

Usability Evaluation and PPGIS: towards a user-centred design approach

Mordechai (Muki) Haklay (Corresponding author)

Department of Geomatic Engineering

University College London (UCL)

Gower Street, London, WC1E 6BT

Phone: (+44) 20 7679 2745, Fax: (+44) 7380 0453, Email: m.haklay@ucl.ac.uk

Carolina Tobón

Department of Geography and Centre for Advanced Spatial Analysis (CASA)

University College London (UCL)

Gower Street, London, WC1E 6BT

Phone: (+44) 20 7679 4260, Fax: (+44) 7813 2843, Email: c.tobon@ucl.ac.uk

Keywords: Human-Computer Interaction, HCI, Usability Evaluation, Public

Participation GIS, PPGIS, User-Centred Design, Wandsworth GIS

Short title: Usability Evaluation and PPGIS: towards a user-centred approach

Acknowledgement: The authors would like to thank Mr M.Hawell of the planning department in the London Borough of Wandsworth for his help in this project, and the team of MVM ltd and David Rix for their willingness and support during the usability testing. Special thanks to S.Brustof. An earlier version of this paper was presented at the first URISA PPGIS conference, 21-23 July 2002, Rutgers University

Usability Evaluation and PPGIS: towards a user-centred design approach

Abstract

Public Participation GIS (PPGIS) is a field of research that, among other things, focuses on the use of GIS by non-experts and occasional users. These users tend to have a diverse range of computer literacy, world views, cultural backgrounds and knowledge. These aspects require that the systems used within PPGIS are accessible and easy to use. Human-Computer Interaction (HCI) the related Usability evaluation techniques focus on how to make computer systems more accessible, while focusing on user needs and requirements. Thus, the synergy between PPGIS and HCI seems natural. In this paper, we discuss the aspects of this synergy, building on our experience from three workshops. We demonstrate how Usability evaluation can contribute to PPGIS research, and how PPGIS research can contribute to the HCI aspects of GIS in general. We conclude this paper with a call for a user-centred design approach to PPGIS projects.

Introduction

Public Participation Geographic Information Systems (PPGIS) is inherently about empowering GIS users from all walks of life and enabling them to use the technology purposefully to capture their local knowledge and advance their goals (Talen 2000, Craig *et al.*). Although the usability of GIS products has improved immensely in recent years, they still require users to have or acquire considerable technical knowledge to operate them (Traynor and Williams 1997). This presents major obstacles to non-expert users in

terms of navigating an interface that embeds a language, world view and concepts that support the system's architecture rather than the user's work view (Goodchild 2002, Ghose 2001, Haklay 2002, Elwood and Leitner 1998, Traynor and Williams 1995). In such situations, HCI issues—concerned with how people design, implement and use computer systems (Myers *et al.* 1996), the usability or the effectiveness of the interaction between humans and machines (Butler 1996), and how computers affect individuals, organizations and society—are vital to the success of PPGIS. Although HCI and a number of usability aspects of GIS received attention in the first part of the 1990s (see Nyerges *et al.*, 1995a; Davies and Medyckyj-Scott 1996, Medyckyj-Scott and Hearnshaw 1993), it seems that within PPGIS research, little attention has been paid to the influence of HCI on research and practice.

This is, in a way, unfortunate as the type of users that are being exposed to GIS in a PPGIS setting are very different from those who have been at the centre of the earlier research on HCI issues in GIS. While this early research focused on the use of GIS by specialists who use the system to accomplish a specific work-related task, PPGIS settings usually call for an open-ended exploration in which users experiment with the GIS and examine various issues that relate to their community and locality. Furthermore, these users may not access the technology in the office but rather in new application scenarios, such as is the case with Internet-based applications which are accessed from the home and the community (Thomas and Macredie 2002, see also Krygier 2002). Combined with the varying level of computer skills and literacy of users in PPGIS settings, these types of applications pose interesting challenges when it comes to evaluate their usability and use in these different contexts.

In addition, within PPGIS research, HCI and usability evaluation can contribute to the subject matter and not just to the improvement of the system used, as other aspects

of this study have shown (Haklay and Harrison 2002, Boott *et al.* 2001). This is due to at least two reasons. On the one hand, HCI techniques, including usability evaluation, are geared towards understanding how people interact with computer applications within an environment. On the other, they are built upon methods researched and validated in a number of scientific fields (Thomas and Macredie 2002), which can aid PPGIS in the design of more robust applications that are accessible to a wider range of users, most of them with little or no experience of GIS. As a result, HCI and usability evaluation methods open new avenues for understanding users' expectations from a GIS, the ways in which they use, understand and value the system, and the role of GIS within the wider societal context.

This paper discusses the HCI and usability evaluation techniques that were deployed in three PPGIS studies— two that focused on PPGIS research and a study that focused on usability— and will demonstrate the contribution of these techniques to PPGIS research. The paper begins with a brief overview of the links between HCI and usability evaluation and GIS. A brief history of HCI research and trends is discussed, as well as related work that has been carried out within Geographic Information Science (GISc). The second part of the paper builds on this theoretical background and demonstrates how HCI and usability evaluation can contribute to PPGIS research and practice. Based on our experience, the contribution of these fields to PPGIS research is outlined first. The contribution of PPGIS to usability is then explained. The final section of the paper discusses these findings within the broader PPGIS framework and suggests that an iterative development process is needed in projects and research wishing to improve the use of the technology and its applications. We conclude with suggestions for future research and developments in this area.

