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## Chapter II

# Usability Dimensions in Collaborative GIS

Mordechai (Muki) Haklay, University College London, UK

## Abstract

*Collaborative GIS requires careful consideration of the Human-Computer Interaction (HCI) and Usability aspects, given the variety of users that are expected to use these systems, and the need to ensure that users will find the system effective, efficient, and enjoyable. The chapter explains the link between collaborative GIS and usability engineering/HCI studies. The integration of usability considerations into collaborative GIS is demonstrated in two case studies of Web-based GIS implementation. In the first, the process of digitising an area on Web-based GIS is improved to enhance the user's experience, and to allow interaction over narrowband Internet connections. In the second, server-side rendering of 3D scenes allows users who are not equipped with powerful computers to request sophisticated visualisation without the need to download complex software. The chapter concludes by emphasising the need to understand the users' context and conditions within any collaborative GIS project.*

# Introduction

The design and implementation of successful collaborative GIS (C-GIS) is a multidimensional challenge. As Armstrong (1994) identified, the crux of this challenge lies in the semistructured nature of the problems that C-GIS is intended to solve. In such situations, only parts of each problem can be defined using formal methods of analysis that are easy to implement with a GIS. However, most of the problem components do not succumb easily to formalism, and an agreed solution can only be reached through discussion and interpretation by the stakeholders. Worse still, in many cases these are "wicked problems" (Rittel & Webber, 1984) where the stakeholders do not agree on the definition of the problem, and the problem itself mutates during the problem-solving process, as a result of the effort itself.

These inherent challenges are well recognised in the literature on the applications of GIS for group problem solving. This literature is inextricably linked to the wider research on Computer Supported Cooperative Work (CSCW) and groupware, which originated in the field of computer science circa 1984 (Grudin, 1994). For many researchers of CSCW and C-GIS, the complexity of group problem solving makes the research and development of such systems more interesting.

One might expect that, on the basis of almost two decades of research, a developer of C-GIS today would have a relatively easy task in assembling an effective system: the extensive literature and much practical experience should have provided clear instructions. After all, many of the tools that were introduced in CSCW research are now available as standard within everyday software, to the extent that the latest version of the ubiquitous Microsoft Office is now promoted as a system that enables group collaboration: "…Office 2003 Editions have improved in four areas: information management and control, business processes, *communication and collaboration*, and personal productivity" (Microsoft, 2004, emphasis added).

However, while the latest versions of commercial GIS packages offer some support for group collaboration, and reliable systems for sharing spatial databases and geo-processing amongst groups are being deployed successfully, these GIS packages do not include groupware capabilities. Therefore, there remains a need for research on end-users' interaction with C-GIS, and for development of easy and effective methods, techniques, and tools to allow the implementation of C-GIS applications. The gap between GIS and other software systems can be attributed to the complexities of geographical information sharing. Only in the mid-1990s did GIS technology reach a level of maturity that allowed the development of information sharing within organisations, in what is termed "enterprise GIS." Enterprise GIS products focus mainly on the storage and delivery of geographical information to a large group of users in an organisational setting. Only recently have products that support centralised geo-processing emerged. These developments are largely technical and occur in a back-office setting, away from end-users' desktops. However, this infrastructure is necessary for C-GIS, and therefore, it is not surprising that the integration of groupware into commercial GIS remains underdeveloped.

As C-GIS develops, many of the techniques of CSCW and groupware can be borrowed, and adapted for a GIS context. This must be done in a way that takes into account the special usability issues of GIS. Here too, we can rely on the accumulated knowledge in the related fields of Human-Computer Interaction (HCI) and Usability Engineering, which have long been part of CSCW and C-GIS research. In this chapter, two case studies illustrate the usability facets of C-GIS.

The chapter opens with a review of the research needs in the area of C-GIS, using the perspective of a decade of research. This is followed by a discussion on the role of HCI and usability engineering research in GIS research in general, and C-GIS in particular. The next section discusses two case studies of developing alternative interaction methods to be used in a C-GIS scenario. The chapter ends with observations on the link between C-GIS and usability studies.

