In a Strange Land
modelling and understanding cyberspace

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Abstract: This paper begins with a long-term view of the development of cyberspace. This includes a brief examination of the worldview of a 16th-century mapmaker and over 4000 years of development from the early massive bureaucracies of Babylon and Egypt to the current day. This discussion shows that cyberspace is becoming an everyday experience and we need to design tools to help people navigate electronic spaces and methods to design the structure of those spaces. The paper moves on to look at the changing face of user interfaces from the business-oriented 'one man and his machine' view of the 1980s to a rich interplay of multiple people interacting with multiple devices often at home or at leisure. Coping with such a radically different world requires general design principles and the latter part of the paper considers various very broad design principles and issues and their applications in HCI and in cyberspace design.

Keywords: cyberspace, interface design, maps, navigation.

1. INTRODUCTION

Accessing information from anywhere in the world, constantly available via mobile phone, owning dozens of computerized appliances – cyberspace is not special but part of mundane life. In this paper we'll take a look at the changing information landscape from pre-history to the current day. We will then look at some of the changes in Human Computer Interaction (HCI) over the last 20 years. Finally we'll see how general design principles can transfer from HCI to cyberspace design.

Originally a mathematician, I have been involved in HCI research since the early 1980s at York, Huddersfield, Strafford and now Lancaster University. Since 1998 I have also had a commercial 'hat' as Director of aQtive limited and now also vfridge limited. At various points in the paper I'll draw on experience from the design of vfridge products: virtual crackers and virtual fridge (from which the company gets its name).

2. SETTING THE SCENE

One Man's Journey

Over the Christmas period I've been reading "A Mapmaker's Dream" by James Cowen (1996). This is based on the journal of a sixteenth-century monk, Fra Mauro, who was producing a world map. Fra Mauro never leaves his cell but listens to the stories of explorers, merchants and sailors in the great age of discovery. He gradually comes to the realisation that to create a faithful representation of the world he cannot confine himself to the physical topography of mountains, rivers and cities, nor even to illustrations of the strange peoples and animals which live in distant lands. In addition, he must grapple with the ideas and imagination of the people who live in those lands and those who visit them, and somehow portray this in the map that he produces. The world is not simply a space that we occupy, but is shaped by our culture, cognition and creativity.

If this was true of the sixteenth-century world of Fra Mauro, it is more so today when the world is shrunk and warped by the threads of information that interweave our daily lives. Cyberspace is not just a matter for science fiction as in Lawnmower Man, the Matrix or the works of Gibson, nor even the province of nerds bent over glowing terminals in dark basements of computer science laboratories. Cyberspace is a day-to-day reality for virtually

every man, woman and child: text messages on mobile phones, bank ATMs, smartcards or simply the television. These flows of information don't just connect and reconnect distant points of the world, they also layer whole new virtual geographies. Relationships are not only mediated by technology, but they often find their focus in artefacts that only exist within the electronic world.

Fra Mauro was truly a modern – he travelled not by ocean ship nor by horse over Mongol plains, but by exploring the ideas and knowledge transmitted to him by others – a navigator of information landscapes.

Four Ages

For tens of thousands of years, humans lived in an *Age of Proximity*, where relationships, power and information only flowed between those physically close to one another.

With the advent of large empires, Babylonian, Egyptian, Roman, many lived in an *Age of Bureaucracy* – efficient lines of communication allowed power to be exercised over thousands of miles, and news and personal communications to flow throughout the reaches of civilisation. Relationships could exist without co-presence and, in modern terms, cyberspace was born.

In the sixteenth century, when Fra Mauro was writing, humanity was at the beginning of a third age, the *Age of Money*. Power relationships and information still flowed through letters and increasingly the printed word, but this came to be dominated by the use of money both as a means of exchange of value and hence power, but also (as became clear much later in Adam Smith's theory of the hidden hand of economics) as a means of exchange of information. Goods flow to where they are needed because money flows in the opposite direction – needs and desires embodied in pounds, dollars and schillings. Although distant relationships still flourished there is an extent to which, just as Laplace substituted field theories for Newton's action at a distance, the field of flowing finance reduced the need for economic action at a distance.

