Section I

Theory

P1: OTA/XYZ P2: ABC
c01 JWBK416/Haklay January 30, 2010 18:12 Printer: Yet to come

1 Human-computer interaction and geospatial technologies – context

Mordechai (Muki) Haklay and Artemis Skarlatidou

This book is about interaction with systems that contain and represent geographic information – information about objects and activities that occur on the face of the Earth. While Geographic Information Systems (GIS) have been around since the mid 1960s, only in the late 1980s was attention turned to the ways in which people interact with them. The recent growth of geographic information technologies (geospatial technologies) – from Internet-based applications such as Google Earth or Microsoft Virtual Earth to GPS-based navigation devices – means that today, there are more people who are exposed to and use geographic information daily than ever before. GIS, though less consumer friendly, is a routine tool in public and private sector organizations where it is being used to manage land ownership, plan public services, locate new shops and design delivery routes.

Case Study 1.1: Should you trust your Personal Navigation Device?

'A 20-year-old student's car was wrecked by a train after she followed her portable navigation device (satellite navigation or sat nav as they are known in the UK) onto a railway track. Paula Ceely, was driving her Renault Clio from Redditch, Worcestershire, to see her boyfriend at his parents' home in Carmarthenshire for the first time.

She was trying to cross the line in the dark when she heard a train horn, realized she was on the track, and the train smashed into the car.

Transport police said drivers must take care with satellite navigation.

The car was carried about half a mile (800m) down the line by the Pembroke Dock to Swansea train, although Ms Ceely escaped injury in the incident near Whitland.

A second-year student at Birmingham University, she had borrowed the sat nav from her boyfriend, Tom Finucane, 21. "**I put my complete trust in the sat nav** and it led me right into the path of a speeding train," she said "**The crossing wasn't shown on the sat nav**, there were no signs at all and it wasn't lit up to warn of an oncoming train. Obviously I had never done the journey before so I was using the sat nav – **completely dependent on it**" she said.'

(adapted from BBC, 2007, emphasis added)

Interacting with Geospatial Technologies Mordechai (Muki) Haklay

Though clearly millions of people are using Portable Navigation Devices (PND) on a daily basis, and many of them complete their journey without any incident of the sort which Ms Ceely experienced, this story illustrates the impact of geospatial technology design. The end results of the design which did not highlight the railway crossing in its cartography almost ended in a fatal disaster.

Significantly, interaction is not the only issue here. The story highlights other aspects of geospatial technologies, which are not covered in this book. For example, there is an issue with the accuracy of the geographic information that was loaded on the device – the information is usually less accurate and comprehensive in rural areas where there are fewer inhabitants. In addition, there is the issue of the algorithm (the software code) that was used to calculate the path that guided Ms Ceely towards the railway crossing: a different algorithm design might have chosen a safer path. These are generic aspects of GIS which are covered in books dedicated to the computational aspects of these systems (Worboys and Duckham, 2004, Longley *et al.*, 2001) or the analysis aspects of geographic information (De Smith *et al.*, 2007). While references will be made to these sources, this book will not discuss these issues at length.

Another facet of Ms Ceely's story is interaction beyond the geographic domain – she was driving her car, and surely she entered the address of her boyfriend's home using the PND interface. Some of the interface is low level – such as the shape of buttons, the order of characters on the screen etc. These aspects of operating a computing device are part of general Human-Computer Interactions (HCI) issues, and there is a wide range of literature that covers the design and study of general computer systems (Sharp *et al.*, 2007, Dix *et al.*, 2004). Here, too, this book will refer to other sources, but it is aimed to be a companion to this literature with a focus on the unique aspects of geographic information and its handling.

After stating what aspects will be excluded, it is time to turn to those that are included. This section of the book covers the basic theory which is needed to understand interaction aspects of geographic information. It starts, in this chapter, with an overview of the two fields that provide the grounding for this book, and which have just been mentioned – these are the fields of Human-Computer Interaction and Geographic Information Science (GIScience). After introducing these fields, the discussion turns to the combination of HCI and GIScience and the third section provides an overview of the main strands of research and development in this area over the past two decades. The chapter concludes with some guidance to useful resources that can be used for further reading in both areas.

