the main role and usability goal 4 (**UG4**): adequate support of synchronous and asynchronous activities. During preparation for the experiment, however, it became obvious that testing both synchronous and asynchronous activities would be time- and information-intensive for the available test subjects. For this reason, particular accent was placed forward on assessing these elements and functionality of the interface which support synchronous (same time/different place) collaborative activities.

5.3.2. Method

User testing provides experimental evidence on the problems that users may experience with a given product (Maguire, 1998). A widely used method to obtain such data in cognitive map use research is the “think-aloud” method. It involves observing users working with a system while they continuously verbalize their thoughts (Nielsen, 1993). This enables designers and usability engineers to identify major misconceptions about the interface of an application. The same author also notes that, “thinking aloud may be the single most valuable usability engineering method” (Nielsen, 1993, p.195). Furthermore, as previously discussed in Chapter 2, observation of representative users should be coupled with video/sound recordings, screen logging, and retrospective interviews in terms of improving the final outcome. This allows exploring user behaviour, reactions and performance after the evaluation phase is completed.

Observing users working with an interface in a usability laboratory is normally based on a particular set of tasks, designed to test and evaluate different aspects of an application’s functionality (or interface) (Maguire, 1998; Nielsen, 1993). As opposed to single-user applications where users perform individual tasks, within the field of Computer Supported Cooperative Work, evaluations are based on collaborative scenarios (Pinelle and Gutwin, 2001) which include not only individual, but also collaborative tasks. Relating tasks to a scenario also increases the users’ understanding of the system and the sense of realistic use of the product (Nielsen, 1993). This was also the adopted approach in this study. Hence, the evaluation involved representative users who perform a set of individual and collaborative tasks according to the previously developed scenario (see Section 3.6.2.2). In line with the scenario, each user had a set of individual instructions and had to “play” the role of one of the developed personas: either Bert or Simon.

In order to simulate a real same time/different place collaborative situation, test subjects were situated at different locations. Normally, such experiments are conducted in specially equipped usability laboratories, described also in Smith and Gorsuch (2004). In essence, it consists of two separate rooms equipped with video/audio capturing equipment, separated by a glass window for the control room. The latter is used by a moderator who can observe both users at the same time and communicate with them through an intercom. Unfortunately, the current set-up of the available usability laboratory differs and for practical and financial reasons could not be adapted in such a way (see also Section 5.3.5). As a result, a number of methodological issues had to be addressed prior to conducting the tests sessions, described in Table 5.2.

As described in Table 5.2, one of the methodological issues that had to be addressed was how to make sure that all users receive the same instructions on working with the prototype and have the same experience before starting the test session. Normally, in similar tests a “hands on” exercise is prepared to instruct test persons on the use of the system (e.g. Blok, 2005; Steves et al., 2001). This is also a perfect opportunity for test subjects to practice “thinking aloud”. However, considering the current set-up, it was inappropriate to sit the users in the same location during the instructions. On the other hand, leaving one of the users alone, while going through the instructions with the other, would have slowed down the experiment. For these reasons, a video tutorial was prepared through the screen recording software Wondershare DemoCreator (URL_5.11). The software package allows creating and publishing Flash-based training courses. One particular advantage is that the simulated tutorials can be enhanced through descriptive text balloons and interactive areas where users can click in order to simulate real use of the product (Figure 5.5).

Table 5.2 Challenges connected with the set up of the usability evaluations and undertaken actions to overcome them

Challenge	Undertaken actions
Observe both users at the same time and record their actions	• Additional room specifically equipped to observe the second user
Provide both users with the same chance to practice with the prototype and think-aloud	• A video tutorial prepared to make sure that all users receive the same instructions, time and chance to practice with the prototype and thinking aloud
There is no moderator with the second person to keep him talking	• Included text in the instructions to make sure that the user keeps on talking
There is no moderator with the second user to help in case of problems	• Additional document "*What to do if something goes wrong*" was prepared • Several hints added in the individual instructions for Bert
Make sure that all test subjects in the groups are treated the same way	• Prepare a script, describing each step in detail, and follow it for all evaluation sessions • Adjust personas in the groups where only female users are present
Make sure that instructions are clear and unambiguous	• A trial test session scheduled in advance of the actual evaluation

As previous studies show (Blok, 2005; van Elzakker, 2004), it is necessary to make sure that the instructions given to users are simple and unambiguous. For this reason, a trial test was scheduled prior to the actual evaluation, which allowed for adjustments to the documents distributed to users during the tests. The trial test also allowed observing any additional problems that may arise during the use of the prototype.

Due to the fact that the second user (Bert/Berta) had to stay alone, particular care was taken that the instructions are clear and unambiguous. Additionally, it was expected, that once left alone, the user may forget to speak, as is sometimes reported in such experiments (e.g. Blok, 2005). Having in mind that the researcher is not present to encourage the user to speak, there was no way to handle this limitation, except to put clear instructions at several parts of the individual document. To prevent any other possible problematic situations, two additional documents[6] were available to both users. The first one ("*What to do if something goes wrong*") explained common problems that may occur in the use of the system and how to solve them. Additionally, a manual ("*Geo Puzzle Manual*") was available to all test persons, where different elements of the interface were explained.

Figure 5.5 Screen shot of the video tutorial used to allow test persons to get familiar with the prototype. Orange balloons describe different parts of the interface and point to interactive areas where the user can click

5.3.3. Participants

In total, 12 participants were used for the tests, organized in groups of two. Six test sessions were considered suitable for the purpose of this study since previous research shows that 5 test sessions can reveal around 85% of the usability problems within an application (Nielsen, 2000). The users that were invited for the usability tests are described in Table 5.3.

As discussed by Cook et al. (2005), it is particularly important to control or isolate independent variables in collaborative experiments. Apart from a participants' familiarity with the tool, such variables include variation in team size as well as individual roles. In order to control such independent variables, particular care was taken to make sure that none of the users had worked with the tool before and none of them knew his/her partner before the tests. Moreover, the users in the groups were carefully preselected based on their areas of expertise. In this sense, users that "played" the role of Simon/Silvia were identified as representative users through the on-line survey and were similar in rank and background while, the users that

[6] These documents can be found at http://geoserver.itc.nl/zorni/Geo_Puzzle/Home.html

"played" the role of Bert/Berta were M.Sc. students. The latter filled in a post-test questionnaire similar to the users in the on-line survey. Their characteristics are described in the Table 5.3.

Table 5.3 Characteristics of test persons in the usability evaluation

Persona	Test person position	Field of expertise	Use of Google Earth	Temporal data
Group 1				
Simon	Associate professor	Engineering geology	Once a week	YES
Bert	M.Sc. student	GEM M.Sc. course	Several times a week	NO
Group 2				
Silvia	Assistant professor	Ecology, GIS and RS	Once a month	YES
Berta	M.Sc. student	GEM M.Sc. course	NO, has it installed	YES
Group 3				
Simon	Senior researcher	Risk and information management	Several times a month	YES
Bert	M.Sc. student	GEM M.Sc. course	Once a month	NO
Group 4				
Simon	Lecturer	Natural resources management	Once a month	YES
Bert	M.Sc. student	GEM M.Sc. course	Once a week	
Group 5				
Silvia	Lecturer	Ecology and environmental impact assessment	Several times a month	YES
Berta	M.Sc. student	GEM M.Sc. course	Several times a month	YES
Group 6				
Simon	PhD-candidate	Natural resources management	Once a week	YES
Bert	M.Sc. student	GEM M.Sc. course	Several times a month	YES

5.3.4. Materials and procedure

Each evaluation session comprised of four steps: introduction, training, think aloud session and interviews.

1) Introduction: In the beginning of each test session both participants were introduced to each other and to the purpose of the test sessions through a presentation[7]. The slide-show contained a schedule of the test, as well as a concise explanation of the method (think-aloud), documents, the actors and the scenario. The

[7] The slide-show can be found at http://geoserver.itc.nl/zorni/Geo_Puzzle/Home.html

participants were informed that the test is strictly related to the prototype and not towards their own skills and knowledge.

