Dynamic Magical Environments

Engaging Interaction based on the Art of Illusion

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School of Architecture and Planning
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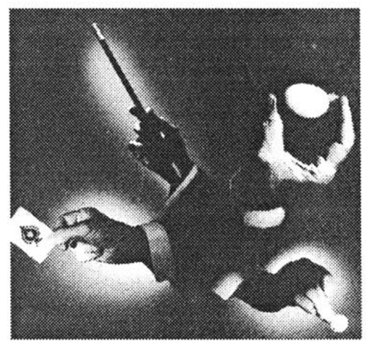
Abstract

This thesis describes design principles to create *engaging* interactive systems based on salient principles of close-up[1] magic. Although, many researches have identified the need to engage the user during the interaction process, there is a dearth of techniques and models for doing so. The term *engaging* is defined to embody characteristics including, *responsive reaction, unobtrusive interface, guided navigation, suggestive exploration and unexpected behavior.* This research has explored the following salient principles of close-up-magic with the goal of designing engaging systems: *framing contexts, focus of attention, continuity, adaptation, element of surprise, and timing and pacing.*

Based on these principles, two prototype applications in the geographic information domain, GeoSpace and MediaMagic were designed. Both systems demonstrate the applications of the principles and exemplify a novel approach for designing engaging systems.



From Magic and Showmanship - Henning Nelms.

Thesis Advisor: Prof. Whitman Richards
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1 Close-up magic is very different from stage magic in that it happens at a very close distance from the audience and is very dynamic and interactive.

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Engaging Interaction based on the Art of Illusion

Ishantha Joseph Lokuge

The following people have served as readers for this thesis.

Whitman Richards
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Head, Program in Media Arts and Sciences

Ron MacNeil
Principal Research Associate
MIT Media Laboratory

Matthew Belge
User Interface Architect
Principal
Vision and Logic

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Most importantly, to Fr. Kuri for his living example of Godliness, without whom nothing is possible.

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Introduction

chapter 1

1.1 Problem Statement and Motivation

Any sufficiently advanced technology is indisinguishable from magic.

Arthur C. Clarke

The explosive growth of information has necessitated new, exciting directions for presenting complex data to users. While much research has focused on the efficient storage, transfer and display of information, there is considerably less emphasis in designing information from a users perspective. For example, where should a users attention be focused in a complex visual display? How should the presentation style adapt to changing users preferences? How can the system stimulate a users interest and curiosity? These questions point to a growing need to develop cognitive models and design principles, that will help create more *engaging* information presentation systems.

Although, the notion of creating engaging presentation systems has been identified to be of critical importance, there is very little direction as to how one might build such a system. Donald Norman discusses some requirements such as the system be responsive, unobtrusive and the input and output languages be interreferential [Norman 1983]. Similarly, Paul Heckel stresses the importance of designing friendly systems and provides many techniques for doing so [Heckel 1982]. Additionally, many closely related domains of interactivity, like video game design, have strived to make their applications engaging to users by using techniques such as attractor mode, animation, sound [Paush 1994], reinforcement learning [Loftus 1983] and emphasizing intensity of interaction [Crawford 1990]. A primary source for identifying the necessary elements for creating such systems are derived from theater and other art forms. One such art form that has developed over a 5000 year history, but is yet to be explored is the art of illusions—magic.

An old German engraving of a close-up magician. The model and principles I discuss are derived primarily from close-up magic. From Magic of the Masters—Jack Delvin

The realm of magic has enthralled audiences for centuries. The craft has developed a plethora of techniques and principles for presenting illusions in very exciting and entertaining ways. Prior to performing, magicians plan on creating a stimulating environment to capture the interest of their spectators. During a performance, a magician will fluidly guide the spectators' attention to different spatial locations to unfold a repertoire of delightful surprises. Some of these may violate peoples' expectations, but nonetheless, the magician successfully maintains logical continuity from one sub-climax to another. On the whole, most magicians succeed in captivating the attention of an audience and keep them engaged during a performance.

1.2 Goals

The primary goal of this research is to design information presentation environments that keep users engaged, as they interact with the environment. The term "engaging" as used within the context of interfaces is still evolving towards a definite meaning. Many different definitions for engaging systems exist. For example, Laurel states that "engagement is what happens when we are able to give ourselves over to a representational action, comfortable and unambiguously" [Laurel 1993]. Norman talks about how the form of interaction can contribute towards the feeling of engagement [Norman 1982]. In magic and drama the engagement factor keeps you involved during the performance. For the purpose of this thesis, I have adopted some well known characteristics of engaging systems and identified new ones. Described below is the complete list of characteristics which I sought to achieve.

Characteristics of Engaging Systems

- *Responsive reaction*— "The system to be responsive, with no delays between execution and the results, except where those delays are appropriate for the knowledge domain itself"[Norman 1983]. Responsiveness is a well known characteristic of most video games which are very engaging to interact with. Similarly, in the information domain the user must be provided with rapid feedback, as the user interacts with objects in the space.
- *Unobtrusive interface*— "The interface to be unobtrusive, non interfering or intruding"[Norman 1983]. The interface must be transparent to the user, enabling seamless information graphics during interaction. If during interaction, users gets distracted by the presence of the interface, the feeling of engagement will be lost.
- *Guided navigation*—The system should guide a user to the relevant information without the user having to do all the work. This is especially relevant for large information bases. The guiding process must not distract the users tasks, but rather enable users to focus their attention on the relevant information quickly.

- *Suggestive exploration*—this is a characteristic that will tend to stimulate a user's curiosity, and hence, the urge to explore. The system should subtly present more information than requested by the user. By visually or otherwise stimulating the user's senses, the user gets engaged in the process of discovery.
- *Unexpected behavior*—this is a desirable characteristic provided it does not confuse the user. Violating users expectations will tend to surprise users; the surprises created must not be confusing. In chapter 4, I discuss and give examples of "meaningful surprises" which can peek the users interest, and hence keep them engaged as they interact with the application.

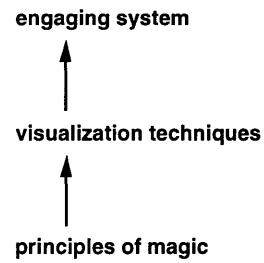


Figure 1.1
The design methodology for creating dynamic magical environments.

1.3 The Magic Potential

My thesis presents a novel approach for designing engaging information systems based on a model derived from the principles of magic. Consequently, the application environments are called Dynamic Magical Environments. Based on my prior experience as a magician and combined with a review of the literature in the field (e.g. [Nelms 1969; Fitzkee 1975a,b, and c; Tog 1993]) I have identified the following principles in magic:

- **Framing Contexts**—this is a sequence of logical steps in an illusion that helps the audience to believe in the resulting climax. Framing contexts enable the magician to lead the audience along a certain path during a performance. In the information domain, framing was applied for *suggestive exploration* and *guided navigation.*
- **Focus of Attention**—this involves controlling the attention of the audience to a specific location or object at any given time during the performance. In the information domain this principle was applied for *guided navigation.*
- **Continuity**—this is a very versatile principle applied throughout the illusion process. Continuity is concerned with moving fluidly from one visual context to another. It was applied to create an *unobtrusive interface.*
- **Adaptation**—the magician is very responsive to audience feedback and moulds the presentation accordingly. This adaptation gives a performance a highly dynamic quality. In the information domain, adaptation was used to create interfaces which exhibit a *responsive reaction.*
- **Element of Surprise**—magic is full of surprises which tend to vio-

late the audiences' expectations. The element of surprise typically occurs at the climax of an illusion. This principle was useful for designing *unexpected behavior* and for creating *suggestive exploration.*

- **Timing and Pacing**—*Timing* involves the time relationships of two actions and *pacing* refers to the time relationship of a sequence of actions. This sequencing determines the subjective perception of time by the audience. In the information domain this principle was applied for *guided navigation* and for *responsive reactions.*

Based on these principles I have developed a *model of presentation* which has been a basis for designing engaging systems. The purpose of the model is to show the dynamic interplay of these principles in a typical illusion and to extract its equivalent application in the information domain. Figure 1.1 shows the research methodology for creating engaging systems. At the base level are the principles of magic identified above. These principles need to be incorporated in information space design so that the *characteristics* of engaging systems can be realized. However, to do so in the information domain, various visualization techniques are used. Chapter 5 explains in detail the visualization techniques used in designing the prototype systems.

Uniqueness of Magic

Few, if any, would dispute the fact that a magic performance keeps an audience gripped throughout the show. The salient principles of magic, mentioned above, are key to achieving this effect on an audience. Thus, in the realm of magic, the principles have been tried and tested time after time, resulting in highly engaging performances. This provides the fundamental motivation for attempting to apply these principles in the information domain to achieve the desired characteristics mentioned above. However, one may ask the question, why magic? Is it possible to arrive at the same (or similar) set of principles by exploring other dramatic art forms? Perhaps. Discussed below are a few unique characteristics of magic which distinguish it from other art forms.

The process of presenting an illusion in close-up magic is very dynamic involving audience participation. In close-up, unlike stage magic, the magician has to continually adapt in response to the behavior of the spectators. Although the magician has an overall objective, he does not have a rigid plan to adhere to. Rather, the magician operates on a sequence of flexible plans, with many different paths towards the climax of the illusion. The specific path he takes will depend on the circumstances during the performance. This is very different from theater where the acts of a play are well structured. A good example is the art of forcing a card, by the classic force (Figure 1.2). The basic effect is

Figure 1.2
The magician keeps spreading the cards while moving the cards towards the spectators hand. Perfect timing is required to execute this force with finesse.

that the audience can select any card from a shuffled deck of cards. No matter what card the audience member chooses the magician can name the chosen card. As the spectator reaches out to pick a card the magician varies the rate at which he fans the deck and the rate at which he moves the deck towards the spectators hand. These two actions enable the magician to force the pre-known card to the spectator, who thinks that he had a free choice. All this happens in a very tight feedback loop; the magician observes the movement of the spectators hand and in fact reacts to this by varying his motion towards the spectator. The point here is that although the magician has a previously set plan of actions, the timing of each is based on the dynamics of the interaction. Contrary to close-up magic, in stage-magic or plays for instance there is very little dynamic interaction of this kind. Hence, close-up magic draws upon the important principle of continuous adaptation in the course of the presentation.

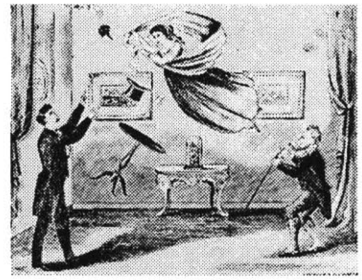


Figure 1.3
Poster of David Devant and Neville Maskelline performing the floaating lady illusion in the 18th Century. From Magic of the Masters—Jack Delvin

The notion of willing suspension of disbelief applicable to theatrical performances is not apt in the context of creating illusions. Since, magic inherently relies on violating peoples expectations, asking audiences to willingly succumb to the effect of the illusion is purposeless. For example, in the floating lady illusion (Figure 1.3), what good is it to ask spectators to imagine that the lady is floating? On the contrary, the spectator will not willfully believe that the lady can float, but the actions of magician will involuntarily make the spectators believe in the impossible. The ability of the magician to create this involuntary response from the audience is very powerful. It is central to the theme of keeping an audience engaged and is achieved by applying the principles identified above.

1.4 Dynamic Magical Environments

To explore the design of engaging information spaces the following two prototype systems were developed: GeoSpace, and MediaMagic. Both these projects exemplify one or more of the principles of magic in action. The overall class of information spaces designed based on these principles are referred to as Dynamic Magical Environments. Hence, GeoSpace and MediaMagic are two such environments, each exhibiting a particular characteristic.

GeoSpace

GeoSpace is fundamentally designed to engage the user by guiding attention, developing framing contexts and enabling smooth continuous transitions from one visual presentation to another. Figure 1.4 shows a scenario from GeoSpace, where the user moves the cursor over a dense map display of Boston. The motion of the cursor triggers certain regions in the map such as Cambridge to be highlighted over other areas (Figure 1.5). The size of the typography and its opacity change dynamically as the cursor moves over Cambridge. This draws the user's attention to Cambridge and its vicinity. The map exhibits a reactive quality by responding dynamically to user-triggered actions.

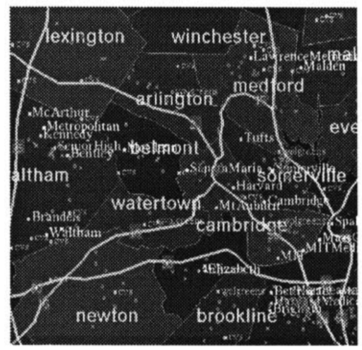


Figure 1.4
Dense map display without attempting to guided users attention.

In addition to displaying Cambridge, the map display also shows information of interest based on a user profile; in this case information on colleges and crime data. These additional information are referred to as framing contexts, since they *frame* the users mind with the idea of encouraging further exploration. These framing contexts are represented as a network of plan structures. Each plan including a specification of related information to display, when the plan is executed. The entire network of plans is referred to as an activation spreading network [Maes 1990]. Plans have activation values, and when the activation values cross a threshold the plan becomes active. The activation values vary gradually, and hence, when mapped to transparency and typography values, the visual transitions occur very smoothly. In Chapter 5, I discuss in depth the representation of plans and the mechanics of the network.

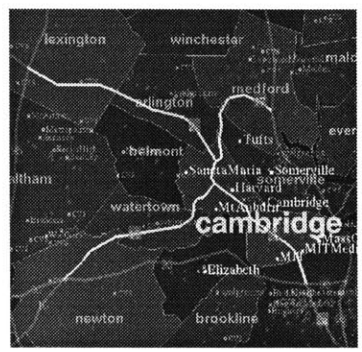


Figure 1.5
System higlighting cambridge and vicinity based on the users request to see cambridge. In addition it shows areas of interest within cambridge, in this case colleges and schools.

MediaMagic

MediaMagic extended the application of the principles of magic further. In this project many of the principles in magic were adopted with the aim of creating an engaging information space. When interacting with MediaMagic it is initially in the form of a geographic space, much akin to GeoSpace (Figure 1.6). As the user moves the cursor over an activity of interest, in this case Boston Aquarium, the space transforms. The geographic map gradually fades away and gets transformed to a three dimensional space of cubes, as shown in Figure 1.7. Each cube represents an activity such as the aquarium, science museum and so on. This transformation is an example of violating a persons expectations, since typically dynamic maps do not behave as mentioned. The activities that migrate towards the aquarium activity are psychologically close to the Aquarium. The psychological proximities were obtained by using clustering algorithms on experiment data [Lokuge, Gilbert and Richards 1995]. In this example the three closest activities to the Boston Aquarium are Franklin Zoo, Sports Museum and Fenway Park. Once the user is within the activity, the system combines visual techniques such as transparency and typography with timing functions. The timing functions help pace the presentation of different visual elements such as a description of the Aquarium, related information, an image of the activity. The overall effect enables the user to focus attention on one aspect on the information cube at a given time.