## Collaborative GIS in the Last Decade

In one of the first discussions of the requirements for C-GIS, Armstrong (1994) identified three main obstacles to the implementation of such systems. First, there was a need for further development of hardware to facilitate CSCW; second, specialised software was required to facilitate group activities in GIS; and third, conceptual frameworks for C-GIS implementation had to be formulated to facilitate the development of coherent and consistent systems.

A decade later, significant progress has been made in all these areas. On the hardware side, most obstacles have been removed. Modern personal computers (PCs) are equipped with fast processors, large storage and memories, and strong graphics capabilities. The ability to display detailed colourful maps, 3D models, or animated maps is integral to the computer systems that are available today (Doyle, Dodge, & Smith, 1998). Furthermore, the networking capabilities in a wired or wireless environment are adequate to enable sharing of geographical information resources within organisations, as well as with other organisations and individuals. Noteworthy is the development of mobile computing and the increased use of mobile telephones, which are, in effect, information devices capable of Internet connection. The ability of existing Information and Communication Technology (ICT) to facilitate large group discussion was demonstrated in the "Listening to the city" event in New York in August 2002, when 4,500 participants discussed the development plans for the World Trade Centre area (Susskind & Zion, 2002). During this meeting, computers and other information devices were used successfully to facilitate deliberation on a major and controversial development plan.

On the software side, a great deal of improvement has occurred in GIS in general, and in C-GIS in particular. With advances in programming tools, knowledge in geographical visualisation, and spatial decision support systems, today's software tools offer sophisticated interfaces that enable users to explore many dimensions of the problem at hand (see Jankowski & Nyerges, 2001 and Laurini, 2001 for examples). Other tools for collaboration, such as shared discussion boards, are also available on the Internet, and are relatively easy to implement. Noteworthy are innovations in methods for Public Participation GIS (PPGIS), which utilise Internet technologies to allow wider access to GIS tools (Batty, Batty, Evans, & Hudson-Smith, 2003; Carver, Evans, Kingston, & Turton, 2001; Kingston, 2002).

As for conceptual frameworks, Jankowski and Nyerges (2001) offer a comprehensive framework for the development of C-GIS, known as Enhanced Adaptive Structuration Theory (EAST2). This is a macro-micro strategy drawing on multiple disciplines. It is based on sociology, philosophy, management science, operational research, planning theory, GIS researchers, and their critics. EAST2 provides theoretical grounding for many facets of collaborative decision-making processes. Other frameworks are offered in the writings of Carver and his colleagues (Carver, 2001; Carver et al., 2001), although less explicitly.

Despite all these significant developments, research into C-GIS is not yet complete. C-GIS seems to be a "wicked problem" all by itself. For example, growing reliance on the Internet as the medium for facilitating collaborations introduced a new set of issues, from the speed of access to the use of the Web browser as the main interface. The current transition to ubiquitous computing, and the need to consider situations where the user is accessing the system from a wide variety of devices, such as computers, digital television sets, and mobile phones, raise further issues that research must address.

In summary, it is clear that within the last decade, C-GIS research and development has matured, and there is now robust and extensive knowledge, which can be used for the development of C-GIS. At the same time, new technological developments require fresh answers, and research into C-GIS is far from complete.

## Human-Computer Interaction, Usability Engineering, and Collaborative GIS

Human-Computer Interaction (HCI) is the term, adopted in the 1980s, to describe the field of study concerned with how people work with computers, and the design of computer systems in such a way that they are usable and accessible to many people. This field is crucial for the development of C-GIS because the users of these systems come from all walks of life, and their experience with computerised systems varies. Moreover, HCI is an essential field for CSCW, and hence, for C-GIS. This section provides a brief overview of HCI and Usability Engineering.

The aims of HCI are to understand how people interact with computerised systems, and to ensure that such systems are "good enough to satisfy all the needs and requirements of the users and other potential stakeholders" (Nielsen, 1993, p. 24). These people, however, may vary in their computer literacy, worldviews, cultural backgrounds, and knowledge of the application domain. Thus, it is important to understand the ways in which people use computer systems in particular settings if system design is to support users in an effective and efficient manner. Furthermore, users expect computer systems to be useful for achieving their goals, not only in terms of the appropriateness of the functionality they may provide, but also in terms of how well and easily such functionality can be operated (Nielsen, 1993; Preece, Rogers, Sharp, Benyon, Holland, & Carey, 1994). Usability is thus a key concept in HCI.

