

Code: CHI-NID

Tangible Linker: organizing and accessing digital contents using untagged tangible objects

*Ho Ying Wong, Shin Takahashi and Jiro Tanaka
*Department of Computer Science, Graduate School of Systems
and Information Engineering, University of Tsukuba
1-1-1 Tennoudai, Tsukuba City, Ibaraki 305-8573, Japan
{hoying,shin,jiro}@iplab.cs.tsukuba.ac.jp*

Abstract Retrieving digital contents consists in some searching operation, which requires some memory effort and can be challenging due to the large amount of contents stored by users. Bookmarks and shortcuts are commonly used to ease the process however in a short term they show the same inconveniences above. We propose a novel solution based on tangible media for mapping multiple digital contents using untagged physical objects. Users can map different kinds of related digital contents, regardless their sources, with physical objects and access directly the desired contents without requiring any search operation. Objects in our system require no modifications; instead we use computer vision for object detection and recognition using a conventional web camera. In our implementation, when an object is placed in front of the screen it becomes part of the computer desktop and can be used to retrieve information. We performed an evaluation experiment and results of the evaluation showed that most users found the system easy to use and the interface intuitive.

Introduction

Modern personal information management (Lansdale, 1988) occurs frequently in computing environments. In such environments, to retrieve digital contents users must reach the content by means of some searching operation, which requires memory effort and turns challenging due to the large amount of contents required for daily work. The conventional solution is keeping bookmarks and shortcuts icons for relevant contents under the WIMP (windows, icons, menu and pointing device) paradigm. This paradigm had gained a remarkable degree of commonality. However, due to the rapid evolution of computer devices, demand for novel interaction paradigms has also increased.

One of such new interaction approaches is by using tangible interfaces, which enables users to interact with computers using physical objects. It is in human nature the skill to sense and manipulate the physical environment (Ishii, 2008). Therefore we can take advantage of this ability by giving physical attributes to digital information, making it manageable in the physical domain. Previous studies had defined 3 types of physical objects to represent digital information: container, tokens and tools (Holmquist, 1999). In particular case of token-based interaction, physical objects are used to access stored information and the nature of which is physically reflected in the token in some way. The objects do not contain the information but act as trigger to show the information through a display device. Several previous works employ electronic tagging to link digital information to physical objects. Such tagging could be computer-readable digital tags like barcodes (Ljungstrand, 2000; Siiio, 1999) or RFID technology (Want, 1999; Bernheim, 2005; Wellner, 1991). This kind of system allows association mostly of a single content per physical object.

In this paper we propose a novel solution based on tangible media for mapping multiple digital contents using untagged physical objects. Since tags are vulnerable to physical damage, deterioration in

time and cause visual occlusion to object appearance, we use instead computer vision for object detection and recognition. This way, any physical object around the user can become an interactive object without restrictions as represented in Figure 1. In addition, considering the immediate information needs where user requires a few subsets of the total contents to be readily available, our system allows users to map different kinds of related digital contents, regardless their sources, with physical objects and to access directly the desired contents without requiring any search operation. The main contribution of this work is to empower physical objects around the user, without any modifications, to become an interactive element in a tangible interface approach. To demonstrate the concept we implemented and evaluate a prototype system called Tangible Linker to organize digital contents using physical objects.



Figure 1: Objects in the surrounding can represent personal information.

Related Work

Physical browsing (Valkkynen , 2005) describes the possibility of digital information management through physical objects under an ambient intelligence scenario. IconSticker (Siio, 1999) presents a metaphor of this concept, by giving a paper representation to digital contents. It consists in transferring the icon on user computer desktop to paper, by converting them into barcode representation and printing them out on stickers. These stickers then can be attached to any physical objects. Access to the icon consists in scanning the barcode on the sticker.

