Visualizing Computational Wear with Physical Wear

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Abstract. Wear is an important source of information supporting our tasks in everyday life. This paper presents the idea of using wear as a new visual attribute for visualizing the computational wear of digital objects, which is defined as a set of attributes resulting from the history of user interactions on the digital objects. As a case study to investigate the feasibility of the proposed idea, we succeeded in visualizing the computational wear of WWW sites with the icons of physically worn appearance.

1. INTRODUCTION

The term wear generally refers to the smudge, tear and damage of objects resulting from constant use. Although we may not be aware of it, wear is a real important source of information in our everyday life. Through wear, histories of our use of items are perceptually available to us in ways that inform and support the task we are doing. The following paragraph is quoted from the paper presented by W. C. Hill, et al. at CHI'92[Hill92].

"Consider some serendipitous uses of wear that everyday life presents. The bindings of cheap paperbacks bend and crack in a manner that allows one to find the last page read. In an auto parts store, the most often consulted pages among many linear feet of catalog are identifiable by smudges, familiar tears, and loose pages. The smudges, tears, and loose pages index to information users are likely to consult. The polished part of a patinaed brass door handle shows where others succeeded in grasping it. The best recipes cards in a stack are often dogged-eared and stained. Weaver describes a rediscovery of the law of first significant digit distribution due to odd smudge patterns on logarithm tables."

These examples tell us such the physics of the world - use leaves wear and wear tell us how to use. W. Hill et al. adopted wear as an important user interface metaphor and introduced the concept of computational wear of digital objects[Hill92,Hill94]. They defined the computational wear of a digital object (e.g. reports, forms, source-code, manual pages, emails) as the history of user interactions with the object. Recording on objects the interaction events that comprise their use makes it possible on future occasions, when the objects are used again, to display graphical abstractions of the accrued histories as parts of the objects themselves. They applied the idea of computational wear to the domain of document processing and proposed a technique called attribute-mapped scroll bars to visualize the wear of documents[Hill92]. With the attribute-mapped scroll bar technique, wear of a document, such as the times a document has been edited or read, appears to users as marks mapped onto the document scroll bars in positions relative to line positions. The length of the mark depicts the magnitude of the wear.

In this paper, we present the idea of using the physical wear as the visual attribute for visualizing the computational wear of digital objects. Rather than the history itself, we define the wear of a digital object as a set of attributes resulting from the history of user interactions on the object. While the physical wear in our everyday life is visually perceptible as the changing in appearance of objects, the computational wear of digital objects, by its definition, is a sort of abstract information. Whether or not users can benefit from the wear information depends largely on how we portray it to users. Fortunately, in most existing user interface systems, digital objects themselves are visually presented as graphical objects based on some metaphors of real world. For example, files and the collection of files are represented as icons of documents and file folders in a desktop metaphor based Graphical User Interface(GUI) system. Our idea is to map the computational wear of digital objects to the wear of the corresponding graphical objects. In other words, we change the appearance of the graphical objects to visualize the wear of the digital objects in a similar way as the real objects change their appearance due to the repeated use of them. Taking the file as the example, we can add finger-marks onto an icon to represent a frequently accessed file or use a rusted metallic-like icon to indicate an aged file never been updated recently. By introducing this wear metaphor in visualizing the abstract information of computational wear, users can directly perceive and use the affordance of wear in the computerized environment and directly import their knowledge of everyday life for using wear to support their interactions with digital objects.

To investigate the feasibility and effectiveness of this idea, we performed a case study on visualizing the computational wear of World Wide Web(WWW) site with physically worn icons. The computational wear of a WWW site is a set of attributes related with the history of how it has been visited and maintained, such as when it was created, how often it was updated or visited, and when it was last updated or visited. A frequently updated site usually contains the latest information and worth being visited. On the other hand, access frequency is a popular method for ranking items of interest. Therefore such kind of WWW site wear information should be useful in supporting users' internet surfing task. To implement the proposed technique, we created an experimental page recording and visualizing the wear information of all registered web sites. On the page, the link to each registered site is shown as a metallic-like texture mapped banner icon. The computational wear of a site is visualized as the rust and smudge of its banner icon. Seligmann and Bugaj[Seligmann97] proposed a similar idea of using physical worn appearance of real paper to visualize the abstract wear information of a web page in their technical sketch presented at SIGGRAPH97. But the detail of the method and the result was not given.

