Interacting with Geospatial Technologies

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Registered Office
John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

Other Editorial Offices
9600 Garsington Road, Oxford, OX4 2DQ, UK
111 River Street, Hoboken, NJ 07030-5774, USA

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Library of Congress Cataloging-in-Publication Data

Haklay, Muki.
Interacting with geospatial technologies / Muki Haklay.
p. cm.
Includes bibliographical references and index.
ISBN 978-0-470-99824-3
1. Geographic information systems. 2. Human-computer interaction. I. Title.
G70.212.H34 2010
910.285–dc22

2009050268

A catalogue record for this book is available from the British Library.

Set in 10.5/12.5pt Garamond by Aptara Inc., New Delhi, India.
Printed in Great Britain by Antony Rowe Ltd., Chippenham, Wiltshire.

First Impression 2010

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Preface

Geographical Information Systems (GIS) have been around for almost 40 years, yet the number of users remains relatively small, and the level of skills required from an operator remains high. In comparison, within two years of releasing Google Earth, 22.7 million people downloaded the application – and many used it. Why?

A significant part of the answer lies in the area of Human-Computer Interaction (HCI) – but there aren't any textbooks for a GIS developer to pick off the shelf to provide the guidelines and information needed to create a successful GIS interface. This book aims to fill this gap, as well as discussing the wider area of geospatial technologies that are currently being developed – from Portable Navigation Devices (PNDs) to Web-mapping applications.

The need for the book emerged from the realization that GIS and other applications of computerized mapping have gained popularity in recent years. Today, computer-based maps are common on the World Wide Web, mobile phones, satellite navigation systems and in various desktop computing packages. The more sophisticated packages that allow the manipulation and analysis of geographical information are used in the location decisions of new businesses, and for public service delivery in respect of planning decisions by local and central government. Many more applications exist and some estimate that several million people across the world are using GIS in their daily work (Longley *et al.*, 2005).

Yet, many applications of GIS are hard to learn and to master. This is understandable as, until quite recently, the main focus of software vendors in the area of GIS was on the delivery of basic functionality and development of methods to present and manipulate geographical information using the available computing resources. As a result, little attention was paid to usability aspects of GIS. This is evident in many public and private systems where the terminology, conceptual design and structure are all centred around the engineering of geospatial technologies and not on the needs and concepts that are familiar to the user.

There is currently no agreed definition of HCI, but a working definition of the Association for Computing Machinery Spacial Interest Group of Computer-Human Interaction (ACM SIGCHI) 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'. Hence, HCI is concerned with enhancing the quality of interaction between humans and computer systems within the physical, organizational and social aspects of the users' environment to produce systems that are usable, safe and functional (Sharp *et al.*, 2007).

Research on these issues is based on the assumption that the needs, capabilities and preferences for the way users perform an activity 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.

Research into HCI aspects of GIS started in earnest in the mid 1980s. In the mid 1990s several books were published in this area, including the books edited by Medyckyj-Scott and Hearnshaw, *Human Factors in Geographical Information Systems* (1993) and Nyerges *et al.*, *Cognitive Aspects of Human-Computer Interaction for Geographic Information Systems* (1995a), although unfortunately they are no longer widely available.

Within GIS research, the basic understanding that 'spatial data is special' and therefore requires special methods of handling, manipulating and interacting is widely accepted. This is also true for aspects of HCI within GIS and therefore there is a need for specific research which deals with the design of interfaces for geographical information.

Today, HCI research in GIS covers topics such as interface design, cognitive models of spatial knowledge, digital representations of spatial knowledge and how well the digital representation of such knowledge in a GIS translates into intuitive human reasoning, the use of geographical information in the knowledge discovery process and many other areas.

This book's aim is to provide an introduction to HCI and usability aspects of Geographical Information Systems and Science and the geospatial technologies that are based on them. Its aim is also to introduce the principles of Human-Computer Interaction (HCI); to discuss the special usability aspects of geospatial technologies which designers and developers need to take into account when developing such systems; and to offer a set of tried and tested frameworks, matrices and techniques that can be used within geospatial technologies projects.

M. Haklay
London, September 2009

About the authors

Mordechai (Muki) Haklay is a Senior Lecturer in GIS at UCL. He has been carrying out research on usability and GIS since the late 1990s and published many academic papers in this area. His research focuses on usability engineering aspects of geospatial technologies.

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Antigoni Zafiri holds an undergraduate degree in Marketing followed by postgraduate studies in Environmental Management and Geographical Information Systems. During her master studies, she carried out a GIS snapshot study and her research focus on usability aspects of GIS.

Artemis Skarlatidou is an Engineering Doctorate student at UCL. Her main research interests involve usability and User Experience elements of web-based GIS. Her EngD focuses on trust aspects of web-based GIS.

Carolina Tobon is a software developer. She holds MSc and PhD degrees in GIS from UCL. During her studies, she specialised in the design and evaluation of visualization tools to support the exploration of large multivariate datasets, and published several papers in this area.