Human-Computer Interaction and GIS

There is currently no agreed upon definition of HCI but a working one describes it as “a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them” (Hewett *et al.* 2002). Hence, HCI is concerned with enhancing the quality of interaction between humans and computer systems within the physical, organisational and social aspects of the users’ environment to produce systems that are usable, safe and functional (Preece 1995). Research on these issues is based on the assumption that the needs, capabilities and preferences for the way users perform an activity within an environment should influence the design and implementation of a system in order for it to match users’ requirements. Knowledge about the users and the work they need to accomplish as well as about the technology is required to meet this approach to systems design, which makes HCI a multidisciplinary field of research.

A brief history of Human-Computer Interaction

HCI’s history is indicative of its multidisciplinary nature as it “arose as a field from intertwined roots in computer graphics, operating systems, human factors, ergonomics, industrial engineering, cognitive psychology, and the systems part of computer science” (Hewett *et al.* 2002). The interest or emphasis in one or more of these and many other fields contributing to HCI has been heavily influenced by the contemporary technological developments. For instance, the origins of HCI are commonly traced back to the 1940s when Bush (1945) proposed the *Memex*, a device for individual use that could speed routine and time-consuming calculations and store, retrieve and project text and multimedia information, among other features. Although the ideas that contributed to the concept of a modern digital computer pre-date the 19th century, the technology

available in Bush's time permitted their implementation into systems (Baecker and Buxton 1987). In the following decades, their development and use triggered the interest in designing systems that could aid human problem solving and creativity (Licklider 1960). Enriching and facilitating people's work through the use of computers is still a major concern in HCI.

During the late 1970s and early 1980s, research was driven by the interest of cognitive psychology on information processing (Lindsay and Norman 1977), which dealt with issues such as perception, attention, memory, learning and problem solving and how they can influence computer and interface design. This was partly possible due to the research on graphical displays carried out during the 1950s and successfully developed in the 1960s (Sutherland 1963). The importance of the quality of the interface and the need for its testing was, therefore, on the agenda from, at least, the 1960s, as shown in the work of Engelbart (1962) and Nelson (1965). However, interest in the usability of single-user computer systems rocketed during the 1980s in response to the personal computer explosion. By that time, the field had been greatly developed and great effort was placed on laying the theoretical foundations of HCI by formalising and developing theories and methods of design that took user needs into account (see, for instance, Card *et al.* 1983).

In the late 1980s and 1990s, multi-user workstations, multimedia and multitasking shifted the emphasis of research towards group working, integration and interaction of media as well as the impact of the new technology in society (Preece *et al.* 1994). Today, research is driven by trends that include the decreasing costs of hardware that have led to larger memories and faster systems; the reduction in power requirements and the miniaturization of hardware that have brought portability (Hewett *et al.* 2002); and the distribution of computing and new input technologies such as voice or gesture that have

broadened the possibilities of user interaction with computer systems. Some of these advances have prompted trends of special interest in PPGIS, which aim at incorporating social concerns and public characteristics in system design. Examples of this include striving for improved access to computers by disadvantaged groups such as disabled users, or interfaces that appeal to a particular age group (Muller *et al.* 1997).

These examples also illustrate the emphasis of HCI in designing user-centred systems, or systems that, from an early stage, involve target users and experts to a great extent to influence the design of the system. In this approach, usability evaluation is central to ensuring the design meets the user requirements. Such a design process is highly iterative and can be quite common, in practice, as user requirements, the design and the final system usually evolve gradually (Preece *et al.* 1994). Therefore, the design process encompasses the understanding of how people do their work in order to implement systems that can allow users to accomplish their tasks effectively, efficiently and satisfactorily.

Usability and Human-Computer Interaction

Apart from understanding how to improve users' work processes, HCI is also concerned with understanding how people use computer systems in order to develop or improve their design. The aim is to meet users' requirements so that they can carry out their tasks safely, effectively and enjoyably (Preece *et al.* 1993). Usability deals with these issues and it applies to all aspects of a system's user interface, defined here as the medium through which a user interacts and communicates with the computer (Nielsen 1993b). Usability refers to the effectiveness of the interaction between humans and computer systems and it can be specified in terms of how well potential users can perform and master tasks on the system (Butler 1996).

A system's usability can also be measured empirically in terms of its learnability, efficiency, memorability, error rate and user satisfaction (Nielsen 1993b). The ease of learning a product is measured as the time it takes a person to reach a specified level of proficiency in using it, assuming the person is representative of the intended users. Efficiency refers to the level of productivity that the user must achieve once the system has been learned. Memorability measures how easily a system is remembered either after a period of not using it or by casual users. An error in this context is defined as "any action that does not accomplish the desired goal" (Nielsen 1993b: 32). Counting such actions provides a measure of a system's error rate. Satisfaction refers to how pleasant the system is to use. Preece and her colleagues (1994) also mentions throughput, flexibility and user attitude towards the system. Ease of use or throughput is comparable to Nielsen's efficiency and error rate as it is defined as "the tasks accomplished by experienced users, the speed of task execution and the errors made" (Preece *et al.* 1994: 401). Flexibility refers to the extent to which the system can accommodate tasks or environments it was not originally planned for. Attitude is comparable to Nielsen's user satisfaction or how pleasant it is to use the system.

All these aspects relate to intrinsic objectives of PPGIS research — to make quite a complex computer technology accessible to a wide range of users, many of them from disadvantaged backgrounds. If we are to increase the access and use of GIS for those who are bringing a diversity of knowledge, technical capabilities and cultural perspectives, we ought to provide them with a positive experience of the technology. In this sense, the principles of HCI and usability evaluation methods provide a sound base for the appraisal of PPGIS research. However, the specific complexity which is inherent in GIS is significant and, therefore, we now turn to discuss the relationship between HCI and GIS.

