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Physical Selection as Tangible User Interface

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1. Abstract

Physical browsing is an interaction paradigm that allows associating digital information with physical objects. In physical browsing, the interaction happens via a mobile terminal – such as a mobile phone or a Personal Digital Assistant (PDA). The links are implemented as tags that can be read with the terminal. They can be, for example, Radio Frequency Identifier (RFID) tags that are read with a mobile phone augmented with an RFID reader. The basis of physical browsing is physical selection – the interaction task with which the user tells the mobile terminal which link the user is interested in and wants to activate. After the selection, an action occurs, for example, if the tag contains a web address, the mobile phone may display the associated web page in the browser. Physical selection is thus a mobile terminal and tag based interaction technique, which is intended for interacting with the physical world and its entities.

In ubiquitous computing, the physical environment is augmented with devices offering digital information and services. Ubiquitous computing can be divided into two broad categories: distributed, in which widgets with user interfaces are embedded into the environment, and mobile terminal centred, in which the user interacts with the devices with a mediator device. In both cases, an important issue in ubiquitous computing is how to interact with the devices embedded into the environment. Physical selection is a direct selection technique for choosing a target in the mobile terminal centred approach.

Computer-augmented environment is a concept very similar to ubiquitous computing. The concept grew from the combination of ubiquitous computing and augmented reality, but common to both approaches is the emphasis on the physical world and the tools that enhance our everyday activities. Another concept close to ubiquitous computing and computer-augmented environments is physically based user interfaces, in which the interaction is based on computationally augmented physical artefacts. Tangible user interfaces are based on tangible or graspable physical objects and are thus closely related to physically based user interfaces.

2. Introduction

Physical browsing is an interaction paradigm that allows associating digital information with physical objects. It can be seen analogous to browsing the World Wide Web: the physical environment contains links to digital information and by selecting these physical hyperlinks, various services can be activated.

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In physical browsing, the interaction happens via a mobile terminal – such as a mobile phone or a Personal Digital Assistant (PDA). The links are implemented as tags that can be read with the terminal, for example Radio Frequency Identifier (RFID) tags that are read with a mobile phone augmented with an RFID reader. The basis of physical browsing is physical selection – the interaction task with which the user tells the mobile terminal which link the user is interested in and wants to activate. After the selection an action occurs, for example, if the tag contains a Universal Resource Identifier (URI, "web address"), the mobile phone may display the associated web page in the browser. Optimally, the displayed information is somehow related to the physical object itself, creating an association between the object and its digital counterpart. This user interaction paradigm is best illustrated with a simple scenario (Välkkynen et al., 2006):

Joe has just arrived on a bus stop on his way home. He touches the bus stop sign with his mobile phone and the phone loads and displays him a web page that tells him the expected waiting times for the next buses so he can best decide which one to use and how long he must wait for it. While he is waiting for the next bus, he notices a poster advertising a new interesting movie. Joe points his mobile phone at a link in the poster and his mobile phone displays the web page of the movie. He decides to go see it in the premiere and "clicks" another link in the poster, leading him to the ticket reservation service of a local movie theatre.

Figure 1. User selecting a link in a movie poster

To better illustrate the evolution of physical selection, the road of digital information from the purely digital form in desktop computers to mobile terminal readable physical containers and tokens is traced through a few well-known and interesting example systems. The beginnings of the desktop metaphor are first described briefly, and then how computing was brought from the virtual desktop to the real desktop, and to the physical world through concepts such as tangible user interfaces and computer-augmented environments. Eventually, these ideas led to bridging the physical and virtual worlds by identifying physical objects, and with mobile computing, also to the concept of physical browsing.

3. Dynabook

Kay and Goldberg (1977) presented the idea of Dynabook – a general-purpose notebook-sized computer, which could be used by anyone from educators and business people to poets and children. In the vision of Kay and Goldberg, each person has their own Dynabook. They envisioned a device as small and portable as possible, which could both take and give out information in quantities approaching that of human sensory systems. One of the metaphors they used when designing such a system was that of a musical instrument, such as a flute, which the user of the flute owns. The flute responds instantly and consistently to the wishes of the owner, and each user has an own flute instead of time-sharing a common flute.

