Université de Montréal

The quantum of control:

Toward a theory of interaction design

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Toward a theory of interaction design

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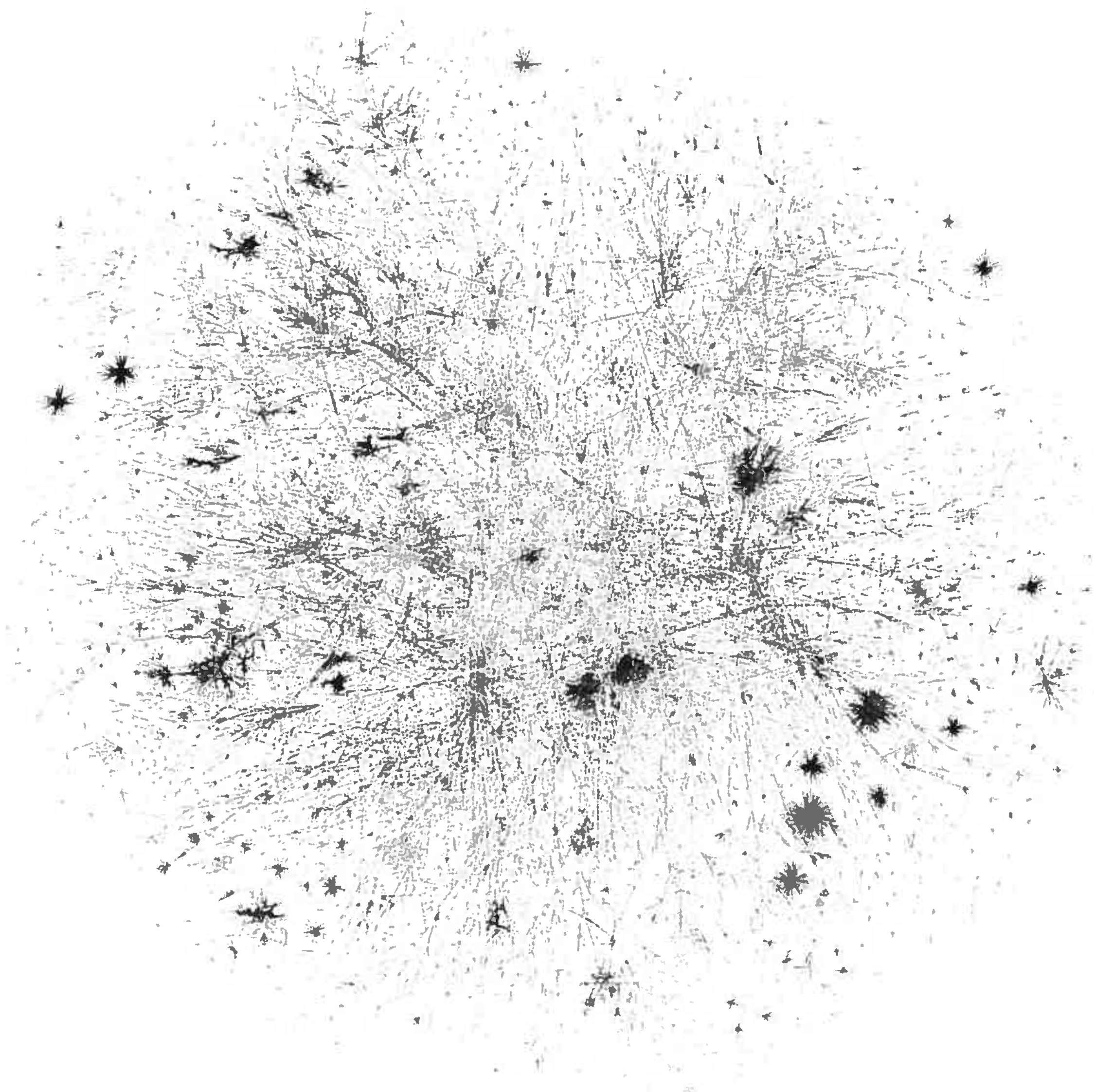

Figure 1: Map of the internet as of November 23, 2003, generated by the Opte project (http://www.opte.org).

Résumé

Le design d'interactivité est une nouvelle branche du design qui s'intéresse aux rapports et aux dialogues que les êtres humains entretiennent aussi bien avec les technologies informatiques qu'à travers elles.

Ce mémoire examine certains des facteurs historiques et sociaux qui ont contribué au développement de ce champ d'intervention, et aborde quelques-unes des principales questions conceptuelles et terminologiques auxquelles font face chercheurs et praticiens.

Parmi celles-ci on retrouve, les difficultés à comprendre et identifier l'interactivité, la nature même de l'informatique comme moyen d'expression pour le design, et les façons par lesquelles les propriétés et structures spécifiques aux technologies de l'information et de la communication affectent la conception.

Le texte conclut en suggérant que les technologies de l'information contribuent grandement à la créaton et au maintien d'environnements de contrôle. Le concept de "quantum de contrôle" est proposé pour englober plusieurs des questions et des préoccupations qui apparaissent lorsque le design porte sur l'interactivité.

Mots-clés

Design d’interaction; technologies de l’information et de la communication–conséquences sociaux; philosophie du design

Abstract

Interaction design is an emerging subdiscipline of design concerned with human relationships and engagements carried out with and through computational technologies. This thesis examines some of the social and historical factors that have informed the development of this field, and addresses some of the key conceptual and terminological issues faced by researchers and practitioners.

These include the challenge of understanding and defining interaction, the nature of computation as a design medium, and the ways in which the unique properties and structures of information and communication technologies affect design.

The work concludes by suggesting that information technologies are deeply implicated in creating and maintaining situations of control. The concept of a 'quantum of control' is proposed as an encapsulation of many of the concerns and preoccupations faced when designing both with and for interaction.

Keywords

Interaction design; information and communication technologies–social consequences; philosophy of design

Table of contents

List of tables

List of figures

Dedication

This thesis is dedicated to my niece Jean Wolfgang Basiletti. I wonder what 'everyday life' will mean when she's my age?

Thanks | Remerciments

Thanks are due first and foremost to my long-suffering partner, Lesley McCubbin, who has put up with me through many years of late nights spent glued to the monitor.

Thanks also to all my family, and especially to my mother JoDee Samuelson, her partner Mari Basiletti, and my father Robin Esmonde-White (families are complicated these days) for their love and support. And to Daniel and Stephanie, who live too far away.

Je dois souligner l'appui de mon directeur de recherche, Professeur Luc Courchesne, ainsi que celui des responsables du programme « Design et Complexité », Professeur Pierrre De Coninck et Professeur Alain Findeli. Merci aussi au personnel de soutien de l'École de design industriel et du Faculté de l'aménagement. Désolé que le texte soit en anglais! Mais nous nous comprenons tout de même…

Last but not least, thanks to my friends and colleagues for the many discussions, meals, arguments, bottles of wine. Kent, Dave, Anne-Marie, Tiiu, Magda, Philippe, Jean-François, Cop and Bev, Pan, and so many others—couldn't do it without you!

1. Introduction

With information technology we are rapidly transforming our society, our organizations, our work, and our lives. All these changes go together. You cannot understand one of them without having at least a notion of the big picture. When we try to see the role played by information technology in these changes, when we try to design good uses of information technology, we resemble archeologists trying to reconstruct an ancient culture in terms of a few technical artifacts left behind. Our interest, of course, is different. We are interested not in describing some definite, actual culture of the past, but in evaluating and choosing between the possible future cultures that could be built on the type of technology we are now busy developing.[1]

[1] Dahlbom, 1996, p. 43.

1.1 Introducing interaction

Un objet seulement technique n'est qu'une utopie.[2]

'Interaction' and 'interactivity' have become commonplace terms in a world increasingly permeated with technology. And although it is not especially clear what interaction means – nor yet what interactivity is – there is nevertheless a rapidly emerging area of design linked with these concepts: interaction design, which can be defined as *the area of design activity most intimately involved with the use of computation as a medium.*[3]

This thesis examines the development, scope and concerns of this discipline, looking into the nature of interaction in order to better comprehend what it means to design it. The text should prove of interest to designers who wish to understand this quickly developing field, to interaction designers interested in situating their practice against a broader backdrop, and to others curious about the new kinds of relationships between humans and machines that are encapsulated in the curious and complex concepts of interaction and interactivity.

In unpacking these terms, this text will navigate through some of the strong currents shaping both contemporary culture (industrial as well as popular) and academic theories: the seemingly inexorable and bewilderingly rapid diffusion of new technologies throughout society, the increasingly significant and often hidden roles played by computers and computation in the course of daily life, and the growing complexity – and sheer abundance – of technologically mediated flows of data and information. The journey raises a number of challenging questions about the relationships between intelligence, agency, culture, identity and the increasingly

[2] Latour, 1996, p. 2.
[3] Section 5 presents several other definitions.

common class of objects that incorporate information and communication technologies (ICTs).

It has become a truism – but is nonetheless true – that these devices are changing patterns of work, life, and play. Both directly and indirectly, they are involved in changing what is designed, how design takes place, and the contexts (at once social, cultural, and physical) within which designs are created and put to use (Pine & Gilmore, 1999; Dahlbom, 1996; Schön, 1974). Moreover, at the time of writing, a further convulsion is appearing on the horizon, as devices representative of what is often called 'ubiquitous computing' (Weiser, 1996; Ishii, 2004) – the integration of computers and sensors into everyday objects – are beginning to appear as mass market products, after many years of research and development. Such technological developments appear extremely likely to complement and magnify the transformations already set in motion by email, the Internet, cellular telephones, databases and similar technological devices, thereby helping to create an ever more computationally intensive context for human existence.

Against this backdrop of rapid social, cultural, and technological change, interactivity and interaction have become the *de facto* terms that describe human engagements with computational artefacts. There are many factors that make it difficult to understand and design such encounters, but there is also a pressing need to better comprehend the nature of these new relationships between networks of humans and machines that are so strongly affecting cultures and environments alike. It is particularly important to develop ways of understanding, discussing and communicating about these tools and systems, both with specialists and with those less familiar with specific technologies and their unique properties and constraints. As Lyytinen (2002, p. 5) suggests,

> *The main challenge for the next decade is to devise better vocabularies that enable us to expand our horizons of [technological] design…, and to formulate novel design approaches that are informed by such vocabularies. Such approaches and vocabularies would overcome the divide between the technical and the social, and inform design not as a singular technical activity, but as spinning a new configuration of thinking, communication and action in our world supported by technological elements that inscribe such behaviors.*

A significant element in this challenge is the reality that, at present, the vocabulary used to discuss and describe interaction design is made up of ambiguous terms, often poached from other academic fields or borrowed from natural language. As a result of this linguistic heritage, these terms often carry residual meanings that make it very difficult to understand the scope and extent of their new uses. Many such words are used to describe engagements with computers – some examples include 'context,' 'interface,' and 'presence' – and their deceptive familiarity can veil and obscure their novel meanings within contemporary technological contexts.

Moreover, the speed and diversity of technical and technological developments makes it extraordinarily challenging to understand the actual state of progress, to say nothing of future trends – even in the very short term. This difficulty in keeping abreast of present conditions likewise leaves little time to contemplate or comprehend the historical, cultural, and social evolution of artefacts and systems.

Finally, complicating the matter still further, interaction design is developing in a contested territory situated between the more traditionally scientific fields of computer science, engineering, and human-computer interaction, the very different cultures of the academic design disciplines and the practical, pragmatic, market-driven realities of professional and industrial practice. This multitude of often divergent viewpoints provide many different ways of understanding what interaction design is – and what it could be.

In response to these many challenges, this thesis works toward the development of a theoretical framework for understanding and describing some core elements of interaction and its associated design practice, while attempting to avoid the many pitfalls, like economic pragmatism, technological determinism and postmodern relativism. It is intended to contribute to a broadening of the spectrum of debate and discourse associated with interactivity and interaction design, while enriching and helping to clarify the theoretical, conceptual, and terminological vocabulary of this rapidly developing field. At the end of the day, all this can be reduced to a simple question: What are we talking about when we talk about interaction?

1.2 Structure of the text

To respond to this question, this work draws on theories and examples taken from a broad range of academic disciplines that include sociology, communication, philosophy, art, design, and computer science. Articulating, sorting, and structuring theories and examples, the text attempts to provide ways of addressing some of the confusion surrounding these new devices that are themselves surrounding citizens in the modern world.

Chapter 2 begins with a look at the relationship between computers, design, and contemporary social and technological changes. A review of some of the many discourses on computation suggests that the intersection of computers and design can be understood at many different levels and in many different ways, and that a 'big picture' perspective is very challenging to establish. But one of the few points of consensus is that computation is both a medium and meta-medium. It allows the emulation, creation and control of a constantly expanding range of previously existing media—including but not limited to image, sound, and text—as well as new forms of analysis, comparison, contrast, correlation and interrelation between these. Interaction design must thus be seen as an engagement both with these media and this meta-medium.

Chapter 3 presents a more detailed examination of some of the technological developments which have led to the emergence of interaction design. More specifically, these include the emergence of so-called ubiquitous computing, the continuing evolution and miniaturization of computers as physical objects, and the convergence of information and communication technologies to form networks. This shifting field of technological potential forms an essential part of the design medium with which interaction designers engage.

Against this backdrop, Chapter 4 examines the emergence of interaction design as a new area of design activity concerned with human engagements both with and through computational technologies. A brief look at four examples illustrates some of the very different areas of design intervention. This then anchors a study of some differences between the design disciplines and the discipline of human-computer interaction. These differences are in turn shown to be reflected in some fundamental ambiguity both in the very concept of interaction and in the many ways in which it is invoked. This teminological vagueness is discussed in some detail, as are some of the deeper philosophical issues that result from the uncertain limits of computation, and thus of interaction.

In Chapter 5, a conceptual vocabulary is proposed that illustrates the structure of interactions. After an examination of the concept of 'context' and some of the many views concerning users and experiences, the technological foundations of interactive systems are then surveyed, with a special focus on the issues surrounding the term 'interface.' The discussion centers on the presentation and explanation of a model of interaction, and concludes with a description of the model's limits and limitations.

Finally, in Chapter 6, the term 'quantum of control' is proposed as a way of encapsulating some emerging themes for interaction design, including those of *measurement*, *networks*, *control*, and *identity*. The concept of a quantum, which makes a twofold reference to the complexity and minute scale at which modern science operates and to the definition of a basic unit of measurement, is considered in terms of both social and mechanical forms of control. These forms of control are also linked to emerging questions of identity, and the concept of a quantum of control helps to bring together and highlight some of these complex issues.

As will be shown through this text, many attempts to explain, position, and define interaction have already been made, and the many debates are far from closed. Nonetheless, as the field continues its rapid development, there is need for a broader view of the nature and preoccupations of these forms of design activity. It is hoped that the models and examples presented in this text will help contribute to the development of such a perspective.

1.3 Sources

This work, though predominantly historical and theoretical in nature, represents the distillation of a number of research and design activities. These include textual and historical research underpinning an interdisciplinary literature review, applied research for two academic-industry collaborations, lessons and themes derived from two interaction design projects, and the preparation, planning, and teaching of two university courses.

Firstly, textual and historical research carried out for this work examined the terminological and conceptual origins of the concepts of interactivity and interaction. This led to a substantial interdisciplinary literature review, summarized in Chapter 2.

Two applied research activities also helped anchor the work. First among these was research carried out as part of the Territoires Ouvertes/Open Territories project at

Montreal's Society for Art and Technology,[4] under the direction of Professor Luc Courchesne of the University of Montreal. The project explores the use of the high-speed Canadian research data network for creative and artistic expression through audiovisual and data transmission. The research work carried out during this project, which incuded the preparation of an extensive text on the concept of presence, led to an improved understanding of visualization and non-standard interfaces, as well as issues related to the larger concerns of telepresence and virtual reality.

The second research project informing this work was *Nouvelles technologies d'éclairage—LED et fibre optique*, carried out for the Institut de Design Montréal under the direction of Dr. Tiiu Poldma of the University of Montreal. This project brought together academic researchers, industry professionals and manufacturers for discussion and debate on the future of lighting technologies and the state of the art in lighting. Research carried out during this project led to the publication of a report (Poldma & Samuelson, 2003) that was disseminated to industry representatives and practitioners. This project helped inform the understanding of contemporary technological trends as presented in the current work.

Design practice through two different projects also contributed to the text. First among these was an interface and software design project carried out for the Montreal-based arts collective [the user] for the project *Ondulations*. This project used the MAX/MSP development environment as the basis of a system for real-time audio generation of extremely low-frequency audio signals.

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[4] The Society for Art and Technology website was online at http://www.sat.qc.ca as of November 12, 2004. The Open Territories/Territoires Ouverts website was likewise online at http://www.tot.sat.qc.ca as of the same date.

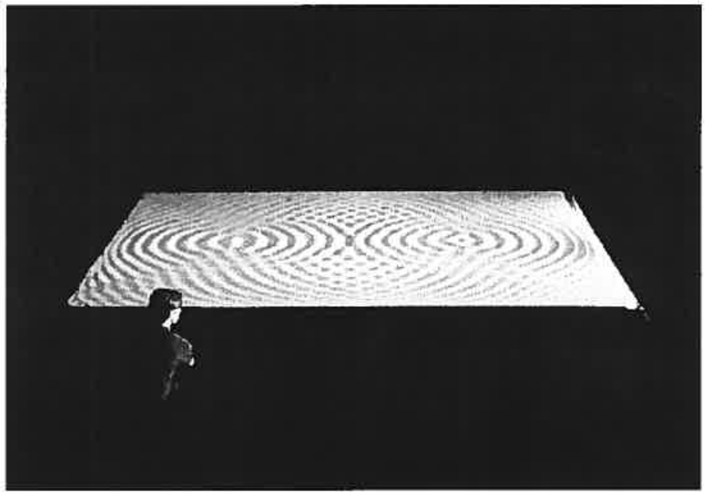

Figure 2: [the user]'s Ondulation *installation*

Work carried out on this project provided a richer understanding of graphic interface design issues and contributed to the development of the technical model presented in Chapter 5.

The second design activity was interface design and database programming for two CD-ROM projects, using Macromedia's *Flash* and *Director* environments. The first of these was a promotional CD-ROM for the University of Montreal's Masters Program in Design and Complexity, containing video, text, and images. The second was a promotional disk created for a museum exhibit presenting past student work in transport carried out at the School of Industrial Design of the same university. These projects provided hands-on experience with the technological infrastructure of interaction design, and with some of the tools used in professional practice. They also provided a deeper understanding of the unique problems and issues faced in computational design.

The final activity that helped inform the work was curriculum development and coursework preparation for several courses at the University of Montreal. This contributed to the development of the structures and models presented in the work. First among these was a multimedia course, intended to provide undergraduate students with a basic understanding of HTML and Macromedia Flash programming for the Internet. The second was a course in applied information technology, in which students were taught to use the Basic Stamp™ microcontroller while developing basic electronics and programming skills.

These varied activities each contributed in different ways to the formulation of the theories and models that are presented in this thesis. They allowed the validation of some themes, the development of others, and above all, an appreciation of the complexity and challenges of design in general, and interaction design in particular.

2. Situating interaction design

"It is really astonishing," continued the Apparition, "how little you people have learned about electricity. It is an Earth element that has existed since the Earth itself was formed, and if you but understood its proper use humanity would be marvelously benefited in many ways."

"We are, already," protested Rob; "our discoveries in electricity have enabled us to live much more conveniently."

"Then imagine your condition were you able fully to control this great element," replied the other, gravely. "The weaknesses and privations of mankind would be converted into power and luxury."

"That's true, Mr.--Mr.--Demon," said the boy. "Excuse me if I don't get your name right, but I understood you to say you are a demon."

"Certainly. The Demon of Electricity."

"But electricity is a good thing, you know, and--and--"

"Well?"

"I've always understood that demons were bad things," added Rob, boldly.[5]

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[5] Baum, 1901, p. 4.

2.1 The backdrop: technological change

> *It has become a cliché that we are experiencing an unaccustomed and accelerating rate of change and that this rate has something to do with technology. But it is not easy to specify the nature of this change, to determine whether its rate has in fact accelerated during the past ten to twenty years, and to explain the presumed uniqueness of our present situation.*[6]

Although Donald Schön wrote these lines some thirty-five years ago, they might as easily have been composed today. They remain strikingly accurate, although the state of affairs has evolved somewhat, and several novel phenomena are certainly now contributing to the ongoing shifts in the technical and social landscapes. Some of the most significant among these new factors are the Internet (Abbate, 1999; Haythornthwaite & Wellman, 2002), the ubiquity of relatively inexpensive communication technologies – particularly cellular telephones and email – that often have global reach (Crabtree, Nathan & Roberts, 2003), and, underpinning and expanding these, the decreased cost and miniaturized scale of computational technologies (Warnecke, Last, Liebowitz & Pister, 2001; Keyes, 2000). Nonetheless, one thing remains unchanged: change itself, and with it, the feeling of being constantly unaccustomed to the 'presumed uniqueness of our present situation.' And this change remains difficult to understand or explain. As French proverbial wisdom has it, *plus ça change, plus c'est la même chose.*

Schön also identified four features that characterized technological development at the time:

> the increasingly important role of science and technology within a wide range of industrial practices;
> the replacement of natural materials with synthetic ones;
> the development and deployment of 'numerically controlled machine tools'; and
> the emergence of 'systems' methodologies and the 'replacement of products by systems.'

[6] Schön, 1974, p. 255.

In addition to these primarily technical characteristics, Schön commented on the broader effects of such technological developments at the level of American society as a whole, noting that these changes simultaneously affected industrial processes, patterns of institutional organization, and – in broader and more general terms – human activities and experiences. In this reading, as in other holistic theories of social change, technologies are recognized as deeply implicated in a complex meshwork of ongoing shifts, affecting material culture, lifestyles, cultural vocabularies and both metaphors and mental images used to describe and understand society and the self (Mumford, 1934; Borgmann, 2001; Toffler, 1980; Naisbitt, 2001; Kling, 1991).

Today, both Schön's list and his comments remain valid, and the factors he identified remain potent forces. However, computers would certainly figure more prominently in any contemporary equivalent; in fact, computational technologies now underpin, intersect with and magnify all the other forms of change identified in Schön's list, and are increasingly commonplace in many other situations that make up everyday lived experience, from banking to shopping, eating, dating, studying and childrearing (Edwards, 1994; Crabtree, Nathan & Reeves, 2002).

As this also suggests, the present wave of computer-related technological change is by no means restricted to workplaces or industrial contexts. From their origins in government research labs and both military and corporate data processing facilities (National Research Council, 1999), computers and their peripherals – most often taking the form of distributed sensors, microcontrollers and embedded processors (Reed, 2004) – have spread outward to factories, banks, homes, cars, blenders, appliances and children's toys (e.g. Oppenheimer & Reavey, 2003). In fact, these technologies are being rapidly disseminated across society at a multitude of levels, and through virtually every sphere of human activity from the public realm of politics[7] to the intimate depths of the body itself. Consider, for example, the discussion of recent advances in neural implants in Donoghue (2002), or recent headlines like "RFID Chips Implanted In Mexican Law-Enforcement Workers."[8]

Contemporary design is set against the backdrop of this continuing technological evolution, and engages with these developing technologies in a variety of different ways and at a number of distinct levels. The process of designing, the tools used for design, and the products, services, and systems created by design activities are all changing in symbiosis with these changes in the social and technical landscapes. It is within this increasingly mobile, rapidly shifting setting that interaction design has emerged as a discipline directly engaging with the new, unfamiliar and often strange forces that are intimately linked with computers – and with the points of contact between humans and these new machines.

2.2 A plurality of literatures

> *One feature of many of the most important advances in science throughout history is that they show new ways in which we as humans are not special. And at some level the Principle of Computational Equivalence does this as well. For it implies that when it comes to computation—or intelligence—we are in the end no more sophisticated than all sorts of simple programs, and all sorts of systems in nature.*[9]

At the same time, computation itself is a quickly evolving phenomenon with boundaries that are anything but clearly fixed. Inextricably integrated into the traditional physical sciences, and increasingly interwoven with the biological and earth sciences, computation as **calculation** (Stein, 1999) has tremendously magnified our ability to simulate, model, and identify statistical trends, laws, and probable outcomes (Schrage, 1999; Sterman, 1991), giving rise to curious new

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[7] For example, at the time of writing, the United States is working toward the computerization of the voting process (through electronic ballot boxes), in response to the technical problems associated with the presidential election held in 2000. Consider, e.g., Mercuri, 2002.
[8] Article dated July 15, 2004, online at http://www.techweb.com/wire/story/TWB20040715S0001 and accessed on August 3, 2004.
[9] Wolfram, 2002, p. 6.

professions like 'data mining' (Fayyad, Piatetsky-Shapiro & Smyth, 1996) while also affecting social and political structures like policy planning, insurance, health care and risk evaluation (Caruso, 2002; Borgmann, 2001).

At the same time, interwoven with the capture, creation, storage, diffusion and modification of images, sounds, and words, computation as **representation**[10] has changed or generated new tactics for creating, accessing, interpreting, transmitting and engaging with a vast and constantly growing range of media forms (Rusterholz, 2003; Wardrip-Fruin & Monfort, 2003; Manovich, 2002).

Furthermore, the expansion of the concept of information to include practically everything – indeed, information has essentially become a force of nature[11] – has had profound implications for the concept of computation as the **processing of symbolically encoded information** (Nadin, 1989; Vera & Simon, 1993). This is perhaps the most conceptually challenging of the many different faces of computing, since it is linked with more profound philosophical questions, particularly that which Love (2004, unpaged) identifies as the question of whether or not "[C]ognition is more than a conscious process that depends on symbol processing."

In fact, at the extreme limit, as the quote that opens this section (written by Mathematica inventor Stephen Wolfram) suggests, there seems to be some seductive promise that information might be a sort of grand, unifying force, capable of explaining and accounting for everything up to and including the very mysteries of thought and consciousness itself, the foundations of human existence. This

[10] This use of the term 'representation' refers to the ability of computers to represent other media; see, e.g., Nakakoji & Yamamoto (2001) or Hayles (2003). This is not directly related to the cognitive science debate over 'representationalism'; e.g. Tye (2002).

[11] Compare, for example, Shannon & Weaver (1964), Shedroff (1999), Taylor (2003), and Goguen (1997) for examples of the range of possible positions regarding what information *is* and *does*.

apparently boundless expansion of the concept of information[12] makes it rather more challenging to realistically appraise the real limits and uses of computation. So too does the tremendous rate of change in computational power, which is now sometimes described as approaching the equivalent ‘processing power’ of the human brain (Kurtzweil, 2001; P.R. Factory, 1997). And even leaving such speculations aside, it is certainly undeniable that computers are allowing new and challenging questions to be posed about thought, experience, and identity.

Backing away from these grandiose themes, and instead searching for books, journals, and other sources of information that will help provide a path through the dense thicket of knowledge about and around computers and computation, it soon becomes evident that there are a number of fields that take computers as a central focus of concern, albeit in very different ways. Furthemore, although most professions and academic disciplines now have some relationship to computers, some are particular hubs for discourse. Briefly describing a few of the most pertinent among these will help to identify some of the range of knowledge currently available and to explain several of the very different perspectives that might help in understanding interaction design.

2.2.1 Computer science

For obvious reasons, one of the most prominent among the disciplines concerned with computers and computation is computer science, itself closely linked to the technical fields of electrical and electronic engineering. Computers are fundamentally electrical and electromechanical devices, deeply rooted in mathematics, physics, and mechanics.[13] They are also remarkable manufactured objects, requiring an immense technical infrastructure of a scale for which there is

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[12] For more on this, see, for example, Lanier (1995), or many of the debates in the *Journal of Consciousness Studies,* or again Supercomputing and the human endeavor (2001).
[13] See, for example, the remarkable press releases from the United States War Department (1946) when the ENIAC—one of the first computers—was first presented to the general public.

no real historical precedent. In fact, computers are probably the most complex objects ever created by humans (Computer Science and Telecommunications Board, 1992), and doubtless the densest, measured in terms of the amount of care, detail, and precision per square inch and ounce. A staggering quantity of energy and resources (particularly water) is required to create the electronic components that make up computers (Kuehr & Williams, 2003), just as many phases of production are required, each accompanied by a set of substantial engineering challenges demanding highly specialized expertise.

The other half of the discipline of computer science, the creation of software – especially large-scale projects, like operating systems – also involves its own set of often esoteric skills, scarcely more accessible and comprehensible than the engineering of complex electronic components. Software is also extremely hierarchical (Agre, 2004), with multiple layers are simultaneously active on any single machine. The level of engagement required for such common design activities as, for example, creating a Web page or writing code in Macromedia's *Flash* environment, is a level comparatively near the surface, while the disciplinary discourse of computer science is often concerned with issues more deeply seated in the machine.[14]

Broadly speaking, computer science can be characterized as functional: it is primarily concerned with making things work, at great speed and with the highest possible efficiency (Dahlbom & Mathiassen, 1997). And the literature of computer science is often technical, frequently mathematical and highly specialized. It is not, for the most part, casual reading, nor especially popular with most designers. Thus, while the improvements in software and hardware which result from the work of hardware engineers and software developers are eagerly awaited and quickly put to

[14] This is a sweeping generalization. Much of the work from institutions like MIT's Media Lab engages with hardware and software design at a more fundamental level. But looking at interaction design curricula **within design schools**, the level of engagement with complex programming and other computer science topics is relatively low; perhaps including some Web design, Flash programming, and at the limit some microcontroller programming and the basic electronics to match.

use, designers are more likely to appreciate the results than to intervene in the process. However, computer scientists and software developers alike frequently describe what they do as design, which further confuses things; see Buxton (2003) for a description of some of the differences between what engineers and designers mean when they refer to "design."

For the design disciplines, probably the most important force emanating from computer science is the pressure generated by the tremendous speed of technical development. The surprisingly successful prediction of increased transistor density that has come to be known as "Moore's Law" (Mattern, 1991) has contributed to the doubling of raw computational processing power approximately every eighteen months over the past fifteen years (Tuomi, 2002), a trend that appears likely to continue for at least some years to come. According to the best current predictions, in the future more computational power will continue to be available in a smaller form factor, resulting in more computationally capable artefacts and reduced price per calculation.

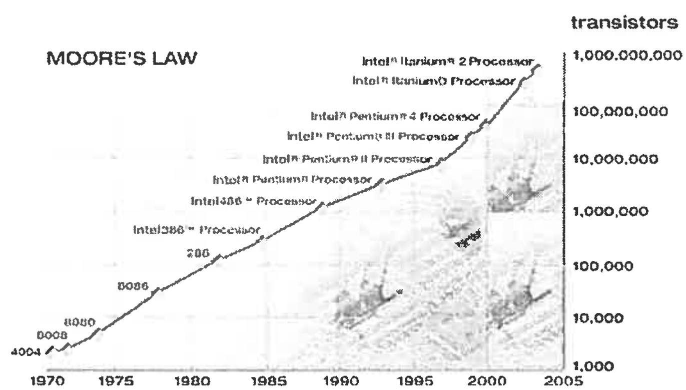

Figure 3: Intel pioneer Gordon Moore's eponymous "Law"

In addition to increasing the power of already existing tools, this will also have consequences both in terms of the speed of obsolescence of objects (since the relentless pressure to upgrade and replace will continue) and that of the cost-effectiveness of the integration of computation into objects. As processors, sensors and actuators shrink to ever-tinier sizes and are made available at lower cost (see, for example, Kahn, Katz & Pister, 2000, or the "Smart mote" and "TinyOS" projects currently underway at Berkeley and discussed in Warneke, Last, Liebowitz, & Pister, 2001)[15], increased numbers of computer-driven products become economically feasible, including – perhaps regrettably – increasing numbers of disposable products[16]. This pressure is likely to have long-term effects on the discipline of design as a whole, but is currently most strongly felt by designers working directly in computational design fields where tools, standards and fashions are all in constant evolution.

In sum, computer science and interaction design can be seen as intersecting in a shared orientation toward future progress. Computer technologies are careening ever faster onwards, while design continues to track, forecast, adapt, and create uses for the new materials, techniques, and possibilities that emerge as information and communication technologies are further refined and spread out to more densely permeate the built environment.

2.2.2 Human-computer interaction

Another focal point for discourse on computation is the subdiscipline of computer science known as human-computer interaction (HCI). As the name suggests, this area of research is primarily concerned with the points of contact between humans and computational objects. For this reason, the field has close ties with industrial and graphic design (Winograd, 1996; Mackay & Fayard, 1997). And though HCI takes many forms, it may be described in general terms as concerned with the *ways that humans put computers to use*. There are thus strong links between HCI, human factors research, ergonomics, and psychology. Karat & Karat (2003) give a very accessible overview of the emergence and evolution of this discipline, which

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[15] The claims of researchers in these fields are often remarkable for their enthusiasm, sometimes reminiscent of the most overblown rhetoric of the dot-com era. Warnecke *et al* (2001), for example, exclaim that "We will program the walls and the furniture, and some day even the insects and the dust" (p. 9). They do not, however, explain *why* we would want to do this.

[16] For example, Swedish company Cypak—http://www.cypak.com—recently unveiled a disposable cardboard 'computer' at a price of approximately $2 (US) per unit at time of writing.

first developed as a hybrid of the behavioural sciences and the computational sciences, and has since expanded to encompass and share many of the preoccupations of the design disciplines (Winograd, 1997; Fallman, 2003)[17].

Chapanis (1965, p. 9)[18] suggests that the origins of HCI can be traced to urgent wartime questions concerning human capacities and sensory abilities:

> *It was not until World War II that a new category of machines appeared -- machines that made demands not upon the operator's muscular power, but upon his sensory, perceptual, judgmental, and decision-making abilities. The job of a radar operator, for example, requires virtually no muscular effort, but makes severe demands on sensory capacity, vigilance, and decision-making ability. This new class of machines raised some intricate and unusual questions about human abilities: How much information can a man absorb from a radar screen?*

The combat-oriented requirements of speed, control, accuracy, repetition, stability, and efficiency certainly played a prominent role in the early evolution of computers and the contact points between humans and this novel class of machine. And the military ancestry of HCI is undeniably distinguished; in North America alone, it can be traced back through such influential work as that of Vannevar Bush, author of the seminal article 'As we may think' (Bush, 1946), often cited as a prediction of hypertext; the early work on graphic interfaces and light pens carried out during the Cold War as part of the Project Whirlwind air defense system (Umpelby & Dent, 1999); the pioneering work of Douglas Engelbart (1988), inventor of the computer mouse; and that of Ivan Sutherland, who developed the first CAD system and the first head-mounted display, both of which contributed substantially to the development of "virtual reality" technologies (Myers, 1998). This heritage helped launch the discipline on an assertive, focused, and direct trajectory, while also facilitating access to substantial financial and technical resources (Lenoir, 2000).

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[17] It is worth pointing out that such generalizations fail to take into consideration the different cultural and historical forces that contribute to a discipline's evolution in particular geographical and institutional contexts; the idea here is not to give a definitive overview, but rather to sketch a very broad outline of a complex and multifaceted entity.
[18] Quoted in Manovich (1994).

HCI is also historically rooted in the physical sciences, and there has accordingly been a disciplinary tendency to prioritize and value those aspects of the relationships between people and computers which can be represented in quantifiable and numerical form (Bannon, 1990). However, the status of the discipline is now changing somewhat as computers continue to diversify and multiply, and contemporary HCI addresses at least three major issues that have proven quite challenging to encapsulate rigorously, definitively, and quantitatively, and that overlap substantially with the design disciplines – and with interaction design in particular.

First among these is the concept of 'usability,' a wide-ranging term that describes the ease with which software and systems can be used, and that has achieved ISO certification as a recognized set of norms, standards and practices (ISO 9241)[19] that are in turn often linked to questions of interface design (Karat & Karat, 2003). Usability and usability engineering are broad and deep topics that exceed the scope of the current work, and that will be addressed only to a limited extent in this text.

The second concern is with 'context,' which has also proven very difficult to define (Moran & Dourish, 2001), but which is recognized as significant both in understanding the situated use of computational systems and as a potential tactic for providing more flexible and responsive input devices. Context is addressed in more detail in section 5.

The last of the three is that with 'experience,' and more particularly 'user experience' (Karat *et al,* 2003; Chamberlain, England, Fiore, Knight & Light, 2004), rather grandiose terms that refer to areas of concern very much shared with other disciplines, including design (Shedroff, 2001; Alben, 1996; Pine & Gilmore, 1998).

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[19] Accessible online at www.iso.org, as of Aug. 15, 2004.

The last of the three is that with 'experience,' and more particularly 'user experience' (Karat *et al,* 2003; Chamberlain, England, Fiore, Knight & Light, 2004), rather grandiose terms that refer to areas of concern very much shared with other disciplines, including design (Shedroff, 2001; Alben, 1996; Pine & Gilmore, 1998). Experience is once again a very complex theme that will only be briefly addressed in passing in the present work; the subject is too vast to be treated to any meaningful extent. However, there is a definite overlap between interaction design and experience design, and a brief discussion of experience appears in chapter 5.

As a result of these and other shared concerns, the relationship between HCI and interaction design is quite close; in fact, interaction design programs are offered both in HCI departments[20] and in design schools.[21] However, these feature somewhat different focuses, methods, methodologies and preoccupations; each seems aimed at the creation of a very different kind of designer. As will be described later in the text, this generates a degree of tension within the discipline. Nonetheless, this academic infighting has by no means prevented the emergence of interaction design as a quickly growing profession with an active community, and many of its practitioners have formal training in HCI.

2.2.3 The 'computational humanities'

At a very different level, a vast quantity of theoretical and philosophical discussion has been generated in recent years by the humanities and social sciences. Particularly with regard to the Internet and "network culture" (Castells, 1996), as well as "multimedia" technologies and "new media" (Wardrip-Fruin & Montfort, 2003; Manovich, 1997), many different disciplines have contributed to the

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[20] These include, among others, Goteborg University (http://www.cs.chalmers.se/idc/ituniv/index_en.html), Stanford (http://hci.stanford.edu/hci.html), and Indiana University (http://www.informatics.indiana.edu/academics/graduate_ms_hci_requirements.asp)
[21] These include, among others, Interaction Ivrea (www.interaction-ivrea.it), the Royal College of Art (http://www.interaction.rca.ac.uk), and Carnegie Mellon (http://www.cmu.edu/cfa/design/programs/mdes/mdes.html)

There are a wealth of texts on identity, culture, and society in the age of the Internet and the era of the disappearing, vanishing, ubiquitous, mobile, invisible, pervasive, persuasive and wearable computer. There are studies of new narrative forms (Murray, 1998), of orality and literacy (Nadin, 1996), of media effects and usages, of chatting, SMS messaging, and Web surfing. Wading through this vast literature, it is difficult to imagine what could possibly be further from the "paperless society" prophesied in the early days of information technology (a theme developed more fully in Dator, 1997); the idea of 'information overload' (Wurman, 2000) seems much more pertinent.

While the variety of discourse makes it once again difficult to generalize, one of the dominant themes at this end of the spectum appears to be that of *identity*, an issue that recurs at multiple levels, including personal, social and cultural (Stalder, 2000). As new technologies facilitate access to human-generated information and communication between people, the ways in which social groups are formed, maintained and interwoven are in turn altered.

As technologies contribute to the management of disease and the understanding of illness, the depradations of aging and the pursuit of youth and beauty, personal identity changes and fluxes, buffeted by the changing winds of popular culture while anchored in the fundamental realities of embodied and social existence. And as digital media spread across the surface of the planet, the forces of globalization become increasingly widespread and complex, with more and more cultures obliged to adapt to the new proximity of an increasingly connected world, and to the accompanying changes in the patterns of language, family life, education, government, employment, leisure and war.

Thus, if computer science can be characterized (however incompletely) as concerned with the efficient creation of effective equipment, and HCI with the structuring and deployment of such equipment in order to create useful tools, what might be called the 'computational humanities' can be seen as concerned with the nature of the identities that these tools are helping to inscribe, facilitate and conjure into existence. With more poetry than science, the humanities pose questions about politics, power, embodiment, gender, love and romance, narrative form, nature and culture, and the construction of self and other. And inasmuch as interaction design is not purely technical and technological, but is rather a human activity carried out by and for human beings, it—like other design disciplines—is likewise obliged to face such questions, whatever form such questioning may take.

2.2.4 Institutional studies

The broad territory between humanities and sciences is home to a wide range of other disciplinary perspectives. Among these, one of the most significant is the substantial interest in the role of new technologies in managerial practice, and the related study of transformations in the nature of work and workplace environments that stem from the deployment of such devices. In one influential example, Zuboff (1988) used ethnographic techniques and in-depth interviews to study the shifts in work practice and power dynamics that resulted from the "informating and automating" of businesses – which is to say, the shifts in structure and function associated with the implementation of computational technologies in the workplace.

In another frequently cited work, Suchman (1997) used similar techniques to study the ways in which specific contextual requirements made it necessary to constantly adapt planned strategies to fit the shifting reality of particular situations, contrasting this constantly evolving and contextually contingent "situated action" to the rigid, logical and goal-oriented forms of both organizational and computational theories of the time.

These and other sociologically and anthropologically rooted concerns were influential in the development of the subdiscipline of HCI known as CSCW – an acronym for 'computer-supported cooperative work' – which is characterized by an insistence on the importance of social interaction and interpersonal communication within technological and technologically mediated environments (Bannon, 1990; Dourish, 2001). This also has strong ties with the field called "social informatics," which, as Kling (1999) explains, may be defined as "[T]he interdisciplinary study of the design, uses and consequences of information and communication technologies that takes into account their interaction with institutional and cultural contexts" (p.24).

Briefly summarizing, both these latter fields of study look at the larger social and institutional settings within which work and other human activities take place. They tend to move away from purely rational and logical models of human behaviour, and propose that it is essential to recognize the sometimes conflicting and often messy (not to mention complex) roles played by context, embodiment, social structures and interpersonal communication in determining behavior. In methodological terms, they tend toward more qualitative forms of research, like ethnography and participant observation – a move away from *predicting and modeling* human behavior to *observing and working with* people.

Thus, if human-computer interaction can be broadly described as being primarily concerned with the way *individuals* engage with information technology, CSCW can be seen as addressing the way that *groups* of people employ and make use of information technologies, especially within workplaces, and social informatics as the study of the *broader social and institutional effects* associated with the use and implementation of these technologies.

The *post facto* nature of these disciplines – the fact that they tend to analyze and study existing situations, providing only limited guidelines for creation or design –

has meant that they are only indirectly useful in real-world design contexts (Crabtree, 2002). However, the lessons to be learned from these disciplines are certainly significant. They include a respect for the particularities of insitutional contexts and the specific character of situated actions, as well as the accompanying challenges in developing widely generalizable theories about the impact and implementation of technologies. This provides a conceptual background and a body of knowledge that can inform interaction design. Nonetheless, the absence of clear and concise metrics, heuristics, or methodologies limit the direct utility of such knowledge in the design process,[22] as do the generally long duration of fieldwork and studies.

2.2.5 Science and technology studies

Moving a step further toward abstraction, the field of “science and technology studies” (or STS) examines the way in which both science and technology are socially constructed and institutionally conditioned. This is sometimes analytical or descriptive, as with much of the work of, for example, Bruno Latour (1999; 2002), whose ‘actor-network theory’ offers a way to consider, describe, and take into account some of the many different forms of agency exhibited by objects, concepts, institutional structures—and, of course, human beings.

Other voices from science and technology studies are rather more critical, particularly with regard to the social consequences of information and communication technologies. Thus, authors such as Winner (1986), Talbott (1995), or Ellul (1964), Mumford (1934) and (rather more obliquely) Heidegger (1977), all suggest that machines and technologies—including, and perhaps especially, computers— strongly condition and control human behaviour, shaping our actions in significant ways and, if judicious caution is not employed, potentially harming or

[22] Crabtree (2002) gives an excellent overview of the issues and literature on this subject.

suggest that machines and technologies—including, and perhaps especially, computers— strongly condition and control human behaviour, shaping our actions in significant ways and, if judicious caution is not employed, potentially harming or diminishing some of the essential but less clearly definable aspects of our fundamental humanity.