The remaining part of this paper is organized as follows: Section 2 presents the basic idea of using the metaphor of physical wear in visualizing computational wear of digital objects and introduces some related works. Section 3 is the details of the case study. Section 4 concludes the paper while indicating some future research directions

2. WEAR METAPHOR FOR VISUALIZING COMPUTATIONAL WEAR

One common approach of information visualization techniques is to organize and present information in a familiar framework of concepts that are already understood. Such a framework is called metaphor. The most successful example of user interface metaphor is the well-known desktop metaphor. With the use of the desktop metaphor together with the menu-driven direct manipulation

GUI, users can easily use their knowledge about the real office environment for accessing the computerized environment. However, we found that the design of most existing desktop metaphor based GUI systems ignore an important attribute of digital objects, that is, the wear of digital objects. Here we define the wear of a digital object as a set of attributes resulting from the history of user interactions on it. While in the real world, documents and file folders usually getting smudged or torn out after being repeatedly used, the document and folder icons in an existing GUI system never change their appearance with the use of the corresponding digital objects. In the real office environment, wear is always an important source of information supporting the daily tasks of office workers. For examples, to find a frequently referred document, he/she may naturally lead his/her hand to pick up a relatively worn file folder first, as the frequent use of the folder tend to make it smudged and soiled. Also, to find a recently used document, a worker will not check the stack of documents covered with heavy dust, and to search for a recently created document he/she will skip those documents whose papers are already deteriorated. Therefore, if we can make the graphical abstraction of digital objects, such as the document or file folder icons, change their appearance according to the wear of the digital objects in a similar way as the real objects get worn out in the real world, then users should be able to perceive and use the affordance of wear on the GUI and directly import their prior knowledge of using wear in the real world for effectively interacting with digital objects. Figure 1 shows an example where the age of files is visualized as the deterioration, and the access frequency is visualized as the smudging of icons. The icon for the well-accessed folder "*dairy*" has smudged and the icon for the document "*test2.doc*" has the finger-marks at the corner readers tend to touch with their fingers. The icon of the old file "*memory.doc*" has stained to be of yellowish.

Figure 1: Adding wear effect to desktop metaphor based GUI

Graphically portraying the wear of digital objects to users is not a new idea. To our knowledge, W. C. Hill and his colleagues are the first group who recognized the importance of wear. As we mentioned in Section 1, they have proposed their attribute mapped scroll bar for visualizing the wear of documents[Hill92]. The File System Navigator(FSN) system[Tesler92] developed by Sillicon Graphics use a landscape metaphor to visualize the file hierarchy. Each file is represented as a 3D box and the size and age of a file is visualized with the size and color of the box. What makes our approach differ from those previous methods is the visual form onto which the computational wear is mapped. Instead of those traditional graphical attributes, such as shape, size or color, we propose to use the physical wear it self as the visual attribute for visualizing the computational wear. With this new method, users can easily perceive the affordance of wear and make use of it even without explicit awareness of doing so, just as what they are always doing in their everyday lives.

3. CASE STUDY: VISUALIZING WWW SITE WEAR WITH PHYSICALLY WORN ICONS

3.1 Computational Wear of WWW Site

The explosive growth of WWW has demonstrated the need to organize, filter, and present information in ways that optimize users' information gain in their limited time. A number of novel information visualization techniques related with WWW have been developed and most of them focus on the visualization of either local or global structure of information provided on WWW[Card96,Andrews95,Hendley95]. Instead of the information provided on WWW, we present, in this case study, a technique for visualizing the wear information of web sites. Here, the wear of a web site is defined as a set of attributes resulting from the history of maintaining and using the web site. Why visualizing such wear information is important? Consider the situation a user trying to find the cheapest airline ticket on WWW for his/her new year vacation. Either hierarchical or key word based search on an existing WWW search engine such as Yahoo[Filo94] results in a large number of sites related with the discount airline tickets. Is there any other information except for the limited information provided by the titles and short descriptions of sites can he/she used for avoiding browsing through all these sites? The answer is no. However, suppose the last updated date of each site is also presented to the user, then he/she can skip browsing all those sites which have not been updated for the past six months, since the airline fare for the new year must have not been announced by airline companies at the moment the sites were last updated. Also a frequently visited site usually has the high possibility to provide tickets of reasonable fare. So if the user has limited time, he/she would like to use this access frequency information for deciding the priority of candidate sites being visited. Moreover, if the above last updated date and access frequency are presented to the user graphically, then he/she can easily perceive the difference among the sites and make his/her decision quickly. The above scenario tells us that although the wear of web sites is not the target information a user wants to gain, but graphically presented wear information can be useful in helping the user to raise the efficiency of information gaining on WWW. Although we define the wear of a web site as a set of attributes resulting from the history of maintaining and using the web site, the detailed attributes can be chosen application and task dependently. In this case study, we visualized the following three attributes.