Catherine Emma (Kate) Jones is a lecturer in Human Geography at the University of Portsmouth. She completed her PhD at University College London in 2008 in the area of Health Geography. She is a specialist in GIS for collaborative research in Social and Urban Geography.

Clare Davies has researched cognition and geographic information since the early 1990s. Currently a Senior Research Scientist at the Ordnance Survey, she focuses on people's concepts and everyday language of space and place, and making geographic information reflect them.

Jessica Wardlaw is an Engineering Doctorate student at UCL. Jessica is researching usable GIS mapping techniques for the analysis and visualization tools that are used to process healthcare statistics in the UK National Health Service.

Jochen Albrecht is an Associate Professor at Hunter College, CUNY. His research concentrates since the early 1990s on the notion of process, both the computer-based representation of the geographic phenomenon as well as the management of GIS workflows.

(Lily) Chao Li holds MSc and PhD degrees in GIS from UCL. Her research interests are in spatial data mining and modelling, mobile geo-services, wayfinding and spatial cognition. Her recent book on "Location-Based Services and Geo-Information Engineering" is published by Wiley.

Robert Laurini is distinguished professor at INSA, University of Lyon, France. He is a specialist in geographic data bases and visual information systems, especially for urban and environmental planning. He published more than 150 peer-refereed papers and several books, among them "Information Systems for Urban Planning: A Hypermedia Cooperative Approach" in 2001 and "Fundamentals of Spatial Information Systems" with Derek Thompson in 1993.

Stephanie Marsh is a Usability Consultant with behavioural research consultancy Bunnyfoot. Her PhD 'Using and Evaluating HCI Techniques in Geovisualisation' was completed at City University in 2007.

How to use this book

Who should read this book

When developing this book, we thought of two groups of readers: first, GIS professionals who are developing applications in their workplace, or students at advanced levels (Masters or PhD) who need to develop a geospatial technology application as part of their research. We expect these readers to have knowledge of GIS, but not to be familiar with principles of usability engineering or Human-Computer Interaction, as these are not covered by the existing literature on GIS and cartography. The second group is of software engineers and developers without an education in geography, cartography or GIS who are developing geospatial technology applications. These readers may have come across some of the principles of user-centred design and usability engineering, as these areas receive some attention in computer science and information technology studies.

While this text can be used as a teaching text, we wrote it for the reader in mind who is self studying the material from the book. We therefore provided in each chapter case studies that illustrate the topics that are discussed in the chapter. We deliberately avoided using jargon from either HCI studies or GIScience. Where we use jargon, we made sure that it is explained.

We did not intend to cover the full area of GIScience or HCI – this is impossible within the limited space of the book, when considering that current popular textbooks on HCI can run to 800 pages, and GIS books hold over 500 and more pages. Instead, we attempted to distil the core issues that are relevant for developers of geospatial technologies, and included sections on further reading that link the chapters to the wider literature. The reference list at the end of the book is also a valuable source as it includes the most significant papers that have emerged from the research into HCI and GIS.

Structure of this book

The book is divided into three parts: Theory, Framework, and Practicalities and Technique. Chapter 1 provides an overview of HCI, GIS and then HCI for GIS. The aim of the chapter is to provide the reader with the intellectual history of these fields, and to understand how they have evolved. It also provides an overview of the topics that will be covered in the book.

The *Theory* section covers the principles and scientific theories that are fundamental to usability. The most fundamental aspect is the issue of human understanding of space, which is covered in Chapter 2. This chapter covers aspects of spatial cognition and other aspects that relate to human ability. Chapter 3 moves to the principles of cartography. These might be familiar to some readers who are coming from a geography background, although it is specifically focusing on aspects of cartography that are relevant to technology design. Chapter 4 moves from the individual to social interaction, and deals with the principles of collaborative computer systems and participatory GIS.

The *Framework* section focuses on the principles of User-Centred Design (UCD) in Chapter 5, with specific discussion of how these design philosophies relate to geospatial technology, and then moves to the practical implementation of UCD in usability engineering in Chapter 6. In this chapter we cover how usability engineering can be integrated into the software development process. For readers who are familiar with HCI literature, this section can be helpful in situating these frameworks within the specific context of geospatial technologies.

The final section of the book moves to *Practicalities and Technique* of creating usable geospatial technologies. We start in Chapter 7 with the principles of application planning, including a look at the process of task analysis, which helps the designer to understand what the user will do with the system, and covers several techniques for carrying out the application planning process. Chapter 8 covers practical aspects of cartography such as selection of colour, the process of classification of data and the organization of map layout. In Chapter 9, the basic elements of an application interface are discussed, including aspects of the graphical user interface. Chapter 10 is dedicated to usability evaluation techniques, and provides a comprehensive description of the various techniques and their role in the development of geospatial technologies. Chapter 11 deals with single user environments, which are mainly desktop systems used in organizational settings, as most GIS packages are, although this chapter also deals with the issue of mobile HCI. Finally, Chapter 12 is dedicated to web-based applications and discusses the various considerations that need to be taken into account when web-based mapping applications are being developed.