In our own time, the latter half of the twentieth century and the dawn of the twenty-first, we have seen the rise of broadcast media, global networking and increasingly universal connectivity. This *Age of Information* is characterised by instant, rich, non-local communication, a focus on artefacts that are pure information, and an interleaving of the physical with the virtual. Not surprisingly one of the areas of most rapid change is e-commerce, as in many ways the informational role of money is replaced with direct

communication between consumer and supplier (or at least their surrogate agents on the web). Also our notions of personal proximity are changing as relationships may be easier to form with those across the world than with our next-door neighbours. Although this de-localising effect may seem a rather dystopic future, there is also the possibility that the ready flow of information may rekindle local economic relationships destroyed during the centralisation of distribution of the twentieth century. Furthermore, if finding our individuality reduced to an email address or web page seems somewhat dehumanising it is infinitely richer than the figure on our bank balance, which defined us during the previous era.

Way finding

This richness comes at a price. In the Age of Money, the information landscape is simple – the cartographer is an accountant and the only navigation skill required is arithmetic. Now we talk of information overload, being lost in hyperspace – our problem is not so much finding information as finding our way through it, through the mass of irrelevant detail on the way. Recall that in the physical world the large spaces are often easier to explore than dense undergrowth – circumnavigation and conquering of the vastness of the Pacific Ocean came in the time of Fra Mauro, three hundred years *before* the exploration of the African inland.

Our first design challenge as information technologists facing cyberspace is therefore to design the maps, compasses, routes and guides to help users through this complex information landscape.

While Fra Mauro had to encompass the intricacies of human interpretations and constructions, beneath them was a fixed, physical, geological substrate, the earth, which ultimately ties down and grounds his map. In contrast, in cyberspace there is no substrate, or at least we create it ourselves. Even whilst the Roman soldier in Palestine writes a letter to his wife and children in Gaul, he knows he is in Palestine, that the letter will travel over sea and land, and that his loved ones are in Gaul. This knowing is a testament to the physicality that undergirds the virtuality of distant communication. Our modern cyberspaces do not have this undergirding. However, we can create it ourselves. As makers of electronic spaces, we choose and shape the fundamental structures that others use and with which they construct their own virtual reality within.

Our second design challenge for cyberspace is therefore to construct structures of the electronic world that are comprehensible for others, a rich substrate upon which they can build.

3. HCI – changes and trends

At the time the Austrian Computer Society was formed 25 years ago I'd never seen a computer except on television. However, for 20 years now I've worked with computers in some shape or form and for most of that time on some aspect of Human Computer Interaction.

During this period we have seen the personal computer revolution, the explosion of the world-wide web and the recent growth of mobile telecommunications. Let's look briefly at two dimensions of change during this period and how they impact software architecture and design methods.