WebSticker by Ljungstrand *et al.* (Ljungstrand, 2000) and AURA by Bernheim *et al.* (Bernheim, 2005) both propose the usage of barcode to represent online information. WebSticker shares the same analogy with IconSticker, while AURA takes advantage of already existing barcode on surrounding objects. They use handheld device with barcode reading function to capture the input and display related information. These mentioned systems are based on visual tagging to identify the object. Other than barcodes, Want *et al.* (Want, 1999) proposes to augment everyday objects via embedded RFID tag.

Compared to previous works, although tags provide higher recognition accuracy, in our system we want to avoid all kinds of computer readable tags and other object modifications to simplify the interaction. Therefore we choose to use computer vision to detect and recognize user objects as they are. Also different from previous works, we combine icons, web links and other digital references into a common launcher, where a single object can represent many references.

System Overview

We propose a novel method to organize and access digital information using physical objects as references containers. Multiple associations between objects and contents are allowed: an object can be associated to many contents and vice versa. In our system, physical objects do not contain physical memory nor tagged. The associations between digital information and the objects are saved in the computer.

The interaction starts when the user places an object in front of the screen (the capturing area). This

setup gives the impression of the object being another part of the graphical user interface, seemingly to extend the digital desktop into the physical world and vice versa. To store a reference into an object, the user places the object in front of the screen, as shown in Figure 2(a), and drags the reference toward the direction of the object regarding to the coordinates system of the screen, as shown in Figure 2(b).

Next time, when the same object is placed in the capturing area, the system automatically recover the list of references and display them on the screen next to the object, as presented in Figure 2(c). User then can access these references by clicking on the link. In Figure 2(d), the user selected a music list file and it is opened in the default music player application. Once the user finished using the object, removes the object from the capturing area and the interface will close automatically (see Figure 2(e)). Additionally the user can hide or control de opacity of the interface and drop in area marker, delete associations and ask the system to trigger automatically the references. As there is no physical memory on the objects, the capacity is only limited by the computer hard drive.

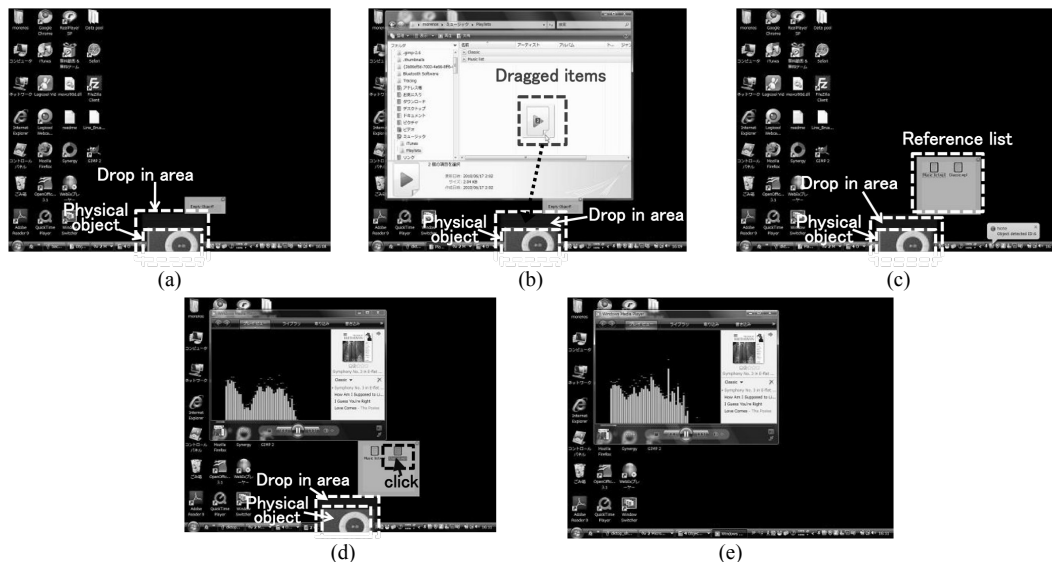


Figure 2: General operation of Tangible Linker. (a) An object is placed in the capturing area, (b) user drags 2 music list files toward to object and drop them in the drop in area, (c) when the object is detected again, the reference list will be shown automatically, (d) user clicks on the reference to open the content, (e) the object is removed and the drop in area along with the reference list disappear from the screen.