As a step towards their vision, Kay and Goldberg designed an interim desktop version of the Dynabook. The Dynabook vision led eventually to building the Xerox Star (Smith et al., 1982) with graphical user interface and to the desktop metaphor of the Star. On the other hand, the original vision of Dynabook was an early idea of a mobile terminal, making the Dynabook vision even more significant in the evolution of physical browsing.

4. The Star User Interface and the Desktop Metaphor

The desktop metaphor refers to a user interface metaphor in which the UI is designed to resemble the physical desktop with familiar office objects. The beginning of the desktop metaphor was Xerox Star (Smith et al., 1982), a personal computer designed for offices. The designers of Xerox Star hoped that with the similarity of the graphical desktop user interface and the physical office, the users would find the user interface familiar and intuitive.

Wellner (1993) stated that the electronic world of the workstation and the physical world of the desk are separate, but each "has advantages and constraints that lead us to choose one or the other for particular task" and that the desktop metaphor is an approach to solving the problem of choosing between these two alternatives.

Like the interim Dynabook, the Star user interface hardware architecture included a bit mapped display screen and a mouse (English et al., 1967). Smith et al. (1982) claim that pointing with the mouse is as quick and easy as pointing with the tip of the finger. However, the mouse is not a direct manipulation device (Wellner, 1993); the movements of the mouse on a horizontal plane are transformed into cursor movement on a typically vertical plane some distance away from the mouse itself.

5. From Desktop Metaphor to the metaDESK

The physical desk led to the desktop metaphor, taking advantage of the strengths of the digital world, but at the same time ignoring the skills the users had already developed for interacting with the real world, and separating the information in digital form from the physical counterparts of the same information. It is also easy to see that the desktop metaphor suits best office tasks and not for example mobile computing. These shortcomings have led to two directions in bridging the physical and virtual worlds:

1. Integrating the physical objects back into the user interface, as is done in the tangible user interfaces approach;
2. Augmenting physical objects with digital information and accessing that information with a computational device, such as a mobile terminal.

In the next subsections, the first of the aforementioned approaches – integrating physical objects with the user interface – is explored through a few example systems that illustrate well the ideas of bridging the gap between the physical and virtual worlds. The DigitalDesk (Wellner, 1993) is an early system for merging the physical and digital worlds in an office desktop setting. It is also one of the pioneering augmented reality systems. Although Wellner's focus was on office systems, his ideas of combining the physical and digital worlds, while taking advantages from each, are still valid in the ubiquitous computing environments. Bricks (Fitzmaurice et al., 1995) and Active Desk is another physical desktop-based system in which physical and digital objects are connected.

5.1 DigitalDesk

Wellner (1993) states that we interact with documents in two separate worlds: the electronic world of workstation (using the desktop metaphor), and the physical world of the desk. Both worlds have advantages and constraints that lead us to choose one or the other for particular tasks in the office setting. Although activities on the two desks are often related, the two are unfortunately isolated from each other. Wellner suggests that "instead of putting the user in the virtual world of the computer, we could do the opposite: add computer to the real world of the user." Following this thought, instead of making the electronic workstation more like the physical desk, the DigitalDesk makes the desk more like a workstation and supports computer-based interaction with paper documents. According to Wellner, the difference between integrating the world into computers and integrating computers into the world lies in our perspective: "do we think of ourselves working primarily in the computer but with access to physical world functionality, or do we think of ourselves as working primarily in the physical world but with access to computer functionality?"

The DigitalDesk system (Wellner, 1993) is based on a real physical desk, which is enhanced to provide the user some computational capabilities. The desk includes a camera that projects the computer display onto the desk, and video cameras that track the actions of the user and can read physical documents on the desk. The interaction style in DigitalDesk is more tactile than the non-direct manipulation with a mouse. The user does not need any special input devices in addition to the camera: pointing and selecting with just fingers or a pen tip is sufficient. The projected images can be purely digital documents, user interface components, and images and text that are superimposed onto paper documents with the existing contents of the paper.

5.2 Bricks

Fitzmaurice et al. (1995) took another step towards integrating the physical and virtual worlds with Graspable User Interfaces, a new user interaction paradigm. They described their concept: "the Graspable UIs allow direct control of electronic or virtual objects through physical artefacts which act as handles for control." Graspable UIs are a blend of virtual and physical artefacts, each offering affordances in their respective instantiation. A graspable object in the context of graspable UIs is an object that is composed of both a physical handle, and a corresponding virtual object.