2) Training and practice: A training session with the prototype preceded the actual evaluation. During each training session, the first user was left alone in the laboratory and instructed to read the provided documents while waiting for the researcher. The second user was taken to a specially equipped additional room (see Section 5.3.5), where he had enough time to read the instructions, ask questions and practise thinking aloud through the video tutorial. The user was instructed to start with his/her tasks when finished with the tutorial. Afterwards, the researcher returned to the usability laboratory where the first user was instructed in the same way.

3) Think aloud session: In each test session, test persons were asked to discuss their planned or actual results on the “Future Land Cover” research project simulated in the developed scenario. The participants did not have any other means to communicate except the provided text-based chat in the prototype. Their overall objective was to report on their results and help each other by sharing current or planned activities. In order to make this task more concrete, test persons were provided with individual instructions (Appendix 4) and asked to answer a number of questions while going through their tasks. The animated map, used during the tests, comprised of 8 10-day composite NDVI images: 7 NDVI images for April, 1998 and 1 NDVI image for September, 2000. The NDVI image for September differed from the rest of the images, as described in the individual scenario for Bert. The individual frames in the animation were pre-processed in ArcGIS and exported as a KML file. Additionally, <TimeSpan> tags were added to the KML file in order to animate the individual frames. During the session, observed difficulties and potential misunderstanding were noted down. These served also for questioning in the final part of the test – the interviews.

4) Interview: On completing their tasks, both users were asked about their experience with the prototype. The interview was conducted in the usability laboratory and comprised of a number of open-ended questions, as well as a number of questions arising during the test sessions.

5.3.5. Physical environment

The means to collect the data presented in this chapter were partially already available in a dedicated usability laboratory specifically equipped for “think-aloud” sessions (van Elzakker, 2004). The laboratory is equipped with a computer where the user can work, and a video camera which captures his/her movement (Figure 5.6.A). Additionally, the laboratory has a digital quad unit, which can merge the signal from several input sources. The digital quad unit is connected to a TV screen where the researcher could monitor the work of both users during the experiment (Figure5.6.B).

In order to simulate a real same time/different place collaborative situation, additionally to the usability laboratory, a specially prepared room was used. This room was close to the usability laboratory and was equipped with a mobile video camera and a computer where the user could sit and work with the prototype (Figure 5.7)

In each test session, recorded input from the usability laboratory included: 1) the computer of the user (screen logging); 2) a video camera which records the upper part of the body of the user; and 3) voice and other sounds in the room. Recorded input from the second room included: 1) the computer of the user and 2) voice and other sounds in the room. All of these were synchronized (Figure 5.6.B) and recorded on VHS tapes which were reviewed later for further analysis.

A **B**

Figure 5.6 Set-up of the usability laboratory: A. The computer of the user (right) and the video camera (left), which records his/her movements. B. The digital quad unit (bottom left) used to synchronize the input from both rooms and a TV screen where the researcher could monitor the experiment

Figure 5.7 Additional room used during the experiment, equipped with a chair and a computer where the user can work (right) and a mobile video camera to capture his/her computer screen (left)

5.4. Results

This section provides a summary of the findings from the usability tests conducted with the six groups of participants, discussed further in Section 5.5.

5.4.1. Time frame and completed tasks

The video tutorial took similar timings for all users in the instruction sessions. Similarly, each test session was completed within a time frame of 30 to 40 minutes. An exception here is test session 4, where the users' discussion diverged from the indicated instructions and the test had to be stopped.

A task was considered finished if both users carry out the indicated activities and are able to answer the associated questions. Even though the degree of details varied, in general all users were able to provide answers to the questions in the instructions manual.

No problems were observed with uploading animated maps, filling in name and comments within the Maps and Places module. Users were able to recollect immediately where to upload maps and did not forget to fill in all necessary fields. Even though the instructions for Bert/Berta indicated that the user should take the control before uploading animated maps, in one group this happened in the reverse order. The user, however, did not have a problem to recollect that the map should be displayed after control over the display is taken.

All users could recollect where to invite temporarily another user to a virtual room. The task to download a map did not create difficulties either. In terms of such simple individual tasks, the choice to separate content in three tabs was well received. The users could recollect where to check whether another user is on-line or not.

All users were very comfortable with the text-based chat. In general, they had no problems with noticing the star in the Chat tab when a new message is sent by their partner. Further, test subjects did not have problems when navigating inside the Google Earth display. Most of the time this happened through the mouse scroll wheel or by clicking inside and dragging the display. Several users preferred to make use of the navigation bar when zooming in/out. None of the other "joysticks" were used.

In general, almost none of the users faced problems with the temporal legend in the Google Earth plug-in. They were comfortable with the provided options to control the animations (play, pause, step forwards/step backward) and were able to track the changes in display and the time line. In general, users were comfortable with the time slider and did not have problems to figure out its functionality and to jump to a particular frame of the animated map. However, some additional problems occurred, which are reported in the next section.

5.4.2. Observed problems

During the test sessions a number of problems were observed. These are described and summarized in Table 5.4, and explained further.

Table 5.4 Observed problems during the usability tests

N.	Problem description	Group/user
1	The user experiences difficulties with the organization of the Projects and Rooms modules	1 (Simon), 2 (Silvia), 3 (Simon), 4 (Bert), 5 (Silvia), 6 (Simon)
2	Visibility of the search bar is limited	1 (Simon), 5 (Silvia)
3	The user does not see the temporal legend in the Google Earth display and does not play the animation	1 (Simon), 2 (Silvia), 5 (Silvia)
4	The user is confused how to play the animation	6 (Simon)
5	The user changes the time range even if this is not his/her intention	3 (Simon), 4 (Simon), 6 (Simon)
6	The information provided in the Maps and Places tab is not explicit and users do not make use of it	1 (Simon), 2 (Silvia), 3 (Simon), 4 (Simon), 5 (Silvia)
7	User is confused because he/she is not aware what his/her partner is doing	1, 2, 3
8	User forgets to take the control before showing to his/her partner a place	1 (Bert), 3 (Simon), 6 (Bert)
9	Users speak of the same territory but for different frames of the animation	3

Usability problem 1 – A number of users had problems with the organization of the Projects and Rooms modules. For instance, in group 1, "Simon" entered another project than the one indicated in the instructions. Similarly confused, in group 2, "Silvia" started creating a new project.

Usability problem 2 – When trying to find a location, the users did not make use of the search bar even if this was their intention. In group 5, for instance, "Silvia" was struggling to find the indicated location and moved the display 21 times, which ultimately did not provide the needed result. When asked later, the user indicated that she did not see the search bar. A similar situation occurred in group 1.

Usability problem 3 - In three of the groups, "Simon"/"Silvia" did not see the temporal legend when "Bert"/"Berta" uploaded and displayed the animated maps. In the first two cases, the researcher decided that this is due to inappropriate instructions and interfered. Even after the applied corrections in the instructions, the same problem occurred in group 5, which resulted in the user not playing the animated maps.

Usability problem 4 – In group 6, the user could not play the animation, even if his words indicated that this was his intention. It took time to recover from this situation.

Usability problem 5 – In several groups, the users were simply trying to rewind the animation, ending up with changing the time range for the animated map. Even though the result was not a significant change in the representation of the animated maps, this was recorded as a problem.

Usability problem 6 – The user did not know immediately where to find the description of the map and its title. Even if these are available in the Maps and Places tab, the user did not look at them. System messages for the title of the map do not give much clue about what is represented. The same problem was observed in groups 2, 3, 4 and 5.

Usability problem 7 – Lack of awareness of the actions of the other user leads to discomfort. Not knowing when the other person is typing or switching between tabs did not hinder collaborative work but resulted in confusion among users. The same situation was observed in groups 1, 2 and 3.

Usability problem 8 – In group 3, the user forgot to take control before showing a location to his/her partner. This problem is not severe, and the users recovered quickly from the situation. This accounted to the fact that normally "Bert" (or "Simon") would ask in the chat tab "*Do you see the location*?". The same situation was observed in groups 1 and 6.

Usability problem 9 – In group 3, the users were speaking about dramatic changes in the territory. However, they were discussing different frames of the animated map, which resulted in confusion.