In addition, a range of different actions give the cubes distinct behavior, which tends to surprise and guide users around the information space. For example, if the user is a child (based on the profile) and she enters the Trinity cube, the system will draw her away from this activity by camera movement, say towards the Children's Museum. This can prevent the user from spending too much time in an uninteresting activity. Another example action is the user of motion to attract attention towards a more interesting activity. In Chapter 4, I discuss specific action-based application scenarios and issues in greater detail.

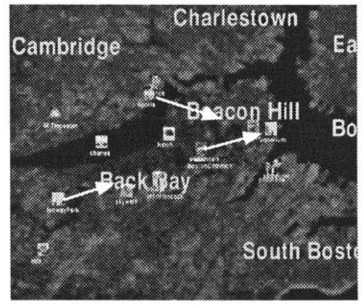


Figure 1.6
Initial display of MediaMagic showing the various activities in the context of a geographic space.

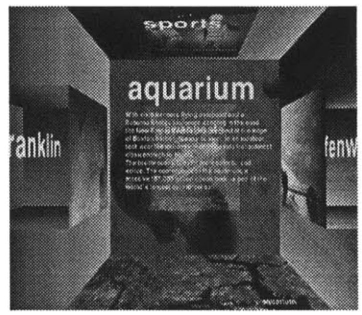


Figure 1.7
The transformed psychological based space of MediaMagic. The user is within the aquarium cube; the related activities surround this activity.

1.5 Conceptual Framework

This section provides a conceptual framework for relating the two rather diverse domains: the realm of magic and the domain of information. This discussion will also help clarify what a reader should expect from this thesis. This thesis does not attempt to create information presentation systems that in any way behave like a magician. Rather, it has researched into the art of creating illusions so as to apply these principles to create more *engaging presentation systems.*

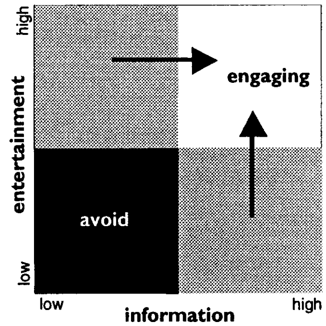


Figure 1.9
Information-entertainment diagram showing the region where engaging informations systems would fall into.

Magic in today's world is primarily dedicated for entertaining people. Interfaces in general do not have this as their primary goal. However, both domains have one motive in common: that of communicating effectively. In the art of illusion, the magician communicates an illusion. In the information domain, the designer communicates complex and interrelated data. Figure 1.9 shows the relationship between the elements, information, entertainment and engagement. Engaging information presentation systems are rich in both entertainment and information as opposed to video games which are low in information but high in information (gray area along the entertainment axis). The block box lacks both characteristics, and is usually well avoided in most applications. The goal then, is to move in the direction of the arrows, towards the design of engaging systems. Although this is a simple framework, it helps to move towards blurring the boundaries between information and entertainment systems: *engaging systems.*

1.6 Ethics

Ethics is a big issue in conjuring as well as in information presentation. For purposes of clarifying the objective of this thesis, it must be stressed here that the goal is not to misrepresent information. Even in the realm of magic, few, if any, misuse the powerful effects of knowing and applying the principles of magic discussed in this thesis. On the contrary, magicians go to great lengths to convince people that magic is merely showmanship combined with sleight-of-hand techniques.

Clearly, it is possible to mis-represent information in many ways. For example, in statistical graphs, by employing different scales for the x and y axes, one can convey different interpretations of the data. The field of mapping is loaded with examples. In graphic design, typography and color can be misused, as done by some advertisers. Likewise, it is possible to abuse the principles discussed in this thesis for misrepresenting information. This thesis has made every attempt to prevent such misrepresentation of data; rather it has focused on information design to engage the user during the interaction process.

1.7 Structure of Thesis

This thesis is arranged into several sections. Chapter 2 describes related research including attempts at designing engaging interfaces. Chapter 3 describes the principles of magic and develops a model of presentation based on these principles. Chapter 4 describes specific application scenarios in the information domain. Chapter 5 describes the design techniques developed and used for modeling the principle s of magic. Chapter 6 concludes with a summary of the uses of this approach and suggests areas for further research.

Related Research

chapter 2

1.1 Magic, Drama and Narrative

When we look toward what is known about the nature of interaction, why not turn to those who manage it best—to those from the world of drama, of the stage, of the theatre?

Donald A. Norman

Although, there is no formal research relating the realm of magic to the domain of information presentation, there is literature that describes the techniques of magicians within the context of User Interface Design. Bruce Tognazzini [Tog 1993] discusses the principles, techniques and ethics of stage magic and their application to human interface design. Independently, I presented my original ideas [Lokuge 1993] relating the principles in magic to the design of user interfaces. While, the above work provided designers exposure to the field of magic, few have actually developed systems on a model directly derived from magic.

Paul Heckel, in his seminal book the "The Elements of Friendly Software Design", mentions design principles for creating very user-friendly applications. He states, "When I design a product, I think of my program as giving a performance for its users." This perspective of designing is similar to the approach adopted in the design of Dynamic Magical Environments, where the showmanship elements of magic are applied in the context of designing information spaces. Heckel mentions some principles such as focus of attention, continuity, maintaining interest, etc, although there is no clear model how one may use one or more of these principles within a given application.

Many interface metaphors and models have been derived from theater (e.g. [Laurel 1991], [Bates 1990]). Brenda Laurel in her book, "Computers and Theater", gives a detailed description of dramatic theory and its application to human computer activity. She focuses on designing engaging and interesting interaction based on these techniques. While much of her work is theoretical, her ideas are clearly substantiated through many examples. Several underlying principles in drama, like theme, complication and resolution of action, discovery, surprise and reversal, echo similar ideas as in magic. Joseph Bates has been actively pursuing some of these dramatic techniques in the Oz project [Bates 1990].

The design of human computer activity has previously been viewed from a narrative perspective in adventure style games and information presentation environments (e.g. [Don 1990; Lehnert 1977; Dyer 1983]). Narrative involves the context of the story as well as the story per se. Don explains how, narrative allows the structure and content of the knowledge base to evolve together while accommodating a variety of contexts defined by the user's specific needs and interests. The GUIDES project [Oren 1990] developed at the Advanced Technology Group at Apple Computer had three agent characters (the guides) each of whom had a different view point about topics related to American History. Each guides role was to navigate users through the database in the course of narration. A subsequent video version incorporated both content and navigation, which users found to be extremely satisfying and engaging.

1.2 Video Game Design

Pausch et. al proposed the potential of creating more compelling and engaging interfaces based on the design and techniques of video games [Paush, 1994]. The use of attractor mode to draw users towards video games was demonstrated during the presentation at CHI'94; this idea is closely related to topics in perception and magic. [Loftus 1983] in the book, "Mind at Play" describes the use of re-inforcement in video games which lead to user-engagement. Emphasizing intensity of interaction has been explored [Crawford 1990] as a means of keeping players engrossed while interacting with the video game.

Although, video games are engaging and highly interactive their domain is typically limited to entertainment. However, when creating *information* systems the task of designing engaging interaction is more challenging; the designer needs to ensure that the space while being engaging is also enabling the user to comprehend the complexity of information. The design of dynamic magical environments have focused on designing engaging *information* spaces, as opposed to engaging interaction for entertainment.

1.3 Visual Techniques

Many visual techniques previously developed in the Visible Language Workshop have provided a means of designing and implementing the ideas presented in this thesis. For example, previous work done at the VLW on typography [Small 1994] and transparency and blur [Colby 1991] are used in the design of the three dimensional information space. Many other visual techniques developed for information exploration such as layers [Belge 1993], aggregation and dynamic queries [Golstein 1994] and magic lenses [Bier 1994] share similar goals in both structuring and presenting the information. While, most of these approaches focus mainly on the technique per se, the approach adopted in this thesis is to combine these techniques with the presentation model derived from the principles of magic.

1.4 Intelligent Multimedia Presentation

Intelligent multimedia systems embody research problems and approaches similar to those outlined in the design Dynamic Magical Environments (e.g., [Feiner 1993; Maybury 1993; Roth 1993]). Maybury introduces an interactive visual presentation method that considers visual presentation as communicative acts (e.g., graphical, auditory or gestural) based on the linguistic study of speech acts [Maybury 1993]. Rhetorical acts, which are a sequence of linguistic or graphical acts are represented in the form of a presentation plan. Although, the representation of the plan structure in Maybury's system is similar to the plans in GeoSpace, the overall system does not have a mechanism to model a users cognitive tasks.

There have been attempts to model the cognitive operations of users to support multimedia communication [Bonarini 1993]. Andrea Bonarini investigated the communication between a driver and a co-pilot by modeling the feature of interaction tools. Drivers' psychological states were observed to derive a model of a typical driver. The results point to the significance of having user-models in intelligent multimedia applications in addition to other issues such as retrieval, storage and transfer of information.

Research in mult-modal interfaces incorporating speech, gesture and gaze [Koons 1993] provides an unobtrusive interface to the information space making the interaction more engaging. The design of dynamic magical environments will benefit immensely, with advancements in speech and gesture recognition technology. Advance eye tracking will enable the system to make interpretations about user's intentions and adapt its behavior accordingly, much like a close-up magician. The current implementation of MediaMagic was designed to be integrated with a FishBoard[2] sensor which allows for gestural input.

2 The fishboard sensor was invented at the Physics and Media group of the Media Lab.

The Realm Of Magic

chapter 3

1.1 Introduction

Someone creates a trick, many people perfect it, but its final success in front of an audience depends on the person who presents it.

—Rene Lavand

The hypothesis of this research is that information presentation based on a model derived from magic will keep users engaged while they interact with the system. In order to realize the special characteristics of magic that lend itself to being highly engaging, it is important to understand the basic principles of magic which have been developed over the centuries. This section will present the most salient principles of magic and will attempt to relate it to information design.

Prior to making this connection, it is imperative to distinguish the difference between a trick and a illusion. The classic example [Nelms 1969] that follows should exemplify this distinction.

> *In 1856, French North Africa was as disturbed as it is today. However, the agitators were not Communists but marabouts-Mohammedian fanatics who worked the arabian mobs into superstitious frenzy by pretending to possess magical powers. The French Government displayed imagination almost unique in official circles and sent a conjurer, Robert-Houdin, to discredit the marabouts by outdoing their magic.*
>
> *One of Robert-Houdin's feats is probably the most perfect example of conjuring ever performed. The marabouts had a trick which apparently proved that no pistol aimed at them would fire. The French conjurer countered by letting a marabout shoot at him and catching the bullet in an apple stuck on the point of his knife. However, Robert-Houdin had announced publicly that his "magic" consisted entirely of tricks, and the shrewder marabouts guessed that his bullet-catching feat could be performed only with his own gun.*
>
> *Some time later, while the Frenchman was stopping in a native village, a marabout drew two pistols from his burnoose and chal-*

lenged Robert-Houdin to a duel in which the marabout claimed the right to the first shot! Robert-Houdin protested but finally agreed to fight the duel under the marabout's conditions at eight o'clock the following morning.

The meeting took place in an open square surrounded by white-washed buildings. The square was packed with Arabs who hoped to see the Frenchman killed. The marabouts produced his pistols which he loaded with powder. He offered Robert-Houdin a handful of bullets. The Frenchman chose two, dropped them into the weapons. covered them with paper wads, and thrust them into the barrels with a ramrod.

The marabout had watched every step and felt sure that his adversary would not escape. He took careful aim and pulled the trigger. Robert-Houdin smiled-and displayed the bullet between his teeth. The marabout tried to seize the other pistol, but the French conjurer held him saying, "You could not injure me, but you shall see that my skill is more dangerous than yours. Watch!"

He fired at the nearest wall. Whitewash flew. Where the bullet had struck, a gout of blood appeared and dripped down the masonary.

In those days, duelling pistols were provided with bullet molds. Robert-Houdin cast two hollow balls of wax which he rubbed with graphite to make them look like lead. One ball was left empty; the other was filled with blood drawn from his thumb. he switched these for the real bullets by sleight of hand. The empty ball went into the marabout's gun and was rammed home with enough force to break the wax into small bits. The blood-filled bullet in the conjurer's pistol was merely pushed into the barrel. It was strong enough to hold together until it struck the wall and splashed with blood.

Every illusion can be conceptually broken into two main categories: (1) the trick factors which comprise the mechanics of the illusion and (2) the non-trick factors which encompass the elements of showmanship described in detail below. It is the latter factors that are relevant to the design of information. In Robert-Houdins bullet-catching routine the overall effect was an illusion which comprised of a few trick elements like, switching the bullets and the fake bullet. However, the illusion as

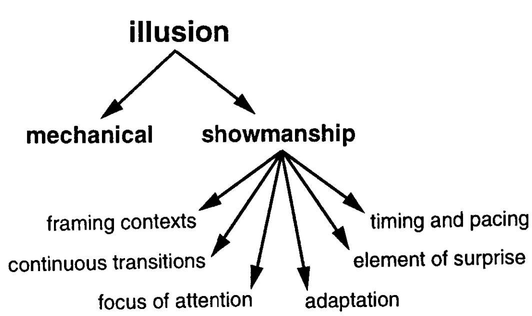


Figure 3.1
An illusion can be sub-divided into the trick elements and the non-trick elements. It is the non-trick elements that are applicable within the domain of intformation presentation systems.

a whole was comprised of many non-trick elements such as focusing the attention of the spectators to enable the switch, framing their minds that he could catch a bullet between his teeth. Figure 3.1 shows the non-trick elements which have been explored in this thesis. These are discussed in greater detail in the next section.

1.2 Salient Principles of Magic

In this section I will first discuss these salient principles in the context of a specific illusion. While doing so, I will refer to possible applications of these principles within the domain of information presentation. The following section integrates the principles so as to develop a model of presentation. The next chapter will show concrete examples of the principles in action, within the prototype systems, GeoSpace and MediaMagic.

A detailed set of fundamental principles of magic can be found in [Sharpe 1988]. While, this is useful to get a feel for the breadth of psychological principles adopted by magicians, it is not necessary for the purpose of developing a model of information presentation. Furthermore, an important aspect of this thesis has been in identifying *which* principles will work within the context of information presentation. As previously mentioned, I have identified the following six principles of close-up magic that can be applied for information presentation:

- **Framing Contexts**
- **Focus of Attention**
- **Continuity**
- **Adaptation**
- **Element of Surprise**
- **Timing and Pacing**

In this section I will illustrate the application of these principles by describing a simple card illusion, *Diminisho.* Although this is straightforward card illusion, the impact on a closeup audience can be quite profound. The effect is as follows: The magician having shown a few playing cards in a fan, gives them a squeeze. The cards become smaller. Another squeeze and they shrink even more. Ultimately, they miraculously shrink to nothing, right in front of the audiences' eyes! To enable the mechanics of the illusion, three different sized cards are required - the rest of it lies in the principles discussed below.