The prototype system in Bricks (Fitzmaurice et al., 1995) consists of Active Desk, the Bricks (roughly one inch sized cubes) and a simple drawing application. As in DigitalDesk (Wellner, 1993), the Active Desk uses a video projector to display the graphical user interface parts on the surface of the desk. Instead of tracking the fingers of the user or a pen tip with a camera, the Bricks system uses six-degrees-of-freedom sensors and wireless transmitters inside the Bricks. The location and orientation data is transmitted to the workstation that controls the application and the display. Although it offers a new user interaction paradigm, Bricks still builds upon the conventions of the graphical user interface in a desktop setting.

5.3 The metaDESK and Tangible Geospace

The metaDESK (Ullmer and Ishii, 1997) is an example of a tangible user interface (TUI, further explored in the next subsection), which brings familiar metaphorical objects from the computer desktop back to the physical world. The metaDESK is an augmented physical desktop on which phicons – physical icons – can be manipulated. The use of physical objects as interfaces to digital information forms the basis for TUIs. The metaDESK was built to instantiate physically the graphical user interface metaphor. The desktop metaphor drew itself from the physical desktop and in a manner of speaking, metaDESK again realised physically the GUI components. In metaDESK, the interface elements from the GUI paradigm are instantiated physically: windows, icons, handles, menus and controls each are given a physical form. For example, the menus and handles from GUI are instantiated as "trays" and "physical handles" in TUI.

Tangible Geospace (Ullmer and Ishii, 1997) is a prototype application built on the metaDESK platform. In Tangible Geospace, a set of objects was designed to physically resemble different buildings appearing on a digital map of the MIT campus. By placing a model of a building on the display surface, the user could bring up the relevant portion of the map. Manipulating the building on the metaDESK surface controlled the position and rotation of the map. The physical form of the objects would serve as a cognitive aid for the user in finding the right part of the map to display. For example a model of a familiar landmark such as the Great Dome of the MIT is easy to recognise on the metaDESK surface. The model thus acts as a container for the digital information and as a handle for manipulating the map. Adding a second phicon on the map rotates and scales the map so that both phicons are over correct locations on the digital map. Now the user has two physical handles for rotating and scaling the map by moving one or both objects with respect to each other, which is very similar to interaction with Bricks.

The Tangible Geospace application already resembles the basic idea of physical browsing. Although the "terminal" is a desk surface and instead of physically manipulating the terminal, the user manipulates tagged objects. The tagged objects act as links to digital information and bringing the "terminal" and the tagged objects together, the digital information can be displayed to the user.

6. Tangible Bits Vision

According to Ishii and Ullmer (1997), the GUI approach falls short in many respects, particularly in embracing the rich interface modalities between people and the physical environments. Their approach to this problem is a tangible user interface (TUI), part of which was demonstrated earlier with graspable user interfaces and the metaDESK platform. TUIs are user interfaces employing real physical objects, instruments, surfaces, and spaces as physical interfaces to digital information, and the user can physically interact with digital information through the manipulation of physical objects. The use of tangible objects – "real physical entities which can be touched and grasped" – as interfaces to digital information forms the basis for TUIs. This use of physical objects as containers for digital information makes tangible user interfaces important to physical browsing.

As a part of their work with tangible user interfaces, Ishii and Ullmer introduced the Tangible Bits vision (Ullmer and Ishii, 1997). The Tangible Bits vision includes three platforms: metaDESK, transBOARD and ambientROOM. Together these three platforms explore graspable physical objects and ambient environmental displays. In the Tangible Bits vision, people, digital information and the physical environment are seamlessly coupled – an idea very similar to the physical browsing systems of Want et al. (1999) and to the Cooltown (Kindberg et al., 2002). An important topic in their work is exploring the use of physical affordances within TUI design. The ambientROOM explores ambient, peripheral media and is outside the scope of this Chapter.