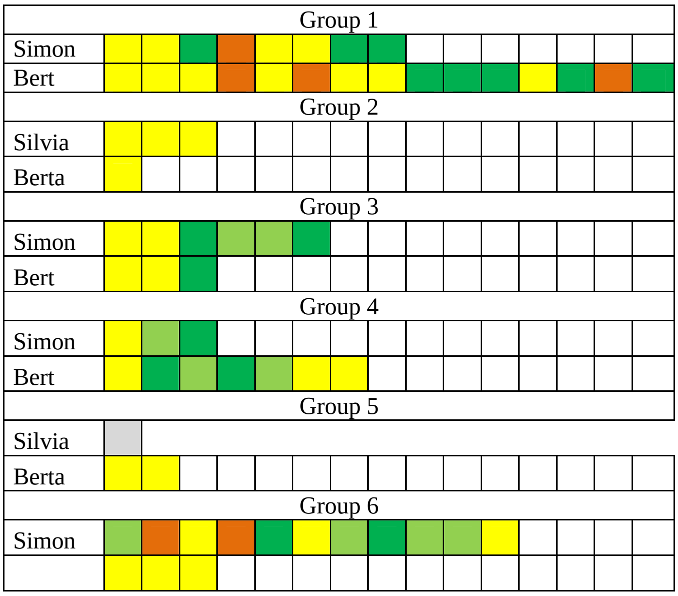
5.4.3. Strategy to play the animated maps

As described in Section 5.2, one of the main constraints of the prototype was lack of synchronization between the animated maps. Since in general users utilize different strategies to work and interact with animated spatio-temporal data (Blok, 2005), it was expected that the users who have to make sense of the animated maps with no other information provided, would interact much more with it. On the other hand, "Bert"/"Berta" were expected to interact less, since the information of what the animated maps show is readily available for them in the documents they received before each test session. In order to compare the use of animated maps between group members and between groups, their actual use during the evaluation was recorded. Observed strategies to play the animated maps are provided in Table 5.5.

As Table 5.5 illustrates, no obvious pattern can be distinguished between group members in different groups. Even though in the beginning of each session the users watched the animated maps without jumping to particular frames (yellow colour), this strategy changed in the course of the "virtual meeting". Users either continued to look at particular frames through the time slider (dark green colour), using the arrows in the temporal legend (pale green colour), or watched several other times the animated maps from start to end. Only few of them changed the speed of the animation (brown colour).

To sum up, users' actions did not have any visible order and were connected with the discussion at hand. A short review of the observed collaborative behaviour is also given in Appendix 5.

Table 5.5 Observed strategies to interact with the animated maps during the experiment



	Action 1: plays the animation from beginning to end and does not stop/pauses
	Action 2: goes back/forward to particular frame through the slider
	Action 3: uses only arrows
	Action 4: changes speed
	Did not play the animation

5.4.4. Interview feedback

All users provided positive feedback after completing the evaluation. All 12 test subjects agreed that such a tool would be useful and complement other collaborative applications (e.g. voice chat or e-mail). Suggestions for improvement were directed towards increasing the awareness between users as well as provision of an audio chat.

5.5. Discussion and summary

This chapter described the evolution and revision of the conceptual design after the focus group discussion and during the implementation. Firstly, a number of readily available examples of code from the Google Earth API gallery were combined with collaborative elements provided by the Ruby on Rails libraries and plug-ins. Secondly, the design and planned functionality was revised in order to prevent problems arising from the use of the application. Finally, a dedicated usability test allowed observing the way users carry out a set of individual and collaborative tasks with the developed interface and the Google Earth plug-in.

The outcome from the usability tests revealed no severe problems during individual work with the prototype. No problems were observed neither when uploading animated maps nor when using the navigation tools within the Google Earth display. Users were able to recollect immediately where information and functionality is situated. Inviting team members to a room, downloading maps or using the text-based chat did not create problems and were well received. Almost all users were able to figure out within seconds how to work with the temporal legend in the Google Earth plug-in and were able to track the changes in display and the time line.

In summary, the six collaborative usability tests revealed a core of similar problems that users experience, which are further discussed. Slight confusion with the organization of the Projects and Rooms modules implies that particular care needs to be taken of the organization of information within the initial modules of the prototype in order to make it more intuitive for users.

Individual problems with the search bar confirmed previously identified usability problems with respect to its position above the map display, reported also in Nivala et al. (2008). To alleviate this problem, it is recommended that the position of this element is re-considered in the future and placed under the map display. This is the place where users were trying to locate it during the test sessions.

Even though one user had slight problems in trying to figure out how to play the animation displayed in the Google Earth plug-in, this did not hinder cooperative work. Moreover, test subjects were able to recover from such problematic situations in a matter of seconds. Major conflicts did not occur regarding the handling of the control over the display. In most cases users refrained from applying changes in the zoom level or the extent set by their partner.

The lack of awareness for user actions led to several problematic situations. It was observed that users were not comfortable when the system did not provide feedback on their partner’s actions. One possible solution for this problem with respect to the text-based chat would be to add sound notification when a user is sending a message or text feedback when he/she are typing in a comment.

The need to represent users’ behaviour is confirmed by the observed situation in several groups, where the users forgot to take control before showing a location to their partners. Afterwards test subjects were not sure what their partner can see on his/her display. While these problems did not have any serious effect on the outcome of the test, in one of the groups the users ended up discussing the same territory but different frames of the animation. The need to represent users and their behaviour has also been discussed by Brewer et al. (2000) and MacEachren and Brewer (2004). The authors argued that, when it comes to geo-collaborative applications, apart from explicit representation of participants, there is a need to add awareness of how users are interacting with the data representations. This argument is further supported by the findings of this study and is even more relevant when it comes to work with animated spatio-temporal representations in view of the outlined situation. One possible solution would be to fully synchronize the visual display among users both in the spatial and temporal domains. This may also help dealing with a situation in which one of the users does not notice the temporal legend and is not immediately aware that the represented data are animated. This issue, however, could not be handled, taking into account the limited timeframe of this research, and therefore is strongly recommended if further work is intended.

Full synchronization, as described in the conceptual design of the prototype in Chapter 4, would, however, also impede work to a certain extent. As observed, users apply different strategies to view and interact with the animated maps. This finding is not new and is also confirmed by previous studies (e.g. Blok, 2005). However, here it was expected that users who have information about the animated maps and are not required to gain new or additional knowledge from it, would interact with it less. As described in the results section, this was not the case. User strategies and the level of interaction with the animated representation differed among users without any clear pattern. One possible explanation is that such interactions are related to the discussion at hand. This observation implies that, in terms of synchronization, users should be able also to desynchronize their displays in order to view and interact with the animated maps individually, without disturbing the work of their partner.

In addition, separating content regarding the maps (including title, legend, and description) from the visual display had a negative effect on collaborative work. As discussed in Chapter 4, separating content in three distinct tabs was guided by several design rules and principles with respect to interface design, as well by the identified usability goals. However, the decision to separate key map elements from the maps display was found not suitable, even when this information is communicated through a text-based chat in real-time. This was confirmed by the observation that, in almost all collaborative sessions, users did not make use of the provided information in the Maps and Places module. A possible solution is to provide this information in the map display as well.

Two interesting observations were made in relation to the set up of the experiment. Firstly, users that were left alone continued speaking throughout the test. On the contrary, test subjects that were left in the usability laboratory had to be encouraged to speak continuously. One possible explanation is the fact that the researcher had to stay in view of the user in the laboratory, due to the nature of the setting and the position of the screen where the experiment was monitored. Secondly, several users noticed that “playing” a role is extremely difficult. A possible reason for this is that users were overwhelmed by having to handle a new interface and process the information in the group and individual instructions. Having in mind the purpose and nature of the experiment, this set up was unavoidable; however, it is strongly recommended that future experiments are much simpler with a lot less information load for the test subjects.

Finally, it should be noted that due to the qualitative nature of the conducted experiments, the presented results are tool- and task-specific but can serve as a stepping stone for further research of both qualitative and quantitative nature.