Framing Context

The first step in any magic routine is to create the right atmosphere by developing a framing context [Nelms 1969] to present the illusion. The objective of framing the minds of the audience is to stimulate their interest in the trick and to make them believe in the resulting illusion. For example, the magician will talk about a topic related to the illusion and encourage the audience to participate. In Diminisho the magician needs to conceal the smaller cards (Figure 3.2a), by holding the larger ones in a fan (Figure 3.2b) the desired effect is achieved. The hands are positioned in Figure 3.2b, to draw attention to the fanned cards. To shrink the cards the first time, the magician merely pushes them lower down (Figure 3.2c), and they appear to be smaller. The magician previously set a framing context by stating that the cards were going to shrink and hence, moving the cards lower achieves the desired effect. If a magician fails in this important step, a general lack of spectator interest will result, dampening the effect of the illusion.

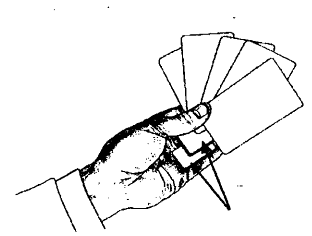


Figure 3.2a
The smaller cards are concealed in the palm as shown by the arrows.

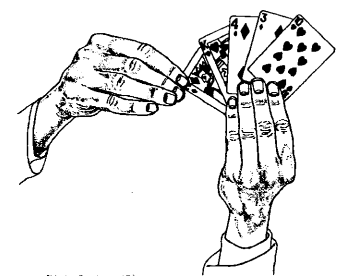


Figure 3.2b
The cards are held in a fan, which is a natural position, and aids in concealing the smaller cards.

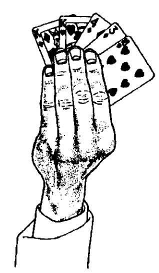


Figure 3.2c
The cards are pushed lower into the hands to create the illusion of the cards shrinking.

Framing generally provides cues that lead the audience along a desired path. In an illusion, the desired path is carefully planned by the magician so that resulting climax is effective. For example, prior to diminishing the cards, the audience must be convinced that the magician is *not* concealing a smaller set of cards. The idea of leading the audience along a specific path is powerful and can be used in the domain of information. Its use however, is not to mislead the audience to believe in something incorrect, but rather to provide visual cues that will induce users to explore the information space.

Inducing exploration was one of the criteria of an engaging system, and hence, the use of framing to induce exploration is important. Framing is also related to the element of surprise. Simply put, the better the magician frames the audiences' mind, the better is the surprise. Essentially, framing helps maintain a logical continuity in an illusion, and when it is time to climax the illusion, the magician reveals an alternate reality—the surprise. The next section describes how this continuity is achieved from one framing context to another.

Continuity

Audience interest during a magic show is of utmost importance for a successful performance. Magicians use many techniques such as adding more color, more movement, more sound, more intensity, more excitement to create an increase in the audience interest during a performance [Nelms 1967]. They also relieve the spectators of any mental effort by sequencing the acts in a logical order to maintain continuity from one step to another in an illusion. If the spectators try to search for a logical connection in the presentation, they miss the next few steps, result-

The illustrations for this example are from Magic of the Masters—Jack Delvin ing in an overall loss of interest. For example, Figure 3.2d,e and f, shows the smooth transition for shrinking the cards further. This effect is achieved by the following three steps:

(1) The magician closes the fan with the right hand (Figure 3.2d)
(2) At the same time, he pulls the next set into view (Figure 3.2e)
(3) In a continuous motion the smaller cards are fanned out (Figure 3.2f)

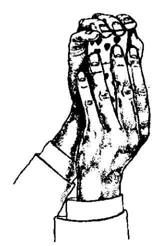


Figure 3.2d
Closing the fan with the right hand.

This idea of continuity deals with the issue of formulating many framing contexts and moving fluidly from one context to another, so that an information seeker can be guided through a complex information space.

Focus of Attention

Controlling the attention of an audience is a well studied art in the realm of magic. Many great conjures almost completely control an audiences' attention by gesturing, movement, the use of contrast, and color [Nelms 1969; Fitzkee 1975]. In magic the attention of the audience is controlled by two processes: direction, which entails drawing attention towards a point of interest, and misdirection which attempts to divert the attention of the onlookers away from some secret maneuver. For example, in the climax of diminisho the cards vanish completely; this is achieved by controlling the attention of the audience to the left hand (direction), while actually concealing the cards in the right hand (Figure 3.2g). If the magician wanted to dispose the cards from his right hand to his pocket without people noticing, he would use misdirection techniques. While, it is not clear how misdirection can benefit users of interactive presentation systems, it's clear that having a system that directs a users attention [Colby 1991; Lokuge and Ishizaki 1994] to a region of the display greatly benefits a users comprehension of the data. It helps a user to visually discern relevant information quickly, and to guide their attention fluidly in the information space.

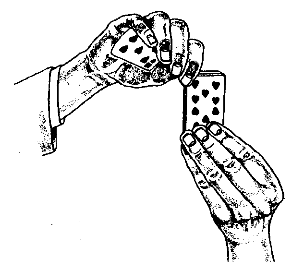


Figure 3.2e
The first set is moved to the plam while pulling the next set into view.

Figure 3.2f
The right hand fans the cards in a continuos motion.

Directing attention by misdirection is well known in the realm of magic. Misdirection is primarily used to conceal a secret move done by the magician. For example, if the magician wanted to dispose the cards hidden in his right hand, (Figure 3.2g) he would first draw attention towards his left hand by gently opening it. Simultaneously, he would turn his body away from the audience and move his right hand into the trouser pocket, where the cards are left behind. Misdirection is very different from *distraction,* in that the actions of the magician fit the overall theme. This prevents the audience from being confused. For example, to dispose the cards the magician could have dropped his wand and while the audiences' eyes move to the ground, he could dispose the cards. The dropping of the wand does not fit the overall theme of the

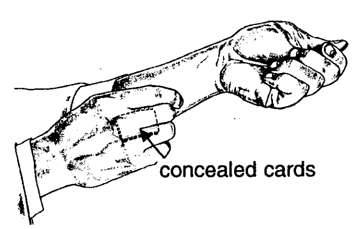


Figure 3.2g
Right hand concealing the cards while the magician guides the audience's' attention along the left hand.

illusion, and hence will distract the audience. This distraction leads to confusion.

Guiding an audiences attention is important in magic, because the magician provides many sources of information which can be distracting. Figure 3.3 shows the magician displaying a deck of cards to be fair, in that it is not pre-arranged in any order. To do so, the faces of the cards should be shown to the audience by spreading the deck. This action involves three main visual elements: the deck of cards and the magician's two hands. Figure 3.3a shows how the hands should be positioned so as to provide only one source of information. The *pointing* action of the fingers helps the audience focus their attention on deck of cards, instead of being distracted towards the magicians hands or some other visual center. Pointing is one of the most important tools of attention control. Figure 3.3b shows an example of multiple sources of information. In such cases the audience does not know where to look and invariably gets confused by the illusion.

In the information domain, there is no explicit magician who does pointing. Instead, pointing is achieved via various visual techniques such as transparency, color and so, and are more related to the technique of *contrast* in magic. Tabulated below are the fundamental techniques adopted in most illusions [Nelms 1969; Ortiz 1994].

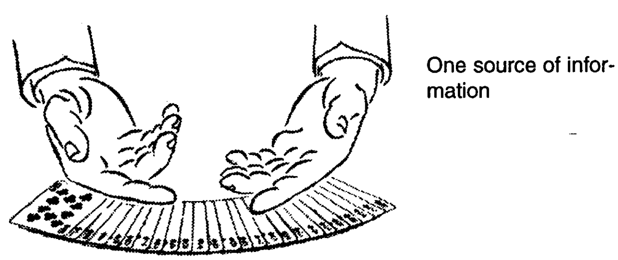


Figure 3.3a
The magician displaying three visual components, but only one source. This makes it easy for the audience to absorb the information.

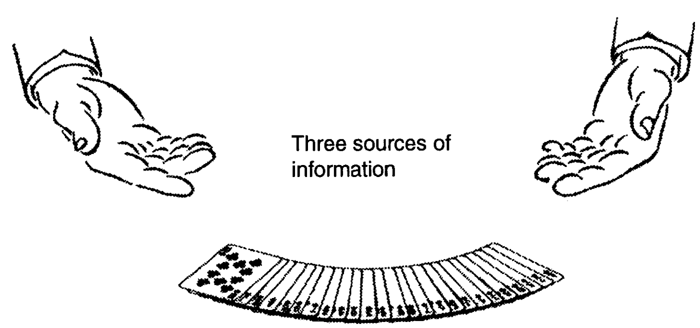


Figure 3.3b
The magician displaying three distince sources of information, making it hard for the audience to focus their atttention on any one visual component. From Magic and Showmanship—Henning Nelms.

Tools	**Description**	**Applicability**
1. Gaze	The audience looks at the point where the magician looks at.	No
2. Pointing	Well known and exploited technique in magic. Pointing usually happens with some body part of the magician.	No
3. Patter	This is very direct; the magician tells the audience where to look.	No
4. Movement	The magician moves an object to draw attention. This is again a very common technique.	Yes
5. Contrast	Something visually different (color, form, etc) from its sorroundings.	Yes
6. Newness	The audience tends to look at the last thing added to to the scene. Interest on an object declines with time.	Yes
7. Sound	Any sound made by the magician involuntarily attracts the audiences attention to the source of the sound.	No

Adaptation to Audience Feedback

In chapter 1, the difference between close-up and stage magic was described. The best example of the importance of adaptation was also exemplified by the classic force—a well known way of making a person select a card known to the magician. Close-up magic, as the name suggests, takes place at a very close range from the audience. The audience, usually limited to about hundred people, interact and provide feedback in various ways to the magician. The magician is very responsive to this feedback, and moulds the performance accordingly. This makes close-up magic highly dynamic and interactive. Stage magic on the other hand is for larger audiences and as such has considerably less interaction. In the model proposed for Dynamic Magical Environments, I use the complex dynamics of close-up magic.

In addition to adapting during a performance, magicians also adapt between performances based on the audiences reactions. This gives an organic nature to a magic performance, with successive acts improving previous ones. Although, this aspect of magical stagecraft takes place outside the stage per se, the concept points for the need to have information spaces that learn about users preferences over longer periods of time.

The notion of having adaptive interfaces is well known and hence, this thesis has not focused extensively on this principle. In addition, to have truly adaptive systems, with complex feedback loops it is necessary to have knowledge of the users intentions, say through advanced eye-tracking or gesture recognition. Hence, the application of this principle is limited to a simple scenario discussed in the next section.

Element of Surprise

Magic is delightful to watch because it is full of surprises, some of which violate users expectations [Fitzkee 1975]. The audience expects to be surprised, but they cannot account for the violation of their expectations, since every step performed by the magician followed a logical continuity. If a magician makes a suspicious move or fumbles while performing, the effect of the surprise is reduced, since the audience will attribute it the mishap on the part of the conjuror. Gradually unfolding surprises in mysterious ways provokes spectators curiosity, while creating a strong mental impact of the situation.

Surprise in magic can take many forms and is usually integrated into the climax of the effect. Typically the audience is made to believe that something is going to happen and the performer reveals something unexpected. Surprise in general tends to violated peoples expectations and hence will arouse their curiosity.

In the conclusion to this thesis, I analyze the effects of creating surprises within interfaces. The term "meaningful surprise" is used to imply that any surprises created in the information domain must not confuse the user in any way. Specific examples of meaningful surprises are given in the next chapter.

Timing and Pacing

Timing in magic refers to the time relationships between two different things [Ortiz 1993]. For example, proper timing is required for most slights, where the magician has to coordinate the actions of the two hands. Timing is also applicable for misdirection purposes. For example, the magician while showing an empty cup with the right hand can "steal" a lemon from his pocket with the left hand. The motion of the left hand must be timed such that it happens just *after* the right hand has displayed the cup. This draws attention away from the "stealing" action.

While timing involves the time relationships of two actions, *pacing* refers to the time relationship of a sequence of actions. This sequencing determines the subjective perception of time by the audience. A slow paced show tends to be boring and hence, the audience looses interest in the performance. For designing engaging interactive systems, the idea of pacing is important. In the example scenario described in the next chapter, pacing is applied to present information about activities in Boston. Each activity comprises of many graphic elements such as an image, a name label, textual description, and related information. The presentation of the different visual elements depends on the pacing relationship between them.

1.3 Modeling the Illusion Process

This section describes a model for presenting information based on the principles of magic discussed previously. The principles in isolation provide a microscopic view much like the design principles of typography, color, layout, etc. However, to realize a more holistic view of the illusion process, I developed the following model. The model shows the potential for applying the principles at different times during the illusion and the dynamic relationships between the constituent principles.

Typically, every illusion has a clear beginning, middle and end (Figure 4.4a). The middle region is composed of a series of sub-climaxes, for example s1 through s4, as shown in Figure 4.4b. In the course of creating the illusion, the magician traverses these sub-climaxes to achieve the desired effect (climax). Each sub-climax corresponds to a desired presentation state required to make the audience believe the final illusion. For example, in the diminishing card trick each reduction in card size corresponds to a sub-climax. Without the sub-climaxes, the spectators would not fully appreciate the resulting illusion, and hence, will not be entertained [Nelms 1967]. Figure 4.4c shows a detailed view of the adaptation process between sub-climaxes. The circles show substates the magician traverses to reach the sub-climax. Its very important for a magician to have a set of alternative paths to achieve the desired sub-climax for a variety of reasons, such as: if the audience gets bored, if the mechanics of the illusion fail, or if the spectators start to figure the magician out!

In addition to having alternative paths for adaptation, the magician sometimes goes back to a previous sub-state (Figure 3.4c). This is nec-

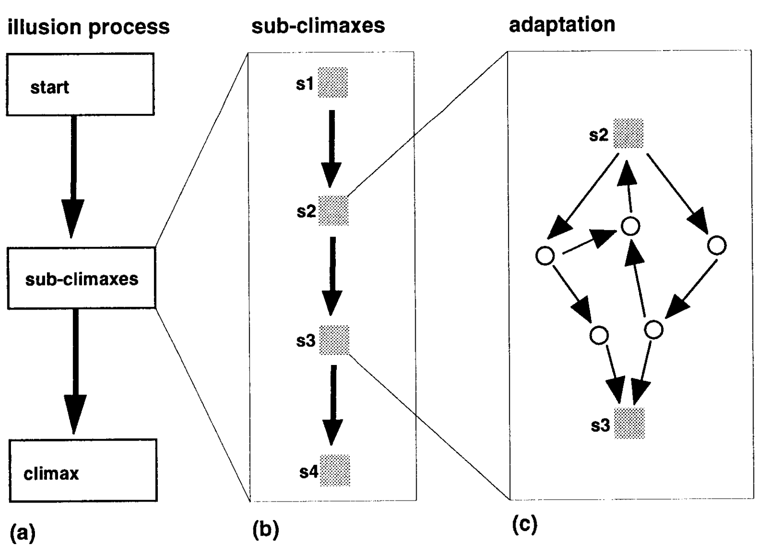


Figure 3.4
Close-up performance model showing the overall structure of an illusion. S1, s2, s3 and s4 are sub-climxes and varies from one illusion to another. The adaptation process is shown in figure (c).

essary to clarify a missed step in the illusion process. For example, if an audience member requests to see a previously shown empty cup, the magician will start over by showing the cup to be empty. This type of adaptation usually happens at the request of the spectators.