The concern with usability issues within Geographic Information Science (GISc) has paralleled developments in HCI, but not without a time lag. The initial concern with GIS usage was mostly about data management (such as handling large files or dealing with different file formats) and manipulations of information (such as overlay analysis or network tracing). GIS usage was initially confined to large organisations and was performed by professional users, such as engineers and drafting technicians. However, by the mid-1990s, the technology had diffused more widely in organisations, and a new generation of non-GIS expert users began to use it in their daily routines. This raised concerns about adapting GIS to accommodate different users' needs. Interest in GIS metaphors and interface design began to emerge from the need to support a wide range of user requirements and tasks some time after HCI had become formalised as a research field, and usability had been accepted as a major research area.

Research on HCI and usability issues in GIS has improved our understanding of user behaviour in a range of user settings (Knapp, 1995; Medyckyj-Scott & Hearnshaw, 1993; Nyerges, Mark, Laurini, & Egenhofer, 1995). Nevertheless, GIS still required users to have, or to acquire, considerable technical knowledge in order to operate the computer system (Traynor & Williams, 1995). A decade has now passed since Traynor and Williams conducted their analysis, yet many of their conclusions hold true. This presents major obstacles to nonexpert usage, since the interface encapsulates a language, worldview, and concepts that support the system's architecture, rather than the user's worldview. These issues have led to interest in the cognitive aspects and the psychological dimensions of user interaction with GIS. Research themes include the ways in which human cognition influences GIS use (Nyerges et al., 1995), how people think about geographic space and time (Egenhofer & Mark, 1995), and how spatial environments might be better represented by computers and digital data.

Within the C-GIS literature, attention to usability issues has reemerged in recent years (Haklay, 2003; Haklay & Tobón, 2003; Jankowski & Nyerges, 2001; Jankowski, Nyerges, Smith, Moore, & Horvath, 1997; MacEachren, Cai, Charma, Rauschert, Brewer, Bolelli, Shaparenko, Fuhrmann, & Wang, in press; Tobón & Haklay, 2003). As researchers integrate new technologies and follow HCI developments closely, new ideas are formulated and tested in GISc. In the following sections, two case studies are used to illustrate how ideas about the usability of GIS can be developed and tested.

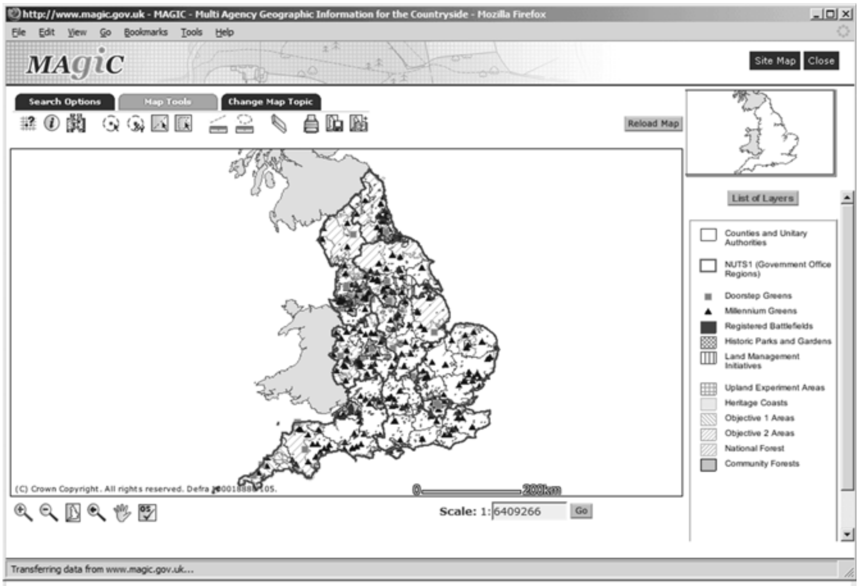
## Improving Online GIS

The provision of maps on the World Wide Web (Web) probably began in June 1993 with the introduction of Xerox PARC Map Viewer (Xerox, 2004). Applications of Internet map servers are now commonplace, and a wide range of commercial and open source software packages enable rapid implementation of GIS applications over the Web. However, many of these packages were developed by traditional GIS vendors, and they carry with them the complexities in user interaction that Traynor and Williams (1995) identified.