6. Conclusions and recommendations

6.1. Conclusions

State-of-the-art web-based virtual globe technology offers a unique opportunity to address the needs of dispersed teams of environmental researchers working with spatio-temporal data. Brought together, developed tools and functionality can be used as a two-way communication channel in a multi-user environment, where animated visual displays enhance group work and generate focused discussions.

However, on our way to develop a web-based virtual globe application, which provides fully adequate support for group work with animated representations, much more attention needs to be paid to the final users, their individual needs and interactions as a group. This study is an effort to gain a deeper understanding in this direction by addressing a number of related research questions.

What are the relevant characteristics of potential users that affect user requirements?

The results from the online survey show consistency of basic user characteristics, related to the use of information technology and web-based virtual globes. This shows that exposure to and experience with desktop and on-line applications is not indicative of differences that design should accommodate. The similarity between these user characteristics implies that the interface of the prototype can employ standard web and virtual-globe terminology and content organization. The most relevant characteristics influencing user requirements in the user profile were found to be the variety of data among users, purpose and frequency of collaboration.

What are the preferences of potential users for collaborative map use?

The vast majority of domain experts prefer a fast website rendered with a lot of space and GIS functionality, which gives all parties an opportunity to apply changes in the uploaded vector and raster maps. Domain experts prefer to have an option to customize the application and be in disposal of tools to comment upon the uploaded maps. A number of users identify security as a prime necessity.

What are the specific usability goals that need to be met in a collaborative web-based virtual globe environment to support dissemination of spatio-temporal data?

Specific qualitative usability goals are related to differences in user characteristics and preferences. Firstly, irregular and less frequent communication on distributed research projects defines learnability and memorability as primary usability criteria determining the effective use of the application under development. Secondly, variance in the utilized data during and after analysis requires that users are supplied with an interactive on-line tool to convert different types of temporal data into animated representations. These vary from satellite images and/or maps, to vector and ground measurements data. Moreover, specific functionality has to be implemented to convert non-temporal data, such as 3D and subsurface models, or spatial averages into KML format. Further, visualization operations for animated maps have to be complemented by other options, specific for the data at hand. Except animation, domain experts need functionality to present location-specific non-spatial data. Finally, there is a need to provide access to previous work on distributed projects and security for all collaborators.

What are the general usability guidelines that have to be followed in a web-based virtual globe environment to support dissemination of spatio-temporal data?

Satisfying user requirements towards collaborative work with spatio-temporal data in a web-based virtual globe environment can be guided by a number of design guidelines. Considering the special purpose of the application, design elements in the user interface should be guided by principles directed towards single-user interfaces that supply interaction to animated maps, general usability heuristics for web page design and specific groupware usability heuristics. Principles for animated maps interfaces include providing options to smooth and filter the data, alternative strategies to interact with the animations and minimizing the footprint of the interface with respect to the main map display. The general usability heuristics relate mainly to maintaining the consistency and users' feeling of control throughout the interface. Finally, the specific groupware heuristics include providing means for intentional verbal, written or gestural communication, support of privacy and coordination between users.

What further insights can we gain from obtained user feedback in terms of effective dissemination of spatio-temporal data in a collaborative environment?

The main benefit of early-user feedback was the opportunity to identify possible barriers for collaborative activities and interface flaws. In terms of presentation of spatio-temporal data in a web-based virtual globe environment the developed low-fidelity prototype allowed identifying several additional user requirements. Firstly, there is a need for effective management and query of information and content within a project or a virtual room. Secondly, in terms of privacy, a requirement is to provide an option to set different access levels to projects, datasets, rooms and display content. Finally, it is required to provide access to the settings of the Google Earth display and overwrite/time-out options of its control.

Which technical solutions can be used to satisfy user requirements for dissemination of animated maps in a collaborative environment?

A number of examples with code from the Google Earth API gallery are suitable to satisfy identified user requirements for collaborative work with spatio-temporal data. These include developed code to toggle on/off and display KML files and to query content within the Google Earth plug-in. Suitable examples provide options to set the opacity of animated maps, receive feedback when the Google Earth display is manipulated, or to place and save non-spatial information within a placemark.

Additionally, a number of collaborative tasks can be satisfied through the libraries, gems and plug-ins of the web application framework Ruby on Rails. Such include providing a text-based chat for explicit communication where all chat sessions are saved, as well as synchronization of the displays for two or more users through the RoR Juggernaut plug-in.

What are the advantages of the selected technical solutions for domain experts who work with spatio-temporal data on distributed research projects?

Design revision and implementation resulting in a unique working prototype allows domain users to upload and edit custom spatio-temporal data or location-specific non-spatial data, such as images or text. Users are able to describe and comment their data in real time with two or more team members. Spatial synchronization of their visual displays provides context for focused discussions, and yet does not prevent individual work. Generated system feedback in the chat window allows users to monitor the activities in a virtual room and handle the control over the Google Earth display effectively.

Support of asynchronous collaborative activities is provided by options to save the chat sessions and system messages, uploaded maps and the last extent and zoom level at which the maps were viewed in a virtual room. Privacy is supported by options to set or deny permanent access to rooms and projects. Moreover, a unique hyper-link is generated to each virtual room which can be used to allow team-members to join a discussion on a temporary basis. The developed prototype is not limited by the number of users and, therefore, can facilitate large on-line “virtual meetings” where animated spatio-temporal representations can serve as a facilitator for focused discussions.

What insights can we gain through usability testing of the developed high-fidelity prototype with respect to effective collaborative work and dissemination of spatio-temporal data in a web-based virtual globe application?

Usability testing of the developed high-fidelity prototype revealed no severe problems with organization or language of the interface. Users can recollect immediately where information and functionality is situated. Individual problems relating to visibility of the search bar, the slider of the Google Earth temporal legend, or the control button did not hinder collaborative work. Discomfort associated with lack of awareness of the actions of users in the text-based chat does not have serious implications for collaborative work.

The main shortcoming of the current functionality offered by the Google Earth API in terms of presentation of spatio-temporal data in a collaborative environment is the lack of possibility to synchronize fully the displays of two or more users in the temporal domain. This is a serious limitation and prevents an adequate execution of work with animated maps during same time/different place collaborative work.

Despite the observed problems the developed prototype is fully functioning and provides a stable platform for conducting real-time geo-collaborative activities, as well as further testing.

6.2. Recommendations for further work

The elicited user requirements and identified advantages and disadvantages of web-based virtual globes are only a small step towards improvement of collaborative mapping and spatio-temporal data dissemination for domain experts involved in distributed research projects. For further work, researchers are encouraged to consider and take into account the following actions:

- Elicit user requirements through background interviews among the members of one, or several, research projects in order to identify key roles and differences in context of use
- Consider developing different collaborative scenarios for more detailed task analysis
- Come up with alternative design solutions in order to address adequately identified user requirements
- Consider a different web application framework during implementation
- Look for a way to automate on-line conversion of different types of temporal data into KML format
- Look for a way to increase the awareness of the animated representations for both users
- Look for a way to synchronize the displays in the temporal domain for two or more users
- Conduct empirical testing, both quantitative and qualitative, with different set of tasks and various scenarios
- Conduct empirical testing while increasing the number of users or the variation within the groups and between them
- Conduct empirical testing with different types of animated spatio-temporal data
- Use a facility which allows the moderator to observe both users remotely without interrupting their activities.