Cognitive Aspects of Human-Computer Interaction for GIS

During the late 1980s, cognitive aspects of HCI for GIS were discussed at workshops of larger conferences or as sections of books where HCI issues in GIS were not their primary focus. The 1990s, however, saw a strong international research interest in the topic. Evidence of this can be found in four workshops that were held between 1990 and 1994 in the US and Europe¹ which explicitly discussed HCI aspects in GIS, as well as in at least two books—Medyckyj-Scott and Hearnshaw (1993) and Nyerges *et al.* (1995)—published solely on the topic (Nyerges *et al.* 1995b).

The interest in cognitive aspects of HCI for GIS can be explained by two main trends. On the one hand, the recent increased availability and power of affordable personal computers broadened their user community, which was no longer restricted to “a technical and mathematical priesthood” (Baecker and Buxton 1987: 51). This new user community both desired and demanded interfaces that required technical expertise as was demonstrated by the commercial success of the Apple Macintosh. On the other hand, GIS had been developing since, at least, the late 1960s and had reached a state where functionality such as map production, display and spatial data analysis was commonly provided (Kuhn *et al.* 1992). Concerns in the GIS community about increasing processing speed and storage requirements were the main topics on the agenda but they expanded at the beginning of the 1990s to include how GIS were used and how they could accommodate users’ needs. This had not been a matter of substantial

¹ ‘Cognitive and Linguistic Aspects of Geographic Space’, July 1990, Spain, NATO Advanced Study Institute. ‘User Interfaces for GIS’, June 1991, USA, NCGIA Initiative 13. ‘Task Analysis in Human-Computer Interaction’, June 1992, Austria, 11th interdisciplinary workshop on Informatics and Psychology. ‘Cognitive Aspects of Human-Computer Interaction for Geographic Information Systems’, March 1994, Spain, NATO Advanced Research Workshop.

interest as advances in GIS functionality to satisfy expert user needs were the focus of computer systems' designers and developers and the systems' manufacturers (Hearnshaw and Medyckj-Scott 1993). It was realised, however, that GIS were "more likely to fail on human and organizational grounds [...] than on technical ones" (Medyckj-Scott 1992: 106) as the deficiencies of the systems in terms of human factors could compromise their future success.

As GIS evolved out of a number of fields including geography, cartography and database management, it requires its users to have considerable knowledge of these fields to operate the system (Traynor and Williams 1995). Furthermore, GIS require users to be computer literate and invest enough time to use "an interface that reflects the system's architecture" (Traynor and Williams 1997: 288). Nevertheless, GIS users vary in expertise and may use the technology in one of a large number of application areas, as well as demand different functionality and analytical power. Accommodating such a wide spectrum of needs is a challenge in its own right that must take into account a number of factors such as the components and requirements of the users' work, their capabilities and limitations, the types of support the system can provide, and where it can be provided most effectively (Muller *et al.* 1997). Continuing research into the understanding of spatial knowledge sources and the representation of such knowledge can provide valuable information in the designing of effective user interface architectures that take into account these factors and can also improve the quality of the users' work.

It is not yet fully understood how spatial knowledge maps "onto functional abilities in thinking about space" (Hearnshaw and Medyckj-Scott 1993: 237), or how well the digital representation of such knowledge in a GIS translates into intuitive human reasoning (Goodchild 1999). Nevertheless, work in these areas has opened areas of research, of particular interest to PPGIS, concerned with enabling the accessibility of the

technology to a wider public. Questions as to whether or how complex models and methods for spatial analysis should be made available to non-experts can develop from the type of research carried out in PPGIS. For example, research into appropriate visualisation (Krygier 2002) or the use of multimedia (Shiffer 2002), can be integrated with mainstream GISc research to improve the usability of GIS for occasional and non-specialist users. Of significance is the concern within PPGIS literature of the limited use of sophisticated functionality of GIS (Craig *et al.* 2002). In the following section, we discuss the role of usability engineering techniques in obtaining information on the interests and needs of a particular user group and the environment for designing applications that suit their requirements. Furthermore, we discuss how these techniques can benefit PPGIS research and practice.

The Synergy of Usability and PPGIS Research

Building on the background of HCI and usability evaluation methods and their applications in GIS, we move to the description of two workshops and a usability evaluation that were conducted in a southern borough of London² and the role that Usability evaluation techniques played in these. The first part of this section describes the two workshops which were aimed at eliciting views and opinions of active publics towards the use of GIS within the physical planning process. Within these workshops, HCI and usability evaluation techniques played an important role in assisting their design and analysis. The second part of this section describes a usability test of an online mapping system that was designed by the local authority to provide access to planning information. In this test, we used knowledge from our PPGIS studies to understand the

² Boroughs are the basic administrative unit of local government in London.

user requirements and to improve the design of the system. Together, these three studies stress the role of a user-centred approach to the design, development and deployment (Landauer 1995, Preece *et al.* 1994) of PPGIS projects which is discussed in the following sections.

Part I: Using Usability techniques for PPGIS research

In the workshops undertaken in the inner London Borough of Wandsworth, we used the focal point of environmental planning as the gateway to the use of GIS as a planning tool, and the issue of brownfield development and the actions of local amenity groups and individual residents as the focus for discussions on PPGIS. The workshops involved a proposed high-density development of luxury homes on the river Thames that was of concern to local residents. These concerns related to the lack of provision for affordable homes and the wider environmental impacts the development would incur—for example, traffic generation and congestion and pressure on local services such as schools, playgrounds and libraries.