Although this model of an illusion process is somewhat simplified, it helps to explain the temporal relationships among the salient principles. For example, in most illusions the element of surprise occurs at the penultimate sub-climax, whereas creating a framing context happens at the beginning.

Clearly, no one model can serve as a basis for designing presentations across multiple domains. The model proposed is primarily for information exploration as opposed to information retrieval. The conclusion to this thesis discusses this in greater detail. The distinction lies in that the user has no specific goals when exploring information, unlike retrieving information. This is very similar to browsing.

This model is required to illustrate the process of applying the principles within the context of an illusion. For example, the framing contexts are typically developed at the beginning of an illusion, from start to reaching the first sub-climax, where as focusing attention is adopted throughout the illusion process. The element of surprise typically happens at the end—the climax, unless the illusion has many surprises. Figure 4.4c shows the adaptation process between sub-climaxes s2 and s3. As mentioned previously, the arrows point to sub-states that the magician can traverse to reach the sub-climax. The multiple paths gives the magician much flexibility to adapt to the situation at hand.

Application Scenarios

chapter 4

4.1 Information Domain

The impact that new information has on people is determined not only by the information itself but also how it is revealed and hot it interacts with existing knowledge and expectations.

—Brenda Laurel

The application of the principles and its associated model within the context of information presentation proved to be the most challenging part of the thesis. While, it was obvious how and why these principles worked in magic to make an illusion engaging to watch, it was initially not clear what the corresponding equivalents in the domain of information. The specific domain I selected was geographic information. This was especially challenging since, (1) the database was complex and so was the map display and, (2) most geographic information systems are designed along the high-information and low-entertainment axis.

Conceptually, the application is designed as a visualization tool for exploring Boston and vicinity. GeoSpace, is a dynamic map which allows the user to query and access information. The geographic map of GeoSpace transforms into the cognitive map of MediaMagic when the user zooms into a specific activity located on the map. MediaMagic is a conceptual space (as opposed to the geographic space) embodying spatial relationships based on the psychological distance between activities. This transformation itself exhibits a smooth continuous transition and represents a graphical surprise. Detailed below are scenarios from GeoSpace and MediaMagic, exemplifying the application of the principles of magic such as the graphical surprise example just mentioned.

4.2 Scenario on Focus of Attention

In the previous chapter I gave examples of controlling attention in the context of an illusion. Controlling audiences' attention in magic is a continuous process, occurring throughout the entire illusion. If an illusion is to work the audiences attention must be always drawn to the cen-

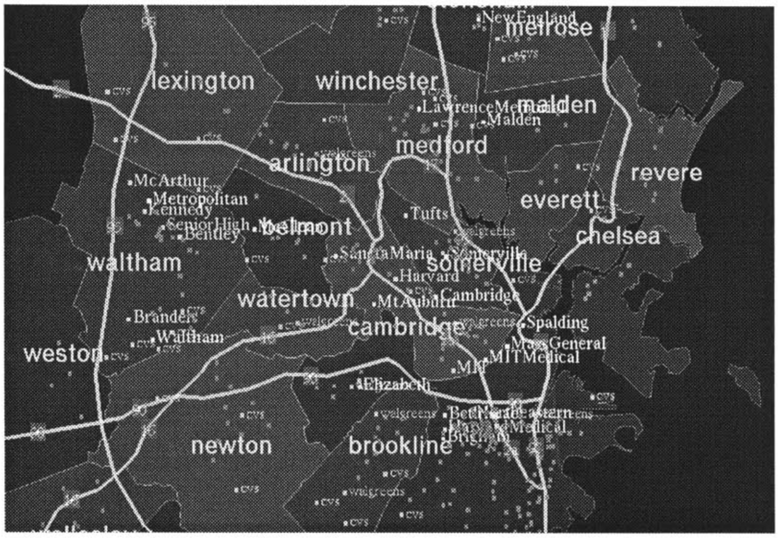


Figure 4.1a
Dense map display of the greater Bosotn area. This is the initial state of GeoSpace.

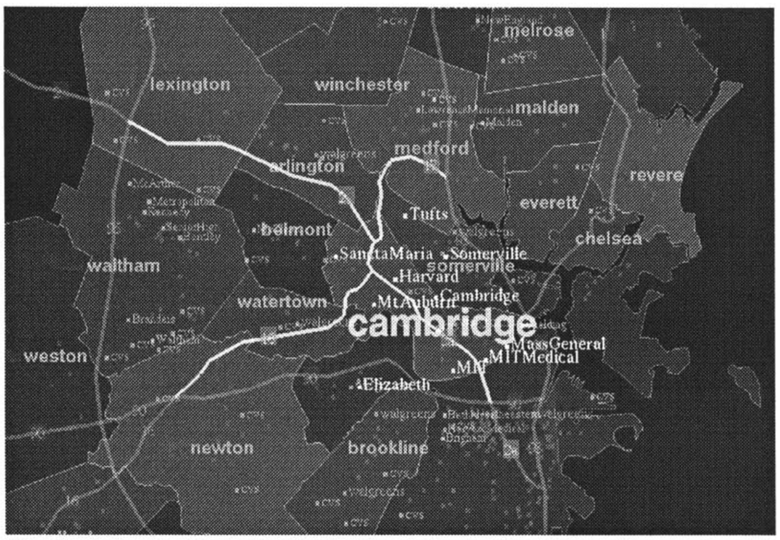


Figure 4.1b
Map display showing Cambridge and sorrounding area. The typographic size and transparency of the relevant visual elements changes.

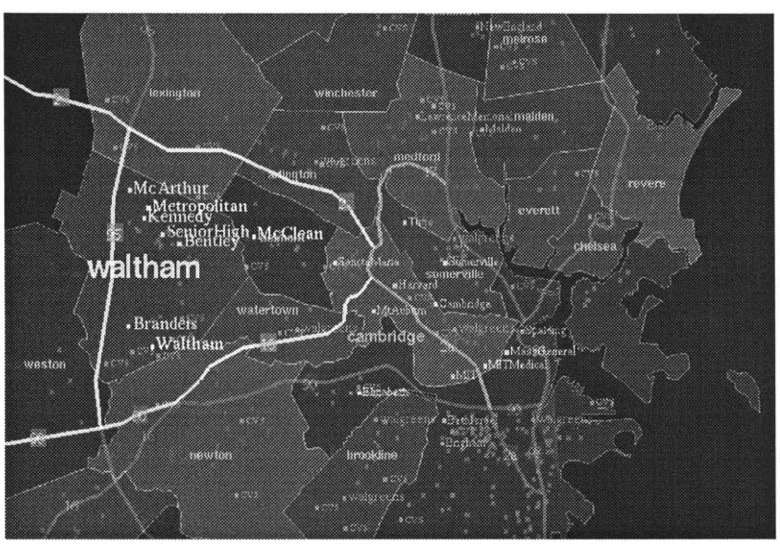


Figure 4.1c
Emphasizing a different area, Waltham. Cambridge gradually decays in prominence.

ter of interest. In an illusion the center of interest is clear, based on the magicians perspective. However, in the information domain the center of interest may vary from user to user and hence the designer must design the information space to accommodate this. The following scenario from GeoSpace exemplifies the use of contrast to control a users attention.

The user moves the mouse over the label Cambridge in GeoSpace. The map display responds by emphasizing Cambridge and the surrounding areas immediately. In this example, the typographic size and the opacity of the graphic elements change resulting in a sharper focus of Cambridge and the surrounding area (see Figure 5.1 b). When the user queries for Waltham, the emphasis shifts to help the user focus his attention on Waltham as shown in Figure 5.1c.

In order to further test this idea of guiding attention, GeoSpace II was designed. GeoSpace II works on large database, TIGER/Line, from the U.S. Census Bureau. Figure 4.2a and b, shows a few states of the map display in GeoSpace II.

In GeoSpace, the region of audiences attention was controlled explicitly, either by the user specifying a query or by motion of the mouse. In MediaMagic, the direction process is more implicit and perhaps, subtle. This is discussed in the scenario for the application of timing and pacing.

The previous example showed how *contrast* was used to control the region of attention in a dense display. The next example from MediaMagic shows the use of motion to switch attention away from one visual context to another. In Figure 4.3 the user has zoomed into the MediaMagic space and is within the Boston Common activity. Based on the user-profile the activity that follows, Children's Museum is more fun, and hence the system wants the user to switch attention away from Boston Common towards the Children's Museum. To do so, the Children's Museum cube very subtly starts moving in a circular manner (white circular arrow). This visual cue prompts the user to keep zooming towards the Children's Museum rather than spend more time at the Boston Common.

As mentioned previously, the direction process is one aspect of focusing the audiences attention. In this case the idea was to draw attention towards a point of interest. However, in the case of misdirection the objective is to draw attention away from one point towards another. The application of misdirection within interactive presentation systems is not clear. In magic for example, misdirection is used to cover a secret

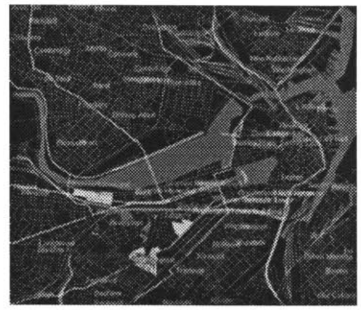


Figure 4.2a
GeoSpace II in its ititial state. The map is very dense including many strrets and highways of Boston and vicinity.

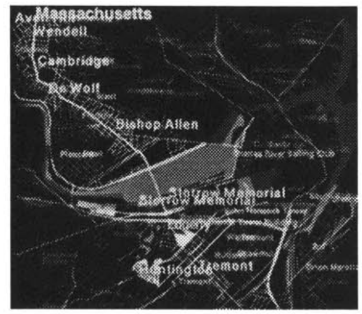


Figure 4.2a
The map display after the user requested to see Massachusetts Ave. All the block groups that mass ave. crossed are displayed with their associated information.

Figure 4.3
As the users enters the Boston Common activity the childrens cube starts oscillating as shown by the arrows.

maneuver. This motivation does not directly translate to the domain of information presentation since, it is possible to achieve any visual effect without the need for misdirecting the user's attention. Although this is true in most cases, there have been instances where misdirection can benefit when there are performance related problems. In such situations one may want to bridge time to create the illusion of continuous presentation. A good example of this is the rotating icon when opening a folder in the Macintosh System 7. The designers of this system were faced with performance problems during the early stages. Many users had complained that the system was too slow. Rather than re-engineer the existing product, they chose to misdirect the user's attention away from the task towards the animated triangle. The results were clear; complaints of performance problems ceased although in reality the task took the same amount of time.

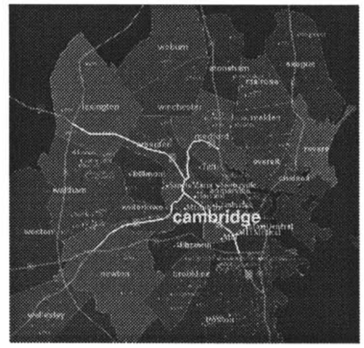


Figure 4.4a
Map display showing crime information after displaying Cambirdge.

4.3 Scenario on Framing Contexts

In magic, framing contexts help the magician to heighten the effect of an illusion. The previous section identified examples of framing in the context of the diminishing cards illusion. This principle occurs always at the initial stage of an illusion; for example, showing a glass box to empty prior to producing a beautiful lady from it, or shuffling a deck of cards before asking a person to take a card and so on. Framing contexts are closely related to the element of surprise, since the better the framing contexts the stronger will be the surprise. As a simple illustration of this relationship consider the production of a woman from two empty boxes. One box is made of glass and the other from black wood. The effect is stronger with the glass box than the black box since, the audience is made to believe that the box is empty. In order to achieve the same effect with the black box the magician would have to take the box apart piece by piece or tilt the box, rotate it and even get a volunteer to vouch for its integrity. The element of surprise is important to keep the audience engaged in the course of the performance and hence, the significance of developing framing contexts.

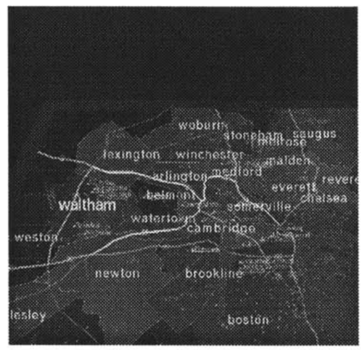


Figure 4.4b
Rotating the plane of the map gradually displays crime information as vertical bars.

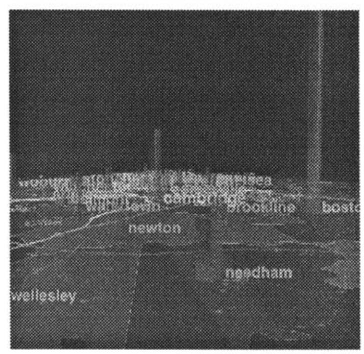


Figure 4.4c
Three dimensional view of crime information.

I was interested in applying the principal of framing to enable the user better explore the information space. Since, framing *leads* a person along a desired path, I set out to explore if I could design the presentation so that the user may seek certain kinds of information over others. Consider the following scenario. The user is new to Cambridge and is looking for an apartment in the vicinity to live in. Now, suppose the user interacts with GeoSpace and requests to see Cambridge with the hope of choosing a location to live in. The system in response can display specific information about Cambridge, highlighting apartments and so on. However, my goal was to see if I could make the user aware about the high crime rates in Cambridge, and consequently to make the user explore areas of low crime. To do this, I framed the user's mind by subtly revealing clusters of crime information on the two dimensional map (Figure 4.4a), when the user requested to see Cambridge. This creates an awareness that crime rates may play an important role in deciding on a location to live in. Having being exposed to the crime factor in Cambridge, if the user wanted to explore crime data further, he can do so by rotating the plane (Figure 4.4b and c). The appearance of the crime statistics as three dimensional bars is quite unexpected, and constitutes what I term a "meaningful surprise". This is discussed in the next section, with more examples of designing surprises in the information domain.

In the above example, framing was achieved by *visually* stimulating the user. A less subtle technique I explored for framing a persons mind was based on camera motion. In MediaMagic, I varied the rates of zooming through the cubes based on how closely an activity matched the users interest profile. This makes the user spend less time on uninteresting activities and more time on interesting ones. For example, activities like Trinity Church and Harvard are of low interest based on a child's interest profile and hence, the system moves the user very quickly through these activities. On the otherhand activities like the Boston Commons and the Children's Museum are prime activities and hence the system moves the user very slowly through these. This gives the user more time to explore these activities.

