Usability and GIS – why your boss should buy you a larger monitor

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Abstract
GIS are complex to use. To operate them, you need to know something about cartography, databases and statistics, and programming skills are also needed. These aspects make operating GIS a challenging and satisfying job, with the pleasure of geographical problem solving added to the mix. However, the interfaces of the software packages that users are forced to use daily are making things worse. Confusing interfaces, complex operations and lengthy processes are all very familiar. But should this be the norm? Can't we have a GIS that is enjoyable to use and enables the users to be productive? These questions are the topics of usability studies and Usability Engineering, which this paper will focus on, as well as demonstrating the real cost of the lack of usability.

Introduction
GIS are complex systems. They are difficult to use and it takes time to master them. For an organisation to run a productive GIS operation there is a need for specialised staff, trained in operating these systems. This seems to be the common conception within the GIS industry.

Actually, most of the complexity is down to the overcomplicated, inconsistent GIS interfaces, which are difficult to use. With almost every new release of major GIS software, the vendors put out announcements of 'many usability enhancements' and promote theirs as 'easy–to-use products'. Yet, the evidence points to the fact that most of the products in the marketplace are far from being easy to use – as can be tested when you put any GIS user in front of a package other than 'their GIS': the GIS that they use on a daily basis. In many cases, the user won't be able to accomplish even simple tasks such as importing data to the GIS and producing a basic map.

The aim of this paper is to demonstrate the impact of this lack of usability, showing that it leads to a measurable reduction in productivity and efficiency. In some cases, improved productivity can be achieved by simply buying hardware, or noticing the layout of the interface – hence the cost-effectiveness of large monitors mentioned in the title. Unfortunately, there are only a few quick fixes, and usability aspects should be integrated into the development of new products. Although without the demand from users and clear requirements in specification documents, the situation is unlikely to improve. Thus, it is important to raise awareness of usability aspects of GIS within the industry.
However, the first question that needs to be answered is 'what is usability?' How can we demonstrate the lack of usability of GIS products?

What is usability?
In computerised systems, the concept of usability emerged from the study of Human-Computer Interaction (HCI). This is an area of study that merges concepts from ergonomics, psychology, design, and computer science to ensure that computer systems are indeed easy to use. However, 'easy to use' should not be the main evaluation criteria for usability. Within the area of HCI, Usability Engineering has focused on this issue and developed a more accurate definition.

Usability Engineering (UE) is an approach aimed at integrating central concepts and lessons that were learned through HCI research into software design processes. Central to UE is the concept of User-Centred Design, Development and Deployment (UCD) (Landauer 1995), an approach that puts the users at the centre of computer application development. From a UCD perspective, the objective of any computer application is to provide functionality and information that will enhance user performance by taking into account the user's goals and tasks. Naturally, UCD focuses on the interface, emphasising that a well-designed user interface should be able to visualise the functionality of the software and allow the user to have full control over the actions of the computer (Butler 1996).

The integration of UCD principles in the software development process is done through the creation of frameworks, techniques, and matrices that can be deployed systematically and rigorously. By developing such methods and tools, UE aims to ensure that the concept of usability is translated into measurable criteria and into a set of actions that the developer can carry out through the life cycle of the software development.

Of course, since UE is reliant on cognitive models of tasks and abstract manipulation of information, and since the final product will be used by a range of users of differing culture, age and education attainment, UE is not an engineering discipline where criteria and methods are rigidly defined and where predictions will work deterministically in every case. Furthermore, it is unlikely that presubscribed matrices set at the early stages of the design process will guarantee a usable end product. The design process itself is very complex and subject to many changes; therefore, too rigidly defined matrices can divert the development process (Dix et al. 2004). Thus, the correct way to view UE is as a toolbox to be used throughout software development processes. By combining the right tools for the appropriate stage of development, it is possible to ensure that the user remains at the centre of the process and by doing so will deliver a usable system at the end.