Like institutional studies, these disciplines tend to focus on after-the-fact descriptions of historical, corporate, disciplinary and institutional evolution, and generally provide few concrete guidelines or methodologies applicable when actually carrying out design within the real-world constraints of limited budgets and constant market pressures. They are also generally evaluative, and sometimes normative, without being prescriptive except in a broad sense. For example, in their discussion of the potential application of social and technological studies to design, Woodhouse & Patton (2004, p. 9) suggest that,

> *[S]trengthening the positive potential of design depends on broadening participation in technological decision making, on reevaluating established roles of experts and laypersons, and on developing new institutions and processes by which technologies could be more deliberately designed by society.*

But, as they also point out, moving from this well-intentioned but very broad viewpoint to the level of the design table or design office, while also remaining financially viable and competitive, is anything but straightforward.

Despite these challenges, there are nevertheless certain lessons – or at least some worthwhile questions – that can be learned from this frequently dystopian and somewhat disheartening literature. One such lesson, which is of direct interest to the design disciplines, is that of the complexity of the relationships between objects and human beings, and the need to move toward a philosophical framework that better recognizes the importance of objects and artefacts (Joerges & Czarniawska, 1998; Winner, 1986). The physical characteristics of objects seem to have often

> *Ethics has always been associated with human-to-human relations. Products, artefacts, built environments, communications, have only entered the ethical domain as tangential, and therefore neutral means, used by humans in their relations to other humans. To date, things, designed things, have not assumed a central or at least symmetrical, role with humans when it comes to ethics.*[23]

But if objects were not central to ethical and philosophical concerns of the past, the modern world – awash in human-created objects and detritus – is making it increasingly and abundantly clear that physical objects and the material environment must be addressed, considered, and dealt with, rather than simply consumed and thoughtlessly discarded.

Another frequent thread in these discourses is what Tenner (1996) has called "unintended consequences," referring to the unexpected or unpredicted effects and side effects of technical innovations that are often visible only in the medium or long terms (Rochlin, 1997). As an example, Tenner (2000, p. 245) points out that

> *As health and longevity improve, society pays more for medical care because large numbers of people live to an advanced age and require even more treatment. In 1997, a research group in the Netherlands even found that if all smokers immediately quit, prolonging their lives, medical expenses to society would increase over time.*

This is an example of what Tenner calls the "revenge of unintended consequences": the difficult and ethically challenging moments where technologies bite back. In the above example, the technology of smoking intersects with the technologies of medical care, those of socially subsidized medicine, and those of politics, creating a complex situation that resembles a hydra more than a Gordian knot. The temptation might well be to take out a sword, but cutting off one head may well only lead to others sprouting in its place.

For interaction design, the lessons to be learned from these disciplines are thus at least twofold. The first is the reminder that artifacts have politics, and that the process of creating artifacts will thus have ramifications at many different levels. At

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[23] Tonkinwise, 2004, p.6.

the same time, the politics of artifacts are not clearcut (Howcroft & Fitzgerald, 1998) and are by no means easily understood or summarized.

The second lesson is that there are likely to be unanticipated consequences from technological interventions. Technologies do not stop developing once put into use; indeed, they take on a new, unique, and sometimes surprising life within each private, domestic and institutional situation. Artefacts are also fundamentally relational, grounded in particular social contexts and situations of use; this makes it difficult to guarantee that success in one site will ensure success (or the same level of success) in every other setting. There definitely remains a great deal of room for individual and collective skill – and thus for both design and designers – in conceiving of and carrying out successful projects.

2.2.6 The (electronic) arts

The last of the contributors to mention in this brief survey of the discourses surrounding computers and computation are the arts. Artists have always engaged in dialogue with the most advanced technologies available – the piano was the most sophisticated machine of its age; photographic film developed at the cutting edge of chemistry and physics; even guitar strings required innovative technical development – and were quick to turn computers to creative use (Computer Science and Telecommunications Board, 2003).

The increasing power of computers have permitted engagement with different forms of media – first math, then text, and on to sound, image, video, and even to what are now called "interactive environments" – and the technological arts have flourished in symbiosis with the spread of these machines. Stephen Wilson's recent tome, *Information Arts* (Wilson, 2002), documents a wealth of contemporary projects that show the range of artistic practices that engage with these new technologies and that are now shown at arts festivals like Ars Electronica, tome, *Information Arts* (Wilson, 2002), documents a wealth of contemporary projects that show the range of artistic practices that engage with these new technologies and that are now shown at arts festivals like Ars Electronica, Transmediale, and DEAF. Manovich (2002) offers a succinct summary of the emergence of new media and the electronic arts, which have gained considerable momentum over the course of the past twenty years, while Wardrip-Fruin & Montfort (2002) provide a collection of many of the seminal texts from the field.

Once again, it is difficult to encapsulate anything about the realm as a whole; it is so vast and varied as to elude any neat categorization. However, it is unproblematic to say that there has been a tremendous exploration of the new modes and potentials of expression that have symbiotically emerged with technological developments. As the concept of information has been broadened and enlarged to include the work of more and more of the senses, media technologies have brought the flexibility and power of information processing to an expanding range of representational forms – from text to sound, image, moving image, three-dimensional image, and even smell and touch. Among other things, this has helped to drastically expand the concept of "interface" – a topic that will be addressed in more detail in chapter 5.

Furthemore, as computational technologies have increased in speed and capacity, they have permitted more and more sophisticated information processing operations to be carried out within a span of time which tests the physical and phenomenological limits of human sensory capacities, bringing the illusion of 'real-time' to an expanding range of media forms.

And the power of the human senses have themselves been expanded; through technology and human ingenuity, it is now possible to see at a distance, visualize the imperceptibly small or the incomprehensibly complicated, and – increasingly – to act on the entities and forms that are so represented. Some of these changes were already possible through the harnessing of electricity and the representation of rate of change. This touches the intimate realm of experience itself, since the range of possible experiences is expanded by the increasing power to control the sensory underpinnings of experience.

The electronic arts are perhaps most significant for interaction design as a domain of creation and experimentation. Motivated by needs which are not those of the marketplace, and open to forms of experimentation that are more open-ended, more politically charged, more playful and more personal than those of other fields, artists and artist-researchers push the boundaries of the expressive and creative potential of media both new and old. The emphases on beauty, intensity, challenge and exploration serve as a necessary counterbalance, weighing in against more functionalist and mechanistic approaches that take speed and efficiency as the sole criteria for successful design.

2.3 Summing up

These, then, are some of the most significant vectors of intellectual and academic activity around computers and computation. They are also some of the bodies of knowledge that could reasonably be expected to contribute – albeit in diverse ways – to a theory of interaction design. Table 1 (next page) summarizes this.

Issue	Relevant disciplines	Key themes
How do computers work, and how are they changing?	Computer science, software engineering, electrical engineering	Power Speed Efficiency
How do people use and engage with computers?	HCI/CHI, sociology, CSCW, social informatics, psychology	Usability Context Interaction
How are computers affecting individual and social identity?	Sociology, philosophy, anthropology; cultural studies; communication; education	Identity Communication Networks
How can computation be understood as a historical development of technology?	Science and technology studies; history and philosophy of science	Evolution Culture Ethics
What new forms of expression and representation are made possible by computation?	Electronic arts; multimedia	Aesthetics Creativity Experience

Table 1: Issues for interaction design

There have already been some initiatives to integrate some of these multiple perspectives. The primarily Scandinavian field of 'informatics,' for one, is a comparatively holistic discipline with a lineage that includes both information sciences and computer science. Dahlbom & Mathiassen (1997, p. 88) describe the threefold underpinnings of the pedagogical practice that they have helped develop for this field:

> *Theory: This process is rooted in scientific disciplines, such as mathematics and organizational behavior that are fundamental to computing. We use this process to develop theories and conceptual frameworks to understand, design, and evaluate computer-based artifacts in use.*
>
> *Design: This process is rooted in design disciplines, such as architecture and industrial design, that share with computing an interest in artifacts in use. We use this process to develop specific design skills and the ability to organize and manage experiments.*
>
> *Interpretation: This process is rooted in the humanities, in anthropology, and history. We use this process to understand and evaluate artifacts in use and problematic situations in computing practices.*

This use of multiple, diverse perspectives – an attempt to face up to the true and evident complexities of technologically mediated situations and experiences –

certainly offers a worthwhile model for the field of interaction design. However, the view of 'design' as represented here might not be identical to that which would be proposed by the design disciplines themselves – although designers have a notoriously hard time explaining just what design is.

2.3 Intersections with design

> *It is…necessary to locate design and the studies it may originate within the space-time framework of "material culture," i.e. the physical world and environment created by human beings and their social relationships associated with, in turn, the abstract and conceptual relationships that determine the generation of knowledge for the interpretation and externalization of the materiality of cultural products through their relationships with objects. Finally, the application of this acquired knowledge has, as its main objective, the improvement of the world… by balancing the relationships between society and industrial production governed by the rules derived from overwhelming technological developments.*[24]

Design is in fact bewilderingly hard to explain, define or delineate (the above quote serves as a case in point), despite a plethora of definitions of various shapes and sizes; see, for example, Love (2003). Design refers to a particularly diverse profession or professions, several academic disciplines, at least one noun and a verb or two, with occasional forays into the realm of adjective and adverb. To confuse things still further, almost every discipline invokes some idea of 'design;' in the computational disciplines alone, notions of design are invoked in the contexts of computer systems, information systems, workplace environments, interfaces, on-line learning environments, and theories and bodies of knowledge. Lyytinen (2002, p. 5) describes this disciplinary breadth particularly eloquently;

[24] Jiménez-Narváez, 2000, p. 38.

> *The challenge—and the beauty—of the analysis and discourse about design as human activity is its generality. Any form of activity counts as design, which involves: intentionality (i.e. is not habitual, based on learned reflexes, or accidental adaptation); is oriented in shaping some future state in the world in the form of an artifact through cognitive engagement and interaction with other artifacts (sketches, patterns); involves some analytic procedures of analyzing or tearing apart the artifact in its environment; and demonstrates a skillful way of accomplishing this either based on garnered experience and/or theoretical (abstract) models of the artifact being designed or its relationships with the environment. Such activities span a wide range of activities from architecture, policy, management, computer engineering, software, industrial 'design,' to graphics design, or marketing campaigns.*

The particular model or concept of design invoked in each of these very diverse forms of intervention is rarely made explicit or elucidated, but it seems quite unlikely that they would all be identical. This in turn reflects two facts: firstly, the *activity* of designing both predates and overflows the *discipline* of design – and, secondly, what professional or trained designers actually do may not necessarily be what others mean in their invocations of the term 'design.'

In fact, activity that could be broadly considered as 'design' occurs in many disciplines, but is often overlooked or taken for granted; thus, for example, Fallman (2003, p. 320) suggests that, although design figures prominently in many HCI research activities (as in, for example, the creation of the specific physical artefacts used to underpin the research process),

> *The design process tends to remain implicit as researchers are embarrassed by not being able to show evidence of the same kind of control, structure, predictability, and rigorousness in doing design as they are able to show in other parts of their research.*

This is, in a sense, unsurprising: it is hard to scientifically explain why, historically speaking, a CRT screen exists precisely as it does, or why a language would have only a certain number of characters represented in a particular arrangement of symbols on a keyboard entry device with a certain fixed number of keys, or why some models of telephones sell better than others. In fact, it's hard enough to study a phone in use without also seeking to understand phone use in any broader sense

– like considering the many factors involved in the history, origins, meaning, cultural underpinnings and phenomenological experience of engagements with telephones.

Furthemore, some things are so deeply rooted in history, custom and habit – as well as the ingeneuity of the designers or communities who first created or spawned them; after all, Shakespeare, that great designer of language, gave English somewhere between 1500 and 10,000 new words (Malless, McQuain & Blechman, 1998) – that nothing will ever explain them with anything like the same degree of certainty that is possible when two measured quantities of pure chemicals are mixed. In short, as a field of academic study, design is stretched between the contingencies of history and technology, the vagaries of embodied human existence and the arbitrary properties of materials, and the relative certainties of the physical sciences, and must judge and balance the pertinence of each – to whatever extent budgets and the institutional dynamics of specific projects permit.

But if both design and computation are difficult to understand and delineate, the relationship between the two cannot be expected to be simple or straightforward. After all, computers serve as tools for design, but they also form the subject of design activity at many levels, from the external form of computational objects to the forms of input devices, the behaviour and appearance of programs and objects, and even the very physical contexts within which systems are deployed. Each of these very different levels is the subject of a particular kind of design activity, and (in a sort of recursive loop), each of these design activities may well include the use of computational tools – 3D modeling, CAD/CAM, CNC, Internet searches, and so on. There is thus simultaneously a centripetal force to the intersection of computers and design (inasmuch as the computers themselves are the subject of design activity) and a centrifugal force, through which design activities actively put these machines to use.

In historical terms, scholars at the University of Wuppertal's program in what they call 'Computational design' have proposed the following structure as a way of situating the role of computers in the evolution of design as a discipline (figure 2, below.) One may or may not choose to accept this rather technocentric view of development, nor the implicit progress it at least graphically suggests, nor again the significance placed on the abstract concept of cybernetics, as opposed to, say, drawing, sketching and modeling, or again building, prototyping and testing.

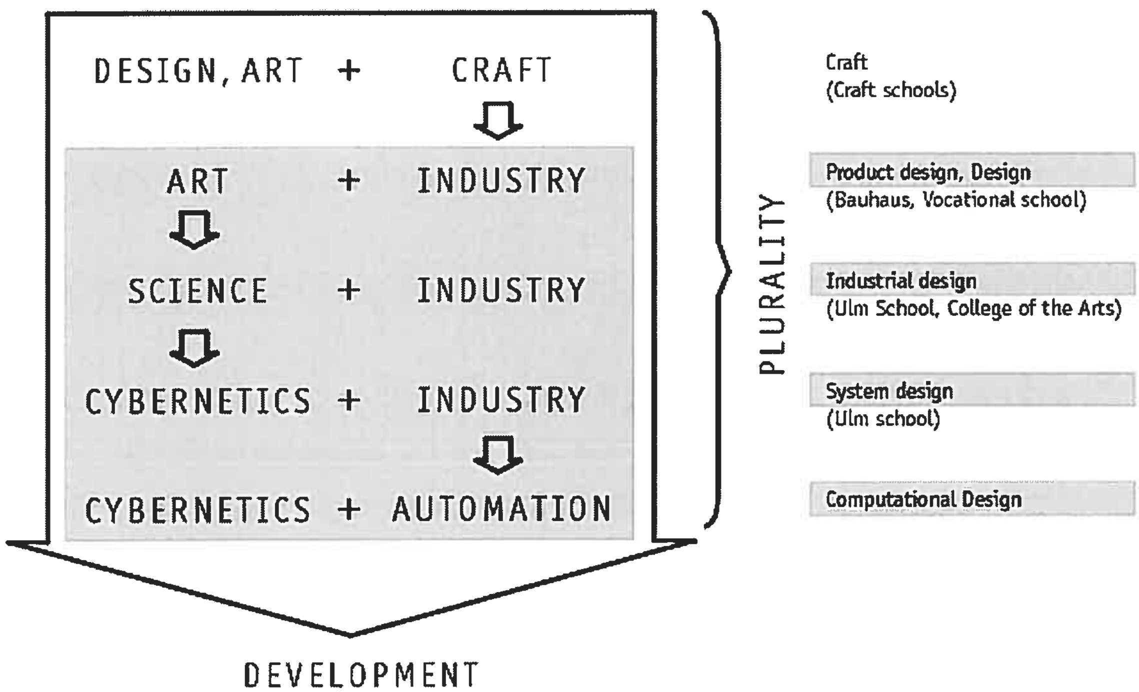

Figure 4: The evolution of design, according to Professor Siegfried Maser at the University of Wuppertal's program in Computational Design[24]

However, it does draw attention to the fact that, both as a discipline and as a field of study, design has been steadily moving away from definitions solely concerned with the creation, decoration, and use of products and objects. Instead, there is an ongoing trend toward a broader consideration of design, taken as referring to acts of creative intervention within complex systems that often involve multiple,

[24] Retrieved from http://www.code.uni-wuppertal.de/uk/computational_design/welcome.html on Sept. 25, 2004.

mechanical – which are radically different in their essences, and therefore challenging (or perhaps even impossible) to definitively compare, comprehend, and predict in objective or numerical terms.

Because of this complexity, and this human-facing orientation, design and design theories involve delicate navigation between the poles of technological and social determinism (Jones, 1998; Clement, 2002). It is certainly necessary to consider the physical, sensorial, and affective qualities of the objects and environments that provide the foundation for experience. But other factors must also be taken into account, including both the active nature of individual human perception and interpretation and the power of the complex institutional, social and cultural forces that condition, frame, inform and ground experience. Andrew Pickering (2001) describes this swirling, restless interplay between humans, objects, and contexts—each playing a different and active role – as the "[D]ance of human and nonhuman agency" (p.2), and it is some of the difficult steps of this particularly modern dance that will be traced in the coming pages.

2.4 Conclusion: computation as medium and meta-medium

> *The protean nature of the computer is such that it can act like a machine or like a language to be shaped and exploited. It is a medium that can dynamically simulate the details of any other medium, including media that cannot exist physically. It is not a tool, although it can act like many tools. It is the first metamedium, and as such it has degrees of freedom for representation and expression never before encountered and as yet barely investigated.*[26]

For the discipline of interaction design, an additional factor in this challenge is the fact that computers are a new medium that emulate, transduce and transform previously existing media. As a medium, computation is simultaneously a conveyer of flows; a substance through which energy passes; and – as McLuhan (1965) famously suggested – a message (Stalder, 2001). Designing with and for

[26] Kay, 1984, p. 59.

computation thus requires an understanding of information and the ways in which it flows through computational networks to eventually become part of human-facing systems. It requires tracking the constantly changing potentials and limits of the technical artefacts that make up these systems and networks. And it further requires a comprehension of the nature of computation itself – the message, one might say, of the medium – and its role in informing and shaping the relationships, both human and electromechanical, of which it is an increasingly intimate part.

What is more, computation is not only a medium; it is also a meta-medium (Kay, 1984). Once information has been captured in numerical form, and a set of processes have been developed for dealing with data, elements can be compared, combined, and cross-referenced in recombinant patterns of arbitrary complexity. Thus, the field of data mining allows advertisers to predict complex demographic linkages between product purchases, addresses, and lifestyle choices (Fayyad, Piatetsky-Shapiro & Smyth, 1996). Artists create links between cloud patterns and musical forms[27]. Algorithms taken from fluid dynamics are directly applied to stocks and bonds (Cunibertti & Matassini, 2001); mathematically derived metaphors and models from genetics are applied to product design and the optimization of mechanical processes; and the foundations of control theory serve to underpin economics and cellular biology alike. If a hammer looks at the world and sees only nails, computers look at the world and see information – a vision within which everything is a medium and where all media are in some fundamental way equal, though some may be more equal than others.

Design activity has often been described as involving a "dialogue with materials" (Holdsworth, 2000; Hjeml, 2002, 2004; Lévi-Strauss, 1972). During the course of such dialogues, the materials at hand, the designer's choices, skills and knowledge, and the context of intervention all guide the process; while the materials do not

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[27] http://www.cloudharp.org, accessed July 12, 2004.

solely determine actions or decisons, neither are they innocent or neutral. Thus, when the choice of materials expands to include the immaterial medium of computation, the rules of engagement change as well. It becomes necessary to understand media, in all their richness and complexity – text, image, sound and electronics, among others – as well as the metamedium which opens the field of potential and helps to shape and guide the interactions.

And, as with all design activities, these must further be balanced against the fundamental and primordial needs to understand objects and artefacts, spaces and contexts, and – above all else – those who make use of the systems, and the varied, often personal, and sometimes surprising uses to which they put these devices and environments.

3. Toward interaction design

We have been moving our arms as though they were levers since we have had levers. We simulate that which we have simulated. Since we have been pastoralists we have behaved like herds of sheep and have needed pastors. This striking back on the part of machines is now becoming clear for all to see: young people dancing like robots, politicians making decisions based on computerized scenarios, scientists thinking digitally, and artists using plotters…[28]

[28] Flusser, 1999, p. 55.

3.1 The broader context

This section will examine some of the diverse factors that have played particularly significant roles in the emergence of interaction design. It begins with some general comments on the technologically supported changes that are now affecting more and more areas of the lifeworld, accompanied by a wide range of consequences both direct and oblique. This is followed by a brief discussion of the emerging field of 'pervasive' or 'ubiquitous' computing, two terms used to describe a group of future-oriented research projects focused on integrating and embedding computational technologies into everyday objects and environments.

These are in turn used to anchor an examination of two aspects of contemporary technological development that appear particularly relevant to interaction design. The first of these is the shrinking physical size both of computers and of the components and sensors that comprise computer systems. The second is the convergence of information technologies with those of communication. Together, these trends make up the infrastructure of networks and systems, which in turn gives rise to what Taylor (2001, p. 106) calls the "moment of complexity." As he describes this,

> *The parameters of the current Information Age become clear when we understand the information revolution not only as a major sociocultural change but also as something like an orbital revolution in which information revolves in such a way that it begins to act on itself. This turn has been made possible by new electronic and telematic technologies, through which information acts on information to form feedback loops that generate increasing complexity.*

New tools have always been built using older tools. But now electronic information itself has become a substance for design, a new, paradoxically immaterial material possessing its own properties and logic. And understanding the complexities of this medium requires entering into the Red Queen's Race[29] of technology; as Larson & Levine (1998, p. 2) suggest, "[If we] are to keep up with a world of technology, that

[29] For those unfamilar with this concept, a much more entertaining read than the present work is Lewis Carrol (1940).

is increasingly changing faster than we can now accommodate, we have only one course of action. We have to embrace technology to cope with the changes introduced and provided by technology."

3.2 The evolution of computation

> *[M]an at present… spends an incalculable amount of labour and time and thought in making machines breed always better and better; he has already succeeded in effecting much that at one time appeared impossible, and there seem no limits to the results of accumulated improvements if they are allowed to descend with modification from generation to generation. It must always be remembered that man's body is what it is through having been moulded into its present shape by the chances and changes of many millions of years, but that his organisation never advanced with anything like the rapidity with which that of the machines is advancing.*[30]

At the same time, there has been little choice but to accept computers. After all, computers and computation have been for several decades increasingly closely coupled with the vertiginously rapid development of the interwoven technological systems that provide the direct material foundation for much of contemporary life and experience (Redström, 2001; Nadin, 1997; Dahlbom, 2000). Computation is central to robotics and process control in manufacturing (Murray, 2003), CAD/CAM and CNC processes in design and conception (Myers, 1996; Board on Manufacturing and Engineering Design, 2002) , and database management for distribution, accounting, inventory, logistics and marketing (Nadin, 1996; Bowker & Baker, 2004).

Computation likewise facilitates and underpins the institutional structures which govern such economic fundamentals of modern societies as taxation, stock markets, and international currency exchange (Edwards, 1994). It is profoundly implicated in the modern biological and life sciences, which has culminated in achievements like the sequencing of the human genome (*Supercomputing and the Human Endeavour,* 2001). And computation is at the heart of modern

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[30] Butler, 1916, p.17.

communication technologies, including the mobile telephone and Internet services, which are changing work habits and institutional structures just as they are contributing to the emergence of new forms of entertainment and play. In short, from engineering and biology to art, leisure, and medicine, computers have proven themselves to be astonishingly universal machines (Leeuwen & Wiedermann, 2002), though perhaps in slightly different ways than Turing might once have imagined.

Of course, the above paragraphs describe a set of radically different examples, each articulated around a specific and complex set of human concerns. Indeed, looking again, it may well seem as though the only common factor in such a list (besides human care and attention) is precisely and solely computation, which is to say, mathematical processes that involve the reliable and controllable storage and manipulation of electromagnetically encoded symbols, at great speed and with high degrees of accuracy. The remarkably sweeping scope of computation is one of the most significant challenges that must be faced when trying to understand or describe interaction. In reality, the similarities between these diverse situations are purely technical, since the range of tasks and human experiences that are involved defy most other kinds of generalization.

Furthermore, within the technologically developed and technologically developing world[31], these interpenetrating and cross-pollinating systems have effects that are simultaneously material and immaterial, physical and social, symbolic and cultural; as Misa (2001, p. 12) describes it,

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· The changes accompanying the novel potential of computers have most directly affected the more industrially developed countries. Computation, and the substantial infrastructure required to make it function, is still expensive and remains inaccessible to most; the luxury to reflect on the consequences – to say nothing of the aesthetics – of technology is reserved for a small and wealthy percentage of the world's population (Borgmann, 1999). Notwithstanding, such technologies are spreading across the whole of the planet; it appears to be the rate of technological uptake that varies, not the fact. This work takes for granted (and the author recognizes his good fortune in being able to do so) the infrastructure and wealth that permit speculation about, reflection on, and occasional attempts to predict the new uses and contexts of technologies as well as the novel needs that accompany them.

> *This apparently smooth, silent functioning of networks of networks, or systems of systems, constitutes an infrastructure of daily life, choreographing the members of modern societies in an intricate routine. Technology…is symbol-making and culture-changing as well as the mundane infrastructure of daily life.*

Like other forms of technology, those involving computation both underpin and inform contemporary objects and environments. Indeed, computation is already inextricably – and often invisibly, or at least unnoticeably – embedded in the fabric of daily life (Alexander, 2002; Sonesson, 1997). The computational character of technological devices can be comparatively explicit, as it is in mobile phones, PDAs, laptops, and similar digital electronic devices. But it may also be implicit, as in the sweeping forms of architect Frank Gehry's Guggenheim Bilbao, a feat of engineering that required a scale and scope of mathematical calculation impossible without this new class of machine. As Taylor (2003, p. 41) suggests,

> *For years, engineers told Gehry that forms he drew and models he created could not be built. It was not until new computers and software programs were created that Gehry and his associates could build what they had long imagined… The new software not only enabled Gehry to transform his models into programs but also significantly influenced the structures he designed.*

And so, by supporting, guiding, permitting and informing the creation of new materials, new tools, new possibilities, new needs and novel services, information and computational technologies are contributing to the changing face of the world, with a curious, far-reaching, complex and constantly shifting array of consequences difficult to identify or describe in any but the broadest terms. Such effects appear quite unpredictable – and are, furthermore, often surprising; as Bruno Latour (2002, p. 250) eloquently describes it,

> *[A]ll technologies incite around them…[a] whirlwind of new worlds. Far from primarily fulfilling a purpose, they start by exploring heterogenous universes that nothing up to that point could have foreseen and behind which trail new functions.*

Myths, legends and stories foretold – or at least imagined – many of our modern technologies: travel through the air, communication at a distance, voyages under the sea and the use of powerful weapons of destruction. But no one anticipated the strange realms of 'weblogging,' email, virtual worlds or computer viruses. Nor could anyone have foretold that 'spam' would account for sixty percent of all email sent in the first quarter of 2004[32], or that pornography would be among the most successful industries in the curious new economies clustered around the Internet[33]. These seemingly arbitrary, somewhat organic, even rather odd phenomena are more reminiscent of Deleuze & Guattari's (1991) vision of "[T]he history of contingencies, and not the history of necessity." As they go on to point out, "[G]reat accidents were necessary, and amazing encounters that could have happened elsewhere, or before, or might never have happened" (p.140).

The history of computers and their related technologies is just such a curious array of brilliant discoveries, fortuitous accidents, and improbable successes. These technological innovations have been caught up in a vortex of increasingly powerful economic forces. And from this has radiated social consequences, rippling outward and washing back in with tidal force, that have helped to shape this strange new world.

Thus, video games now rival cinema as a cultural force, and are quickly surpassing film in economic terms, just as they now drive technological innovations in the field of computer graphics faster even than the military-industrial complex that first developed these devices (Lenoir, 2000). Meanwhile, three-quarters of Britons now have cell phones (including over ninety percent of the younger generation, according to Crabtree, Nathan & Roberts, 2003). Canadians have, on average, more than two computers per household, and more than half now connect to the Internet from home on a regular basis[34]. And any number of such statistics can be summoned up through search engines like the ubiquitous Google at a moment's notice, taken from constantly enlarged and updated stores of information – much of

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[32] At the time of writing, the latest statistics (from which this was taken) were available at http://www.brightmail.com (accessed July 5, 2004).
[33] At the time of writing, http://www.internetfilterreview.com suggested that 25% of search engine requests were porn-related, as were some 12% of all web sites.
[34] Statistics Canada, The Daily, Thursday, Sept. 18, 2003.

it free, some of it accurate – constantly generated by sources around the planet. Though the effects of such changes in the fabric of daily life are far from obvious, the sheer fact of change appears undeniable (Rochlin, 1997; Kling, 1991, 1996).

3.3 Accelerating uptake

Moreover, the rate of manufacture, distribution, and utilization of these technologies is continuing to accelerate at breakneck pace. At the time of writing, annual transistor production is approximately 10^{17} annually[35], ranking these objects among the most numerous human-manufactured devices on the planet. Meanwhile, researchers are fast approaching the goal of moving computation to the scale of the atom (Advanced Research and Development Activity, 2004), continuing a century of astonishing progress in maximizing speed and minimizing size.

Since the global geographical distribution of transistors and other computational devices is rather less than uniform, if production forecasts prove accurate, those living in more technologically advanced societies will soon be surrounded by even more unimaginable numbers of devices destined for computational ends[36]. In fact, at a much higher level of physical object than the humble transistor, the statistics are already impressive (though obsolete as soon as they are published); according to recent studies, over half of all Canadian households have at least one email-compatible computer,[37] while American households already contain, on average, some 50 microprocessor-controlled devices[38]. Even more dramatically, Tennenhouse (2000) commented on the "[E]ight billion or more computational

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[35] Board on Chemical Sciences and Technology, 2003, p. 78.
[36] Already our ability to conceptualize large numbers seems inadequate when dealing with abstractions like 'terabytes,' operating at a massive scale that is literaly close to that of the traditional 'grains of sand on a beach' analogy. It is doubtful that most people (starting with the author) have any meaningful way of conceptualizing even one billion, let alone the vastly larger, yet somehow controlled, numerical chimeras that are now to be found everywhere—including inexpensive consumer-level electronics. These huge numbers are so inconceivable as to be almost meaningless.
[37] Statistics Canada, CANSIM, table 358-0006. Available at http://www.statcan.ca/english/Pgdb/arts52a.htm and accessed August 1, 2004.
[38] According to Notre Dame University (2003), *Signature* 5:1, available at http://www.nd.edu/~engineer/activities/embedded.pdf and accessed July 5, 2004.

nodes" (p. 44) deployed in 2000 alone, most of which were designed to directly communicate with other nodes rather than with human beings. Tennenhouse further commented on the surprising lack of discourse concerning this rapidly increasing number of networks of computers and embedded devices designed to operate with relatively limited and only occasional human input.

Alongside this tremendous growth in processors, the Internet has likewise grown at an exponential rate, and now features more than 230 million distinct web hosts.[39] Google for August 19, 2004 reports that it searches some 4,285,199,774 web pages, while the International Telecommunications Union[40] lists the total number of Internet users worldwide as approximately 675 million in 2003. Of course, without understanding the exact nature of each of these particular studies, such data gives only an vague idea of the real scale of use. However, even allowing for significant flexibility in interpretation, it is undeniable that many (but by no means most) people are directly using, and in many cases profiting from, the Internet. And as these figures change, flux, and swell, the existence of the "digital divide" – separating the rich from the poor and the wired from the isolated – also becomes an increasingly politically charged reality (U.S. Department of Commerce,1999 & 2000).

Such figures attest to the remarkable rate of global technological uptake; after all, the computer has a very short history as a domestic appliance, while the transistor has existed for not quite a century. But however striking the current rate of diffusion, these statistics pale in the face of the prognosis for an increasingly computationally mediated future. This prediction goes by many names, including calm technology (Weiser, 1996), ubiquitous computing (Weiser, 1991), context-aware computing (Winograd, 2001), pervasive computing (Ark & Selker, 1999), invisible computing (Borriello, 2000), embedded computing (Dourish, 2001), ambient intelligence (Mattern, 2004), and disappearing computing (Redström, 2001)

[39] According to http://www.isc.org statistics for January 2004, accessed as of August 12, 2004.
[40] According to http://www.itu.int stastics for 2003, accessed as of August 12, 2004.

– just some of the terms used to describe the many future-oriented research projects which look forward to a time in the very near future where computation will have become as commonplace as electricity, that other great intangible force of the modern world (Weiser & Brown, 1997).

3.4 'Ubiquitous computing'

> *Among the few common threads in predictions of future technology …is that we will see more convergence of information and communication technologies, blurring the lines between tasks and activities and between work and play. We will have "ubiquitous computing" … and "pervasive information systems"… We will become "intimate with our technology"… and "information overload" will be more of a problem than ever.*[41]

Amidst this panoply of names, the research that most directly addresses these emergent technological forms is most commonly described as 'ubiquitous computing.'[42] As the name implies, this arises from a vision of a future within which the lifeworld will be increasingly 'informated,' to use the term coined by Zuboff (1988), and perhaps also 'multimediated', as Sonesson (1997) describes it – two ways of saying that more and more tasks and objects of daily life will involve computers, whether directly and indirectly, implicitly or explicitly. Bohn, Coroama, Langheinrich, Mattern & Rohs (2003) identify some of the main technological underpinnings of this trend: tiny, cheap processors with integrated sensors and wireless communications, the association of information with everyday objects, the possibility of remotely identifying and locating objects, and the development of "electronic paper" technologies.

At the time of writing, their list appears reasonable, though to it several additional technological tendencies can be appended: the increased presence of cameras

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[41] Borgman, 2000, p. 15.
[42] See Ishii's (2004) comments on the original meaning of this term.

(capturing, and sometimes analyzing, both still and moving pictures)[43], the ubiquity of communication technologies, especially wireless telephony, email, and chat services, and the omnipresence of various types of screens displaying moving images and dynamic information. Furthemore, at least as significant as any of these individual tendencies is the trend toward their collective interconnection within a 'datasphere' of networked databases (Goguen, 1999).

Harbingers of this next stage of technological development include the increasingly widespread use of biometrics (technologies which identify a person through the analysis of a unique physical characteristic, such as fingerprint patterns; see, e.g., Woodward Jr., 2001), location tracking, in such forms as those of GPS systems and cell phone position detection (Farmer & Mann, 2003) and RFID tags. Also known as 'smart' tags, these last are small scale, low-power, relatively short-range radio-frequency devices that embed a small amount of data in a form that may be read at a distance; see, e.g. Want, Fishkin, Gujar & Harrison (1999).

To take one particularly telling real-world example, Wal-Mart, a powerful force in mass consumer culture, recently required of its suppliers that, by January 2005, all products destined for their vast distribution network must be tagged with RFID tags in order to facilitate the optimization of the company's remarkably efficient just-in-time inventory management systems (Ferguson, 2003). While the date may have been overly optimistic, such a shift will almost certainly take place in the next few years. Wal-Mart's earlier use of inventory tracking systems was an important reason for the suceess of UPC codes (Golan, Krissoff, Kuchler, Nelson, Price & Calvin, 2004), and has been recognized as an important part of their successful business strategy (Hoppe, 2001); the shift to these new technologies is no doubt designed in the hope of creating similar effects.

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[43] Farmer & Mann (2003) report that there are now more than 26 million surveillance cameras worldwide, and that, in perhaps the most extreme case, the average resident of London, England is filmed by more than 300 cameras per day.

However, early attempts to implement ubiquitous computing technologies have not been free from controversy. For example, experimental deployal of RFID technology included tests carred out in England as part of a partnership between Gilette and the Tesco supermarket chain. These tests tracked razor blade inventory from factory to point of sale, but were discontinued after sustained public protest connected with isses of privacy and surveillance (Want, 2004; Farmer & Mann, 2003). A rather more sinister example that helps to explain some of this often vague and nebulous public discomfort was the 2003 *World Summit on the Information Society*, at which participants learned that the badges issued for the summit had been secretly tagged with RFID devices that were used for data harvesting. Hudson (2003, unpaged) reported that,

> *[T]he hidden chips communicate information via radio frequency when close to sensors that can be placed anywhere from vending machines to the entrance of a specific meeting room, allowing the remote identification and tracking of participants, or groups of participants, attending the event.*

This is in turn representative of another widespread trend; technologies of surveillance, both covert and overt, are becoming more commonplace, from cameras to highway toll cards, identity cards and passports, and even banknotes. These all figure among the first examples of large-scale, real-world implementations of ubiquitous computing technologies. Furthermore, this tendency toward heightened levels of security and surveillance—often involving the use of comparatively sophisticated technologies—has been given extra impetus by the current context of global political instability (Bowyer, 2004; DeRosa, 2003).

And so, as this evolution continues, social and legal systems worldwide are struggling to develop laws and standards that will guide, contain and constrain the use—and abuse—of these and similar devices (Woodward Jr. 2001; Brown & Cloutier, 2003). Likewise, questions of privacy, control, and identity are raised with increasing frequency as this technological uptake continues to accelerate; a useful bibliography can be found in Viseu, Clement & Aspinall (2003). This forms an important part of the social and cultural background against which interaction designers carry out their work, with scant recourse to legal, social, or cultural examples, dealing with new situations where no clear precedents are available and where both ethics and politics are cloudy and contested.

The present era thus appears to be one of adjustment during which standards, norms, and structures are in constant evolution, while the context of intervention constantly shifts underfoot. And if the few examples described above show some of the ways in which technology is continuing to spread, they also attest to the fact that the results are never solely technical, but rather have a series of effects that ripple outward, initiating and helping to shape change at the personal, social, and societal levels.

3.5 Computers as objects

> *Where a calculator on the ENIAC is equipped with 18,000 vacuum tubes and weighs 30 tons, computers in the future may have only 1000 vacuum tubes and weigh only 1 1/2 tons*[44]*.*

Underlying these transformations is a development that is particularly relevant to the design disciplines: the physical and structural evolution of computer technologies. When considered solely as physical objects, computers have changed in scale, power and functionality more rapidly than any other human invention. The change in functionality is particularly dramatic, and arguably unprecedented:

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[44] Popular Mechanics (1949).

> *In 1945 the maximum rate of calculation that a normal person could sustain over prolonged periods of time was about one operation per second. By 2005, just 60 years later, the rate of calculation on the fastest supercomputer is expected to exceed a hundred trillion operations per second.*
>
> *...[N]othing else in human history has advanced by a factor of a hundred trillion. Not a single step on two legs to going to the Moon. Not a mud hut to Manhattan. Not the first scratchings of the cuneiform on a clay tablet to the entire text holdings in the Library of Congress.*[45]

Perhaps because of this phenomenal progress in the facilitation of calculation (an undeniably invisible process), theories about computational technologies have often focused on the disembodied and abstract dimension of information, or 'virtuality.' But while it is true that information relies on abstract representation, and that the electric and magnetic forms in which it is encoded are invisible and intangible, the reality is that computers are very much objects, and objects that require a particularly vast infrastructure to support their manufacture and use. Laboratories have technicians specializing in cable management to ensure that their arrays of machines are correctly and unobtrusively wired, while cities and whole countries are rewiring with fibre optic lines (Mitchell, 1995) to replace existing copper infrastructures. Meanwhile, "wireless" communication – which actually requires a great many wires to supply the electrical grid that sustains and nourishes it, and a great many more in the devices themselves – becomes more widespread every day. As Moles (2000) puts it, "An immaterial culture is emerging. It exists only because a heavily material base supports it and makes it possible" (p. 268).

Similarly, silicon chips are themselves among the most industrially demanding objects ever mass-produced, requiring huge, dedicated facilities that siphon tremendous quantities of energy and water (Williamson, 1997). And at the other end of their life cycle, the disposal of 'technojunk' is a problem that is far from solved (Boon, Isaacs & Gupta, 2000), though exporting electronic waste to developing countries has moved the problem neatly out of sight for the short term, at least for

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[45] Dr. Stephen Younger, as transcribed in Supercomputing and the Human Endeavour, 2001, p.24.

the wealthy. But in reality, the digital domain is as far from wireless as offices are from paperless, and the abstract and often disembodied experience of information in no way negates the undeniable and fundamental physicality of information systems. Like it or not, computers are objects and will forever remain objects.

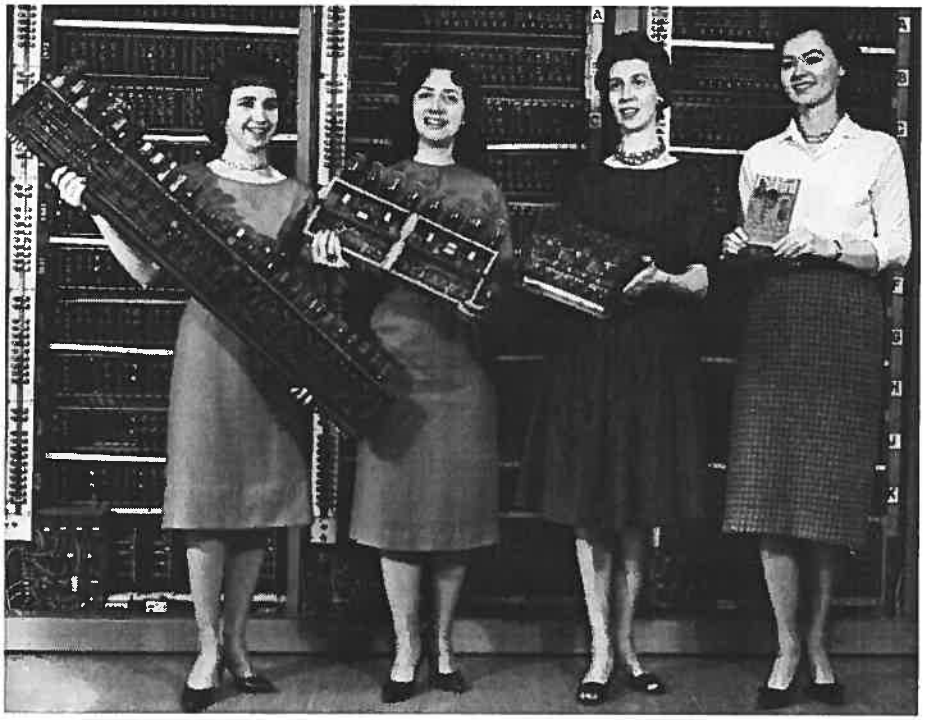

Figure 5: Early computers (women employed to calculate complex mathematical equations) standing in front of Eniac.

For design, the tangible character of the artefacts is very significant, and the evolution of the computer-as-object is intimately linked with that of of interaction design. The development of computers as objects, though slightly less drastic than the speed of change in processing power, has nonetheless involved a shift from lumbering behemoths to tiny motes that has taken place over the course of less than one hundred years.

Along the way, computers have created and demanded different articulations of space—physically, with regard to temperature, humidity, and electrical supply (Haigh, 2001), but also institutionally and socially, since the functions associated with computation have changed as drastically as the objects themselves (Grudin, 1990). Perhaps most importantly, the simple but undeniable reality that computers are constantly smaller, cheaper, and more efficient means that they are more and more widely used to supplement, complement, or even displace existing technologies, bringing their own particular structural logic to bear in the process—a logic that will be more closely addressed in coming sections.

Moreover, at the present time, the complexity of the computer-as-object is continuing to increase, and at least two factors can be identified in this shift. The first is the webwork of sensory connections which are being created between computer systems and the real world. As Holmquist, Mazé & Ljungblad (2003, p. 2) comment, this contributes to the novelty of these objects:

> *By using sensors, computer-enabled artifacts can gather information about the environment and the actions of users–they become aware of their surroundings and may even act on their own behalf. Such "smart" everyday objects represent an entirely new product category.*

But these objects are not only connected to the world around them (a topic that will be revisited in section 5), but to each other as well. This represents the second development in the complexity of these systems, and the last major factor that will be examined in this section: the increasing extent and speed of communication between clusters of these objects, which has made the logic of networks such an integral and intimate part of daily life.

3.6 Network logics

> *Manuel Castells suggests that modern society from the 1980s onwards constitutes a network society, and that the unity in the diversity of global restructuring has to be seen in the massive deployment of information and communication technologies in all spheres of modern social life. Innovations in the field of communication and information technologies therefore represent, not unlike the eighteenth-century industrial revolution, a major historical event and a fundamental change in the material as well as the social structure and culture of society.*[46]

It has become commonplace to suggest that the present period is one of 'network culture' and that this is an age of 'network society.' (Joyce, 2000; Taylor, 2001; Castells, 2000). Like computation itself, networks have come into being both as a physical reality (that is to say, a tangled grid of cables and physical devices) and as a metaphor that helps to describe and make sense of existence. Networking provides a way of describing machines, friendships and institutional economic relationships alike. And as with 'computation,' different concepts of 'networks' are invoked across a broad range of disciplines in very diverse ways and for equally varied purposes, with the result that the idea of a 'network society' means quite different things to different people. In fact, at least three kinds of networks can be identified; in increasing order of abstraction, these are *technical* networks, *social* networks, and *metaphorical* networks.