Since, this kind of framing can influence the users actions quite dramatically, it must be based on definite preferences indicated by the user. Alternatively, the user should be able to override the framing actions of the system if they interfere with the users interaction desires.

4.4 Scenario on Element of Surprise

Few systems deliberately attempt to violate users' expectations. In most cases when a system behaves differently than expected, it is due to a "bug" in the program. Surprises of this kind tend to frustrate and confuse users. In magic, however, peoples expectations are violated without confusion. They may not know how the illusion was done, but the gradual unfolding of surprises makes sense to the audience; hence the term "meaningful surprises".

To apply the principle of surprise, I explored the different kinds of surprises that happen in magic. The two main categories which are applicable for the domain of information are as follows: (1) Surprises that violates users prior knowledge about how a system works and (2) Surprises that violate user's expectations *during* the interaction. The former relies on identifying and applying interaction behavior uncommon to existing applications. The latter depends on establishing an anticipated system behavior prior to surprising the user. Examples of both types of surprises are detailed below.

Example: Two to three dimensional crime information

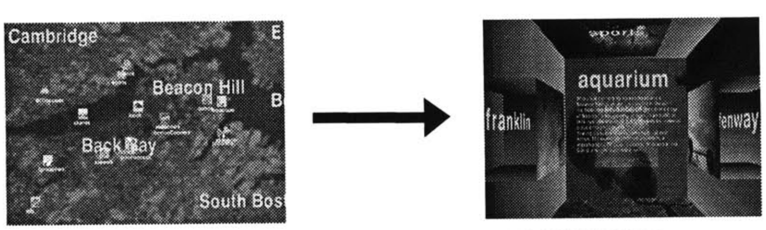
The two dimensional display shows clusters of crime information (Figure 4.4a). However, by rotating the plane the user sees the gradual appearance of vertical bars (Figure 4.4c) showing a statistical comparison of relative crime levels for different counties. The design of this transition inevitably tends to surprise most users, since they do not expect this to happen.

This transition from two to three dimensions is a good example where the users expectations are violated, without confusing the user. As the three dimensional bars appear the user may wonder what is happening, but will soon reconcile the space based on what he saw before—the two dimensional clusters of crime information. Thus, when attempting to create surprises it is important to have a logical continuity from one visual state to another. In this example, the visual states correspond to the two and three dimensional crime displays.

In the current implementation the user has to explicitly rotate the plane of the map to see the three dimensional representation. However, the surprise would be more effective, if the system automatically performed the camera motion in response to the user's request to see crime information.

Example: Transition from geographic to conceptual space

In the following interaction, surprise is based on peoples notion of how dynamic maps work in an electronic environment. Typically, in most geographic information systems the user can access and manipulate information by querying a database, clicking on regions of the map or some other form of interaction. Contrary to the above mentioned techniques of interaction, I attempted to create an interaction behavior that was meaningful, but yet unexpected. The example involves the transi-



geographic space

conceptual space

Fiugre 4.5
Transition from two dimensional geographic space to three dimensional conceptual space.

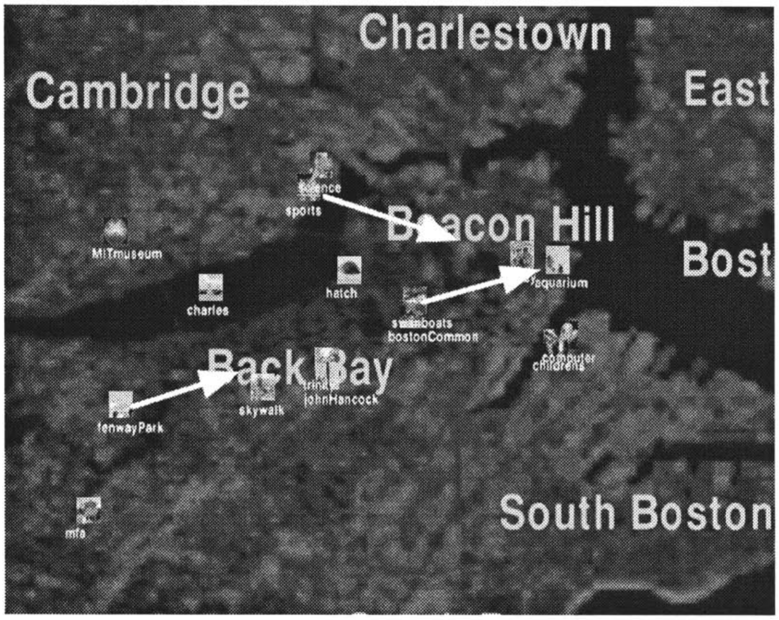


Figure 4.6
As the user zooms into the Aquarium activity, the realted activities start migrating towards aquarium The white arrows show the direction of motion. The geographic map starts fading out.

tion from the two dimensional geographic space to a three dimensional conceptual space (Figure 4.5).

Suppose the user wants to explore the Boston Aquarium activity in greater depth and presses the left mouse button to zoom into the image representing the Aquarium activity. As the user keeps zooming in, the activities that are related to the aquarium migrate towards the image of the aquarium (Figure 4.6). Simultaneously, the geographic space fades away and is replaced by the conceptual space of cubes. Each cube is an activity corresponding to the images on the geographic map. This transition is very visual and unexpected by a first time user.

The logical continuity in this transition is not as obvious as the previous example. The transition is designed so that the activities that migrate towards the Aquarium are same activities that the user sees when within the Aquarium cube. Hence, the user can account for the images animated during the first part of the transition.

Example: Cubes that behave differently
Both the above examples relied on users prior knowledge to create meaningful surprises. However, it is also possible to surprise users by making them first expect a certain behavior and doing something else instead. The particular behavior I examined was to create expectation in the way the related activities displayed themselves. Typically, as the user moves through the cubes, the related activities are displayed as shown in Figure 4.7a. If the user spends more time in a cube, the related activities will rotate to display their face with the image and return

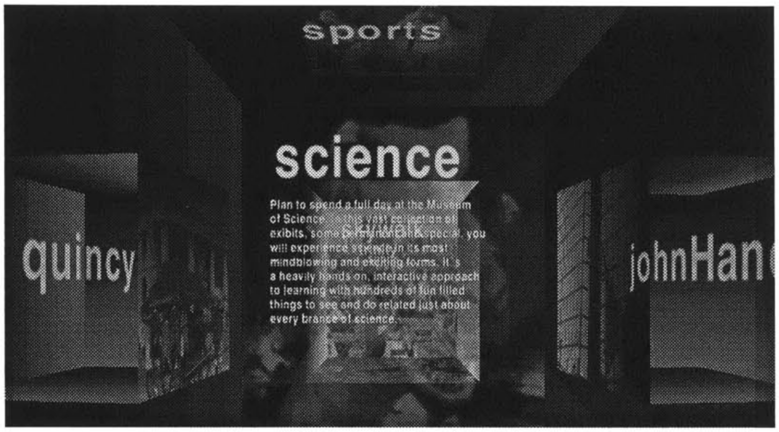


Figure 4.7a
The system briefly displaying the activities related to the Science Museum activity, before attempting to surprise the user.

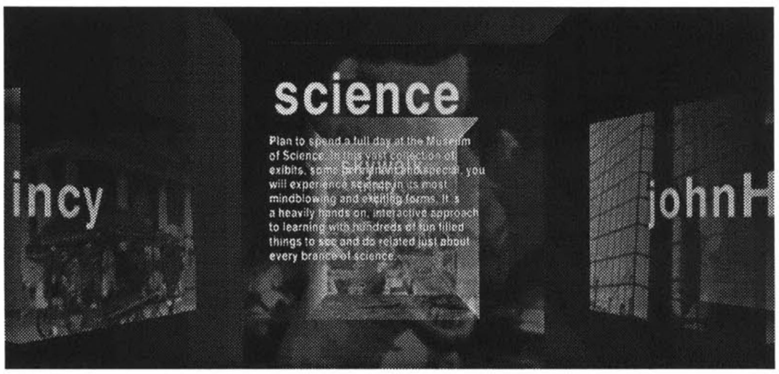


Figure 4.7b
The related cubes start rotating away from the activity of interest. The activity at the top is not shown in this figure and Figure 4.7c.

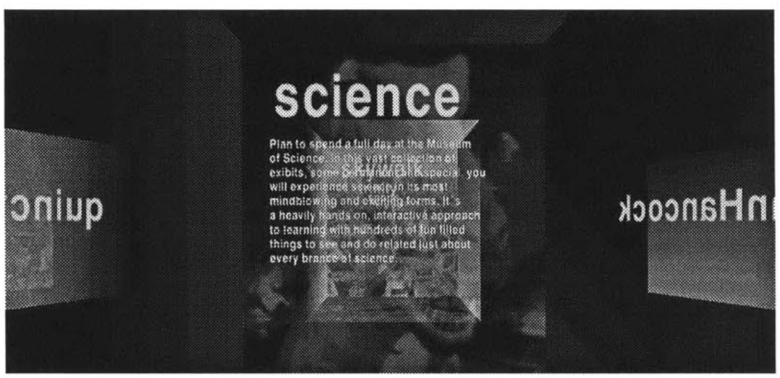


Figure 4.7c
The related activity cubes keep rotating while detailed information about the Science Museum starts fading in.

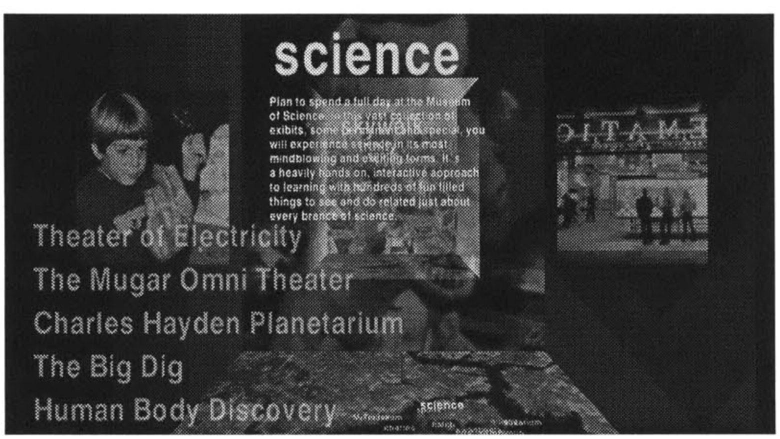


Figure 4.7d
The detailed information such as the top five events at the Science Museum are finally revealed behind the rotating cubes.

to the original position. After the user moves through a few cubes, he will naturally learn to expect this behavior. Clearly, a violation of this expectation will surprise the user.

Based on the user's interest profile the Science Museum has a high preference and hence, an ideal candidate for keeping the user engaged. The surprise happens when the user enters the Science Museum activity. After the related activities rotate to display their face, they do not return to the original location. Instead, they keep on rotating until the backs of the cubes are displayed (Figure 4.7c). At this stage the system has behaved differently from what the user was expecting. As the rotation continues, the system gradually presents additional information, such as the top five events in the museum (Figure 4.7d). The justification for presenting this additional information was based on the high priority of this activity over the others.

Surprises of the latter type are particularly powerful at keeping people engaged, since they build expectation on the fly. In the former examples, the designer makes certain assumptions about what a general user knows and attempts to do something different. While this may work the first few times, the effect of the surprise will be reduced in subsequent interactions. However, in the latter example, there is greater potential to vary the behaviors of the cubes giving the system an organic structure with evolving properties.

4.5 Scenario on Timing and Pacing

The previous chapter stressed the importance of timing the sequence of acts in an illusion. Proper timing was essential for successful execution of certain sleights. However, the concept of pacing was discussed to be even more important since, pacing controls how an audience perceives time. I use pacing to control the level of detail of the information presented and to guide attention. For example if the user enters the MediaMagic space and continues to zoom through the space, the system presents a very course level of detail: the activity names and the associated image (Figure 4.9a). While browsing, if the user discovers an activity of interest and pauses on that activity, the system will fade the image out and fade-in text associated with the image to be displayed (Figure 4.9b). If the user chooses to spend even more time in the activity, the system will display the related activities (Figure 4.9c) and eventually present additional information as discussed in the previous section on the element of surprise.

Image of Activity
↓
Description
↓
Related Information
↓
More Information

Figure 4.8
The pacing sequence of a typical presentation when the user enters an activity of interest.

The pacing sequence can be interrupted by the user at any time during the presentation. This is shown in Figure 4.9d,e and f, where the user is

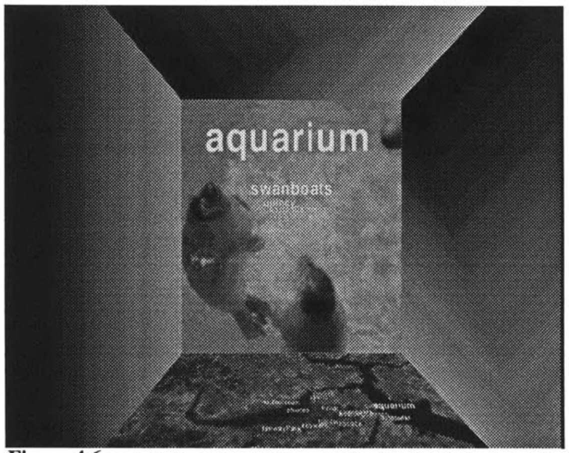


Figure 4.6a
The user has just entered the aquarium cube. The image of the aquarium is still visible.

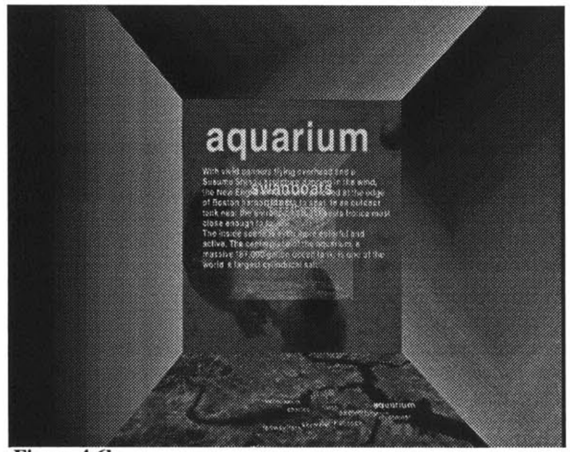


Figure 4.6b
The image gradually fades away and a textual description of the aquarium appears.

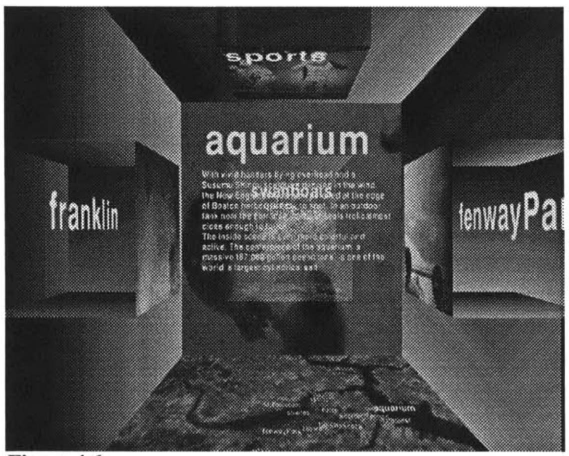


Figure 4.6c
The activities related to the aquarium becomes visible. In this case Franklin Zoo, sports museum and fenway park.