One of the outcomes of UE and HCI studies is a body of knowledge defining what usable computer systems are. For example, over the years the definition of a usable computer system has evolved to include the following criteria:

- Effective – allowing the user to achieve the specific goal accurately and completely.
- Efficient – achieving the specific goal accurately with as little work and time as possible.
- Error tolerant – in any system, it is expected that the user might make mistakes. The system must recognise these mistakes, and allow the user to recover from mistakes they have made (as in the case of undo).
- Learnable – the system should help the user to learn its functionality, as well as learning more powerful options as they develop their knowledge about it. It should also be easy enough for infrequent users to work with the system easily without extensive retraining.
- Satisfying – the work with the system should ideally be enjoyable, or at least pleasant and satisfying to use.

Despite the fact that all these criteria cannot be quantified unambiguously, they provide a set of principles that can then be translated into specific measurements and expectations to guide the development process. To further integrate these criteria in the design process, many methods have been developed over the years (Mayhew 1999). These methods cover the whole development process and borrow concepts from many fields of study including Psychology, Anthropology, Ergonomics, and, naturally, the wider field of HCI, turning research outcomes into tools. For example, at the beginning of the software design process, ethnographic techniques can be used to understand the user's context within the process of requirement analysis. At the final stages of the development, direct observation studies, where users are asked to carry out tasks with the system, are used to check how successful the system is in terms of its learnability or to identify usability problems that have not been found in earlier stages.

The problem with GIS usability

After reviewing the concept of usability, we can turn to GIS. It is easy to find severe usability problems in GIS interfaces – even amongst the leading products.

For example, users of Pitney Bowes' MapInfo Professional (MapInfo for simplicity's sake) are familiar with the proliferation of tools that are integral to the package. Sometimes, these tools are used to perform a very simple task that should be part of the core interface (adding a scale bar or north arrow to a map) and sometimes very complex operations (Figure 1). The user is left to wonder which tool should be used for a given task and in what way. Furthermore, MapInfo's interface is archaic and has not been modernised for over a decade, thus keeping interaction metaphors that were suitable for Windows 95 but are not for the current generation of office applications.

From a usability perspective, the MapInfo interface is inconsistent – with no coherent logical structure in the order of the tools, their naming conventions or their interfaces. This leads to problems in memorability – even if you have used a function once, it is hard to remember where to find it and then how to operate it successfully. Often for new and expert users alike it is not obvious when the functionality exits within the GIS and time is lost searching for the functionality. This reduces efficiency, reduces its learnability and can be dissatisfying to the user. Furthermore, if you try to switch on too many tools, the interface will become messy and difficult to handle. Some tools will float in the workspace whilst some are only accessible from the tools drop-down menu, as demonstrated in Figure 1.