Technical networks refer to the tangible—and often updated or upgraded—objects that provide the material infrastructure for the global flows of electromagnetically encoded information. These may be wired or wireless, but are in all cases built atop the flow of electricity. In fact, the development of the electrical distribution network over the past one hundred and fifty years has allowed the emergence of a strange new class of physical object that only takes on its full identity as part of a distributed system. The generation of electricity, together with the mapping of the grid to distribute power, came into existence alongside with the use of controlled and

[46] Stehr, 2000, p. 83.

encoded electrical communication at a distance. In symbiosis with these new potentials came new objects, ontologically incomplete (dumb, mute, and ineffectual) without constant nourishment in the form of electrical power or encoded information. Flows of electrons merged with and amplified the existing flows of fuels – wood, coal, gasoline, oil – of raw materials and food, of communication and of human beings. And the results of this are now densely interwoven:

> *Through the telephone into satellite based global telecommunication systems; through the toaster into integrated electricity grids fed with nuclear energy; through wrist watches into a technical system called World Time anchored even deeper in the universe.*[47]

These technical networks underpin all interaction design activity. They determine who can be reached by these technologies, by what means, and at what speed. And with two terabytes of data traveling across the Internet each day, and $1.5 trillion of foreign currencies exchanged across the communication channels of electronic commerce on a daily basis (Sequeira, Chiat & McAleer, 2004), access to networks has become an urgent political and economic issue for countries and corporations alike (OECD, 2002).

Through and across these tangled wires, discussions of **social** networks make reference to the widely dispersed social relationships that are increasingly common within modern societies which are both extremely mobile and highly connected. Such mobility involves both the real world and the virtual domain; if the average distance that the average inhabitant of the Earth travels has grown from 3.6 to 13 kilometers over the past fifty years (Hoete, 2003, p. 215), this impressive rate of growth scarcely compares to that of the volume of information now constantly exchanged across the surface of the planet. Each day, billions of phone calls, emails, faxes, Web searches take place, changing patterns of family and friendship, work habits and even romance and dating (Wellman & Hampton, 1999).

[47] Joerges & Czarniawska, 1998, p. 382.

These diverse forms of computer-mediated communication (also known as CMC) have certainly affected social connections – but not necessarily as one might have expected. Thus, for example, Wellman & Hogan (2004) report that according to their studies it appears that,

> *Internet users are more likely to read newspapers, discuss important matters with their spouses and close friends, form neighborhood associations, vote and participate in sociable offline activities. The more they meet in-person or by telephone, the more they use the Internet to communicate. This "media multiplexity" means that the more people communicate by one medium, the more they communicate overall. For example, people might phone to arrange a social or work meeting, alter arrangements over the Internet, and then get together in person.*

Social networking, facilitated by technological innovations, thus forms a very real part of modern experience. Romance, work, friends and family are all caught up in these networks, as are communities of interest and shared knowledge that may now be geographically separated by great distances. And the nature of these changes – which go far beyond the scope of the present document – will surely continue to evolve in the course of coming years and decades.

Finally, **metaphorical** networks are also common, though, as Latour (1999) points out, even the particular value attached to this metaphor is not entirely stable. Latour actually suggests that a subtle transformation has taken place, as a result of an acceleration of the technical processes and the scientific progress in creating complex sociotechnical structures:

> *[With] the Web everyone believes they understand what a network is. 20 years ago there was still some freshness in the term. What is the difference between the older and the new usage? Network at the time clearly meant a series of transformations—translations, transductions; now, on the contrary, it clearly means a transport without deformation, an instantaneous, unmediated access to every piece of information.*[48]

In sum, the term "networks," as a blanket description for anything governed by a structural logic of interconnected and mutually communicating nodes, is now used to explain everything from new corporate structures to new urban planning

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[48] Latour (1999, p. 15)

strategies for lifelong learning. Knowledge networks are invoked as metaphors for the idealized flow of knowledge, expertise, and information between members of organizations that are likewise interconnected financially and economically (Powell, 1998; Miettinen & Hasu, 2002). High-tech startup firms are described in terms of 'clusters' and 'hubs,' interconnected nodes forming part of larger patterns, and the metaphor of networks has become almost as prevalent as that of computation.

And so, across a multitude of meanings, the very concept of "networks" now makes reference to dynamic, complex, and interconnected systems within which perturbations and changes propagate rapidly, with effects that are often indirectly rather than directly causal and that extend almost instantly over great distances. Interaction design has come into existence as a result of these networks, and these networks form part of the evolving computational design material with which designers now engage.

3.7 Conclusion: full speed ahead

Whatever surprises the future will doubtless hold, it appears highly likely that, as computational technologies are introduced into more and more mass market products and into private and public spaces, individuals will be called on to engage in ever-more intimate relationships with constantly increasing numbers of computational devices during the course of daily lived existence.

Similarly, as both the size and cost of components and systems continues to decrease, and as information processing power continues its seemingly inexorable progress along the path set out by Moore's strangely accurate "law" (Tuomi, 2002) it appears likely that the social, economic, domestic and cultural landscapes will continue to be marked by the constant, rapid, and global change that has characterized the past several hundred years, and that has accelerated still faster through the course of this last century.

Finally, as networks extend further, infusing personal, public, domestic and natural spaces with devices dedicated to the collection, storage, and transmission of data and information, the context of lived experience will continue to change in strange and surprising ways. Against this backdrop, there will be space – and need – for design and designers to work with, for, and sometimes against the new flows initiated, created, and shaped by new technologies.

4. Interaction design

[I]nteraction design has developed as a discipline concerned with the interplay between physical and visual form and computationally mediated behaviors within interactive products.
–Ullmer (2002, p. 53)

In portraying the broadening scope of computing, I have alluded to many existing disciplines, ranging from linguistics and psychology to graphic and industrial design. Human-computer interaction is by necessity a field with interdisciplinary concerns, since its essence is interaction that includes people and machines, virtual worlds and computer networks, and a diverse array of objects and behaviors.

In the midst of this interdisciplinary collision, we can see the beginnings of a new profession, which might be called "interaction design." While drawing from many of the older disciplines, it has a distinct set of concerns and methods. It draws on elements of graphic design, information design, and concepts of human-computer interaction as a basis for designing interaction with (and habitation within) computer-based systems. Although computers are at the center of interaction design, it is not a subfield of computer science.
–Winograd (1996, p. 160)

Defining effective interaction design is a complex and difficult task. I found this out when I served as one of the advisors and jurors for the ACM interactions Design Awards. These awards recognize products that provide people with quality experiences. One outcome of this effort was a set of criteria that attempt to define successful interaction design. These include understanding of users, an effective design process, and a final product that is learnable and usable, needed and desired, manageable, appropriate, mutable, and offers a satisfying aesthetic experience... In the time that has passed since the criteria were developed, I have had the nagging feeling that something was missing. We defined the things that contribute to effective interaction design in rational, logical terms. Perhaps because of this, I noticed that people often miss the context by severing the criteria from the heart of the matter: quality of experience.
– Alben (1996, p.14)

By interaction design, we mean 'designing interactive products to support people in their everyday and working lives.' In particular, it is about creating user experiences that enhance and extend the way people work, communicate, and interact.
–Preece, Rogers & Sharp (2002, p.6)

Interaction Design is a design discipline dedicated to:
- *Defining the behavior of artifacts, environments, and systems (i.e., products)*

...and therefore concerned with:
- *Defining the form of products as they relate to their behavior and use*
- *Anticipating how the use of products will mediate human relationships and affect human understanding*
- *Exploring the dialogue between products, people, and contexts (physical, cultural, historical)*

–Reimann (2001, ¶ 5)

[Computer] processing plus [networked] access plus sensors will set the stage for the next wave – interaction. By "interaction" we don't mean just Internet-variety interaction among people – we mean the interaction of electronic devices with the physical world on our behalf.
- Institute for the Future (1997, p. 116)

4.1 Understanding interaction design

As the previous chapter suggests, computer technologies are both intimately and intricately linked with the evolving processes – both creative and industrial – now associated with the conception, manufacturing, distribution, use, consumption and disposal of objects, environments, services and systems. In symbiosis with these changes to the built environment and the ways in which it is conceived and constructed, designers are now called on to imagine, create and coordinate physically, cognitively, and emotionally affective and effective infrastructures that support, structure and guide both work and play.

And so, within increasingly data- and information-driven social and cultural systems, contemporary designers work with (or sometimes against) technological and technologically supported responses to an expanding range of design problems – many of which, in a recursive loop, are themselves the results of technological developments. Better email management tools, for example, are only needed because of the proliferation of email; new solutions also generate new problems.

The field of interaction design has developed over the course of approximately the past fifteen years as a new area of design activity that addresses the needs, solutions, possibilities and constraints connected to human engagements with computers and computational devices. As such, it draws on knowledge and tools developed by a number of existing professions and fields of study; as outlined in previous chapters, these include (but are not limited to) computer science and human-computer interaction, information science, sociology, industrial design, graphic design, psychology and anthropology (Winograd, 1996; Preece, Rogers & Sharp, 2002).

Furthermore, despite its rapid development, the domain of interaction design is relatively new, unfamiliar to most, and often rather technical. As well, the conceptual and theoretical vocabulary is still developing and remains vague, and frequently confusing. Accordingly, as an introduction to the topic, this chapter begins by considering four very different examples of interaction design activity.

The similarities and differences between these cases are then used to help reveal some trends and common features as well as certain points of divergence and dispute within this emerging discipline. If the academic heritage of interaction design can be best understood as a hybrid between the design disciplines and the field of human-computer interaction, there are nevertheless points where these two fields appear to have rather different perspectives and preconceptions – which are in turn distinct from those of professional practice.

Finally, two major difficulties in establishing any clear definition of the field are identified and explored: firstly, the linguistic problem of defining the term 'interaction' itself, and secondly, the conceptual challenges posed by the expanding and seemingly limitless scope of computation.

4.2 The scope of interaction design: four examples

Before talking more abstractly about what the discipline is, it will be useful to consider some examples of what interaction designers do and create. The four following examples demonstrate some of the range of interaction design activity, as regards the nature of the interventions, the scale of the projects, the methods or methodologies employed and the results of design activities. The challenge of finding disciplinary common ground will be made evident even from this brief overview.

4.2.1 SHS Orcas: Sharing information

Calde, Goodwin & Reimann (2002) offer an account of the SHS Orcas project, for which California-based Cooper Interaction Design[49] – a pioneering firm in the professional practice of interaction design – was contracted to provide design services. The goal of this project was to design a "[H]ealthcare information system that would… provide true integration of clinical, financial, and case management information, allowing comprehensive management of long-term healthcare facilities" (p. 2). The design team thus worked to create systems that would permit the timely collection, distribution, and display of relevant information in order to meet the needs of a range of health care providers and administrative staff within the social and institutional contexts of large hospital environments functioning within the United States medical system.

The design process, as described in the paper, included interviews and ethnographic studies, character and scenario creation, prototyping, and field testing. These research and design activities led to the generation of detailed specifications and descriptions. The product was then completed, implemented, and brought to market by a third party. The resulting system is now available for purchase and is reportedly in use at numerous facilities.

The case study focuses on the integration between multiple users with a variety of needs, all of whom engage with relevant subsets of a common, constantly shifting, frequently updated data set. Other key elements in this example include the use of ethnography in the design process and the emphasis on the development of 'personas' – characters used as archetypal figures in the scenario-based "goal-driven" design method developed by Cooper (1999).

[49] Online at http://www.cooper.com as of June 12, 2004.

As the authors describe it, the design artifacts that resulted from the process were, primarily, a set of detailed specifications and prototypes of WIMP (windows-icon-mouse-pointer) interfaces designed to display and permit certain kinds of engagement with contextually appropriate subsets of the complex network of data used to represent the state of a patient's corporeal and financial health within the framework of a U.S. hospital system. One of the proposed interfaces also included a networked, wall-mounted touchscreen incorporating a bar-code scanner (for inventory tracking) and a biometric, fingerprint-based login system (for security and verification). However, the majority of the devices were based on keyboard-mouse interaction and computer monitors.

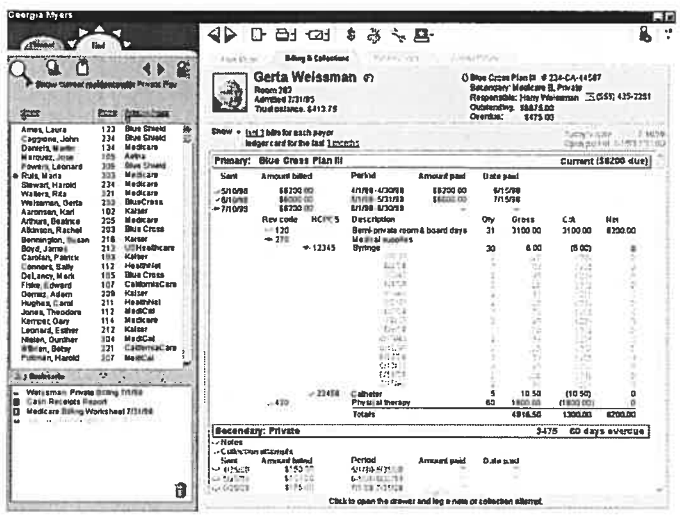

Figure 6: Interface prototype, from Calde et al (2002)

"Interaction" in this context refers to a range of computer-mediated engagements with a centralized data-set. Whether in the form of a manager retrieving information about a particular patient's insurance status, or of a nurse using a bar code scanner to indicate that a particular medication was administered, interaction describes the points of contact between humans and machines that center on retrievals from and additions to a centrally maintained and managed stock of information. The machines, input devices, and screens are central design features, while the structure of the system as a whole is paramount.

4.2.2 *bottles*: Physical bits

Ishii (2004) describes the creation of *bottles*, an example of what are often called "tangible user interfaces" (Computer Science and Telecommunications Board, 2003; Ullmer, 2002). These are computational devices that place a special emphasis on physical form – shape, size, weight, texture, materiality – as well as on embodied engagements with physical objects with behaviors and properties enhanced through information technologies.

The *bottles* are ordinary (albeit attractive) glass bottles with custom-designed, invisible radio-frequency sensors located in the stoppers. These form part of a system that also includes,

> *A triangular table with a distinct circular central area. The table houses three Color Kinetics™ lights, a speaker system, a tag-reader board and an electromagnetic sensing coil embedded in the surface that detects the presence and state of bottles on the desktop.*[50]

Figure 7: A bottles *configuration, from Malazek, Ishii & Wood (2001)*

Participants engage with the system by opening or closing the bottles, removing them from the table, or replacing them on the table. These events trigger the playback of music from speakers hidden below the table, while also activating

[50] Ishii, 2004, p. 1032.

changes in the light patterns generated by the color-changing luminaires below the table. Together, the system creates the illusion that music is contained within the bottles, to be released only when the stoppers are removed.

Under the direction of Professor Ishii, the Tangible Media Group[51] at MIT's Media Lab has been particularly active in furthering research on the creation of connections between computerized information and physical objects; Ullmer (2002) describes the theoretical underpinnings of this area of research in considerable detail. Such work draws attention to the potential of representing information in more intuitive physical forms, making use of the novel features of digital media while retaining the human scale and ease of use of the physical world. As Dourish (2001b, p. 231) describes it,

> *[A]lthough the world of physical reality is one with which we are deeply and intimately familiar and one in which we are, as organisms, evolved to operate, most interactive systems make very little use of these natural skills and abilities in supporting interaction. The relationship between physical and computational interaction is largely limited to pressing keys and moving mice…Along with his students, [Ishii] has developed a wide range of technologies that bridge between the world of atoms and the world of bits, manifesting computational entities as objects and images in the physical world, and using physical interactions as a means of controlling computational entities.*

Interaction, in the *bottles* example, refers to the physical manipulation of the bottles and stoppers in order to access a range of potential system behaviours. This form of interaction merges the familiar solidity and known physical properties of tangible objects with the unfamiliarity of computationally extended behaviors. In this particular case, the system also has an element of magic created by the literal transparency of the technology, while themes of embodiment, of sensory pleasure and of aesthetics are also explicit concerns in the work.

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[51] http://tangible.media.mit.edu/

4.2.3 University of Michigan business school: Web design

Brinck, Ha, Pritula, Lock, Speredelozzi, & Monan (2003) describe the redesign of a Web site for the University of Michigan business school. This large-scale project, involving more than 3000 pages, included both a publicly accessible component and a secure internal network (intranet) requiring a secure login. The original site was a jumble of smaller, independent subsections that had organically developed over time; the ten-month design project involved restructuring and reorganizing the navigation tools, interfaces, and overall visual design of the site, creating visual and navigational unity while increasing usability. The content and many of the Web applications remained largely unchanged during the course of this development.

The case study presents the project as an iterative, "[U]ser-centered design process grounded in a metrics-based user-testing plan" carried out in phases which included "[S]trategy and user needs analysis, conceptual design, prototyping, production, and deployment" (Brinck *et al*, 2003, p. 3). The design team worked in close collaboration with the client and the various stakeholders throughout the process.

In their description of the project, the authors address the information architecture of the site; visual design issues; administrative and institutional issues; issues relating to user testing, prototyping, and expert review; the implementation of accessibility (for visually or otherwise impaired users); strategies for long-term modifications and updates; and quality assurance throughout the process with user testing based on client-supplied demographic information.

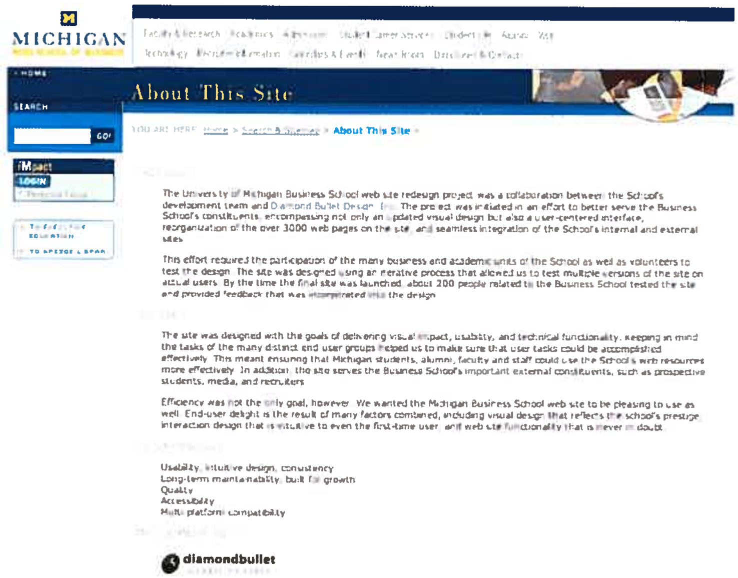

Figure 8: Redesigned University of Michigan Web site, online at http://www.bus.umich.edu/SearchSitemap/AboutThisSite.htm

In this case, interaction refers to navigation through a Web site using a standard mouse and keyboard. The structure and placement of menus, the underlying information architecture, and the clarity and coherency of graphic design are the primary means through which the goals of good interaction (as defined for the purposes of the project) were achieved. User tests and validation included quantitative data (the percentage of tasks successfully completed, and the time required to carry out tasks) as well as qualitative data, including questionnaires and structured post-use interviews.

4.2.4 *The Visitor*: Electronic arts

The Visitor: Living by Numbers (Fundació "La Caixa", 2002) is an interactive art installation created by Canadian artist Luc Courchesne, professor at the School of Industrial Design of the University of Montreal. The installation uses a specially designed lens and single-channel projection system to create a full 360° projection on a custom-built hemispherical screen. Visitors to the installation are thus entirely surrounded by a seamless, continuous video image created by a single video projector. The projection system is called the Panoscope[52], and two versions currently exist; the first is a smaller device for use by one person, while the second is a larger, inflatable dome that can accomodate approximately three people at a time. A still larger version is in development.

Figure 9: Large version of the Panoscope

The raw material for *The Visitor* is a series of audiovisual sequences set in Japan. They were shot on location, in high resolution, using a special mirrored lens mounted on a high-definition camera, then edited into short sequences that begin and end at a crossroads (sometimes physical and sometimes metaphorical or narrative). Visitors to the installation navigate through an interactive narrative, traveling through the virtual space and making plot choices by speaking aloud. A voice recognition system, set to recognize only the numbers one through twelve, activates the appropriate video sequence, depending on the particular number selected and the participants' current location within the overall story sequence.

The project explores the novel narrative and cinematographic potential of new technologies. The panoramic form of the immersive video environment offers multiple degrees of freedom for participants in the installation. They can (and must)

[52] Online at http://www.panoscope360.com as of Jan. 23, 2005.

choose what part of the image to look at, while the possibility to influence or shape the unfolding story offers a very different kind of freedom – one often associated with interactivity – which is to say, the freedom to choose from a selection of predetermined options.

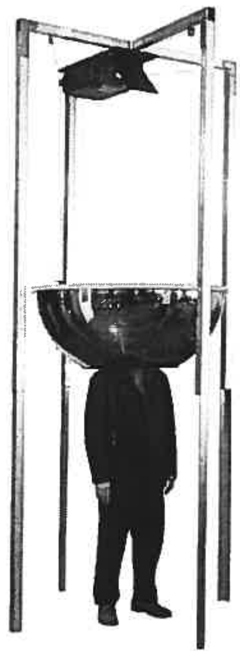

Figure 10: Smaller Panoscope *system*

Interaction with the work means making a vocal selection from among the available options – quite literally "living by numbers" – in order to navigate through the branching structure of the video sequences. Depending on the choices that are made, the story may take any of several paths and finish at one of a number of different endings, while during the course of the narrative, subplots (including stories recounted by the actors in the installation) can be explored to a greater or lesser degree. Interaction thus implies a visual and emotional engagement both with a moving image and with the whole experience of exploration and immersion in an artificial world and a choice-driven narrative structure.

4.3 Situating the discipline of interaction design

These few studies give an idea of the range of products, services, and contexts that could fall under the heading of 'interaction design.' The scope and scale of these contexts, products, goals and methods are quite diverse, ranging from objects to environments, systems, and experiences, and including hardware, software and physical environments. In certain cases the goal is to create something new; in others, to improve or alter existing structures or activities. In some cases, the goals are predominantly functional; in others, aesthetic. In some cases, the projects are academic, research-driven interventions; in others, they serve practical day-to-day needs of particular businesses and demographic groups.

The forms of interaction are also very different. In the *SHS Orcas* project, the centralization of data and the improved ability of different stakeholders to quickly and easily access and act on relevant sets of information are central. In *bottles*, the physical and poetic dimensions of interaction are highlighted, and the objects that permit engagement with the system are the primary focus of design activity, though the overall system behavior is also important. In the *University of Michigan business school* example, interaction refers to the accesssing of information at a distance, as well as to a form of engagement where the key aspects are graphic design and information architecture. And in *The Visitor*, the mode of interaction (voice recognition) is very different from the results of interaction (the playback of immersive video sequences), while the environment, content, and structure are all component parts of a single overarching experience. Finally, a further dimension – not discussed in detail in the above descriptions – are the social interactions that take place around the *bottles*, as well as within and around *The Visitor* installation.

As these examples demonstrate, the breadth of the discipline is large, which makes it very difficult to discuss in general terms. Furthemore, the field is still very young: no history of interaction design has thus far been written, and the academic literature is comparatively limited, with few journals or conferences directly addressing these topics (Ehn, 2002). And although a quickly developing field, interaction design remains largely practice-based; as a result, the majority of published texts are case studies that focus on relatively specific applications[52].

To help in understanding the discipline, it is useful to consider some of the models that have been proposed, like that of Preece, Rogers & Sharp (2002).

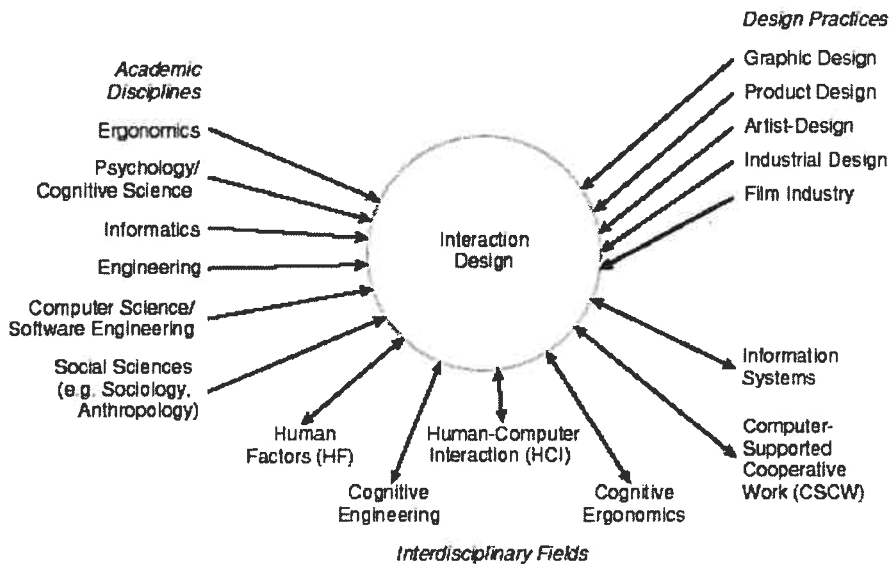

Figure 11: Interaction design, as per Preece, Rogers, and Sharp (2002).

This model emphasizes the role played by science and engineering (especially the cognitive flavors – cognitive science, engineering, and ergonomics) within interaction design, while assigning a rather secondary role to a variety of "design practices." It represents a relatively traditional HCI approach, primarily academic, research-oriented and focused on the sciences.

A quite different view is that presented by Shedroff (2004) whose model (reproduced below as figure 12) situates both interaction design and cognitive

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[52] See, for example, the AIGA "Experience Design" archives online at www.aiga.org and accessed on August 5, 2004.

science as parts of a much broader field called "experience design." Business, visual design, and history are all portrayed as rather more important concerns than those of science and engineering, while anthropology and sociology are also more closely linked to interaction design than are any of the harder sciences. This approach is more representative of the professional practice of interaction design, product-oriented and driven by market logics and institutional pressures.

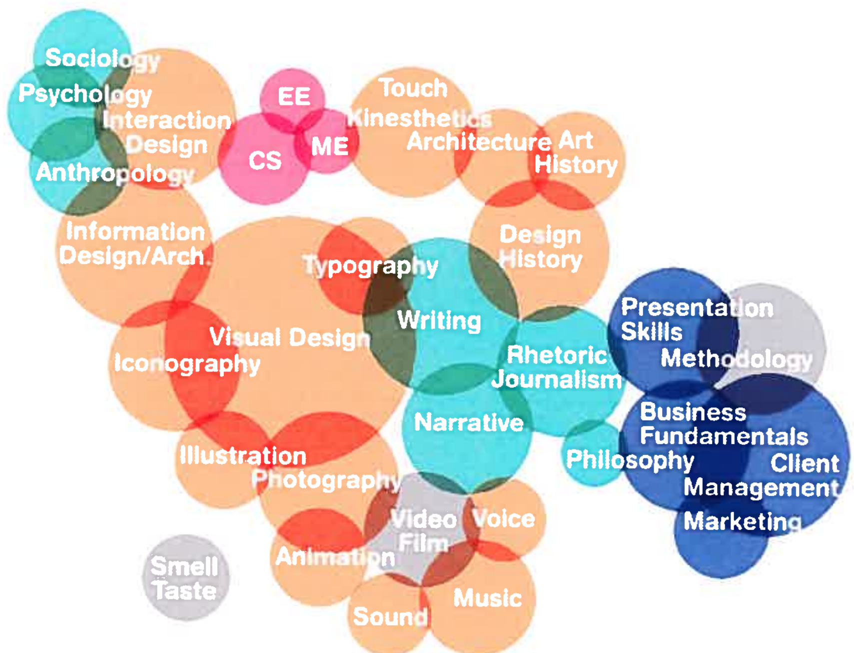

Figure 12: Experience design, as per Shedroff (2002).

These two very different perspectives are dauntingly wide-ranging in scope. Taking a rather different approach, figure 13 (next page) represents this author's attempt to situate interaction design by illustrating a few of the dimensions of Winograd's (1997) description of an 'interdisciplinary collision' between the fields of human-computer interaction and the design disciplines, particularly graphic design (for the creation of screen-based interfaces and software applications) and industrial design (for the creation of the hardware that gives form to interaction).

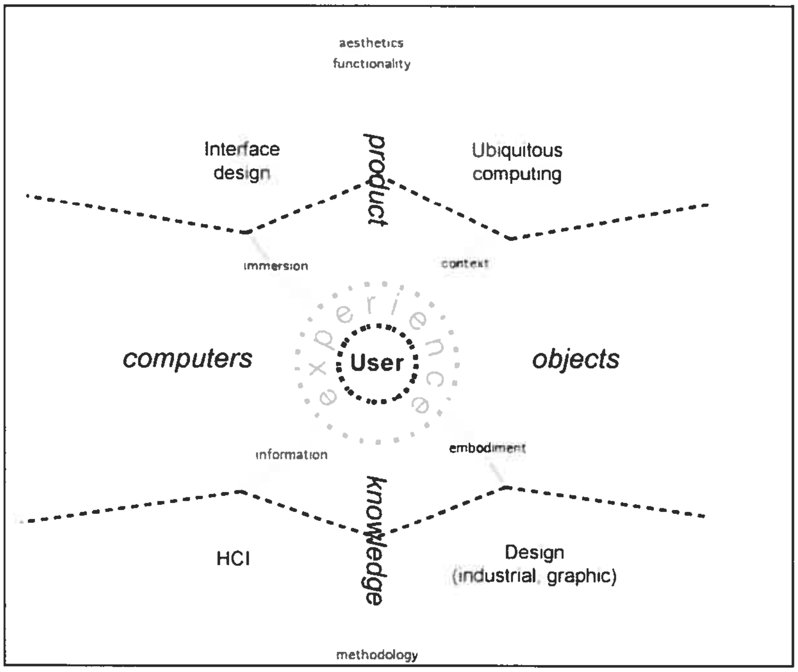

Figure 13: An alternative model of the discipline of interaction design

In this model, interaction design is presented as the point of convergence (and occasional conflict) between two disciplines that are concerned with the points at which *computers are given form as objects, artefacts, and systems that support and underpin human experiences*. It is likewise the point at which knowledge, both individual and disciplinary, is brought to bear on the design of such objects, artefacts, and systems. From this perspective, two distinct kinds of products and environments are produced through these design activities.

The first are those that might be called 'traditional' interfaces, though thirty years is not a particularly long tradition. At least for now, this refers to software-based devices and products that use the so-called "WIMP" (windows-icon-mouse-pointer) paradigm (e.g. Beaudouin-Lafon, 2000), which implies the use of a monitor, keyboard, and mouse connected to a computer display. This paradigm include most of the most common computer products: software packages, Web pages, interactive kiosks, ATMs and the like.

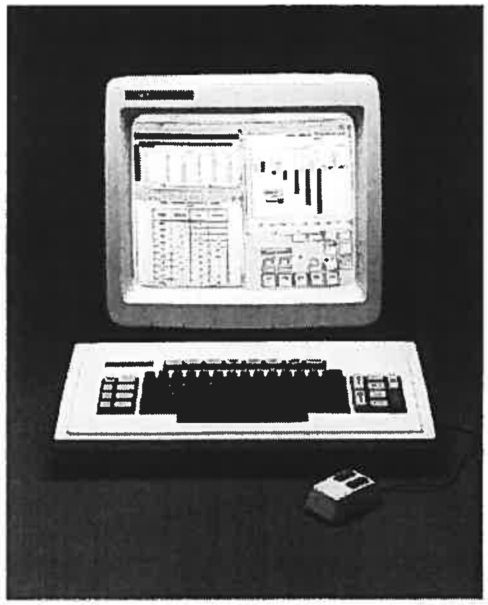

Figure 14: An early example of the WIMP paradigm.

Because of the rapid growth and development both of personal computing and the Internet, the design of these systems is the activity most often carried out by present-day interaction design professionals. Web design, for example, has become a common career path for graduates from computer science departments and design schools alike, while user interface design remains largely screen-based (as can be seen in frequently cited references, like Schneiderman & Plaisint, 2004). These are far and away the most common kinds of interaction design, and have quickly developed to the point where they form diverse and multifacted worlds unto themselves, with their own protocols, programming languages and associations and conferences (both professional and academic).

In the case studies described above, both the *University of Michigan business school* and *SHS Orcas* projects can be seen as examples of this kind of interaction design activity. In such contexts, ‘interaction’ typically means that people using the systems employ some combination of pointing device and keyboard to select and modify textual or graphic material displayed on one or several screens (though the tasks that are carried out through this process can vary drastically). In certain cases, other input devices may also be used, like the tactile screens and bar code readers described in Calde *et al* (2002).

These latter are in turn more closely related to the other kind of products that are developed through interaction design activity: physical objects that are part of a computational system or systems, but that are not specifically 'computers' in the normally understood sense of the term. Such objects may incorporate computational technologies in any or all of a range of different forms, including the active form of sensors and input devices, the passive form of embedded data, and the technical forms of microcontrollers and networked communication technologies.

The *bottles* example described above is a case in point; the result is distinctly computational, but the form of engagement with the computer is very different. Work of this kind is also sometimes called "physical interaction design," a term used at, among other institutions, the Interactive Telecommunications Program at New York University's Tisch School for the Arts[54]. Much of this work remains experimental, artistic or academic, but an increasing number of industrially produced objects – like blenders, televisions, microwaves, DVD players, and laundry machines – make use of similar technologies, as do many other complex mechanical devices and systems.

Even more experimental examples of this kind include a wide range of traditional objects incorporating computers, like mugs (Gellersen, Beigl & Krull, 1999), dishes, toys, clothes, and the like – often called "smart" objects (e.g. Gellersen, 2001). Similar work includes what is generally called "wearable" computing (Mann, 2001; Billinghurst, 2002), referring to computers that are designed to be included in

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[54] On the web at http://itp.nyu.edu/ and accessed Feb. 12, 2004.

clothes, jewelry, or other items of apparel – a step beyond even so-called "mobile" computing, lightweight and portable computational devices.

And although interaction design is often focused on the level of the individual object, computational interventions may also address larger environments. As one example, *The Visitor* represents a much more immersive, spatially driven form of interaction, one that encompasses participants both mentally and physically. In other projects, cell phones and wireless networks provide the underpinnings for urban-scale interaction. And in a case like Arup Lighting and UN Studio's *Galleria West* makeover in Korea, where the entire building cladding becomes a computer screen, the boundaries between architecture and interaction become much less clear.

Figure 15: Arup Lighting and UN Studio's LED screen for the Galleria West fashion mall in Seoul, South Korea

Interaction with such devices and objects is much more difficult to describe in any abstract or general terms. In fact, once engagements with computers move away from the relatively well-understood territory of screens and keyboards and into the realm of everyday objects, applicances, machines, tools and toys, it becomes much more challenging to develop generalizable design principles, guidelines, or strategies.

However, between these two poles – the realm of 'traditional interfaces' and that of 'smart objects' – there is a wide and expanding range of devices, including personal data assistants (PDAs), cellular telephones, video game consoles and other consumer electronic gadgetry. These make use of a variety of different forms of input, including keyboards, keypads, joysticks and pointers, handwriting and speech recognition systems and so on. Machines of this kind are now found in pockets, households and public spaces throughout much of the developed world; children's toys and video games, electronic musical instruments and biomedical devices may all be seen as falling at different points along this spectrum.

This broad spectrum of products and concerns in turn helps to account for the scope of courses offered as part of interaction design curricula, which might include interface design, graphic design, web design, usability, human factors and ergonomics, programming and even embedded microcontroller programming,[55] not to mention courses addressing the psychological, experiential and social aspects of engagements with information and communication technologies, as well as design courses dealing with the physical characteristics of objects and environments. This breadth of products and systems may also explain some of the confusion that surrounds the term 'interaction design' – though other factors are also at work in this terminological ambiguity, as will be shown through the course of the next sections.

4.4 A disciplinary collision

The above models of the discipline appear relatively straightforward, if technically complex. So why should the emergence of interaction design be described as a collision? What are the points of conflict, and why should any such clash take

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[55] Four design-oriented institutions are Interactive Ivrea (www.interaction-ivrea.it), the Royal College of Art (http://www.interaction.rca.ac.uk), Malmo University (http://www.dh.umu.se), and Carnegie Mellon (http://www.cmu.edu/cfa/design). Looking at their curricula provides some insight into the set of skills seen as relevant to the discipline.

place? These questions can be answered at a variety of different levels, since these conflicts are simultaneously academic and institutional, theoretical and practical, and the symptoms are manifested in the form of different methodologies, presuppositions and conceptual frameworks, and design practices and priorities. Discussing a few points of divergence will help to illustrate some of the dimensions of this clash of cultures, and to suggest some of the areas of significant disciplinary concern.

4.4.1 Contexts of intervention

One of the most obvious differences between the cultures of HCI and of design is their focus on different contexts of intervention. Bannon (1991) has commented on the historical tendency of HCI to rely on traditional, lab-based scientific experiments. The speed of technological diffusion and development has often outpaced such experiments, making any potential generalizations obsolete before they can be put to direct use; Newell & Card (1985) referred to this problem as "The race between the tortoise of cumulative science and the hare of intuitive design" (quoted in Bannon, 1991, p. 39). However, the level of exhaustive description often sought by the physical sciences is extremely challenging to attain in the real-world contexts within which day-to-day human activities unfold, a problem that is in no way simplified by the fact that software and hardware change – sometimes drastically – every few months.

Outside of laboratories, HCI has been primarily concerned with interventions in workplace environments. Hindus (1999, p. 199) summarized the situation at the turn of the millennium, and concluded that

> *Technology in homes has to date received little attention within the research community. A quick check of the ACM Digital Library shows that there is at least an order of magnitude more papers about offices and workplaces than about homes and consumers (and the latter totals only a few dozen publications over the last decade).*

Thus, during the historical evolution of computer science and HCI, relatively little attention was paid to domestic environments or public spaces – at least from an academic perspective. The vast majority of published texts in HCI and related disciplines focused on work, work-related tasks, and workplace environments; in fact, even the names of whole areas of research, like CSCW (computer-supported cooperative work) reflect this preoccupation (Crabtree & Rodden, 2004; Frolich & Kraut, 2003). It is beyond the scope of the present text to comment on the complex relationships between academic discourse and industrial realities, but it would appear that designers, industries and artists have been somewhat more eager than academic researchers to address domestic, public and private spaces. This situation is slowly changing, but appears to have strongly shaped the disciplinary evolution to date.

At the same time, it seems self-evident that the information ecologies of domestic environments, like those of public spaces, are not identical with that of workplaces (Hindus, 1999; Csikszentmihalyi, 1995). The projects, concerns, preoccupations, and goals are different, as are specific priorities and requirements. For this reason, "usability" will mean one thing in a living room, and quite another in an air traffic control tower (Chorianopoulos, Lekakos & Spinellis, 2003; Wickens, Mavor, Parasuraman & McGee, 1998 ; Rochlin, 1997) and the techniques and tactics for appropriate design will also differ. For example, in the home, pleasure, emotion, and satisfaction (as well as aesthetics and even fashion) are generally as important as the fundamental engineering concerns of efficiency and speed.

In fact, Frolich & Kraut (2003) comment on studies of domestic computer use to suggest that computers in the home are often used for leisure time (time that would most probably have otherwise been used for watching television, according to the study). But leisure is, by definition, not first and foremost about efficiency in any wider sense. Likewise, both the strong sales of video games and the economic scale of the Internet pornography industry highlight the reality that domestic computer use is significantly enmeshed with entertainment, which once again tends to make workplace-related studies less directly relevant.

Work may be entertaining, but that is rarely its primary goal, and good design principles for the workplace do not necessarily translate directly into other areas of human concern. Moreover, the last examples mentioned above – video games and porn – also point to the larger social concerns and issues which develop symbiotically alongside such technological developments, since neither of these two are normally considered as entirely beneficial social phenomena. They are, however, very real parts of many people's daily lives.

In contrast with the traditions of computer science and HCI, the design disciplines have always addressed a very broad range of interventions. In the preface to Jones' (1998) *Design methods*, C. Thomas Mitchell coments on the evolution of design from an earlier context involving "[T]he drawing of objects that are then to be built and manufactured" to the more complex "[P]rocess of devising not individual products but whole systems or environments such as airports, transportation, hypermarkets, educational curricula, broadcasting schedules, welfare schemes, banking systems, [and] computer networks" (p. ix). This list includes *public spaces* like airports and stores, workplaces, *private environments* including domestic spaces, and even *abstract spaces* (like the 'problem-space' of an educational curriculum or a welfare scheme) – a very wide spectrum. If less rigorous in their approach, design techniques are perhaps more realistic in their acknowledgement of the diversity of contexts of intervention and the unique character and requirements of each setting.

Interaction design is similarly now being called on to address public spaces, workplaces, and domestic environments. And at the same time, the very tools both used and created by the discipline are changing the nature of the divisions between these very disparate settings (Agre, 2001). Cell phones, email, and the Internet lend themselves to a wide range of uses; if employees sometimes play games and communicate with friends while at work, they also answer email and make phone calls from home, while commuting, and outside of normal office hours. Teleworking is becoming increasingly common, while computer technologies are being developed that specifically target the last refuges of private space, including bathrooms and bedrooms (e.g. Park, Won, Lee & Kim, 2003).

Thus, as a discipline, interaction design must be concerned both with the traditional differentiations and ways of understanding spaces and with the new ways in which contexts are established and maintained by different social groups for different purposes. Designers must also work to understand what the needs and priorities are in different settings and contexts of intervention, striving to retain an acceptable degree of rigor and method while remaining flexible enough to adapt to the specific needs of particular environments.

4.4.2 Pleasure and usability

The computational disciplines' historical emphasis on labs and workplaces may also help to account for some of the other dimensions of this disciplinary collision. For example, there is presently a great deal of interest in better understanding the role of emotion and pleasure in computer use. Recent publications like those by Norman (2004), on the role of emotion in product design, by Jordan (1999), on the significance of pleasure and aesthetics, or that edited by Blythe, Monk, Overbeeke & Wright (2003) – centered on the rather unfortunate term "funology" – all point to a dissatisfaction with narrow interpretations of usability as defined solely in terms of increased functionality and the efficient and timely execution of tasks. Traditional computer science and HCI perspectives have tended to ignore or marginalize such basic human traits as pleasure, aesthetics and emotion. Zhang & Li (2004) provide a particularly useful guide to the literature on this topic.

This relatively new recognition of the importance of emotion and pleasure is related to the diffusion of computers throughout domestic and personal settings, and to the accompanying changes in the commercial forces governing the computer industries. On-line retail, video games and cell phones have generated such massive economic pressures that fashion and entertainment are now recognized (eagerly by industry, often more grudgingly by academics) as part of the new reality of designing with and for computers. And if the metrics of the marketplace do not figure easily in the objective equations of the physical sciences, they nonetheless drive innovation (and sales) in the real world, and are central concerns for funders of industry projects. In practice, interaction designers must balance what will sell, what is fashionable, what is well designed, and what is most usable, all with the goal of creating the best possible products.

A closely related battle, though one fought on slightly different ground, is that of functionality versus aesthetics. Wensveen & Overbeeke (2004) provide an overview of some of the recent research demonstrating that functionality and aesthetics are by no means mutually exclusive but can and should indeed be complementary. But although design as a discipline normally defines itself in relation to art as well as to both science and technology (Findeli, 2000), traditional academic training in human-computer interaction has not necessarily prioritized or valued aesthetics (or even basic principles of graphic design) as a core element of training.

Of course, design training can be similarly caricatured as prioritizing appearance over function and style over substance. But good design, like good work in HCI, must deal with form and function alike, making the best possible compromises wherever needed and whenever possible. It would be foolish to deny that the criteria of efficiency, clarity and ease of use are vital, especially in mission-critical tasks (Rochlin, 1997). There are many well-documented cases in which problems caused – at least in part – by bad interface design have resulted in serious damage to life or property (Wallace & Kuhn, 1999).