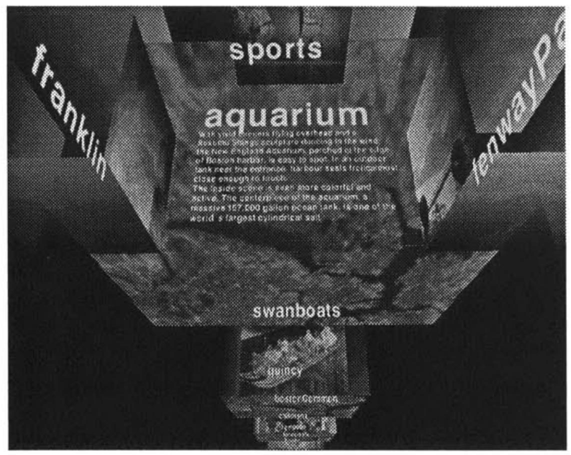


Figure 4.6d
The user can get different views by moving the mouse. This view provides the user an overview of what activities are to come.

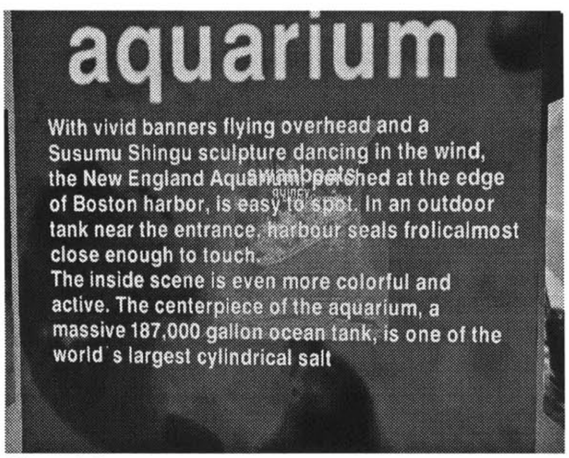


Figure 4.6e
The user has zoomed into the aquarium space and is almost at the end of boundary of the cube.

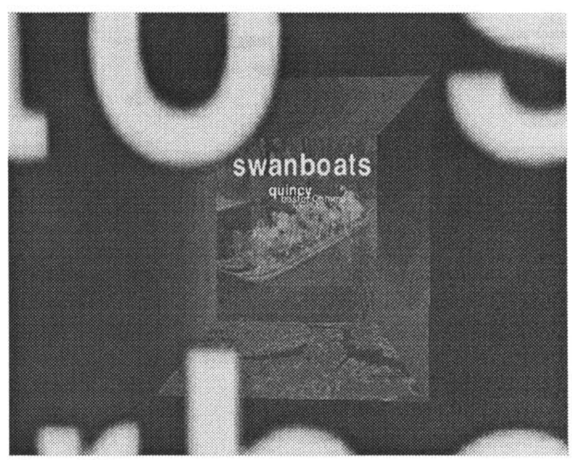


Figure 4.6f
The next activity becomes visible, as the user leaves the aquarium cube.

rotating the camera to get a different view (Figure 4.9d) and eventually zooms past the Aquarium activity to the next activity—Swan Boats.

4.6 Scenario on Smooth Continuous Transitions

Typically, continuos transitions were designed between two or more *visual contexts*. A visual context corresponds to the state of the display at any give time. Hence, a visual context can occur at any state of the application such as during framing, directing attention, creating surprises, pacing and so on. Both GeoSpace and MediaMagic exemplify many situations of continuos transitions.

In GeoSpace for example, the transitions between two visual contexts, such as from Cambridge to Waltham, occur very smoothly. This is achieved by combining visual techniques such as transparency and typography with activation spreading techniques. Chapter 5 on design techniques will describe in detail the mechanism in which these smooth transitions are achieved. In MediaMagic, smooth continuous transitions occur when the image for the activity gradually fades away, to be replaced by a description of the activity (see Figure 4.9a and Figure 4.9b). The more salient examples are tabulated below with a categorization of the particular visual context the system is in.

Example	**Category**	**System**
1. As the user moves from Cambridge to Waltham the system changes the transparency values and the type size	attention	GeoSpace
2. Two to three dimensional crime information by rotaing the plane of the map	surprise	GeoSpace
3. Fading image replace by textual description	pacing	MediaMagic
4. Displaying related activities	pacing	MediaMagic
5. Displaying additional information while related activities rotate away	surprise	MediaMagic

4.6 Scenario on Adaptation

This principle was the least explored in my thesis, primarily due to lack of sophisticated technology for identifying users feedback. Magicians have a complex apparatus for receiving and processing information. Hence, they can be very responsive to audiences' reactions. For example, if the magician senses that some spectators are bored he can divert his attention in their direction. In general a magician can change the course of a performance based on the kind of feedback received *during* the presentation.

Similar to a magician, the ideal goal is to build a highly adaptable system which takes users feedback dynamically and responds to these actions. A highly reactive system will keep user's engaged as mentioned previously in Chapter 1. Two specific examples of adaptation are presented below. Both make reasonable assumptions about the users interactions and responds accordingly.

Example: Level of detail
In this example, adaptation is based on the amount of time the user decides to spend in the MediaMagic space. Figure 4.10 shows the adaptation that occurs when the user moves through the corridor in MediaMagic. The amount of time the user spends in a cube determines the level of detail presented by the system. For example, if the user is browsing through the space very quickly, the user sees an overview of the information space comprising of images and the activity name. However, if the user pauses in an activity of interest, the system starts to present a textual description of the activity and eventually related information. Even a simple adaptation scheme such as this gives the

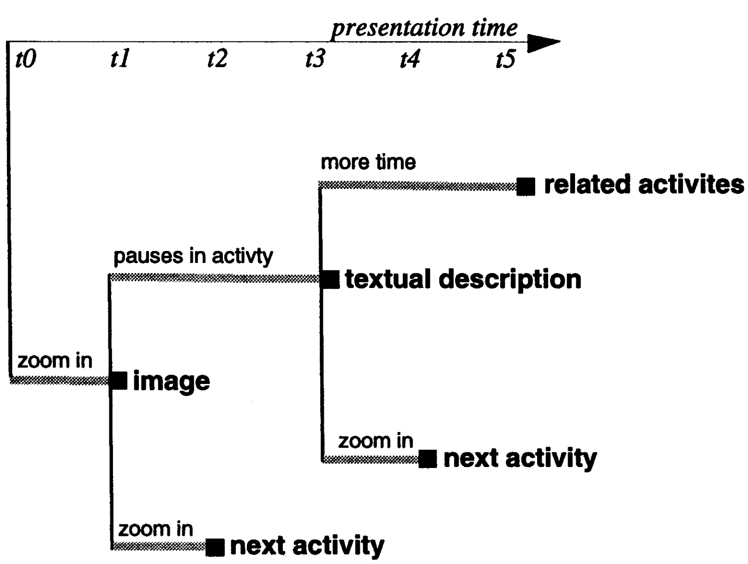


Figure 4.10
An example adaptation process in MediaMagic. The gray lines indicate the different paths the system can take based on the users imput. The black squares denote the actual state the system is in during the presentation.

system a more dynamic quality. This dynamic behavior makes the system more responsive to user interaction.

In the next example, the adaptation process occurs over a longer period of time. The user while interacting with GeoSpace requests to see hospitals in the area. Subsequently the user requests to see pharmacies. If the user request this sequence of queries over a period of time the system should identify it as a pattern and modify its behavior. The result being, the user requests for hospitals and the system displays both hospitals and pharmacies. Currently, GeoSpace has a framework for learning user-preferences such as the hospital/pharmacy example. However, the user must explicitly indicate to the system when to adapt. Future systems should observe users behaviors and perform the adaptation in a more dynamic and implicit manner.

Design of Prototype Systems

chapter 5

5.1 System Architecture

We see with our mind as much as with our eyes, since experience, memory and belief add expectation to the picture presented to our physical vision. In consequence, it would sometimes be true to say that believing is seeing.

S. H. Sharpe
Conjurere's Psychological Secrets

Many different techniques have been used in achieving the behavior in GeoSpace and MediaMagic. As mentioned in the introduction, the emphasis of this thesis is not so much on these techniques but rather, the design methods based on the principles of magic. However, the techniques are useful to exemplify the means to achieving the effects described. These techniques are some of many potential ways of implementing the desired design. Figure 5.1 shows the underlying system architecture. The blocks correspond to functional modules implemented for each stage of the prototype system.

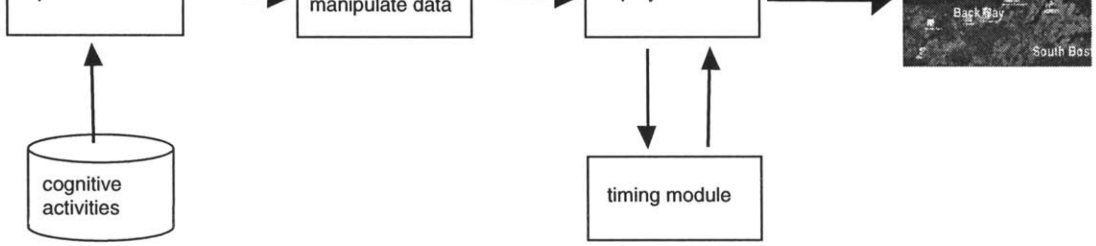


Figure 5.1
Block diagram showing the underlying system architecture. The data is first parsed from the cartographic database and stored as manipluatable structures. Display methods combined with timing relationships create the final visualization.

5.2 Domain Knowledge

The framing contexts described in the example scenarios are represented in the form of domain knowledge. The first step in the application was to build the domain knowledge from the TIGER/Line cartographic database. The data is in the form of thirteen flat files, each specifying a different record type. This data was parsed and represented in the form of presentation plans, which comprise the core domain knowledge. In essence, a plan consists of a list of sub-plans, a list of conflicting plans and a list of effects. The effect list specifies the goals which will be achieved when the user queries or interacts with the system.

Typical presentation plans are shown in Figure 5.2. The first plan represents a schema for displaying transportation information in the map. Basically, it says that in order to display transportation information, the system must also display place names, bus routes and subways. The plans also indicates that hospitals and bookstore are not relevant when displaying transportation. The second plan shows the representation for the previously discussed example of framing a user who is new to Cambridge. Since, the user is interested in crime information and colleges, the the sub-plan list will contain this information.

Plan:	**{Show_Transportation}**
Sub Plans:	**{Know_Place_Names, Know_Bus_Routes, Know_Subways}**
Conflicts:	**{Know_Hospitals, Know_Bookstores}**
Effects:	**{Know_Transportation}**
Activation:	**0.5**
Plan:	**{Show_Cambridge}**
Sub Plans:	**{Know_Colleges, Know_Crime_Data}**
Conflicts:	**{Know_Hospitals}**
Effects:	**{Know_Cambridge**
Activation:	**0.3**
Plan:	**{Aquarium}**
Sub Plans:	**{Related Activities}**
Conflicts:	**Null**
Effects:	**{Display Aquarium}**
Activation:	**0.7**

Figure 5.2
Typical presentaions plans. The sub-plans list corresponds to the graphical effect achieved when the plan becomes active.

In the first version of GeoSpace the plans were constructed manually by the designer. In a subsequent version (implemented by Jon Levene) the plans were automatically constructed based on data provided by the census bureau.

The third plan shown above is from MediaMagic. In this case the plans specify which activities to display when the user enters Aquarium activity. The plans in MediaMagic were constructed based on a psychological experiment using non-metric scaling techniques. The basic idea of these plans is that activities which are considered conceptually related are clustered together, as opposed to the geographic proximity of the activities.

5.3 Activation Spreading Network (ASN)

The activation spreading network (ASN) combined with the presentation plan modules constitutes the heart of the attention guiding techniques. The activation network models the focus of attention and continuity principles from magic. The functions of the ASN are as follows:

(1) To allow users to focus their attention to relevant information quickly. For example, as the user moves over a certain region of the map the map highlights that area.

(2) To enable smooth transitions from one visual state of the display to another. Consider the example when the user requests to Cambridge and then shifts his emphasis to Waltham. The transition from Cambridge to Waltham happens smoothly as a result of the activation spreading network.

(3) To suggest alternative options by activating different regions of the display. This will motivate a user to explore information which s/he may have not done otherwise. It will also help users formulate information seeking goals for future interaction

Figure 5.3 shows a schematic diagram of an activation spreading process. The activation network segment corresponds to the plan for displaying Cambridge. The network is comprised of all the plans in the domain knowledge. Each plan has an activation value which is changed based on the users interaction with the system. For example, when the user requests to see Cambridge, the system injects a certain amount of energy to the plan module associated with Cambridge. When the activation level exceeds a certain threshold, positive and negative energy is sent to other plan modules connected by hierarchical links and conflicting links respectively. The system iteratively injects a constant amount of energy to fluidly change the overall activation state. In every iteration the activation levels are normalized to the most active plan. This causes the irrelevant information plans to decay, and thus the user can focus on the requested plan.

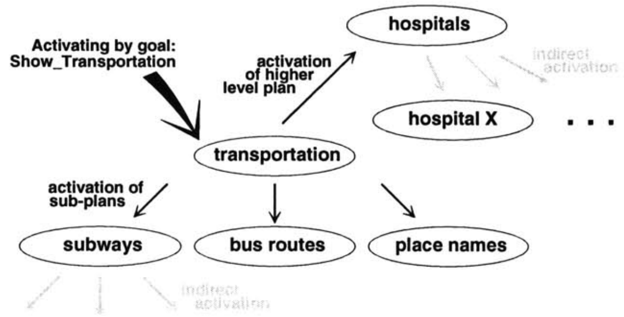


Figure 5.3
Schematic diagram of typical acitvation spreading process. This network segment corresponds to the plan Show_Cambridge.
[Lokuge and Ishizaki, 1995].

For example, when the user specifies a query such as "Show me transportation", know_transportation becomes the current information seeking goal. The system then injects activation energy to the plans that contain know_transportation in the effect-list. When a plan module's activation level reaches a certain threshold, it spreads energy to the plans in the sub-plan list. A plan also spreads activation energy upwards to the higher level plans that contains know_transportation in their sub-plan list. This upwards activation results in activating indirectly related information.

An activation spreading network not only presents the immediately relevant information, but it can also preserve the user's previous states of exploration. When a user requests new information, the system seamlessly transforms the previous state into the new state. The network can also prepare for the user's future request by activating plan modules that are potentially relevant in the following interactions. This could greatly assist users to formulate subsequent queries towards satisfying a particular goal.