As for recruitment of participants, we invited two distinctive local groups of residents to the two workshops. We recruited fourteen people for the first workshop all of who were active members of the Wandsworth community. For the second workshop, we recruited nine participants who had objected to a planning application in the Borough during the last twelve months, two of which had participated in the first workshop. Participants varied in computer literacy from the novice to the experienced. All respondents were white and predominantly middle class. In this regard participants were typical of those ‘active publics’ other studies of public participation in planning have recorded (Thomas 1996, Rydin 1998).

Both workshops were structured in three parts: an introductory plenary session, a practical session and a focus group discussion. The introductory session outlined the basic features of the GIS and the database that was compiled for the workshop. During the practical session, participants worked around a free-standing PC in groups of two or three for 90 minutes. Each group was supported by a GIS ‘chauffeur’ and group facilitator. The GIS ‘chauffeur’ is a person familiar with the GIS and the data content of the system. The chauffeurs demonstrated some of the basic tasks and then encouraged participants to take control of the mouse and keyboard and to navigate their own way through basic operations of the system. The facilitators encouraged users to verbalise their thoughts regarding their interactions with the software. After a break, some of the facilitators moderated an hour-long focus group discussion by an experienced member of the research team followed the practical. All the discussions during the workshop were recorded and transcripts prepared. We used an off-the-shelf GIS package (ESRI’s ArcView) in both workshops which also provided multimedia access to specially designed web pages or existing websites. For a full description of these workshops and the substantive outcome, see Boott *et al.* (2001) and Haklay and Harrison (2002).

There are four identifiable HCI and usability evaluation techniques that we have used within these workshops which are discussed in turn in the paragraphs to follow:

- the reliance on chauffeurs to ‘drive’ the software,
- the use of software to record the interactions between the users and the system,
- the instruction to facilitators to encourage participants to verbalise their thoughts regarding the interactions and the development of a task list to guide the process, and

- the use of tasks or scenarios to obtain information about users' performance and attitudes towards the system.

The use of 'chauffeurs' has long been an established practice in studies of computer-supported collaborative work (CSCW) (Nunamaker *et al.* 1991). This technique was identified and adopted in GIS studies in the mid 1990s by researchers who explored the potential of GIS within the CSCW framework (Shiffer 1995a, 1995b, Jankowski and Nyerges 2001). In essence, the chauffeur acts as a mediator between those who need to use the GIS but lack the technical know-how, and the system. Hence, the chauffeur 'drives' the system on behalf of the users. In the two workshops, this was especially valuable as, apart from the complexities of an unfamiliar GIS interface, world view and concepts that are encapsulated in the software itself, the user must be familiar with the datasets and the information they contain. Thus, without extensive training it is unlikely that an occasional user would make the most of an off-the-shelf GIS (Traynor and Williams 1995). In terms of PPGIS research, the use of chauffeurs could reduce the technical complexities that the participants experience when working with a GIS, as a professional assistant is always present. However, we did not assume that the same person would have the skills as a facilitator to guide the participants through the process and to encourage them to focus on the issues that were at the centre of the research project. Thus, in every group we had an experienced facilitator, with a solid background in conducting qualitative research plus a chauffeur to drive the system. One of the outcomes of our PPGIS workshops is that, in an ideal situation, it would be better to have a chauffeur/facilitator rolled into the same person as this will make the analysis more accurate and can make the whole experience more natural. This requires a high level of competency in GIS combined with qualitative research and facilitation training. Unfortunately, there is a lack of such researchers due to the internal 'cultural divide' in Geography, Urban Planning and related disciplines and it is hoped that the growing

interest in socio-technical topics such as PPGIS will bring to the fore a new generation of researchers with appropriate training.

For the purpose of analysing and understanding how users perform tasks with computers, HCI literature advocates the complete recording of the interactive session, including the audio and the computer screen. The recording can assist in analysing what the participants viewed on the screen during the session and provide a better understanding of the relationship between the specific images that appear at a specific point and the topics that were discussed. They can be used to time different tasks and evaluate the performance of participants in accomplishing them. For the purpose of PPGIS studies, the recording provided a much needed augmentation of the current practice of analysing the textual output in the form of transcripts. The session recording enables the researcher to associate the discussion to the results obtained by the users in each task, as well as to analyse the sequence of events that led to a specific comment about the system or the information obtained.

The practice of asking participants to verbalise their experience with the system is aimed at understanding a range of cognitive activities such as the users' conceptual model, especially with regards to their expectations of the system's behaviour, while performing a specific task. As we found out from encouraging the participants to discuss their thoughts while using the system, this practice was very useful within our PPGIS workshops. Participants provided clear examples of the difficulties in respect of the concepts that are intermingled in the GIS package. For instance, participants with little computer experience commented on the difficulty to understand the meaning of operations such as 'zooming to active theme' as well as on terms such as 'butt', 'mitre' or 'pan'. For experienced GIS users, similar concepts together with their interfaces may be obvious and the fact that they draw heavily on multiple fields becomes unnoticeable.

However, by asking the participants to express their thoughts, we could understand better some of the main limitations or intimidating factors to using a GIS for the user group.

In usability evaluations, the definition of tasks and task analysis is used to obtain a quantitative measure of performance in terms of the time it takes to accomplish a task, or success/failure rates (Preece *et al.* 1994). Task analysis frameworks such as Rasmussen's (1986) that aim at controlling complex processes by mapping them in a simple manner in a display, have been considered for GIS interface design and understanding complex user tasks (Kuhn *et al.* 1992). Within our studies, we used this concept to guide the participants through a set of activities that were designed to provide a specific experience with the software, but also to explore PPGIS research issues. For example, towards the end of the practical session in the workshops, we guided the participants to try to add information to the system on topics that did not exist in the system's database. This was based on the emphasis in PPGIS literature on the importance of local knowledge and the ability to integrate it into a GIS. By putting this 'task' on the list, without a clear definition of what type of information the participants were expected to fill in, we encouraged them to discuss the type of information that they would like to capture, as well as the value of that information.