The transBOARD (Ishii and Ullmer, 1997) is an interactive surface in spirit of both the vision of Tangible Bits and Weiser's vision of boards as one class of ubiquitous computing devices. This kind of interactive surface absorbs information from the physical world and transforms it into digital information what can be distributed to other computers in the network. The transBOARD uses hyperCARDS, which are paper cards with barcodes to identify and store the strokes on the physical board as digital strokes. The cards can be attached onto the transBOARD and the when the strokes are recorded and stored, the barcode of the card is associated with the location of the stored data. The board contents can this way be saved, taken to other computers and replayed when the card is introduced to a suitably equipped computer again. Whereas the metaDESK is an interactive surface, which can also alter its contents, the transBOARD is a simple recording device. The interesting idea here from the point of view of physical browsing is "saving the contents of the board into a card", making the card a container for or a link to the information.

7. Closely Coupling Physical Objects with Digital Information

In their further work, Ullmer and Ishii (2001) re-defined tangible user interfaces to have no distinction between input and output. According to their definition, physical objects act both as physical representations and controls for digital information. With the new definition, tangible interfaces give physical form to digital information instead of just associating physical objects and digital information, employing physical artefacts both as representation and controls for computational media. The important distinction between tangible user interfaces and traditional input devices that have physical form – such as keyboards and mice – lies in that the traditional input devices hold little representational significance. In graphical user interfaces the information representation is separated to displays.

In physical selection, the control and representation (input and output) are not integrated as tightly as in this model for tangible user interfaces. This definition of tangible user interfaces separates TUIs somewhat from physical browsing. In physical browsing, the links are rarely controls, and the physical objects with tags only represent the information, but do not dynamically display it. The physical object acts only as an input token to the mobile terminal.

7.1 mediaBlocks

MediaBlocks (Ullmer et al., 1998) are small, electronically tagged wooden blocks that serve as phicons (physical icons) for the containment, transport and manipulation of offline media. They allow digital media to be rapidly stored into them from a media source such as a camera or a whiteboard and accessed later with a media display such as a printer or a projector. MediaBlocks thus allow "physical copy and paste" functionality. MediaBlocks do not store the media internally but instead they are augmented with tags that identify them, and the online information is accessed by referencing to it with a URL. MediaBlocks function as containers for online content and they can be understood as a physically embodied online media. Ullmer et al. see mediaBlocks as filling the user interface gap between physical devices, digital media and online content. They intended mediaBlocks as an interface for the exchange and manipulation of online content between diverse media devices and people.

Several tangible user interfaces described earlier have influenced the design of the mediaBlocks (Ullmer et al., 1998). Bricks (Fitzmaurice et al., 1995) were among the first phicons, although Bricks were not containers for digital content but instead were used to manipulate digital objects inside a single area, the Active Desk. In metaDESK (Ullmer and Ishii, 1997), phicons were used, not only as short cuts to digital information, but also as physical controls – for example rotating a phicon on the metaDESK rotated the displayed map. The functionality of mediaBlocks as storage devices for whiteboards draws from the transBOARD (Ishii and Ullmer, 1997), but instead of barcodes, electronic tags are used to link to the contents of the board. Ullmer and Ishii (1997) see RFID tags as a promising technology for realising the physical/digital bindings.

The contents of mediaBlocks remain online and that makes mediaBlock seem to have unlimited data storage capacity and rapid transfer speed when the block itself is moved around or the contents are copied just by copying the link to the online content (Ullmer et al., 1998). MediaBlocks can also contain streaming media. One role of the mediaBlocks is to support simple physical transport of media between different devices. Copying and pasting information is a commonly used function in graphical user interfaces and mediaBlocks are intended to provide the same functionality to physical media. Ullmer et al. have built slots for mediaBlocks in different devices such as whiteboards and printers but also on desktop computers.

In addition to adding mediaBlock interfaces to various existing devices, Ullmer et al. (1998) have built special devices for mediaBlocks. The media browser is used to navigate sequences of media elements stored in mediaBlocks. The media sequencer allows sequencing media by arranging mediaBlocks on its racks. This extended functionality is beyond the scope of this Chapter.