Although many forces are involved in such situations, such as the market forces that push for rapid commercialization – sometimes at the expense of stability or reliability – or the institutional forces that will govern the actual use of systems *in situ*, interface design is nonetheless a vital component of these systems. And in this form of design, traditional usability engineering and human factors research methods presently offer best tools for verifying system design in situations where system failure would have catastrophic consequences. Emotion and pleasure may well be of secondary importance in such cases; it would be particularly foolish to replace the dogma of efficiency with one of pleasure. Only the nature of each individual project can determine the project's true requirements.

Interaction designers would seem well advised to be familiar enough with both sides of these arguments to be able to articulate their position in an informed and inclusive way, and to develop positions and choices that are both defensible and reasonable. These issues are unlikely ever to be completely resolved; the tension between form and function, for example, has a long and distinguished history, and it is almost certain that no one universal solution or model will ever apply equally to all aspects and contexts of lived experience. Interaction design may also not lend itself well to being reduced to universally applicable laws and checklists; different projects will have unique, distinct requirements, and the skill and judgement of individuals and teams (supported by methods and methodologies as required) will continue to play a vital role in the success of design interventions.

4.4.3 Sustainable development

> *Design, when nourished by a deep spiritual concern for the planet, environment, and people, results in a moral and ethical viewpoint. Starting from this point of departure will provide the new forms and expressions - the new aesthetic - we are desperately trying to find.*[56]

A very different expression of the disciplinary collision can be found in the positions regarding environmental concerns to be found in the discourses of HCI and design. For example, it is reasonably common for design to be defined in explicitly normative terms. Thus, Jiménez-Narváez (2000) refers to design's concern with the "improvement of the world," and Papanek (1995) to its "spiritual concern," while Simon (1969) famously commented that "[E]veryone designs who devises courses of action aimed at changing existing situations into preferred ones" (p.54), opening the door to a host of questions regarding what is to be preferred and how one should determine and measure such preferences – questions that have both personal and political dimensions.

As part of this normative element in the basic disciplinary definition, design often recognizes broader environmental considerations as part of the overall field of disciplinary concern. Though industrial and social conditions do not always allow these to feature prominently in real projects, as part of academic practice there is some desire to have these factors feature explicitly within disciplinary definitions. Thus, for example, the architectural community, in the 1993 UIA/AIA World Congress of Architects, issued a Declaration of Interdependence for a Sustainable Future[57], stating that,

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[56] Papanek, 1995, p. 235.
[57] Published on the web at http://www.context.org/ICLIB/UIAAIA.htm and accessed on Sept. 14, 2004.

> *We are ecologically interdependent with the whole natural environment. We are socially, culturally, and economically interdependent with all of humanity. Sustainability, in the context of this interdependence, requires partnership, equity, and balance among all parties.*

In this, as in many other theories from the design disciplines, ethics, sustainability, human dignity and a sense of the sanctity of nature and that of human experience co-exist with (and are adapted to) the economic and institutional realities linked with the constant pressure to produce products for sale and consumption. If pragmatics have their role in this – since, as Ozbekhan (1969) puts it, "A planning-relevant framework needs… always to reveal what ought to be done, what can be done, and what actually will be done" (p.124) – such reflections nonethless start from a more fundamental philosophical question: what *ought* to be done.

This is, in principle, not so different from computer science; the Association for Computing Machinery introduces its code of ethics the following:

> ***Contribute to society and human well-being.***
>
> *When designing or implementing systems, computing professionals must attempt to ensure that the products of their efforts will be used in socially responsible ways, will meet social needs, and will avoid harmful effects to health and welfare.*
>
> *In addition to a safe social environment, human well-being includes a safe natural environment. Therefore, computing professionals who design and develop systems must be alert to, and make others aware of, any potential damage to the local or global environment.*[58]

This appears very similar to the architectural equivalent presented above. The differences are thus less related to the respective disciplinary definitions than to the day-to-day reality of ongoing publications and discussions, in which computer science and HCI (and, one might add, interaction design) have remained largely mute on issues of sustainability and environmental awareness.

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[58] Published online at http://www.acm.org/constitution/code.html and accessed on Sept. 19, 2004.

Computer ethics is a fairly active field, though often dissasociated from mainstream computer science and industrial practice. However, its primary focus is on human-centered ethical issues. And the digital library of the ACM (the main professional association for the computational professionals), with its wealth of publications, provides only a tiny handful of texts addressing sustainability, recycling, or other environmental concerns. It has, to understate the case somewhat, not been a hot topic within the discipline, though work such as that of the non-profit Computer Professionals for Social Responsibility[59] provides a limited forum for discussion. Nonetheless, it appears that, at the present time, environmental concerns are even more of a marginal issue in the computational disciplines than they are in the design world.

Designers are often caught between the desire to do good and the desire to do good work, and environmental concerns have not infrequently been more of an academic preoccupation than a pragmatic reality. However, faced with the undeniably real problems of relying on, engaging with, helping to design and eventually disposing of increasing numbers of toxic machines with finite useful lifespans, interaction design – like all other areas directly concerned with the built environment – will be obliged to pose questions regarding the wider, broader, and longer-term consquences of these design activities. This is likely to become even more urgent as a result of the decreasing size and cost of computers, since such trends lend themselves particularly well to the structural logics of disposability and obsolescence.

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[59] Online at http://cpsr.org/issues/env as of Nov. 12, 2004.

4.4.4 Science and design

> *Science tells us how best to do things we have already decided to do, not why we should do them. Its province is the province of means not ends. That is its glory—and its limitation.*[60]

A final – and particularly theoretically challenging – dimension to this disciplinary collision is the nature of the relationships with different scientific communities. HCI, like its parent discipline, computer science, has been relatively successful in maintaining a position close to the physical sciences, and HCI courses are almost always offered within computer science departments. The position of the design disciplines is rather less clearly defined (Petrina, 2000b; McPhee, 1996), as can be seen by the spectrum of schools in which it is taught. These include art schools in some cases and engineering or technical schools in others[61]; design is thus very much an applied science, inasmuch as it is a science at all (Friedman, 1997), albeit one that has adopted many preoccupations (and some methods) from the social sciences.

These different relationships to the traditions of science in turn have some bearing on methods and methodologies. Both interaction design and HCI address two different phases of project development: the process of *designing*, and the process of *testing and validating the results of design activity*. The former issue is more closely related to ongoing dialogues about **design methods**, and the latter to those concerned with **usability**.

Usability, a set of techniques and tactics ensuring that computer devices are easy, safe, understandable and pleasant to use, has become something of a keystone in the scientific foundations of HCI. The relative success and comparatively widespread adoption of usabiity testing (as well as the stronger flavor known as usability engineering) have provided a set of methods and tools that allow both

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[60] Kimball, 1994, p. 42.
[61] A reasonably comprehensive list that shows this range is available at http://www.core77.com/design.edu/ (accessed July 12, 2004).

quantitative and quantitative evaluation of interfaces and tasks, particularly those involving WIMP-based interfaces. And the financial benefits of usability testing are now relatively well documented (e.g. Marcus, 2002) – though not proven beyond any possible dispute[62] – a fact that may offer a degree of institutional leverage for those involved in the design process when the time comes to prove that there is a demonstrable return on investment from design activities – or simply that design has value and should be taken seriously.

But usability can only be evaluated after the fact, once product design or an iteration of the design has been completed. And while iterative design and incremental design are options that may be used when resources and time permit, it remains the case that the actual design must first be carried out before usability testing can truly begin. Nor is this process easy to carry out according to strict scientific principles; Myers (1993), describing the many challenges faced in designing and implementing interfaces, points out that the 'skill of designers' is often as significant a part of the process of design as any particular method or methodology.

Historical attempts to make the design *process* more scientific, as opposed to evaluations of the *results*, have proven challenging both within the design disciplines themselves and within the realm of HCI. From the design end, there have been many attempts to formalize methods, thereby putting the discipline of design on a more scientific footing. But the history of such design methods has been somewhat checkered; in fact, many of the attempts to create formal design methods were later repudiated by their most ardent advocates, including Christopher Alexander (1964), an early proponent of design methods and the creator of the influentual concept of 'pattern languages,' and John Christopher Jones, a leading design methods scholar whose later rejection of such methods

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[62] See http://www.boxesandarrows.com/archives/report_review_nielsennorman_groups_usability_return_on_investment.php, online as of Sept. 19, 2004.

complained about "[C]omputer use, behaviorism, and continued attempts to fix all of life into logical frameworks" (quoted in Bayazit, 2004, p. 21; this text offers an excellent survey of these issues and a substantial guide to the related literature).

At the present time, the scientific status of design methods may be described as *contested*. While method is certainly required and methodologies are regularly used, claims for definitive design methods are fairly muted. Interaction design is no exception; it appears to be evolving as a discipline with, as Dahlbom (1996, p. 43) puts it,

> *[A]n interest in the contingent and exceptional more than in the general, in local design principles more than in general laws, in patents more than in publications, in heuristics and innovations more than in methods and proofs, in the good and beautiful more than in the true.*

Pragmatically speaking, designers must act, whether the scientific justification is complete and rigorous or not. And when used, the research methods that are to inform the design process must be faster and more flexible than those of traditional, rigorous scientific practice. As a result of this, there are certain trends toward ethnography and field research, particularly in the accelerated forms sometimes called 'technomethodology' or 'rapid ethnography' (Crabtree, 2002; Dourish & Button, 1998). It remains, however, uncertain just how scientific such methods are.

And so, if Herbert Simon's (1968) vision of a "science of the artificial" continues to inspire HCI and design alike, it has yet to give rise to a mature, respected, and broadly applicable scientific practice of design that can be applied to the process of creation. Science underpins and provides foundational knowledge for design, and scientific techniques may be used to analyze the results of design activity, but design's deeper relationships to science (not to mention the converse) remain fundamentally uncertain.

4.5 Deeper waters: Concepts of interaction and interactivity

> *Interactivity is something researchers study, new technology commercials promote, and designers create. It's not something people do. People use the internet, watch TV, shop, explore, learn, send and receive email, look things up... The word interactivity and its derivatives are used to represent so many different meanings that the word muddles rather than clarifies the speaker's intent. The construct is worth salvaging carefully so future research more clearly defines the interaction parameters of interest and specifies what aspect(s) of interactivity are being examined.*[63]

Although there are doubtless other dimensions to this collision, the above examples give an idea of some of the different areas of debate and discourse. But beyond these challenging questions, an even deeper issue underpins this discussion: a surprising lack of clarity about what the words "interaction" and "interactivity" actually mean.

Graphic design activity is concerned with the creation and production of graphics, however broadly construed that may be (perhaps including perception, psychology, optics and the like); product design with the world of products; and exhibit design with that of exhibits. So what is an 'interaction'? With what range of goals, needs, and desires does it engage, and what substances and materials are involved in its creation? How can one establish limits and boundaries, precedents and examples, and trends to watch in the future?

As it turns out, substantial problems must be confronted in attempting to deal with this question. Many attempts have been made to characterize, define, or provide typologies of interaction and interactivity; consider, for example, Jee & Lee's (2002) extensively referenced list :

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[63] Heeter, 2000.

The complex nature of interactivity itself may have contributed to the lack of agreement (Cho and Leckenby 1997; Wu 2000). Over the years, researchers have studied interactivity as a part of the communication process (e.g., Blattberg and Deighton 1991; Kirsch 1997; Milheim 1996), medium characteristic (e.g., Hoffman and Novak 1996; Steuer 1992), communication system property (e.g., Neuman 1991; Rice 1984), individual trait (e.g., Chen 1984), psychological state (e.g., Newhagen, Corders, and Levy 1995), and variable characteristic of communication settings (e.g., Rafaeli 1988). There have also been propositions that interactivity should be considered as a multidimensional construct (e.g., Fortin 1997; Heeter 1989; Williams, Rice, and Rogers 1988).

But even after wading through and digesting these and many other attempts to delineate and define interactivity (like those of Svanaes, 2000; Shedroff, 1999; or Steed, 1996), the terms still remain astonishingly vague and unclear. While there are doubtless many reasons for this, two appear particularly significant: the problem of natural language meanings, and the totalizing discourse that has often been associated with computational research.

4.5.1 Natural language meanings

interact: act in such a way as to have an effect on each other
interaction: reciprocal action or influence
interactive: (of two people or things) influencing or having an effect on each other;
(of a computer or other electronic device) allowing a two-way flow of information between it and a user, responding to the user's input.[64]

The first difficulty encountered in trying to define "interaction" is quite simple: the word has a wide range of natural language meanings borrowed from everyday life. While 'interactivity' is something of a neologism, 'interact' and 'interaction' have been perfectly respectable English words since at least the middle of the 19th century, and their Latin roots give them a distinguished etymological heritage. They are words so intimately familiar that no one pauses to question their meaning. But when more closely examined within the context of new technologies, their

[64] Adapted from The New Oxford Dictonary of English, 1998, p. 950.

meanings are far from clear, and attempts to clarify them have been generally unsuccessful; consider, for example, Heeter's (2000, unpaginated) suggestion that

> *An interaction is an episode or series of episodes of physical actions and reactions of an embodied human with the world, including the environment and objects and beings in the world. These actions and reactions are actual interactions, a subset of the range of potential interactions of the human and the world at that time and place.*

The confusion (and vast scope) of this and other definitions of interaction seem to be related to a basic linguistic uncertainty: in the course of normal lived experience, kinds of interactions with which everyone is familiar include *physical* interactions between objects, like a cup placed on a table; *social* interactions, like a conversation with a friend; and *abstract* and *symbolic* interactions, like the interplay between stocks traded on the financial markets.

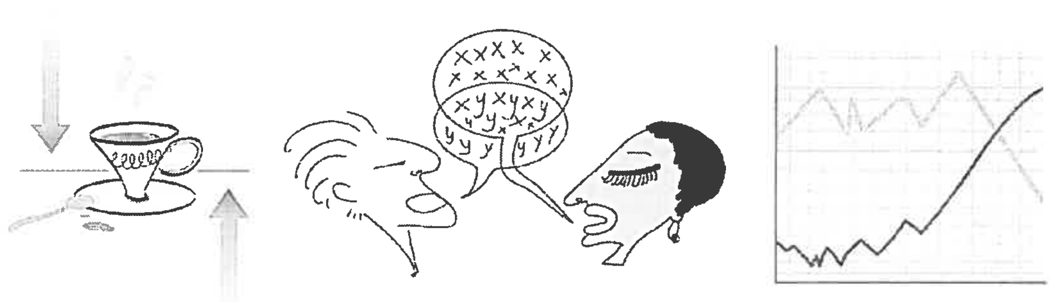

Figure 16: "Interactions"[65]

And computers undoubtedly engage with, magnify, and alter all of these forms of interaction. From the original role of computational machines as calculators of ballistics trajectories (Edwards, 1996) to the minute precision of contemporary computer numerically controlled (CNC) manufacturing processes, computers have provided ever more detailed and rapid control over *physical* parameters (Murray, 2003). Simultaneously, new communication technologies that rely on the speed and precision of computers and data processing devices are indisputably contributing

[65] Image courtesy of L. McCubbin.

to new patterns of *social mobility and communication* (Crabtree et al, 2002). And finally, databases and the widespread availability of rapid calculation have profoundly altered banking, investment, and similar practices involving *abstract symbolic* exchange, storage, and calculation (Kaitovaara & Nurminen, 2002).

But in each of these cases, the forms of engagement and the modes of interaction are radically different. It is, in fact, only at an extremely abstract level (a purely technical level, where the phenomena are described as information exchanges or energy transfers) that one can find a common ground allowing these activities to be described as similar in any meaningful way, and substantial differences still remain. This does not prevent them from being conflated and confused; thus, for example, Díaz-Pérez & Rossi (2003, p. 2) suggest that

> *The phenomenon of interaction is present in all activities of our lives, whether it involves objects or human beings. From the moment we get up till it is time to go to bed again we are constantly interacting with the objects around us in order to achieve some specic purpose: our breakfast cup of coffee, the car we drive to go somewhere, the fork we eat with or the bed we sleep in.*

The term 'interactivity' has the same etymological root and shares many of the same problems. The range of objects, events, and experiences that can be described as 'interactive' is vast, especially if 'interacting' is taken to mean nothing more than any relationship of mutual influence. In this broader sense, quarks and electrons could surely be described as interacting with one another; as might cells, viruses, and bacteria, animals and plants, humans, planets, and stars (not to mention beds, forks, cups of coffee and human beings). In sum, the universe that is described by contemporary physics, biology, economics and ecology is, in such an interpretation, one that is profoundly and essentially interactive.

The natural language meanings with which this term resonates are, in short, extremely confusing. If everything, everywhere is always already interacting, what would it mean to design an interaction? To put it another way, what could it possibly mean to design something which would *not* be interactive? And what, if anything, remains of the unique role of human beings in such interactions? Noted cognitive scientist David Kirsh (1997, p. 83) draws particular attention to this last point, suggesting that

> *If we consider examples of interactivity in daily life, our clearest examples come from social contexts: a conversation, playing a game of tennis, dancing a waltz, dressing a child, performing as a member in a quartet, reacting to the audience in improv theater.*

When more carefully considered, this is actually a very curious comment; it is actually quite difficult to imagine anything less inherently technological (or, for that matter, less like using a computer) than "dressing a child," except perhaps "reacting to the audience in improv theatre." And while there may be some merit to the metaphorical use of these examples as exemplary of the kind of encounters or sentiments designers should seek to produce, there is another issue that underlies the use of these profoundly human examples. This leads to a final challenge in defining interactivity – one more philosophical in its origins.

4.5.2 Limitless computation?

> *The mind is a computational system, the brain literally performs computations (which are sufficient for intelligence), and these are identical with computations that could occur in computers.*

The above quote is Margaret Boden's (1990, p. 7) summary of the artificial intelligence theories propounded by influential researchers Allen Newell and Herbert Simon. Their position is exemplary of the so-called "hard" or "strong" AI theories of the 1950s and 1960s, brimming with technological enthusiasm and bold predictions that computational processes would soon overtake language, thought, and consciousness. Simon & Newell's (1958, p.19) original clarion call sums up this position – a prognosis that has not aged particularly gracefully:

> *It is not my aim to surprise or shock you... [b]ut the simplest way I can summarize is to say that there are now in the world machines that think, that learn and create. Moreover, their ability to do these things is going to increase rapidly until—in the visible future—the range of problems they can handle will be co-extensive with the range to which the human mind has been applied.*

This early wave of research activity appears not to have yielded the results that were originally anticipated; not only are there no robotic butlers on the market as of 2005, but even seemingly simpler tasks, such as robust and reliable speech recognition, have proven far more challenging than were foreseen at the time. And the indisputable successes of modern computation appear to be much more closely linked to massive calculation than to the creation of "intelligence" in the conscious and human sense of the word.

However, such 'strong' artificial intelligence theories are still alive, and have been given a contemporary makeover in recent works like Kurzweill (1999) and Wolfram (2001); or again in Supercomputing and the human endeavour (2002). The certainty that humans will be able to manufacture consciousness seems to transcend logic and pass into some strange netherworld of science-based faith.

At the same time, it is certainly undeniable that computation has proven to be a powerful tool for exploring consciousness. The model of the human being as an 'information processor' is still widely used in the disciplines of cognitive science, cognitive psychology, and human factors;[66] the diagram reproduced below makes this analogy between human systems and computational systems particularly clear.

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[66] See, for example, the discussion and bibliography in Sanders & McCormack (1993), pp. 61-85.

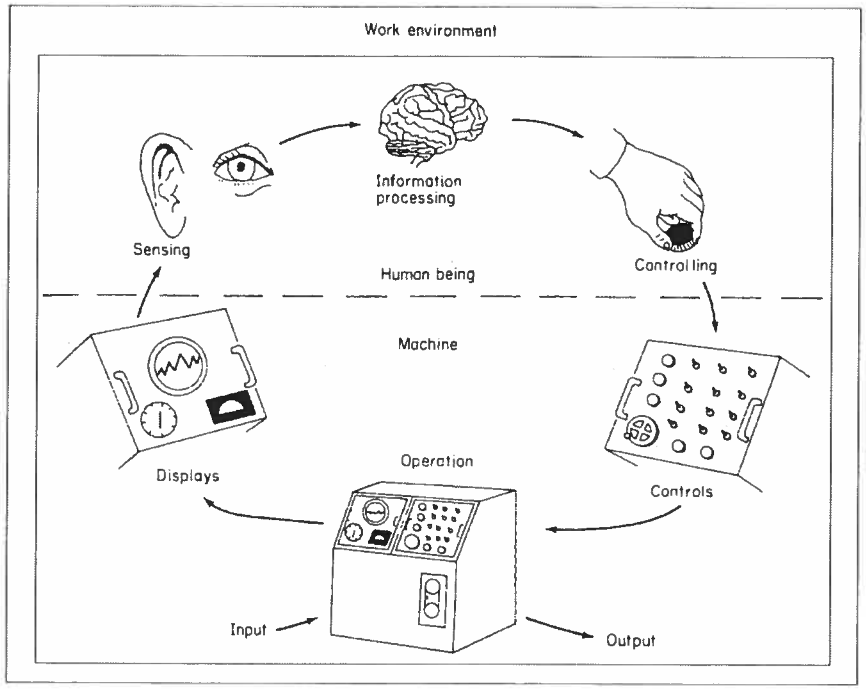

Figure 17: Humans as information processors[67]

However, the "hard" claims of early artificial intelligence researchers (and their contemporary disciples) were rather dogmatic in their materialism, going beyond mere analogy into the realm of the ontological. Computers are necessarily conscious, they claimed, since consciousness is essentially, profoundly and fundamentally computational. From such a viewpoint, to return to Kirsh's earlier comment, "dressing a child" does indeed become something very much like "using a computer", since an interaction is no more than an interaction – and the line in the image above represents a mirror, not an analogy, and still less a division.

At the same time, whatever one's beliefs on this subject (and all dogma aside) it is certainly the case that all the dotted lines that separate humans from machines are getting thinner; as Margolin (1995, p. 354) points out,

[67] Reproduced from Sanders & McCormick (1993), p.15.

> *As artificial beings like cyborgs or replicants more closely represent what we have always thought a human is, we are hard pressed to define the difference between us and them. This is the problem that Donna Haraway addressed with her myth of the cyborg, which draws humans into a closer relation with machines. 'No objects, spaces, or bodies are sacred in themselves,' she argued in* A Manifesto for Cyborgs; *'[A]ny component can be interfaced with any other if the proper standard, the proper code, can be constructed for processing signals in a common language.'*

In other words, all that is required to plug human and machine together is an interface – not a passive space, but rather an active zone where the two elements are transformed into equivalent and equal forms. Again, computers are seen less as a tool or an object; they become extensions of humanity that blend seamlessly with bodies and minds.

These processes of transformation and exchange are in turn tied to the concept of information itself, the insubstantial substance at the heart of information technologies and the language that permits this translation between very different forms of signals. As Taylor (2003, p.4) points out, information is not what it used to be; in fact, in the modern understanding of the term,

> *Information is not limited to data transmitted on wireless and fiber-optic networks or broadcast on media networks. Many physical, chemical, and biological processes are also information processes.*

Here too exists a substantial terminological challenge; there is a wide gap between the 'common-sense' meaning of information – the way it is habitually understood in everyday life – and the more specific meaning of 'information' as used in the technological domain (Borgmann, 1999), and more particularly in scientific discourses based on the pioneering telecommunications work of Shannon & Weaver (1964).

The technical details of this gap are beyond the scope of the current paper; suffice it to say that, from this more scientific point of view, information is now treated very much as a force of nature. And as Mahoney (2002, p. 26) suggests, this force both builds on and extends existing scientific paradigms; in other words,

> *While the laws of thermodynamics remain in force, they are supplemented by the laws of information and computation, which define limits and possibilities of a different kind. In one area after another, from genetics to psychology, scientists see the world as running code, and they seek to work in the world through that code.*

Thus, through a series of transitions linked to a particular interpretation of information, computation moves from a purely mathematical process, to an all-encompassing process seen as governing biological and physical processes alike, and finally to an elemental force of nature seen as potentially capable of accounting for thought and consciousness itself. Through this movement, the scope of information and information technologies expands virtually without limits, engulfing everything from rain and gravity to conversations and finance.

Likewise, computers may be tools that extend human capacities, or devices that become part of the body and mind, or perhaps even conscious entities that are fundamentally similar to humans. Nor are these strange theories the exclusive purview of science fiction authors; many leading scientists and researchers have published extensively on these topics. Given this morass, then, it is not surprising that interactivity should be hard to define.

4.5.3 Stepping back

Of course, none of this kind of speculation will directly help anyone make a better Web page, Internet site or software interface, the activities most often carried out by contemporary interaction designers. And these last comments move particularly far from the realm of practice, into a grey zone where philosophies of science and the limits of scientific knowledge are bound together in a space of abstraction that is of primarily academic interest.

Nor does such debate clearly define interaction or interactivity; indeed, it raises many more questions than it answers. Nevertheless, these theoretical and terminological issues are of disciplinary importance for at least three reasons: firstly, they appear to condition the ways in which vocabularies are built up and discourse is framed and constructed, and may thus help to account for at least some of the misunderstandings and general lack of clarity about interaction. Ontologies and metaphysics do underpin the construction of vocabularies, and the haze of uncertainty surrounding information, technology and information technologies makes it particularly easy to be terminologically and conceptually vague.

Furthermore, there are many disciplinary preconceptions in both the design and computational literatures that can make it difficult to decipher what is actually being said and what is at stake. The issue of artificial intelligence, for example, arises surprisingly frequently in the computational literature, given that there is so little evidence of concrete results in the realm of everyday lived experience. When trying to make sense of the limits of the computational medium, through examination of the different literatures and histories, it becomes necessary to have some understanding of these issues as well as how they fit into a broader picture.

The second reason is closely related: when the time comes to teach or explain what it is that interaction designers do, it will be necessary to have some idea of what interaction actually is. As Findeli (2000) has pointed out, having a model of design is essential for teaching design; this is no less true for interaction design than for any other aspect of the discipline. Design is already complex enough as a term, and its inherent uncertainties are only compounded by the addition of fashionable but ill-defined terms – like interaction – invoked in such a way as to mean all things to all people. Nor does it help to define such concepts in purely technological terms, since the limits of these technologies are constantly shifting, and their eventual limits are quite simply unknown.

The third and final reason is historical. When seen from even a very short-term historical perspective, the development of information technologies, the rise of the

Internet and the spread of computation are all phenomena that have taken place during amazingly short periods of time. During this brief period, the technical transformations have been truly remarkable. It would be extremely short-sighted to believe that this transformation has come to an end, or even that it has reached any stable state. Interaction (like design itself) is not a thing but a process, and an evolving process at that. For it to become a discipline, it must be understood both in terms of what it is, what it has been, and what it may become—as well as what it is not.

For the purposes of the present work, it suffices to raise these insoluble philosophical issues as a reminder of the extent to which terminological and disciplinary uncertainties are linked to more deeply rooted ontological choices – and as a way of showing the challenges involved in any definitive description.

4.6 Conclusion: an emerging discipline

Interaction design, like other design disciplines, unfolds at the junction of science, engineering, and art; it is likewise enmeshed in the pragmatic realities of rapidly changing and evolving industrial and corporate cultures. The phrase refers both to an academic discipline and to a professional practice, and both practice and discipline appear likely to continue to rapidly evolve in a complex and symbiotic relationship with the powerful cultural, sociological and economic forces linked with information and communication technologies.

The academic fields that have contributed most directly to interaction design are human-computer interaction (itself a complex and multidisciplinary discipline) and design (certainly no less complex), especially industrial and graphic design. There are distinct differences between these disciplines, in terms of approaches, goals, traditions and methods, and these differences in turn contribute to the difficulties in communicating both about interaction and about design.

At least two major challenges must be addressed in understanding and delimiting interaction. First, there is the problem of the natural language associations of the terms 'interaction' and 'interactive,' which, if not carefully managed, expand the range of potential 'interactions' to include practically everything – especially given that 'interactive' seems to be a word that magically helps to sell products.

Secondly, attempts to define interaction in exclusively technological terms move the discussion squarely into the midst of ongoing computer science and artificial intelligence debates over the nature of computation, consciousness and experience itself – debates that seem unlikely to reach any closure in the short term.

A much more pragmatic approach is to look at the technological underpinnings and structural characteristics of interaction design activities. While by no means solely technological in scope or intent, certain technical characteristics are particular to interactive systems, especially with regard to the hardware that supports and shapes such systems. Accordingly, the following section will examine the structure of interaction, looking more closely at the various components that make up such systems, and once again placing a special emphasis on vocabulary and terminology.

5. Dimensions of interaction

Two parallel universes exist today – the everyday analog universe we inhabit, and a newer digital universe created by humans, but inhabited by digital machines. We visit this digital world by peering through the portholes of our computer screens, and we manipulate it with keyboard and mouse much as a nuclear technician works with radioactive materials via glovebox and manipulator arms. Our machines manipulate the digital world directly, but they are rarely aware of the analog world that surrounds their cyberspace. Now we are handing sensory organs and manipulators to the machines and inviting them to enter analog reality.[68]

[68] Institute for the Future, 1997, p. 120.

5.1 Overview: Spaces, places, users and machines

> *The ideal designer of an interactive system would have expertise in a range of topics: psychology and cognitive science to give her knowledge of the user's perceptual, cognitive and problem-solving skills; ergonomics for the user's physical capabilities; sociology to help her understand the wider context of the interaction; computer science and engineering to be able to build the necessary technology; business to be able to market it; graphic design to produce an effective interface presentation; technical writing to produce the manuals; and so it goes on.*[69]

The design of interaction and interactivity involves the creation and conception of devices and systems that allow and facilitate engagements with and through computation in the service of human needs and desires. And as the above quote suggests, such interventions may be informed by a vast, diverse and growing body of knowledge. Thus, complex and proprietary vocabularies are developing to help describe and understand these devices, systems and contexts, as well as the technologically mediated experiences that result from computational engagements. However, these vocabularies vary somewhat from discipline to discipline, and are not always clear or consistent even within individual fields of study (Bannon, 1997).

In order to address this issue, the following sections provide a brief introduction to some of the most commonly encountered terms used to explain and describe this new technological realm. Based on this, a model of interaction is presented, following which each of the constitutive elements are discussed in greater detail, anchoring the terms in more specific disciplinary concerns and preoccupations. Since each of these topics has an extensive body of associated literature, this text will do no more than survey some of the most significant concepts and keywords from the lexicon of interaction; some of the other shortcomings of the proposed model are addressed at the end of the chapter.

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[69] Dix, Finlay, Abowd, & Beale, 1993, p. 3.

5.1.1 Contexts

All interactions take place within physical, cultural, and social environments, and acquiring an understanding of these environments generally forms an important part of the design process. In computational discourse, the term "context" is frequently used to refer to these different settings, or at least to those aspects identified as most relevant to the design and analysis of human encounters with computer systems. Several different concepts are encapsulated in this term, and two of these will be addressed in the following chapter.

Firstly, although globalization appears to be creating a degree of worldwide homogeneity (with computers playing a central role in this trend), cultural and socio-cultural differences nonetheless remain important factors in the use and interpretation of systems. Thus, cultural factors – of which language is the most evident – are now widely recognized as an important part of system design, and most recent models of context accordingly include some reference to culture.

Secondly, context may also refer to physical environments, social surroundings or a combination of the two; the distinction between 'spaces' and 'places,' long employed in environmental psychology and the design disciplines, is often used to distinguish between the physical and social aspects of environments and situations.

5.1.2 Users and user experiences

Within these contexts, 'users' is the term that is most frequently employed to refer to the people who put these objects and systems to use. However, since computers are now used in very diverse settings by extremely varied social and professional groups in order to achieve many different ends, the concept of a universal, abstracted 'user' is somewhat problematic. On the other hand, certain aspects of human existence remain comparable, at least in statistical terms. These include physical characteristics like those described by anthropometrics, human factors and ergonomics, as well as mental characteristics like those addressed by psychology, information processing and cognitive ergonomics. This range of possible interpretations, from the most universal to the particular and situated, generates some internal tension within the concept of the "user."

One point of agreement is that users are those who use systems. And this use in turn anchors the phenomenological and experiential dimensions of such technological encounters, most commonly referred to as "user experience." Again, there are few terms that are more personal or more difficult to define than "experience," but engagements with computer systems certainly have some novel characteristics, and a vocabulary is emerging to help describe these. This lexicon includes the concepts of *immersion*, *presence* and *flow*.

5.1.3 Interfaces and beyond

Finally, at the physical and tangible level where interaction designers most directly act, user experiences involve engagements with a wide range of electronic and electromechanical devices and systems. Although very diverse, these systems have certain structural characteristics that are not identical to those of previously existing machines; perhaps most importantly, they can be considered as being constructed from three primary components, which can be called the *enter*, the *outer*, and the *inner*.

Firstly, systems have some way of extracting or receiving information from the outside world; this will normally – though not always – involve some level of direct human control or input. Although this is often called the 'interface' or 'input,' there are some challenging ambiguities associated with these terms. The term 'enterface' is thus proposed as a way of referring to a broader spectrum of input devices than has traditionally been associated with the concept of the 'interface.'

Secondly, systems have a range of different ways of providing output – information or sensory stimuli – to human participants and operators. They will normally provide some form of feedback, whether visible, audible, tactile, or a combination of sensory forms. Though this has most often been associated with images and text displayed on a CRT or LCD monitor (and sometimes with sound and audio as well), many other options are now available, and the term 'outerface' is proposed as a way of describing this range of output options.

And lastly, between these two physical parts of the system – between input and output, action and reaction – is a series of invisible transformations, or mappings, that will dictate the semiotic structure of the system. Input signals (whether generated by humans or other sources) are interpreted, transformed, compared, and potentially stored or sent to another machine or machines, in either raw or processed form. This series of processes results in a combination of distributed information-processing events (potentially extremely complex as well as geographically extended) that finally give rise to the system responses. This internal processing can be called the 'innerface'—the hidden workings of the machine.

5.2 The structure of interaction

Below is a schematic model of a structure that helps situate the different elements listed above. It is similar to the 'man-machine' schemas of, for example, Figure 17 (p. 98) but with a few significant changes, most notably the inclusion of different forms of context, the focus on the points of transformation and transduction that bridge the physical, electrical, and electronic realms, and the proposal of a new terminology to describe the increasingly broad range of human-facing input and output devices.

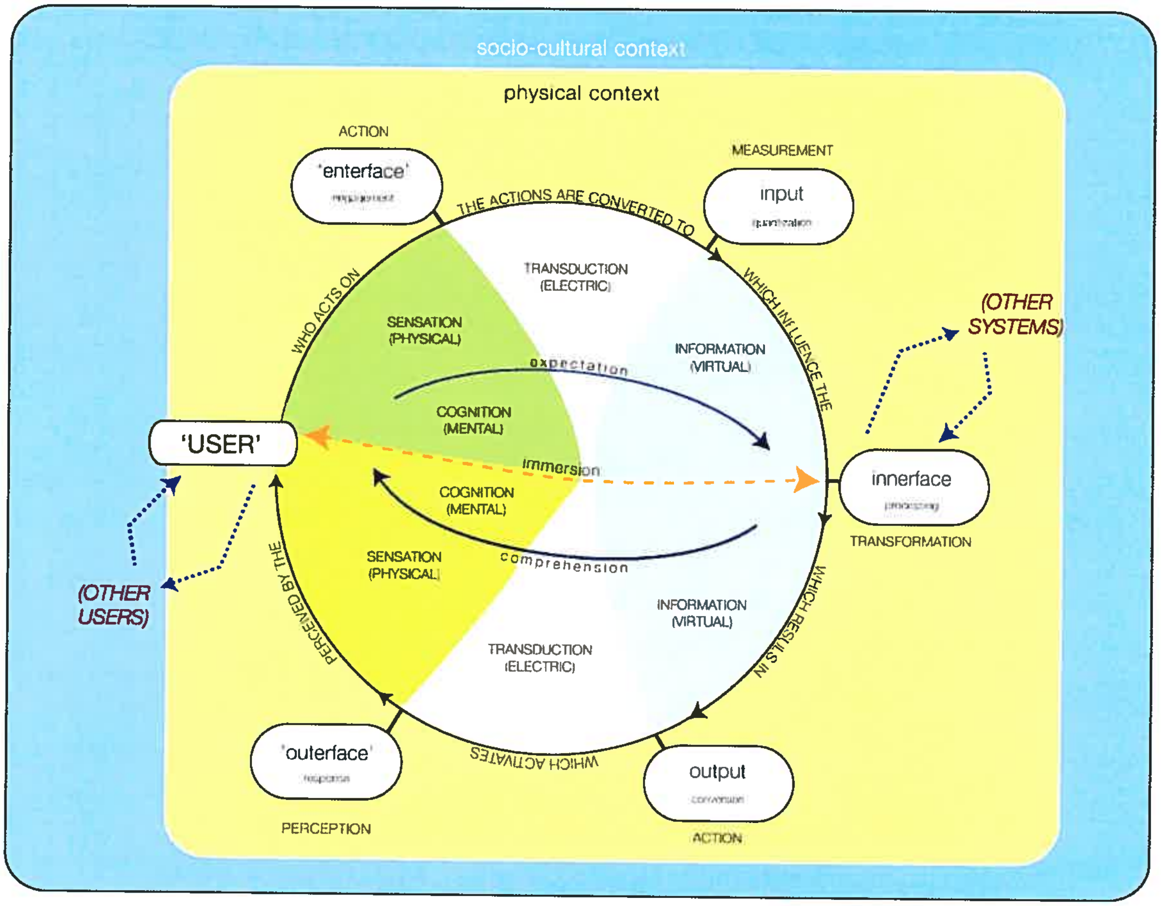

Figure 18: A model of interaction

A brief discussion of the various key terms used in this model will help to illustrate some of the scope of discourse involved with each of these. This chapter is thus something of a conceptual guide to the vocabulary of interaction design, and this discussion begins with the wide-ranging concept of 'context' – everything surrounding encounters between humans and computers.

5.2.1 Context

> *How can we confront the blooming, buzzing confusion that is "context" and still produce generalizable research results?*[69]

Context describes the setting for action, the backdrop against which human activities take place; the factors that comprise context may be physical, social,

[69] Nardi, 1996, p. 70.

institutional, cultural or some combination of the above. At a minimum, context will include the sum of everything studied in the information gathering and research phases that take place at the outset of the design process and that inform the 'problem-space' within which an design intervention or project is situated.

The study of context has for several years been common in many different computer-related disciplines, and there is presently a very active field of research known as "context-aware computing" (Moran & Dourish, 2001; Salber, 2000). However, the particular way that this term is employed within these computational discourses is not identical to the intuitive way in which it is generally understood in everyday life (Brézillion 1999), nor yet to the way it is understood in the design disciplines, in which it is rarely analyzed to the same degree of precision.[71]

The remarkably fine grain of detail in computational definitions of this term is made clear in one of the most frequently cited of these formulations, that of Dey, Salver, & Abowd (2001, p. 106), who suggest that context refers to

> *[A]ny information that can be used to characterize the situation of entities (i.e. whether a person, place or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves. Context is typically the location, identity and state of people, groups and computational and physical objects.*

This definition is clearly conditioned by the particular requirements of computer systems, and more specifically by the need to encode data—that is to say, properties such as location, state, and identity – in the form of measurable and numerically representable variables (Schmidt, 2002; Agre, 2001).

However, this and similar definitions have also proven rather challenging to put into practice in more than rudimentary form. How, for example, does one describe the 'state' of 'people' in any meaningful, computer-detectable sense? How are limits to

[71] The discussion of site analysis in Xu (2003) provides a good example of the level of detail in traditional design analysis of context.

be set on what will be considered as relevant, especially as regards the user? In practice, choices are made to select particular aspects that are judged as pertinent to some particular situation, often meaning those that can be readily extracted from the setting at a reasonable cost and with acceptable levels of physical and mental intrusion.

As another example of the sweeping nature of computational definitions of context, consider the following figure, from Schmidt (2002, p. 29). This shows a model of a proposed 'context feature space,' something of a comprehensive map of all possible knowledge about a particular situation at a given moment in time.

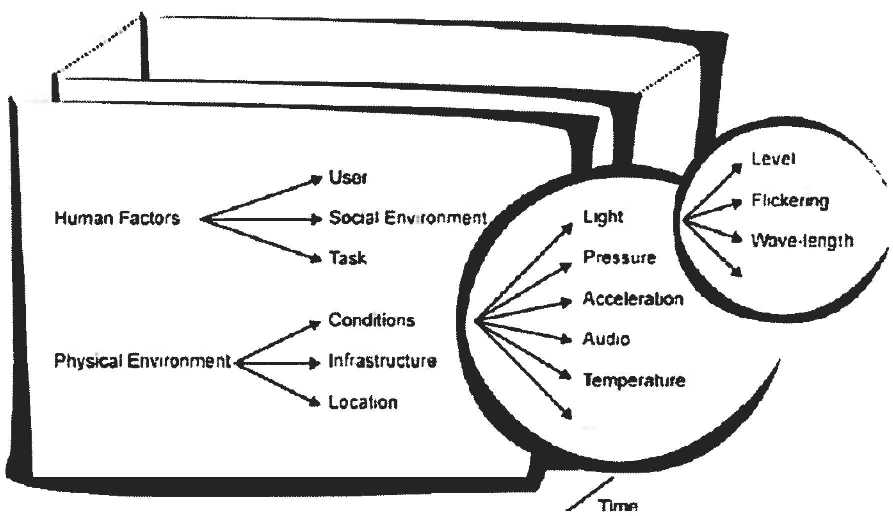

Figure 19: Context feature space, from Schmidt (2002)

The enlargements on the right-hand side of the diagram focus on an external, physical phenomenon – 'light' – rather than on the 'human factors.' But these factors, including the 'user,' are nevertheless presented as apparently subdivisible categories that – like 'conditions,' 'light,' or 'wavelength' – could in turn be divided and subcategorized to an arbitrary degree of precision. This highlights a substantial challenge in these models of context: beyond the physical attributes (which, like 'location,' may not be as straightforward as it appears), context is defined in terms of the limits to which information concerning human activities, thoughts, emotions, tasks and social relationships can be measured, extracted, analyzed, comprehended, and categorized – and eventually used as inputs to computer systems.

This interpretation of context is thus at once sweepingly vast and minutely detailed, a combination that offers little hope for closure. When actually engaged in designing, it is only possible to take into account smaller subsets that cannot hope to achieve this level of total detail. One way of structuring this, which helps to situate many of the key issues from the interaction design literature, is to distinguish between *cultural* context, *physical* context, and *social* context.

5.2.1.1 Cultural context

> *The social subject is neither wholly determined nor wholly free, and the constraining factor is the weight of cultural history – conventions about the division of labor, gender, and generational roles, relationships to authority, etc... From this perspective, the understanding of and interaction with media can only be understood as a situated phenomenon that manifests available cultural practices (from the domestic to the global) and the dominant forces that shape them.*[72]

The relationship between culture and computer technologies is complex and densely entangled. If culture is disseminated and created using technologies, technologies also help to shape culture; what is more, these relationships are neither linear nor causal, but are rather dynamic, organic and heterogeneous (Ess, 2003). Furthermore, it is true that the contemporary trends toward globalization, facilitated and accelerated by new media and new technologies, have generated fears of cultural homogenization (a topic with a substantial literature; a succinct overview can be found in O'Loughlin, Staeheli, & Greenberg, 2004). However, despite the shrinking of the planet wrought by new technologies of transport and communication, it is clear that there remain substantial differences between

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[72] Berry-Flint, 2002, p. 13.

different societies and cultures, and that these differences affect both interpretations and experience.

Thus, even the most pragmatic, action-oriented models of human behavior – like the cybernetic Observation-Orientation-Decision-Action (OODA) loop popular with both military and business strategists (Commission on Physical Sciences, Mathematics, and Applications, 2000; Bridges, 2004) and reproduced below as Figure 20 – will leave a space for 'cultural traditions' as part of the complex interplay between information flows, genetic heritage and individual thought, analysis and choice that make up the 'unfolding interaction with the environment' in which computers play increasingly significant roles.

