Token-Based Access to Digital Information

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Abstract. Several systems have been designed where a physical object is used to access digital information that is stored outside the object, but as yet no common vocabulary exists to describe such systems. We introduce a schema with three types of physical objects that can be linked to digital information: *Containers* are generic objects used to move information between different devices or platforms; *tokens* are used to access stored information, the nature of which is physically reflected in the token in some way; and *tools* are used to manipulate digital information. This paper gives special notice to token-based access system, and design implications for such systems are discussed. As an example of token-based access we have implemented *WebStickers*, where physical objects can be coupled with WWW pages. We present some examples of how tokens are used to access digital information in this system, and discuss future work in this area.

1 Introduction

In recent years, one of the most compelling visions of the future of computers has been that of *ubiquitous computing*, where computers would leave the desktop and move into the world that surrounds us [14]. By shifting the emphasis from the universal functionality of desktop workstations to small, dedicated computational tools, proposed ubiquitous computing environments hope to make computers as readily available and easy to use as notepads and whiteboards. In some ways, this vision is starting to make its way to reality, and with the continued miniaturisation and decreasing prices of PDAs and embedded processors, much of the technology required to make these visions a reality now exists.

However, with the increased power and complexity of portable computers, there is also the risk of simply replacing one problem with another. By moving all computing functions from one platform to another, perhaps we will not always gain as much as we would hope. Even worse, advantages taken for granted with stationary computers (large screens, high computational power, access to high-speed networks, etc.) are often missing on mobile devices. There is a risk that rather than simplifying the use of computers, the proliferation of a multitude of computational devices will instead make for higher complexity – thus achieving the opposite of the goal of ubiquitous computing.

An alternative approach to accessing and manipulating digital information is to use physical objects that are not in themselves computers, but nevertheless are used for representing information. Most types of information today exists in digital form, including text, images, music, films, and so on. With a suitable infrastructure, it should be feasible to have access to any book ever written, every piece of music ever recorded, any piece of art ever painted, anytime, anywhere, without the need for a physical carrier. However, this might also lead to serious problems in designing the human interface; experiences with the World Wide Web have already shown us that designing the interface to a practically limitless information space is extremely difficult.

But humans are inherently good at managing physical space, by ordering and sorting artifacts in their environment. Our senses give us many clues to the properties of physical objects, so that we are able to draw many useful conclusions from the way objects look and feel and how they are arranged in our environment [3]. We might take advantage of some of these capabilities when designing systems for accessing digital information, by using physical representations that are in themselves not carriers of information, but act as pointers to some online data.

In this paper, we will examine several such systems, concentrating on approaches where digital information is distributed using physical objects that represent some digital information or computational function. The process of accessing virtual data through a physical object we will term *token-based access to digital information.* The purpose of this paper is to systematise the properties of such systems, and to put them in relation to systems using other approaches, thus forming the basis for a discussion of how we can use properties in the physical world to help us better interact with distributed digital information.

2 Physical Objects as Representations of Information

There is a long history of the use of physical items to represent information, without the item actually containing the information that it represents (cf. [6, 16]). Souvenirs, photographs and keepsakes aid in the remembrance of places, past events and persons, by acting as a trigger for the user to remember certain information. The pieces used in board-games act as representations of the players through which they can perform their actions (cf. [15]). Gambling tokens used in casinos represents a value that is not inherent in the actual piece of plastic, much like the value of paper money traditionally has been guaranteed by a government's gold reserve. Cards of various kinds (calling cards, debit cards, etc.) are used to access assets – telephone call minutes, money stored in a bank account, etc. – that are not stored in the physical cards themselves.

Similarly, tokens in human-computer interaction will trigger the display of information that is digitally stored outside the token in some way. In the research community, several recent systems use physical objects without any inherent computational properties as representations of digital information in some way or another, but there is as yet a lack of vocabulary for describing and analyzing such systems. To facilitate a discussion, we will first introduce three different classes of physical objects that represent digital information or computational functions: *tokens*, *tools* and *containers*.