7.2 Other Removable Media Devices

In addition to mediaBlocks, other removable media devices exist, from floppy disks to more current DVDs and USB sticks, which were not ubiquitous technologies at the time of the development of mediaBlocks. Ullmer et al. (1998) claim that an important difference between these technologies and mediaBlocks is that mediaBlocks store only a link to the online media instead of recording the actual content onto the storage device.
However, nothing prevents us from storing links to online media on the other removable storage media, even onto floppy disks if we so desire. This way any storage device can support almost infinite space and varying bandwidths, just as Ullmer et al. (1998) describe MediaBlocks. They claim that other media transport devices are accessed indirectly through graphical or textual interaction. But what prevents us from "auto playing" for example video files from a USB stick when it is inserted into a projector? Ullmer et al. also mention the lack of disk drives on the different media sources and targets, but neither are there mediaBlock slots on commercial devices. Granted, it is not feasible to have for example DVD drives on many devices simply because of the physical dimensions and power requirements. However, many current media devices have USB ports and can record content to USB disks and read from them. Additionally, the devices Ullmer et al. augmented with mediaBlock slots, had only one such slot and only their custom-built browsers and sequencers took advantage of the possibility to contain many blocks at the same time. So, looking briefly, it seems that the mediaBlock concept would not be valid any more.
Still, mediaBlocks have a property that is extremely useful for physical interaction. They contained electronic tags that are small and cheap compared to current storage devices, allowing the use of one block for one link, thus making it possible to physically sort the blocks and extend the manipulation and sorting of digital content into the physical world just as Ullmer et al. (1998) intended. This is a powerful interaction paradigm and the mediaBlocks demonstrate it well.

8. Token-Based Access to Digital Information

Token-based access to digital information means accessing virtual data through a physical object. The paper of Holmquist et al. (1999) is among the first systematic analyses of systems that link physical objects with digital information. They defined token-based access to digital information as follows:

> "*A system where a physical object (token) is used to access some digital information that is stored outside the object, and where the physical representation in some way reflects the nature of the digital information it is associated with.*"

Holmquist et al. (1999) enumerate the two components in a token-based interaction system: tokens and information faucets. Tokens are physical objects, which are used as representation of some digital information. In physical selection, the tokens correspond to the tagged physical objects and provide links to digital information related to the objects. Information faucets or displays are access points for the digital information associated with tokens. In physical selection, the faucet corresponds to the mobile terminal, but in theory, it can be any device capable of reading the tag and presenting the information it links to.

The physical objects (tokens in previous paragraph) are further classified into containers, tokens and tools (Holmquist et al., 1999). Tools are physical objects that are used to actively manipulate digital information. They usually represent some computational function. For example, in the Bricks system (Fitzmaurice et al., 1995), the physical bricks could be used as tools by attaching them onto virtual handles on a drawing application. The lenses in the metaDESK system (Ishii and Ullmer, 1997; Ullmer and Ishii, 1997) also correspond to tools. Tools do not have a direct counterpart in physical selection.

Containers are generic objects that can be associated with any type of digital information (Holmquist et al., 1999). They can be used to move information between different devices or platforms. The physical properties of a container do not reflect the nature of the digital information associated with it. For example, mediaBlocks (Ullmer et al., 1998) are containers, because by merely examining the physical form of a mediaBlock, it cannot be known what kind of media it contains.

Tokens are objects that physically resemble in some way the digital information they are associated with (Holmquist et al., 1999). That way the token is more closely tied to the information in represents than a container is. The models of buildings in Tangible GeoSpace (Ishii and Ullmer, 1997; Ullmer and Ishii, 1997) are an example of tokens.

In physical selection, it does not matter (technologically) whether the object is a container or token. In an ideal case the information and the object are connected, but nothing prevents a user from sticking completely unconnected tags and objects together.

The two most important interactions in a token-based system are access and association (Holmquist et al., 1999). The user has to be able to access the information contained in the token by presenting the token to an information faucet. Association means creating a link to the digital information and storing that link in the tag of the token so that it can be accessed later. Holmquist et al. note that it may be useful to allow associating more than one piece of information to a single token and they call this method overloading. When the token is brought to a faucet, the information presented to the user may then vary according to the context, or the user may get a list of the pieces of information stored in the token. This may present problems to the physical hyperlink visualisation, as is shown later.

Holmquist et al. (1999) note that it is important to design the tokens in a way that clearly displays what they represent and what can be done with them. This refers to taking into account the existing affordances of the existing physical object in question when linking it to some digital information, but it can also be applied if a specific "link container" is designed for a link.