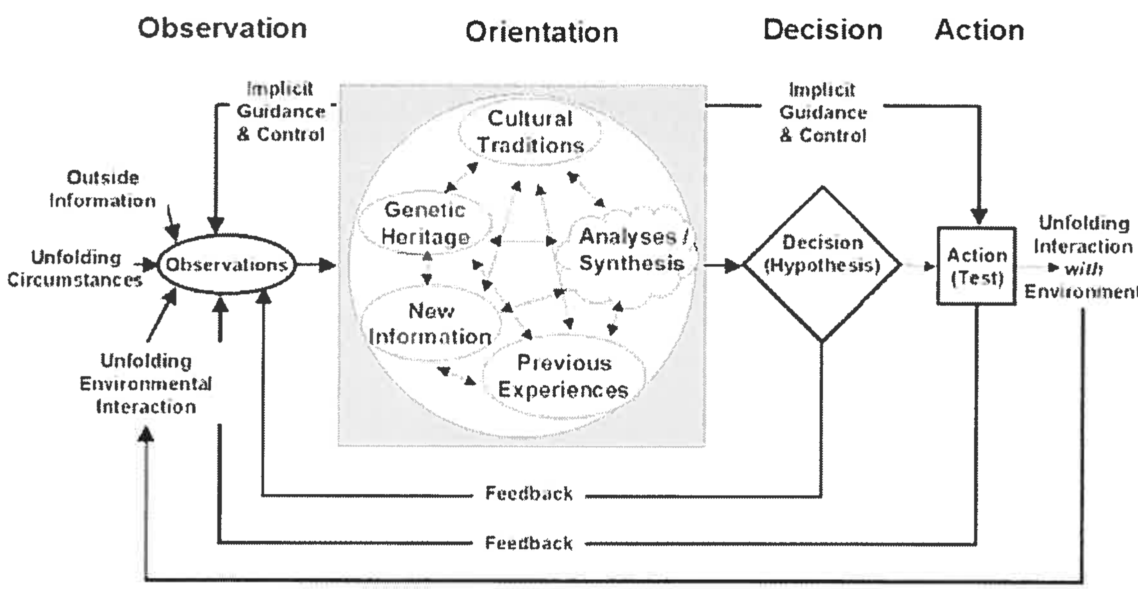

Figure 20: The OODA model, from Bridges (2004).

Such cultural effects may take many different forms, including the many issues (by no means straightforward) linked to language itself. There are no shortage of other cases to illustrate cultural differences; one simple example is the emotional associations of particular colors, as is the case with marriage gowns, traditionally red in China but white in Europe and North America (Sloane, 1989). Such historically rooted (and thus in some sense arbitrary) traditions have practical implications, such as the association of moods and emotions with particular colors and events. To continue the above example, it cannot be taken as a given that everyone, everywhere will “know” that white is a inherent symbol of purity, nor that red denotes anger. There are substantial if uncertain limits to the universality of meanings and interpretations across (and sometimes even within) cultures, and these limits figure as part of the scope and challenge of interaction design.

Hamelink (1997, p.8) draws attention to some of the other challenges that are brought into increasingly sharp relief by the ease of information flow in the modern industrialized, networked world, with its boundaries less sharply determined by geography and history:

> *With more information available in digital form, there will also be more information that people would prefer to have censored: the transnational nature of digital networks creates situations in which information is illicit in the sending country and perfectly acceptable in the receiving country, or vice versa. Although this has always been the case to some extent, the sheer velocity and flexibility of information transmission now make border controls less realistic than ever before.*

The need to find ways and methods of designing for increasingly geographically dispersed and culturally diverse audiences is an important issue in modern design practice (Vatrapu, 2002). Information designers, Web designers and interaction designers are obliged to face these issues particularly directly, since the unprecedented global reach and immediacy of access to the vast quantities of information available via the Internet means that there is now a great deal of interplay between graphic and visual norms that may have originated in other cultures, while designers may well have only a limited knowledge and understanding of their potentially widely dispersed audiences.

Some of the larger companies doing business on the Internet (Amazon, eBay, and the like) have addressed this through a range of strategies at the institutional scale; Perrault & Gregory (2000, p. 230) identify three of these:

Globalization
The adaptation of marketing strategies to regional requirements of all kinds (e.g. cultural, legal, and linguistic).

Internationalization
The engineering of a product (usually software) to enable efficient adaptation of the product to local requirements.

Localization
The adaptation of a product to a target language and culture (locale).

While not necessarily addressing more profound or subtle issues of cultural identity, such tactics offer ways of avoiding at least the worst errors of ignorance, like those that led to Microsoft's admission[73] that basic geographical and cultural errors incorporated in a number of software packages had cost the company millions of dollars.

In a somewhat more detailed study of this issue, Marcus & Gould (2000) provide an analysis of socio-cultural context, using a model originally developed by Dutch theorist Geert Hofstede. This latter model addresses much subtler forms of cultural difference, such as the variations in power relations (often linked to gender) that are accepted as norms in different societies. Such analyses provide a more thorough conceptual framework for understanding cultural differences, but do not offer any fixed set of rules for designing across the boundaries between cultures, societies, regions, and demographics. They offer the possibility of being more sensitive to local issues, but no clear-cut methodology that will guarantee universal success.

And since computers are not yet automatically able to reliably and consistently translate even the written word, much less the subtleties of spoken words or complex imagery, communication among and across cultures remains something

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[73] Paul Brown, of the Guardian, reports on some of the recent cultural issues concerning Microsoft products at http://www.guardian.co.uk/uk_news/story/0,3604,1285890,00.html (accessed on Sept. 19, 2004); "Perhaps the best known, and one of the most expensive, errors was a colour-coded world map showing time zones, which showed the disputed Jammu-Kashmir region as not being in India—an offence under Indian law. The mistake led to the whole of the Windows 95 operating system being banned in the country, losing large sales. For its replacement…Microsoft removed the colour coding and sold 100,000 copies in India."

to which humans must attend. Such design work requires some background knowledge, a good deal of sensitivity and a degree of pragmatism – with perhaps even an occasional tinge of nostalgia when faced with the increasing global homogenization of fashions, goods and services, and the erosion of languages, cultures and traditions.

Basic, profound questions of alterity underpin this issue: to what extent is human experience universal? To what extent do culture, language, and environmental factors fundamentally affect experience? No simple answers to these questions are to be found; physical context, by comparison, provides somewhat more solid foundations, together with the possibility of more universal factors.

5.2.1.2 Space and place: physical and social context

It remains very difficult to draw a clear line between the cultural, social and physical aspects of environments and contexts. Concepts like 'work' and 'home' are complex constructs that include social, personal and physical characteristics, all of which are in turn influenced by multiple strata of culture and history (including both geographical and institutional factors, e.g. Agre, 2001) as well as by individual choice. Furthermore, the growing personal mobility faciliated by computational devices like portable computers and PDAs, together with the social trends toward 'digital nomadism' and increasing physical travel (Hoete, 2003), are putting many traditional spatial, functional and cultural boundaries into question.

Nonetheless, there remain important distinctions between the social and physical realms. One such distinction is quite simply *measurability.* Using the languages and techniques of science, mathematics, and engineering, it is now possible to sense and measure many of the physical attributes of environments with a very high degree of precision, but social aspects (both personal and institutional) remain much subtler and harder to capture parametrically.

The distinction between 'spaces' and 'places' is often employed as a way of differentiating the physical and quantitative parameters of environments from the more personal, emotional and affective dimensions that help shape the human experiences unfolding within these settings. Harrison & Dourish (1996, p. 68; italics in the original), define these as follows:

> Place *is the concept of space inextricably linked with the wealth of human experiences and use occurring within it: Place is a space which is invested with understandings of behavioral appropriateness, cultural expectations and so forth. We are located in space, but we act in place.*

This model, as well as the terminology of spaces and places, are commonplace (indeed, to the point of being taken for granted) in the design disciplines as well as in other pertinent fields like geography and environmental psychology; in comparison, the computational disciplines seem only recently to have discovered the need for this distinction. In such readings, places are not treated as physical containers for users and tasks, but rather as settings – both social and personal – that are rich with memory and emotional resonances, and imbued with potential for actions and tasks.

But objective spaces are much easier to measure (and thus to use directly as part of computational systems) than subjective places. For instance, physical criteria like lighting, air quality, and temperature are comparatively simple to electronically sense; in fact, the thermometer is often cited as one of the first examples of a cybernetic system with broad real-world application (Murray et al, 2003). A degree of automation based on such measurements is now reasonably commonplace in industrial settings (and in some 'early adopter' residential settings), whether in the form of systems for lowering nighttime temperatures, automating lights, maintaining security, or the like. Greenberg (2001, p. 264) lists some of the other forms that are now often encountered; these include, for example,

> *[O]ff-the-shelf lights that turn on when they detect someone within a room, or outside security lights that turn on when any motion is detected, or toilets that flush when someone stands up, or automatic sink taps that turn on when they detect something in the sink.*

There remain some functional, practical problems with even these relatively simple technologies (especially taps and toilets). But these are comparatively minor issues compared to those faced when attempting to introduce sophisticated new technologies into the course of everyday lived experience, thereby moving closer to the more personal issues of place.

As an example, Agre (2001) considers cell phone etiquette, commenting that the ringing of a cell phone may have a different meaning in a restaurant, a theatre, or an automobile. It can be a welcome chance to connect with a friend, or a disruptive event that generates a hostile response from others. This is an example of a technology that could be seen as potentially benefiting from some "awareness" of context (Fogarty, Lai & Christensen, 2004); it is easy to imagine a scenario where a phone would permit only the most urgent messages to interrupt events like theatre performances or concerts, and would do so in the least obtrusive possible manner.

But to do so would require that the device 'know' where it is, what events are taking place, what the urgency of the call or incoming message is, and perhaps even something of how the recipient would judge the particular situation. This need for a degree of "intelligence" or "agency" is in fact fundamental to the distinction between spaces and places. Spaces can be described and measured in comparatively neutral terms, but places are fundamentally and essentially human, and so far, the most accurate control mechanism remains human judgement.

Some space-based devices are now mature enough to use in the interaction design palette, with certain kinds of input – most notably GPS data and location-based sensor systems – having proven reliable and inexpensive enough to deploy in mass market products. As a result, many automotive systems now include on-board navigational aids,[74] just as cell phones are now required to provide location data. A variety of projects are taking advantage of the capacity to link information with geographical location; this topic is addressed in a later section.

Place-based technologies, in contrast, remain very much at the experimental stage; Ciolfi (2004) provides an extensive overview of the existing literature on this subject, which includes laboratory experiments with media spaces, smart badges, and similar technologically complex environments. However, thus far, there have been no successful mass-market deployals of place-based technologies; they remain speculative and experimental.

On the other hand, there is a great deal of interest in understanding place using less technical tactics. In computational discourses, reference is often made to the work of Suchman (1987), whose sociologically and anthropologically informed analysis of institutional and social contexts helped contribute to a broadening of the scope of HCI. Dourish (2001b, p. 235) comments that such

> *[S]ocial analyses look beyond simply the interaction between an individual user and a computer system. They look at the context in which that interaction emerges – the social, cultural and organizational factors that affect interaction, and on which the user will draw in making decisions about actions to take and in interpreting the system's response…[I]]nstances of interaction between people and systems are themselves features of broader social settings, and those settings are critical to any analysis of interaction.*

Studies of this nature are often premised in theoretical approches like activity theory and situated action, and employ methodologies like ethnography and ethnomethodology. Rogers (2004) provides a succinct overview of the historical intersection of these social concerns with the traditional computational disciplines, while Bannon & Bødker (1991) give a more critical account of the cognitive approach in HCI, and call for a deeper understanding of social context – as well as both artefacts and places – in system design.

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[74] The best-known example in North America is probably the OnStar system—www.onstar.com, online as of Nov. 2, 2004—developed and marketed by General Motors.

But the challenges of such analyses are numerous; they are costly, time-consuming, demand specialized expertise and are difficult to justify in terms of short-term, concrete and guaranteed financial advantages. Nonetheless, if space is easier (and often cheaper) to measure, place is, as Dourish (2001) puts it, where the action is.

To sum up, the concept of context is used both to refer to something that designers may study and engage with to better understand the backdrop and setting for design activity, and to a set of parameters that can be automatically detected, sensed, and used as input to computational systems. On the one hand, the concept informs the sphere of activity and influence of interaction design and designers; on the other, it describes part of the palette of technical and technological tools available for use in design activities.

Across this wide range of meanings, context remains an important concept for interaction design, and one which is almost certain to evolve substantially in coming years. But because of the scope of the term, and the number of different ideas that are in play – as well as the natural language meanings of the term – it is important to clearly understand the range of different models of context as well as the aspects of lived experience that they address.

5.2.2 Users and experiences

Engagements with and through computational technologies thus unfold within rich and diverse social and cultural settings that provide the ground for engagement; they also take place within physical environments that may be mobile or static, private or public, relatively neutral or emotionally charged. These different forms of context form part of the horizon of design activity.

Within these environments, users put systems to use, and this use in turn contributes to particular kinds of experiences. However, both the concept of the "user" and that of "experience" have changed somewhat over time; like the other terms thus far discussed, they are invoked in rather different ways by various communities. It is once again useful to briefly consider both the nature of these concepts and the ways in which these terms are employed, and the following sections accordingly address these two terms.

5.2.2.1 Users

> *In believing the Platonic mythology of the cool, clean electro-world…we sought the absolute and we found only products. They are not user-friendly products, because the users are not the kings. The users are the prey. And the users are not innocent either. The users are us - they are just like the rest of us.*[75]

Part of the measure of success of a project is the satisfaction and well-being of the people who will use the product, environment or system being produced. The most common term used to describe these people is 'user' or 'end user.'

However, as computers have spread throughout societies, their communities of use have now expanded to the point where talking about a 'user' of a computer doesn't necessarily mean anything much more specific than 'a human being, often but not always younger, probably (but not definitely) from a wealthy country and/or demographic group.' Given the statistics on cell phone use, ATM banking, computer ownership, Internet use and video games, billions of people can now be said to be 'users' of these technologies, and as a result, generalizations about all these people are of necessity very general indeed.

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[75] Sterling (2004), unpaged.

In comparison, in even the very recent past, there were only a handful of computers on the planet, and a 'user' meant something very different; historical texts (meaning anything more than about two decades old) must be interpreted accordingly. A useful reminder of this is found in Grudin (1990), who traces the evolution of computer users through five historical stages, which can be described as follows.

	Historical stage	User characteristics
1	*Hardware*	Engineering ability
2	*Software*	Programming ability
3	*Displays; keyboards*	Perception and motor response
4	*Applications*	Cognition and comprehension
5	*Organizations*	Context

Table 2: The evolving user, adapted from Grudin (1990).

During the early decades of computer use, only experts came within sight of computer systems, and the literature from the period reflects this narrow market; the 'users' were engineers, generally male, normally well-educated and typically employed in particular kinds of institutional contexts.

Later, through the rapid evolution of computers, at different periods – and from a range of differing perspectives – users were described in many different ways: as potential sources of errors (in the cases of flight control systems and nuclear power plant control systems); as components or cogs in organizational machines (in Management Information Systems); as partners in social interactions (in collaborative design and participatory design theories); as audience members (in metaphors of computers as theatre; e.g. Laurel, 1991), and quite simply as consumers[76]. The particular problem-spaces associated with each of these different "users" are diverse enough to put into question the general value of the term.

[76] See, e.g. Kuuti (2001) for a decription of these various perspectives.

Budd, Taylor, Wakkary & Evernden (2003, p.139) explain that, within the various fields of computational design, the increased focus on users has more recently led to the development of several distinct fields of study. During the Cold War era of the late 1960s, as they explain it, the original field of ergonomics,

> *[S]plit into the related science and kinesiology based field of human factors, the political and social movements in Scandinavia that became known as participatory design … and the cognitive science and design methodology of user-centered design. The commonality of these movements was an increased concern on the user or human recipient of design.*

Although sharing thiscommon focus, each of these three fields appears to have a somewhat different perspective of what constitutes "the user." Briefly discussing the three will help to illustrate the range of potential models of the user, as well as showing the range of discourses encapsulated in this single term. Naturally, it will be possible only to present a cursory and somewhat one-dimensional view of these fields, each of which has its own history, its internal disciplinary debates, and its professional realities. The positions presented here are overstated for the purpose of clarity; the realities are, of course, much subtler and more complex.

a) Human factors

> *Human factors discovers and applies information about human behavior, abilities, limitations and other characteristics to the design of tools, machines, systems, tasks, jobs and environments for productive, safe, comfortable, and effective human use.*[77]

Human factors took firm root during the first half of the 20th century, as the more technologically advanced countries' rapidly developing capacities for industrial production were applied to the urgent needs of war. Wartime efforts meant addressing both the age-old questions of creating and distributing vast numbers of adequately functional uniforms, boots, and weapons (as well as food, fuel, and ammunition), and the novel needs connected with increasingly complex weapons systems and machines of unprecedented mechanical power, speed, and

[77] Sanders & McCormick (1993, p.5).

systems and machines of unprecedented mechanical power, speed, and complexity, including aircraft, mechanized weaponry, telecommunications apparatuses and devices devoted to encryption and decryption.

Particularly in these latter cases, detailed information about the physical and cognitive abilities and limitations of human beings became a valuable commodity, providing a source of considerable military power (Myers, Hollan & Cruz, 1996). A closer symbiosis between men (and more rarely women) and machines was seen as contributing to a more efficient and more effective army. Texts like the classic *The Measure of Man* (Dreyfuss, 1959) would later help to summarize the wealth of physical, ergonomic and methodological data that were collected and compiled during the course of this tremendous effort, as information theory and knowledge about human perception, decision-making and cognitive processes and abilities all contributed to the development of models of average human beings described in the form of *clusters of statistical and numerical parameters*. Somewhat tellingly, it was some years before this was updated as *The Measure of Man and Woman* (Tilley, 2002).

These statistical and anthropometric models are also the bodies of knowledge that most closely correspond to a traditional engineering stance; indeed, the discipline of human factors has also sometimes been known as 'human engineering' or 'human factors engineering.' Perhaps the most famous representation of this body of knowledge in relation to computers is the Model Human Processor (Figure 21, next page) – something of a high water mark in the parametric and numerical representation of human physical and cognitive processes.

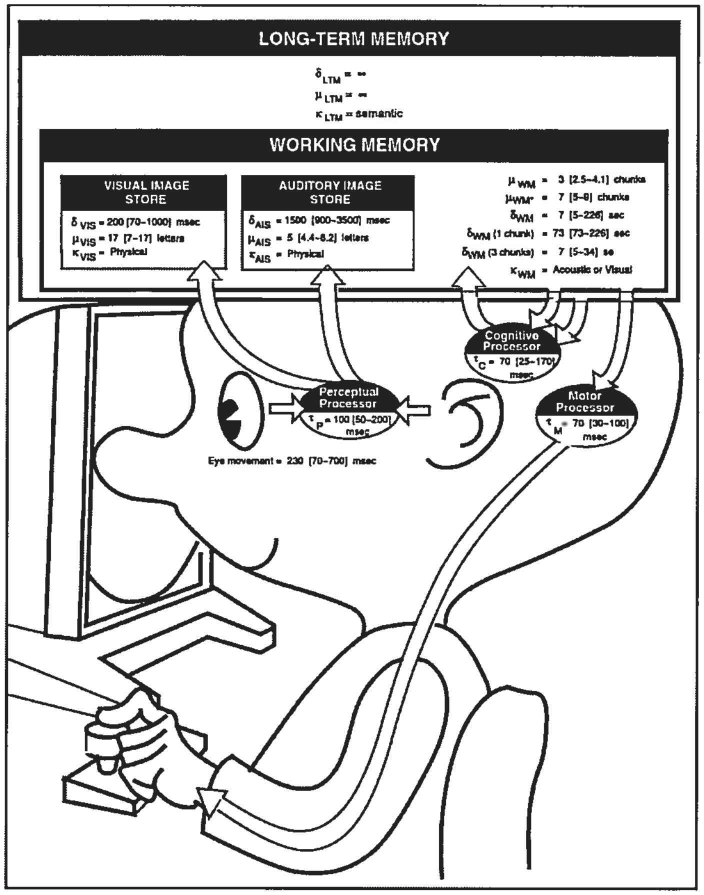

Figure 21:The 'Model Human Processor' (from Card, Moran & Newell, 1983).

From this perspective, the "user" is an essentially anonymous figure, potentially representative of a particular population or demographic group, who can be described in terms of a set of physical and cognitive attributes that fall within a range of statistically significant norms that have in turn been determined through extensive laboratory research and that are constantly being refined and extended. These may also be encapsulated in principles like "Fitt's Law" (Walker & Smelcer, 1990) which describes the time required for a user to point to an icon or other delineated area on a computer screen using a mouse or pointing device. Such principles are probably the most universal and generalizable interpretation of the term "user," and though they have certain theoretical and practical pitfalls (Bowie, 2003; Bannon, 1991a), they provide a very firm foundation for system analysis.

b) User-centered design

> *[I]t is important to distinguish between bespoke (custom-built) and off-the-shelf products... UCD [user-centered design] can apply to either kind of product - but in one case you might be working with the real users, while in others working with 'representative' users.*[78]

In comparison with the discipline of "human factors," "user-centered design" (or UCD) refers more to a philosophical stance than to an established discipline. UCD describes a position and a set of beliefs and values that have in turn led to the development of a variety of methods and methodologies that are fairly loosely defined and are actively evolving.

According to ISO standard ISO/IS13407, *Human-centred design processes for interactive systems*, user-centered design describes a design approach that involves users in the design process in order to produce a more usable system or product (ISO, 1999). Input and guidance from future users of the product are thus obtained using a variety of techniques and methods and incorporated at different stages of the development, with the overall goal of creating an end product that will match the needs and requirements of users as closely as possible. In theory, user-centered design aims to better serve the user's needs and desires by ensuring that designers have a deeper, more firmly rooted understanding of the context, tasks and needs associated with particular interventions and projects.

The most important factors in the actual use of this philosophy are probably *budget* and *scale*. Although many studies suggest that making systems more usable is not only cost-effective but distinctly profitable (Marcus, 2002; Bias & Matthews, 1994; an extensive bibliography can be found in Donahue, 2001), there are definite costs in time, money, and personnel associated with field research, usability testing and iterative design, all of which figure among the main tactics used by practitioners of UCD. These costs, which must be amortized over the lifespan of the projet, are

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[78] Gulliksen, Lantz & Boivie, 1999, p. 7.

mainly incurred at the outset. As a result, in the business world, different corporate cultures determine the degree to which these principles will actually be considered as priorities.

There are also significant factors linked to the scale of the project. A mass market project must necessarily address a larger and less clearly defined group of potential users than a custom or "bespoke" project; unsurprisingly enough, the larger the group, the more challenging it becomes to select representative individuals as the basis for generalization. This is, of course, a basic concern of all industrial design activity, which Fischer (2001, p. 248) sums up neatly:

> *One of the fundamental problems of system design is how to write software for millions of users (at design time), while making it work as if it were designed for each individual user (who is known only at use time).*

This problem has been at the heart of many efforts to provide individualized services and experiences within the context of industrial scales of production. Contemporary trends like "skinning," "personalization," and "mass customization" (Piller, 2002) all represent responses to this problem, in the form of more or less successful efforts to provide millions of people with mass-produced tools and objects that are either adapted or adaptable to suit their individual needs. However, the balance between individual needs and large-scale production is still in many cases weighted toward the latter, since the industrial reality of economies of scale cannot be easily ignored.

And so, depending on the two factors described above (among others; see, for example, Reich, Konda, Levy, Monarch & Subrahmanian, 1996), models of the user invoked in user-centered design may range from the universal to the particular. Some projects – particularly larger-scale interventions – will tend to employ more universal models that can be very close to those of the human factors approach outlined above. For example, techniques such as heuristic testing (Nielsen & Molich, 1990; Nielsen, 1994; Rogers, 2004) do not necessarily directly involve end users, but rather rely on a panel of experts who cross-reference a product against a range of heuristics that are derived from models of human behavior and cognitive process. In such cases, and rather confusingly, the "user-centered" in UCD does not actually mean that there is any direct involvement of actual users (Gulliksen, Lantz & Boivie, 1999); it is thus part methodology, part philosophy, and part rhetorical flourish.

Smaller projects, or those carried out for more clearly defined groups, may use finer-grained, less generalized models of users, such as those produced through the use of methods such as "personas" and "scenarios" (Cooper & Reimann, 2003; Grudin & Pruitt, 2002). These latter techniques rely on the creation of fictional, archetypal characters created to represent the most important attributes of those judged as likely to use the system. Typically based on ethnographic research and other social science research methods, personas and scenarios represent a bridge point between the impersonal, archetypal and statistically defined human figures that constitute the "users" of human factors research, and the specifically situated, contextually grounded realities of participatory design.

c) Participatory design

> *Two important features of participatory design shape its trajectory as a design strategy. The political one is obvious. Participatory design raises questions of democracy, power, and control at the workplace. In this sense it is a deeply controversial issue, especially from a management point of view. The other major feature is technical—its promise that the participation of skilled users in the design process can contribute importantly to successful design and high-quality products.*[79]

Participatory design also describes a design approach, stance or philosophy, and one that is more explicitly political than either human factors or UCD. Employing a participatory design approach will normally mean that the design process is carried out in the closest possible intimacy with some or all of the people who are actually

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[79] Ehn, 1993, p.45.

going to use systems. Thus, some or all of the anticipated end users will be involved directly as participants throughout the design process (Muller, 2003). This is very different from traditional workflows, in which designers create a requirements specification document that is then handed over to the developers (Reich et al, 1996).

In the context of computer systems, the participatory design approach is historically connected with projects carried out in the northern European countries during the 1970s, which gave rise to what is now referred to as the "Scandinavian approach" (Sandberg, 1979). These projects were motivated by concerns regarding the effects of information technologies on workers and workplaces; there was a strong desire to develop tactics that would allow workers to have more influence on the design and introduction of computer systems into the workplace (Kuhn & Winograd, 1996). Judging by the literature, early projects in this tradition seem also to have been quite political, driven in large part by trade unions' desire to ensure that their members would neither be imposed on nor rendered obsolete by the relentless march of technology.

Grudin & Pruitt (2002) point out that some of the original characteristics of participatory design included "[L]ong-term engagement with particular participants, and the empathy, commitment and deep understanding that such engagement can bring" as well as, "Attention to the sociopolitical and 'quality of life' issues...including values, fears, aspirations, and so forth." Job design and job satisfaction were also recognized as important goals for designers and managers alike. These altruistic and humanistic principles helped create links between participatory design and other politically motivated movements, including feminism and post-colonialism.

However, these goals are not clearly and unambiguously aligned with the core business purpose of maximizing profits. Participatory design processes are typically long, and the end results are unpredictable and relatively open-ended. Grudin &

Pruitt (2002) report on some of the more recent corporate efforts to adapt, extend and rationalize elements of the participatory design approach through the use of a variety of tactics, including the use of low-fidelity mock-ups and prototyping, increased engagement and communication with potential users and an emphasis on site visits and understanding of the work context. These are, however, somewhat diluted from the original goals of participation, and represent the institutional desire to capitalize on the perceived benefits of participatory design without necessarily accepting either the uncertainties of an open-ended process with no fixed methodology, or that of a reduced degree of control over the final results.

Participatory design is not one thing or theory but many. However, one common point is that it is generally inaccurate to speak of a 'model of the user,' since the process of design will *directly* involve many different shareholders. Indeed, designers are to be considered as users, and users as designers, albeit to some varying degree. Nonetheless, whatever the degree of invovement, the goal is that at least some of the people who will use the products are directly involved in the design of the tools and systems created to meet their needs: the "users" really are the users.

Very different philosophies and positions thus underpin these different concepts of the "user," which results in the term having a very wide range of meanings. Models of users may be bottom-up, potentially starting from the level of granularity of individual neurons and motor responses, and building upward through more or less complex models. They may include detailed analyses down to the level of individual keystrokes (Card et al, 1983; John & Kieras, 1996) or up to the level of heuristics based on human cognitive activity or statistically generalized from the resuts of large-scale laboratory research projects.

At the other extreme, user models may be top-down, based on real people or on ethnographically informed, fictionalized characters set in complex social contexts, and constructed around an array of desires, needs, and goals that include personal motivations, institutional priorities, and cultural preoccupations.

These two extremes may be complementary, but do not overlap to provide any exhaustive, closed, complete model; there remains a wide territory between these two poles where the ability to describe and predict remains incomplete. Both concepts and models of users are essential, but also quite delicate; interaction projects are, after all, no more universally successful than are Hollywood films, despite access to vast bodies of knowledge about human behaviour as well as a wide variety of tactics for testing and analysis.

Scenarios and personas require skill and expertise to create, maintain, and use, and are as much art and craft as science, while more rigorous keystroke-level models do not readily scale up to encompass real-world settings involving complex social interactions. It remains the task of designers to find the best ways of working with and for models, methods, and people, in the service both of particular projects and of the "users" – whoever they may be.

5.2.2.2 User experiences: Immersion, presence, and flow

> *Over the last two hundred years, we have witnessed a shift from an Agrarian Economy based on extracting commodities, to an Industrial Economy based on manufacturing goods, to a Service Economy based on delivering services, and now to an Experience Economy based on staging experiences.*[80]

If users are the people who put systems to use, experience is what happens in their minds and bodies during the course of this use. A wide range of topics – including, among many others, those encapsulated in the concept of context – converge in

[80] Gilmore, 2003, p. 1.

this vast and sweeping term, which is playing an increasingly prominent role in the design disciplines.

In fact, the more experiential and phenomenological aspects of engagement with products, goods, services and environments are of central concern for the modern areas of study called “experience design” (Shedroff, 2003) and – in the computational realm – “user experience design” (Vredenberg, 2003), just as they are central to what is often called the “experience economy” (Gilmore, 2003; Pine & Gilmore, 1999). Different models of experience, more or less explicitly detailed, and with very diverse preoccupations, are brought to bear in each of these cases.

Several rather different aspects of experience seem to be important, insamuch as they can be discerned behind the thick haze of marketing. Firstly, the rise of experience as a concern for designers reflects the enviable wealth and freedom of many modern societies, and the fact that it has become possible to devote time, effort, and energy to deliberately creating, designing, and shaping experiences instead of focusing on functional concerns like efficiency, productivity, or simple survival (Davis, 2001). After all, during periods of war or famine, the primary focus is not likely to be the design of experience. But during times of relative peace and plenty, and especially within a commercial context within which consumer choice is a primary concern, experiences become both commodities in their own right and ways of distinguishing and selecting between different commodities.

This particular interpretation tends to links experience with branding in general and environmental branding in particular. In such cases, experience refers to the association of particular kinds of mood, emotion, sentiment and sensation with specific products or environments; these may in turn be connected with a particular company, business, title, or corporate identity (Shedroff, 2001). What is perhaps most important in such cases is that a recognizable thread links diverse experiences that take place at different moments, and that these experiences are both memorable and somehow identifiable.

This also means that such concepts of experience have strong resonances with time. They encapsulate *anticipation*, the expectation of things to come; the *phenomenological moment*, the constantly moving window during which experiences take place; and *memories* of experiences past (Sanders, 2001). This in part helps to explain the strong connection between experience design and the performing arts, the media arts, and what are often more generally called "time-based media."

And taking this one step further, Pine & Gilmore (2003) use the metaphor of theatre to anchor their discussion of what they have called the "experience economy," where artifice, drama, sets and props are all used in order to create, support and enhance distinct and memorable experiences, Much of what seems to be at stake in this comparison is a reference to the heightened intensity of theatrical experience, the sense of being unusually awake, alert, and engaged – a feeling or psychological state distinct from the normal flux of events, and accompanied by sensations that distinguish themselves and stand out in memory (or perhaps even the unconscious mind) as unusually vivid.

For interaction design, these factors in turn raise questions both about the nature and the appropriate level of intensity of these engagements. Such questions include the following: Should people attend to the encounter with the system, and to what level should they be explicitly and consciously aware of the encounter? How long should engagements last, and how intense should they be? These and similar questions have led to the development of specialized terms that are used to describe experiences within technological contexts, of which three of the most common are 'immersion,' 'presence,' and 'flow.'

a) Immersion

The term “immersion,” in the discourses of virtual reality and new media, refers to the extent to which a person is psychically and physically enveloped by an artificial world or computer-generated environment. This is sometimes described in terms of the technologies used in the system; thus, for example, Slater & Wilbur (1995) suggest that “Immersion is a description of a technology, and describes the extent to which the computer displays are capable of delivering an inclusive, extensive, surrounding, and vivid illusion of reality to the senses of a human participant” (p. 28). Douglas & Hargadon (2001), in contrast, draw on a more psychological sense of the term to describe the “immersive” experience of reading, which more closely resembles Murray’s (1997, pp. 98-99) description:

> *Immersion is a metaphorical term derived from the physical experience of being submerged in water, We seek the same feeling from a psychologically immersive experience that we do from a plunge in the ocean or swimming pool: the sensation of being surrounded by a completely other reality, as different as water is from air, that takes over all of our attention, our whole perceptual apparatus.*

In this latter sense, immersion is a way of describing an engagement so absorbing that it excludes practically all other stimuli. Sensory immersion may be part of this, and many technologies create situations providing high levels of sensory stimulation (including head-mounted displays or virtual reality systems, like *The Visitor*, discussed in chapter 4). But in most accounts, sensory immersion alone is not considered as the sole criterion; just as all films are not successful in creating the same degree of ‘suspension of disbelief’, not all sensorially rich situations are immersive in the sense of generating human engagement, care, concern, and emotional investment.

Like interactivity, immersion is a complex construct that refers to both the physical and mental aspects of an encounter or engagement with technology. But however it is defined, immersion refers to absorption and focus. The term thus draws attention to the power of computers to create situations that can powerfully engage and enfold human attention, sometimes to the exclusion of almost all else. As a result, immersion can be a danger (since it can distract from the needs of the body, leading to repetitive strain injuries or other corporeal problems), but is more often treated as a goal or hallmark of success – proof that the system is one to which people are drawn, and within which they will seek to immerse themselves, whether to carry out a task, to pursue a goal, or for pleasure or perhaps escape.

b) Presence

Closely linked to the concept of immersion is that of *presence*. Presence is the locus of experience, the point where the physical and mental components of lived reality meet (Riva, Davide & Ijsselsteijn, 2003). It refers to the sense of being in a space, environment, or situation. This may be a real place, a fictional place, an imaginary place, or even to a non-place conjured up by technology (like the strange and intimate space of the telephone or teleconference) that lasts only as long as the transient technological structure that underpins it. Presence is also a phenomenon that is at once apprehended through the senses and felt, experienced, and remembered – in sum, it is a complex physical, mental and emotional construct, that may also be socially and culturally informed.

Presence seems to have become a topic of particular interest precisely because it is now so often put into question by technologies. Dreams are perhaps the archetypal form of this questioning: in a dream, one is often in a place other than where one's body happens to be – but a dream is a kind of place with no objective or external existence. Books, movies, and telecommunications are all externalized variations on this theme of imaginary or fictional spaces, while new technologies provide a range of other options (such as telephones, televisions, and teleconferences) that likewise create a sense of presence in a virtual space.

However, perhaps the most novel aspect of presence in some parts of this technological realm – like videoconferences, telephone calls, or certain on-line experiences and virtual reality environments – is that others can join you in these strange new spaces and share an experience that is common at least in the sensory realm (though perhaps less so in the realm of personal experience and interpretation); this is sometimes called "co-presence" (Ijsselsteijn & Riva, 2003).

Presence thus describes the location (both physical and psychic) of the locus of attention, with a special emphasis on the space within which engagements unfold. Like immersion, it is most often considered as a goal but may also be a problem. In a teleconference or a virtual reality environment, it is generally considered as desirable to create a sense of shared presence – the feeling of 'being there' to a degree that will allow for authentic and meaningful communication. However, presence can also be a problem, since people can be physically present but psychically absent – certainly a desirable state when speaking with a loved one over a great distance, but probably less so when behind the wheel of a car.

c) Flow

The last of these three experiential terms is 'flow,' a term developed by psychologist Mihaly Csikszentmihalyi (1992) to describe the experience of engagements that are at once so challenging and satisfying that awareness of the passage of time disappears. As Douglas & Hardagon (2001, p.163) describe it, flow is

> *[A] condition where self-consciousness disappears, perceptions of time become distorted, and concentration becomes so intense that the game or task at hand completely absorbs us... Since flow involves extending our skills to cope with challenges, a sense that we are performing both well and effortlessly, this state hovers on the continuum between immersion and engagement, drawing on the characteristics of both simultaneously.*

Although it refers to a broad range of situations in everyday life, from sports to cooking and work, the term "flow" has also been widely adopted by the HCI community to describe engagements with a range of information and communication technologies, including such activities as playing video games (Johnson & Wiles, 2003) and surfing the Web.

Flow, like immersion and presence, is generally seen as a good thing and a desirable state of being; thus, for example, Finneran & Zhang (2002) quote studies showing that flow has been linked to increased exploratory behavior, communication, learning, positive affect and computer use generally, and conclude that "[C]omputer-mediated environments that are conducive to flow will yield positive attitudes and outcomes for users." Thus, like immersion and presence, flow is an experiential state that designers seek to create and evoke. Moreover, flow states, although difficult to describe, are characterized as pleasurable and rewarding, involving constant challenge at a level that is difficult but not impossible to overcome.

In the brief and limited typology of experiences presented in the current work, if immersion is primarily related to the senses and presence to place, flow is itself closely linked on the one hand to tasks and the carrying out of tasks, and on the other to time and awareness (or lack of awareness) of the passage of time. Immersion may be more or less active or passive, while presence is a constant (one is always 'somewhere', whether it be outside or within the machine). In comparison, flow refers to a state of constant challenge, effort and engagement, an experience that is neither wholly self-conscious nor yet unconscious, but rather one that unfolds at the functional cusp of consciousness.

> *Let's just think of human experience as the phenomenal unfolding of awareness in real time, a movement which tugs against the network of concepts and significations while tending toward the condition of more direct sensation or intuitive perception.*[81]

Across the many realms of computational discourse, the concept of experience serves a variety of different purposes. Beyond a connection with the commodification and branding of time, sensation and emotion, experience also makes reference to the fact that computer systems may be tools that require total and undivided attention and absolute delicacy and care, just as they may be invisible elements embedded in the equipment of daily life, invisible and unnoticed. Furthermore, engagements with computer systems may be fleeting, or wholly absorbing for hours at a time.

The three terms identified above – immersion, presence, and flow – all refer to different aspects, intensities and dimensions of the experience of engagement with computer systems. Each may be defined in technological terms (through descriptions of the technologies which underpin the engagement), biophysical terms (through the measurement of various corporeal responses during engagements with the system or environment), or experiential terms (which will normally rely on participant reports or questionnaires that describe the encounter or engagement). This range of possible descriptions attests to the complexity of this term, with its many links to cognition, embodiment, and temporality – the fundamental questions and issues of phenomenology (Merleau-Ponty, 1962; Heidegger, 1962)

Through the creation and shaping of these encounters, interaction design offers the potential to exercise a degree of control over the extent, length of time, and degree of intensity with which people will engage with a device or system. The phrase

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[81] Davis, 2001, ¶2.

"experience design" reflects the power of objects and environments to give structure and form to experience, to delineate, facilitate, and control or guide the flux of sensory stimulation and conscious experience – and to create a backdrop against and within which particular kinds of interaction (and thus of experience) will unfold by design.

5.2.3 The system: interfaces and beyond

These technologically mediated forms of experience are made possible because of a particular kind of machine that gives shape to interactivity and interactions. This new class of device has certain novel characteristics, though these are extremely challenging to explain and describe in abstract and general terms. One way to begin is by looking at the most common term presently used to describe the human-facing aspects of computer technologies: the "interface." As it turns out, there are several different (and sometimes incompatible) ways of interpreting this word, and examining these meanings will help to uncover some of the related issues.

Firstly, in computational discourses, the interface has typically been used to refer to the parts of the system on which people can act. Thus, in recent years, it has most commonly referred to the combination of a computer monitor, keyboard, mouse, and some software application that generates images and text on a monitor.

At the same time, the term "interface" is also used to describe a variety of other input devices, often referred to as "novel interfaces." A good example of this kind of device is Michel Waisvicz' "The Hands" (below). This is a complex assembly of different sensors – including pressure, rotation, and acceleration – that together offer many degrees of simultaneous real-time control over different parameters of electronic music in live performance. Other such "novel interfaces" include head-mounted displays, speech and sound input devices, automotive control simulators, flight simulators, DJ music control devices and the like (Nielsen, 1993).

Figure 22: 'Novel interface': Michel Waisvisz' "The Hands"

But in these cases, the term 'interface' seems often to refer only to the input, not to both input and output. In other words, an image of a button projected on a screen is considered as part of the interface, but music played over a speaker as a result of the button being pressed may or may not be. Nor does it make sense to speak of a car or its acceleration as an interface, but the gas pedal could be so described. The interface, it seems, typically describes action or the potential for action, while the relationship to reaction is much less clear.

To further confuse things, if the interface sometimes describes only an input device and sometimes both input and output, in computer programming the term 'interface' also refers to the point of contact between different program components, a junction point where data is transferred according to specified protocols. Thus, any search for the term 'interface' in a computational context yields hundreds of texts concerned with the way that different parts of software packages communicate amongst themselves.

And in a final twist, the 'interface' may also describe the gap or boundary between the realm of the physical and sensory and that of data and information – that is to say, the invisible line between the real and the virtual. This is much closer to the original, natural language meaning of the term 'interface': the dimensionless line that separates two immiscible fluids like oil and water.[82]

In sum, packed with a variety of different meanings, the term 'interface' ends up somewhat overstuffed, a polysemy that makes it more difficult to communicate clearly about what systems are, what potential for action they offer, and how the results of actions are displayed, presented, and understood.

Complicating the matter even further, it is increasingly common to encounter systems that share the technical infrastructure of 'interactive' systems, but that provide little or no sign of interaction. Presence-based and location-based systems, for example, may not give any sign of system activity or provide any 'interface'; thus, for example, a rental car may well have a GPS system tracking the vehicle location, but the tracking may be invisible to the driver. Or the vehicle itself may become the input device, while the system provides screen-based or audible feedback about road conditions and the best possible route to take in order to reach some specific destination. In such cases, the term 'interface' again seems somewhat awkward and unsatisfactory, both too limiting and not adequately descriptive.

The concept of the interface developed during a time when computers were larger, less common and much less diverse, and when both the tasks and the group of potential users were more limited and easier to describe – but this is far from the contemporary reality. Thus, to provide a somewhat clearer way of describing and

[82] The author is obliged to Professor Luc Courchesne for his help with this clarification.

discussing systems, the present text proposes to distinguish between three components of interactive systems, which will be called the 'enterface,' the 'innerface,' and the 'outerface.' These different "faces" of the system are the stuff of which interaction design is made, and the following sections address each of these in turn.

5.2.3.1 "Enterfaces": bringing the outside in

Within this proposed typology, the 'enterface' describes the point of contact where data from the outside world is made available to computational systems; it is a bridge point between the physical and electronic realms by way of electricity. Each of these modalities (the physical, electrical, and electronic) has particular and unique structural properties, all of which contribute to the structure of information systems. Humans act and perceive in the realm of the physical and analog; the transduction to electrical representation offers the speed of light characteristic of electromagnetic energy; and finally, the electronic realm is the site of increasingly minute, precisely controllable, repeatable, recordable and mathematically comprehensible operations.

The enterface is also a site where both human agents and nonhuman devices act, since computers simply do not function without some form of input. The first communications with these machines were carried out by humans who used patch cords, vacuum tubes and solder – and soon after, punched cards and keyboards – to pass commands from the physical realm to the electronic domain and back again. But it was not long before sensors and sensor systems were also employed to serve a range of industrial, military and administrative purposes; signals from radar, sonar, thermometers, accelerometers and the like all became available as raw material for computational processes, just as other human-facing tools were designed, including the SAGE air-defence system's "light guns" shown below.

Figure 23: SAGE air-defence system light gun

As the spread of computation continued, many novel tactics were developed to bridge the gap between the physical and virtual domains. Computer screens with text-only "command-line interfaces" and the later development of "GUIs" (graphic user interfaces) allowed text and images (with sound in an occasional supporting role) to be used as tools for engagement with the steadily increasing computational power of these new machines. And with the implementation of windowing systems and pointers – most notably the mouse – the contemporary 'interface' paradigm was complete.