1.1 Human-computer interaction and usability engineering background

The first commercially available computers that appeared in the 1950s were very large and expensive machines that could only be operated by specialists who were able to program them. Technological advances however, have dramatically changed this situation by decreasing both the cost and size of computers. The advent of the silicon chip, for instance, allowed the miniaturization of circuits and the development of powerful computers with large storage capacities. This also facilitated the innovation of the personal computer (PC) in the 1970s, which in the 1980s came to be used by a wide variety of people who were not computer experts or programmers but who utilized computers for a vast range of applications. The success of the PC, however, has also been made possible by improved understanding of the ways in which humans interact with computers, since this has enabled the design of systems that support a larger user population with the broadest range of requirements.

Human-Computer Interaction (HCI or sometimes the variant CHI) appeared during the 1970s, emerging from the fields of ergonomics and 'Man Machine Interaction' that can be dated back to the 1940s. The original focus of HCI was in issues of the 'User Interface' or those aspects of the computer systems with which the end-users come into contact (like screen layout). During the mid 1980s, the term HCI was adopted and the field became broader – aiming to tackle all aspects of interaction with computers. Each of these fields illuminates a specific aspect of computer operation and use.

HCI has implications for many aspects of information systems. For example, Landauer (1995) used the lack of usability as an explanation for the productivity paradox – the fact that in spite of the continual and growing investment in computerized systems in the workplace, the productivity of the American workforce did not increase (and even decreased in some sectors). Some evidence shows that similar trends can be observed in other Western countries. This trend is identified in the period between the early 1970s and the early 1990s. Landauer's explanation for this paradox is that a lack of attention to usability when computerizing work processes and tasks results in wasted effort and counterproductive software products. Computers do not necessarily improve productivity – they can actually hamper it in applications that deal with more sophisticated manipulation of information rather than clear-cut calculations.

One of the core concepts that emerged from HCI research is User Centred Design, Development and Deployment or UCD (Landauer, 1995; Sharp *et al.*, 2007; Dix *et al.*, 2004). While User Centred Design is covered in detail in Chapter 5, it is worth noting here that it is a development philosophy that puts usefulness and usability at the centre of the process and evaluates them empirically. Put simply, within UCD, developers and designers are required to put the end-user at the centre of the design process. Thus, it requires the designer to understand what the user's work environment looks like; what tasks they are trying to accomplish; what the requirements and needs of the user are etc. In adopting the UCD concept, the likelihood of creating useful and effective systems increases.

HCI aims to create systems that provide functionality appropriate to their intended use, and which are 'good enough to satisfy all the needs and requirements of the users and other potential stakeholders' (Nielsen, 1993: 24). These people, however, may vary in their computer literacy skills, world views, cultural backgrounds or domain knowledge. 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 *et al.*, 1994).

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.*, 1994). 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, 1993). 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 with the system.

P1: OTA/XYZ P2: ABC
c01 JWBK416/Haklay January 30, 2010 18:12 Printer: Yet to come

A system's usability can also be measured empirically in terms of its learnability, efficiency, memorability, error rate and user satisfaction (Nielsen, 1993). The ease of learning a product is measured in 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, 1993: 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 mention 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.

Usability Engineering (UE) (which is covered more fully in Chapter 6) is an approach aimed at integrating central concepts and lessons that were learned through HCI research into software design processes in a way that they can be applied in a consistent and efficient manner in software development projects.

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.

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 with 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, in the software development processes, it is unlikely that presubscribed matrices that were set at the early stages of the design process guarantee that the system will be usable. The reason for this is that the design process itself is very complex and often changes, and therefore matrices that are defined rigidly might divert the development process to ensure that the final system satisfies specific tests, even if overall performances are not satisfactory. Thus, the correct way to view UE is as a toolbox that can be used throughout software development processes, and, 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 the resulting system is usable.

Despite the fact that the usability criteria that were mentioned above (learnability, efficiency, memorability, error rate and user satisfaction, flexibility) cannot be quantified unambiguously, they provide a set of principles that can then be translated into specific measurements and expectations and guide the development process. To further integrate these criteria in the design process, many methods have been developed over the years. 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 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 learnability or to identify usability problems that have not been found in earlier stages.

In summary, UE as an applied practice is now a maturing discipline with a wide acceptance of its importance and relevance to software development processes. UE principles are now taught as part of the computer science and software engineering curriculum, as they are seen as an integral part of the education of software developers.

1.1.1 Contributing disciplines

HCI is based on multidisciplinary research and draws on lessons learned in Computer Science, Cognitive Psychology, Social and Organizational Psychology, Ergonomics and Human Factors, Linguistics, Artificial Intelligence, Philosophy, Sociology, Anthropology, and Engineering and Design (Preece *et al.*, 1994).