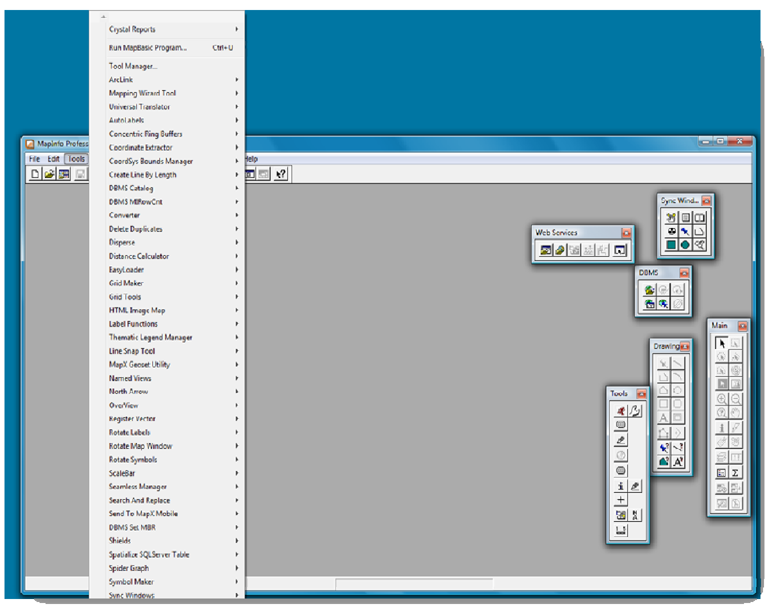

Figure 1 – MapInfo interface – notice the list of tools

The market leader in desktop GIS is also difficult to use. Users of ArcGIS experience daily frustration and the learnability of the product is low, hence the need to guide users through lengthy training sessions. An indication of the frustration is that, at the moment, ArcGIS is the only software product with a dedicated Facebook group specifically for complaining about it, with over 1200 participants. Besides the frivolity of this group, it does signal that there are some deep emotions that the use of the package ignites. Clearly, in terms of satisfaction, ArcGIS is not doing well.

Another common problem with GIS packages is error tolerance (Figure 2), as demonstrated by this online rant on Facebook: "At least yours still has the decency to apologize! Mine crashes without any indication leaving me wondering for 5-10 minutes whether it's just taking ages to open the doc or if it has called it a day. I have become VERY familiar with consulting the task list. Ag man, [this is] so boring!" (Anita Adendorff (South Africa) wrote at 8:07pm on 29/8/2007).

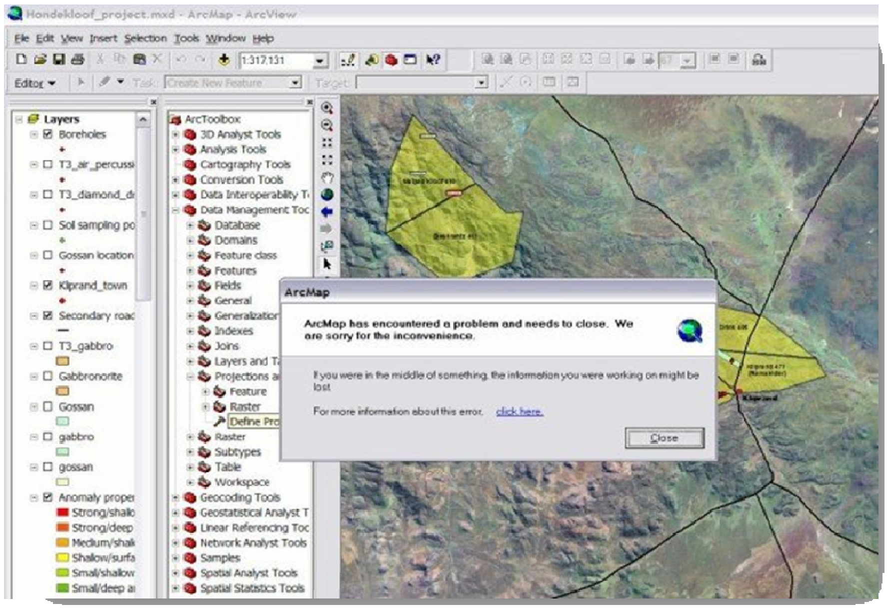

Figure 2 – Error reporting in GIS – still too common and the message doesn't tell the user what they have done incorrectly

Significantly, the problems with ArcGIS or MapInfo are easier to demonstrate, due to their market leadership and the large number of users using them. Similar or worse problems can be demonstrated in just about every product in the marketplace – including Open Source products. In many cases, the satisfaction from using GIS is in the triumph of managing to complete the task, not from the ease of use or the elegance in which it was completed.

Part of the reason for the problems with GIS is that developers are continuously focusing on functionality in terms of data management, visualisation, and interoperability, and interfaces were traditionally sidelined and thought about only as a way to bundle the packages together. There are, however, deeper reasons for this complexity.

Why GIS are difficult to use

One of the signals that something more significant is happening with GIS is that it still requires users to have or acquire considerable technical knowledge in order to operate it successfully – an observation that is true today despite all the developments. GIS builds on knowledge in geography, cartography, statistics, database management, and computer programming (Traynor and Williams 1995). Consider, for example, how many times the term 'field' might be used in the documentation of an agricultural application – it will be included in the discussion on the field (raster) or object (vector) model, to describe fields in the database, in the discussion of data collection as in 'field GIS', to define an area in a form (text field), and finally to define the attributes of polygons that are captured in the application – the real fields. The meaning of each instance of the word 'field' is rather obvious to experienced GIS users, but can present major obstacles to non-experts since the interface encapsulates the language, world view and concepts that support the system's architecture rather than the user's world view.