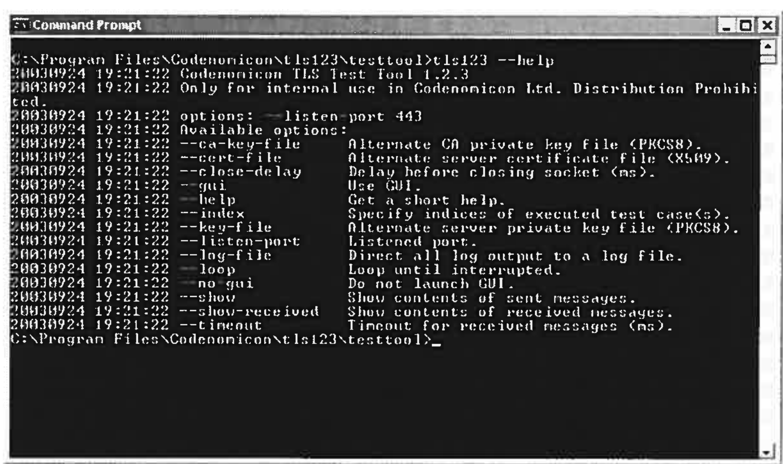

Figure 24: Command-line interface

However, today these represent only a subset (albeit a particularly common one) of engagements with computer systems. Many other devices – like the gas pedals of most recent-model cars – are now just as much input devices as are computer keyboards, inasmuch as they provide ways for humans to engage with and control computational processes. Likewise, children's toys are increasingly frequently computerized, as are telephones, bank machines, subway machines, air travel – the list is extensive, and shows no signs of slowing or stopping. Some of these devices require explicit human control. Some of them are designed to be as unobtrusive as possible, demanding neither attention nor control. Others leave no place at all for control.

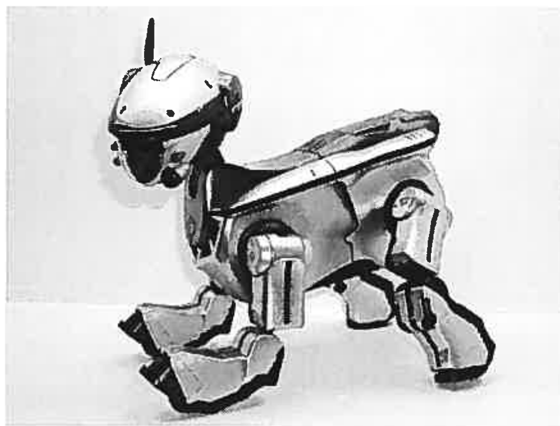

Figure 25: AIBO robot dog; face as enterface

The enterface thus refers to two different aspects of computer systems. Firstly, it can be technically defined as the sensor or sensor systems that translate information about a specific range of actions, events, or phenomena into electrical and electronic control signals. Taking a few examples from the realm of the electronic arts, computational control signals have been generated by such diverse means as voice, brainwave activity (Hjelm, 2002), and stock market fluctuation (Erickson, 2002); researcher Stephen Wilson (2001) provides a very extensive list of other examples in his substantial work *Information Arts*. In the modern world, anything that is *measurable* and that *varies with time* can be used as a control signal or enterface device (cost-effectiveness, pertinence, creative, legal and technical constraints permitting). This is not a new insight; after all,

> *Norbert Weiner, the pioneer researcher in cybernetics wrote, in The Human Use of Human Beings, that 'every instrument in the repertory of the scientific instrument maker is a possible sense organ.*[83]

Alternately, the enterface can be defined in more human-oriented terms, and considered as the location of embodied encounter with the system – the point at which a human being will act on the possibilities, structures, and constraints that have been made available by the system designers. One of the most common terms associated with this latter, more experiential approach is the concept of 'affordance,' developed by J. J. Gibson (1979) and later popularized in the HCI community by Donald Norman (1990). "Affordances" are the possible actions that an object allows. This includes the physical properties (or their representational equivalents, in the case of images displayed on computer screens) that demonstrate or suggest how it would be possible to make use of the object, often through some metaphorical resonance with the physical world, like buttons, sliders, or knobs.

One way of reconciling these two rather different concepts of enterfaces is through the concept of *instrumentality*. The word 'instrument' can be seen as possessing two distinct meanings, one musical, the other scientific and surgical, and the enterface may be considered as occupying the continuum between these two kinds of instruments.

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[83] Druckrey, 1995, ¶ 6.

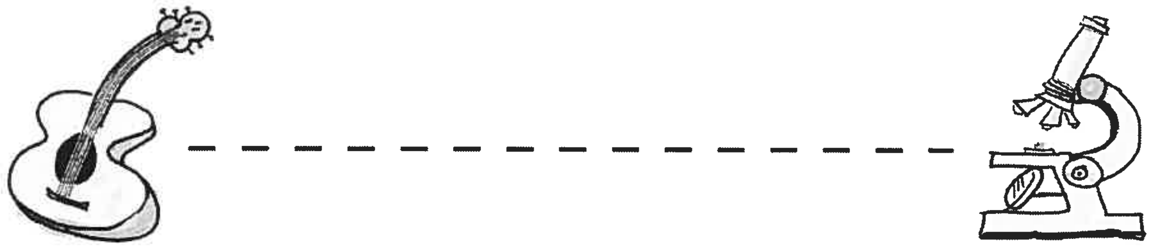

Figure 26: The spectrum of instrumentality[83]

At the one extreme, the enterface can be a device for particularly fine-scale, rapid, responsive, explicitly human control of a system. Unsurprisingly, some of the clearest examples of this form of instrument are those specifically constructed for the creation and control of music; a very brief historical survey of such systems is provided in Mulder (1994). In these cases, the system is explicitly tailored for individual, expressive, artistic control, and particular emphasis may also be placed on overcoming the challenge of performance, rather than on ease of use.

Games also often exploit this kind of interaction, exploiting often playful dimensions of embodiment and physical challenge; consider, for example, the device developed for Konami's popular "Dance Dance Revolution™," (see below), in which players dance on a sensor-equipped pad while executing increasingly complex sequences of foot movements.

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[83] Image courtesy of Lesley McCubbin.

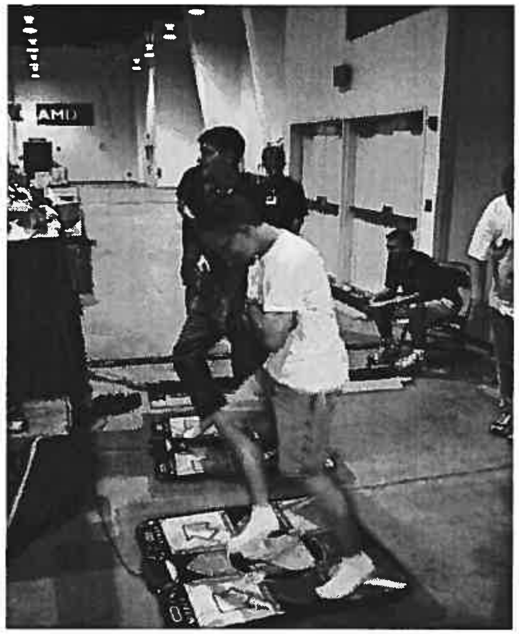

Figure 27: Konami's "Dance Dance Revolution"

The other end of the spectrum describes situations where the enterface requires little or no physical human intervention, and serves primarily as a way of extracting data from the world. A concrete example of this is the 'congestion charging' system recently implemented in London's downtown core (Transport for London, 2003). In this system, an elaborate system of cameras, linked to pattern recognition software and to a centralized database, captures license plate information of motor vehicle traffic entering central London and verifies that each vehicle has been registered with the system and that the appropriate surcharge has been paid.

This creates an automated toll service involving millions of daily transactions, within which the system automatically records, interprets, and acts with a minimum of direct human intervention; presence alone serves as the user's input, with operators standing by to monitor, verify, and troubleshoot the system. The success of this system's implementation in London has led to more widespread use of these technologies, and the image reproduced below illustrates one such system in some detail.

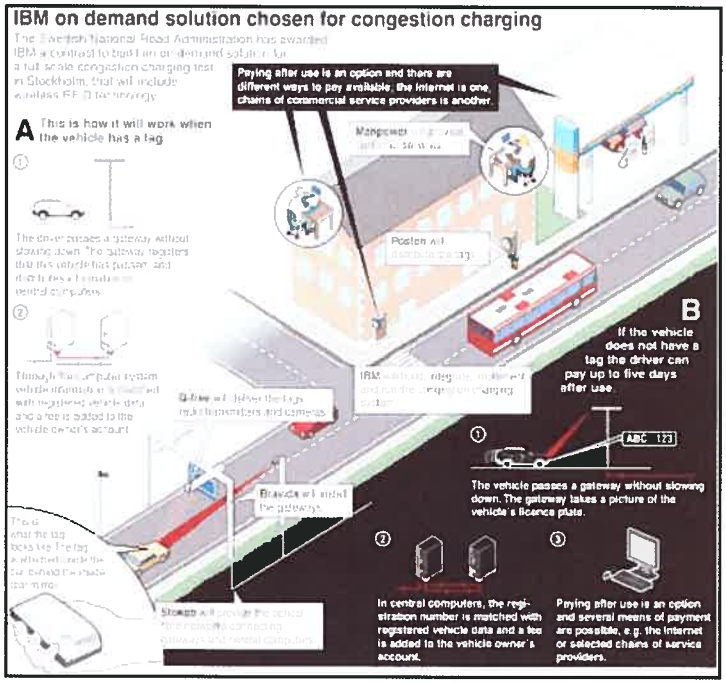

Figure 28: IBM's congestion charging system

The goal of these latter systems is to create an optimally streamlined interaction, where the end user need do nothing in particular in order to engage. This actually amounts to turning presence itself (in this case, the presence of a car) into a service that is quantifiable and traceable – and that must be paid for. In this sense, interaction becomes as much about being controlled as about controlling, a theme that is further developed in chapter 6.

Through the various examples presented above, enterfaces can thus be seen to encompass a very broad range of devices. Somewhere toward the more musical end of the spectrum is what is most often referred to as an "interface": a keyboard and pointing device, a combination that offers a high (and sometimes almost virtuosic) degree of control. Nearby on the spectrum are the curious little gamepads that give access to the world of video games, as well as the many variations on portable telephones and PDAs, with their range of tiny screens, pens, touchpads and keyboards.

Figure 29:Research in Motion's popular "Blackberry" PDA

The design of these devices is a well-documented and active field of study – as well as a challenging design activity – that builds on rich traditions of symbolic representation, ergonomics, and cognitive psychology to develop strategies for creating meaningful assemblages of language, images, sounds, pictograms, and other human symbol systems (Myers, 1998) that communicate the possibility for actions and their consequences.

Figure 30: Moderately complex screen shot, from Discreet's 'Combustion' software

But whatever the modality of input, designing enterfaces is a challenging and complex activity that must balance technical limitations with perceptual, institutional, cultural and physical realities, while also engaging with the particular properties inherent to the medium of computation. Interaction designers may work with novel devices or familiar ones, with emerging technologies or those with relatively established standards and habits, with human control or electromechanical control or some combination of the two, all the time striving to best meet the requirements of particular projects – and those of the people who will use these devices and systems to meet their needs.

5.2.3.2 "Outerfaces"

> *What calculation is all about is computing cold sums into new things that have never existed before… But now that one can re-code numbers in the form of colors, shapes and sounds with the aid of computers, the beauty and depth of calculation are there for all to feel. One can see its creative force on computer screens, hear it in the form of synthesized music, and in future one will probably be able to experience it 'hands on'… The exciting thing about calculation is not that it cobbles the world together (writing can do this as well) but that it is capable of projecting other worlds from within itself for all to feel.*[85]

For designers of computationally enhanced products, it also makes sense to distinguish between the way devices obtain input signals and the way in which the resulting system processes are represented in human-facing and machine-facing form. In the latter cases, CRT and LCD monitors (displaying text and both still and moving images) are currently the most common form through which interactive system processes are displayed to humans, but are far from the only option. Sound is also commonplace enough, while physical objects – motors, lights, appliances, and the like – are also increasingly often controlled by machines, and all indications are that this trend toward computerized control of objects in the "real world" will continue to grow.

The term 'outerface' is accordingly proposed as a way of describing the wide range of devices that are now used to provide the visible, audible, tactile, and multisensorial results of system operations, and for which no term exists other than "output device" – or sometimes (and, as we have seen, rather confusingly) "interface."

The utility of this distinction is made evident when the mode of interaction and the nature of the system response are very different, whether in terms of form or content. To take a comparatively trivial example, a DVD remote control presents the results of system activity in audiovisual form; a tactile, potentially text-guided mode

[85] Flusser, 2002, pp. 64-65.

of input is transduced into a radically different mode of output. The reaction takes place at a distance, with no perceptible link to the action; in fact, the relationship between the two might as well be described as magical, since most people have no particular understanding of what actually takes place behind the scenes so that the push of a button can control a complex electromechanical device.

To take another common example, consider an automatically flushing toilet. In this case, there is no direct human control whatsoever, nor any feedback beyond the execution of the function. Neither light nor touch nor blinking screen indicates the success or failure of the system; the sole indication of interaction is the activation of the mechanical system. This kind of logic is now often applied to doors, heating and lights, and will only be more commonplace if the logic of 'smart' buildings and objects continues to develop and expand.

The steadily expanding range of outerfaces can be quickly surveyed by touching briefly on four themes. Moving from the least to the most tangible, these are *visualization*, *simulation*, *multimedia*, and *process control*. Examining these four will help give a more coherent overview of the palette of output devices now available to interaction design. Figure 31, below, summarizes the key concepts in the framework that will be described in more detail in the following sections.

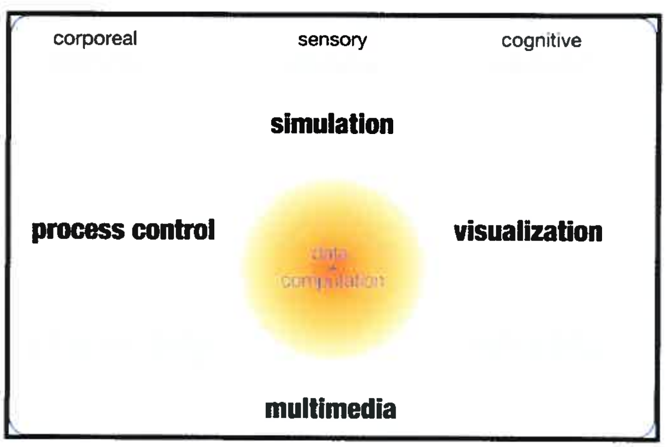

Figure 31: Forms of the outerface

a) Visualization

> *What do you do when you want to describe a phenomenon that has never been seen before or features which have never been noticed or deemed as relevant to the depiction of a phenomenon or process? A new material image has to be created alongside the associations and conventions that establish it as an image of something that deserves a place in our experience.*[86]

Visualization refers to the process of giving form to clusters and sets of data that have no inherent shape or visual structure. If "visualization" is taken literally, it refers to the generation of images displayed on a computer screen or printed on paper; if it is considered more metaphorically, it can also include other sensory forms, like the less common acoustic equivalent, 'sonification' (Noirhomme-Fraiture, Scholler, Demoulin & Simoff, 2002). But this latter interpretation is much less often encountered; as Friendly & Denis (2004, p. 2) describe it,

> *[V]isualization is generally applied to the visual representation of large-scale collections of non-numerical information, such as files and lines of code in software systems, library and bibliographic databases, networks of relations on the internet, and so forth.*

Like so many things in the computational realm, even this seemingly straightforward description is not entirely unambiguous, since the concept of 'non-numerical' information is somewhat questionable (as Chapter 4 demonstrated); after all, the simple fact that information has been transferred to the computational realm implies that it is numerically representable at some level. It would perhaps be more accurate to describe visualization as the *articulation of data into forms that bear human meaning*.

Interpreted in this way, visualization is a powerful and ancient process that long predates computation. Tables, graphs, maps and even the written word can be seen as variations on the theme of visualization; all provide some means to see what lies within, determine answers to questions and perceive or identify relationships that might otherwise remain undiscovered. As Friendly & Denis (2004,

[86] Gooding (2003, p. 4).

unpaged) explain, “In this sense… visualization takes us back to the earliest scratches of forms on rocks, to the development of pictoria as mnemonic devices in illuminated manuscripts, and to the earliest use of diagrams in the history of science and mathematics.” Their remarkable website, “Milestones in the History of Thematic Cartography, Statistical Graphics, and Data Visualization,” provides a wealth of historical information and examples of the use of visualization in the sciences. In a similar vein, and in more traditional printed form, the work of Edward Tufte (1990, 1997, 2001) offers many illustrations of this rich history and proposes some fundamental principles for visualization.

Visualization is a wide-ranging, complex and very active field, closely linked to advances in computational graphics, display technologies, and computer hardware generally. A detailed investigation of the topic is beyond the scope of the present document. However, looking at a few examples will help illustrate the range of projects and situations that it encompasses.

The first example is the Opte project that aims to create maps of the Internet (see Figure 1, page iii). This project shows the extent and nature of the Internet, in a form that is neither strictly geographical nor yet exclusively numerical, but rather one that shows relationships and hierarchies. Figure 32, below, shows a very small subset of the data retrieved from the project; the numerical values that identify Internet servers are visible where they are not too densely overlapped. The image thus represents connections between objects that are partly physical and partly virtual; each has some machine attached to it, but the spatial and tangible relationships are not the main focus of attention: what it most clearly shows is the form of a network.

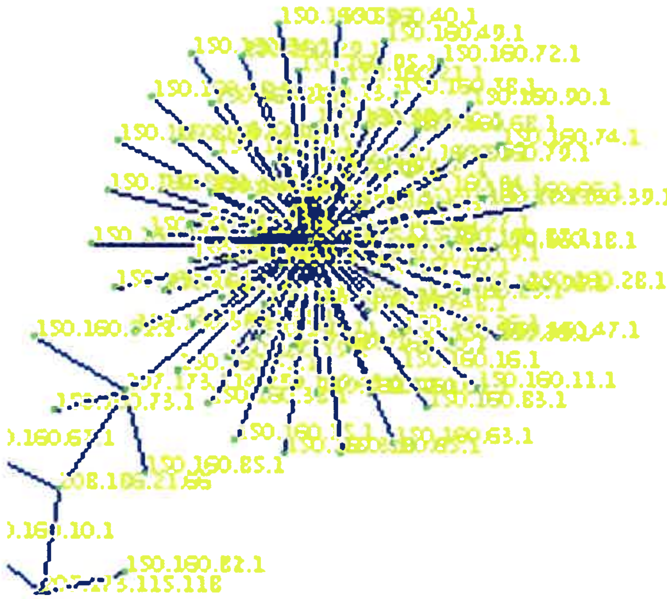

Figure 32: Network visualization

Another example is the website "They Rule,"[86] established and maintained by artist Josh On and the San Francisco-based collective *Futurefarmers*. This works in a quite different register of information, though there are similarities both in the node-network form of the representation and in the abstract nature of what is brought to light through the process of visualization. The site is linked to a database that lists American corporations and organizations together with their boards of directors, major political donations, and a range of other information freely available from public databases. Visitors to the website can choose to view existing maps or create their own representations of the interconnections between different companies that result from the overlaps of their boards of directors. Figure 33, below, shows the network of interconnections between the cabinets of two successive American presidents from rival political parties, revealing the "six degrees of separation" – in this case, more like three – that link these two powerful and influential groups.

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[86] http:www.theyrule.net, accessed on Sept. 23, 2004.

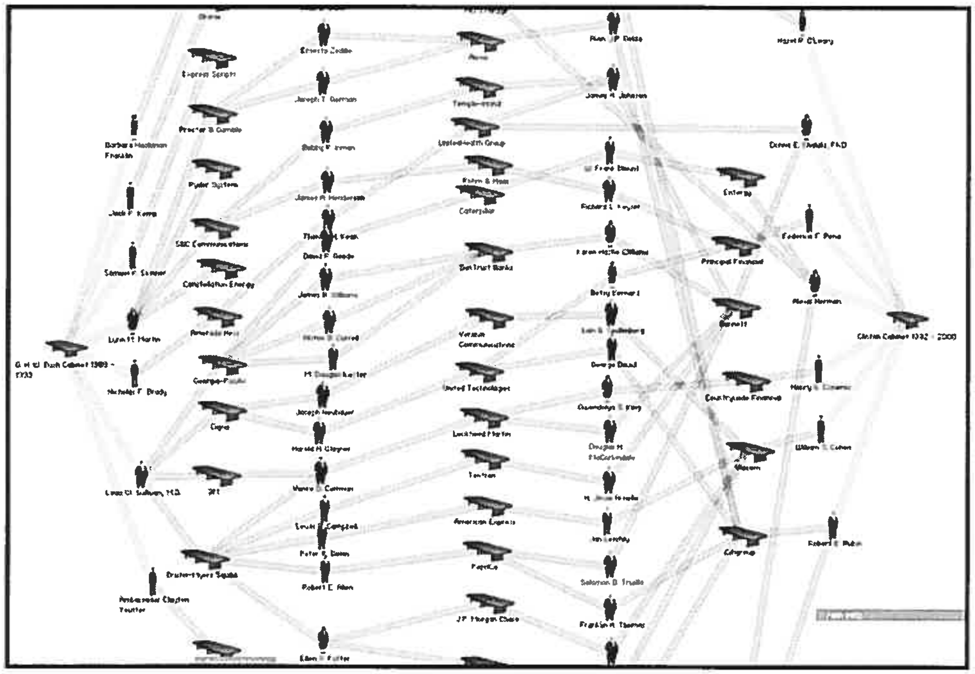

Figure 33: "They Rule" data visualization

In both these cases, visualization allows multiple connections, linkages, and patterns to be seen and understood in a single glance and without the need for elaborate explanations. Visualizations show that pictures can be worth even more than a thousand words, since no amount of text could ever represent such structures in such a comprehensible, memorable and striking form.

Finally, a much less benevolent use of advanced visualization technologies is described in Edwards (1996a, p. 3). As he recounts,

> *In 1968 the largest building in Southeast Asia was the Infiltration Surveillance Center (ISC) at Nakhom Phanom in Thailand…. Inside the ISC vigilant technicians pored over banks of video displays, controlled by IBM 360/65 computers and connected to thousands of sensors...The sensors -- shaped like twigs, jungle plants, and animal droppings – were designed to detect all kinds of human activity, such as the noises of truck engines, body heat, motion, even the scent of human urine. When they picked up a signal, it appeared on the ISC's display terminals hundreds of miles away as a moving white "worm" superimposed on a map grid.*

This last example, where human activity is represented as a dot on a map, moving in real-time, is closely related to what is known as GIS (geographical information systems). These are computer systems that use geographical location as the organizing principle for data structures (Commission on Geosciences, Environment and Resources, 1997). It is likewise similar to what is known as "augmented reality" (Azuma, 1997), the superposition or mapping of data onto locations, objects or people. As Azuma (ibid, p. 385) explains, these technologies have been widely commercialized for "Medical, manufacturing, visualization, path planning, entertainment and military applications." The ability to track people, objects and data in real time is a significant contemporary technological development, and one that will be addressed in other sections.

In all of these very diverse forms, visualization refers to the creation and manipulation of semiotically significant, graphically appropriate, functionally effective and aesthetically satisfying representations of information. Much interaction design activity involves the use of visualization, since a great deal of what is done with computers touches on operations that are carried out on abstractions that exist only within the machine, and that must be given an intelligible, human-facing form. But at the same time, not all forms of the outerface deal with the same level of abstraction; simulation, for example, has a somewhat different connection to reality.

b) Simulation

> *The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal. With appropriate programming such a display could literally be the Wonderland into which Alice walked.*[88]

This somewhat menacing quote by Ivan Sutherland, the engineering visionary responsible for such technological innovations as the head-mounted device (Sutherland, 1968), had strong resonance during the last decade of the twentieth century. In popular culture and academic studies alike, the idea of artificial control

[88] Sutherland, 1965, p. 508.

over the entire range of the human senses was popularized through iconic references like *Star Trek: The Next Generation's* "Holodeck" and the related academic discourse like Murray's (1998) *Hamlet on the Holodeck*, as well as through Hollywood blockbusters like *The Matrix* (Wachowski & Wachowski, 1999) and *Existenz* (Cronenberg, 1999), both of which featured even more visceral forms of sensory stimulation using direct neural connection – "jacking in" to the brain itself.

This is one meaning of simulation pushed to its logical extreme; it is closely related to artistic creations like frescoes, dioramas, and film, all of which create varying degrees of human sensory immersion within an artificially created universe. It is also the concept most closely linked to so-called "virtual reality" – the ability to create audio and video signals that create a sense of "being there," or, as Riva (2001, p. 48) describes it, "[T]he full immersion of the human sensorimotor channels into a vivid and global communication experience." Simulation in this sense primarily refers to sensory plausibility, the ability to create an environment that engages a significant part of the human sensorium in a way that is somehow analogous to normal lived reality (though, as the image below shows, this is only the case for the person whose senses are so engaged; to onlookers, the connection to another reality is much more abstract).

Figure 34: CAVE virtual reality environment

There is also a second important meaning behind the concept of simulation: the modeling of orders of reality beyond the purely visual and sensual, including those addressed by fields of study like physics, economics, and psychology. In this latter interpretation, simulations represent the convergence of statistics, calculation, models and algorithms to form mathematical models based on massive calculation and datasets of arbitrarily large scale. Examples of this range from the playful and successful "Sims" family of games[88] to investment models that represent such abstractions as stock market fluctuations and commodity prices.

Figure 35: SimCity urban simulation

Though often playful, such models can also be extremely serious; for example, the Club of Rome created a computer model treating the entire world as a system in order to create the widely read and hotly contested book *Limits to Growth* (Meadows, Meadows, Randers & Behrens III, 1972), while Schrage (2000) discusses the widespread use of simulations in modern business practice, including many of the world's largest corporations. As an extreme example of the significance of simulation in the modern world, Edwards (1996a) describes the strange way in which simulations became a vital part of United States policy planning during the

[88] A trademark of Electronic Arts, Inc.; online at http://thesims.ea.com/ and accessed on Sept. 12, 2004.

Cold War – a game played without any certainty as to the rules, nor yet limits as to the size of the wager. As he describes this strange setting (Edwards, 1996a, p. 13),

> *Inside the closed horizon of nuclear politics, simulations became more real than the reality itself, as the nuclear standoff evolved into an entirely abstract war of position. Simulations– computer models, war games, statistical analyses, discourses of nuclear strategy—had, in an important sense, more political significance and more cultural impact than the weapons that could not be used. In the absence of direct experience, nuclear weapons in effect forced military planners to adopt simulation techniques based on assumptions, calculations, and hypothetical 'rules of engagement.'*

Summing up, simulation refers either to the creation of a situation that appears as real or to that of a situation that can be treated as real for experimental purposes, or sometimes both. Compared with visualization, the concept of simulation is perhaps one degree less abstract; simulation always has some connection to reality, either the reality of human experience in space and time as experienced through the senses, or some external reality, a subsection taken from a constantly changing and evolving world affected by a multitude of complex and interlinked factors.

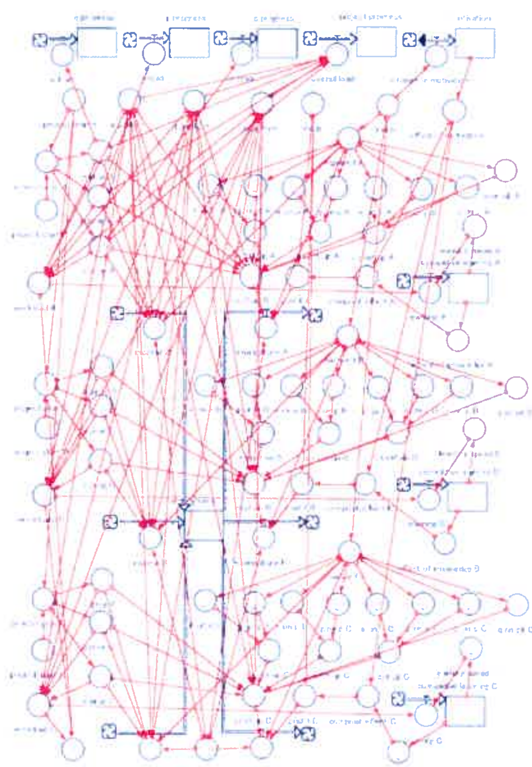

Figure 36: "Just-in-time" construction cost simulator

At the same time, simulation and visualization are in no way mutually exclusive, and many computer applications actually rely on both simultaneously. Word processors, for example, simulate ink and paper, while providing iconic visualizations of the many computational tools and procedures that can be applied to the textual data. Similarly, many video games use simulations of physical laws – like gravity, inertia, and optics – while also providing visualization of parameters (for example, the score in the game) that have no direct real-world equivalent. Interaction designers work inside multiple loops of simulation and visualization, using them as tools with which to build other tools and as tactics for designing and presenting abstractions drawn from the realm of information.

c) Multimedia

> *What multimedia refers to in [relation to computers] is the electronic representation of multimedia. While this may include either analog or digital multimedia, it now largely embodies multimedia in its digital form. In its current state, electronic multimedia usually appeals to the human senses of sight and sound, and occasionally, touch; it remains to be seen how electronic multimedia will be used with respect to most of the remaining senses. The current dominant types of electronic multimedia include video, images, audio, graphics, and speech.*[90]

The concept of "multimedia" – like its close relative "new media" – is rather loosely defined, amorphous and all-encompassing. Over time, it has been variously used to refer to slide shows, animations, CD-ROMs, video clips, site-specific art installations and 'mixed media' works, only some of which are computational. The etymology of the term is at least partially responsible for this ambiguity; television, for example, can be seen as at least two distinct media, one visual and one audible, and televisions can also be used to represent and display other 'media,' such as photographs, paintings, drawings, sculpture, etc. Cinema has incorporated sound as a matter of course, with occasional forays into haptics (like the vibrating seats featured in certain 1970s disasters films) and even odors and wind (as in inventor Morton Heilig's 1962 "Sensorama" device, described in Steed, 1996).

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[90] Fritts (2000, p. 4).

featured in certain 1970s disasters films) and even odors and wind (as in inventor Morton Heilig's 1962 "Sensorama" device, described in Steed, 1996).

Figure 37: "Sensorama' multimedia system; sights, sounds, and even smells.

As Sterling (2004, unpaged) points out, media are both ancient and diverse; in fact, throughout history,

> *People have created media out of smoke, silk, braided yarn, flowers, stone, wood, palm leaves, wax, skin, and hair. There is media for the wilderness, the tent, the home; for horseback, cars, trains, and aircraft; for towns and massive urban centres. Media is a highly variegated set of specialized substances.*

In a similar spirit, Packer (1999) makes a historical link between 'multimedia' and the Lascaux caves – which use space and light as 'media' – as well as to Wagner's theory of the *Gesamtkünstwork* (Total Art Work), an all-encompassing experience that utilizes all of the senses to envelop audiences within worlds of artifice and experience. The arts have long since recognized this potential; for example, *Relâche*, a Dada 'ballet' staged in 1924, featured music by Eric Satie and film by Réné Clair, with dance, theatre, performance and electric sets; no computers were needed for this proliferation of 'interactive' media. And so, as with so many of the terms which surround the discourse of computation, it is challenging to find the essence or novelty of 'multimedia,' or to tie it to any particular technology.

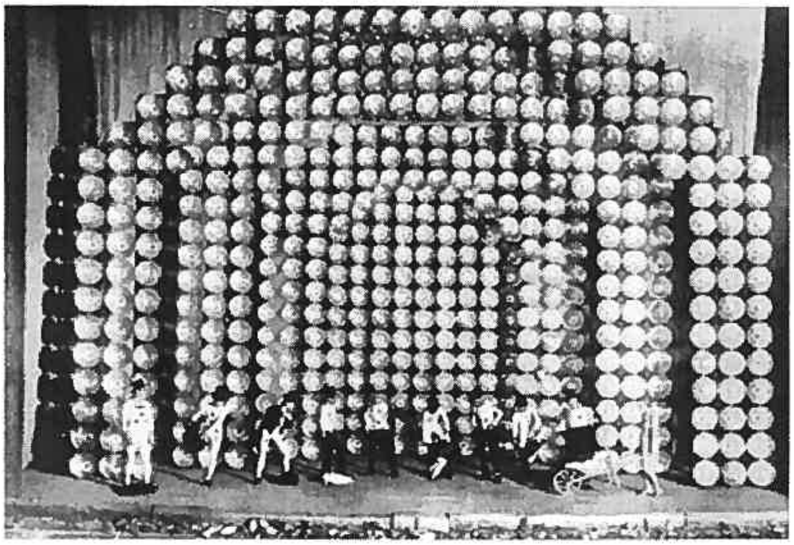

Figure 38: "Relâche', a Dada ballet from 1924

Though multimedia may be neither novel nor essentially computational, there are nonetheless *new* media, new in function as well as in form. Media, once imported into the computational domain, take on novel properties that are linked to the structures of information technologies and thus to both mathematics and electronics. Such media are, as Manovich (2001) calls it, 'numerically encoded' and 'transcoded' – brought into a realm where they can be mathematically adapted, adjusted, compared, reconfigured and recombined. Furthermore, the falling cost of digital representation and storage have made it cheaper and easier to both create and shape media at will, which in turn has meant that there are quite simply *more* media: more text, more images, more sounds, lights, and colors; the 'multi' in front of modern media is thus as much a reference to multiciplicity as to anything else.

Figure 39: Times Square, NYC. Architecture or multimedia?

Manovich (2001) also identifies three other characteristics of new media, which he calls *modularity*, *automation* and *variability*. These are other factors that distinguish computational multimedia from all previous media forms. **Modularity** refers to the object-oriented potential of computational media; different units can be defined, even within a single image or sequence, and these units can be treated as distinct entities. Sound can be treated as part of a video sequence or as a separate stream; each image of a video sequence may be an entity or the whole sequence can be so defined; and each module can be used, repurposed, reutilized, copied or transformed, without any change to the 'original' data.

The two other factors are closely linked; **automation** is the capacity to apply processes or procedures without the need for explicit control over each parameter. Once a process for changing an image has been established, the same process can be applied to any number of images. And **variability** results from the above factors; each module can have automated treatments applied to it, and if different parameters are selected, the end result will likewise be different. The combination of these last three factors is part of what is often called 'interactivity'; they result in more dynamic and responsive media.

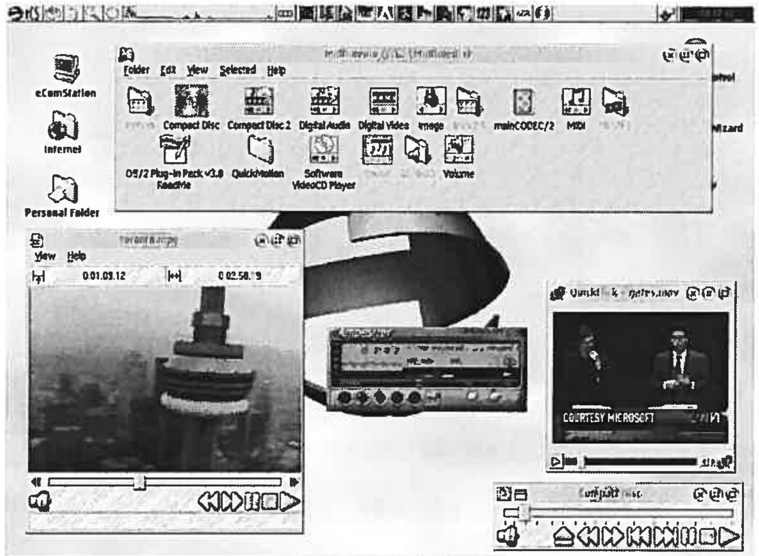

Figure 40: What gets marketed as 'multimedia'

Thus, summing up, in popular culture and marketing, multimedia is generally considered as referring to images, video, and sound displayed on a computer. But in a wider sense, multimedia makes reference to an array of proliferating, potentially time-varying, reactive or interactive media that have some of the properties of traditional representational form but that have been transformed by the passage into the computational realm. Designers work both with and within these media, shaping both containers and content while combining computational media with other tactics of representation and presentation. And at the same time, the range of what can be considered as media is continuing to expand, and increasingly touches on the 'real world' of physical objects – the last dimension of the outerface.

d) Process control

The fourth and final element in this proposed typology is that made possible by the computerized control of mechanical and electromechanical processes. This is an increasingly common part of everyday life, though one that is often overlooked or simply taken for granted. From CD and DVD player mechanisms and hard drive read/write heads, to complex vehicles like Segways and Stealth bombers (both of which are inherently unstable, and require constant and elaborate computational control so as not to immediately and painfully succumb to the pull of gravity), and on to CNC machines and industrial processes, computers are essential for the control of a vast number of physical processes in the "real world" of physical and mechanical objects. And although control systems have long been the territory of engineers (as well as a few brave hobbyists and artists), the increasingly low price and relative accessibility of these technologies – as well as the convergence of programming languages and code with microcontrollers – is now making them a more common part of the computational design medium.

Thus, a growing number of academic programs (including MIT's Media Lab, NYU's Interactive Telecommunication Program, the Swedish collection of labs known as the Interactive Institute, Italy's Interactive Ivrea, and the Royal College of Art in London) are training designers in the basics of electronics and programming, especially through the use of microcontrollers and other 'system-on-a-chip' standalone computers. The program at NYU, as one example, addresses what they term 'physical computing' (O'Sullivan & Igoe, 2004) the use of computers and networks to control motors and other real-world objects.

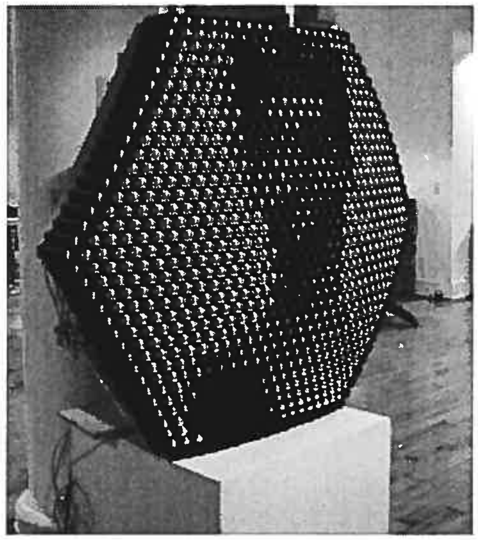

Figure 41: "Shiny Balls Mirror" (2003), by ITP educator and artist Daniel Rozin

The image above shows the "Shiny Balls Mirror" created by ITP educator and artist Daniel Rozin. This 'mirror' is a collection of mirrored balls painted black on one side. The balls rotate under computer control to show either the reflective or matte sides. A camera, pointed outward from the mirror, detects the image placed in front of the mirror. A custom-designed computer program then breaks the image into pixels, analyzes the luminance values, and rotates the mirrored balls to create a low-resolution 'reflection' of the scene unfolding in front of the camera.

While this, like many of the projects at these institutions, is artistic or experimental in nature, these academic programs are also a reflection of contemporary industrial culture: the cost of microcontrollers has now plummeted to a point where it has become plausible to put a computer into practically any mid-sized consumer product, while the number of students with programming knowledge and ability has drastically increased.

In one comparatively simple industrial example, Oppenheimer & Reavey (2003) describe the process of redesigning a blender from an interaction design perspective. Their text places special emphasis on the behaviour of the blender, and more particularly, on the use of complex motor actions governed by a microcontroller, with resulting mechanical behaviours that would have been prohibitively costly to design, implement and manufacture in analog circuitry. They take this as

> *[P]roof that "ubiquitous computing" is here now—everywhere. What used to be a simple motor with some speed control switches is now a complex, flexible, computerized control system.*

Another striking example is automobiles. Not only do cars now involve a great deal of robotic intervention during the process of production,[90] but once completed, the finished products are hubs for computer-controlled processes, mostly invisible to the user but vital for the smooth and effective response of the vehicle and its subsystems. Thus, for example, a report recently published by IBM (Arthur, Breed & Schmitt-Luehmann 2003) points out that luxury vehicles now contain an average of 105 microcontrollers, and further comments that cars are being gradually transformed from mechanical to computationally enhanced electromechanical devices[91].

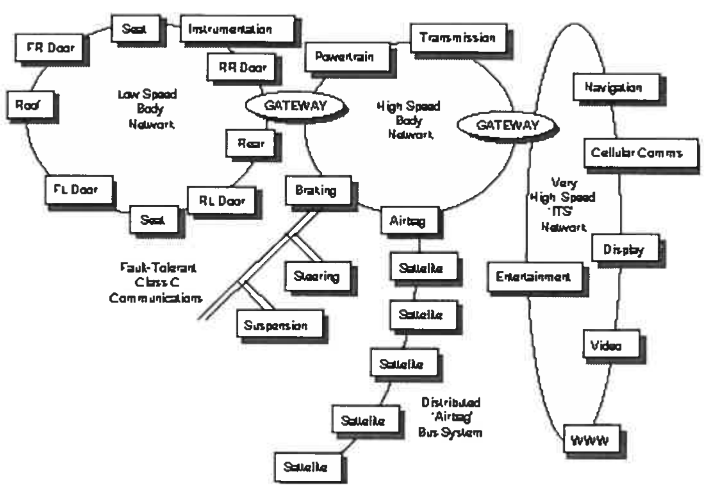

Figure 42: Schematic representation of automobile computer subsystems, from Bannatyne (2003)

The range of control systems varies dramatically, from relatively simple applications, like opening and closing valves or turning motors on and off, to extremely complex systems for aeronautic and large-scale industrial applications. However, as control

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[90] UNECE Press Release ECE/STAT/03/P01 suggests that, in Japan, Italy and Germany, there is more than 1 robot per 10 human production workers in the automotive industries.

[91] See www.hondata.com for an even more striking example of this (accessed June 12, 2004).

systems become cheaper and more commonplace (and as the tools and interfaces for creating and managing them converge with those of other information technologies), interaction designers can increasingly consider them as potential systems components that use physical and electromechanical behaviours for interactive information display. Beyond the novelty value, the more fundamental question remains the same: finding the most relevant, effective and appropriate way of giving human-facing form to the hidden workings of information systems.

> *Although design contains elements ensuing from experiences involving language, design is essentially a non-verbal human activity. Its means of expression and communication are grounded in the visual, but extend to sound, texture, odor, taste, and combinations of these (synaesthesia), including rhythm, color, and movement.*[93]

The term "outerface" offers a way of describing what happens as the result of a computer system operation, the human-facing component of the system that provides feedback that users will in turn sense, interpret, and understand. The proposed distinctions between these different outerface forms are quite arbitrary in some sense, since all forms of computer output are scaffolded on the precise and fine-grained control of electromechanical devices (particularly monitors and display technologies), and all can thus be seen as 'process control.' Likewise, the fact that almost anything can be described as a 'medium' makes the term 'multimedia' so open-ended as to risk being meaningless.

Nonetheless, however fluid these differentions may be, they do provide a set of conceptual tools for describing, situating, and differentiating between these devices, and the spectrum that is discussed above can be summarized as follows:

> ***visualization*** is characterized by a focus on the representation of abstract data;
> ***simulation*** is more closely linked to realism and reality;

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[93] Nadin, 1997, p. 590.

> ***multimedia*** focuses on the representation, cross-pollination and precise control of previously existing media forms; and
> ***process control*** is associated with control over the physical world of 'real' objects.

Language, the written word, and images (both still and moving) remain and will almost certainly the predominant modes of output from computation systems. This reflects the efficiency and precision of visual (and especially textual) modes of communication, characteristic of the 'cold' cultures of literacy as opposed to the fleeting, 'hot' experiences of orality. However, other forms of engagement with computational devices are daily becoming more commonplace, and the stage seems set for the lines between people, objects, machines and computers to become even less clear than is already the case. This is the context in which interaction design is emerging, and the field of concerns with which it will engage.

Furthermore, as the range of output devices continues to expand, while input devices become more diverse and less well understood, the connections between input and output are also become increasingly complex. These linkages are created and maintained through the third and final component of systems: the innerface.

5.2.3.3 "Innerfaces": storing and shifting

> *Though hard to interpret, the hardware is at least tangible. Software, in contrast is elusively intangible. In essence, it is the behavior of the machines when running. It is what converts their architecture to action, and it is constructed with action in mind; the programmer aims to make something happen.*[94]

The last of the three elements that comprise the infrastructure of computational systems described in this text, the "innerface," is a term coined in the present text to refer to the realm of programming and software, a domain of conceptual and technical concerns one step removed from direct human contact.

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[94] Mahoney, 1988, p. 122.

Designers in most schools and studios (not to mention most other human beings) are normally kept busy enough understanding, learning, and coping with the software applications that result from the activities of developers and programmers, without delving deeply into the technical details of shared libraries, command lines, database structures and optimized algorithms. This level of insulation from what goes on "under the hood" is one of the main reasons that graphic interfaces have become so popular – and that computers have become such an integral part of daily life.