As has already been highlighted, the technological developments and particularly the development of personal computers (PC) lead to the establishment of HCI as a discipline. HCI plays an essential role in the design of the user interfaces and thus in **Computer Science**, by investigating the interaction of users with computerized systems. At the same time Computer Science contributes to HCI, as it provides the technological knowledge, which is necessary to implement such designs. Such developments include, among others, debugging tools, prototyping tools and user interface development environments.

The discipline of **Ergonomics** and **Human Factors** is mainly concerned with the physical characteristics of the interaction between humans and computerized systems. For example, among several other issues, the discipline is concerned with the human anthropometry and its relation to the working environment, human cognition and sensory limits, design for people with disabilities, the physical attributes of displays and design for a variety of different environmental settings. Therefore, the discipline is of particular importance to HCI, because it can help understand the human capabilities and limitations and the human factors which influence the use of a system.

Cognitive Psychology plays an important role in HCI theoretically and instrumentally. Theories of cognitive psychology provide the basis for understanding how humans process information based on elements such as perception, attention, memory, problem solving and learning. These theories provide the basis for predictive models for the evaluation of alternative designs before their actual implementation. In addition, it has led to the introduction of new issues to the research agenda of HCI, such as how the design can enhance learning activities or minimize memorization. Notably, experimental techniques used in psychology for data collection were adopted in HCI (e.g. the Think Aloud protocol).

Sociology and **Social and Organizational Psychology** involve theories and models concerned with human behaviour in social and organizational contexts. Such theories are of particular interest for HCI in order to understand how humans behave and interact when they are engaged in common tasks using computerized systems, as well as how the social environment influences this interaction. Within this context philosophical theories also influence HCI, for example Heidegger's philosophy of familiarity.

Anthropology and **Ethnography** brought to the attention of HCI the elements of situated action and the importance of context. An important contribution of this field to HCI was the method of naturalistic observation, which helped HCI researchers overcome problems associated with laboratory experimentation by observing the user in real environments.

Linguistics, the field that examines the characteristics of natural language, for example its structure (syntax) and meaning (semantics) is of particular importance for HCI, especially for the development of natural language interfaces. From a similar perspective, research in the field of **Artificial Intelligence** is significant for the development of intelligent interfaces, which incorporate knowledge and cognitive structures similar to those developed by humans.

Finally, **Engineering** is a discipline mostly concerned with the development of specific systems, devices and product design. The role of Engineering from a HCI perspective is essential for ensuring that products are developed according to specifications. The role of Design in HCI is also important because it enhances creativity and brings into the field additional usability elements, such as aesthetics.

1.1.2 Areas of research and activity

HCI advances were directed by the rapid technological developments and the progress in each of their contributing disciplines. At the same time, the introduction of new systems has established new modes of interaction, thus creating new needs for HCI research.

For example, HCI was traditionally concerned with the design and evaluation of user interfaces, so that they were of a standard to be used by their intended users. Understanding the user requirements and expectations for the design of usable systems is still the main concern of HCI. However, HCI researchers nowadays have to also consider how sound, hand gestures, touch and speech recognition can all be incorporated into the user interface.

Ubiquitous Computing (ubicomp) is another example of how technological developments influence research activity in HCI. Ubiquitous Computing involves a set of computing devices and infrastructures which can support different tasks in the general environment and covers devices that can be integrated in buildings fabrics or outdoors. This new paradigm creates new types of interactions, which are different to the traditional desktop user interface. Context-awareness, interaction transparency, users' mobility, social acceptance and other user experience elements are different in the context of ubiquitous computing, and therefore demand specific investigation.

The advent of the Internet has been a strong influence on HCI. There is now a plethora of different Web-based interfaces and a need for people to access them for the completion of everyday tasks. E-banking, e-commerce, Web-mapping applications and social networking websites are just a few examples of such Web-based systems. These systems should not only be usable by a specific group of people, but usable and accessible to the majority of Internet users. As a result, accessibility (i.e. designing for people with disabilities), universal design, peoples' privacy and security concerns are all concepts which have entered into the research agenda of HCI as result of the use of the web.

Furthermore, HCI has traditionally been concerned with Computer Supported Collaborative Work (CSCW) and how people use computerized systems for the completion of common tasks (see Chapter 4). However, developments such as the use of Intranet by many organizations and e-learning collaborative interfaces have created new opportunities for HCI research.