The biggest challenge in using activation spreading networks is to design the network so that the transitions are smooth. For example, the activation values should not decay too fast. In such a case even after a few queries the first plan would have decayed. To experiment with the system two variables were identified which control the following: (1) the amount of energy injected to the plan (2) the amount of energy spread during the activation spreading process. These values were adjusted visually for each application, until the desired effect was realized.

5.4 Experimental Methods

In order to structure the information space of the Boston activities in MediaMagic, the following experimental methods were adopted: Multidimensional Scaling (MDS) and Trajectory Mapping (TM). These methods take similarity ratings as a distance measure and output a geometric depiction of the "mental space" that reflects the similarities between the input events.

MediaMagic uses these outputs and hence is a conceptual space where the various activities for Boston are spatially located according to their psychological proximity to each other. The premise for doing so was based on mental model research which points to peoples personal preferences for exploring the information space as an alternative to the highly structured geographic map. For example, children will be more likely to see Aquarium, Science Museum or Magic Show, rather than Trinity Church or Harvard which may be of greater interest to adults.

An example of an MDS space for our fifteen Boston activities is shown in Figure 5.4 (based on the average of the pairwise similarity ratings of the three authors). Not unexpectedly, activities like the Aquarium, Zoo and Fenway Park (baseball) appear near each other, and distant from shopping areas like Newbury Street or Quincy Market.

Missing from this MDS plot, however, is a notion of how one might move through this space of activities in some meaningful way. For this we need to identify paths in the MDS space. Recently a new scaling paradigm has been invented called Trajectory Mapping (TM) that enables us to recover this information [Richards & Koenderink, 1993; Gilbert & Richards, 1994]. The result is the pretzel-shaped path shown in Figure 2b.

Like most MDS methods, the TM experimental technique begins with two samples. However, instead of judging their similarity as in MDS, now the task is to imagine a conceptual feature or property that links the two samples. Then one extrapolates in both directions to pick two more samples from the set. So, for example, let the initial two samples be Quincy Market (shopping and historic) and Swan Boats in the Public Garden (play and history). The extrapolations from Swan Boats to Quincy Market might be Newbury Street (elegant shopping), whereas in the opposite direction the choice might be the Aquarium. Details of the method appear elsewhere [Richards & Koenderink, 1993]. The method has the further advantage of also allowing the experimenter to recover an MDS space from these judgements. If the cognitive space

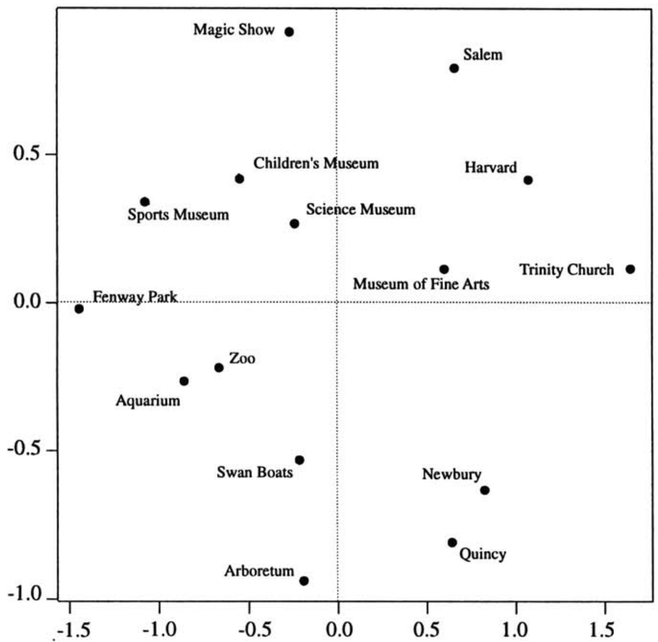


Figure 5.4
MDS space for the activities based on the average of the three subjects' pair-wise similarity judgements.

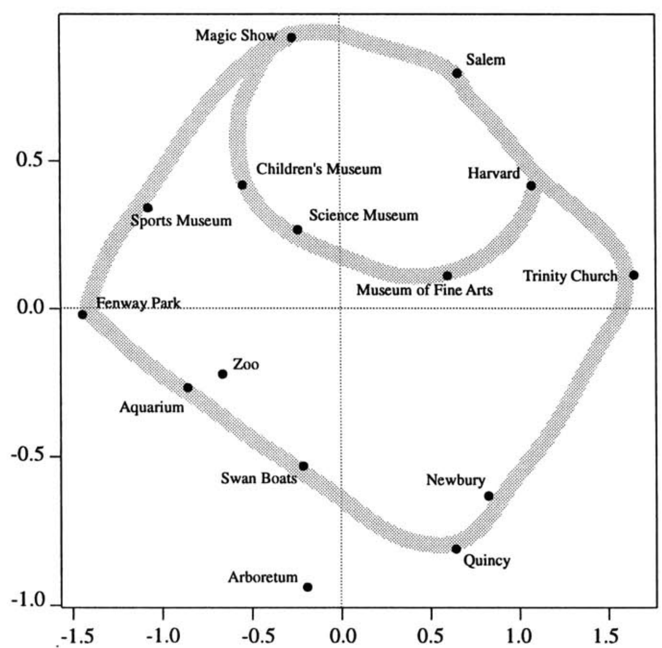


Figure 5.5
TM paths from two subjects superimposed on the MDS space.

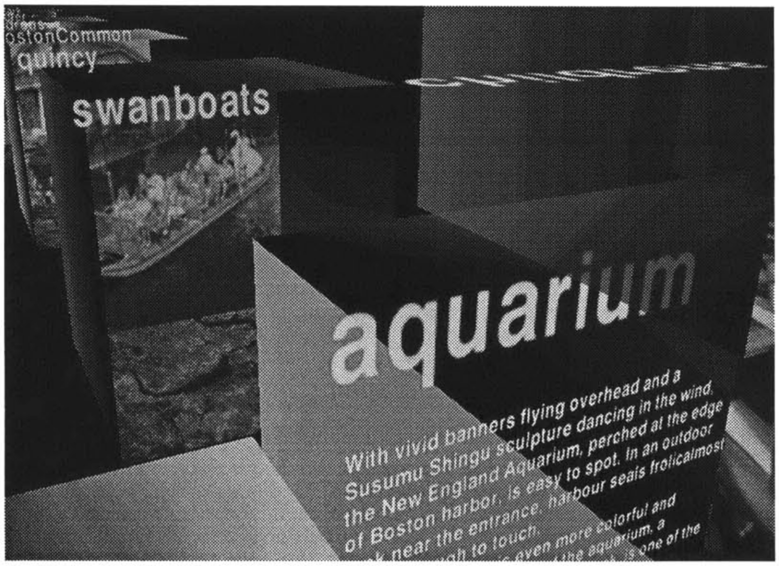


Figure 5.6
The underlying structure of MediaMagic is based on the MDS results. The three psychologically closest activities to aquarium are, Franllin Zoo, Sports Museum and Fenway Park.

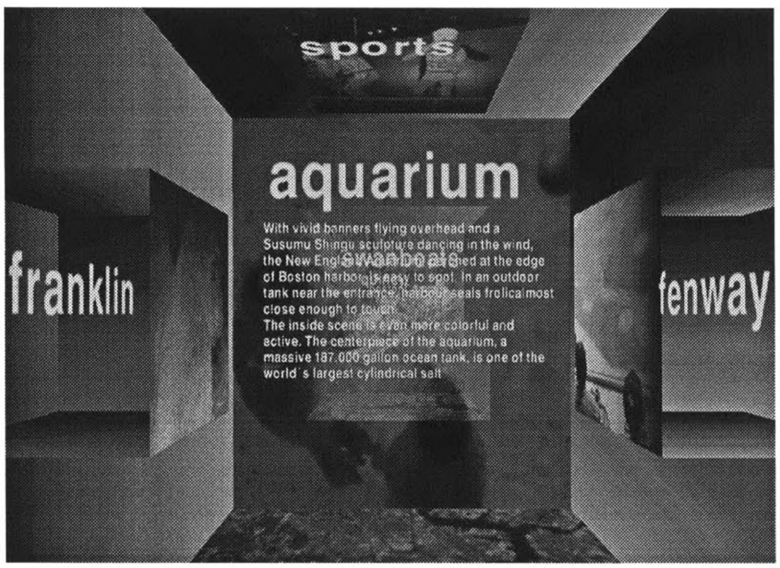


Figure 5.7
A view of MediaMagic depicting the path starting at the aquarium, movimg through Boston

uses a consistent set of features throughout, i.e. homogenous, then we expect the classical MDS method and TM to yield similar spaces. This indeed was the result here. For clarity however, Figure 5.5 uses the Shepard MDS space for both. The path shown, however, is recoverable only from the TM method.

The MDS space and the TM paths were used as a basis for structuring the information space in MediaMagic. The paths are used by the system to lead the user through the information space. Figure 5.6 shows how traversing the path will appear to the user. The path sequence starts at the Aquarium moves to Swan Boats and then to Quincy. In MediaMagic the information space is designed so that given an activity, the three closest activities (based on the MDS data) surround this activity. For example, Figure 5.7 shows the user interacting with Aquarium. The systems displays the related activities to be Fenway Park, Sports Museum and Franklin Zoo.

5.5 Visual Design

The prototype systems presented in my thesis use several visual techniques that have already been developed at the VLW [Cooper 1994; Small 1994; Colby 1990]. In particular, I have explored the use of transparency, three dimensional graphics, and typography within GeoSpace and MediaMagic. For purposes of clarity, I will first describe the applicable techniques in GeoSpace and then proceed to describe the design of MediaMagic.

Design Techniques in GeoSpace

The map display in GeoSpace has many layers of information each corresponding to a different data set. Typical layers include, highways, roads, railroads, landmarks, hydrography and so on. In total there are eighteen layers of information. In order to guide a user's attention the system visually discerns the relevant information from the rest of the data. This is achieved by changing the transparency value of the graphic object. Typical graphic objects are highway segments, landmarks, name labels and so on. If the graphic object is a typographic object, such as the name Cambridge, the type size is changed in addition to changing its transparency value.

The visual design techniques are based on the activation level values discussed previously. Higher the activation value, the more important the information is considered to be and hence, has a higher opacity. Information that is not relevant is displayed almost transparent. The activation levels are in essence mapped to transparency values and/or typographic sizes on the map display. This technique models the contrast technique for guiding a persons attention. In addition, transparency and typography provide visual cues for framing a user to explore a particular path. This is achieved by increasing the opacity of the path the system would want the user to explore. For example, when the user requested to see Cambridge, the system will display Cambridge while visually discerning crime information and colleges. This scenario was discussed in depth in Chapter 4.

The use of three dimensional graphics is restricted to the display of statistical graphs of crime information as shown in the figure. Here again, transparency is used to make the bars gradually appear as the plane of the map is rotated. The angle of rotation is mapped to the opacity of the bars to achieve the desired effect. The use of three dimensional graphics was explored further within MediaMagic, which is described below.

Design Techniques in MediaMagic

The spatial layout of MediaMagic was already discussed in the previous section. In this section, I will focus on the design of each activity, which is represented as a cube of information. The cube was an interesting and deliberate choice, given the many possibilities. The primary reason for using a cubic structure was to give the user a feeling of being outside and inside the sub-spaces (activities) at various points in time. To do this, an enclosed object was required. In addition, the original image was rectangular in form, and since the design involved the transformation of the image to form the space, a cubic shape suited well with the back face of the cube holding the image. Further, the remaining sides were used to represent windows to the related activities as shown in the Figure 5.8 below.

The design of the cubes and their spatial location enable various behaviors of the cubes. The behaviors are represented as actions and are discussed in greater detail in the next section. For example, one action is the rotation of a related activity (see Figure 5.8) to reveal hidden information about the activity of interest. These actions are triggered based on timing relationships. The longer the user spends in a cube, the more things happen. In addition to time triggered actions, the user can move around the space by camera movement as shown by the arrows in the figure below.

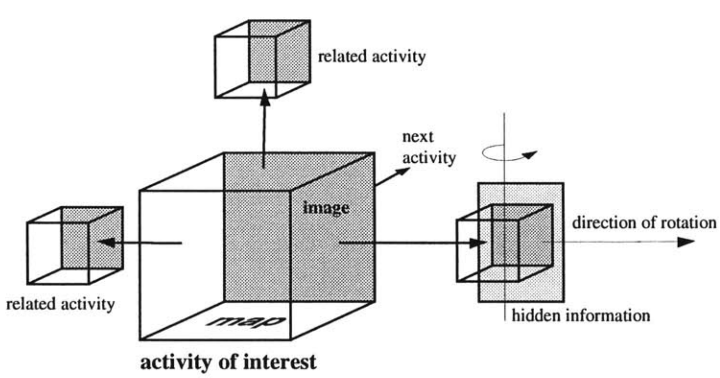


Figure 5.8
The visual design of each cube provides a window to enter each of the other related activities.

5.6 Situated Actions

This section describes a simplified approach for pacing a sequence of actions. Actions in this context are a set of behaviors attached to the cubes and its constituent parts. The function of each action is to create a framing context, guide attention and violate a user's expectation. Typical scenarios were discussed in a previous chapter; here I describe the complete range of possible actions, and the mechanism for triggering them.

The term situated action is similar to Suchmans idea of plans being represented as situated actions [Suchman 87]. The basic idea is that the actions of the system are not intended to satisfy a global plan; instead they are reactive behaviors in responsive to a given circumstance—hence the term *situated action*. This approach fits the close-up model of magic discussed previously. In MediaMagic, actions correspond to explicit behavior of the cube in response to particular *user interaction.*

The behavior of the cubes are based on simple timing relationships which regulate the presentation sequence. The section on application scenarios discussed in detail the overall effect of the actions and the use of them for modeling the principles in magic. Hence, I will not delve deeply into the behavior of a particular action; however, described below is the complete range of actions and their their triggering mechanisms:

- **Image Action**—as the user enters the cube the image representing the activity gradually fades away. The image although very translucent is still perceptually discernible. This make it possible to have typography overlayed on the image without disrupting readability.
- **Description Action**—as the image fades away a description of the activity fades in. Transparency values of the typography are based on the duration the user spends in each cube. Hence, if the user browses through the activities very quickly, only the images would be displayed.
- **Related Activities Action**—if the user spends more time in the cube, the system shifts the emphasis to related activities. The related activities are based on the non-metric scaling techniques described in the previous section. This action causes the related activities to gradually present themselves. The activity name and an image becomes visible to the user.
- **Rotational Action**—when a cube is no longer interesting it rotates away from the center of interest. This rotational motion is combined

with the image action to reveal additional information about a specific activity. For example, when the user entered the Science Museum activity, the system displayed additional information about the museum such as the top five events to do. However, prior to doing so, the activities that were related to the science museum rotated away from the information space.