Last update date.
This attribute gives a measure to the usefulness of a web site. A newly updated site usually contains latest and timely information.

Total access times.
Total number of user access gives the measure to the popularity of the site. A well-accessed site usually contains useful information.

Last access date.
Measure the recent popularity and also the usefulness of a site.

3.2 Mapping to the Physical Wear

As we mentioned in the beginning of this paper, the term wear refers to the smudge, tear and damage of objects resulting from constant use. In this paper, however, we would like to use the term wear in a broader sense to include also the weathering, which is the deterioration, decay and change in appearance of objects due to the physical and chemical conditions of surrounding environment. The rust of metals and efflorescence of stones are the typical examples of weathering. The accumulation of dust can also be considered to be a kind of weathering from the point of view that it is caused by the physical condition of the surrounding environment. Through the weathered appearance, people can guess the age of an object and understand the environment the object has been placed. Moreover, as constant and careful maintenance usually can slow down the speed of weathering, we can also get some information on how an object has been maintained from its weathered appearance. Therefore we suggest to map those attributes related with the ages and maintenance of digital objects to those visual effect of physical weathering, while using the visual effect of physical wear in the narrow sense to visualize those attributes resulting from the history of user interactions with digital objects.

In this case study, an experimental web page is created for recording and visualizing the computational wear of all registered web sites. The page consists of metallic-like icons for the links to the registered web sites. The three chosen attributes, last update date, total access times and last access date of each site, are mapped to the wear of the icon in the following ways:

Last update date
The last update date of a web site is visualized with the rust of its metallic-like icon. The length of the period from the last updated date to the current is mapped to the magnitude of the rust. When a site is newly updated, its icon has a new and shining appearance as shown in Figure 3(a). Then as the time past over, the icon gets rusted gradually (Figure 3(b) -> (c)->(d)) to reflect the aging of the site.

Figure 3 Visualizing last update date with the rust of icons.

Total access times

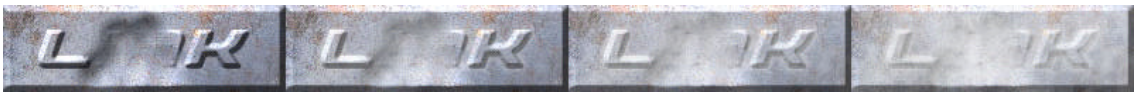
The total number of use access is mapped to the wear and smudge of the icon. Here we mimic the wear of a physical push button caused by constant use. The part of a button frequently touched with users' fingers is usually worn out and smudged with finger-marks. As shown in Figure 4, icon (d) represents a well-accessed web site and the total access times decreases from icon (d) to (a).

(a) (b) (c) (d)

Figure 4: Visualizing total access times with the wear and smudge of icons.

Last access date

The length of the period from the last accessed date to the current is mapped to the amount of dust accumulated on the surface of the icon. This is again a mimic of the real world - the surface of an object not been used for a long period is usually covered with dust, and a recent use of the object will clean away the dust. Figure 5 shows the four icons representing the web site of different last access date. Figure 5(a) is the latest accessed site and the last access date getting older from Figure5(a) to (d).



(a) (b) (c) (d)

Figure 5: Visualizing last access date with the accumulation of dust on icons.