On the other hand, programming is fundamental to the medium of computation. The structures and selections made at the levels of operating system and application are intimately linked with the possibilites that will be available at the level of user engagement. Particular systems, languages and applications have their own particularities, strengths and weaknesses, and programming both enables and underpins the 'dialogue with immaterials' that characterizes interaction design.

In practice, a range of different levels of engagement with programming characterize present-day interaction design activities (Stott, 2002). In academia, industry and practice alike, small companies and individual designers use a range of languages (including XML, HTML, Javascript, Java, UML, Lingo, ActionScript, C++ and many other development tools and authoring environments) to create Web pages, interactive kiosks, software interfaces, and the like. In some cases, entire projects may be done by small teams, or even by one person, though this is most often the case for projects carried out at small and medium scales – somewhat analogous to artisans in other design disciplines.

In the academic realm, MIT's Media Lab has been particularly influential in training and fostering artist-designers who explicitly use code as a design medium. Some of the better-known results include John Maeda's Design by numbers (Maeda, 1999), a language for graphic design and visual expression, and Fry & Reas' *Processing*[94], an environment similar to Java but designed specifically for graphic output and visual interface design. Other environments originally designed for artistic production within academic contexts include Miller Puckette's *Max/MSP*[95], a graphic interface system originally designed for electronic music production, and now used for a range of interactive media applications. These environments all require a more or less direct engagement with the raw material of computer programming.

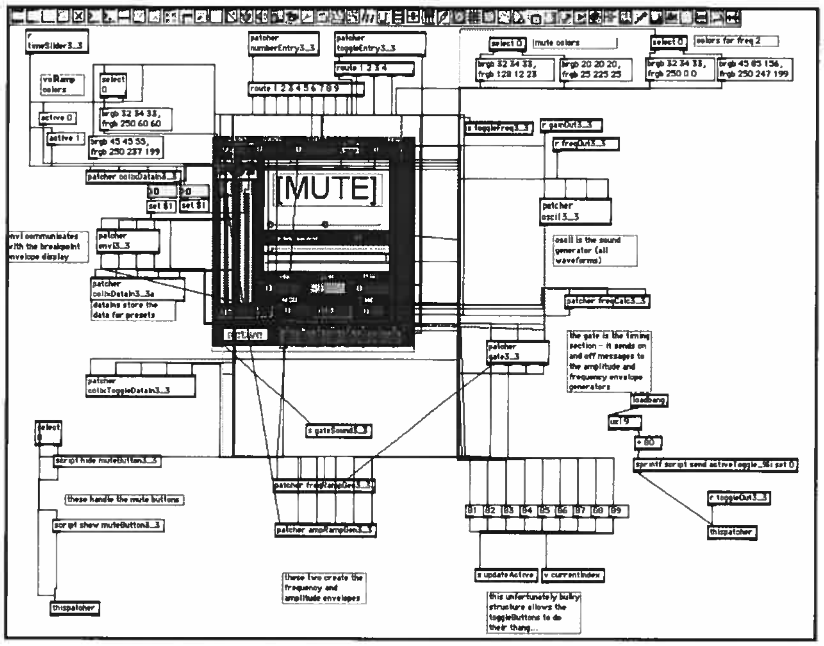

Figure 43: Max/MSP graphical programming environment

In contrast, Reimann (1999) points out that in mainstream industrial practice, "designers rarely code." Larger design teams—and more elaborate projects—will normally include specialized programmers who collaborate with interaction and interface designers, just as they may have individuals or teams specializing in usability testing.

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[94] http://www.processing.org, online as of March, 2005.
[95] Now commercially available at www.cycling77.com, as of Sept., 2005.

While programming knowledge remains useful in such settings, it may not be directly put to use. Within larger corporate contexts, designers often focus on the establishment and creation of detailed specifications, on the development, management, and evaluation of user and usability studies, and on the overall planning of system behaviours and appearance, particularly at the level of the interface (in the traditional meaning of this term). Communicating between the different stakeholders involved in the process— including marketing, development, and management teams—also becomes an important part of project development. This range of activities leaves little time for the technical details of writing, debugging and optimizing code, particularly in projects involving programs that can be measured in millions of lines of code.

Programming is an essential but esoteric realm of concern with a host of domain-specific issues. For the purposes of this text, without delving too deeply into the technical details of programming or those of any particular operating system or application, it is possible to identify three themes that provide some understanding of what is at stake and that permit discussion of a few of the major issues. These themes are:

Mapping, or creating meaningful connections between input and output. This is the core of interaction design.
Algorithms, the computational equivalent of mechanical components. These are the building blocks from which programs are fashioned.
Databases: the main representational form of the electronic realm, a novel form of shared memory.

Brief discussions of each of these three aspects will close this discussion of the three different faces of computational systems.

a) Mapping: The invocational gap

> *Something as apparently simple as a user clicking on a web page link actually invokes a sequence of events at multiple levels: an application passes a request to the operating system, triggering signals in local and network hardware, passing a sequence of events through TCP-IP networks to the addressed server. The server responds to the http request, and finally, within some milliseconds, the user reads the page she has invoked. For users, though, this is only one invocational event.*[97]

Clicking a mouse, or pushing a button connected to a computer system, is an act with consequences that are impossible to describe in abstraction: almost anything might happen. A button could do nothing, or might launch a missile in a simulated world – or in the real world, for that matter – or play a movie, or modify some invisible parameter in computer memory, or in a nearby database, or on the other side of the planet. Hypothetically it could do all of these, or some random selection, or each successively, just as it could then be set up to report the action to a government agency, advertising agency or hacker.

Media theorist Chris Chesher has described this chasm between human action and electromechanical reaction as the "invocational gap," and it both forms the space and establishes the territory of sign and symbol within which the innerface is constructed. Designers and programmers are responsible for bridging this gap by creating meaningful, comprehensible and coherent relationships between action and perception, thereby ensuring that people understand what *is* happening, what *will* happen and what *could* happen.

This fundamental need for meaning and understanding is in turn responsible for the close connection between computational design and semiotics – the study of human sign systems. As Nadin (2001) points out, computer systems are always scaffolded on deeper-rooted forms of communication, action, and symbolic understanding. In his words,

[97] Chesher, 2002.

> *Interactions can be direct: raising one's hand in greeting, pounding on a table, pulling a lever, cracking an egg, for example. Or they can be mediated: showing a picture in reference to a physical phenomenon, touching a soft-button on a copy machine in order to execute a desired operation, or clicking on an icon in order to connect to a Web address. A simulation is a mediated interaction through which we settle in the representation of what is simulated under the assumption that some coherence is preserved between the real and the represented. This is the underlying cognitive assumption of semiotics.*[98]

Semiotics has always been concerned with the different degrees of connection between the signifier (the sign or symbol that invokes meaning) and the signified (that which is represented by the sign or symbol). From photographs to pictographs, knobs, and words, the relationship between signs and meanings are varied and complex; much ink has been spilled in attempting to explain how meaning emerges from signs and symbols, and a great deal of mystery still remains.

In the computational realm, these different levels of interaction – which may appear more or less natural, intuitive or direct – are suggested or facilitated by the interface, presented through the outerface, and supported by the innerface. But when compared with the truly direct, intuitive and natural character of most physical interactions, the semiotics of computer systems are complex, dynamic, fluid and cognitively driven. Media researcher Stephen Wilson illustrates some of the possible arrangements of links, passages, and connections in the following diagram that shows a range of possible hypermedia structures.

[98] Nadin, 2001, p. 438

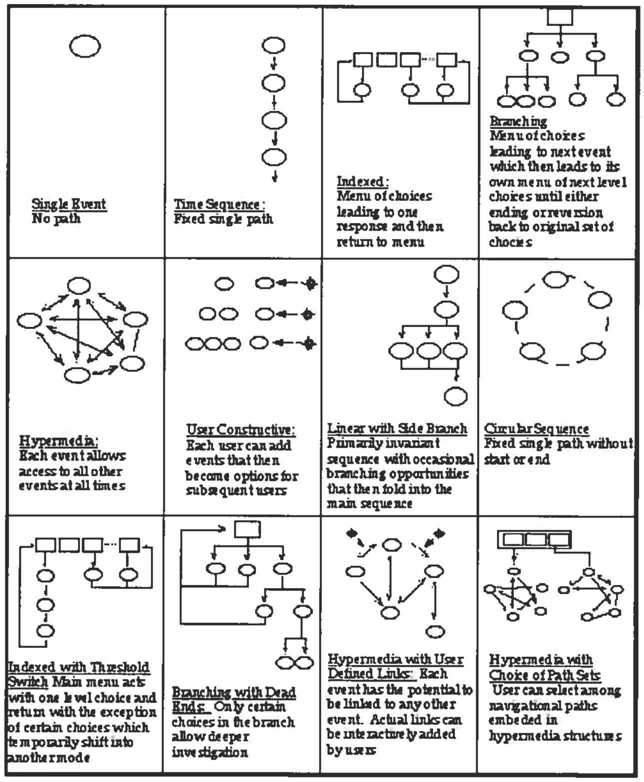
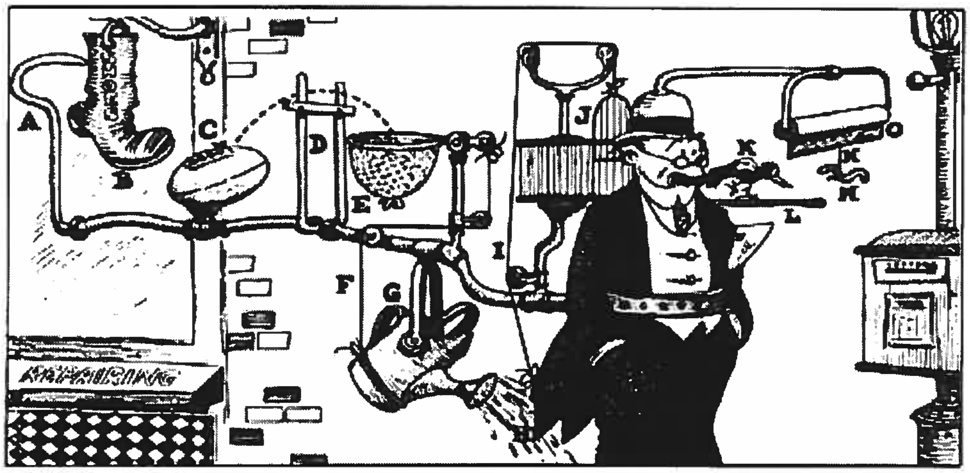


Figure 44: Hypermedia structures, from Wilson (1993)

This abstract, schematic representation is particularly evocative of the forms of interaction that characterize Web pages, CD-ROMs and hypertext, where selections are made between a number of discrete units or chunks. The diagram shows relatively linear, step-by-step forms of interaction, where one choice can be made at a time; it is less evocative of more dynamic systems with many simultaneous variables, like video games or simulations, where choices and boundaries are not as clear-cut, and where the state of the system will depend on many different interconnected parameters that independantly evolve through time, incluing some that are dependent on networked communication or external data acquisition.

Nonetheless, the diagram does make it clear that many different variations are possible, and also helps to illustrate the semiotic complexity of new media. There is no denying that mechanical systems are complex in their own ways, and a mechanical system could be set up to perform any one of these functions, patterns, or sequences in much the same way; Rube Goldberg's eponymous machines (like the one shown below) are a tongue-in-cheek reminder of the mechanical complexities that are possible with enough ingenuity and without any computational assistance.



Keep You From Forgetting To Mail Your Wife's Letter RUBE GOLDBERG (tm) RGI 048

Figure 45: "Rube Goldberg" machine

But the image is also a reminder that mechanical systems, once put into place, will remain relatively stable and consistent: the same button (or the same boot) will trigger much the same behavior each time it is toggled or activated. It would require a great deal of energy and effort to retool one of Goldberg's machines, and the result would be likely to look rather different.

In contrast, when dealing with computers, the rules change constantly, while the physical components typically stay the same. In the space of a few moments, a computer keyboard becomes a way of controlling a video game, then a tool for banking, a way of writing to a friend and then a means of trading stocks. Video screens give easy and immediate form to multiple tasks, switch from personal to corporate without effort and provide simultaneous access to multiple channels or streams of information. This fluidity and flexibility of information technologies, like the universality of computers themselves, represent both a design feature and a challenge – like a blank page or a fresh canvas, but with a drastically wider range of inherent potential.

And so, one of the crucial parts of the innerface, as it concerns interaction design, is its role in supporting, facilitating, and creating satisfying, comprehensible and meaningful relationships between inputs and outputs—a task often called 'mapping' (Garnett & Goudeseune, 1999; Mynatt & Edwards, 1992). But at the same time, the very idea of mapping is suggestive of a view from the outside, the perspective of a system designer or information architect, who can see the system as a whole from some point of omniscient overview and who already has a well-formed mental image of the whole (what is often called a 'mental model.')

From an experiential point of view, Chesher's term 'invocation' better captures the nature of the phenomenon. This is in part because the idea of invocation has a magical connotation. Science fiction author Arthur C. Clarke came up with the phrase that is now called Clarke's Law: "Any sufficiently advanced technology is indistinguishable from magic" (Computer Science and Telecommunications Board, 2004). In this sense, the concept of invocation captures something of the magical quality of modern technology, the reality that ancient myths and legends have been given form in mysterious little capsules of metal, glass and plastic. Flight through the air, communication at a distance, heat and cold, voices from the ether, all have been made available with the wave of a hand or the tap of a switch (and the swipe of a credit card).

Furthermore, the idea of invocation is a reminder that interaction is about action: the goal is always to make something happen. In this sense, invocation refers to what the user both can and must to do to bend the system to his or her will: like a magician with powders and beakers, people learn that the tiny icons on a screen, or the small buttons on a black box, will give certain predictable results when invoked in particular ways—at least if the gods are kind.

The idea of the 'invocational gap' thus refers to the semiotic space between action and reaction and also serves as a reminder that the experience of a system is very different for the designer and the end user: to make a successful invocation, one must follow the rules. Moreover, innerfaces are built within a realm of open-ended signification where the meaning of computational input events—buttons, keys, mouse movements, breath or mere presence—is constantly constructed and must be explicitly maintained, explained, and comprehended. This is what interaction designers do, building a technological surface or skin over the mysterious guts of the system. Meanwhile, under this skin – and within the electronic complexities of the system itself – two of the most important concepts are *algorithms* and *databases*.

b) Algorithms: One step at a time

> *If in physics the world is made of atoms and in genetics it is made of genes, computer programming encapsulates the world according to its own logic. The world is reduced to two kinds of software objects which are complementary to each other: data structures and algorithms… Any process or task is reduced to an algorithm, a final sequence of simple operations which a computer can execute to accomplish a given task.*[99]

Deep within the machine, system goals are carried out through a set of processes or algorithms captured and expressed in some programming language. Algorithms form the mathematical and logical bridge between the description of what a system should do, what it actually will do, and how it goes about doing it, step by step by painstaking step, and millions, billions or even trillions of times each second.

An algorithm is a detailed recipe for carrying out a task, a step-by-step procedure for solving a problem. Algorithms can exist at different levels of detail and operate

[99] Manovich (2000), p. 181.

with very different granularities; descriptions may be given at a high level of abstraction, or at a very fine level of detail. To take a very simple example, the standard procedures taught to students for carrying out tasks like multiplying and dividing numbers can be seen as algorithms. Many possible procedures exist, more or less efficient with regard to the number of steps required and the effort of execution, since there are many different ways of mathematically addressing any given problem. And once established, algorithms can also be nested and layered; an algorithm for multiplication can be constructed from a set of other algorithms, including those for addition, storage and retrieval, and so on.

To take a slightly more complex example, the computational process for changing the brightness of an image can be described as an algorithm. Each pixel that forms part of the image file is associated with a certain number of magnetically encoded bits of information that describe its luminous intensity and perhaps color as well. A brightness algorithm might pass successively through each pixel's stored value and increase the value or values associated with luminosity, resulting in a brightening of the image. Even more sophisticated algorithms might consider not only single pixels but also neighboring values, or perhaps look for patterns in the image file as a whole. Algorithmic modifications can also more radically change the nature of data to the point of unrecognizability, or produce particular effects (visual examples include blurs and deformations) through specific mathematical transformations.

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Figure 46: 16 algorithmic variations on a theme

Since algorithms are mathematical abstractions, there would be, in theory, no difference in the final result were this to be carried out by a machine, a human, or any other means – biological, chemical, mechanical, or any other form of computation. However, this is only true in purely logical terms, viewed from the Olympian heights of physics and engineering. At the level of human perception and experience, the results of massive algorithmic power create distinctly new phenomena. As Manovich (2003, p. 19) explains, reflection of a biological reality that reflects the nature of embodied experience. A similar form of time-dependency also applies in the realm of mechanical devices and process control; a robot may not be able to stand up straight if an inadequate number of motion and gravity measurements are available during each time period for control of the motor systems, despite the fact that the underlying rules of mathematics and physics don't change.

Algorithms, then, are a curious raw material with properties that remain mathematically and theoretically identical at different scales and speeds of operation, but that create results that offer different possibilities for real-world action (and particularly for human perception) as the time frame changes. More or less closely bound to the contingent and arbitrary limits of human perception and natural laws, algorithms can exist in the abstract realm of pure mathematics, but may also be obliged to straddle the wide gulf between the arbitrary imperfections of human embodiment and the rarified Pythagorean perfection of numbers and information.

Algorithms are also far from equal; somewhat like traditional baking, similar processes and ingredients may produce very different results in the hands of a trained chef. Furthemore, like contemporary industrial-scale baking, the processes and components may be carefully guarded industrial secrets, highly engineered by teams of specialists and protected by a complex maze of patents and laws.

Algorithmic operating instructions have been embedded in the design of many industrial and household utilities. They underpin the daily use of telephones, automobiles, cameras, TVs and radios. Hospitals, factories, banks, and shopping centers all depend on the algorithms that control inventories, transactions, communications and security. They are a ubiquitous support of contemporary mass culture. Likewise, algorithmic procedures are also deeply embedded in the digital tools used in the arts and design; the widespread use of these tools has dramatically influenced the practice of film, architecture, photography, music, industrial design, and all the disciplines of electronic sound and image. The ubiquity of these mathematical tools has also created many unlikely alliances; after all, no one foresaw that mathematics—and especially the applied mathematics of computer science—would ever become so fundamental to so many areas of science, commerce, and art, nor yet that the mathematics of scale would touch on such diverse aspects of contemporary life.

Algorithms figure among the most abstract aspects of computation, and because of the specialized mathematical and programming skills required for their mastery, they are not a realm where interaction designers tend to innovate or lead. Instead, interaction design is the art of building tools that permit people to engage with the ephemeral and intangible power of algorithms, building skins over these mathematical and conceptual skeletons to permit operations to be carried out on information (and its poor cousin, data). These operations are sometimes consumed or used directly, but may also be stored, preserved, and accessed, especially in the metaphorical 'bases' that form significant parts of modern life in industrialized societies.

c) Database logic: storing the invisible

> *We are going to set up a great computer program. We are going to introduce the many variables now known to be operative in the world around industrial economics. We will store all the basic data in the machine's memory bank; where and how much of each class of the physical resources; where are the people, where are the trendings and important needs of world man?*[100]

A further dimension of the innerface – and the last to be discussed in this section – is the possibility it offers to *access* and *build* a remarkable form of dynamic electronic memory: databases. Databases are indisputably the most complex human structures ever created for organizing and structuring information. Whether

[100] Fuller, 1967, p. 71.

in terms of sheer numbers of items stored[101] or in terms of the speed and accuracy of access, databases outstrip all previous forms of data storage and retrieval by orders of magnitude.

The principles behind databases are both simple and ancient; they are nothing more than organized, structured collections of data. Ordered and indexed by category, by number, by name, or by other selected and defined characteristics, databases are hierarchically structured containers within which anything that can be numerically represented can be stored and retrieved. Metaphorical references to libraries, government records and accounting ledgers are somewhat valid, but not entirely accurate; major differences include the vast scale of storage, the rapidity of retrieval, the ability to make and update multiple simultaneous copies that have only the most tenuous physical existence and the indifference to both geographical location and physical medium of storage (after all a database can be anywhere, or distributed over many different machines, using one storage media or many; the perceived result remains the same). Last but not least, databases are closely linked to computerized time; the times at which entries and withdrawals are made in the memory 'banks' can be captured and stored as still more data, the vast number and fleeting nature of these transactions notwithstanding. These characteristics make databases very much a part of network logic; the Internet itself is, after all, built atop a multitude of interconnected databases.

Like computers themselves, databases have spread far afield, from labs to corporations and on to desktop and mobile phone alike, and now serve as the main repositories for the information generated in increasingly vast quantities by a growing range of human efforts and activites. A report by the United States National Academy of Sciences (Commission on Physical Sciences, Mathematics, and

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[101] The number of items stored is stretching the limits of language; having moved from *mega* to *giga* to *tera*, the next step is to *peta*. See, e.g., http://www.dmreview.com/article_sub.cfm?articleId=8182.

Applications, 1999, pp. 17-18) points out the extent to which databases have become significant:

> *As a result of the near-complete digitization of data collection, manipulation, and dissemination over the past 30 years, almost every aspect of the natural world, human activity, and indeed every life form can be observed and captured in an electronic database. There is barely a sector of the economy that is not significantly engaged in the creation and exploitation of digital databases, and there are many—such as insurance, banking, or direct marketing—that are completely database dependent.*

While the rhetoric of such claims is clearly overblown (it seems evident that neither every aspect of human activity, nor yet of every life form, can be 'captured'), the modern dependency on data is certainly unprecedented, and computerized data has become a valuable and prized resource in the modern economy; see, however, McDermot Miller (2002) for an description of the challenges faced when trying to establish the true value of these intangibles. This financial value has created a feedback loop, as technologies for extracting, storing, analyzing, presenting, archiving, transferring and transmitting data have in turn become the focus of tremendous research efforts (OECD, 2004). Thus, not only are these technologies already extremely advanced, but they continue to evolve at the same blistering speed as other information technologies.

Like so many computational innovations, the concept of a data base found its first expression in the American military during the period following the Cold War. In a remarkable essay, Haigh (2004) traces the historical origins of the term 'data base' to its earliest expression. In his explanation of the etymology of this phrase,

> *By the late 1960s…*data base *was a common expression in corporate computing circles, largely replacing the hubs, buckets, and pools in which data had previously been rhetorically housed. The term was imported from the world of military command and control systems. It originated in or before 1960, probably as part of the famous SAGE (Semi Autonomous Ground Environment) anti-aircraft command and control network…The System Development Corporation, or SDC (Baum, 1981), a RAND Corporation group spun off to develop the software for SAGE, had adopted the term* data base *to describe the shared collection of data on which all these views were based.*

From the outset, then, the idea of a database contained certain key concepts. Databases were a common, shared resource that might be simultaneously accessed by many different people. They could be quickly updated for all users, operating within or beyond the limits of human 'real-time.' They were intimately linked with large-scale military and corporate structures, driven by the needs of power, command and control. And they permitted different views, different repurposings, and different uses of the same shared data; the container and the content were separated, allowing different filters to be applied.

Since then, the major changes have been in the scale of the technologies and the power of the underlying hardware; most of these basic principles have remained fundamentally the same. Goguen (1999) has identified some of the other contemporary trends in databases that appear highly relevant for interaction design:

❖ increasing **size**, tending towards the truly vast
❖ increasing **sophistication and convenience** of access mechanisms, tending towards analysis and away from mere query
❖ increasing **invisibility**, by absorption into the application and/or the user interface
❖ increasing **circulation** and **sharing** of information
❖ increasing **coordination** with other databases and applications
❖ increasing **amounts** of personal information
❖ increasing **commercialization** of information

Table 3: Trends in databases, from Goguen (1999)

These are important driving forces in the expanding role of databases, and there are many examples to illustrate each. **Increasing size** needs no special explanation;

the size of databases already surpasses any human sense of scale. The **increasing sophistication and convenience** can be seen in such trends as the rise of search engines and the incluson of search tools in most computer systems as well as the Web itself. If Google has recently emerged as a powerful economic force, it is certainly because of the sophistication and convenience of the tools they provide for accessing the vast database called the Internet. Likewise, e-commerce and courier services are both more sophisticated and more convenient than ever before, thanks to powerful and well-integrated data management.

The **increasing invisibility** is more subtle, since it refers to situations where processes are hidden behind a layer of invocation. Database lookups are wholly invisible; when a search engine places individually targeted advertisements on a page of results, there is no sign of the sophisticated processes that have gone on behind the scenes. Likewise, consumer profiling by geographical location, customer loyalty cards or other techniques is a common practice that relies entirely on databases, but that is completely invisible to the end user. Invisibility can thus be taken as a reference to the increasingly pervasive character of these technologies.

Finally, t**he increasing circulation and sharing** of information, the **coordination** with other databases and the **commercialization and personalization** of information are three trends that are being negotiated in the face of public fears, legal concerns and personal choices. They are played out in the realm of politics, law, ethics and perhaps even faith, and Chapter 6 more directly addresses these concerns.

Databases are crucial tools in interaction design. They provide invisible but essential support for many of the procedures and processes that are used in computational design, and form part of the horizon of possibilities for interaction. As is the case with algroithms, designers must create skins atop the very flexible skeleton of data, determining how to best provide timely amd access to the most relevant information, how to manage or hide complexity without reducing utility, and how to manage many different levels of access, different perspectives, and different needs – all within the particular logic of a given project, and within the constantly shifting realm of technology itself.

The innerface is the most difficult of the three 'faces' to describe and discuss, since the world of programming and its languages and structures are far removed from the concerns of most people in their day-to-day lives, as well as from much of what most designers do. Programming is both rational and intuitive, like mathematics and like language; it provides a particular way of looking at and addressing the world.

Designers are not, generally speaking, leaders or innovators in programming, though there are exceptions to this as to any rule. However, regardless of the extent to which programming forms part of everyday activities, it is important to have some understanding of the immaterial stuff of which programs are made. Databases and algorithms are the raw materials that underpin the fundamental concern of mapping, all of which combine to underpin human experiences.

There are a number of important issues that must be considered when designing, and while these seem self-evident, the design of many objects of daily use suggests that these considerations are not always adequately taken into account. There is a gap between the designer's understanding of the system and its behavior, and the user's comprehension of these structures. There is a gap between the designer's informed understanding of engagement and the end user's more magical experience – the "invocational gap." And lastly, there is a wide chasm between the purity of mathematics and physics and the contingencies imposed by embodied existence, as well as the sometimes arbitrary (but nonetheless real) factors linked with human perception, cognition, emotion, culture and history.

Though programming may not be part of day-to-day design activity, interaction design requires some understanding of the true nature of the complex processes that take place behind the scenes. Whether on the surface where the relationships are established between what humans will do and what they will understand as having done, through the algorithms that detemine the details of what will take place, or in the databases that store data and track time, the innerface provides an invisible, intangible and unavoidable support for interaction.

5.3 Conclusion: a model of interaction.

As the preceding sections demonstrate, the deceptively simple model presented at the beginning of the chapter unpacks to reveal a very broad spectrum of considerations that form the sphere of concern of interaction design. These include the social and cultural contexts that surround designs and designers, the physical and institutional contexts within which devices are put to use, and the nature of the spaces and places where these interactions unfold.

Interaction design likewise involves an understanding of users (however this term is to be interpreted) as well as their needs and goals. This in turn helps to give form to the kinds of experiences, level of engagement, and duration of the encounters which are to be designed. This array of information and knowledge guides the creation of the points of contact between users and systems.

When designing these human-facing system components, some key considerations include the degree to which system activities and responses are visible to the users, the kinds of controls that are availble to users and the ways in which these are represented, and the degree to which these engagements will be monitored, stored, and accessed, both locally and remotely.

If nothing else, this discussion strongly suggests that discourses focusing narrowly on keyboards, mousing devices, and monitors are conceptually inadequate for dealing with the complex, computationally mediated contexts that are increasingly common in contemporary experience, and that seem poised to become still more commonplace throughout the foreseeable future. This model accordingly represents an attempt to better understanding the nature of these novel contexts for intervention.

The model of interaction proposed in this text is, however, limited in several significant ways. Firstly, it is a view of the phenomenon and not of the experience, which is to say that it represents a view from the outside that does not correspond to anyone's actual engagement with such a system. It is intended solely as a conceptual model for considering the elements which make up interactive systems, and one that helps to contextualize and situate the often complex vocabulary.

Secondly, it is mainly concerned with individual engagements with relatively closed systems. As such, it does not account for situations involving multiple users, and thus can be seen as representing what Bowers (1998, p. 38) calls the 'dominant scenario' in the literature on human-computer interaction:

> *[A] single human individual user interacting with a technical system via manipulations made at the interface [where] the user has a full frontal orientation to the interface and…quite delicate actions (a mouse click here and key press there) have whatever effects the application in question has been designed to realise.*

As Bowers goes on to point out, the realms of social engagement with interactive systems has ben relatively little explored; this is certainly an area which should be more carefully addressed, and is a topic for future work.

And thirdly, the technical details of systems are not specifically addressed in this model. Models such as this are of limited utility, in the sense that the dialogue with the material of actual systems – the software and technology – has a reality all its own, and one that often dominates the design process. Nor does this model explicitly address the complex interplay of power and decision-making within institutions and organizations that are likewise involved in the design process. As the old proverb would have it, theory and practice are identical only in theory.

The main purpose of the model and of the chapter is to draw attention to the fact that interactive technologies are much more complex than models premised exclusively on 'dialogue' and 'face-to-face communication' between 'man and machine' would suggest, and that new vocabularies, both conceptual and linguistic, are required for dealing with (and designing) such situations. Murray (2003, pp. 4-5) has suggested that, for the field of control systems design,

> *The challenge... is to go from the traditional view of control systems as a single process with a single controller, to recognizing control systems as a heterogeneous collection of physical and information systems, with intricate interconnections and interactions.*

The discipline of interaction design faces this same challenge, compounded by the additional complexities of increasingly distributed social systems and constantly shifting contexts of intervention – as well as the need to remain focused on human beings and human needs within a technological culture that puts into question the particular and unique qualities of human existence and experience.

6. The quantum of control: four themes for interaction design

> *To what extent do men control technology? If control is understood to mean either the exercise of a dominating influence or holding in restraint, then much of modern literature would find the matter of control at best paradoxical. One now finds persistent depositions given about… a continuing and ever-accelerating process of technical innovation in all spheres of life, which brings with it numerous "unintended" and uncontrolled consequences in nature and society…In other words, the same technologies that have extended man's control over the world are themselves difficult to control.*[102]

[102] Winner, 1977, p. 28.

6.1 The quantum of control

Previous chapters have discussed some of the past and present of interaction design. The text has addressed several aspects of the technical and social backdrop, provided brief explanations of a few sample projects, and given an overview of some of the areas of current research regarding the various components of interactive systems. Building on this conceptual base, this final chapter takes a more speculative approach, proposing four themes less closely linked to what interaction *designers* do than to the forces that appear likely to shape the evolution of interaction *design*. The themes are **measurement, networks, control** and **identity**.

These four themes can be distilled into a single concept: the *quantum of control*. First and foremost, this is a legal term that refers to the degree or measure of control and responsibility possessed by a person or legal entity. It is thus something of a basic unit of accountability: people and other agents are considered as responsible in some meaningful way and to some measurable degree. The scales of justice, one might say, are often weighed in the quanta of control. A similar measured logic applies in many contemporary economic and political systems: one share in any public company, like one vote, provides – in principle – precisely one such unit.

But in practice, not all situations are so easily analyzed; in fact, the complex dynamics of corporations and governments often make it very challenging to know who or what is actually responsible or accountable for decisions. Information technologies make this both clearer (since there may exist electronic traces of the particular choices that were made, the times when they were made and a variety of other related data[103]) and less clear (since it is particularly challenging to determine

[103] To take an example at a relatively small scale, airplanes and cars both contain 'black boxes' which are routinely retrieved from accident sites to provide information on the events which took place in the final

who is at fault when a large and complex system collapses or behaves unexpectedly; designers, programmers, administrators, politicians, and others all have roles in such situations)[104]. In the real world, the quanta of control are caught in a webwork of relationships, and may also carry a strong political charge.

Taken in isolation, the word 'quantum' has a somewhat different meaning: it represents to modern science something of what the 'atom' meant to early philosophers – a basic and fundamental unit of measurement – but with quite different connotations. The atom seems, in retrospect, remarkably solid and easy to understand; the idea of a basic building block or smallest possible grain of matter dates back at least to the ancient Greeks (Wynn & Wiggins, 2001) and is built into the structures of contemporary education and language. Most people now have some common-sense understanding of what an atom is, however inaccurate that understanding may be when judged against the mysteries of modern science. By comparison, a quantum is a much more recent and far more abstract concept, connected with the inscrutable realm of modern physics.

The quanta of science are invisible and intangible; they can be accessed and understood (to some limited extent) only through the use of powerful theoretical, mathematical and mechanical apparatuses. Quanta are apparently governed by strange and often counterintuitive laws, exist at an infinitesimally tiny level completely unrelated to that of normal, embodied, lived experience, and seem to be in a constant, swarming state of mutual interactions. All of these points help to make the quantum a useful metaphor for computing (Manthey & Moret, 1983): an invisible, mathematically described, statistically predictable and incorporeal – but still, in some sense, real – phenomenon.

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moments before impact. These are now considered as admissible as legal evidence in many cases. See Hubbard (2000) for one such example.

[104] This is discussed in more detail in Nissenbaum (1996), Parrow (1986), and Joerges & Czarniawska (1998).

The idea of control also contains its own share of paradoxes, though these are somewhat easier to grasp, just as they are more human in scale. Control is often personally desired, though both individually and culturally feared. It is recognized that objects, employees, inventories, societies, crime and the economy all need to be kept under control; indeed, all systems (except natural ones) seem to require a degree of management and control. But at the same time, control also has more than its fair share of sinister connotations – like the themes of crowd control, mind control, and thought control – perhaps best captured in the public imagination by George Orwell's famous *1984* (Orwell, 1949), with its evocation of the omnipresent and panoptic eye of Big Brother. And these themes of control are closely linked to technology – and more particularly to computers. Stalder (1999, p. 38) sums it up succinctly:

> *Computers are a control technology. They allow us to create, manipulate and control data events. The spread of computers throughout our society fundamentally affects the distribution of controlling power.*

Computers may be seen as facilitating an increasingly fine-grained control of processes and systems, across a variety of distinct realms – informational, electrical, mechanical, institutional and social – that can in turn be interconnected and interlinked to arbitrary degrees of complexity. These forms of control have emergent effects that can transcend the local consequences of individual choices or selections. And so, for better and for worse, the medium of computation is inherently a medium of control.

In very diverse ways, then, the idea of a quantum of control – both in the specific legal sense and in its constituent terms – can be linked to a number of themes that are relevant to interaction design. The concept resonates with situations in which different human, mechanical, and electronic agents intervene with different degrees of control at different times, as well as with the challenges of establishing accountability and responsibility in such settings. It resonates with contexts within which technologies, calculation, statistics and probabilities are major factors. And it resonates both with the ability to measure and the limits of measurement and with the need to control – as well as the more or less subtle negotiations through which control is created and maintained.

The following sections will address the concepts of the quantum and of control in more detail. These discussions will turn in the concept of *identity*, both that of objects and of individuals. The sweep of information technologies is moving both toward increased measurement and increased control, and identity is an essential part of this movement.

6.2 The quantum

The term 'quantum' has often been used as a metaphor; Bowker & Star (1997) report on a somewhat curious use of quantum physics to explain why capturing nursing tasks in database-compatible terms is so challenging, while Arrida (2002) uses ideas borrowed from quantum physics as the foundation for a discussion of urban planning. The concept can also be easily misused; in a particularly notorious case, Alan Sokal (1996) managed to have a completely spurious paper published in a prestigious cultural studies journal by invoking notions of "quantum gravity" in a text supposedly discussing literary criticism and theory. Sokal's later work includes a pointed critique of inappropriate and inaccurate uses of scientific metaphors, especially when a complex, unfamiliar, or obscure term or phrase is used to supposedly 'illustrate' a concept.

Duly warned, the present text uses the term 'quantum' in two ways, neither of which is directly linked to any of the subtler debates of contemporary science. The first is quite literal; it refers to the role of measurement and the need to *quantify* and *quantize* when developing information systems. The second is a more speculative and metaphorical use, where the concept of quanta is used to refer to complex systems made up of vast numbers of minute parts in constant and mutual interaction. Since there are no other terms to neatly express this idea, the metaphor will perhaps be excused.

6.2.1 The quantum as measurement

> *[Herman] Hollerith was a savvy entrepreneur who founded the Tabulating Machine Company in 1896, which he subsequently sold to the Computing-Tabulating-Recording Company (CTR) in 1911. CTR was created when International Time Recording Company merged with Computing Scale Company to specialize in clocks and grocery weights and measure information technology products.*[105]

Herman Hollerith, though hardly a household name, is best remembered today for his work in developing early information processing systems that were based on the punched cards originally developed to control the Jacquard loom (Schubert, 2004). Hollerith's systems were used to facilitate and automate the collection of census data for the United States government. Not coincidentally, this work directly contributed to the later founding of the IBM corporation (Computer Science and Telecommunications Board, 1999), and thus influenced the history of information processing. And as the above quote suggests, Hollerith's work took place during the historical period at which two forms of measurement converged: that of *data* and that of *time*.

In fact, the mathematical and numerical basis of all digital technologies means that measurements are unavoidable. Two fundamental concepts in the digital realm are *quantization* (Bargiela & Pedrycz, 2002), the process through which analog values are transformed into numerical form, and *quantization error*, the degree of precision with which this process is carried out. Quantization is thus closely correlated with the quality of data: the better the process of measurement, the more accurate the electrically encoded record of reality, and the more precise the degree of numerical

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[105] Schubert, 2004, p.2.

control that will be possible. And both of these terms stem from the same linguistic base: the quantum, the smallest unit defined within a system.

Numbers are the most straightforward form of data to deal with in the digital domain, but written text is also comparatively lightweight (leaving aside all questions of meaning). It requires just a few digital bits to encode a single letter, and only a few more to establish a unique identification code for every word and phoneme. The collected writings of all the authors of antiquity could be stored, letter by letter, on an inexpensive consumer hard drive, and data grows cheaper by the day.

Of course, some written languages (including Japanese and Chinese) offer their own challenges, since not all scripts are as easily reduced to a handful of discrete components as are those based in Latin, Greek and Arabic cultures. Keyboard input, for example, is much more challenging in the case ideographic languages, and a great many workarounds (involving additional physical and cognitive effort) are required.

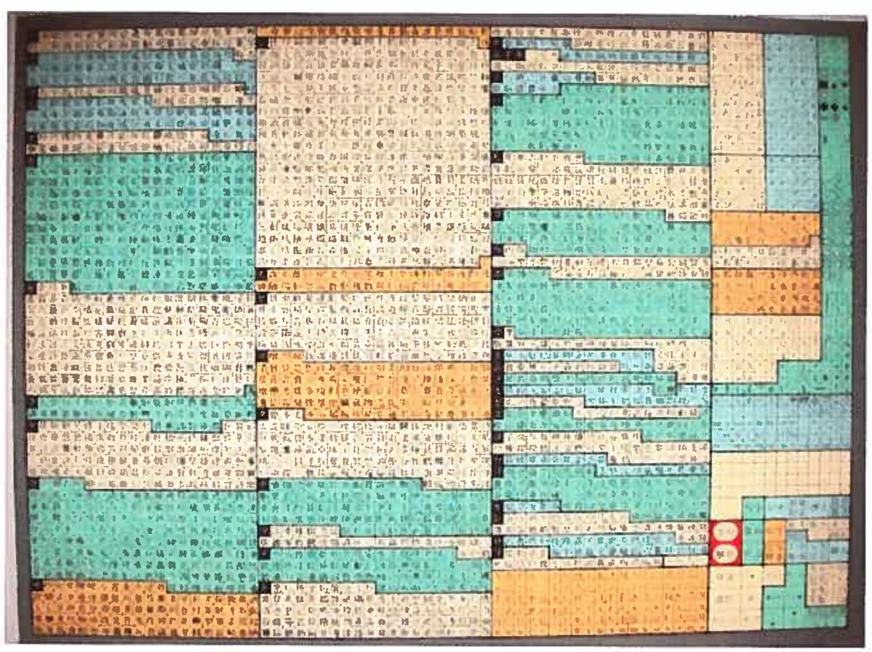

Figure 47: Kanji tablet, a tool for Japanese text input

But however complex these language systems may appear to the naked human mind, the datarate required for the selection, storage or reproduction of any written word – even the most calligraphic – is trivial compared with that needed for audiovisual media, where recordings and representations are always approximations. In the case of images and sounds (as well as movements, brain waves and similar phenomena), what is measured is not a limited, finite and human-generated symbol system, but rather some set of parameters directly extracted from physical reality; furthermore, they involve the dimension of time.

It is true that the quality of media recording and reproduction has now reached a point where the unaided human sensory apparatus may be unable to distinguish (in certain controlled settings) between 'real' images and sounds and their 'artificial' reproductions, and it is almost certain that technological innovations will continue to push the boundaries of perception and reproduction alike. Nonetheless, in the audio, video, and tactile realms, there is always more to reality than is encoded, encapsulated, or reproduced, and it is (and will forever remain) necessary to carry out measurements with some degree of precision and some margin of error.

Thus, whether recording sound or controlling individual pixels on a screen or guiding the rotations of a motor, at some point basic units must be established and set. How many pixels, how bright, what color, and for how long? How many turns of a motor before it will stop, and with what precision does it operate? How many choices will be offered in a menu? What will be the range of values accessible through a slider? What units are to be selected, and how are they stored and accessed? If time plays a role, how is it to be subdivided and managed? In all such cases, units must be selected and measurements taken, and both the choice of units and the quality of measurement will influence the end results.

Of these diverse forms of measurement, that of time has been particularly significant; from time-motion studies to robots programmed with master craftspeople's movements, control over subdivided time and its correlation with action has become fundamental to the intricate choreographies of modern industrial practices and control systems (Bargiela & Pedrycz, 2002). Likewise, in today's marketplace, from the logistics of individual production lines and transport systems to the dispersed structures that facilitate just-in-time manufacturing, the ability to use time as a controlled variable is invaluable (Lee & Whitley, 2002).

And to make this possible, time itself has been quantized, broken up into units derived from the vibrations of atoms and wholly detached from the natural cycles that guided life through most of human history. Historian Lewis Mumford has commented extensively on the quantization of time and the effects of such external timekeeping on social structures; as he explains it, (Mumford, 1934, p.15),

> *In its relationship to determinable quantities of energy, to standardization, to automatic action, and finally to its own special product, accurate timing, the clock has been the foremost machine in modern technics… [It] is a piece of power-machinery whose 'product' is seconds and minutes; by its essential nature it dissociated time from human events and helped create the belief in an independent world of mathematically measurable sequences: the special world of science.*

The concept of 'time-based media' likewise derives from this ability to represent and capture time; the very passage of time becomes a timeline, a programmatic sequence of events that unfolded in the linear form of magnetic tape, and now in the dimensionless space of computational representation. Measured time has become an independent variable, that can be controlled, sped up or slowed down, replayed in loops or fractured. This is perhaps closest to the traditional representational systems of dance and music; musical notation lends itself particularly well to the logic of discrete parametric events unfolding in measured time.

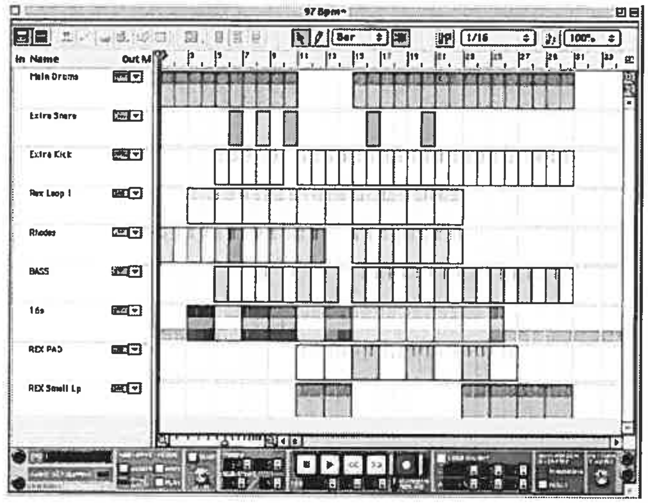

Figure 48: 'Reason" electronic music sequencer; time as the x-axis.