User Experience (UXP) is a relatively new but yet very popular and interesting area of research within HCI. UXP, as its name suggests, involves more aspects than simply developing usable interfaces based on Usability Engineering principles. The elements of engagement, satisfaction, aesthetics, emotions and many others are all important for the final UXP that a user will have by interacting with an interface, although usability is still central. This means that a system that is not usable, is less likely to satisfy the end-user. However, designing for emotions and affective interaction involves taking more parameters into consideration, compared to a design where usability is the only concern.

At the same time, there is an increasing need for the taxonomy and evaluation of HCI methods, as well as developing new methods. As a result, HCI researchers have started to consider what techniques are most suitable for the evaluation of specific interfaces, as well as the nature of usability problems that each method reveals. This research activity, which is concerned with the evaluation of HCI methods, is very important, especially from the industrial perspective.

1.2 Geographic Information Systems and science history

While the term Geographic Information Science (GIScience) was suggested only in 1992, the history of the field goes back to the 1950s and the early days of computing. A decade after the first digital computer became operational, geographic application started to emerge – notably in the military, which has a long history of map use.

In 1964, Roger Tomlinson and his colleagues at the Canada Land Inventory had the task of compiling an inventory of the national land resources. While the system was mainly aimed at providing tabular output (the area of the plots and their use), it required the digitization, storage and manipulation of geographic information. Around the same time, the US Bureau of Census developed the tools for the Census of Population of 1970, and as part of it, created a digital map of all streets in the United States as part of the Dual Independent Map Encoding (DIME) programme. Here the system was aimed at producing maps and potentially also producing mapping outputs.

The 1960s was also a period of development of geographic information software in various universities, including work in Harvard University's Laboratory for Computer Graphics and Spatial Analysis, where software called SYMAP and later the ODYSSEY GIS first appeared.

Figure 1.1 shows the computing environment that was used to develop these systems, and Figure 1.2 shows a sample output of SYMAP.

Noteworthy is also the work of Ian McHarg in *Design with Nature* (1969). McHarg advanced ideas about environmentally sensitive planning while using the overlay technique that later became one of the major analysis techniques in GIS. In the early 1970s, a computerized implementation of his methods was developed.

Through the 1970s, commercial applications of GIS started to emerge, with companies such as Environmental Systems Research Institute (ESRI), Intergraph and IBM developing bespoke applications and projects that analyzed geographical information.

By the end of the decade, computer costs dropped and their computational power increased to the level that allowed corporations and central and local government agencies to use them for a range of applications. Thus, the early 1980s saw the emergence of commercial GIS software, with ESRI's ARC/INFO appearing in 1982. The 1980s are also significant because of the advent of Personal Computers (PCs) and the increased use of these affordable computers by more and more users. One of the first products that took advantage of the PC's abilities was Mapinfo, launched in 1986.

Figure 1.1 Computers of the type used to produce early digital maps (Courtesy of Carl Steinitz)

GIS continued to evolve during the 1990s, with other geographic technologies joining in. For example, the GPS system, which was operational in 1981, gave an impetus for the creation of companies such as Garmin (established in 1989) that developed consumer-oriented navigation devices. However, until 2000 these navigation devices had a limited accuracy due to a feature of the GPS signal termed 'selective availability,' which restricted the ability to apply accurate positioning to military applications. On 1 May 2000, the US President, Bill Clinton, announced the removal of selective availability of the GPS signal, and by so doing provided an improved accuracy for simple low cost GPS receivers. In normal conditions this made it possible to acquire the position of the receiver with an accuracy of 6-10m, in contrast to 100m before the 'switch off'. Attempts to develop location-aware devices (in what is known as location-based services) started in the mid 1990s, and were based on information from mobile phone masts or other beacons. However, these methods did not gain much market share due to technical complexity or lack of coverage. The switch off of selective availability changed this and by mid 2001 it was possible to purchase a receiver unit for about $100. These receivers enabled more people than ever before to use information about locations, and led to the creation of products such as PNDs, location aware cameras and mobile phones and many other technologies that are based on location and geographic information. The second part of the 2000s saw a rapid increase in the development and deployment of geospatial technologies.