The use of examples in case studies

Each chapter in this book includes at least one case study. The aim of the case studies is to illustrate issues that are discussed in the sections in which they are integrated, so as to make the principles and the points of the discussion concrete and tangible. To provide a comprehensive overview of usability aspects we used cases where we highlight some good aspects and some bad aspects in different geospatial technologies and applications. It is very important to note from the outset that none of the criticism is aimed at singling out the developers of a specific application or case. These are examples of problems and issues that are widespread in the area of geospatial technologies, and the specific cases that are presented can be praised for many of the elements that they do include and implement. We hope that even if some examples are critical of a specific system, they will be used as a motivation for improving it. Significantly, all our examples are not designed to single out any system as the worst offender, rather to show the problems with the current state of the art.

Acknowledgements

First and foremost, to all the authors who contributed to this book, which was challenging to write. Your efforts and insights are sincerely appreciated.

Many people contributed to the development of this book. I am always in debt to Professor Angela Sasse, of UCL computer science department, who guided me to readings in HCI over a decade ago during my PhD studies, as well as Dr Paul Densham, who introduced me to the early research on HCI and GIS from the 1990s. Professor Paul Longley provided invaluable advice on early ideas for the book. I would also like to thank many colleagues and students at UCL who helped in researching HCI aspects of GIS, including Rachel Alsop, Sephi Berry, Steve Bosher, Claire Ellul, Steve Edney, Nicola Francis, Kate E. Jones, Hanif Rahemtulla, Ana Simao, Artemis Skarlatidou, Carolina Tobón, Tina Thomson, Jessica Wardlaw, Antigoni Zafiri and the participants in the studies that we have carried out.

Special thanks to researchers from across the world who provided inspiration and insights for this book, and especially to Eran Ben-Joseph, William Cartwright, Nicholas Chrisman, Jason Dykes, Max Egenhofer, Corné van Elzakker, David Fairbairn, David Forest, Reginald Golledge, Jenny Harding, Ari Isaac, Piotr Jankowski, Robert Laurini, David Mountain, Timothy Nyerges, Barbara Poore, Alexander Pucher, Adena Schutzberg, Carl Steinitz and the members of the ICA commission on Use and User Issues.

Finally, thanks to my partner Tanya Pein, who has provided consistent and loving encouragement and support during the process of conceiving and writing this book.

Section I

Theory

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)

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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.

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

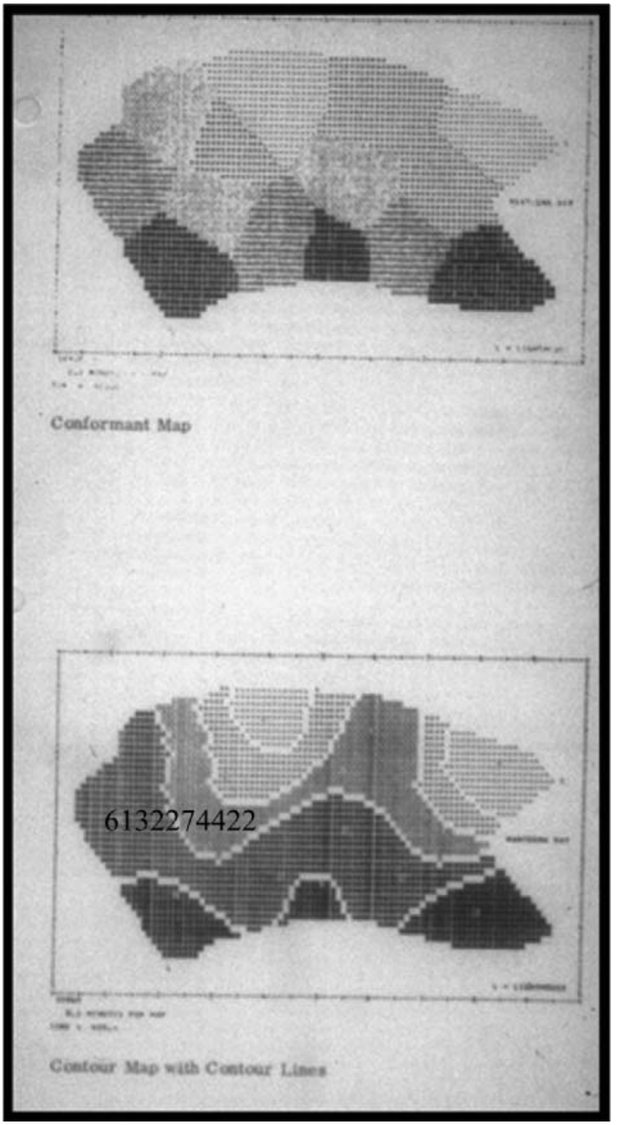

Figure 1.2 Sample of early outputs from a mapping package that Ed Horwood developed (Courtesy of Nick Chrisman)

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 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.