- **Revealing Action**—revealing action takes place when the system wants to reveal additional information. This action is applied to gradually display both image and text and is usually combined with the rotational action.
- **Movement Action**—when the user is within a cube of low interest based on the user's profile, and if the next cube in the TM path is of a higher preference, this action will be triggered. The next cube will sinusoidly start oscillating along the x and y axes. The movement action was inherently very engaging and as such effective. A broader range of moving actions will make the information space very dynamic and highly engaging.
- **Camera Action**—if the user is within the lowest priority activities, the system will pull the user out of that activity towards the next one. The camera action is a zoom in and out operation which changes the camera view distance. Again, it is possible to have more camera actions such as rotating the entire information space, translating objects in space and so on.
- **GeoSpace Action**—moving into a cube activates the geographic map elements on the base of the cube. This was designed to keep the user oriented within the conceptual space. The user can see the location of the activity on the geographic map while being emersed in the conceptual space.

Conclusions

chapter 6

6.1 Summary

New ideas come from having different perspectives and juxtaposing different theories. Incrementalism is innovation's worst enemy.

Nicholas Negroponte
Wired, April 1995

This thesis has explored the design of engaging information presentation systems based on the following salient principles of magic: creating atmosphere, focus of attention, continuity, adaptation, timing and pacing, and the element of surprise. To investigate these principles within the context of information presentation systems, two prototype applications, GeoSpace and MediaMagic were developed. Both systems adopted a wide range of techniques for achieving the desired effects. In some cases one technique would effect more than one principle from magic. For example, framing contexts were developed by presenting related information with a higher opacity value. This was also instrumental in guiding a user's attention along a specific path. This kind of overlap created a rich and interesting interplay in the overall design, since all the principles shared a unifying goal: to design an *engaging presentation system.*

In the course of analyzing the principles in magic and exploring their application within the domain of information, several observations were made. Some of observations point to interesting conclusions regarding engaging interfaces, while others raise more research questions for future work. Discussed below is a summary of these observations.

6.2 Observations

This section describes an analysis of the principles of magic that worked effectively, in the domain of information. Although, an in-depth usability study to test the working of the prototypes is beyond the scope

of this thesis, I will attempt to conclude which techniques demonstrated the characteristics identified in Chapter 1.
Activation spreading networks combined with visual design techniques worked well visually, to help users focus their attention on one region of a dense display. However, the important question is if focusing attention necessarily makes the interface engaging? Recall that in magic, controlling attention was important to make the audience look at a particular place at a given time so that important steps in the illusion process would not be missed. In addition for the need to guide attention in magic, the *manner* in which it is done is also important. As mentioned before its is the guiding process in magic that keeps audiences engaged. This proved to be the case in the domain of information too. The need to guide attention was clear, since the map display was very dense and guiding attention enabled the user to identify the relevant information quickly. However, the level of engagement depended on how the system was designed. The example of using motion in MediaMagic, where the cube rotated felt more engaging than mere change of transparency in GeoSpace.

While the above mentioned methods use visual techniques, focusing attention also involved developing framing contexts represented as plan structures. The plan structure represents an object in the magic world that a magician tries to draw attention to. Inherently, if the object is uninteresting so is level of audience interest. This leads to the conclusion that in GeoSpace for example, the pre-condition list in the plan structure can determine the level of engagement. Although, intuitively obvious, this needs to be tested further and is area for future work.

The idea of violating user's expectation is relatively new to the information domain and comes directly from one of the principles of magic. In fact, this is a fundamental characteristic of any illusion and perhaps, the one criteria known to all lay people. Violating expectations inherently keeps people engaged, since it arouses their curiosity. This makes a person wonder and explore. While, well suited for engaging people, this principle if not applied with caution, is also the cause for much confusion. A surprise in magic must be the result of some logical continuity. Similarly, violation of user' expectations in the domain of information must have some meaning—hence, the term "meaningful surprises". The transition of GeoSpace from two to three dimensions to reveal the crime bars was a meaningful surprise, since the three dimensional bars of crime related to the previous two dimensional clusters of crime. The design of the MediaMagic transition from a geographic space to a conceptual space was less direct, and hence the possibility of confusion. Why do the images move? This only becomes clearer once you zoom all the way to the MediaMagic space and see the related activities.

These are the same activities that moved during the transformation. In general, the element of surprise though a powerful tool for designing engaging interfaces, needs to be used with caution.

The principle of timing and pacing proved to be very interesting and versatile in its application. Although, it was classified as a salient principle, its application was useful for: (1) directing attention, (2) creating surprises and (3) continuous transitions. By pacing the information flow, it was possible to present a sequence of information graphics much like a series of sub-climaxes in magic.

6.3 Future Work

This research also points to the class of application environments that these techniques maybe suited towards. It is noteworthy to draw a distinction between information exploration and information retrieval systems. In situations where the user's primary goal is to retrieve information, it may not be necessary to design systems based on these principles, since they may actually come in the way. However, in the case of information exploration, much like browsing, the user has no specific goal but rather a higher level objective. In the prototype example, the user is new to Boston and has no idea where to live or what activity to see. In such situations, adopting the techniques lead to a richer and more engaging interface, since the user will tend to look at information he may not otherwise have done.

Designing a web browser based on the the principles of magic could potentially enable better exploration of the internet. Imagine a browser that guides you to all those exciting home pages, instead of you having to work your way through an arduous array of links. In addition, while it guides you it could also surprise you with new information and adapt dynamically to your changing preferences. Further research and testing is necessary to establish the range of application domains that can use these principles during their design.

Principles of Magic

This thesis examined the salient principles of magic which were relevant for creating engaging information systems. As magicians we have an ancient heritage to rely on; the principles described are well documented in the literature of magic. However, when applying it to information design we can benefit by having a better understanding of *why* these principles work from a cognitive perspective. For example, research in visual perception of scene changes experimentally demonstrates that large changes in an image may go unnoticed [Rensink

1995]. Further research of this kind will enable us to understand the perceptual and cognitive processes involved in creating illusions.

Engaging Characteristics

This research has taken a step towards better defining and designing engaging interfaces. To facilitate better design, further research is required to determine the additional characteristics that make a system engaging. This will also create a more formal basis for evaluating a design in terms of its level of engagement.

Range of Techniques

This thesis focused more on applying the principles of magic, rather than identifying specific techniques in the visual domain. For example, the use of activation spreading combined with transparency is just one way to guide a persons attention. Similarly, using transformations was one technique for creating meaningful surprises. Much research effort can be devoted to identifying and testing a much broader range of techniques for achieving the design of dynamic magical environments. Since, specific techniques may work only in some domains, having a wider range will give designers greater flexibility in choosing an appropriate technique for their application.

Modeling the Process

While this research applied the principles of magic within two prototype systems, it did not test the complete model of close-up magic. By complete model, I mean the overall process including the capability to adapt extensively based on user feedback. With advanced techniques for assessing the users intentions such as eyetracking, gaze and gesture recognition methods it should be possible in the future to model the process with a high degree of accuracy. Even the simple example of forcing a card (described in Chapter 1) requires many complex perceptual and cognitive operations. Further research in this area will help model close-up magic more accurately, with exciting results.

In the future, as the information explosion matures, the need to *engage* the user during interaction will be imperative. The magic principles and visual techniques presented in this thesis can serve as a guide to better design future systems. The engagement factor cannot be appended as an afterthought to designed systems, but rather, it needs to be incorporated *during* the design process.

Bibliography

[Ahlberg94] Ahlberg, C and Shneiderman, B. Visual Information Seeking: Tight Coupling of Dynamic Query Filters with Starfield Displays. *Proceedings of SIGCHI'94 Human Factors in Computing Sysytems,* Boston, MA, ACM, April, 1994.

[Anderson83] Anderson, John. A Spreading Activation Theory of Memory. *Journal of Verbal Learning and Verbal Behavior 22,* pp.261 295, 1983.

[Belge93] Belge, Matt, Ishantha Lokuge and David Rivers. Back to the Future: A Graphical Layering System Inspired by Transparent Paper. *In Proceedings (Companion Volume) of INTERCHI'93.*

[Bergman81] Bergman, Hans, Brinkman, Albert, and Koelega, Harry S.,"System Response Time and Problem Solving Behavior," *Proceedings of the Human Factors Society,* 25th Annual Meeting, (Rochester, NY, October 12 16,1981) 749 753.

[Colby91] Colby, G and Scholl, L. Transparency and Blur as Selective Cues for Complex Visual Information. *International Society for Optical Engineering Proceedings,* Vol 1460, 1991 pp. 114 124.

[Cooper94] Cooper, Muriel, et.al. Information Landscapes. MIT Technical Note. April 1994.

[Crawford90] Crawford, Chris. "Lessons from Computer Game Design." *In The Art of Human Computer Interface Design,* edited by Brenda Laurel. Reading, Massachusetts, Addison Wesley, 1990.

[Davenport94] Davenport, Glorianna and Friedlander. Interactive Transformational Environements: Wheel of Life. MIT Media Lab.

[Don90] Don, Abbe. "Narrative and the Interface." *In The Art of Human Computer Interface Design,* edited by Brenda Laurel. Reading, Massachusetts, Addison Wesley, 1990.

[Fitzkee75] Fitzkee, Dariel. *Showmanship for Magicians.* Lee Jacobs Productions, P.O. Box 362, Pomeroy, Ohio, 1945, 1975.

[Fitzkee75] Fitzkee, Dariel. *The Trick Brain.* Lee Jacobs Productions, P.O. Box 362, Pomeroy, Ohio, 1945, 1975.

[Fitzkee75] Fitzkee, Dariel. *Magic by Misdirection.* Lee Jacobs Productions, P.O. Box 362, Pomeroy, Ohio, 1945, 1975.

[Goldstein94] Goldsteing, Jade and Roth, Steven. Using Aggregation and Dynamic Queries for Exploring Large Data Sets. *Proceedings of SIGCHI'94 Human Factors in Computing Systems,* Boston, MA, ACM, April, 1994.

[Gillan90] Gillan, Douglas and Breedin, Sarah. Designers' Model of the Human Computer Interface. *In Proceedings of CHI '90.*

[Heckel91] Heckel, Paul. The Elements of Friendly Software Design. Sybex, Almeda, CA, 1991.

[Kay91] Kay, Alan. "User Interface: A Personal View," In Brendal Laurel(ed), *The Art of Human Computer Interface Design,* Addison Wesley, Reading, Mass., 1991.

[Laurel93] Laurel, Brenda. *Computers as Theatre.* Addison Wesley Publishing Company, Inc.

[Loftus83] Loftus, Geofrey and Loftus, Elizabeth. *Mind at Play. The Psychology of Video Games.* Basic Books, In., Publishers, New York, 1983.

[Lokuge93] Lokuge, Ishantha. Whats Magical About Graphical User Interfaces: Applying the principles of magic to graphical user interface design. SunSoft, Chelmsford, MA.

[Lokuge94] Lokuge, Ishantha and Ishizaki, Suguru. GeoSpace: An Interactive Visualization System for Exploring Large Information Spaces. *In Proceedings of CHI' 95,* Denver, Colorado.

[Maes90] Maes, Pattie. Situated Agents Can Have Goals, *In: Designing Autonomous Agents: Theory and Practice from Biology to Engineering and Back,* edited by P. Maes, MIT Press/Bradford Books, 1990.

[MacNeil] MacNeil, R. Adaptive Perspectives: Case-Based Reasoning with TYRO, The Graphic Designer's Apprentice, *IEEE Workshop on Visual Languages.*

[Maybury93] Maybury, Mark. Planning Multimedia Explanations Using Communicative Acts. *In Intelligent Multimedia Interfaces,* Mark Maybury. AAAI Press and the MIT Press, 1993.

[Mackinlay86] Mackinlay, J.D. Automating the design of graphical presentations of relational information. *ACM Transactions on Graphics,* 5 (2), 110 141.

[Nelson91] Nelson, Theodor Holm. "The Right Way to Think about Software Design," In Brenda Laurel(ed), *The Art of Human Computer Interface Design,* Addison Wesley, Reading, Massachusetts, 1991.

[Nelms69] Nelms, Henning. Magic and Showmanship, *A Handbook for Conjures.* Dover Publications, Inc., New York

[Norman83] Norman, Donald, "Some Observations of Mental Models," In Gentner. Dedre & Stevens, Albert L. (Eds.), *Mental Models,* Hillsdale, N.J.: Lawrence Erlbaum Associates, 1983.

[Norman88] Norman, Donald. *Psychology of Everyday Things* (Now Design of Everyday Things). Basic Books, 1988.

[Oren90] Oren, Tim, Gita Salomon, Kristiee Kretman and Abbe Don. "Guides: Characterizing the Interface. In Brenda Laurel(ed), *The Art of Human Computer Interface Design,* Addison Wesley, Reading, Massachusetts, 1991.

[Papert93] Papert, Seymour. Mindstorms: Children, Computers, and Powerful Ideas. New York: Basic Books, 1993.

[Pausch94] Pausch, Randy, Rich Gold, Tim Skelly, and David Thiel. What HCI Designers Can Learn From Video Game Designers. *In Proceedings of CHI '94.*

[Rensink95] Rensink A. Ronald, Kevin O'Regan and and James Clark. Visual Perception of Scene Changes Disrupted by Delocalized Transients. *To Appear in EVCP '95*, Tubingen, Germany.

[Richards93] Richards, Whitman and Jepson, A. What's a percept. *Technical Reports on Research in Biological and Computational Vision* at the University of Toronto.

[Richards93] Richards, W. & Koenderink, J.J. Trajectory Mapping ("TM"): A new non-metric scaling technique. *Proceedings of European*

Conference on Visual Perception, Edinburgh (Abstract). MIT Center for Cognitive Science Paper #48 and AI Memo #468, 1994.

[Roth93] Roth, Steven F., and Hefley, William E. Intelligent Multimedia Presentation Systems: Research and Principles. *In Intelligent Multimedia Interfaces,* Mark Maybury. AAAI Press and the MIT Press, 1993.

[Rubinstein84] Rubinstein, Richard and Hersh, Harry. "Design Philosophy,". Chapter 2 in the *Human Factor" Designing Computer Systems for People,* Digital Press, Burlington, MA, 1984.

[Shepard62] Shepard, R.N. The analysis of proximities: Multidimensional scaling with an unknown distance function. I & II. *Psychomtrika,* 27, 125-140, 219-246.

[Suchman87] Suchman, Lucy A. *Plans and Situated Actions.* Cambridge University Press, 1987.

[Shneiderman87] Shneiderman, Ben. *Designing the user interface: Strategies for effective human computer interaction.* Addison Wesley, Reading, Mass., 1987.

[Shneiderman88] Shneiderman, Ben. "A Nonanthropomorphic Style Guide: Overcoming the Humpty Dympty Syndrome." *The Computing Teacher* (October, 1988) 9 10.

[Tog93] Tognazzini, Tognazzini, Bruce. Principles, Techniques and Ethics of Stage Magic and Their Application to Human Interface Design. *In Proceedings of INTERCHI'93.*

[Tufte83] Tufte, E.R. *The Visual Display of Quantitative Information.* Graphics Press, Cheshire, CT, 1983.