Another challenge that modern desktop GIS represent is that the main form of representing and manipulating the information is through maps, and thus the graphical application is central to the interaction of the user with the data.

All these aspects make the issue of GIS usability more challenging and interesting.

What can be done?

Within the GIS research community there is a growing interest in developing Usability Engineering methods that are specific for GIS. UE for GIS includes tools and methods that have been designed or adapted in such a way that they take the special characteristics of geographical information and its manipulation into account, and assist in the design of user interaction. UE for GIS provides a set of tried and tested methods that have been proven to be effective for GIS. There are plenty of lessons that were learned from the use of UE techniques as part of GIS research, and these provide a basic body of knowledge including methods and matrices that have been found to be the most useful. By taking into account the special characteristics of GIS such as the size of the map or the representation of the information, proper evaluation techniques and design guidelines can be adopted (see also Davies et al. 2005).

Importantly, GIS developers must recognise the differences among the users of GIS and geospatial technologies. Techniques that are suitable for evaluating public web mapping sites will not necessarily be suitable for experienced desktop GIS users. However, as Unwin (2005) noted, the GIScience research community knows very little about the characteristics, needs, skills, and context of these users, be they 'Google™ Earth browsers' who enjoy using a geobrowser at home or experts who work with GIS on a daily basis.

The remainder of the paper demonstrates how, by taking the special characteristics of GIS in usability analysis, it is possible to provide usability guidelines with a clear return on investment and improve the productivity of GIS users.

Paper maps and computer screens – mind the gap!

One of the often overlooked aspects of computer maps is the impact of screen resolution on the display of information. Current pixel sizes of standard computer monitors mean that the physical resolution of the information displayed on them is equivalent to about 90 pixels per inch on a desktop computer and about 120 pixels per inch on a laptop. In comparison, printed maps (such as Ordnance Survey or A-Z maps) are printed at printing resolutions of about 1200 dots per inch. Although the relationship between screen pixels and printing should not be viewed and calculated simplistically, the significance of this is that a paper map can display 6 to 10 times more information per square inch than a standard computer monitor.

To make this issue less theoretical, look at Figure 3. This is a scan of Mini London A-Z, measuring (when open) about 153x180 mm. The area marked in red shows the coverage area of Google Maps, on a 1024x768 monitor, measuring 183x245 mm. Even so, the Google Map does not include all the street names and features that can be found on the A-Z, simply because of the relatively low resolution. Both maps are at about the same practical resolution – you can read all the street names and see all the features – yet you can cram over 12 computer maps into an object that is two-thirds of the physical size of the computer monitor and still read the text clearly.