Increasing Multiplicity

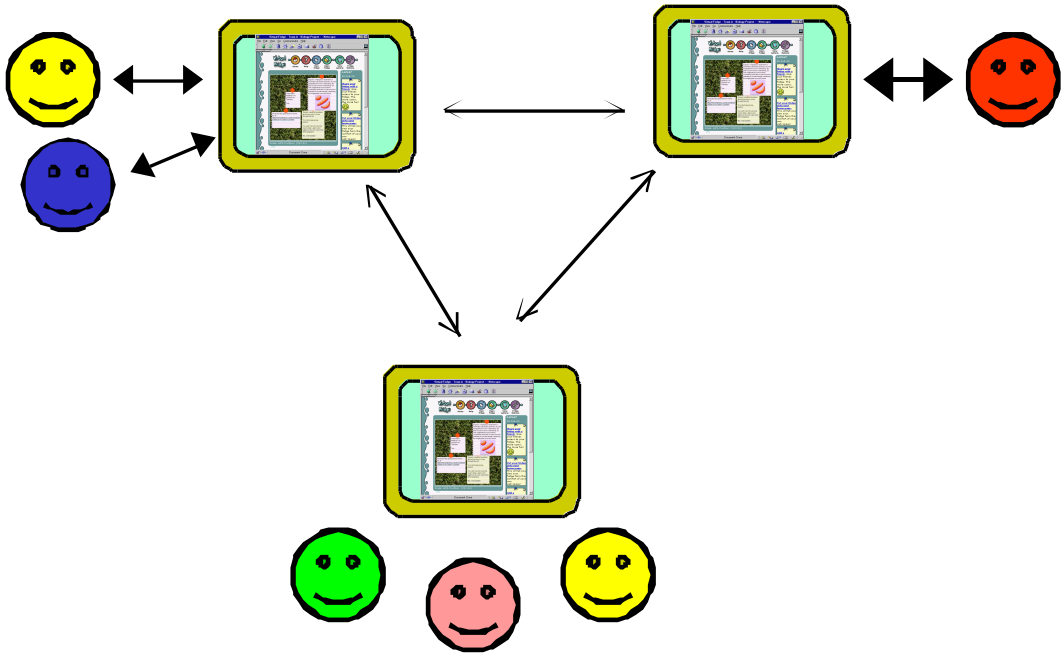
The 1980s were dominated by the growth in personal computers. HCI also saw its fastest growth during that period and not surprisingly the majority of analysis techniques and models have an implicit assumption of 'one man and his machine'. (Note, the use of the word 'man' here is not accidental. Throughout the 1980s the majority of computer users were male, and the term used for HCI in the UK was MMI – man–machine interface – now a very politically incorrect term!). My own early work on formal modeling of interactive systems was very definitely in this mode (although the mathematics at least is without any gender bias!) (Dix, 1991)

The latter half of the 1980s, and the 1990s, saw the growth of Computer-Supported Cooperative Work (CSCW) and Groupware as important areas in their own right. Much of my own work from 1990 on is related in some way to CSCW. This certainly moved away from 'one man and his machine'. Various systems aimed to help people working in the same place, most notably various meeting support systems (e.g. Xerox's CoLab (Stefik, 1987)). However, the clearest examples of groupware tend to be those involving some level of distribution: email, bulletin boards, online chat, Lotus Notes, desktop video. These

distributed systems almost universally adopt a model of 'lots of people, one machine each'. This is a sensible assumption from a time when the dominant user groups academics or business people with desktop computers.

If you watch a family using standard 'family' web software (e.g. yahoo clubs) something different happens: instead of one person using one machine, two or three people hang over the screen at the same time. But the software isn't designed for this and the login-logout cycle is long. When Ann claims the keyboard from Jane, one of two things happen: you may see messages of the form "This says its from Jane, but it's really Ann.", or, alternatively, Ann logs out, logs in again as herself, navigates to the appropriate message board and then enters her message ... then when Jane wants to say something ... For chat systems the latter is particularly disconcerting for the remote participants as all they see is a system message saying "Jane has left."!

So, when we designed vfridge's 'virtual fridge', a form of 2D noticeboard, we allowed multiple simultaneous logins at the same machine with a rapid toggle between active users. To my knowledge, this is the only current system that is optimised for this kind of use, but I'm sure we will soon see this become the norm on software for the home and family.



virtual fridge allows multiple simultaneous users at the same machine

However, this is not the end of the story. Increasingly, users have multiple computational devices (recently I counted four on my person: a mobile phone, a camera, a smart card and my car keys). Currently our interactions with these are of the 'one person and their device' kind, but as technologies such as Bluetooth and support frameworks such as JINI and UP&P mature this will change. Soon we will find ourselves in a situation where multiple people are interacting with multiple devices, some physically shared (such as electronic whiteboards), some networked together locally, some networked remotely; the world of cyberspace is reified in devices around us and in so doing the physical world is remapped.

Work and Fun

> all work and no play
> makes Jack a dull boy
> *Traditional saying*

HCI is replete with methods, analysis techniques and notations. Some are aimed at describing how the computer behaves from the user's perspective. However, these applied earlier in the design cycle aim to describe either the user's cognitive state in terms of goals and the way the user fulfils them, or, at a work/job level, in terms of the tasks the user has to perform and how they decompose into sub-tasks. Underlying all these models is the implicit assumption of a work ethic – people are using computers in order to accomplish a task and want to do so as efficiently and effectively as possible.