Implementation

The prototype of Tangible Linker was implemented in Microsoft Windows platform. Current version tracks drag-and-drop operations from two applications: the file explorer and Firefox Internet browser. The object recognition module was implemented in Visual C++ 2008 and OpenCV image processing library. The graphical user interface was implemented in Visual C# 2008. We used a Logitech uncalibrated web camera for input image capturing. In current version, the objects and corresponding references database are stored locally.

Background subtraction

We use a web camera to capture images of the object placed in front of the computer screen. To simplify the background subtraction, a polarized filter lens is used to cut down the light emitted from the screen. Additionally, we choose the recursive technique Approximated Median Filter (Cheung, 2004) to model the background. It has the advantage of no buffer for previous frames is required, it recursively updates a single background model based on each input frame.

Object recognition

To model the input object, a set of features is extracted from the object image: 1) Gaussian color distribution (mean vector and covariance matrix) from the HSV color space, 2) color histogram on hue and saturation channels of the object image (also in HSV color space), 3) Size proportion of the contour formed by the object image pixels. The first two metrics determine the color distribution of the object and the last one determines the approximate size of the object regardless of rotation. These features are kept in an object database. Using a likelihood function, a newly detected object is compared with those already known for recognition. Once an object is detected and recognized, the user then can associate and retrieve information from this object.

User interface

In our system, the desktop screen area remains as the interactive space. Nevertheless, it is extended seemingly to the real world: when a physical object is placed in front of the screen, it becomes part of the desktop environment acting like an interactive element. The screen portion occluded by the object (drop-in area) represents the physical object on the desktop environment. It serves in addition as a destination spot for ordinary drag-and-drop operations supported by the operating system. Therefore, when the user selects one or multiple items, it is possible to drag-and-drop them into the drop-in area to map those digital items into the object. When the mapping is succeeded, both sound and visual feedback are given. Mouse clicking the drop-in area shows the list of mapped items. Upon removal of the object from the screen area, the drop-in area will disappear. For information retrieval, the user simply places back the object to access the list of mapped digital items. Both mapping and retrieving digital information operations do not imply any extra workload to user (generating and attaching barcodes or RFID tags, scanning the tags, etc).

Experiment

The aim of our experiment is to find out end user's opinion about using any physical object to access digital information, study their behavior when mapping information to physical object to and the intuitiveness of the system as a possible future interaction solution.

Methods

A total of 14 participants joined the experiment, ages ranged from 21 to 37 years old. 11 participants are expert computer users and the remaining 3 have basic operation skills. The experiment was conducted individually. It started with an explanation of the system and a small demonstration of Tangible Linker and the available functionalities. Then participants were asked to perform a predefined task using the system. The task consisted in classifying and retrieving digital contents from a pool of 35 files of various types (documents, images files, URL, etc) and topics (math, computer science, travel, restaurants, services, etc). They had to classify the information under any criteria most suitable to them to be recovered afterwards. Both classification and retrieval were achieved using our system. We provided a set of daily physical objects for the experiment, but we encouraged the participants to use their own objects. Each participant decided the final subset of objects used in the experiment and the respective mapping of contents. The experiment allowed us to observe user's habit of sorting and storing information that require later recovery. Most importantly, let the user experience a system that is completely different to conventional WIMP interface. To evaluate the system, after contents mapping was completed, we asked the users to retrieve 12 particular contents using the physical objects. Also we applied a questionnaire to collect users' opinion based on their experience.

Results

A 10 minutes training was given before the experiment. No participant requested trial attempts before the experiment. Most of the participants showed excitement about using any available physical object to interact with the computer.

Different criteria were used to classify the files but mostly they sorted by file type. The number of

objects used for the experiment varied among 5 to 7 items to map the whole digital data pool. Some participants showed concern about forgetting where they have stored some specific information. During the retrieval phase, when this problem was presented, they tried to associate the requested information according to their own visual perception of the object and most of the times it was a correct retrieval (a hit): as presented in Figure 3, 144 out of 168 attempts (14 users, 12 retrievals each) they were able to recover the requested information at once. Only once a participant had to try 5 objects and once for 6 objects to retrieve the requested information.