For example, the UK MAGIC system (Figure 1), which provides access to multiple environmental scheme and designations data sets, uses highly specialised icons and phrases in its interface: for example, "Zoom to full extent — Display the national map" or "Measure Area — click on the map to trace a polygon and measure its area." These instructions assume that the users understand such concepts as the "full extent" of a geographic layer, or what the term polygon means and how to trace such an object. MAGIC is a very rich and extensive system, and its functionality is to some extent comparable to a desktop GIS. However, users are expected to learn the system's jargon in order to operate it, because the system is not built in a way that provides easy access to many users, including those with limited mapping and GIS knowledge.

Such problems are by no means unique to the MAGIC system. Rather, they highlight generic issues with Internet mapping systems: most of them take the

*Figure 1. The UK MAGIC system (http://www.magic.gov.uk)*




metaphors, methods of interaction, and concepts of existing GIS packages, and copy them to the Web environment with little or no change to the interface. However, the Web is fundamentally different from the desktop environment (Nielsen, 2000), and to make Web-based mapping systems accessible and usable, developers must take into account the unique characteristics of this environment.

The demand for a different approach to user interaction over the Web derives from the characteristics of the Web, including the range of users, many of them with little or no experience of GIS (Longley, Goodchild, Maguire, & Rhind, 2001). Users may use the system only once or very rarely: for example, a laywoman may access MAGIC as part of information gathering for her planning application, or to learn about environmental designation in her locality. Such limited use reduces the effort that the user is willing to invest in learning a system (Nielsen, 2000), and therefore, requires the developers to ensure that the system is accessible without a lengthy training period. Another issue is access to the information from multiple information devices, with different screen resolutions and colour depth (Nielsen, 2000). The application might be rendered on a PC monitor, or on a television set that is equipped for Web browsing, or on a mobile phone.

Within C-GIS applications, there is a special need to consider these issues carefully, and to develop solutions that are inclusive, and enable the widest range of users to engage with the system in an enjoyable and productive manner. For example, if a C-GIS project is attempting to engage marginalised communities in a collaborative planning effort, the developers cannot ignore users who are using older computer systems with limited screen resolution. An application that does not work on such computers may further alienate users, and send the message that "you can only participate in the process if you have access to the latest technology." Thus, in C-GIS, usability has an ethical and moral dimension, too.

In the two case studies described here, another characteristic of the Web was taken into account as a usability challenge: the speed of access, and its implications for how the user interacts with the system. Current statistics highlight the divide in speed of access. By the end of 2004, 58% of adults (and 52% of households) in Great Britain used the Internet. Of these, only 41% use fast, broadband connections (ONS, 2004, 2005). Therefore, the majority of Internet users have a limited bandwidth, and this influences their interaction with remote Web sites. This is especially important in interaction with systems that contain large graphical files, such as Web-based GIS. Here, the most important information on the page is the map itself. In a C-GIS session, the user is required to interact with the system extensively through such operations as zooming, panning, or adding points and areas to the map. Over slow Internet connections, network latency makes each operation longer, because the user must wait for the complete transfer of the map from the server before each activity. For many users, this latency leads to frustration and loss of interest in the application and, by implication, withdrawal from the collaborative process for which the system was designed.

Therefore, C-GIS needs to develop techniques and methods that can work over limited bandwidth connections while providing an engaging experience for users. Two such methods are described in the following sections: first, digitising an area on a Web-based GIS using Javascript (Dynamic HTML – DHTML) technique, in order to minimise interactions with the server (Edney, 2001); and second, a server-side rendering technique to allow user-defined 3D visualisation over limited bandwidth connections (Berry, 2004).