2.1 Tokens, Tools and Containers

We will call an object a *container*, if it is a generic object that can be associated with any type of digital information. We will call it a *token*, if the digital information associated with the object is reflected in the physical properties of the token in some way, thus making the object more closely tied to the information it represents. Finally, some physical objects are to be considered as *tools*, since they are used to actively manipulate digital information, usually by representing some kind of computational function. Some accounts of related work should help clarifying these distinctions.

Containers. Several systems have been proposed in which digital information can be attached to physical objects, often to simplify the task of moving information between various computers and/or display devices. In the *pick-and-drop* approach [7], a pen was used as a container to physically "pick-and-drop" digital information between computers, analogous to how icons are “dragged-and-dropped” on a single screen. *Informative Things* [1] let ordinary floppy disks act as pointers to online information by associating them with a digital ID. A disk could thus be shared between users as usual, but would seem to have “endless” storage, since no information apart from the ID was actually stored on the disk. The authors also discuss some future scenarios where other objects might be used as “Things”. *mediaBlocks* were small wooden blocks which let digital information be stored and accessed through a variety of different means [12]; for instance, after first associating a block to a digital whiteboard, the block could be used to transfer the scribbles on the whiteboard to a laser printer for printout. Finally, in the *Passage* system [8] information of various kinds could be moved between different computers by “attaching” it to small physical objects called “passengers”.

Although all these systems in some sense could be said to use “tokens” to represent digital information, we prefer to call these objects *containers*. Unlike what we will term tokens, containers are generic, in that the physical properties of a container do not reflect the nature of the digital information it is associated with. Taking mediaBlocks as an example, note that by merely examining the physical form it is impossible to know if a block is associated with say a video clip, a PowerPoint presentation or a whiteboard scribble. This generic quality makes containers potentially very useful for the distribution and manipulation of a variety of digital information, but it also means that containers do not provide any additional cognitive cues for the user as to what their “contents” are. Furthermore, containers are mostly used for short-term distribution and access, making them inherently transient in nature.

Tokens. In our definition, *tokens* are objects that physically resemble the information they represent in some way. Tokens are typically only transient if the token itself is short-lived. In the *metaDESK* map-display system [11], a set of objects were designed to physically resemble different buildings appearing on a digital map. By placing the models on a horizontal display, users could bring up the relevant portion of the map, and 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. In the *ambientROOM* [4], objects were used to represent various types of information, and by bringing an object to an information display, an “ambient” display of that information could be accessed. For instance, by bringing a toy car close to a speaker, ambient sounds reflecting the activities in a toy project could be heard.

In the electronic tagging system described in [13], an object could be augmented with a digital ID tag allowing it to be linked to some digital information, thus letting the physical objects act as a pointer to the digital information. Some examples included a book that was associated with appropriate electronic information, such as the author's web page or a relevant page at an on-line bookstore, and a watch that was associated with the user's on-line calendar. Similarly, in the *WebStickers* system [5], users could attach barcode stickers to objects, and then associate a barcode to a web page that was somehow relevant to the object. (This system will be described in more detail later.)

Tools. Finally, some physical objects are used as representations of computational functions. We will call such objects *tools*. Some tools act as "handles" to manipulate virtual objects. In the *Bricks* system [2], a physical "brick" was attached to a graphical object on a horizontal display, and could then be used to move and rotate the on-screen object. By employing two bricks, a graphical object could be scaled and distorted. Some tools physically resemble the computational function they represent. In the metaDESK system, a physical representations of a magnifying glass was used to invoke functions similar to those of the *magic lenses* explored in graphical UIs [9]. By manipulating the physical magnifying glass, the user could apply the lens functions to a part of the map, thus seeing an alternative display "through" the lens represented by the magnifying glass. Other physical representations such as a "flashlight" were also used. In the electronic tagging system mentioned above (cf. [13]), a French dictionary was associated with a language translation function, so that a text could be translated simply by bringing the physical representation close to the screen where the text was displayed.