Table 1 shows their opinion about some aspects of the system based on their experience for the appointed task. In general they found the system easy to use, the set of commands intuitive and do not require memorizing specific actions. The view of the object in front of the monitor gave them the impression that the object was part of the desktop. However more verbose user feedback was recommended since this is an unconventional interaction approach. Some participants argued that the experiment task did not reflect their ordinary working scenario and found the tool not suitable for the task. However they expressed interest in using it for other purposes, for example to classify their files by job, others suggested using it to manage photo albums and music lists.

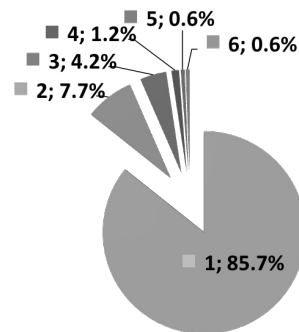


Figure 3: Number of attempts to retrieve requested information, 144 from 168 retrievals were succeeded in the first attempt, which is 85.7% of retrieval experiment. Only once a participant had to tried 5 and 6 objects to retrieve the requested information.

Table 1: User opinion about the usability of Tangible Linker, average value (and standard deviation) on a 5 points scale.

Questionnaire item	Average (std. dev.)
Is the method intuitive to learn?	4.93 (0.27)
Is the software easy to use (mapping, removal and retrieval)?	4.40 (0.42)
Are the additional functionalities useful	3.44 (0.80)
Is the software efficient for the experiment task?	3.93 (0.92)
Do you consider the software useful?	4.29 (0.99)

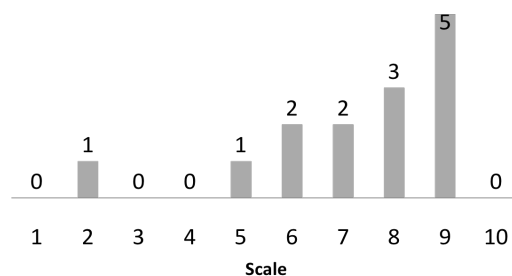


Figure 4: General opinion about Tangible Linker in a scale of 10 levels, 1= poor, 10=excellent.

We also asked their degree of satisfaction using the file system browser and favorites folder of a web browser (bookmarks) in comparison to our system. The average score (out of 5 points) and standard deviation for the file browser was 3.57(1.22), for the bookmarks was 4.29(0.91) and for

our system 3.79(1.05). While users liked our interaction system, they prefer bookmarks for their immediate availability. Some participants found it tedious to get into many directories when access a file. Our system can help them to avoid this problem without accumulating icons on the desktop environment.

Figure 4 shows the general opinion about the system. We got positive feedback with the exception of two cases (mark 5 and 2). The lowest mark belonged to a participant who considered the system should run over the Network, enabling to retrieve information stored in an object from any computer. Finally, 11 out of 14 participants showed interest in using Tangible Linker for daily activities.

Conclusion and future work

This paper described a new tangible interaction method based on untagged physical objects. An alternative solution to WIMP is proposed for retrieval of information without involving conventional searching procedure in graphical user interface. In our system, objects require no modifications and no previous setup so any object around the user space can be integrated with the digital desktop. We implemented the prototype system Tangible Linker to show how surrounding objects can be augmented to represent digital information. By using our system people are capable to relate easily information with physical objects by visual perception. The experiment showed that users are eager to explore new interactive environments, for example our tangible interaction method, in their daily activities, using ordinary objects to ease their work. We believe this is another step towards a true ubiquitous environment where seamless interaction with any physical object is possible.

As future works, we will extend our system to be available in a networked environment where users can share information simply by exchanging physical objects as well as access to shared data a, for example in a cloud computing environment. Also, although our object detection and recognition system is simple and works well for several cases, we will improve its recognition accuracy using supervised machine learning.

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