3.3 Implementation

3.3.1 Creating icons

Recently, for the purpose of realistic image synthesis, several techniques have been developed for modeling and rendering the wear and weathering phenomena[Dorsey96,Dorsey99]. Although these recent research results demonstrate the possibility to establish a direct mapping between the numerical description of computational wear and the graphical representation of physical wear, automatic generation of worn appearance seems to be still difficult, especially when several effects need to be added together just as in our case. Currently, all the icons are manually generated with Adobe Photoshop 5.5. Each icon is mapped with a texture which is the composition of rust, wear and dust layers. Since the rust is the change of material, it is the lowest layer. On the top of the rust layer, the worn and smudged appearance is added and finally the layer of dust is added. With four different levels for each attribute, we totally generated 64 icons and store them in a lookup table of size 4.4.4 (Figure 6).

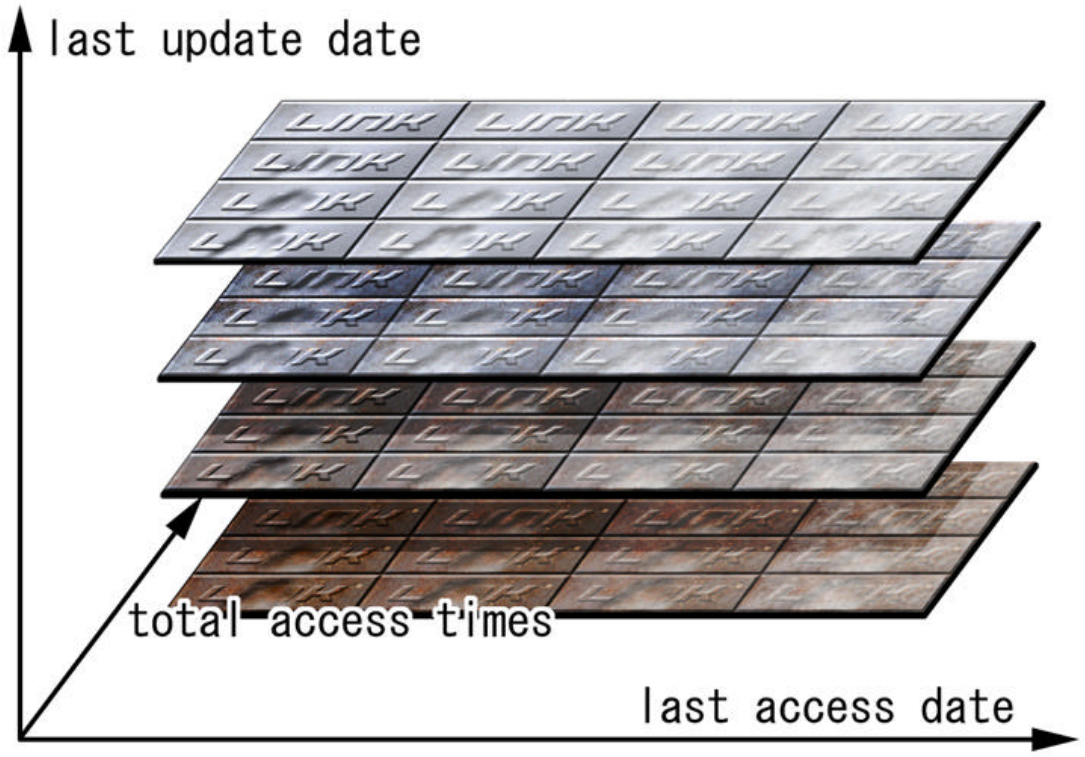


Figure 6: Lookup table of pre-generated icons.

Figure 7 depicts the visualization pipeline. At the center of the system is the Visualization Server which is implemented as a CGI program written in Perl language. The URLs and the wear information of all the registered web sites are maintained in the Registered Sites Database. The Visualization Server keeps retrieving the information from the Registered Sites
Database at some specified time interval and choosing corresponding icons from the Icon Lookup Table based on the wear information of the registered sites. Those icons are then displayed on the Visualization Page together with other text information about the sites(See Figure 8). The total access times and the last access date of a registered web site is updated by two Perl programs - Total Access Times Modifier and Last Access Date Modifier, respectively. These two programs modify the total access times and the last accessed date information in the Registered Sites Database when a web site is newly visited. The execution of the programs can be started from the visited web site by embedding the URLs of the programs into the HTML file of the site as the *img* tag or other tag. This method, however, requires the cooperation from the owner of the web site. Currently, both of the two programs are started from the Visualization Server when a registered site is accessed from the Visualization Page. The last update date of each registered web site is obtained by visiting

each site constantly and extracting it from the *Last-modified* entry in its HTML data. This is realized by executing the Last Update Date Modifier program from the Visualization Server.