Sometimes the distinction between a tool and a token or a container will blur, since when a physical object is attached to a virtual, direct manipulation of virtual properties using the physical representation might become possible. In the metaDESK, models of buildings (tokens) were also used to scale and rotate a map, analogous to the Bricks system. In mediaBlocks, several mediaBlocks (containers) could be used in conjunctions with a workbench to sequence a presentation; the completed presentation could then be associated with a new block. Such "hybrid" systems, where a physical representation has several possible uses depending on the context, are an area where we expect to see much development, but we will consider them outside the scope of this paper.

2.2 A Note on Vocabulary

The definition of *token* in the online edition of the Merriam-Webster Collegiate Dictionary includes:

1 : an outward sign or expression <his tears were tokens of his grief>
2 a : SYMBOL, EMBLEM <a white flag is a token of surrender> **b** : an instance of a linguistic expression
3 : a distinguishing feature : CHARACTERISTIC
4 a : SOUVENIR, KEEPSAKE **b** : a small part representing the whole : INDICATION <this is only a token of what we hope to accomplish> **c** : something given or shown as a guarantee (as of authority, right, or identity)
(Note: meanings **5** – *resembling money* – and **6** – *tokenism* – have been excluded)

Our intention with this choice of word is to show that a token is a "small part representing the whole", in that properties of the digital information are reflected in the token, and that the token should have some characteristic of the information it is linked to. We considered using some other term, in particular the word *phicon,* which has been used for physical counterparts to GUI icons, but decided against it. In the literature, the term phicon has been used both for what we define as tokens (e.g. the models of buildings in the metaDESK [11]) and for containers (e.g. mediaBlocks [12]), creating some confusion, which we sought to avoid with this choice of terms.

3 Token-Based Access to Digital Information

As we have seen, there are several different approaches to how we can let a physical object represent some kind of digital data or computational function. We will in the following concentrate on what we term *token-based access to digital information,* because this is an area that provides many design opportunities that should be further explored. We will define token-based access to digital information as:

> *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*

A token is a representation of some digital information, but only by association and resemblance – a token is not a computer or a display. Instead, the user will have to bring the token to some kind of external device to access the associated information.

3.1 Components

In a token-based interaction system, users will need to have access to two types of components:

- *A set of physical objects which are used as representation of some digital information.* These objects we will call tokens
- *A set of access points for the digital information associated with tokens.* These access points we will call *information faucets,* or faucets for short

We have chosen the term *faucet* rather than a term such as *display,* since it can be any type of device capable of presenting information, not just a graphical computer display – perhaps a speaker, a tactile device, etc. Importantly, while a token is by definition not a computer (it typically contains no computational power), neither should a faucet be considered as a computer from the user's point of view. Instead, tokens and faucets together comprise a system that provides users access to digital information – the fact that computer technology, networks, etc., might feature heavily in the implementation of such a system should not need to be of concern to the user.

3.2 Interaction in token-based access systems

Interacting with tokens can be either to access the information associated with a certain token, or to create or modify such associations. These two aspects of the human-computer interaction we will call *access* and *association* respectively.

Access. Fundamental for any token-based system is that it allows a user to access a certain piece of information by means of presenting a token to an information faucet. By controlling the availability of tokens it is possible to control the access to information. For instance, if we allow for a number of copies of the same token to be made, several people will be able to access the information, perhaps simultaneously. Conversely, if we want to restrict access, we might only allow one instance of a token to be produced, and through some measures make it impossible to copy, thus letting the token act as the single “key” to the information in question.

We might also want to introduce some additional constraints on information access. For instance, a *combination* of tokens might be used to access the information associated with all the tokens simultaneously. A more interesting option is to use the combinations as such to form criteria for information access. For example, if two tokens represent work in a joint project, certain aspects of that work might only be accessible when both tokens are presented simultaneously, much like we might require more than one key to open a door.

Depending on the present purpose, information access might be constrained by physical *location* as well. For example, some information might only be applicable at a given location (e.g. a building) and by using tokens that only work with local faucets any distribution beyond that location can be limited. Correspondingly, public information that is meant to be widely distributed will have to use tokens that do not pose such a limitation, but instead are applicable to variety of faucets.