One of the most active areas of development is the delivery of geographic information over the Internet, especially using the web. From an early start in 1993, the use of the web to deliver geographic information (GI) and maps was burgeoning. However, within this period there has been a step change around 2005 in the number of users and more importantly in the nature of applications that, in their totality, are now termed 'The Geographic World Wide Web' or the GeoWeb. The number of visitors of public web-mapping sites provides an indication of this change. In mid 2005, the market leader in the UK (Multimap) attracted

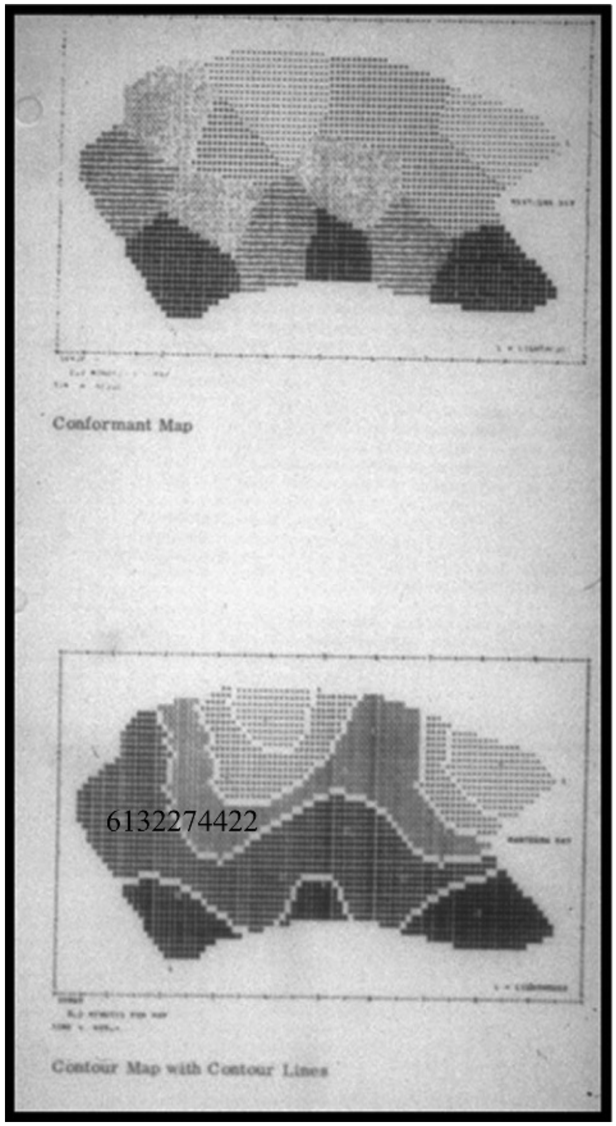

Figure 1.2 Sample of early outputs from a mapping package that Ed Horwood developed (Courtesy of Nick Chrisman)

7.3 million visitors and in the USA, Mapquest was used by 47 million visitors. By the end of 2007, Google Maps was used by 71.5 million and Google Earth by 22.7 million, while Multimap and Mapquest also increased their use. Moreover, by mid 2007 there were over 50,000 new websites that were based on Google Maps, whereas in the previous era of Internet mapping, the number of mapping websites was significantly smaller, due to technical and financial barriers.

An interesting note is that throughout their history, GIScience and geospatial technologies are showing a distinctive lag behind many applications of computers – from the appearance of the first commercial GIS packages in the 1980s – while accounting and database

P1: OTA/XYZ P2: ABC
c01 JWBK416/Haklay January 30, 2010 18:12 Printer: Yet to come

packages appeared in the 1970s, to the rapid growth of web-mapping in the mid 2000s, while e-commerce and many other web applications have been deployed extensively since the mid 1990s. This is due to the complexity of geographic information processing, the need to provide high quality graphic output, as well as the volumes of data that are required in such applications. As we shall see, this has an impact on the attention to, and the development of HCI techniques in GIS.

1.2.1 Contributing disciplines

Despite having been written over a decade ago, the analysis of Traynor and Williams (1995) in their *Why are Geographic Information Systems Hard to Use?* is still accurate. What they noted is that GIS requires its users to have knowledge in multiple domains. GIS builds on knowledge in geography, cartography, statistics, database management and computer programming as core disciplines, with usually an application domain such as logistics or geomorphology where the application is used. The core contributing disciplines are as follows:

Geography contributes to geospatial technologies by providing methods of analysis and ways to consider and solve geographical problems. The use of maps for analysis, or the integration of methods such as overlay analysis, are based on techniques that have been used for many years in geographic research.

Cartography is the discipline that specializes in the production and study of maps and charts. Cartography contributes to GIScience in guidelines to produce maps and techniques such as thematic mapping, where different elements in the map are coloured according to a specific variable (see Chapter 3 for further discussion).

Statistics is significant in GIScience since most of the data are represented as numbers, and many of the queries and analysis rely on statistical techniques. For example, before deciding on the colouring of a thematic map it is advisable to analyze the variable that will be used for the visualization to decide how best to group the variables when displaying the map. There is also a sub-branch of statistics that deals with spatial statistics (or geostatistics) – from understanding the impact of different area units on statistical analysis to development of regression techniques that take location into account.