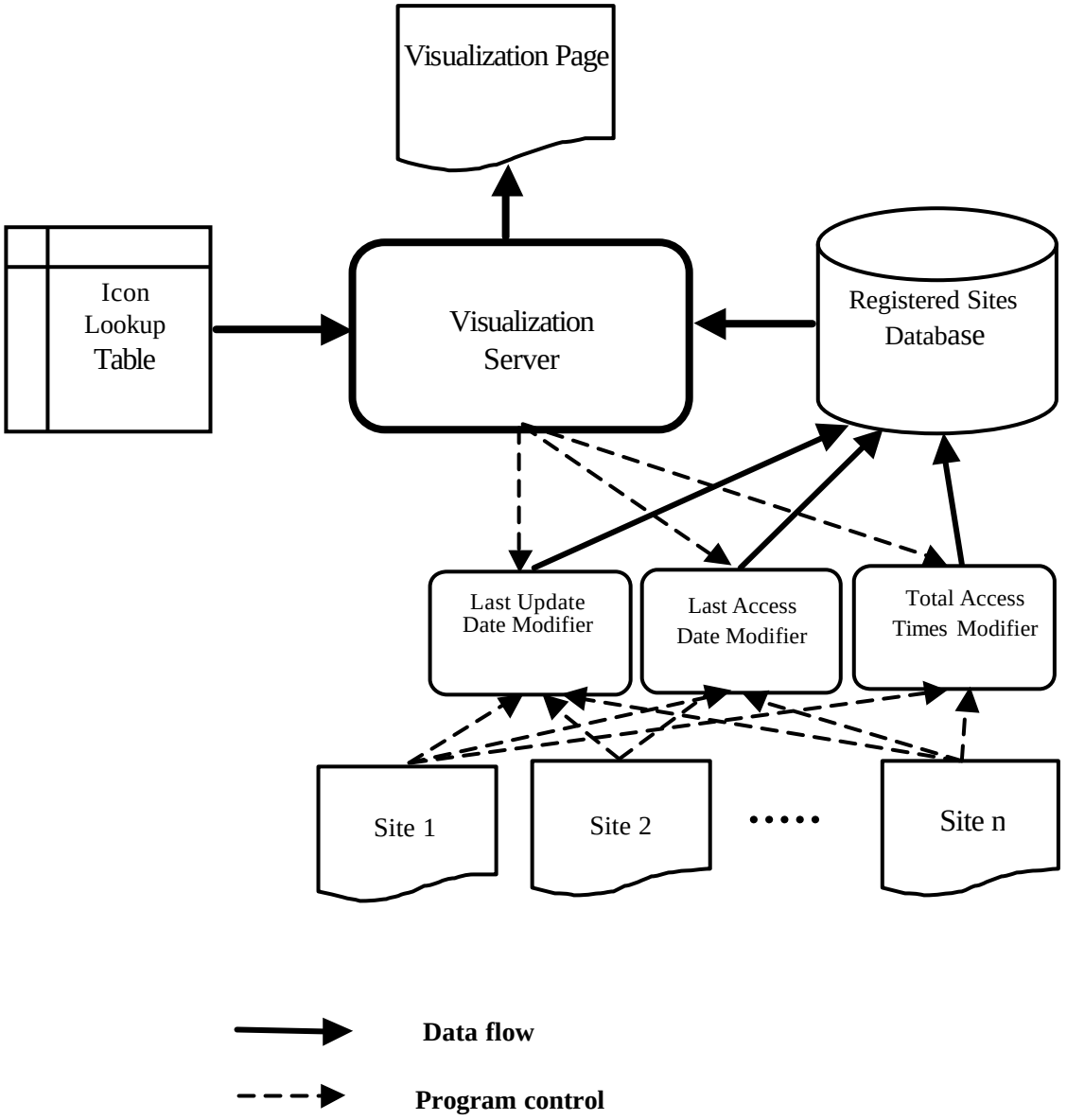


Figure 7: Visualization pipeline of the experimental site.