Finally, it must be noted that other qualitative research and analysis techniques were used in tandem with the HCI and evaluation methods. The use of focus groups, as well as the techniques employed to elicit substantive findings in the workshops go beyond the remit of this paper. Having stated this, it is clear that we would not have reached many of the main results of the workshop without the reliance on the HCI and evaluation techniques.

Part II: Using PPGIS research to improve usability

The next phase of the development occurred as a result of an initiative by the local authority, the London Borough of Wandsworth, to further develop their website. Wandsworth is considered one of the most forward-looking in terms of public participation and innovative use of Information and Communication Technologies (Carver 2001). It was one of the first local authorities to provide full access over the Internet to all the documents, which are used in its development planning (including letters of objection and minutes of the planning committee). The local authority also promotes public involvement in service delivery, and in the case of its planning department, this includes the involvement of advisory committees, community panels and attitude surveys. This innovative approach was recognised by the central Government, which recently (mid 2001) granted the Borough funds to further develop its website as part of the Government 'pathfinder' initiative towards e-government (DETR 2001). As part of this initiative, the planning department decided to provide a wide range of services online, including the ability to complete an application for planning permission over the Internet. As the planning department was aware of our workshops, we were asked to help in the design and testing of the system. While the original remit of our involvement in this project was to ensure that the system will be 'user-friendly and easy to use', we were able to advise the Borough based on the outcome of our workshops and to integrate some of the wishes of the local residents into the system. Thus, the PPGIS workshops contributed to the usability of the system and influenced the design and structure of a usability test.

Within this project we conducted a usability test based on common practices within the HCI and usability evaluation literature. Our approach was based on Nielsen's (1993a) "Guerrilla HCI", which allowed us to run the tests with a relatively small group

of participants and use the computer training facilities of the local authority. As for recruitment, we followed the method of the second PPGIS workshop. We sent email messages and posted letters to approximately 110 people who had objected to planning applications (either online or offline) in the last year, a list that was compiled by the local authority's planning department. From this list, we recruited nine participants who were able to attend the testing session. Just as in the previous workshops, participants varied in computer literacy from the novice to the experienced.

The testing session opened with a brief introduction of the reasons for conducting the testing, its potential contribution to the design of the final system in terms of making it more accessible and easy to use for the Borough's community, as well as the role of the university team as independent consultants to the local authority. After explaining the purpose of the evaluation, participants were asked to start using the system and to complete a set of four specific tasks using the system:

- Task 1 was intended to allow participants to use the application for the first time and become familiar with its main functionality by navigating to locations of interest. This allowed the evaluation of the navigation tools, including a menu with a list of locations that took the users to predefined areas of interest in Wandsworth. It also permitted the evaluation of the background maps for providing contextual information about locations of interest.
- Task 2 was aimed at testing the usability of the system for displaying layers of planning constraints and using the layer selection functionality for obtaining details about them.
- Task 3 built on this and included not only mapping further planning constraints but also navigating the map to compare map themes or layers and obtaining detailed information from selected planning constraints.

- Task 4 included using all the functionality they had learned, after at least 30 minutes of interaction with the application, to find information about the planning constraints for a particular building.

As can be seen in this list, the design was geared towards the evaluation of the system itself and our aim was to discover if the participants were successful in performing a specific task with the online application. We used recording software to capture the audio and video interactions to aid us in the analysis of the individual sessions. Each participant was encouraged to try to complete the task without help and only when it was clear that the interface was misunderstood or the participant was 'lost', an observer standing by provided hints about operating the system. The observer also completed an observations sheet to ensure that we could capture the main issues during the session. After completing the test, we asked participants to complete a questionnaire about their experience. The whole session took about 30 minutes. While the main issues and the lessons about the system that we gleaned through the usability testing were valuable and some integrated into the final system (see <http://www.wandsworth.gov.uk/pathfinder/pathmappingwandsworth.htm> or Figure 1), in the following paragraphs we will focus on the contribution of the three studies to this system.

Contribution of the studies to a user-centred system design

Four main contributions can be identified that stemmed from the two PPGIS workshops and the usability test and were integrated into the system (or were integrated into its development plan):

- informing community members about relevant planning content,
- content and presentation of layers in the GIS,

- the navigation and control of the mapping environment, and
- the general usability of the final application.

Informing community members about relevant planning content

During the workshops and the usability test we found that local residents felt it was difficult to find and learn about proposed developments in their area. Within the online system, a module was devised and termed ‘My Community’ which was aimed at enabling Borough residents to interactively define a geographical area on the map that was of interest to them. Once defined, the system logs a planning application within this area and sends an email message to the user with details about relevant planning constraints, thus enabling more active participation from the user.

[Figure 1 – Wandsworth council online GIS]

Content and presentation of layers in the GIS

The way in which the system presents and integrates geographical information is based on the results of our three studies. We found that participants were interested in the integration of aerial photographs with map information, so as to make it more accessible to people with limited map reading skills and to provide better contextual information about the neighbourhood and the area. Another finding was the need for an easy and clear access to the Unitary Development Plan—a document and related maps that define the planning restrictions in different areas in the Borough and resemble zoning ordinances in the US. Participants were interested in the ability to click on a specific area on the map and seeing which policies applied to that location, including hyperlinks to the relevant sections in the policy document. These two requests were integrated into the final system and are available to all local residents over the Internet.