However, even on the earliest computers, there are also games. Are these just a triviality , a frivolous use of serious technology? Well, after military use, graphics and virtual reality research has been pushed to its limits by both games and media use ('Gladiator' and 'The Perfect Storm' were only possible through sophisticated graphics and the 'Star Trek Voyager" opening sequence is really a showpiece of graphics effects), so certainly there are serious outcomes from leisure applications. And, for HCI, games also present a unique challenge – the user experience is far more central than for 'serious' applications, but is subtly different. What does it mean to have an 'efficient and effective' video game? Furthermore, designers of work software can be lazy, people have to use it to do a job, but play is optional – if a game isn't good to use it isn't used and isn’t sold.

If we look at current use, especially on the Internet, the boundaries are becoming blurred. Is e-shopping a 'work' experience – trying to gather provisions as efficiently as possible? I often ask groups of people whether they have done any e-shopping. Most raise their hands. I then

ask whether they have been e-shopping or e-buying. The men (typically) look confused! Buying is work, shopping is an experience. Many sites are attempting to recreate this experience – and the best trying to create similar but different experiences suited to the online world (for example Siegel's 'Futurize your Enterprise' (1999)) focuses heavily on creating communities of customers/users). There is also a small community of people in HCI interested in this area. This has included panels at the ACM CHI conference on the lessons of game design for HCI and in the UK the third annual 'Computers and Fun' workshop organised by the British Computer Society's HCI SIG.

I've had to grapple with these issues at vfridge. A minor (but great fun) product is 'virtual crackers'. These are a bit like electronic greetings cards, but with an extra twist. The key design factor is the user experience. The recipient of a cracker gets a page with a closed cracker on it, they click the cracker and it slowly pulls apart and, to the sound of a bang, the cracker opens and the user is able to reveal the sender's greeting, a joke and further links to an electronic toy and a mask to print and cut out. This does not replicate the details of the experience of pulling a paper party cracker, but tries to capture some of the sense of hidden-ness of the closed cracker, the suspense as two revelers pull at each end and the climax as the cracker bursts and the contents spill out. There is no 'goal' or 'task' for virtual crackers and the layers of interaction are not designed to give the user the most efficient path through the system; instead, they create their experience deliberately by lengthening the interactive path. Traditional HCI is certainly important in designing forms, page layout, etc., but there is an additional element – the design of fun.

4. Design for HCI and Cyberspace

So, we see a changing face of HCI, from individual business use to dynamic groups of interacting people using multiple devices in their everyday lives. How do we design spaces and systems? Will the models and methods of HCI developed over the last 20 years of the twentieth century help in the opening 20 years of the twenty-first?

As I teach HCI I have found that I increasingly return to broad issues of design – not HCI design specifically, but design in general. This is perhaps because I am looking towards novel devices and modes of interaction and so it is the more general principles that transfer.

Let's look briefly at broad design issues and how they impact both traditional HCI and the design of cyberspace.

What is design

I toy with different definitions of design, but here is one I use:

> Design is achieving goals within constraints

The goals here should be interpreted broadly including 'entertaining the user'. The goals remind us to always ask what is the *purpose* of a design. In HCI, why does the user want to use this system? What do they want to achieve?

The constraints include any predetermined materials or platforms. Also important for HCI, and software design in general, are existing systems that the user may be using or the system must interoperate with.

Note also that goals may be plural: different stakeholders wanting different things. This, together with the constraints, reminds us that design is also an exercise in trade-offs. One of the reasons for the poor performance and poor reliability of many interactive systems is that they try to achieve an ideal design goal in a way that cannot be realised on the chosen platform.

Abstraction and grounding

In all disciplines we find that it is the fundamental principles and theories that can be reapplied as circumstances change. As a mathematician I always look for general rules and abstract models of which the specifics are but particular instances. However, such abstraction can become self-serving, divorced from the things it seeks to explain. It is common in computing to find academics proposing formal models, which, upon examination, do not map onto the real world at all – idealisations, not abstractions. Practising software engineers also often spend great effort in producing architectural designs, object hierarchies, etc., only to find them changing beyond recognition when actually used. Abstractions allow

generalisation, continual grounding in actual examples means that the abstractions reflect reality.