Figure 8 shows a snapshot of the Visualization Page. The link to each registered web site is graphically presented as a worn icon. A mouse click on an icon will jump to the corresponding web site. The way to quantize each of the three attributes into 4 different levels can be specified interactively with the input menu provided on the top of the Visualization Page. Through the worn appearance of icons, we can easily get the information such as, the first site entitled “site1 HOME” is

a newly updated page, the site “Xiaoyang Mao Associate Professor” is relatively well accessed but has not been updated for a long time, the site “site02 HOME” has been well accessed, and the old and rarely accessed site “Soryu Winwery” has not been visited for a long time.

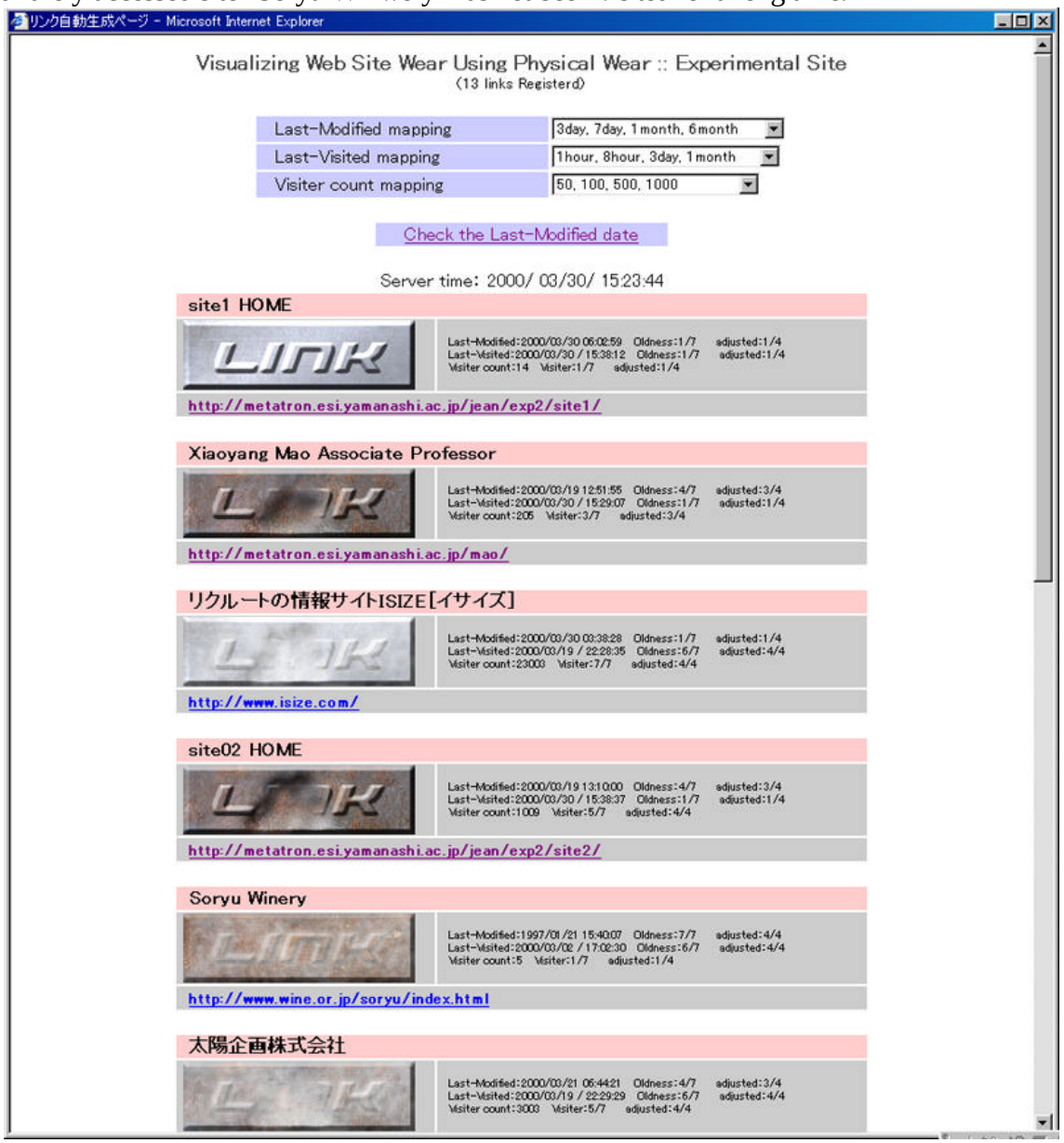


Figure 8: Visualizing Web site wear with worn icons.