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7.2. On-line sources

URL_1.1: Overview and comparison of virtual globes: http://en.wikipedia.org/wiki/Virtual_globe

URL_1.2: KML documentation: http://code.google.com/intl/bg-BG/apis/kml/documentation/

URL_1.3: GIMMS NDVI Animation product: http://gis.uml.edu/mediawiki/index.php/GIMMS_NDVI_archive

URL_1.4: KML animation of tree dynamics: www.barnabu.co.uk/files/kmz/tree-population-animation.kmz

URL_1.5: Rising sea level animation: http://www.google.com/gadgets/directory?synd=earth&hl=bg&url=http://maps.google.com/maps/gx%3Foe%3Dutf-8%26output%3Dghapi%26q%3Dhttp://bbs.keyhole.com/ubb/download.php%3FNumber%3D847094%26thumbnail%3D%26screenshot%3Dhttp://img217.imageshack.us/img217/836/rslaup1.jpg

URL_1.6: England's population density animation: http://www.barnabu.co.uk/population-density-england-1891-1991/

URL_1.7: Visualization of GeoRSS earthquake data (live feed data from USGS): http://www.fmepedia.com/index.php/Earthquake_KML_Streaming

URL_1.8: Hurricane Katrina Temporal animation for Google Earth: http://www.gearthblog.com/blog/archives/2006/09/katrina_time_animati.html

URL_1.9: Google Earth API Demo Gallery with the application EarthPad: http://code.google.com/apis/earth/documentation/demogallery.html

URL_1.10: The KML Factbook: http://www.kmlfactbook.org/

URL_3.1: SurveyMonkey official web-site: www.surveymonkey.com

URL_4.1: Google Earth user guide, Viewing Timelines: http://earth.google.com/intl/en_uk/userguide/v5/ug_gps.html#timeline

URL_4.2: Axure RP Pro: http://www.axure.com/

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URL_4.4: Interviewing: listening to groups and individuals: http://www8.utsouthwestern.edu/vgn/images/portal/cit_56417/20/27/205324FG_&_INTERVIEWING.pdf

URL_4.5: Usabilitynet.org, Focus groups: http://www.usabilitynet.org/tools/focusgroups.htm

URL_5.1: The Google Earth API official web site: http://code.google.com/apis/earth/

URL_5.2: The code of EarthPad in the Official Google Earth API samples and issues tracker gallery: http://earth-api-samples.googlecode.com/svn/trunk/demos/earthpad/

URL_5.3: The Google Earth Examples gallery: http://earth-api-samples.googlecode.com/svn/trunk/examples/

URL_5.4: Fetch KML: http://earth-api-samples.googlecode.com/svn/trunk/examples/kml-fetch-checkboxes.html

URL_5.5: Draggable Placemark, Google Earth API examples: http://earth-api-samples.googlecode.com/svn/trunk/examples/placemark-dragdrop.html

URL_5.6: Geocoding via the Maps API, GE API examples: http://earth-api-samples.googlecode.com/svn/trunk/examples/geocoder.html

URL_5.7: Setting feature opacity, GE API examples: http://earth-api-samples.googlecode.com/svn/trunk/examples/opacity.html

URL_5.8: Viewchange Event, GE API examples: http://earth-api-samples.googlecode.com/svn/trunk/examples/event-viewchange.html

URL_5.9: The Ruby on Rails official web site: http://rubyonrails.org/

URL_5.10: GeoRuby Documentation: http://georuby.rubyforge.org/georuby-doc/index.html

URL_5.11: WonderShare Demo Creator official web site: http://www.sameshow.com/demo-creator.html

8. Appendices

Appendix 1: Invitation letter and User questionnaire

A. Invitation letter, distributed to potential users through e-mail

Dear Sir/Madame,

My name is Zornitza Yovcheva and I am currently a student of the Erasmus Mundus M.Sc. course in “Geo-information Science and Earth Observation for Environmental Modeling and Management” (GEM) as a joint initiative from the University of Southampton (U.K.), University of Lund (Sweden), Warsaw University (Poland) and ITC (the Netherlands).

As part of my M.Sc. thesis I am designing a web platform which will help researchers to share data and present their research in the form of maps/animated maps over the Internet and discuss these with remotely situated colleagues in real-time. As current scientific projects involve, more than ever before, dispersed world-wide teams of researchers and policy-makers, the main aim of my study is to improve collaboration and geospatial data dissemination.

The design of the platform will be directed towards effective collaboration and work with spatio-temporal data. In my effort to build such a tool, the main focus will be not only on functionality (what can you do with the platform), but also on usability (how effective and easy it is to use such a platform).

To make this effort successful, I would like to kindly ask You to participate in a dedicated online survey, the objective of which will be to provide feedback on:

- The nature of the data you work with;
- How you normally present your research results (maps vs animation);
- Current ways to collaborate with colleagues;
- The problems you experience in this effort;
- Your preferences for future products which will make this effort easier;

This information will allow me to take under consideration your particular needs and requirements for dissemination of spatio-temporal data and collaboration with fellow colleagues, and will be used for the design of the tool. Additionally, it will direct the choice of participants in a dedicated group (which will further discuss possible design solutions) and test sessions (to assess the usability of the chosen design).

Please note that the data from this survey is confidential and any personal information will not be disclosed. If you have questions related to the survey, or to my research, please do not hesitate to contact me (yovcheva20290@itc.nl), or my first supervisor, Dr. Corné van Elzakker (elzakker@itc.nl).

To participate, click on the **link** below:
[Undisclosed]
Please, complete the survey **before 14 October 2009 (Wednesday).**

Thank you in advance.
With my best regards,
Zornitza Ivanova Yovcheva
GEM M.Sc. 2008 – 2010
International Institute for Geo-Information Science and Earth Observation
Enschede, the Netherlands

1.B. Collaboration and spatio-temporal data dissemination questionnaire

Questionnaire administered through an on-line survey and designed to gather user characteristics, preferences and context of use of spatio-temporal data. The on-line survey was administered in the period 7.10.2009 – 13.10.2009. The collector in SurveyMonkey was closed officially on 14.10.2009.

Q1: Your gender is:
- Male
- Female

Q2: Please, specify your background education and highest degree attained:
(e.g. M.Sc. in Geography)

Q3: What is your current position?
- Student
- PhD
- Assistant professor
- Professor
- Other (*please, specify*)

Q4: What is your current position?
(If you are a student, please indicate the course you are currently enrolled in)

Q5: How long have you been working with computers?
- Less than 1 year
- 1-3 years
- More than 3 years

Q6: Please, rate the speed with which you type on a computer keyboard:
- Very slow
- Slow
- Moderate
- Fast

- Very fast

Q7: How often do you use the Internet?

- Every day
- Several times a week
- Once a week
- Several times a month
- Once a month
- Less than once a month

Q8: Please, specify your main activities on the Internet: (*More than one answer possible*)

- Entertainment (e.g. listen to music, watch video on-line)
- Communication (e.g. voice chat, chat, e-mail)
- Research (e.g. find articles, read journals, books or other relevant to your research resources)
- Education (e.g. on-line course)
- Other (e.g. shopping, on-line banking, news and weather reports)

Q9: Are you currently using the Google application "Google Earth"?

- YES
- NO, but I have it installed on my computer
- NO, but I have used it before
- NO, but I am using (have used) a similar product (NASA World Wind, ArcGIS Explorer, MS Virtual Earth or similar)
- NO, I have never used Google Earth or a similar product

Q10: How often do you use Google Earth (or a similar product)?

- Every day
- Several times a week
- Once a week
- Several times a month
- Once a month
- Less than once a month

Q11: Do you work with temporal data?

(*Please note, that "temporal" here refers to data for different moments in time (e.g. two or more remotely-sensed image, maps, vector or statistical data for the same area but for different periods of time*)

- Yes
- No

Q12: Please, complete the sentence: In my work, the input data most often are: (*More than one answer possible*)

- two or more **remotely-sensed images**.
- two or more **maps**.
- **vector data**.
- **statistical data**.
- other type of data (*please specify*):

Q13: Please, complete the sentence: In result from my work, most often is:

- two or more maps for the same area but for different moments in time.
- two or more maps for the same time period (e.g. monthly or yearly averages).
- a single map (e.g. monthly or yearly average).
- other output (e.g. statistical data):................................

On the screen below you can see a sequence of maps of vegetation greenness. Often, such dynamic presentations are referred to as **animated maps**, or simply "**animation**".

Q14: Do you use animation in your work?

- Yes
- No

Q15: Please, complete the sentence: in my work, I use animation when:

- I am trying to get an idea about my study area and explore my data.
- I want to confirm something I am not quite sure about (a hunch or hypothesis).
- I want to show my results to someone.
- I want to do something else (*please specify*):

Q16: Please, complete the sentence: When I work with animation, most often I

- create the animated maps myself.
- work with ready-made animations.