Association. If the association of digital information with a physical token is unconstrained and at any time allows the user to re-associate the token with any other piece of information, we are close to the properties of containers. However, when using tokens it is more interesting to investigate different ways of constraining the set of possible associations. For example, we might want to restrict the associations of a certain kind of tokens to a certain kind of information, thus avoiding some confusions between the how the properties of the token are reflected in the information it represents. We might also make the associations fixed once and for all, making the connection between the token and a certain piece of information as static as possible. This would typically be the case in a public display system, say an interactive museum exhibit, where one would not want the users to be able to change the way information is associated with the physical objects on display.

Further, we might allow a user to associate more than one piece of information to a certain token. This we may call *overloading*. Overloading a token with information might have various effects. For instance, the token might represent different pieces of information at different locations or in different contexts, as is often the case with everyday objects. Alternatively, the user might be able to access several different pieces of information at the same time when applying the token to a faucet. In the latter case, the information might be displayed with a choice of which information to present.

4 A Sample System for Token-Based Access: WebStickers

As an example of token-based interaction, we have developed the WebStickers system [5]. This system is quite flexible, in that it uses the Internet for distribution of data, and thus we can use any computer with the appropriate (off-the-shelf) hardware as a faucet. The system allows users to couple identifiers in the form of barcodes to locations on the World Wide Web. Users are given a set of stickers with pre-printed unique barcodes, and can then attach the stickers to any object they want to use as bookmark. Users then use a barcode scanner to associate a barcode with one or more web pages, and are able to return to a page by again scanning the corresponding barcode. The idea is to allow users to take advantage of the properties of any object in their surroundings and use these properties as cognitive cues to the finding a certain web location.

The system is implemented as a database accessible via HTTP. In the database, identifiers in the form of unique character strings are coupled with URLs. An off-the-shelf barcode reader is used to scan barcode stickers, which are printed on sheets of adhesive stickers using a standard laser printer. A small client application on the user's computer monitors incoming characters from the barcode reader, matching identifiers with URLs by calling the on-line database, and displaying the corresponding web page in the user's browser. To create new associations, the user simply change the mode of the client program from *Goto* to *Learn*, and the currently displayed web page is associated with the scanned barcode in the server database. Using codes coupled with URLs in a database, rather than coding URLs directly into barcodes, makes it possible to create new associations or change old associations easily.

4.1 Modes of Interaction

The WebStickers system provides a basic form of access to web pages through tokens. There is currently no provision for more advanced access forms, such as those provided by combinations of tokens or based on specific locations. As for association, WebStickers currently allows totally free association between web pages and tokens, placing the responsibility of finding the correct token on the user making the association. This is reasonable considering the experimental nature of the current system, but in future versions it might be useful to introduce some restrictions. Introducing ready-made tokens for specific tasks might also be considered. (We already have one such ready-made token in the form of Post-It notes – see below.) WebStickers does allow for a form of overloading, by letting the user associate more than one web page with a single token. When such a token is accessed, the user is presented with an intermediate web page where she can choose from a list of URLs.

4.2 Types of Tokens

With WebStickers, we have been able to experiment with a variety of different tokens as representations of web-based information. Here are some examples.

Transient tokens. For web page bookmarks that are only meant to be kept for a short time, say no more than a few weeks, we have been using books of Post-It notes with pre-printed barcodes. After associating a note with a web page users can then scribble a comment on the note that helps them remember what web page the note refers to, and attach it to their screen, their notice board, someone else's door, etc. Post-Its are explicitly designed for short-term information, making them ideal tokens to represent transient web bookmarks. After a while the glue in the note will cease functioning and the note will fall off whatever surface it is attached to, at which time the user can select to transfer the bookmark to a more permanent location, or discard it completely.