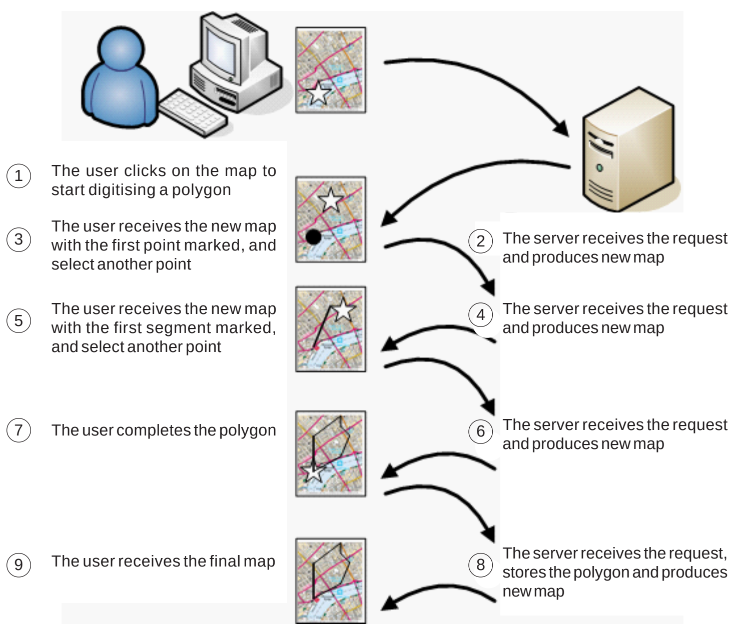
It is important to note that, in both cases, the technique was developed as a demonstrator of the integration of usability considerations in Web-based GIS. Therefore, the analysis of users' needs was not based on analysis of the specific application, and how it would be used. Both projects assumed a scenario that was described above: the user is not familiar with GIS and would like to use the GIS as part of a wider task, be it filing a planning application or writing an essay. Furthermore, it is assumed that the user is connected to the Internet through narrowband connection, and is using a computer 3-5 years old. The user is not assumed to be savvy technically and, therefore, is unfamiliar with software installation and configuration. No assumptions were made about age, gender, or socioeconomic status.

## Outlining an Area in Web GIS

In a regular Web-based GIS (such as the MAGIC system), the polygon tracing functionality is implemented through an interaction between the client and the server in the following sequence (Figure 2): The user clicks on the map. This sends a message to the server, which responds by rendering a new map, this time with the selected point marked on the map. The user continues and selects further points to trace the edges of the polygon. After each click, the server renders the segment of the polygon that has just been traced, and sends a new image of the map to the client. At the end of the process, the user chooses to complete the polygon and submits it to the server, which then writes it to its database and issues a final map with the new polygon visualised. This is a relatively basic operation in C-GIS and during a session, the user might be asked to digitise several areas.

As Figure 2 shows, the process necessitates many map requests from the server: even a fairly small polygon with four vertices will produce six map refreshes. The use of a live site (the Royal Borough of Kingston's ISIS system) revealed that

*Figure 2. User interaction with server during digitisation of a polygon*



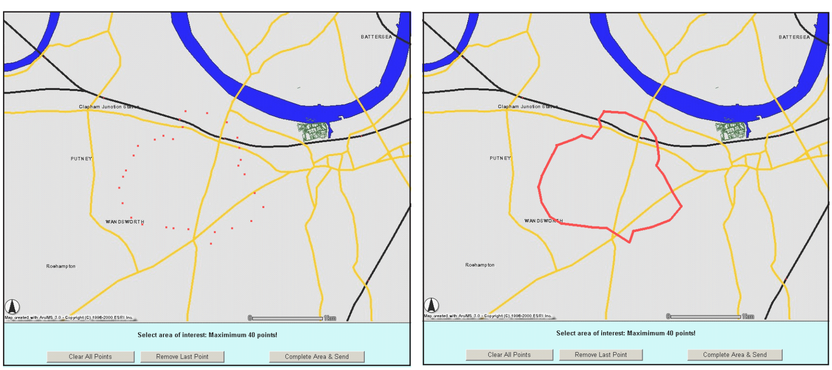
each such request requires about 8 seconds over a 56 Kbps modem, and digitising a simple polygon can take more than a minute. This is clearly a long period of time, and beyond what users expect from a truly interactive system.

One method of providing interactivity is to develop a client-side application that the user downloads and installs on his/her computer to allow client-side interaction (plug-in). Such applications have existed in the GIS field for some time, and they provide good interaction capabilities. However, the use of plug-ins is not suitable for occasional users, as it requires technical capabilities on their part to install the packages and to spend time downloading the installation file.