During the usability sessions, participants used the different layers and followed the information on the pages to retrieve information of interest.

The navigation and control of the mapping environment

During the design and implementation of the online system we encouraged the developers to make the control and navigation of the map as simple as possible. The observations during the preliminary workshops suggested that even operations like zooming in and out and panning can be difficult to novice users, and that they found the concept of zooming by clicking on the map more natural than the more sophisticated method of drawing a bounding box on the screen. The final system is based mainly on one click navigation (zoom in, out and panning the map), while advanced navigation functionality is separately available. Furthermore, to get information from the system, the user only needs to click on the map while the information panel is visible.

The general usability of the final application

Finally, the usability test contributed to improving the final system interface in terms of enabling non-expert users to use it more efficiently and purposefully. By running a usability test, the developers and our research team were able to locate and remove some problems with the interface. Some of these included: lack of feedback after the user had issued a command to indicate whether the system was performing any operations; lack of visual guidelines on the interface to indicate how tools were operated; and a selection of symbology on the map and layer representation that made it difficult to read the map at some zoom levels. By ensuring that the final application was more usable and accessible, the online GIS can potentially be used by more people and increase their participation.

Towards a User-Centred Design, Development and Deployment Cycle

Based on the process that the three studies started, we can envisage an iterative development cycle for PPGIS projects. By and large, such a cycle should be based on the concept of user-centred design, development and deployment as suggested in the HCI literature (Landauer 1995, Preece *et al.* 1994). While such development is generally recommended on the premise that the system implementation is more likely to be successful, within a PPGIS setting this can prove to be vital in ensuring that the system achieves the goals of improving participation and opening up new arenas for public involvement in planning and management processes. As Elwood (2002) noted, the use of software is at the same time an empowering and disempowering process and despite advances in the Graphical User Interface (GUI) design of modern GIS, these systems still require users to hold a wide range of skills and background knowledge to operate them. This presents major obstacles for occasional or novice users, or those not interested in investing a considerable amount of time to acquire such skills.

It is significant that the sophisticated interface of advanced Web-based GIS such as ArcIMS, is using all the complex terminology and iconography of a full-scale GIS. For many users, such an approach means that the system is less accessible and intimidating. As a number of studies have demonstrated, in some cases users are reluctant to ask for computer assistance as this is perceived as degrading or associated to social costs (Harris 2000). Considering the range of operations that are common in the PPGIS literature (mainly local data entry and spatial queries), there should be a way to deliver this functionality within an application that is as easy to use as buying a book over the Internet or sending an email message.

As was shown, a user-centred design approach to PPGIS projects will not just contribute to the project itself but will also provide, as a by-product, rich and detailed accounts about the ways in which different users with a diversity of backgrounds and needs use GIS to advance their own goals. This means that such an approach contributes substantially to the way in which we understand how PPGIS operates as a socio-technical object. Although we have not fully analysed the transcripts of the usability session, there are some discussions and opinions about the system that are very similar to the other two workshops. In a broader project, it can be envisaged that the cycle will move on by observing the ways in which the intended users use the final system over a period of time. Using techniques such as online questionnaires or analysis of the system's log files—which record every interaction between the end-user and the system—the system designer can learn about how the system works and continue to improve it if necessary. In general, PPGIS projects should be seen as an open-ended process in which the system is being developed and adapted to the changing needs of the local community and where designers and maintainers must be sensitive to the changing goals and objectives of their end-users.

There are, of course, some issues to consider. For example, in a Web-based environment the log files can be adapted in such a way that they will provide a full account of the session and become material for research. Doing so without prior notification to the end-user amounts to surveillance and can undermine the confidence of users and their trust in the system designers. Thus, within PPGIS projects, it is doubly important to use a transparent design approach and to advise the users if such forms of interaction recording take place (and possibly to allow users to opt in or opt out of being recorded).

Conclusion and future research directions

In this paper we have presented the connection between HCI, usability evaluation and PPGIS. We have demonstrated how this connection is not just natural but also very valuable within the societal stance of PPGIS. Building on our three case studies, we have suggested the adoption of the user-centred design, development and deployment approach to PPGIS projects, pointing to the main issues that ought to be taken into account when adopting such methods. There are, however, other aspects of current activities in GISc research that relate to HCI and that can be integrated into PPGIS research. First, the development of tools in the area of geographic visualisation (GVis) that allows the interactive and dynamic exploration of spatial data has renewed the interest in human factors of GI. These tools rely on the users' perception of visual stimuli (Gahegan 2001), which in turn depends on the GUI supporting defined users' tasks. The type of tasks that these systems can support is yet to be fully understood. Research in this area may illuminate how we can better support the visual exploration of spatial data, which can be of significant value in some PPGIS settings. Second, issues surrounding naïve geography (Egenhofer and Mark 1995) and the representation of knowledge in ways that can accommodate local perceptions and 'mental maps' can be valuable to approach and integrate local knowledge in PPGIS. Finally, natural spatial queries, such as the work on 'query by sketch' (Egenhofer 1997) can provide ways to interrogate spatial databases that reflect human understanding of spatial knowledge rather than the system's architecture (Freundschuh and Egenhofer 1997). These are just a few of the areas that are relevant for current PPGIS research.

Probably the most important lesson from our project is that ease of use and user friendliness are characteristics of software that are more elusive than they first seem to be. Even if the PPGIS designers believe that they have managed to create something that

is easy to use, only appropriate testing—even using simple methods such as Nielsen’s—will show if the design is successful in meeting users’ needs or not. It seems to us that in PPGIS projects, this is not just a technical obligation, but also a moral one.