Databases and data structures are critical to the storage and manipulation of geographic information. First, because the data is voluminous – for example, a modern mapping of building outlines in an area of 1 km sq can contain up to 100 000 pairs of coordinates – and that is before roads and other features are added to the map. Second, databases are required to be designed specifically to be able to deal with spatial queries, spatial indexing and other specific capabilities that are required to manage geographic information. In terms of data structures, GIS require the use of specific geometric data and therefore store the information either as points, lines and area objects (vector data format) or as a grid of values (raster format).

Finally, there is the need to program many GIS in order to perform analysis functionality, since many of them are operating as a toolbox. This means that in many cases the user needs to consider what they are trying to achieve in their analysis task, and then string together a series of actions to achieve the needed outcome. Thus, many GIS include the ability of end-user programming, and the users are expected to be able to use this capability.

Case Study 1.2: What do you mean by 'Field'?

One of the examples of how these disciplines contribute to the complexity of GIS is to consider the different semantic meaning of the term 'field' in the documentation of an agricultural application – it will be included in the discussion on the field (raster) or object (vector) model which are ways of representing the underlying data; to describe fields (columns) in the database that is used in the application; to define fields (areas of data entry) in forms; and to define the attributes of area objects that are captured in the application – the real fields. This is rather obvious to experienced GIS users, but presents major obstacles to non-expert users, since the interface encapsulates a language, world view and concepts that support the system's architecture rather than the user's world view.

1.2.2 Areas of research and activity

The area of research that is associated with GIS and geospatial technologies is GIScience. The term was coined by Mike Goodchild in 1992 and has since received wide acceptance. While this book will focus specifically on HCI aspects, it is worth considering the wider topics that are covered by this discipline. A short definition of GIScience is as the science behind geospatial technologies.

The first aspect of GIScience is linked to the collection of data about objects such as buildings, and activities such as traffic jams, on the face of the Earth. Here, GIScience relies on techniques that come from the field of Geomatic engineering and the use of aerial and satellite imagery for data capture.

The next aspect is representation, since there are many decisions that are being made about the way in which the information is stored and manipulated. The representation can influence aspects such as accuracy, volume of data and the computational effort that is required to manipulate it. Naturally, this is linked to methods of assessing accuracy and uncertainty.

Third, is the development and assessment of a range of analytical methods – from the calculation of the shortest route between different locations, to the advanced geostatistical techniques that were mentioned above.

Fourth, is the need to display geographic information – which can include maps, tables or 3D depictions.

Finally, there are many questions about the impact of geospatial technologies on society and the way they are used by different groups and communities. This is more a concern about the wider implications of using geospatial technologies than the ways in which they operate.

The University Consortium for Geographic Information Science (UCGIS) maintains a GIScience research agenda on their website (www.ucgis.org) and the website is also a good source of information on GIScience research.

1.3 Human-Computer Interaction and GIScience research

The first research publication which deals directly with the HCI aspect of GIS can be traced back to 1963. Malcolm Pivar and his colleagues used a PDP-1 computer at MIT to allow for an interactive analysis of oceanographic data that was collected during the International Geophysical Year of 1958 oceanic research cruises. The vision of an interactive atlas was the motivation behind their experiments:

> *[I]n preparing a printed atlas certain irrevocable choices of scale, of map projections, of contour interval, and of type of map (shall we plot temperature at standard depths, or on density surfaces, etc.?) must be made from the vast infinitude of all possible mappings. An atlas-like representation, generated by digital computer and displayed upon a cathode-ray screen, enables the oceanographer to modify these choices at will. Only a high-speed computer has the capacity and speed to follow the quickly shifting demands and questions of a human mind exploring a large field of numbers. The ideal computer-compiled oceanographic atlas will be immediately responsive to any demand of the user, and will provide the precise detailed information requested without any extraneous information. The user will be able to interrogate the display to evoke further information; it will help him track down errors and will offer alternative forms of presentation. Thus, the display on the screen is not a static one; instead, it embodies animation as varying presentations are scanned. In a very real sense, the user 'converses' with the machine about the stored data. (Pivar* et al., *1963: 396)*

The text goes on to describe a rudimentary system that projected a series of dots onto the screen, with the very basic ability to zoom in and visualize the data. Nevertheless, what Pivar and his colleagues describe above is a vision that would not materialize for average users for three decades!