Java-based applications offer another alternative, but they require download time before the user can access the maps, and they may lead to compatibility problems, especially with older computer systems that do not have the latest Java virtual machine.

Edney (2001) developed an alternative interaction method by transferring the digitising process to the client side, using the in-built programming capabilities of Web browsers. In this method, every time the user selects a vertex on the map, a point appears on the browser screen, but without the lines that connect the vertices in the common implementation. Only when the user selects to complete the polygon and clicks on a button to do so, does the browser send the list of coordinates to the server, which produces the final polygon and returns a map with the completed polygon. Figure 3 shows a sample polygon that was digitised in this way. This method reduces to one the number of interactions between client and server during the digitising procedure: a request is sent to the server, and a new map is drawn only when the user has completed the digitising.

*Figure 3. Left: The digitised points. Right: Appearance of a polygon when returned from the server (Source: Edney 2001)*



Regular GIS users may find this method of interaction counterintuitive, as they are used to the full interactivity of lines appearing between the digitised points. Indeed, this is possible in Javascript, and it could be implemented by creating a set of dots in a straight line that connects every two vertices of the polygon, thus creating the frame of the polygon as a "dotted line."

The visualisation of the vertices alone is less than ideal as it does not provide the user with the full outline of the polygon, and it increases the mental load by requiring the user to remember the set of points selected. However, it was decided to evaluate the usability of such an alternative and, to our surprise, many users found this method acceptable, especially those without prior experience of GIS.

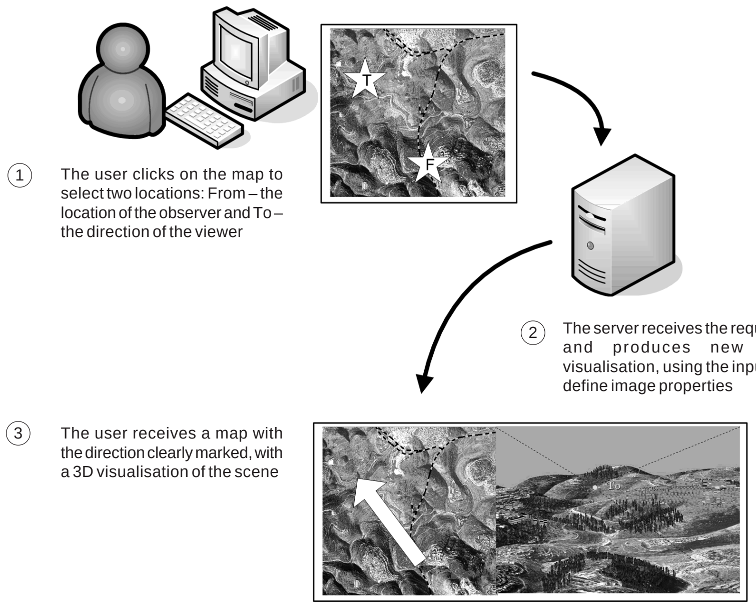
Recent developments in Web mapping, such as Google maps, demonstrate that it is possible to provide sophisticated interactivity with basic browser capabilities such as DHTML. Using these capabilities, and taking into consideration the nature of the user's interaction with the system, can improve the user's experience with the application.

## Server-Side Rendering of 3D Visualisation in Web GIS

The development of client-based digitising in Web GIS provided an example of a microchange to the user interface: the implementation does not require a change to the design of the interface, and it follows the same convention of interaction as the equivalent server-based method. Thus, it demonstrates how usability considerations can lead to changes in user interface, which are mainly technical, and do not intervene with the wider "look and feel" of the system. While the method is clearly advantageous in comparison to the common server-side method, the implementation is largely technical and "transparent to the user." In other cases, problems with bandwidth and computer capabilities need to be integrated into the general design of the system. They therefore influence the interface of the system in a more fundamental way.