Q17: What software do you use to create your animated maps?
(*If you are not sure, please write "I am not sure" in the text box*)

Q18: If you have to explain to someone an environmental process (e.g. change in land cover, weather dynamics, change in population growth), what would you prefer to use?

- I prefer to use a series of individual maps and/or images
- I would use animation
- I prefer to use something else (*please specify*):

Q19: What is/are the reasons behind NOT selecting animation?

(*More than one answer possible*)

- I don't find animations useful.
- I don't know how to create animations.
- I find creating animations time-consuming.
- I don't know how to work with animations.
- I have seen animations several times and I did not like the quality.
- I would not use animation because:

Q20: Do you use NDVI data in your work?

- Yes
- No, but I have worked with NDVI data before
- No, I have never used NDVI

Q21: In your work, are/were you part of any project which involves work with people in another country, city or institution?

- Yes, I am currently part of such a project
- Yes, I was involved previously with such a project
- No, my work is independent

Q22: As part of your work, you are/were required to:

- Share your results with someone else and work with him/her during the project.
- Work independently but share your research progress at regular intervals of time.
- Work independently and only present your research results at the end of the project.
- None of the above (*please specify*):

Q23: How do/did you establish contact with such distributed teams (other researchers and people working on the project)? (*More than one answer possible*)

- Personally (meetings, conferences, etc)
- E-mail
- (Voice) chat
- Telephone
- Regular mail
- A dedicated web site
- A dedicated software application
- Other (please specify):

Q24: How often do/did you have to establish contact with such teams?

- Every day
- Several times a week
- Once a week
- Several times a month
- Once a month
- Once every three months
- Once every six months
- Once a year
- Less than once a year
- Other (*please specify*): ....

Q25: Do you share your work with another person in the form of maps? (*Please note, that this question relates to single/multiple static maps, as opposed to animated maps (animation)*)

- Yes
- No

Q26: Please complete the sentence: I share my map(s) (*More than one answer possible*)

- when I am doubtful about something and I want to get a different expert opinion or additional information about my study area.
- when I have an idea about something (hypothesis or assumption) and I want to analyse my data with the help of someone else.

- when I would like to present my results.
- for another reason (*please specify*)

Q27: Currently, when you share your map(s), you do this in the following way:
(*More than one answer possible*)

- I present personally and I explain what the audience is seeing.
- I send the maps through e-mail and explain there what they show.
- I send the maps through regular mail (on a CD or printed).
- I upload my maps on a dedicated web site and explain there (through a text window) what they stand for.
- I upload my maps on a dedicated web site and explain there (through a chat windon/voice chat in real
  time) what they stand for.
- I use specially dedicated software to send my maps over the Web.
- I share my maps in another way (please specify):

Q28: How would you prefer to share your map(s) with people situated in a distant location (another country, city or institution) in the future?
(*More than one answer possible*)

- I would prefer to do this **personally**, because I want to explain what the audience is seeing.
- I would prefer to send the maps through **e-mail** and explain there what they show.
- I would prefer to send the maps through **regular mail** (e.g. on a CD, printed).
- I would like to upload my maps on a dedicated **web site** and explain there (through a text window) what
  they stand for.
- I would like to upload my maps on a dedicated **web site** and explain there (through chat window/voice chat in real-time) what they stand for.
- I would prefer to use a specially dedicated **software** to send my maps over the Web.
- I would prefer to use something else
- Please, provide explanation for your answer:

Q29: Do you share your work with another person in the form of animated maps (animation)?

- Yes
- No

Q30: Please, complete the sentence: I share my animated map(s)
(*More than one answer possible*)

- when I am doubtful about something and I want to get a different expert opinion or additional information about my study area.

- when I have an idea about something (hypothesis or assumption) and I want to analyse my data with the help of someone else.
- when I would like to present my results.
- for another reason (*please specify*)

Q31: Currently, when you share your animation(s), you do this in the following way: (*More than one answer possible*)

- I present personally and I explain what the audience is seeing.
- I send the animation through **e-mail** and explain there what it shows.
- I send the animation through **regular mail** (recorded on a CD or tape).
- I upload my animation on a dedicated **web site** and explain there (through a text window) what it stands for.
- I upload my animation on a dedicated **web site** and explain there (through a chat windon/voice chat in real time) what it stands for.
- I use specially dedicated **software** to send animation over the Web.
- I use something else (please specify):

Q32: How would you prefer to share your map(s) with people situated in a distant location (another country, city or institution) in the future?
(*More than one answer possible*)

- I would prefer to do this **personally**, because I want to explain what the audience is seeing.
- I would prefer to send the animation through **e-mail** and explain there what they show.
- I would prefer to send the animation through **regular mail** (e.g. on a CD, printed).
- I would like to upload my animation on a dedicated **web site** and explain there (through a text window) what they stand for.
- I would like to upload my animation on a dedicated **web site** and explain there (through chat window/voice chat in real-time) what they stand for.
- I would prefer to use a specially dedicated **software** to send my animation over the Web.
- I would prefer to use something else
- Please, provide explanation for your answer:

Q33: What are the most common problems you encounter in your effort to share your data or present your research results (maps, satellite imagery, vector data, etc.) to someone who is situated in another country, city or institution?
(*More than one answer possible*)

- Big file sizes

- Incompatibility of formats (the other person often cannot open the files)
- No place where I can upload my files
- Bad quality of maps and animation when I convert to lower size
- No place where I can place text and explanation of my data/results
- The people I would like to share my data and results with do not have access to Internet
- Huge fees to send data through regular mail
- It takes too much time to send data through regular mail
- The expenses and the time it takes to travel and present results personally
- Other problems (please specify):

Q34: Please, complete the sentence: The ideal web site where I can share and present my research results in the form of maps or animation would:
(*Here you can specify what would you like to be able to do at such a web site, how it would look like, what tools it would include, and anything else that comes to your mind related to such a platform*)

Q35: Your needs and preferences will be taken into account. Would you like to participate further in the design of the tool? *(You may choose to participate through providing additional information about your preferences and work, participate in a discussion group or the final evaluations)*

  - No, I don’t want to participate further
  - Yes, I would like to participate further

Q36: How would you like to participate?
(*More than one answer possible*)

- You can contact me if you need further information
- I would like to participate in the discussion (focus group) of a possible design solution
- I would like to participate in the final evaluation of the platform (through usability test sessions)

Q37: If you would like to participate, please specify:
Your name:
Your e-mail:

Thank you for your time!
If you have further questions,
please contact me (yovcheva20290@itc.nl)
or my first supervisor, Dr. Corné van Elzakker (elzakker@itc.nl).
With my best regards,
Zornitza Yovcheva

Appendix 2: Focus group materials

A. Focus group invitation letter

Dear Sir/Madam,

I contacted you previously with respect to the on-line survey “Collaborative mapping and spatio-temporal data dissemination” as part of the first stage in the M.Sc. thesis “Collaborative mapping and spatio-temporal data dissemination through a web-based virtual globe application”. As stated previously, I am designing a web platform which will help researchers to share data and present their research in the form of maps/animated maps over the Internet and discuss these with remotely situated colleagues in real-time.

Since the accent in my research is primarily on usability of the platform under development (the main focus being the users of the application), I would like to express my sincere gratitude for your participation. Your initial input as a potential user has proven valuable and insightful. For this reason, I would like to invite you to participate in the second stage of my research, which will be conducted in the form of a short evaluation (not more than an hour – hour and a half) of a preliminary design solution of the web-based platform under development.

The planned evaluation will take place in a scheduled lecture room at ITC, Enschede, in the period 18-25 November 2009. The session will comprise of a short presentation of the purpose of the study, and a demonstration of a prototype of the platform, followed by a discussion in a small group of 6-7 participants. You will be asked to provide feedback to what extent can the preliminary design satisfy your needs to share spatio-temporal data and present your research results to researchers in another country, region or institution (as part of the same research project). Please note, that the meeting will be recorded, however, the gathered data is confidential and will be aggregated before analysis so that no personal details are revealed in the final report.