Later, Ullmer and Ishii (2001) chose to describe the physical elements of tangible user interfaces in terms of tokens and reference frames. They consider a token a physically manipulatable element of a tangible interface, such as a metaDESK phicon (Ullmer and Ishii, 1997; Ishii and Ullmer, 1997). A reference frame is a physical interaction space in which these objects are used, such as the metaDESK surface. Ullmer and Ishii (2001) accept the term container for a symbolic token that contains some media (again, as in mediaBlocks (Ullmer et al., 1998)) and the term tool for a token that is used to represent digital operations or function. Considering physical selection, we are mostly interested in the terms container and token, which take approximately the same meaning as defined by Holmquist et al. (1999).

9. A Taxonomy for Tangible Interfaces

9.1 Definitions for Tangible User Interfaces

The term "tangible user interface" surfaced in Tangible Bits, in which Ishii and Ullmer (1997) defined it as a user interface that "augments the real physical world by coupling digital information to everyday physical objects and environments". In Emerging Frameworks for Tangible User Interfaces, Ullmer and Ishii (2001) re-defined tangible interfaces as a user interface that eliminates the distinction between input and output devices. However, they were willing to relax the definition to highlight some interaction methods.

Fishkin (2004) describes the basic paradigm of tangible user interfaces as follows: "a user uses their hands to manipulate some physical object(s) via physical gestures; a computer system detects this, alters its state, and gives feedback accordingly". According with his definition, Fishkin created a script that characterises TUIs:

1. Some input event occurs, typically a manipulation on some physical object by the user, and most often it is moving the object.
2. A computer senses the event and alters its state.
3. An output event occurs via a change in the physical nature of the object.

Fishkin (2004) describes how the script applies to metaDESK (Ullmer and Ishii, 1997). The user moves a physical model of a building on the surface of the metaDESK. The system senses the movement of the model and alters its internal state of the map. As output, it projects the new state of the map onto the display surface. Another of the examples Fishkin gives, is the photo cube by Want et al. (1999). Bringing the cube a specific face down onto the RFID reader is the input event. The computer reads the tag on the cube in the second phase of the script and in the third phase, displays the associated WWW page as an output event. The output event in Fishkin's script does not thus happen in the physical object that contains the tag, but it can occur in another object, the display terminal in the photo cube case.

Similarly, we can see that physical selection is a user interaction method in a tangible user interface. In the first phase of the script, the user manipulates the mobile terminal for example by bringing it close to a tag. The tag reader in the terminal reads ("senses") the tag and alters its state according to what it is programmed to do when the tag in question is read. In the output phase, an action linked to the tag is activated and the action is visible on the screen of the phone (for example a WWW page) or can be sensed in the environment (for example an electronic lock has opened).

As Fishkin (2004) himself notes, any input device can fit into this script. Even a keyboard in a desktop computer is a physical object. Manipulating it causes an input event to occur and the computer senses the event, altering its state and produces an output event on the computer screen. Therefore Fishkin does not characterise an interface as "tangible" or "not tangible", but introduces varying degrees of "tangibility".

9.2 The Taxonomy

Fishkin proposes a two-dimensional taxonomy for tangible interfaces. The axes of the taxonomy are embodiment and metaphor. Embodiment describes to what extent the user thinks of the state of computation as being inside the physical object, that is, how closely the input and output are tied together. Fishkin presents four levels of embodiment:

1. Full: the output device is the input device and the state of the device is fully embodied in the device. For example, in clay sculpting, any manipulation of the clay is immediately present in the clay itself.
2. Nearby: the output takes place near the input object. Fishkin mentions the Bricks (Fitzmaurice et al., 1995), metaDESK (Ullmer and Ishii, 1997) and photo cube (Want et al., 1999) as examples of this level.
3. Environmental: the output is around the user. For example, ambient media (Ishii and Ullmer, 1997) corresponds to environmental embodiment.
4. Distant: the output is away from the user, for example on another screen or in another room. Fishkin mentions a TV remote control as an example of this level.

Physical selection typically has embodiment levels from Full to Environmental. Often the output occurs in the mobile terminal itself (Full), but if the output device is rather seen to be the object the user selects with the terminal, the embodiment level is then Nearby. Physical selection can also cause actions around the user, in the environment. As the photo cube (Want et al., 1999) is very closely related to physical selection, we should probably take Fishkin's classification of the photo cube to correspond to the classification of physical selection, making therefore it Nearby.