Visualisation in 3D-GIS (or Virtual-Reality GIS – VR-GIS) has recently gained popularity, and it is now part of the standard visualisation in GIS (Haklay, 2002). In urban planning, for example, the use of computerised 3D models is now commonplace (Batty, Chapman, Evans, Haklay, Kueppers, Shiode, et al., 2001). Therefore, in many urban problems in which C-GIS is deployed, researchers and practitioners want to use computerised 3D models as part of the system (Hudson-Smith, Evans, Batty, Batty, 2002; Talmor, 2004). While the use of 3D models creates a more realistic representation of the problem situation, it also creates a major technical obstacle: the delivery of these models over the Internet. Although the delivery of 3D visualisations over the Internet has been possible for well over a decade, Internet browsers are still incapable of rendering 3D data

*Figure 4. User interaction in 2-D system to produce 3-D visualisation*



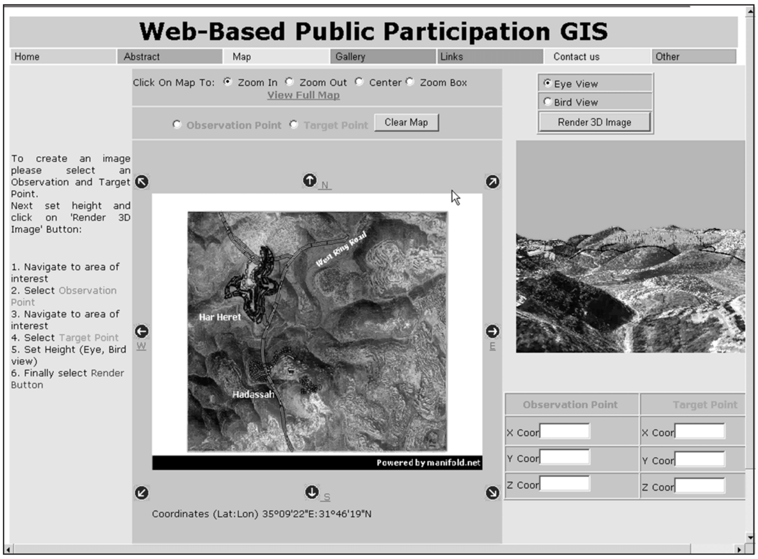

without the use of specialised software. Today, products like TerraExplorer from SkyLine Software Systems, or NASA's World Wind, provide the needed visualisation capabilities, but their data demands mean that they do not perform well over narrowband connections. They also demand the user to download the specific package and install it before accessing the content, which is what the user wants to see in the first place.

A possible solution for this problem is to enable users to create 3D visualisation of a selected scene and view it over the Internet, but without any requirement to download and install specialised software. This can be done by sacrificing the interactivity of the 3D environment and keeping the delivery of the spatial information in 2D. The process is described in Figure 4.

The user is using a regular map interface. On this interface, the user selects two points. First the user selects the location of the point of view of the observer. This is followed by the "to" location: the point on the map towards which the observer is looking. Once these two points are set, the user submits the two locations to the map server over the Internet. The server, which runs 3D visualisation software, uses the two locations to render the image and returns the static 3D visualisation to the user.

Such a system is implemented by coupling an Internet map server with a 3D GIS. The Internet map server can be based on topographic maps, street maps, aerial photographs, or other combinations of mapping products that will help users to

*Figure 5. Coupled 2-D and 3-D interface for participatory GIS (Adapted from Berry, 2004)*




locate their points of interest in the study area. The 3D GIS will include Digital Terrain Model (DTM) to describe the surface of the study area, with additional information to describe built structures, trees, and other natural features that should be rendered in the final image. The system is programmed to assume that the observer is standing at the "from" location, and therefore, the point of view is calculated at 1.8m above the surface. The visual field is calculated in such a way that the target point is at its centre. The resulting system can provide a user interface of the sort shown in Figure 5.

The actual implementation of the proposed solution proved more difficult to implement than originally envisaged, due to difficulties in coupling Internet map server systems with 3D visualisation packages (Berry, 2004). However, some analysis of the potential of this coupling in C-GIS can be conducted.

The advantages of this method are that it eliminates the navigation complexities of immersive virtual reality systems and the restrictions of narrow bandwidth. It also makes it possible to share points of view and visualisations with other users. Each of these issues is discussed briefly.