This is also true of users within computer systems and electronic environments – they need both solid examples and general understanding:

Concrete example:

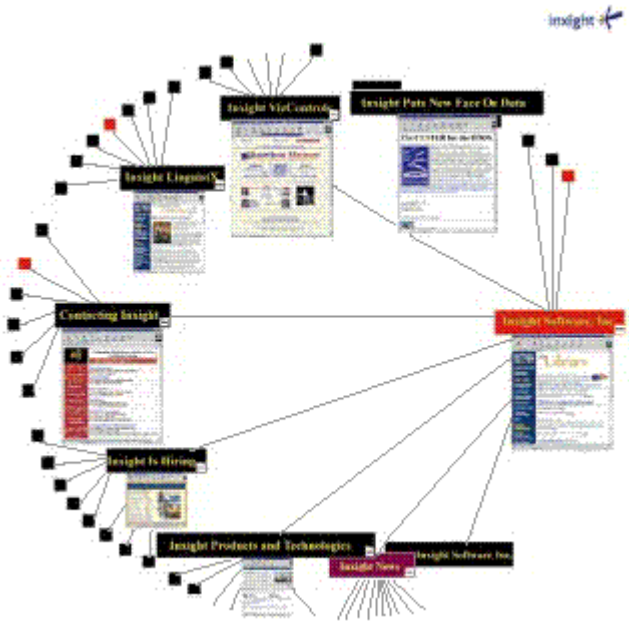
1. note the number on the tape when you start recording
2. when you finish recording press rewind
3. when the tape stops rewinding press play
4. skip the adverts by pressing fast-forward until they stop.

Abstract rules:

- fast forward and rewind move the tape quickly in either direction.
- if the tape is playing when you fast forward or rewind, you see the picture pass quickly (useful for finding things).
- if the tape is paused when you fast forward or rewind, you don't see the picture, but the tape moves forward or back more quickly (useful for skipping large amounts)

The concrete examples are what you need when you first learn, when you are under pressure, or when you just want to do it. The abstract rules help you to deal with different situations that you've not dealt with before (e.g. how to find a scene in the middle of a programme). The abstract rules help you integrate and understand the concrete examples and the concrete examples give meaning and context to the abstract rules.

In many visualisation systems there are different ways available to see details and to get broad overviews. For example, fish-eye displays show a detailed map in the middle of a distorted view of a larger area (Furnas, 1986) and the hyperbolic tree draws a hierarchy in a 2D representation of hyperbolic space (Lamping, 1996). The ability to drill down from summary data to details in data-mining applications and in tools such as SAP or BAAN is also an example of this.



Hyperbolic Tree – Inxight Software

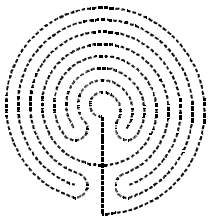
Many hypertext systems and web sites offer global maps to help users navigate, but one of the problems of the web as a whole is that its highly interconnected nature makes it hard to represent in 2D maps except locally. Similarly an atlas' maps have trouble dealing with a spherical earth, but for the Internet this is worse as there is no equivalent of the globe.

Scenarios

One common form of grounded representation in HCI design is the scenario – or in simpler terms, the story. A scenario is a description of an actual or proposed walkthrough of a system. In HCI this includes many user-focused details such as actions with non-computer artefacts and possibly user intentions. Scenarios do not capture all the possible behaviours of a system or user; other representations, such as state transition networks or cognitive models address this. However, scenarios ground and validate these other representations and are excellent tools for communication.

We find scenarios or their equivalent used in the design of any dynamic or interactive artefact, not just computer systems. For example, an architect will create a scale model of a shopping mall, but in talking through the design will walkthrough it, either verbally, or increasingly using virtual reality simulations. Scale models tell you what the building is like at a frozen moment in time, scenarios tell you about the dynamics and … again … experience. Recall

the crackers 'experience': a screen shot of a cracker page would not be a sufficient description, we need to hear the story of the interaction.