Fishkin defines the second axis, metaphor, as "is the system effect of a user action analogous to the real-world effect of similar actions?" Fishkin divides his metaphor axis to two components: the metaphors of noun and verb. Thus, there are five levels of metaphor:

1. No Metaphor: the shape and manipulation of the object in TUI does not resemble an object in the real world. Fishkin mentions the command line interface as an example of this level.
2. Noun: the shape of input object in TUI is similar to an object in a real world. The tagged objects Want et al. (1999) developed correspond to this level of metaphor. For example, their augmented bookmarks resemble real bookmarks.
3. Verb: the input object in TUI acts like the object in the real world. The shapes of the objects are irrelevant.
4. Noun and Verb: the object looks and acts like the real world object, but they are still different objects. In traditional HCI, an example of this level is the drag and drop operation in the desktop metaphor.
5. Full: the virtual system is the physical system.

Physical selection can be seen to correspond roughly to the Noun metaphor. Again, we can safely assume Fishkin's classification of Want et al.'s examples as guidelines.

Advancing on the metaphor scale means less cognitive overhead as the object itself contains in its shape and function information about how it can be used in a tangible interface. However, decreasing the level of metaphor makes the object more generic and re-usable. Therefore, the level of metaphor should, if possible, be designed consciously to suit the task (Fishkin, 2004). For example, among the strengths of Bricks (Fitzmaurice et al., 1995) and transient WebStickers (Ljungstrand and Holmquist, 1999; Ljungstrand et al.,

2000) are the possibilities to contain any information, and to act as operators to any virtual functions.

9.3 Comparison to Containers, Tokens and Tools

Fishkin (2004) compares the containers, tokens and tools of Holmquist et al. (1999) taxonomy to his own. Containers are fully embodied in the Fishkin taxonomy and use the verb metaphor. The information is considered to be inside the container and moving the container moves the information. As long as a container does not employ the noun metaphor (the shape does not resemble the data), the container retains its generic and flexible nature and can contain any information.

Tokens are objects that physically resemble the data they contain and thus correspond to the noun metaphor (Fishkin, 2004; Holmquist et al., 1999). Like containers, they can also be used to move information around and therefore also correspond to the verb metaphor, making them span the metaphor scale from Noun and Verb to Full.

As physical selection is mostly about containers and tokens, it can be seen as having the embodiment of any level, but particularly from Full to Environmental, as noted earlier. The metaphor level of containers and tokens and thus tagged objects is something between only Noun or Verb, and Full. Fishkin's own analysis of how the taxonomy of Holmquist et al. maps to his taxonomy seems to be slightly ambiguous. Perhaps we can say that even the steps in Fishkin scales are not binary but different tangible interfaces can be seen as having different degrees of "Noun-ness" or "Nearbyness".

10. Conclusion

In this chapter, physical selection, an interaction task for mobile terminal based ubiquitous computing, has been discussed. Physical selection allows the user to select a tag-augmented physical entity for further interaction, combining digital information and services with real-world objects. This close coupling between physical and digital worlds resembles tangible user interfaces and in this chapter, physical selection has been examined as a form of TUI. Physical selection can be seen as one kind of tangible user interface, with different levels of embodiment and metaphor. The tagged physical objects map to tokens and containers in a taxonomy for token-based tangible user interfaces. Examining this interaction paradigm in this way allows us to better understand the tag and mobile terminal based interactions in the light of the previous work in tangible user interfaces.

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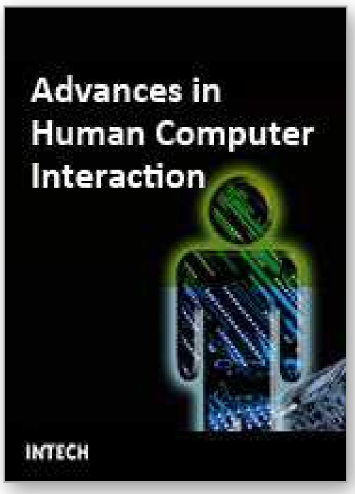

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In these 34 chapters, we survey the broad disciplines that loosely inhabit the study and practice of human-computer interaction. Our authors are passionate advocates of innovative applications, novel approaches, and modern advances in this exciting and developing field. It is our wish that the reader consider not only what our authors have written and the experimentation they have described, but also the examples they have set.

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