Tokens with a direct digital analogy. Some WWW bookmarks have a direct counterpart in the real world. For instance, when referring to the proceedings from a conference, it is often more comfortable to use the physical book than to read from an on-line proceedings page. However, when a paper is to be e-mailed to someone else, when it is to be searched for specific terms, when we need to quote some sections, etc., having easy access to the electronic version is useful. We have been using the pre-existing barcodes on conference proceedings for coupling them to their on-line counterpart. Since a book of proceedings is an archival object, it will mostly be stored away on a bookshelf. When working with a book, the user will take it down and bring it to her desk, and now through the WebStickers association she can have immediate access to the corresponding on-line documents as well.

Tokens tied to a certain activity. We have experimented with using objects that are tied to a specific activity as bookmarks to related web pages. A Swedish-English dictionary has been associated with the web page of the Encyclopaedia Britannica, the thought being that when users are searching for a word this web page will come in handy if the physical dictionary is not sufficient. Similarly, a user has tied the cup used for drinking the morning coffee to the URL of the morning news (made available on the Internet by the national radio station), thus tying the activity of drinking coffee to listening to news updates.

4.3 Conclusions from the WebStickers system

By constructing a system for token-based access that allows a wide variety of tokens to be associated with a very large information space (the World Wide Web), we have been able gain experience in how virtual properties can be reflected in physical objects. We have found some very obvious correspondences, such as that between Post-It-notes and transient bookmarks, but feel that it would be useful to generalize the discussion of how to design tokens. In the following, some initial design ideas for future token-based systems will be given.

5 Fitting the Token to the Task

Since a token typically will need to have little or no inherent computational resources, many of the constraints posed on the design of ordinary computers will not have much effect. For example, a token will not need any display; it will not need to have a processor or a power supply; it will be much less sensitive to wear and tear, and so on. This leaves us with far more freedom to design and build the tokens according to other criteria.

The most important criterion will be to design the tokens in a way that clearly displays what they represent and what can be done with them, i.e. their *affordances* [3]. Matching the affordances of the token with the task it is designed to be used in, can be done in a number of different ways including the use of different materials, sizes and shapes. Since tokens are not self-contained but tied to information faucets, the interaction can also be designed to take other factors into consideration, such as the physical position or usage context.

Just like when designing graphical interfaces, care must be taken when designing tokens. For instance, often certain shapes or colors convey values or meaning specific to a culture, like the symbol of the cross does in Christian religions. Whether such cultural values should be used or avoided, will depend on the kind of information to represent and who are going to use it in what context. However, token-based interaction systems will be less loaded with predefined meaning if strongly established symbols are avoided. Below we will sketch some of the possibilities for how the properties of digital information can be reflected in the design of token-based interaction.

5.1 Materials

Tokens can be made in a variety of materials depending on what they should represent. Tokens that represent information that is only meant to last for a short while might be made of material that wears out easily. Consider for example the difference in paper quality between books and newspapers, and in the glue used on Post-It notes and postage stamps. Here, the lack of durability of the newspaper and the glue on the Post-It note are not faulty but intended, since they represent information which is only intended to be used for a short time. A book, on the other hand, is intended to be kept for some time, and a stamp should stay stuck on the envelope that it was attached to.

Similarly, tokens made in fragile materials can be used to represent information that should be handled with care. Tokens made in very heavy materials can be used to represent information that is not supposed to be transported very far from its current location. Tokens representing information that is to be used frequently by a certain user might take the form of jewelry or perhaps a belt made in some comfortable material.

5.2 Sizes and Shapes

Tokens can come in many different sizes and shapes depending on the purpose. For example: tokens that are meant to be passed between users should be graspable. Tokens that are private should afford hiding and must thus be small enough to fit into a pocket or perhaps into the palm of a closed hand. Very large tokens will be harder to move without attracting attention and thus suitable to represent information that is of public interest. If we have a large number of tokens that we need to store in the same place we might want to make them easy to stack or pile. They will then have to have a size and shape that afford this, meaning that tokens similar to cards or discs might be more suitable than tokens similar to marbles.