The potential dynamics of a system are inherently branched and non-linear. Scenarios are important because our experience, however branched and complex within space, is always linear through time. We live a single thread of life, not a multiplicity of potential paths. This is why it is easier to browse a simple history list for a hypertext than a more complex representation. Mazes are synonymous with complexity, but strangely enough early mazes were essentially linear: they had one spiral or convoluted path. Fisher (1990) calls these unicursal mazes. In Greek legend Daedalus, who designed the Minotaur's labyrinth, also threaded a sea shell by tying a thread to an ant's leg. It seems likely that this is a parallel of Ariadne's thread in the labyrinth and that the Minotaur actually lived in a spiral maze.

Even if we can't give overall 2D or 3D maps of complex information spaces, it is always possible to offer linear paths through. It is quite common to find guided tours of various kinds in hypertexts, for example Nick Hammond's early work at York using a tour bus metaphor.

The Golden Rule of Design

We move now from the grounded scenarios back to general principles. The golden rule of design which I find myself repeating again and again is:

Understand your materials

Take a metal chair design and build it in plastic. What would happen? It would break or collapse. Different materials require different designs to achieve the same purpose.

In HCI the materials we draw on include the computers, user-interface toolkits, programming languages, web servers and other things with which we create interactive systems. The materials also include the people who use them. We need to understand the properties of computer systems – what is possible, what is not – and the properties of people – what they can do and what they can't. How often do you hear air or train crashes dismissed as 'human error'. Once you've blamed the driver you can ignore the problem! But if a bridge fails due to a metal strut buckling, we don't dismiss this as 'metal error' and blame the strut. Humans are

adaptable, responsible, able to cope and deal with tremendous complexity, but have known limitations and failure patterns. The study of human cognition and psychology in HCI is part of that grappling with the properties of our raw materials.

In addressing the design of cyberspace we also need to understand the computer and human materials.

Virtual objects are not like physical objects. Physical objects are constructed of matter and exist at one point in space and time. They have continuity of existence (no sudden jumps between locations, no disappearing and reappearing). In contrast virtual objects have the properties of a magical world. They are formed from pure information which may be replicated, existing at several places in the same system or may even disappear and then reappear. For example, in the UNIX file system, blocks of zero data are not physically stored in the filing system, but instead are 'called into existence' when required.

Virtual space also has different properties from the familiar 3D Euclidean world – non-linear, non-local, often discrete. In a recent ACM TOCHI paper, others at Lancaster and I try to construct taxonomies, conceptual frameworks and formal models for the broad classes of 'spaces' we find in the virtual and physical world (Dix, 2000).

Understanding the human as material for cyberspace is perhaps most challenging. How do people model, manipulate and navigate in physical space? If we understand this we can start to construct virtual spaces that retain the essential nature of space that makes it comprehensible. For many designers of virtual worlds the focus is on 3D realism, but it is far from clear that our internal models of space are Euclidean 3D. We are good at physically manipulating 3D objects, but our vision is nearer 2D than 3D and when we move it is mainly on a 2D ground plane. Helicopters are hard to fly partly because true 3D navigation is not natural for us and this is also evident in desktop VR systems: if you ever rotate your viewpoint away from the ground plane, it is very hard to re-orientate yourself.

Recently, in a keynote for CVE2000, I grappled with some of the complexities of our attempts as humans to model and understand space (Dix, 2000b). This took me through more than four millennia: from Babylonian maps through numerous models of cartographers,

mathematicians, physicists, psychologists and architects to the present day as well as the latent representations of poets, hymn writers and artists. Our worlds are not 3D Euclidean, but a strange mix of paths and landmarks, where distance is measured as much by familiarity and importance as by miles on the ground.

early 'T' map (Asia at top, Europe lower left, Africa lower right, Jerusalem at the centre)