First, many users experience problems negotiating their way through the terrain in immersive virtual reality environments, such as SkyLine TerraExplorer (MacEachren, Kraak, & Verbree, 1999). This may influence their understanding of the issues that are being discussed within the system. Worse, it may disempower them by making them feel that they are incapable of engaging with the system. The simplified interface ensures that the visualisation will be produced from a realistic point of view, from the ground or from a vehicle, unlike the bird's-eye view or fly-through visualisations used in many architectural simulations of development projects. After all, when encountering the finalised project, most people will experience this realistic point of view, not the more compelling view from above.

Second, the use of server-side rendering reduces data transfer between the server and the client, and thus, is more suitable for users with narrowband connections. Users receive a rendered image that they can download easily, and view without any need for specialised software. If they wish to produce a different point of view, another set of clicks on the map will produce the required image.

Finally, the creation of a static point of view opens up the possibility of interaction with other users in the discussion of the proposed plan. Indeed, immersive environments are capable of allowing multiple users to interact both with 3D models and between themselves (Hudson-Smith, 2004). However, these immersive environments require specialised software, broadband connections, and state-of-the-art computers. The creation of simple static images enables multiple users to use the shared 2D map to show other users specific points of view that are important for them, and to annotate the map and the image with details of their personal point of view, in a way similar to those described by Carver and his colleagues (2001) or by Laurini (2001).

However, the proposed solution removes all the advantages of interactive immersive environments, as described by Hudson-Smith (2004) and others. Indeed, in situations where it can be guaranteed that all users have fast computers, broadband connections, and technical assistance for software installation, full immersive interaction provides advantages that cannot be ignored.

## User-Centred Design for Collaborative GIS

The two case studies that have been discussed here provide examples of a major consideration required in collaborative GIS: the need to ensure that the system is designed around the user. This is usually known as user-centred design (Dix, Finlay, Abowd, & Beale, 2004; Landauer, 1995). In this mode of development, the design of the system starts with the user in mind. The analysis looks not only at the technical requirements of users, but also at the context in which they will use the system, their environment, and other factors that will influence their interaction with the system.

As previously noted, C-GIS is by itself a "wicked problem": as we integrate GIS as a common tool for planning activities at various organisational and spatial scales, the variety of users increases, as does the range of skills that the system must accommodate. In the case of C-GIS, these skills include map reading, computer operation, and data analysis, to name but a few. Therefore, system designers must consider the full context of their users. Where and when will they use the system? What type of computer will they use when accessing the system? What will be the bandwidth of their network connection? Understanding the full context of the user will enable differentiation in the design of systems that will be used in the workplace, where technical assistance is at hand, and the goals and objectives of the users are clear; and systems that will be used after working hours, at home, where technical assistance is less likely to be available, and narrowband connection to the Internet is common.

Once they understand user needs, context, and capabilities, developers must consider the technical solutions available to them. GIS software vendors will naturally promote their latest products, and many developers will be inclined to use the latest technology (such as immersive virtual reality products). This technical drive by software vendors and developers may lead to systems that reduce rather than increase the collaborative potential of GIS, by sending the wrong message to users: "Unless you've got the latest computer and you are computer literate, you cannot join this discussion." Clearly, this is not the goal of collaborative GIS developers.

It is worth noting that many techniques are available to capture user requirements (Dix et al., 2004). They range from a series of focused interviews to elaborate anthropological studies in which the developers observe the users in the daily environment in which they will use the software. Most of these methods are easy to implement and relatively inexpensive. They should therefore be integral to any C-GIS project.

The two case studies demonstrated that critical evaluation of user needs can challenge the current state of the art in GIS interface. The server-side digitising procedure is a simple solution technically, and it is therefore not surprising to see that software vendors choose it. However, it is clearly not the right solution from the users' perspective. Similarly, the provision of 3D visualisation through immersive virtual reality software is an attractive solution: it is engaging and interesting for the developers, and it is relatively easy to implement. However, from the users' perspective, a simple solution might provide the main advantages of the immersive environment without the technical complexities that it entails.

As noted at the beginning of this chapter, collaborative GIS is a fruitful area of study. It can lead to many enhancements and innovations in the user interface that can influence everyday use of GIS. This chapter demonstrates that the integration of Usability Engineering principles with C-GIS development can ensure that the effort that developers are putting into these systems will result in enjoyable, efficient, and effective systems.

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