It should not be surprising that the geographical information was used to demonstrate man-machine interaction (a term that is the precursor of HCI). The information lends itself to graphic displays and interaction for this type of information, as a lot of it is stored and presented in the form of maps or charts, and the graphical representation is a critical aspect of many cartographic and geographic analysis activities. Thus, the maps were required as both input and output of computerized processing, in contrast to the textual and numeral information that was a common input and output of most computer applications at the time.

As noted in the overview of GIScience and GIS, during the 1960s and 1970s research and development focused on the basic technologies. The quality of output from early GIS was basic, or in the words of Ian McHarg in an interview in 1995: 'Absolutely terrible. I mean there wasn't a left-handed, barbarous, mentally deficient technician who couldn't do better than the best computer. Terrifying'.

The need to develop the fundamental data structures and the first analysis techniques led to a focus on the functionality of GIS. In other words, the developers were concentrating on achieving the required task with computers, and were not concerned with the way it should be used by end-users. A correct assumption in that period was that any user of GIS was, by necessity, very familiar with both computers and with low level programming.

Only with the introduction of commercial GIS packages in the 1980s, did the issue of interaction with GIS come to the fore. Yet, for the first half of this decade most users were specialists and had significant GIS and computing knowledge. However, by the end of the decade, with the rapid advent of PCs and the proliferation of UNIX-based engineering workstations, the range of users and applications had increased dramatically and researchers turned their interest to HCI aspects of GIS.

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

Concerns in the GIS community about increasing processing speed and storage requirements were still the main topics on the research 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 interest previously, as advances in GIS functionality to satisfy expert user needs were the focus of computer systems' designers and developers and the systems' manufacturers (Medyckyj-Scott and Hearnshaw, 1993). It was realized, however, that GIS were 'more likely to fail on human and organizational grounds [. . .] than on technical ones' (Medyckyj-Scott, 1992: 106) as the deficiencies of the systems in terms of human factors could compromise their future success.

This early research highlighted the many domains of knowledge that GIS incorporate. Furthermore, it noted that 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). This is as true today as it was two decades ago, and one of the core issues with GIS is that its 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.

Several strands of research emerged during this period. This included an interest in usability and design aspects – such as the design of new graphical interfaces to manipulate geographic information; understanding spatial cognition and the way in which humans understand spatial concepts and use them in their daily life; developing task models and understanding task analysis for GIS; use of GIS in collaborative settings where several people use GIS together in a cooperative process of geographic problem solving; and cartographic visualization and the use of computer graphics' ability for novel visualizations of geographic information.

Human-Computer Interaction remained one of the main strands of GIS research. Today, it appears in several areas which are covered in the UCGIS research agenda and in various research groups of international organizations, such as the International Cartographic Association commissions. Cognition of geographic information remains an active area of research with a growing interest in the way different people perceive and use it for various tasks – Chapter 2 is dedicated to this area. The area of visualization of geographic information, now known as geovisualization, deals with the various possible ways to visualize geographic information through the use of computers. This topic is covered in Chapter 3. The interest in collaborative and cooperative applications of GIS has continued and even increased, following the advent of the web, and Chapters 4 and 12 discuss these aspects. With the increased use of mobile devices and the proliferation of applications, GIScience researchers are developing novel interfaces that take into account the size of the device and the context of the user – these devices are covered in Chapter 11. The interest in the general use of GIS and geospatial technologies has gained momentum in recent years and there is a renewed interest in understanding how people utilize geospatial technologies as part of the design process. This aspect is covered throughout the book. Finally, the representation of human semantic understanding of geographic information in the form of computerized ontological representation has received much attention in recent years and it is covered in Chapter 2.

Summary

This chapter has provided an introduction to and an overview of the fields that form the basis for the topics in this book – Human-Computer Interaction and Geographic Information Science. We have seen that both areas are strongly interdisciplinary, that is, they rely on many other areas of science to provide theories, methods and techniques. Both areas are now mature and well established, and therefore for a person who is new to these areas they might seem puzzling and bewildering. At the same time, they offer a very wide range of lessons that can be learned and integrated into a coherent framework according to the needs of a specific project. In the past two decades, special attention has been given to aspects of HCI for GIScience and the lessons from these research projects are the basis for this textbook.