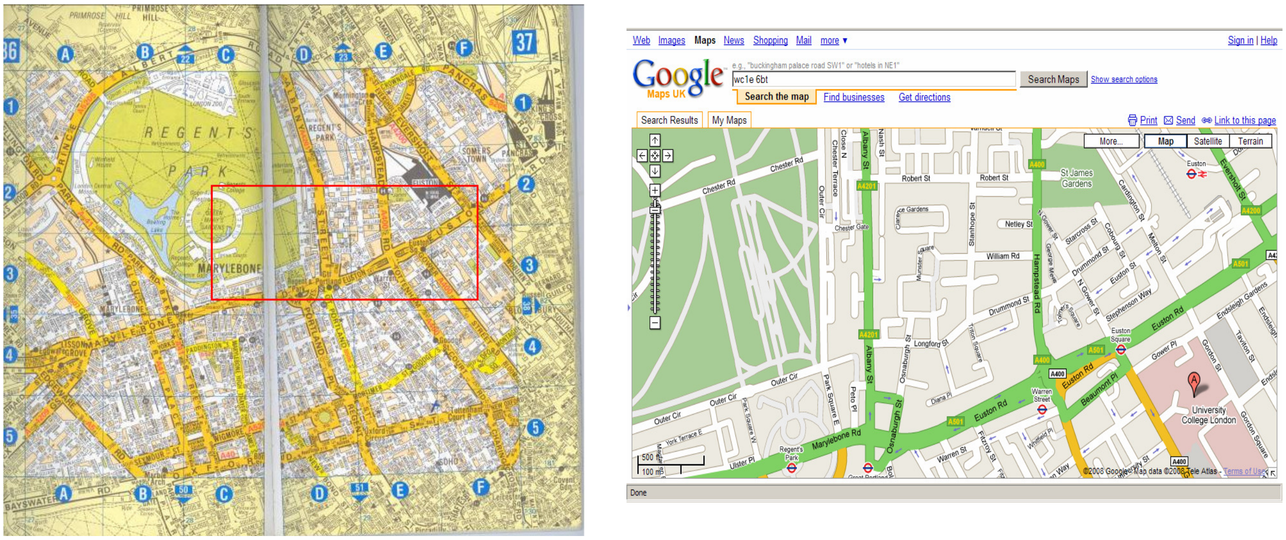

Figure 3: Mini London A-Z and Google Map of the Regent's Park area of London

With maps, the amount of information that can be viewed at one time is critical, since maps are about the context as much as about the specific location that the user is focusing on. This difference in resolution and the need to view information within the context are the reasons that some of the most common operations in any GIS are zooming and panning. However, zooming and panning are not actually part of the user's task, which is about navigation, designing a new road or performing socio-economic analysis. Often time is spent interacting with the map rather than completing the task in hand, and all this interaction means that the information we can retain about the task in the short-term memory is reduced as data patterns are lost whilst the map takes time to render as it pans/zooms. This has a direct impact on the user's productivity.

The impact of map area on productivity

During a snapshot study that was carried out recently to evaluate how users use their GIS (Haklay and Zafiri 2008), the fact that the effective map area in GIS applications is limited came to light (see Figure 2). Figure 2 was undoubtedly taken by an intermediate user of GIS.

Note that, the active area of the map is 53% of the total screen assets. In our study, we also identified cases where the screen area was a mere 25%. On average, ArcGIS users have 56% of their screen assets dedicated to the map. In other words, the software presents the user with an interface whereby, in the worst case, almost three-quarters if it is taken up by functions, buttons, and commands not used frequently and, because of the small map area, the user is forced to use many more pan and zoom operations.

Importantly, pan and zoom operations are not free. With each operation, the GIS retrieves data and renders it: an operation that can take from a fraction of a second if the map is simple to 20 or 30 seconds in more complex datasets. According to common usability guidelines, an application is considered interactive if it responds within 1-2 seconds, as after this period the user's attention can be diverted and the previous operation is forgotten.

To investigate the impact of screen size and the time spent on the non-task specific interactions, we devised a simple pilot experiment that was carried out by two intermediate GIS users. The users created two simple maps of car ownership across London and its suburbs using census data. In the first experiment the users created a map of households with a car, for a town centre in the east of London, using MapInfo and a large 24-inch monitor and resolution of 1920x1200. In the second experiment the users created a map of households with two cars, for a town centre in the west of London. This time MapInfo was used but with a much smaller monitor of about 17-inch and resolution of 1024x768. Both participants conducted the experiment on the larger screen first.

For each experiment a desktop recorder was used to capture the on-screen activity and interactions of the users within the GIS. This enabled the interactions linked to zooming and panning to be coded using video analysis software. Figure 4 shows a timeline of the types of map interactions linked to either changes of scale or panning by participants 1 and 2 (as labelled in the Figure) as they create the map on the large screen. The majority of interactions occur in the later part of the experiment when the users were trying to find the correct scale to display the map. In experiment 1, participant 1 created the map using less than 10 interactions, whereas participant 2 used 36.