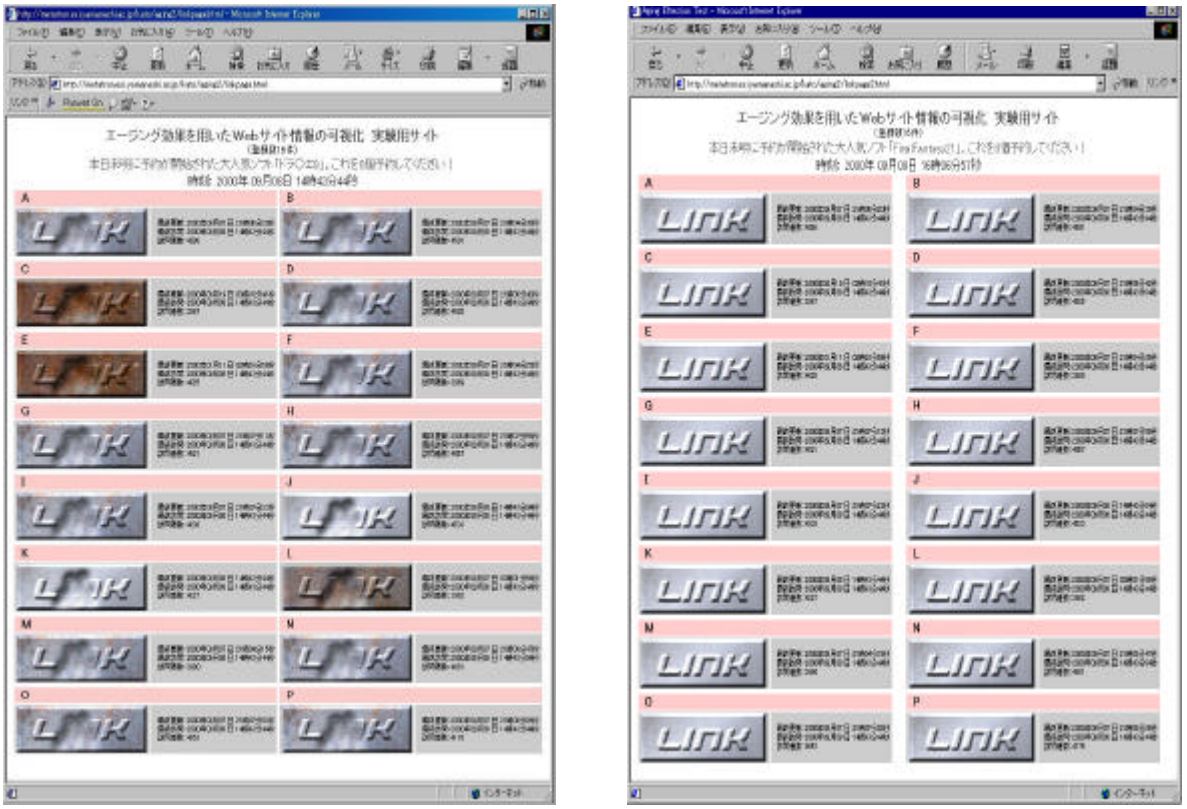
The Visualization Server presented here is a small test site simulating the existing WWW site search engines and hence the proposed mechanism for visualizing the wear of registered web sites can be easily integrated into those existing search engines.

3.4 Evaluation Experiment

We conducted an experiment to test whether the visualized wear information is useful for the search task on Web pages. In particular, we compared the completion time required for the online ticket reservation task performed on the following two functionally identical portal pages containing the links to the Web sites of ticket suppliers:

Case 1: visualized portal page (See Figure 9a):
The last update date, total access times and last access date of each site is graphically presented with the physically worn icon in the way described in Section 3.2.