Further reading

As noted in the introduction to this chapter, this book is not intended to be a primer to either HCI or GIS, but to provide information about the intersections between the two areas. To learn more about these two specific areas, the interested reader can use the following sources:

GIScience and GIS

There are now many resources that are available online and offline as an introduction to GIScience and GIS. The most popular textbook which provides an introduction to this area is Longley *et al.*, 2005, *Geographic Information Systems and Science*. The book covers the principles of GIS, its applications, techniques and practical implementation aspects in the operational use of GIS in business.

For a general introduction to GIS, the website http://www.gis.com/, which is maintained by ESRI, is a very useful introduction and provides many examples for GIS use. A more technical explanation of GIS principles is provided on the UK Ordnance Survey website http://www.ordnancesurvey.co.uk/oswebsite/gisfiles/.

Beyond these introductions to the tool itself, there are websites which are dedicated to GIScience. As noted, the UCGIS http://www.ucgis.org/ provides a list of issues that are part of the GIScience research agenda, announcements on conferences and scientific meetings. Further information and links to European activities are available on the Association of Geographic Information Laboratories in Europe (AGILE) site at http://www.agile-online.org/.

There are also many standards that have been set in the area of GIS, and many of these can be accessed through the Open Geospatial Consortium website http://www.opengeospatial.org/ as well as ISO technical committee 211.

Leading academic journal publications dedicated to GIS include the *International Journal of GIScience*, *Transactions in GIScience* and *Computers*, *Environment and Urban Systems*.

HCI and usability

As a wide and more established area than GIScience, there is a multitude of resources that provide an introduction to the area of HCI and Usability Engineering. Two popular books that provide an extensive introduction to these areas are:

Sharp *et al.*, 2007, *Interaction Design: Beyond Human-Computer Interaction*. The book takes an holistic approach to design, and explains the concept of user-centred design through the different stages of the design process. Another book, by Dix *et al.*, 2004, *Human-Computer Interaction*, takes a more traditional approach to the discussion of the elements of HCI, and covers most topics in a comprehensive manner.

For a general introduction to HCI and Usability Engineering, the Association for Computing Machinery Special Interest Group on HCI (SIGCHI) website provides a lot of information including a suggested curriculum for HCI http://www.sigchi.org/. Another popular site, focusing mostly on web usability, is Jakob Nielsen's http://www.useit.com/. The information on the site provides methods and techniques that can be applied across a wide range of activities and not only Web-based ones.

On the research side of HCI, the online bibliography http://www.hcibib.org/ is useful for finding academic publications in relevant areas. In addition to ACM SIGCHI, the British Computer Society has its own HCI group http://www.bcs-hci.org.uk/.

There are now international standards in the area of HCI, including ISO 20282: Usability of everyday products, ISO/IEC 18021: Information Technology – User interface for mobile tools and many others. Of these, the ISO 9241 is the most significant, covering principles and practical aspects of working with computers. It also covers ergonomic aspects of working with computer screens as well as the design of interfaces and forms.

Leading academic publications in the area of HCI include *ACM SIGCHI Interactions*, *ACM Transactions on Computer-Human Interaction*, *International Journal of Human-Computer Studies* and the proceedings of the CHI conferences which are available on the ACM digital library.

HCI and GIS

There are several books that have been dedicated to HCI and GIS which, although they are from the mid 1990s, still function as useful resources.

The collection of papers edited by Medyckyj-Scott and Hearnshaw, 1993, *Human Factors in Geographical Information Systems* deals with aspects such as the actual work environment of GIS users, and different aspects of designing and implementing GIS. The main advantage of this book is that it includes lessons from human factors and ergonomic studies.

Nyerges *et al.*, 1995a, *Cognitive Aspects of Human-Computer Interaction for Geographic Information Systems*, is based on the outcomes of the NATO workshop that was the first meeting which focused on cognitive aspects of GIS. It provides a lot of grounding in cognitive elements of GIS and many of the observations which are included in this book are still useful and valid.

The Conference on Spatial Information Theory (COSIT) which runs every two years is the premier conference in the area of HCI and GIS, though it mainly focuses on theoretical aspects of spatial information.

P1: OTA/XYZ P2: ABC
c01 JWBK416/Haklay January 30, 2010 18:12 Printer: Yet to come

Revision questions

1. What are the main milestones in the development of HCI and GIScience as separate fields? Try to set a timeline for the major developments in each area to understand how they evolved.
2. Why did the development of Human-Computer Interaction in GIScience only start in the 1980s?
3. Compare the fields that contribute to HCI and to GIScience. What is the overlap and where do the two fields diverge?
4. Considering the time lag of geospatial technologies and other computer applications, what HCI issues do you predict will emerge in GIScience research in the next decade?