All efforts will be made to ensure that the meeting is arranged in a suitable for all participants time. This aspect will be determined additionally. If you are interested in the project and would like to participate, please reply to this letter specifying the day and time convenient for you. Please note that the sessions can be arranged between 10-11 h. in the morning, and 14-15 h. in the afternoon within the stated period (18-25 November 2009).

If you have questions related to the survey, or to my research, please do not hesitate to contact me (yovcheva20290@itc.nl), or my first supervisor, Dr. Corné van Elzakker (elzakker@itc.nl).

I would like to thank you again for your time and attention and will be looking forward for your positive reply.

With my best regards,

Zornitza Yovcheva
GEM M.Sc. 2008 – 2010
International Institute for Geo-Information Science and Earth Observation
Enschede, the Netherlands

B. Individual documents distributed to users during the focus group discussion

User evaluation and discussion of the web-based application
"Geo Puzzle"
Conducted on 10.12.2009

Purpose of the meeting: to receive feedback on how useful and suitable the web site "Geo Puzzle" is for environmental researchers and with respect to your own work

What will be done:

- **1st part - Introduction** to the use of the web site through fictional people and fictional scenario;
- Questions and comments;
- **2nd part - Evaluation through discussion** with the group – mark and suggestions how can the web-site be improved?

My job:

- Answer questions and keep track of time;

Your job:

- Share remarks and comments with the rest of the participants;
- Evaluate the web-site through a discussion with the group;

Please, keep in mind that:

- The evaluation is directed towards the web site and **not** towards your skills or knowledge;
- Feel free to express your opinion;
- The more critical you are, the better;

- The data you provide is strictly confidential; some of your remarks will be presented in the final report without disclosure of **any** personal information;

Element	Your mark
Work with spatio-temporal data /during a virtual meeting/	
Creating animated maps /Datasets module/	
Tasks during a virtual meeting	
Privacy issues	
Conflict situations	
Overall impression of the web-site	

Marks (1-5):
1 – Not useful
2 – Needs a lot of improvement
3 – May be improved
4 – OK, but slight changes needed
5 – Very useful

Appendix 3: Interview and focus group results

#	Suggestions and problems	Potential improvement	Status
General			
1	The place of the "Exit" button in Datasets module is confusing	Move the "Exit" button in the upper right part of the interface	Adjusted in second LFP
2	Provide a good tutorial with video	---	Second priority
3	Provide good privacy policy	---	Second priority
4	Change the name "Action points"	Intuitive name, e.g. "Project plan"	Adjusted in the HFP
5	Confusion about the "Active" and "Passive" links next to each project	Remove links. The status of the project may be determined through the colour of its name.	Planned for implementation
Virtual room and work with maps			
6	Color of the description of a room is confusing.	Change from blue to grey	Adjusted in the second LFP
7	If the number of rooms in a project is large, organize them in an intuitive way	Arrange rooms in the Rooms module to appear in order: from last active to non-active rooms	Planned for implementation
8	Add option to choose e-mail and send a message together with the temporary invitation link	Added e-mail bar and message field in the Users tab	Adjusted in the second LFP; Planned for implementation
9	Set history time-span of a virtual room's chat window	Provide a link to the settings of a virtual room and its modules	Second priority
10	Set automatic zoom for the Google Earth display in a virtual room	Provide a link to the settings of a virtual room and its modules; automatic zoom for each uploaded map;	Second priority
11	Provide automatic notification to all members	Send automatic notification to members of a room	Second priority

	when changes in a virtual room occur	through e-mail when changes occur	
12	Provide an option for data exchange in a virtual room	Add a workspace in Maps and Places tab where users can upload different from KML files	Second priority
13	Provide access to actual values and attribute tables	On clicking the display the user gets actual values and attribute tables in a balloon	Out of the scope of this study
14	Provide an option to change the colours of the maps	Access to change the colours through the settings of each map	Out of the scope of this study
Privacy issues and conflict situations			
16	Set access to participants when creating a new virtual room	Rooms should be organized in three tabs according to access level: My rooms, Member and Public	Planned for implementation
17		Provide option to invite new team members to a room	Planned for implementation
18	Set access level to a particular dataset	Provide three access levels: My datasets, Member and Public	Second priority
19	Provide access to people that are not part of a project through a temporary invitation link	Provide users that are not part of a project with a temporary account and limited access	Second priority
20	Attach different level of access to the maps	Provide the user with an option in to adjust the settings for each map	Second priority
21	Set a time-span and overwrite option for the control of the display	Set time-out when a user is inactive for certain time (he/she looses the control of the display)	Planned for implementation
22	Provide an option for a private chat in a virtual room	A pop-up window where private chat between members can occur	Second priority

Appendix 4: Individual instructions for test subjects in the usability tests

Individual instructions for Bert

You are currently working on your vegetation model. You have simulated the **temporal variation in vegetation** in Andalucía, Southern Spain, for the period **01 March 2020** to **20 May 2020**.

You have 8 maps (one map for every 10 days) showing the variation in **vegetation greenness** for this period (greenish means more vegetation, while brown means less, see Figure 1). You are very happy; however, the vegetation for **10 April 2020** to **20 April 2020** does not look good: there is much more variation than expected and the map looks strange and different from the rest.

For your meeting you have quickly prepared an animated map. Its name is "**Simulated_vegetation.kml**" and is located on the Desktop of the computer. Through the animated map Simon will be able to see better that the map for 10-20 April 2020 differs from the rest of the maps. You will have to show it to him and explain what it is about. You have no idea why the vegetation in April behaves like this so you will **figure out whether it makes sense for Simon**.

Figure 1. Your animated map showing simulated vegetation greenness for the period 01 March 2020 – 20 May 2020

You also want to validate your results. The problem is that you do not have all the data that you need. The data that you need is **simulated precipitation** for 2020. You have to find it from somewhere quickly, because **next week** you have to be ready with the validation. You are particularly interested in 2 areas: one is near Barbate and the other one near Los Barrios (see additional printed map; note that this map is for reference only).

Your goal: Figure out whether your results make sense for Simon and whether he has the data that you need.

Tasks

Please, **DO NOT STOP** saying aloud what you think and what is happening.
You can start when you have gone through the tasks.

1. Log in:
   User name: simon
   Password: simon123
2. Enter the room "Update for Simon" in the public "Future Land Cover" project.

Hint*: If Simon is not on-line when you are ready, you will have to wait for him.*

3. See whether Simon has logged in. May be you can greet him, before you start updating him on your results. Make sure he agrees that you start explaining first.
4. Before showing him your maps, the first thing you need to make sure is that you have the control so that Simon can see when you move the display. Afterwards, you can upload your animated map and show it to Simon.

Hint*: the file is called "****Simulated_vegetation.kml****" and is located on the Desktop of the computer.*

Hint*: note that the animated maps are not currently synchronized, so if you can see the animation running on your screen,* **Simon will not be able to see this***. You can also remind him that he needs to play it for himself.*

5. The map that you have prepared to show to Simon does not have a legend and he may get confused. However, you have all the information about this map in the "***Scenario***" section. Explain to him what the animated map shows. Be explicit (your purpose is not to hide information from him); answer the question and continue to the next task.

Question 1: Does Simon understand what you are working on?

Answer:………………………………………………………………………………

6. Now tell Simon what you are worried about. Find out what does he think about your results, answer the questions below and move to the following task.

Question 2: What does Simon think about this sudden shift of vegetation in April? Does he find it strange as well?

Answer:………………………………………………………………………………

7. Ask Simon to explain what he is currently working on, answer the questions below and move to the following task.

Question 3: What is Simon currently working on?

Answer:………………………………………………………………………………

8. **Show** him the validation sites you need data for (remember that this **DOES NOT** mean that you have to upload a new map. Just move the display to show him the places). Explain to him what you need (simulated precipitation data for

2020, you can also refer to the Scenario) and figure out whether he will be able to help you. Answer the question and move to the following task.

Question 4: Does he currently have the data for these areas?

Answer: ………………………………………………………………………………

9. Ask him to show you the areas he will have data for. Once he shows you, mark them on the printed map in front of you with a cross (X), answer the question below and move to the following task.