Case 2: not visualized portal page (See Figure 9b):
The last update date, total access times and last access date of each site is not visualized and each site has the same icon.



(b)

Figure 9: Two portal pages used in the experiment. (a) The wear information of each site is visualized with a physically worn icon. (b) Icons of the same appearance are used for all sites.

In either case, a subject can find the last update date, total access times and last access date from the text displayed right to the icon. During the experiment, subjects were asked to order total eight tickets by accessing the web sites of ticket suppliers through the portal pages. To simulate the real

online ticket reservation system, the stock of tickets at a site is reduced or supplemented randomly at a random time interval. The total times of access increases when a site's ticket stock is reduced and the last update date of a site is set to the time when its ticket stock is supplemented. The environment was built on MS windows 98. 12 subjects, with 6 for each case, participated in the experiment. They are graduate and undergraduate students, All of them are used to the internet surfing. Each subject received a brief introduction to the task and the meanings of the wear information visualized on the icons. There was no practice session. For each case, subjects performed one block of trials. A block completes when the subject successes in reserving 8 tickets. Figure 10 compares subjects mean trial completion time for Case1 and Case 2.

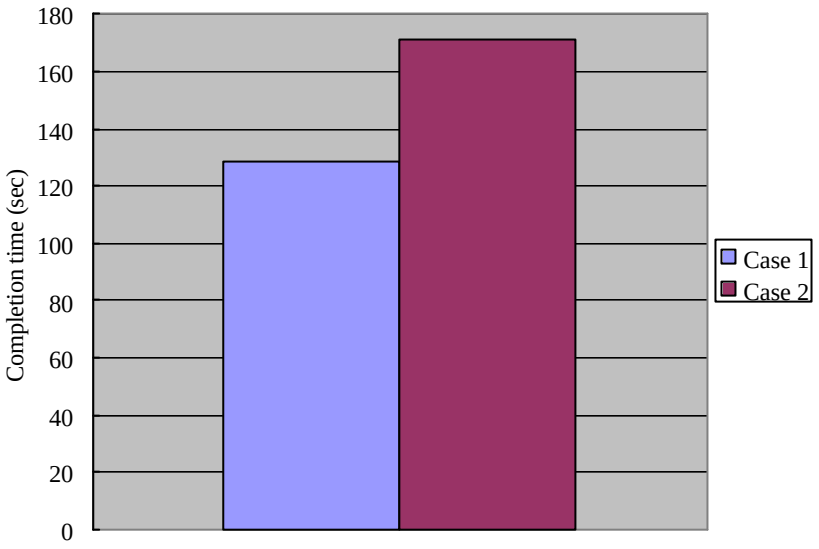


Figure 10: Mean trial completion time for Case 1 and Case 2

Repeated measures analysis of variance with trial completion time as the dependent variable was conducted on the data. A significant main effect was found for the interface used ($t(10)=2.2723$, $p<0.05$). That is, over all, the visualized portal page was 25% faster than the not visualized page.

4. CONCLUDING REMARKS

We have presented a idea of using the visual effect of physical wear for visualizing the computational wear of digital objects. To explore the feasibility of the idea, a case study on visualizing the wear information of WWW sites with worn icons has been performed. In the real world, the histories of our use of items are perceptually available to us through wear in ways that inform and support the task we are doing. By using the wear as the metaphor in visualizing the abstract information, users can directly import their knowledge of everyday life to the computerized environment and making use of wear in supporting their interaction with digital objects.

Currently we are still undergoing further evaluation of the effectiveness of the presented technique. We need to compare our physical wear metaphor based visualization method with those methods

mapping the computational wear to the traditional visual attributes such as size, color and shape. Although the digital objects chosen here are WWW sites, the proposed technique can be easily extended for visualizing the computational wear of other digital objects, such as documents, programs, emails, and so on. Combining the wear with other information visualization metaphor can widen the application fields of the technique. Currently the icons used in the case study are manually generated. Developing techniques for automatically mapping abstract information to wear appearance is another important future research direction. Recent progress of image synthesis technology in the realm of computer graphics may bring the hope to the real.

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