Moving from the fine detail of time and data to a much broader scale, enumeration and classification (which likewise require both *measurement* and *decisions about what can and will be measured*) are also vital in the creation of demographically and statistically based models and systems, like censuses or elections, and thus of systems that will be designed to support and facilitate these processes. Bowker & Star (2001) take the 2000 U.S. elections as an example. In this case, decisions were made based on very small numerical differentiations that were in turn premised in fundamental social and political questions, given shape in part by the physical form of ballots: Who is a citizen? Whose vote counts? What votes are to count?

Bowker & Star use the example to point out that, in order to count in the modern world, one must stand up and be counted – and the tools used by those responsible for counting must be carefully chosen, properly used and well calibrated. In such cases, units of measurement are once again critical – though the measurement of citizenship and rights seems, somehow, rather different from measuring the speed, velocity, or frequency of keystrokes.

In fact, the movement of a data input from a physical act to a symbolically charged action that is meaningful in human terms is a subtle but essential transduction between different kinds of measurement. The image below is a reminder of this; it shows Hollerith's original patent application for the 1890 census machine. The device was set up to distinguish between 'native,' 'foreign,' 'colored' and 'white' residents; both the particular grain of detail and the eventual use to which the data was put doubtless responded to the particular political requirements of the time.[105] Measurement is, after all, both creative and objective; it represents the expression of particular, specific structuring principles, and the giving of a particular order to the world. The way information is collected, and how it is broken down, strongly influences the range of possible future uses.

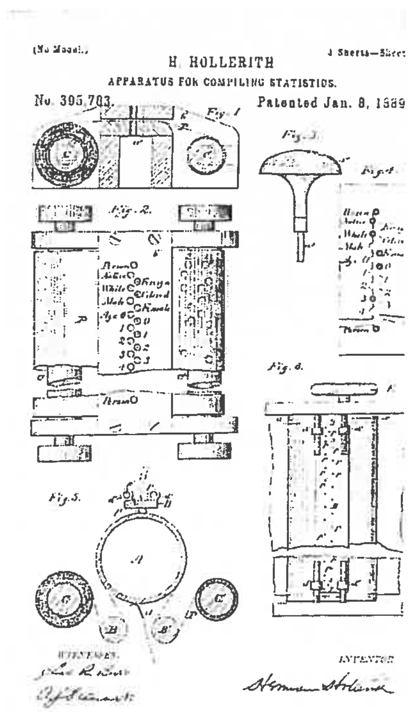

Figure 49: Hollerith's 1890 census compilng device

And so, while challenging at many different levels, measurement is central to interaction design. Through the precision of the instruments used as input devices,

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[105] Today, a surprising number of government forms still force one to lie (or at least to choose the least inappropriate option). Canadian tax forms, for example, do not recognize the profession of design; the limited granularity of choice reflects the difficulty of capturing complex realities in database-friendly lists.

the level of detail allowed by the symbolic systems used for representation and storage, and the semantic, conceptual and ontological structures that determine both the choices that are proposed and the framework within which these choices are embedded, measurement serves both as tactic and tool. At the same time, knowing what to measure –and deciding when measurements can be judged as sufficient or adequate – may be as challenging as the measurement itself. Nonetheless, computational interactions are shaped and guided by particular ways of acquiring, representing, structuring and giving form to information. And, as a result, a part of interaction design is the art, science, and technology of measurement. This gives, one might say, the grain of the medium of computation – and the quantum of control.

6.2.2 The quantum as network

> *Everybody in the world has six billion relationships to other individuals, and every one of those relationships has a certain informational architecture. That doesn't even include the relationships between people and organizations (banks, schools, governments), and between people and objects (computers, cars, refrigerators). If all of those many relationships are continually present, then some method is needed to keep the endless updates under control.*[107]

Those who work with computers become accustomed to dealing with gigantic numerical abstractions as a matter of course. Databases are huge, the Internet is enormous, and even humble consumer electronics are now measured in millions and billions (or megas and gigas). The vibrations of crystals drive the electrical convulsions of information at rates that are incomprehensible if not unfathomable. Meanwhile, these numbers are getting bigger all the time; for example, the new plan for Internet Protocol addressing, IPv6, features a 128-bit address space. This provides some 6.5×10^{23} addresses for every square meter on the surface of the planet, which would, in principle, allow every coffee cup and window and book in the world to have a unique identity that could then be associated with other data

[107] Agre, 2001.

(Greenberg, 2004). The theme of *digital identity* will be explored in more detail in an upcoming section.

These huge numbers in turn underpin increasingly dense networks of interrelationships. From stock markets and postal services to Web pages and email, the many relationships between objects, people and information are more thickly woven and more rapidly updated than ever before – and, thanks to information technologies, more often tracked, recorded, visualized and made present. Meanwhile, cell phones, microcontrollers and sensor networks, increasingly common and increasingly small, are now converging with other computational technologies, generating even more relationships characterized by even less delays.

The quote from Agre that opens this section is a curious but telling image; one does not normally consider one's relationships with other residents of the planet in terms of informational architectures, particularly since most of these relationships do not exist in any meaningful way. But the quote is of the ways in which relationships are being made both present and explicit in the world of real-time networks. While the extent to which this will develop remains speculative, and the uptake and acceptance of these technologies will be governed by legal systems and economic pressures as well as a degree of personal choice, it is becoming imaginable (and even somewhat plausible) that doors, windows, cars and people should all be present on the network, along with time, place and perhaps activities – the "location, identity and state" that was encountered in the discussion of context in chapter 5.

And once this information is in the system, it can be visualized, stored, considered as part of larger patterns, mined, analyzed and exploited. This speculative vision is at the heart of the second interpretion of quanta; not isolated, granular atoms, but active elements that form part of a vast and growing system.

Foreshadowings of this connected world can be found in the modern sciences, which are generating increasingly sophisticated models and simulations of objects and phenomena. These are made possible through the increasingly fine-grained breaking up of the world into measurable units – or parameters – that can then be captured, recorded, and processed in information systems. And as a result of this, many academic disciplines have now defined and established units that can be computationally treated, studied and analyzed; in epidemiology, public health, zoology, and biology alike, professionals work with 'populations,' 'generations,' and 'cohorts' (Gilleard, 2004; Schaefer & Wilson, 2002).

These statistical defined entities, created for particular research needs, and are based on particular combinations of age, genetic background, geographical location and the like. They form units of measurement, composed of discrete subunits that can themselves be measured to some arbitrary degree of precision, and that can be seen as having particular kinds of ongoing relationships.

As an example in a purely physical register, Edwards (2000) discusses the way in which computational advances have allowed models of the Earth's atmosphere to be divided into increasingly small units, each representing a small portion of the total volume of the atmosphere. As he points out, over time, it has been possible to develop finer resolutions for these models, with more complex, more complete rule-sets that govern the evolution of these models through time, in turn allowing correspondingly greater accuracy; the line between simulation and reality grows ever thinner. Moreover, the data collection requires communication and collaboration across countries, linguistic barriers and occasional political problems.

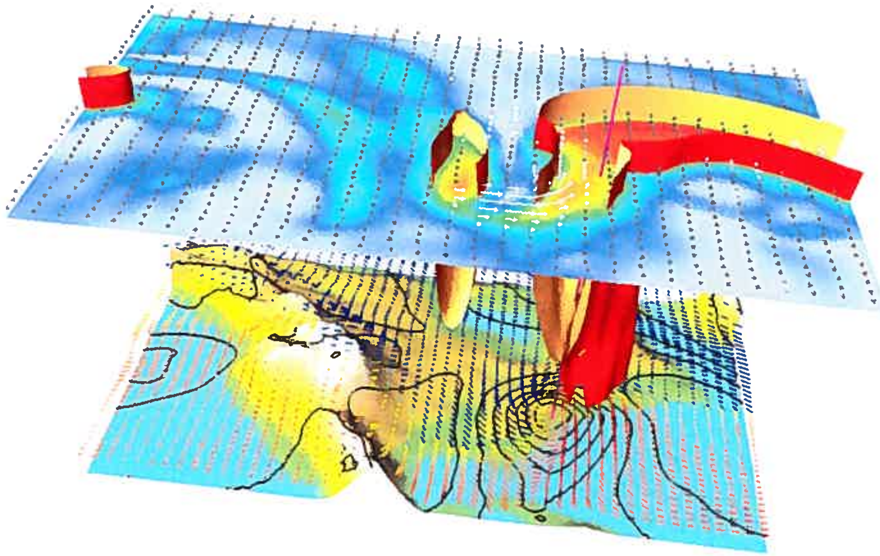

Figure 50: 1993 blizzard model, created by the United States National Oceanic and Atmospheric Administration

Nor is atmospheric modeling an isolated example; the granularity of a wide range of models of the world - from the economic to the meteorological - has steadily increased over the past century. This is largely due to purely technological advances; the sheer memory capacity and computational velocity of modern machines makes it possible to simultaneously model vast numbers of particles – millions, billions, or even more – that are governed by increasingly sophisticated sets of rules.

This is in turn expressed even at the level of nomenclature; at the time of writing, one of the most powerful computers on the planet is the "Earth simulator," a Japanese machine used for atmospheric modeling and Earth sciences, that reportedly carries out some 40 trillion calculations per second (Habata, Yokokawa & Kitawaki, 2003).

The scale and reliability of these computational processes are truly bewildering, as are the feats of engineering that generate these devices. These constant innovations have led to a world in which massive calculation has become big business, from data mines to render farms. And as more data becomes available in less time, with more information available that could potentially inform or influence decisions, both the scope of measurement and the scale of calculation will continue to change.

These are the realities that interaction designers will face in the years to come, as ever-more powerful machines become available at reduced cost to serve increasing populations with diverse needs, within a context in which more and more information from multiple sources becomes available in real-time across constantly expanding networks. Interaction design will be called on to control these powerful flows, channelling the increasing pressure of information and shaping it into meaningful and comprehensible forms.

6.3 The question of control

> *Around the turn of the century (the 19th century) we began to build artifacts and create technology which we are unable to understand, properly monitor, or control; systems of such complexity that we as a species may lack the intellectual bandwidth ever to fully comprehend. A jet engine is one such complex and chaotic device (another common example is the internet) – despite following a very simple design principle and being made of fairly well understood components, once it is assembled and put into use, it defies our abilities to monitor, control, and predict its behavior. This reflects a number of fundamental failures: our lack of advanced sensing equipment to properly monitor the device's components, our lack of understanding of chaotic physical systems, and our willingness to build and use things which we do not understand and cannot properly control.*[108]

But control is also a very difficult concept to come to terms with. The above quote, for example, from artificial intelligence pioneers Wheeler & Mitchie, actually raises some peculiar questions: Are jet engines actually in any meaningful way the same as the Internet? Would it suffice to have adequately advanced sensing equipment, and sufficient understanding of chaotic systems, to 'properly control' a system like

[108] Wheeler & Mitchie, 2002, p. 23.

the Internet? And what would such control be? Would it be control of the form, of the content or of the use?

Two things are, however, abundantly clear. Firstly, in the modern world, computerized or 'informated' objects are increasingly enmeshed with situations of control (Beninger, 1986; Agre, 2004; Zuboff, 1988; Rochlin, 1997). And secondly, there is a willingness to build things that can only barely be controlled.

Within computerized systems, properties and parameters of objects and entities – the flows of audio and video streams, the locations of cars, computers, and cell phones, the locations and rates of flows of goods and services, the activities of employees, passengers, and citizens, the state and status of machines – can be increasingly precisely identified, and to some degree controlled. And as computer systems allow for the extraction of more usable and operationalizable data from the world, different kinds of control become possible.

Moreover, these control relationships are by no means straightforward. If computers provide users with degrees of control over particular situations, they also control the situations to some degree, providing particular ways of framing and engaging with particular contexts. Moreover, in a third – and often overlooked – form of control, once situations are brought under control, it then becomes necessary to maintain that control; this is where the logic of 'endless updates' to which Agre earlier referred truly comes into its own. After all, the systems that humans design do not have the same kind of organicity as natural processes that have proven themselves self-sustaining over long historical periods. As Winner (1977) explains,

> *A consequence of artificiality is that human beings find themselves responsible for an increasingly large share of worldly concerns. Structures of a natural or traditional sort were for the most part self-maintaining in the sense that deliberate control was not required to keep them intact. Artificial structures, in contrast, must be maintained since the 'second nature' now produced is not a part of the world's original process of self-adjustment.*

More and more contexts that involve deliberate and explicit control, guided, structured and informed by increasingly precise measurements, and taking place at inhumanly rapid, ever-increasing rates: these are the forces operating behind the scenes in the development of interaction design. And within these many forms of control, operating at multiple levels and composed of extremely diverse materials, two appear as particularly noteworthy: numerical control and social control.

6.3.1 Numerical control

> *Biologists are using ideas from control to model and analyze cells and animals; computer scientists are applying control to the design of routers and embedded software; physicists are using control to measure and modify the behavior of quantum systems; and economists are exploring the applications of feedback to markets and commerce.*[109]

Among the many mysteries of engineering can be counted the realm of systems engineering known as "control theory." This field of study traces its ancestry to innovations like the steam pressure control systems of Watt's early wood-fired engines (Panel on Future Directions in Control, Dynamics, and Systems, 2003) as well as the pioneering cybernetic work of Norbert Weiner (Mindell, Segal & Gerovitch, 2003). The fundamental principles of control theory – identifying desirable states and adjusting mechanical or electronic systems to produce such states – have proven invaluable in manufacturing, aeronautics, and process control, to list just a few among many disciplines. And, since feedback loops are dependent on measurement and may also depend on communication (for the transmission of remote data, like economic information or the state of the stock market), as

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[109] Murray, 2002, pp. 79-80.

technologies of measurement and communication continue to develop, so too will the need for control.

The mathematical and technical foundations of control theory are daunting. Despite this, their real-world applications have permeated mainstream culture, both in the infrastructure of electrical grids and computer networks and in such common consumer devices as automobiles, CD players and hard disk drives. And this is primarily due to computers, which are superb control devices. With response times far faster than those of human beings, with inhuman precision and undivided attention, computers lend themselves extremely well to the control, automation, and management of mechanical processes.

And as lower costs, smaller sizes, and increased power all converge, sophisticated computerized control mechanisms are now becoming viable in an increasingly wide range of devices, including the relatively small scales of project with which interaction designers are likeliest to engage. The following few paragraphs show some examples of the current state of control; these supplement and extend the examples presented in the earlier section on process control (discussed in Section 5.2.3.2).

Figure 51: CNC sand sculpture device

The Stratograph device shown above, created by artist and educator Bruce Shapiro[109], is a computer-controlled sand sculpture generator. Software-driven stepper motors guide and dictate the position, rate of flow, and color of sand deposited by a motorized funnel. Over time, the device creates an image by layering different colored particles of sand within an acrylic tube; as the image shows, the resolution is surprisingly sharp.

Although this project is artistic in scope and intent, the technologies used for this project are essentially the same as those used in the CNC machining processes that are increasingly commonplace in industrial fabrication, which are in turn not dissimilar to those used for rapid prototyping. These technologies make the line between physical reality and infromational representation somewhat less obvious; indeed, MIT's **Center for Bits and Atoms**[110] – a renowned facility for research in new fabrication technologies – states as part of their mission statement that,

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109 www.taomc.com, online as of April 1, 2005.
110 http://cba.mit.edu/, online as of April 1, 2005.

Just as personal computers made the capabilities of mainframes accessible to ordinary people, CBA researchers are now doing the same with industrial machine tools, developing means for "personal fabrication" that will bring the programmability of the digital world to the rest of the world.

In other signs of the times, inkjet printers are now being reconfigured to create everything from tissues to consumer electronics; technologies for cutting, grinding, depositing, forming, shaping and bending matter grow ever more sophisticated and, gradually, less expensive and less difficult to use. The computational realm addressed by interaction design and the physical realm addressed by traditional design disciplines draw ever closer together – thanks in no small part to control.

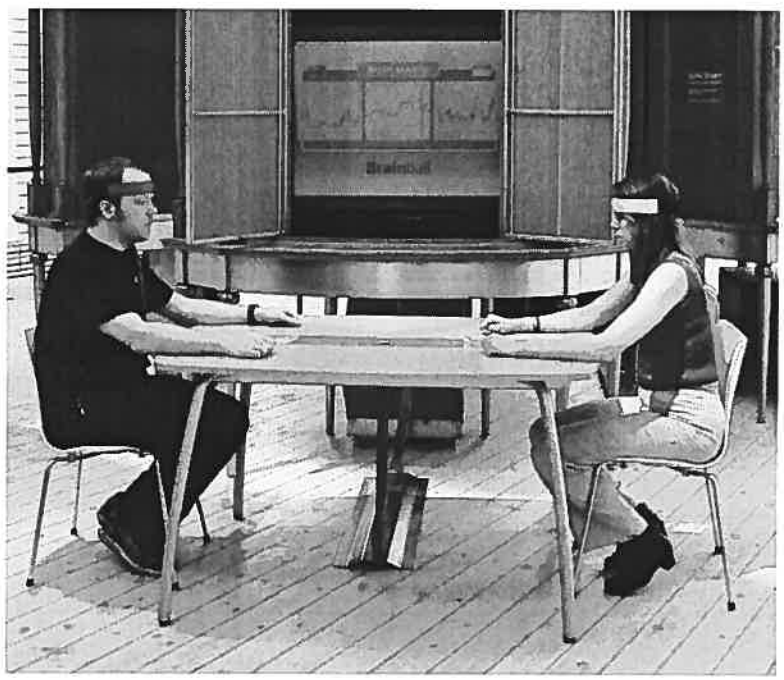

Figure 52: Brainball, *created at Sweden's Interactive Institute*

An example at a somewhat larger scale comes from Sweden's Interactive Institute, a network of labs addressing specific research themes. The project shown above, the 2002 **Brainball**, from the Smart Studio[111] in Stockholm, is a playful exploration of both visualization and process control.

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[111] Online at http://smart.tii.se/smart/ as of April 10, 2005.

In the project, two participants sit at opposite ends of a table and put on head-mounted sensor bands that record and monitor brainwave activity. A metal ball is placed on the table between them. The ball's position is controlled by a series of electromagnets located under the table, and the magnetic field is in turn controlled by a computer that monitors the participants' brainwave activity. The system is set up as a game; points are scored by relaxing more than the other participant. This creates a strange form of competitive relaxation; the goal becomes to relax more, faster, and better than the opponent!

Again, while this project is light-hearted and entertaining, it has resonances with other ongoing technical developments. Brain interfaces are a growing area of interest; evidently, it would be of benefit to many disabled people if they were able to control real-world processes simply by thinking. The project also suggests medical applications; a machine for relaxation might just what an information-drenched world needs. And the device is a reminder of what is often called "cyborg culture," the closer linkages between the body and mechanical devices under cybernetic control.

As a last, and even larger example, the German *Blinkenlights* project (Figure 53, below) uses buildings themselves as outerface devices. Existing buildings (chosen with an eye to their architectural style) are fitted with lights that are connected to a central server. This allows the windows of the whole building to be used as a low-resolution screen. In some installations, the server is also connected to a phone line; participants could dial in and engage with the system using their own phones, either displaying images or even playing simple games like Tetris.

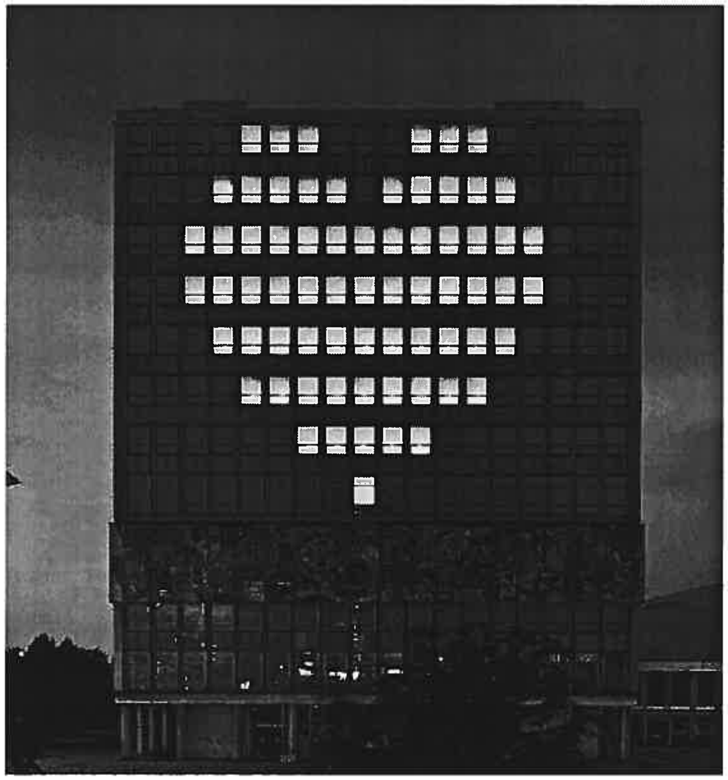

Figure 53: The Blinkenlights project

Once again, though experimental and light-hearted in approach, this project is closely related to both building and home automation technologies – the "smart homes" and "smart buildings" that have been explored in a host of research projects in the past decades, but that have not yet taken firm hold in mass markets.

These few examples, at a variety of different scales, help to show some of the ways in which control technologies are changing the relationships between computation, information and physical reality. The concept of virtuality, though not without truth, is not the whole story of computers, nor yet of interaction; a closer integration with physical reality is another increasingly important dimension in these relationships, and control is at the heart of this.

6.3.2. Social control

> *What we need is an inventory of the ways in which human behavior can be controlled, and a description of some instruments that will help us achieve control. If this provides us sufficient 'handles' on human materials so that we can think of them as one thinks of metal parts, electric power or chemical reactions, then we have succeeded in placing human materials on the same footing as any other material and can proceed with our problems of system design. Once we have equated all possible materials, one simply checks the catalogue for the price, operating characteristics, and reliability of this material and plugs it in where indicated.*[113]

In a very different register, social control is another well-documented (and extremely controversial) use for computers and information systems. In North America, this tendency is perhaps most visible in high-tech workplaces, where computer-faciliated surveillance has become commonplace. For example, information systems are now often used to monitor telephone workers' productivity, timing their transactions with customers, their average time-per-call, their habits of arrival and departure, and even the total time spent on bathroom breaks.

This opens the door for particularly controversial forms of managerial and institutional control (Rochlin, 1997; see especially chapter 4). As the Information and Privacy Commissioner of Ontario (1992, foreword) describes it,

> *Without some measure of privacy, employees may find themselves without control over their personal information, their behaviour or their person. The potential exists for employers to know about all aspects of their employees' lives including their health, genetic and psychological make-up, finances, schooling, past experience, how they spend their private time, and how they behave in the workplace from minute to minute.*

This is a clear example that links to the larger contemporary debates over what information should be shared – and who should be able to access it. To take a particularly delicate example, as the science of genetics allows for better identification of genetic risk factors, ethical questions quickly arise; the Council for Responsible Genetics[114], a nonprofit organization founded in 1983 in

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[113] Boguslaw, 1965, pp. 112-113.
[114] http://www.gene-watch.org, online as of August 12, 2004.

Massachusetts by scientists and public health advocates, has records of more than 200 cases of genetic discrimination, cases in which genetic "predictions" prevented seemingly healthy applicants from having access to employment or health, life or car insurance. In such cases, it becomes abundantly clear that control over statistics and information permits a finer grain of control over business logics of investment and risk – but this is not without its ethical quandaries.

As another controversial example, as governments revive the idea of national identity cards (e.g. Secretary of State for the Home Department, 2003), debates are arising about the possibility that these forms of control may be used on a nation-wide scale. Already air travel is rather more closely controlled than it was in the kinder, gentler era before the attack on the United States that took place on September 11, 2001, and it seems virtually certain that travel in the future will be more closely monitored than ever before. It also seems inevitable that such control will involve information and communication technologies.

These represent some of the more direct uses and fears of social control – the ability to impose and automate more or less Taylorist modes of optimally efficient production, or to control the right to travel at a time and by the means of ones' choosing, or to demand and use even more intimate data about probable health and lifespan. And still more insidious fears are linked to what is called "function creep," the gradual repurposing of information systems over time to serve different goals than were originally specified or intended. As Bowyer (2004) describes one such example,

> *[I]ndividuals can have an identifying card attached to their car that allows them to pay automatically at toll booths. The original purpose is simply to provide greater convenience to individuals and to generally speed the traffic at the toll booth. But if the record of toll payments made by an individual would later prove useful in another context, for example in a court case to prove or disprove who had been where at what time, then courts would typically order that the information be provided.*

"Function creep" describes the fear that technologies of control will spread out from their original roles to find their way into other aspects of life. Just as drivers' licenses have now become identification for many North American activities, often serving as a proof of identity as much as any proof of ability behind the wheel, technologies can easily and imperceptibly slide away from their original purposes to become something more than was originally intended, promised, legislated – or designed.

Already, the ethics of interaction design are connected to these concerns, and designers will be obliged to consider the legal, ethical and moral consequences of interventions and activities. But the even deeper fear is that, as this progress continues, the combination of more densely interwoven systems collecting ever more personal information will impinge on something especially fundamental: identity.

6.4 Identity

> *When we use simple devices to move, position, extend, or protect our bodies, our techniques change both objects and bodies. And by adopting devices we do more. We change our social selves… [T]echnology helps shape identity. Our material culture changes by an unpredictable, dialectical flux of instrument and performance, weapon and tactic.*[115]

In the modern world, information and communication technologies are increasingly used to create and maintain different forms of identity. Whether in the form of cell phone numbers, Web addresses and IP numbers, bar codes or other tags, it is now possible (and increasingly commonplace) to use electronic techniques of identification to connect information to particular places, objects, times and events – as well as to people, whether with or against their wills (Black & Smith, 2003). From children in theme parks (like Denmark's Legoland, where children are tagged with RFID locator bracelets) and criminals out on probation (Farmer & Mann (2003) to razor blades on shop shelves and pallets of products on trucks, systems for

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[115] Tenner, 2003, p. 29.

identifying and tracking objects, products, people and other entities are increasingly commonplace, sophisticated and interconnected.

Issues related both to human identity and to the identity of objects are thus part and parcel of the new digital economy, already feature prominently in interaction design, and appear likely to be even more prominent in years to come, as the interwoven logics of databases and networks are applied to more objects and contexts. The following sections present a brief overview of these two trends.

6.4.1 Human identity: personas and shadows

> *To be useful for social control, data must be able to be related to a specific, locatable human being. Organizations which pursue relationships with individuals generally establish an identifier for each client, store it on a master file and contrive to have it recorded on transactions with, or relating to, the client. The role of human identity and identification in record systems is little-discussed, even in the information systems literature.*[116]

The question of personal identity is among the more delicate areas affected by information technologies. McLuhan's (1970) premonition that "The more the data banks record about each one of us, the less we exist" (p.13) serves as a succinct summary of some of the basic existential fears of a developing surveillance society wherein the human condition will be in some way reduced or constrained by the power of technology (Smith, 2002). Today, although contemporary relationships between technology and identity are anything but straightforward, at least two different aspects of these relationships are at play in the technological landscape.

The first, and most direct is manifested in the form of objects attached, connected to, or embedded in the body, that create tangible linkages between physical and digital identities. Three distinct kinds of technologies may be involved:

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[116] Clarke, 1994, p. 85.

***In* the body**: physically embedded computer chips (e.g. Warwick, 2004)[117] similar to those that have been used to track migratory animal populations, and which may be linked to GPS or other position tracking systems.

***On* the body**: physical objects including bracelets, smart cards, cell phones and other portable devices that have a unique and trackable identity.

***Of* the body**: biometric data including fingerprints and retina scans and, slightly less directly, recognition of other unique physical traits including facial features, gait or voice (see chapter 3 of Computer Science and Telecommunications Board, 2002, for a detailed discussion of this issue).

These different technological tactics all more or less directly link the physical realm of individual identity with the intangible realm of data. Each of these is useful for certain applications and has particular advantages and disadvantages in technical, social, and ethical terms.

The other form of human identity, somewhat more subtle, is that known as the 'digital identity' (Clarke, 1994) or the 'digital shadow.' This represents the sum of all stored data associated with a particular individual's name and institutional identity. This data is maintained in a number of databases that may or may not be interconnected. Thus, in addition to governmental and institutional data (including, for example, medical, tax, and criminal records[118]), vast quantities of consumer-related data are now generated each day, including banking transactions, point-of-sale purchases, Internet surfing habits, and the like. These may or may not touch deeper questions of identity, just as even the most detailed information about genetic makeup and personal history may not touch the core of who a person is – but not are they entirely unrelated.

[117] The use of subdermally embedded identification chips seems to be becoming more commonplace.
[118] The particular set of data which can be accessed via the Internet varies from country to country.

Some of these actions are especially easily captured in information systems. For example, all engagements with information and communication technologies can (and often do) leave traces; for example, Internet "cookies" are used to track Internet usage, including pages viewed and the time of viewing. Telephone companies track and log phone calls together with number, duration, and location. Credit card payments are also tracked, as are 'loyalty card' systems such as Air Miles. Email communication is likewise notoriously open to these forms of data harvesting. Clarke (1994) refers to this array of incremental signs, representing a sum of individual choices tracked by a variety of machines, as the "digital trail."

The term most often associated with these two forms of identity is *privacy*. The complex issue of privacy involves a balance between the powers accorded to the state, the limits on actions taken by corporations and companies, and the fundamental rights of the individual. It is thus to a substantial extent played out in the realm of politics and law. Furthermore, privacy touches a fundamental human chord, and perceived violations of privacy are generally unpopular (Orlikowski & Iacono, 2000). This topic thus represents a fluid and negotiated zone that encompasses social acceptance of technologies, public comprehension of the issues, and fundamental trust in both public and private institutions. It is a moving target; for example, at present, there seems to be a greater willingness to accept less privacy in return for a higher perceived level of security (De Rosa, 2003).

At the same time, the digital shadow is growing ever longer, as the cost of generating, storing, and accessing records constantly shrinks. Strangely enough, although trivial information about Internet viewing habits and toothpaste preferences might seem useless, it appears that this is not entirely the case. The financial value of personal information is undeniable, even in the limited form of an email address, as the epidemic of 'spam' attests: junk mail is a phenomenon only because it is effective.

In fact, in one of the strangest twists, 'identity' is so valuable that it is increasingly frequently stolen:

> *Identity theft has become one of the fastest growing crimes in Canada and the United States. In the United States, identity-theft complaints to the Federal Trade Commission have increased five-fold in the last three years, from 31,117 in 2000 to 161,819 in 2002. In Canada, the PhoneBusters National Call Centre received 7,629 identity theft complaints by Canadians in 2002, that reported total losses of more than $8.5 million, and an additional 2,250 complaints in the first quarter of 2003 that reported total losses of more than $5.3 million.*[119]

Thus, though it is necessary to have a digital persona in order to carry out transactions within the digital economy, digital identities have their own pitfalls and perils; the "novelty of the present situation" also means that public awareness and comprehension of these issues is often limited.

Interaction designers are obliged to face questions regarding the ethics and pragmatics of the right to privacy, while continuing to work with and explore the potential of these new technological developments. And as personal data becomes more socially significant, designers will no doubt also be called on to help manage this data, particularly since managing personal information requires time. After all, as more actions leave ever more traces in the electronic realm, it will require increasing energy and effort to keep these endless updates under control.[120]

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[119] http://www.psepc.gc.ca/publications/policing/Identity_Theft_Consumers_e.asp, accessed on Sept. 12, 2004.

[120] One concrete contemporary example: Edward Kennedy, a member of the United States Senate, is reported to have experienced recurring problems in air travel, due to his presence (presumably erroneous) on a list circulated by the United States Transportation Security Administration ("Kennedy's name accidentally on 'no-fly' list," The Globe and Mail, Friday, August 20, 2004 , Page A10). At present, clear mechanisms for correcting such digital identity-related issues do not exist. It seems clear that this represents a substantial design challenge, though the political charge may be too strong for design alone.

6.4.2 The identity of objects

> *Much of what is collected in databases are facts not about physical reality (e.g., the position of a building in coordinate space), but rather about human agreements (contracts), about classification according to some culturally fixed rules (e.g., who is an adult) and about social arrangements (ownership rights).*
>
> *These are not physical but nevertheless very "real". Many important aspects of our daily life fall in this category: neither money nor marriage or companies are physically existing and can be touched. They are related to physical objects and have specific relations between them but their existence is not physical in nature.*[121]

The concept of "physical objects" in the "real world" is something of a last recourse of solidity; like Bishop Berkeley's rock, it seem as though such objects are undeniably obvious and should be inherently straightforward to describe, and this is in many cases true. However, Frank (2003) provides convincing arguments that the world of objects, as described through language (including the languages of databases) is only partially physical, and is also very much social and socially constructed.

To take a classic example, a river flows, meaning that the matter that constitutes it constantly changes; it forks and splits (emerging from many sources and becoming many different objects) and eventually terminates, which will normally involve some transition zone. During the course of these travels, it may be put to many different uses and its chemical composition may even change; water rights in such cases may become as much political as physical.

Taken as an object, a 'river' is not as easily comprehended as is, say, a 'table,' nor are its limits as clearly defined; it has a different relationship to temporality and solidity. However, it is still in some sense an object – or at least, it must be treated as one in order to form part of an information system. Moreover, however twisting and convoluted, a river is more easily understood as an object than is the future

[121] Frank, 2003, p. 7.

value of a stock or commodity – or, for that matter, a family. In reality, many 'objects' in the computational realm more closely resemble the objects of 'object-oriented' programming than they do chairs, plates, or even rivers.

As a result, just as is the case with humans, two very different kinds of identity can be computationally associated with objects. Once again, the first of these is tangible, directly associated with particular physical objects, and employing technologies identical to those used for human identification: physical codes stored in circuitry or tagged with bar codes, magnetic strips, RFID tags, and similar technologies. Common examples now encountered in daily life include personal computers, mobile telephones and cars (especially rental cars), all of which are commonly equipped with technologies that permit their identification as uniquely enumerated entities.

In more speculative territory, British scientists have recently patented a system for embedding bar-code like information within the genetic code, suggesting that it may be possible to individually 'tag' – or "brand" – individual cells within organisms, particularly those that have been genetically modified. At the same time, the frontiers of nanotechnology have given such novelties as corporate logos inscribed at a scale visible only with an electron microscope. This combination suggests the possibility of inscribing identity into the animate and inanimate realms alike.

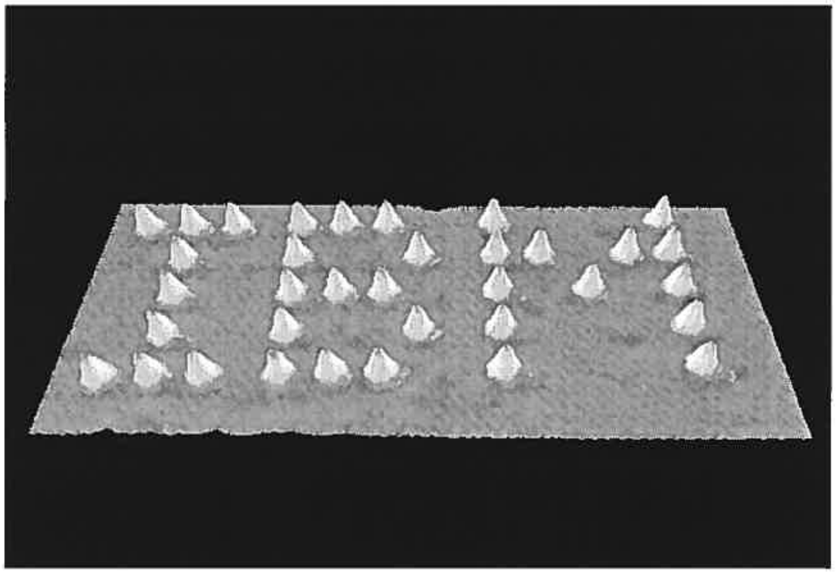

Figure 54: Nano-scale IBM logo made up of individually placed atoms (Overholt, 2001)

And once again, as with human beings, the other form of identity is purely electronic – bits of data filling virtual slots in databases. Such data includes social 'objects' like marriages and stock ownership that may have only the tenuous physical existence of computational variables but that nonetheless affect lived reality, with consequences that belie their insubstantiality. After all, as Latour (1990, p. 60) points out,

> *By working…on fragile inscriptions that are immensely less than the things from which they are extracted, it is still possible to dominate all things and all people.*

These kinds of objects, the externalized memory and records of humanity and of human social structures, are increasingly stored, accessed, transferred and transmitted electronically. Likewise, the identities of objects are intertwined with human identities, in networks of ownership, debt, status, responsibility and rights. The tangled relationships between real objects and virtual objects, between physical reality and the virtual realm of data, and between human identities and those of objects are all part of the strange new networked world that is appearing, semingly inexorably, through the medium of computation.

6.5 In closing: the quantum of control

Much of the excitement of interaction design is its complexity. Interaction designers address challenging problems within complex settings, creating products and environments that are extremely technical in their infrastructure and requirements but profoundly social in their implications and implementations, and that bridge the uncertain gap between the physical and virtual domains.

At many different levels, questions of granularity and measurement figure in the structure of information and the nature of control over information systems. Both tactics for measurement and systems of classification will help to shape the architecture of the system, and will affect the way interaction with computer devices is structured and shaped.

Interactive systems also operate with a range of levels of control. Control relationships may be personal, since individuals want to be able to control systems in some way to meet their needs and goals. They may be institutional, since companies want to have some measure of control over the behaviour, productivity, and characteristics of employees and of customers. And they may be social, since computer systems are playing increasingly important roles in both modern citizenship and social identity in a constantly shrinking world.

But at the same time, computational systems are increasingly numerous (challenging the limits of human attention), increasingly complex (challenging the limits of human mental and physical capabilities), and increasingly capable of carrying out complex processes with some degreee of autonomy (challenging the limits of human control).

As these trends continue, the development of technology, rapid dissemination , and tremendous scope of technology are all contributing to the modification of existing forms of identity, as well as creating new kinds of identities that exist only within the digital domain. Measurement and control both act on and affect these forms of identity, and the ethical and social concerns connected with these themes appear likely to be significant concerns for the discipline of interaction design in coming years.

The complexity and scope of these issues and concerns makes it difficult to communicate clearly and effectively about them. The concept of the 'quantum of control,' provides a way of addressing and encapsulating some of these broad issues in a manageable and comprehensible concept. Though limited and imperfect, it serves as a focal point for reflection and discussion of some of the forces that are shaping contemporary culture.

7. Conclusion

For all the sophistication of the systems analysis going into mechanical systems, we seem unable to mount any reasonable analysis of the human-machine system, except by reducing the human being to a mechanical element of the system.

A much more fruitful approach would be to consider the machine within its human context. In this way we would elevate the machine, not through the crazy imputation of emotions and thoughts to it, but rather through the recognition that our conversation with the machine is, in the end, a conversation with ourselves.[122]

[122] Talbott (2004).

7.1 In summary

The term 'interaction design' has emerged over the course of approximately the past twenty years as a reference to those areas of design activity most directly engaged with electronic and computational media. There is thus a strong correlation between the emergence of this discipline and profession and the dramatically rapid increase in the social significance of computers, the Internet, multimedia, and digital communication technologies.

Each of these technical advances has had powerful, sweeping, unforeseen and often unplanned social and economic effects. They have also generated an almost unmanageable and bewilderingly diverse array of texts, images, theories, conferences, trade shows, products and services. Amidst this proliferation, the discipline and profession of interaction design remain hard to define or pin down, and they continue to rapidly evolve and change.

During the same historical period, and against the backdrop of an explosive development and dissemination of new technologies and the increasing globalization of industrial and post-industrial societies, the design disciplines have been striving to develop methods and strategies that are solid, verifiable, and rigorous – and that are widely recognized and accepted as such. At the same time, the spread of computation out of the office, workplace, and laboratory into domestic, private, and public spheres has created a contemporary context within which computer technologies are central to a wide and constantly growing range of human activities; this has in turn led to a vast expansion of the scope of human-computer interaction.

As an academic discipline, interaction design is thus located at the intersection of two quests for reliable and robust methods and theories: one rooted in the physical sciences, the other in engineering, arts, and crafts, and both concerned with human experiences and engagements that involve artificial objects that are computational or computationally enhanced.

It is questionable whether the 'interaction' in interaction design is, or should be, understood as fundamentally or necesarily technological – or, indeed, whether anything can truly be said to be purely technological. But it is also more than merely coincidental that interaction design has coevolved alongside these new technologies of information and computation; there are indisputably close ties between the medium of computation and the discipline of interaction design.

And computational technologies – though tremendously varied in scale and function – share certain characteristics, possess particular kinds of limitations, and embody certain structural properties. The evident and undeniable complexities of mathematics and engineering are only a part of this much larger whole, since, if computers are fundamentally mathematical and electrical, they are also profoundly symbolic. As such, they engage with, expand, and alter many human systems of representation, including such diverse symbolic forms as language, visual media, and scientific data.

At the time of writing, it appears probable that four contemporary trends will continue:

- increasing numbers of computational devices;
- increased power, reduced size, and lower cost of such devices;
- increasing interconnectivity between these devices; and
- increased numbers of sensor systems connecting systems to the outside world.

The convergence of these trends appears poised to create a context within which some devices are given increasing degrees of autonomy or agency, since human beings have a limited focus of attention that cannot be directed simultaneously to a multitude of devices. A part of future interaction design work will thus be to determine and design the degree, extent, and nature of human control within complex technologically and computationally mediated contexts.

Moreover, computational devices are particularly susceptible to surveillance and to the invisible and imperceptible exchange and transfer of information. The cost – both material and computational – of acquiring, copying and transferring information, including information about human engagements with technology, is extremely low. For this reason, computers have entered into an increasingly intimate and sometimes troubling dialogue with questions of privacy, freedom, individuality, and identity. As a result of this, it is now both necessary and possible to determine, design, and manage the degree, extent and nature of certain kinds of social control, and this too will continue to form part of the field of concern of interaction design.

The concept of the 'quantum of control' offers a way of summing up many of these concerns and preoccupations. Through a metaphorical resonance with the new sciences of massive calculation and statistics, through questions linked to measurement and the technologies and ethics of measurement, and through questions of the identities both of objects and of people, the idea of a quantum of control provides a focal point for reflection on the deeper questions that underpin this emerging discipline – and thus on the question with which this text opened: what are we talking about when we talk about interaction?

7.2 Future work

> *This invasion by active knowledge tends to transform man's environment and man himself – to what extent, with what risks, what deviations from the basic conditions of existence and of the preservation of life we simply do not know. Life has become, in short, the object of an experiment of which we can say only one thing – that it tends to estrange us more and more from what we were, or what we think we are, and that it is leading us… we do not know, and can by no means imagine, where.*[123]

Although the topics addressed in this text are very broad, several specific directions for future work have become clear. Firstly, the technical possibilities and social consequences of information and communication technologies are very much a moving target. It will thus remain an ongoing challenge to keep abreast of the 'state-of-the-art' of the various technical components that make up interactive systems, while also striving to understand what will become technologically and economically viable in the short- and medium-terms. Both technology tracking and futurology have a role to play in this.

Secondly, the present work does not address models of social interaction, nor does it address issues of computer mediated communication within novel technological contexts. Computers are increasingly commonplace in social settings, and the social dimensions of computer technologies are recognized as being of great significance. Old paradigms of single users alone with single machines are no longer adequate for understanding the true complexities of social and technical networks, but new paradigms are still in development.

And lastly, this work remains theoretical in its scope. It does no more than set the stage for actual design activities and design interventions, which would use the theoretical framework and concepts set out in the text to help inform projects and case studies. This text is thus more a beginning then an end.

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[123] Valéry, 1989, p. 71.

It tells the story of the ongoing exploration of a complex reality: that, like all technologies and all tools, those of computation and calculation are anything but neutral; they effect and affect, inscribe and modify. And try though one might to define technologies in purely pragmatic, practical, physical or mathematical terms, they elude any such tidy categorizations. Technology is a mirror that reflects human existence – sometimes flawed, often beautiful, and occasionally alarming. Interaction by, with and through technology offers tremendous possibilities and carries many responsibilities – both to one another and to a world increasingly shaped and transformed by human actions and inventions.

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