Question 5: Would he have data for other areas? Where?

Answer:………………………………………………………………………………

10. When you are finished answering, thank to Simon. Your favorite TV show will start soon so it is time to go.

Individual instructions for Simon

You are working on a model which simulates the **temporal variation in precipitation** for **2020** for several key areas in Southern Spain (marked also on the map, see additional printed map). This is a very hard effort and you still **do not have the results** (so you have **no maps** to show to Bert) but you expect them to be ready next month **(February, 2010)**.

However, you have **some idea** what the results will be. What you expect is that during the year 2020 there will be almost **no differences** in the monthly precipitation values and **no extreme events** in Southern Spain.

Your goal: You need to update Simon about your expected results and figure out what is he working on currently.

Tasks

Remember, that you can refer to the information provided in the Scenario as many times as you want.

Please, **DO NOT STOP** saying aloud what you think and what is happening.

You can start when you have gone through the tasks.

1. Log in.
2. Enter the already created **public** project "**Future Land cover**"; enter the **public** room "**Update for Simon**".

Note*: If Bert is not on-line, you will have to wait for him. Please, be patient!*

3. When Bert logs in, greet him and check with him whether he minds to start first.

4. Wait for him to explain what he is currently working on and try to understand what his results are. Answer the questions below and move to the following task.

Question 1: What is Bert showing you? Can you explain what his results are?
Answer:………………………………………………………………………………

5. Try to get more information from him (asking him questions through the chat window); answer the questions below and move to the following task

Question 2: What is Bert worried about?
Answer:………………………………………………………………………………
Question 3: Do his results make sense for you? Why?
***Hint**: Remember that you are expert in climate modeling and you already have some idea how the precipitation will behave in 2020. May be you can use this knowledge to figure out whether Bert's results make sense.*
Answer:………………………………………………………………………………

6. Explain to Bert what you are currently working on and when you expect to have results.
7. Figure out what data does he need. Answer the question and move to the following task.

Question 4: What does Bert need?
Answer:………………………………………………………………………………

8. Mark on the **printed map** which areas he is interested in (this map was provided together with the instructions). Move to the following task.

9. Explain to Bert what you are currently working on and move to the following task.

10. **Take the control** and show him the planned sites you will have results for (this **DOES NOT** mean that you need to upload a map; just navigate to those area and make sure he sees them). When you make sure he sees the areas, move to the following task.

11. If you have not discussed yet, you need to get some more information from him and answer the question below:

Question 5: Would your results be useful for him? Why?
Answer:………………………………………………………………………………

12. When you are finished answering, thank Bert for his update. It is coffee time and you have to go.

13. You remember that you have to update Prof. Brown (the main coordinator on the project) about your virtual meeting with Bert. You don't want to miss the free coffee in the canteen, so you will provide access to Professor Brown to the room: the meeting is recorded so she can enter herself and see what you have discussed with Bert. Invite her to become a member of the room so that she can check the meeting and is updated on your progress. Her e-mail is **pbrown@abv.bg**;
14. Before you log out, download the map that Bert has shared. It may become useful later.

Thank you for your time!

Appendix 5: Observed collaborative behavior during the usability tests

Group 1
When the test session started, Bert proceeded to upload the maps, as indicated in the instructions, which left Simon wondering what to do while waiting [comments: "*Nothing happens*"]. When Bert took the control and uploaded the animated maps, Simon did not try to interact with the display (e.g. zoom in/out) but was waiting patiently for his partner to explain the maps. While Bert was trying to make sense of the animated maps himself no communication took place. The researcher interrupted and encouraged Simon to play the animated map. When the users switched to the second part of the scenario, Simon did not have a problem remembering where the control is and how to take it. After showing his locations, Bert requested the control and Simon released it. However, after a system message appeared that Simon has given up the control, Bert proceeded to navigate to his locations, forgetting to push the "Control" button. It took him several seconds to recover but finally he was able to show to Simon the indicated locations and the tasks were completed successfully.
Group 2
After asking whether she can start first, Berta proceeded to upload her maps. She filled in extensive description of the map, however, after uploading it Silvia asked: **Silvia says:** Now, can you explain what I'm looking at?13:40 Similarly to group 1, Silvia did not make use of the Maps and Places tab to look at the description of the map. **berta123 says:** Yes, you are looking at the change in vegetation over time between 1.3.2020 - 20.5.202013:40 **Silvia says:** I zoomed in. But it is not clear to me what I'm looking at.13:41 Silvia was zooming in and out, trying to figure out what the map stands for. Initially, she did not see the temporal legend. The users did not have problem with taking and giving control. **berta123 says:** I will give up the control so that you can show the locations14:06 **berta123**: has given up the control14:06 Upon taking the control, Silvia comments "*I have no idea if she can see now where I am*". In general, no new problems were observed but the interaction took place in the same manner as in group 1. All tasks were completed.
Group 3
In this group, the participants were instructed that the tasks are collaborative in nature and may not follow the order in which they appear in the individual instructions. Similar to other groups, Simon did not see the temporal legend and was

waiting for Bert to explain. After Bert explained that the maps show temporal variation in the vegetation for the period 01 March 2020 to 20 May 2020, Simon proceeded immediately to play the animation. He did not change the zoom level or extent within the display and was waiting for Bert to explain his results. The user even asked Bert to zoom in an area where the changes are more dramatic. Coming to the second question ("What is Bert worried about?"), Simon was expecting that Bert jumps to a particular frame of the animation. After waiting for him for some time, he figured out that Bert does not have control over the animations and started jumping to different frames through the slider. Even though not in the instructions, Simon asked Bert whether the changes he has observed appear everywhere or only in particular territories. At this moment Bert was looking at a different frame (number 6) and noticed that the changes are most dramatic in the west part of the territory. He zoomed into this location. At the same moment Simon was looking at the first frame of the animation and did not see any dramatic changes. The final tasks did not create confusions.

Group 4

The introduction session and the test took longer than other groups. In this case Simon had problems going into a role and delved very much into the content. The user was very thorough and meticulous, went through his tasks several times and through the manual. However, when the test session started he forgot to refer to his instructions. On uploading his maps Bert filled in very descriptive title and comments about the map which also appeared as a system message. However, Simon was still confused:

Bert: has uploaded new map 'Temporal variation in vegetation of Andalucia, Southern Spain from teh period 01 March 2020 to 20 May 20202'16:39

Bert: has loaded map in Earth16:39

simon says: so what do I see?16:41

Simon did not figure out to check the description of the map, and had problems finding it even after Bert asked him to do so. This was because the page was scrolled down, leaving the Maps and Places tab out of sight. It took several seconds for the user to find out what the problem is. Bert was following the tasks, while Simon went to the content which resulted in a long conversation. Even though the map helped to focus the discussion, no more interaction with the display took place. Eventually, the researcher had to interfere and end the test.

Group 5

When the test session started, Berta explained what the map stands for [**berta123 says:** The map shows simulated vegetation from the 1st of march to the 20 of may, 202013:35]. Silvia did not play the animation, did not move the display or interact with it in any way. This happened also after Berta asked specifically that Silvia has a look at the maps [**berta123 says**: Could U, pls, have a look at them?13:37]. There was no reaction or a try to interact with the display, even after, several minutes later Berta requested: [**berta123 says**: First, I wanted to ask whether these maps make sense for U13:38]. There were no problems with the second part of the scenario.

Group 6

After the test session started, a problem with the second camera had to be fixed. This, however took only several minutes and did not seem to bother Bert, who continued speaking and following his tasks. After uploading the map, Simon went to check its title and description immediately. Unfortunately, the description did not help the user too much as it was scarce in details ("Simulated vegetation"). Thereafter, Bert communicated that this is a temporal map which triggered a reaction from Simon to play the animated maps. Users were able to go into a role very well, and finished all tasks and answers. They had no problem with interchanging the control and showing the locations indicated in the instructions. At one point the messages Bert was sending were not appearing in Simon's chat window. This continued only for several seconds and the researcher did not interfere. Bert could not find the indicated locations in the Google Earth display. Simon asked to take the control and located the places.