REFERENCES

- Baecker, R. M., and Buxton, W. A. S., 1987, A Historical and Intellectual Perspective. In *Readings in Human-Computer Interaction: A Multidisciplinary Approach* Edited by R. M. Baecker and W. A. S. Buxton (San Mateo: Morgan Kaufmann Publishers, Inc.), 41-54.
- Boott, R., Haklay, M., Heppell, K., and Morley, J., 2001, The Use of GIS in Brownfield Redevelopment. In *Innovations in GIS 8: Spatial Information and the Environment*, edited by Halls, P. (London: Taylor and Francis), pp. 241-258.
- Bush, V., 1945, As We May Think. *The Atlantic Monthly*, 176, 101-108.
- Butler, K. A., 1996, Usability Engineering turns 10, *Interactions*, 3(1), 59-75.
- Card, S. K., Moran, T. P. and Newell, A., 1983, *The Psychology of Human-Computer Interaction*. (Hillsdale, NJ: Lawrence Erlbaum Associates).
- Craig, W.J., Harris, T.M., Weiner, D., 2002, Community Participation and Geographic Information Systems. In *Community Participation and Geographic Information Systems*, edited by Craig, W.J., Harris, T.M., Weiner, D. (London: Taylor and Francis), pp. 3-16
- Carver, S., 2001, *Participation and Geographical Information: a Position Paper*. Paper presented at the ESF-NSF Workshop on Access to Geographic Information and Participatory Approaches Using Geographic Information, Spoleto, 6-8 December 2001. <http://www.iapad.org/bibliography.htm>
- Davies, C. and Medyckyj-Scott, D., 1996, GIS Users Observed. *International Journal of Geographical Information Systems*, 10(4), 363-384.
- DETR, 2001, *On the path to E-Government – Council pathfinders picks*. News Release 164: 22 March, (London: DETR).
- Elwood S., 2002, GIS use in community planning: a multidimensional analysis of empowerment. *Environment and Planning A*, 34(5) 905-922.
- Elwood, S. and Leitner, H., 1998, GIS and Community-based Planning: Exploring the Diversity of Neighborhood Perspectives and Needs. *Cartography and GIS*, 25(2), 77-88.
- Engelbart, D. C., 1962, *Augmenting Human Intellect: A Conceptual Framework*. Summary Report AFOSR-3223, Stanford Research Institute (SRI), October, 133.
- Egenhofer, M. J., and Mark, D. M., 1995, Naive Geography. In *Spatial Information Theory: A Theoretical Basis for GIS*, edited by Frank, A. U. and Kuhn, W., (Berlin: Springer-Verlag) Lecture Notes in Computer Sciences No. 988, 1-15.
- Egenhofer, M.J., 1997, Query Processing in Spatial-Query-by-Sketch. *Journal of Visual Languages and Computing*, 8(4), 403-424

- Freundschuh, S. and Egenhofer, M.J., 1997, Human Conceptions of Spaces: Implications for GIS. *Transactions in GIS*, **2**(4), 361-375
- Gahegan, M., 2001, Visual Exploration in Geography: Analysis with Light. In *Geographic Data Mining and Knowledge Discovery*, edited by Miller, H. J. and J. Han (London: Taylor and Francis), pp. 260-288.
- Ghose, R., 2001, Use of information technology for community empowerment: transforming Geographic Information Systems into community information systems. *Transactions in GIS*, **5**(2), 141-163
- Goodchild, M. F., 2002, Forward, In *Community Participation and Geographic Information Systems*, edited by Craig, W.J., Harris, T.M., Weiner, D. (London: Taylor and Francis), ix-xxiii.
- Goodchild, M. F., 1999, Reflections of a Past Editor. *Geographical Analysis*, **31**(4), 328-331.
- Haklay, M., 2002, *Public Environmental Information Systems: Challenges and Perspectives*, PhD thesis, Dept. of Geography, University of London.
- Haklay, M., Harrison, C. M., 2002, The Potential for Public Participation GIS in UK Environmental Planning: Appraisals by Active Publics, *International Journal of Environmental Planning and Management (JEPM)*, **45**(6), 841-863.
- Harris, K., 2000, "Everyone gets booked" exploring ICTs in low-income neighbourhoods. Community Development Foundation, 42.
- Hearnshaw, H. M. and Medyckyj-Scott, D., 1993, The Way Forward for Human Factors in GIS. In *Human Factors in Geographical Information Systems*, edited by Medyckyj-Scott, D. and Hearnshaw, H. M (London: Bellhaven Press), pp. 235-243.
- Hewett, T. T., Baecker, R. M., Card, S. K., Carey, J. G. Gasen, M. M. Mantei, G. Perlman, G. W. Strong and B. Verplank, 2002, Curricula for Human-Computer Interaction. http://www.acm.org/sigchi/cdg/cdg2.html#2_1, Accessed May 2002.
- Jankowski, P., Nyerges, T., 2001, *Geographic Information Systems for Group Decision Making: Towards a Participatory Geographic Information Science* (London: Taylor and Francis).
- Kuhn, W., Willauer, L., Mark, D. M., and Frank, A. U., 1992, User Interfaces for Geographic Information Systems: Discussions at the specialist Meeting. In *User Interfaces for Geographic Information Systems: Report on the specialist Meeting*, edited by Mark, D. M. and A. U. Frank, (Buffalo, NY: NCGIA).
- Krygier, J.B., 2002, A praxis of Public Participation GIS and Visualization. In *Community Participation and Geographic Information Systems*, edited by Craig, W.J., Harris, T.M., Weiner, D. (London: Taylor and Francis), pp. 330-331.
- Landauer, T. K., 1995, *The Trouble with Computers* (Cambridge, MA: MIT press).
- Licklider, J. C. R., 1960, Man-Computer Symbiosis. *IRE Transactions on Human Factors in Electronics*, HFE-1, 4-11.
- Lindsay, P. and D. A. Norman, 1977, *Human Information Processing: An Introduction to Psychology* (New York: Academic Press Inc.).
- Medyckyj-Scott, D., 1992, GIS and the Concept of Usability. In *User Interfaces for Geographic Information Systems: Report on the specialist Meeting*, edited by Mark, D. M. and A. U. Frank, (Buffalo, NY: NCGIA), pp. 105-110.
- Medyckyj-Scott, D. and Hearnshaw, H. M. (Eds.), 1993, *Human Factors in Geographical Information Systems* (London: Bellhaven Press).