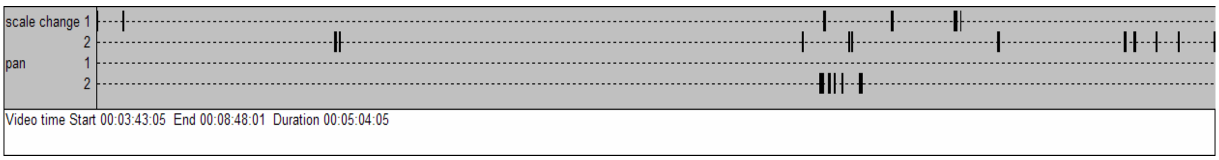

Figure 4: Number and types of interactions used to create map on large monitor

By comparison, Figure 5 shows the types of map interactions linked to either changes of scale or panning by participants 1 and 2 as they work on the small monitor. Interestingly, both participants used a different technique to create the maps on the small screen. In the second experiment 71% more panning interactions were used than when the experiment was conducted on the large monitor. An increase was also observed in the amount of time the users spent zooming in and out of the map, where 67% more interactions occurred when using the smaller screen.

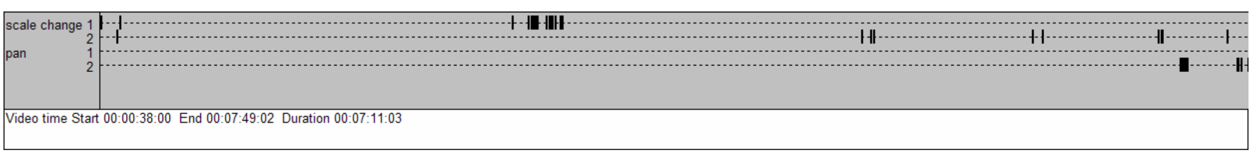

Figure 5: Number and types of interactions used to create map on small monitor

In total, the participants used 69% more interactions to complete their task using the smaller screen, all contributing to a reduction in efficacy. Each participant stated that it was much easier to work on the larger screen, because there was room for a large map and space to have the floating toolbars. So whilst this was a pilot experiment and the number of participants prevents any detailed statistical analysis of the results, there is certainly enough initial evidence to imply that larger screens increase the efficiency and effectiveness of the GIS. The evidence from other areas of research are showing the same link between productivity and screen size (Nielsen 2006), though in the case of GIS the productivity gains are more significant.

Until Usability Engineering becomes more ingrained in GIS systems development and the applications themselves can be considered more usable, there are ameliorating actions that can be taken to reduce the impact of the poorly designed interfaces. Increasing the size of the monitor on which GIS users have to work will simply enhance their work experience and increase the efficiency and effectiveness of their work. Considering that the cost of a modern, good-quality 24-inch monitor is about £500, it seems ridiculous that, with such an impact on productivity, GIS users are not equipped with these monitors as standard.

Conclusions

This paper highlighted that GIS are difficult to use, partially due to their intrinsic complexity but also due to their interfaces and the difficulties operating them. The internal complexity of geographical problem solving in GIS is a reason to enjoy a career in GIS. However, the fact that many users feel that they are capable only of accomplishing relatively simple tasks successfully should be a cause of alarm to GIS vendors and developers. Too many users feel that these modest achievements are despite the software that they are using, not because of it. If interfaces were modernised, then users will be able to focus on the challenges of solving a problem, rather than operating the GIS itself.

Beyond these aspects of job satisfaction, GIS usability has a direct impact on users' productivity and can be translated, through cost-benefit analysis, to financial sums, so usability investments can be justified to decision makers.

Furthermore, the paper clearly demonstrated that there is a value in understanding the usability of GIS by analysing the specific characteristics of GIS and not by just treating it as any other software package. The specific aspects of GIS such as the use of the map as an interface, or the various areas of knowledge that are required for GIS operation, should be included in the design of usability studies and when recommendations are written.

Finally, take this paper to your boss – and explain to her why she would gain in productivity by buying you a larger monitor!

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