Further, the size and shape of the tokens can help restricting their use to avoid mistakes. Consider puzzles: besides the color of a piece, its shape determines where in the puzzle the piece can be applied. This is especially obvious in puzzles made for small children where each of the very few pieces fit into a certain slot. In the case of token-based interaction, using shapes that only fit in certain slots can be used to determine which information faucets are applicable. If the information the token represents is of a kind that only can be accessed in certain information faucets, the shape of the token can be made in a way that only will fit into proper kind of faucets.

5.3 Usage Context

Everyday objects are often used within a special context, and when moved out of that context their "meaning" tend to change. As an example, take the many knives used in a kitchen for different purposes, e.g. cutting bread, meat, fish etc. Sometimes they are stored in drawers in the kitchen. Now imagine what happens if we instead store them in another drawer in the apartment, say, where you usually store your socks or underwear. If someone found your kitchen knifes in your bedroom drawer, he or she would definitely react differently compared to if he or she had found them in the kitchen. Thus, the very location of tools and objects can convey meaning. This should be acknowledged when using tokens for interacting with computers, by means of for example how to constrain access to (e.g. *location* and *combinations* of tokens) and associations (*overloading* tokens) with information.

Thus, we have seen how a wide variety of virtual or digital properties can be reflected in the design of the components of a token-based access system. We have in this paper only been able to sketch the outlines of these possibilities, and many practical design experiments and evaluations will be needed before any firm conclusions can be drawn or any solid design specifications can be given.

6 Conclusions and Future Work

We have attempted to show that token-based access to digital information is a valid interaction paradigm that can be used to support access to information in a distributed computing environment. Token-based access systems differ from container-based systems in that they imply a stronger coupling between physical and virtual data, i.e. the properties of a token should reflect the properties of the data it is associated with. This makes it possible to design tokens that provide users with a strong cognitive support for accessing information in distributed systems. It also opens many possibilities for building in aspects of the user interaction into the token itself, rather than having these solely confined to the virtual domain. For instance, by designing tokens with certain physical properties, say tokens that are easy or difficult to share between users, it is possible to have some desired affordances physically reflected in the token.

For future commercial applications, we can see many situations where it would be more convenient to use token-based access than a physical carrier of information. The music business is currently a good example. With forays already being made into distributing music on the Internet using the MP3 format, in the future it might be feasible that rather than buying a music carrier such as a CD or DVD, consumers will purchase a small token representing a recording. By bringing such a token to a suitable player (faucet), the user can then listen to the music associated with the token. Unlike a CD, the token would never run the risk of being scratched, and through encryption of unique IDs on each token, music companies can make sure that their music is protected. Technical realization of such a system is already possible [10].

As we have seen, several systems for token-based access to digital information have already been realized in research labs, and several systems have also been constructed where physical containers and tools are used to distribute and manipulate data. This serves to prove the technical validity of such systems, and technology for tagging and sensing objects is already good enough to construct useful applications. However, neither this paper nor most previous work has been able to more than touch on some of the most important aspects of token-based access.

In particular, matters concerning security, privacy and rights concerning information associated with tokens need to be considered. Can valuable information be safely made available on public networks without the risk for unauthorized access? Should tokens be possible to copy, and what will then happen to the information and associated access rights? Who should have the right to modify materials associated with a token, and who should be allowed to modify the associations themselves? In the experimental applications, the impact of such decisions has been limited, since the systems have been used only to a limited extent and by a limited audience of mainly expert users, but in the future these questions may come to have a serious impact. The validity of token-based access to digital information is probably more dependent on the resolution of such issues than any technological hurdles.

Before general token-based systems break into the mainstream, we will have to take these matters into consideration, and will also have to refine the way such systems are designed, improving their properties from a user perspective. In this paper we have sketched some initial possibilities for tokens-based access to digital information, but much more work needs to be done in this area. This work must be guided by experiences in disciplines such as user-interface design, industrial design and ergonomics, making for a truly cross-disciplinary challenge. We believe that with the correct approach, systems offering token-based access to digital information can prove very useful in the development of future distributed computing environments.

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