- Muller, M.J., Wharton, C., McIver, W. J., Laux L., 1997, Toward an HCI research and practice agenda based on human needs and social responsibility, in conference *Proceedings on Human factors in computing systems*, 1997, Atlanta, Georgia, United States, pp. 155 – 161
- Myers, B., J. Hollan, I. Cruz, S. Bryson, D. Bulterman, T. Catarci, W. Citrin, E. Glinert, J. Grudin, Y. Ioannidis, R. Jacob, B. John, D. Kurlander, D. Olsen, R. Pausch, S. Shieber, B. Shneiderman, J. Stasko, G. Strong and K. Wittenburg, 1996, Strategic Directions in Human-Computer Interaction. *ACM Computing Surveys*, 28(4): 794-809.
- Nelson, T.H., 1965, A File Structure for the Complex, the Changing, and the Indeterminate. *Proceedings of the ACM National Conference*, pp. 84-100.
- Nielsen, J., 1993a, Guerilla HCI: Using discount usability engineering. In *Cost Justifying Usability*, edited by R Bias and D Mayhew (Boston: Academic Press).
- Nielsen, J., 1993b, *Usability Engineering*. (San Diego, CA: Morgan Kaufmann).
- Nunamaker, J. F., Dennis, A. R., Valacich, Joseph S., Vogel D. and George, J. F., 1991, Electronic Meeting Systems. *Communications of the ACM*, 34(7), 40-61.
- Nyerges, T. L., Mark , D. M., Laurini ,R. and Egenhofer, M. J. (Eds.), 1995a, *Cognitive Aspects of Human-Computer Interaction for Geographic Information Systems* (Dordrecht: Kluwer Academic Publishers).
- Nyerges, T. L., Mark, D. M., Laurini, R. and Egenhofer, M. J., 1995b, Cognitive Aspects of HCI for GIS: An Introduction. In *Cognitive Aspects of Human-Computer Interaction for Geographic Information Systems* edited by T. L. Nyerges, D. M. Mark, R. Laurini and M. J. Egenhofer (Dordrecht: Kluwer Academic Publishers), pp. 1-8.
- Preece, J., 1995, *Human-computer Interaction* (Wokingham, England, Addison-Wesley).
- Preece, J., Benyon, D., Davies, G., Keller, L. and Rogers, Y., 1993, *A Guide to Usability: Human Factors in Computing* (Dorset: Addison-Wesley).
- Preece, J., Rogers, Y., Sharp, H., Benyon, D., Holland, S. and Carey, T., 1994, *Human-Computer Interaction* (Harlow: Addison-Wesley).
- Rasmussen, J., 1986, *Information Processing and Human-Machine Interaction: An Approach to Cognitive Engineering* (New York: North Holland).
- Rydin, Y., 1998, *Urban and Environmental Planning in the UK* (London: Macmillan).
- Sutherland, I. E., 1963, Sketchpad: a Man-Machine Graphical Communication System. *Proceedings of the Spring Joint Computer Conference*, (Detroit: Michigan), pp. 329-346.
- Shiffer, M. J. ,1995a, Environmental Review with Hypermedia Systems. *Environment and Planning B*, 22, 359-372.
- Shiffer, M. J. ,1995b, Interactive Multimedia Planning Support: Moving from Stand-alone Systems to the World Wide Web. *Environment and Planning B*, 22, 649-664.
- Shiffer, M.J., 2002, Spatial Multimedia Representations to Support Community Participation. In *Community Participation and Geographic Information Systems*, edited by Craig, W.J., Harris, T.M., Weiner, D. (London: Taylor and Francis), pp. 309-319.
- Talen, E., 2000, Bottom-Up GIS: A New Tool for Individual and Group Expression in Participatory Planning. *Journal of the American Planning Association*, 66(3), 279-294.

- Thomas, H., 1996, Public Participation in Planning. In *British Planning Policy in Transition: Planning in the 1990s*, edited by Tewdwr-Jones, M., (London:UCL Press), pp. 168-188.
- Thomas, P. and R. D. Macredie, 2002, Introduction to The New Usability. *ACM Transactions on Computer-Human Interaction*, **9**(2), 69-73.
- Traynor, C. and Williams, M. G., 1995, Why are Geographic Information Systems Hard to Use? *CHI'95 Mosaic of Creativity*, Denver, Colorado, ACM/SIGCHI, 288-289.
- Traynor, C. and Williams, M. G., 1997, A Study of End-User Programming for Geographic Information Systems, *Empirical Studies of Programmers: Seventh Workshop, ESP7*, Alexandria, VA, ACM Press.

Figure 1 – Wandsworth council online GIS