Fundamental rules of navigation

Another set of HCI rules that I quote repeatedly concern navigation and thus translate easily into cyberspace design. At any point when using an interactive system it should be possible to know:

where you are
where you've come from
what you can do
where you will get to

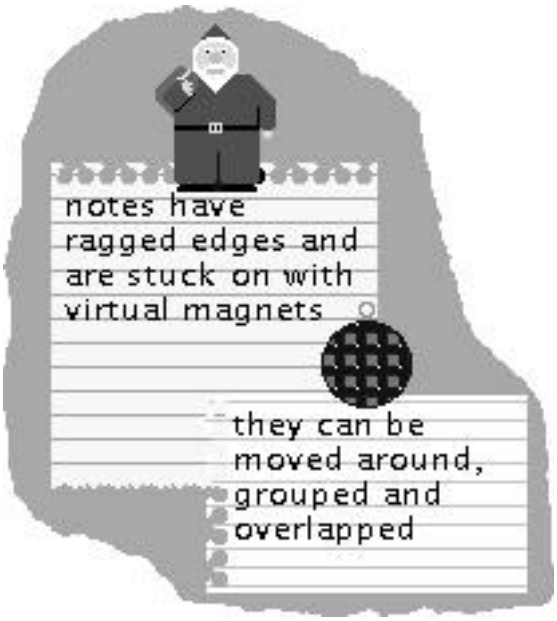
Look at the first of these "know where you are". How many times have you re-visited a bookmarked web page only to discover it has no links (neither descriptive nor hyperlinks) back into its broader context? How many computer systems hide significant parts of their internal state (effectively where you are) so that deterministic internal behaviour appears random from the outside?

Command line systems give quite a good view of what you have done before ("where you've come from" – history), but rely entirely on your understanding of the system to know what the

current state is ("where you are") and your memory or ability to read a manual for what command to type next ("what you can do"). In contrast, graphical systems are relatively poor at history before ("where you've come from"), but better at state ("where you are"). They are also better with menus and buttons saying "what you can do", but with typically only single word legends it is hard to work out what they will do ("where you will get to"). With multimedia web pages we have come full circle on the third rule ("what you can do"): you move your mouse aimlessly over a field of images and icons hoping that one will highlight, display a tool tip, or animate and show you where to click!

Designing environments

In some ways it's easiest to write software to *do* something. We get the specification of what it must do, perhaps some statistical calculation, we write the algorithms and it is there. However, much of the software we use is there to help *us* do things: word processors, operating systems, etc. Some of these, such as the word processor, we may think of as tools (although they are unlike physical tools), but others, such as the desktop interface, function as an environment in which we act. In a collaborative setting this is even more important – an environment is a place we meet, work, have fun. The job of an architect is not simply to design a building, but to design a space in which people live.



Virtual fridge is an informal 'noticeboard'-like application. It takes the metaphor of a fridge door, which, across the world, is a place where families and housemates post things to remember, messages to one another, postcards from friends, all stuck on with colourful fridge magnets. There are many informal 'family' areas on the web, but virtually all are built upon 1970s bulletin board technology designed by computer scientists, for computer scientists, in the days of character terminals. Under a thin veneer of graphics the structures remain the same. A bulletin board forces users to formally articulate structure in terms of topics and sub-topics. In contrast those who have studied 2D surfaces over the years, such as Xerox Whiteboards (Donahue, 1986) or York Conferencer (McCarthy, 1990), have

found that users create their own implicit structures using proximity, grouping and overlapping.

5. FURTHER INFORMATION

This paper has taken a lightning tour from 16th-century Venice, through traditional HCI, to the reaches of cyberspace. Whether we like it or not, we are living in a richly connected world where the virtual and physical are interlinked and layered upon one another.

For more about standard HCI techniques see my co-authored HCI text book (Dix, 1998). For more on the nature of cyberspace see my research topics page on cyberspace [W01]. Also my paper at CVE2000 describes some of the different kinds of models of space in mathematics, physics and other disciplines (Dix, 2000b). Finally for more about vfridge or aQtive see the respective web pages [W02, W03]

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7. LINKS

[W01] `http://www.hiraeth.com/alan/topics/cyberspace/`

[W02] `http://www.vfridge.com/`

[W03] `http://www.aqtive.com/`