A Tabletop Interface Using Controllable Transparency Glass for Collaborative Card-based Creative Activity

Motoki Miura and Susumu Kunifuji

School of Knowledge Science,
Japan Advanced Institute of Science and Technology
miuramo@jaist.ac.jp, kuni@jaist.ac.jp

Abstract. Conventional tabletop systems have focused on communication with virtual data, using *phicons* or physical objects as handles. This approach is versatile, given the full use of a horizontal display. However, we consider that an another approach can be formulated that can support normal specific tasks on a table. We have developed a card-handling activity environment enhanced by a tabletop interface. We use a glass tabletop with controllable transparency to improve surface scanning and the display of supplemental data. We describe the architecture of the tabletop system and its design criteria. Due to its simple configuration, this tabletop system can handle a large number of paper cards, as used in the KJ method. Therefore, our system can be used to enhance card-based tasks by showing additional data, and it provides the ability to review transactions by recording the tasks.

Key words: Knowledge Creation, Physical Label Works, Ubiquitous, Paper and Pen

1 Introduction

A great deal of research has been conducted on tabletop interfaces. In general, the term *tabletop* represents a table installed as a relatively large horizontal display, which is intended to facilitate collaboration among multiple users surrounding the table. The characteristics of the tabletop interface are: (1) multiple users can join the workspace on equal terms, and (2) the users can place objects on the tabletop and interact with the physical objects as well as virtual objects shown on the surface. Since these characteristics are promising for improving collaboration, considerable research is being conducted on the tabletop interface.

The philosophy of the tangible user interface (TUI) and the concept of extending table-based activity into the virtual world are promising. These concepts and technologies can be gradually and naturally applied to extending the conventional tasks performed on a table, using ubiquitous computing. We chose a knowledge creation activity that involves handling a set of paper cards, in the manner of the KJ method, and developed a tabletop system called AwareTable to gradually extend the activity.

The concept of "gradual extending" in this paper refers to a phenomenon in which the system provides intermittent support, when necessary. In the case that we can accept the intermittent system support, the system can be realized by simple configuration. AwareTable provides two time-sharing functions: a scanning tabletop and displaying of additional data. We aim to augment paper card-handling activity without attaching any special devices to either the cards or the user's hands.

2 AwareTable

Here, we describe the functions, design guidelines, and implementation of AwareTable.

2.1 Functions and Design Guidelines

The primary function of AwareTable is to record paper card transactions during card-handling activities for future reference and review. To fulfill this purpose, the system must be able to detect individual paper cards, and record the location of the cards on the table.

DigitalDesk[1, 2] and EnhancedDesk [3] capture photo images of the tabletop with a camera located over the table to recognize objects and fingers. This approach is straightforward, but the objects on the table require visual markers on their upper sides to distinguish them. Also, mounting a camera over the table requires a supporting post. To provide for mobility of the table, and operability with conventional card handling, we set the following design criteria for AwareTable:

1. No additional visual markers or tags are attached to the upper side.
2. During operation, no devices are attached to the paper cards.
3. The table should contain all required devices.
4. Multiple paper cards and their IDs should be detected.
5. The table should display additional data on the top surface.

To meet these criteria, we used a glass with controllable transparency as the tabletop screen material[1]. The glass looks similar to frosted glass in its normal state, but the transparency can be instantly changed by applying an electric potential, since the glass incorporates a liquid crystal layer. **Figure 1** shows the configuration of our tabletop system. To utilize the characteristics of the glass material, the system can detect both the locations and IDs of multiple paper cards by capturing their images with a camera mounted under the tabletop. In the frosted glass state, the top acts as a screen that can display additional data by projection. The projector can also be located within the table. The system can recognize paper cards or objects using visual markers printed on their backs. Therefore, the system can improve both the table's mobility and operability. By controlling the transparency of the glass, accurate scanning of visual markers and improvements in the visibility of additional projected data can be achieved.

[1] UMU SmartScreen developed by NSG UMU Products Co. Ltd. `http://www.umupro.com/`

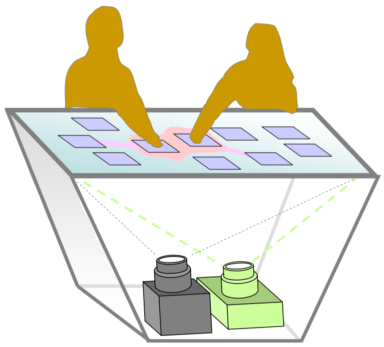

Fig. 1. Configuration of AwareTable. Both camera and data projector are installed in the table frame.

2.2 Configuration

AwareTable includes (1) a glass tabletop with controlled transparency, (2) a camera for capturing visual markers on the bottom of the paper cards, and (3) a projector for displaying additional data. Digital pens store handwritten text or drawings written on the front side of the cards. The visual markers on the backs of the paper cards are printed using a standard laser printer.

2.3 Scenario in KJ method task

We describe a scenario for using the AwareTable with the KJ method[2], with multiple users. In preparation, the users print visual markers on the lower side of the paper cards. The users write their thoughts or ideas on the paper cards with a digital pen. The relationship between the paper card and the text can be either established using Anoto pens or some other technique. One solution is having the user write a number on the paper card, and letting the system recognize it. After writing, the users place the cards on the table and move them with their hands. In the KJ method, deep understanding of the text written on the card is important. However, the size of the card is insufficient to indicate its context or any background information. In such cases, AwareTable displays the context on the tabletop screen near the card. While the screen is off, the users can record the transactional process of card organization in the scanning mode. This record can be used to recall the process, or for further organizational tasks in both the physical and virtual worlds. In addition, the scanned data can be distributed to a distant place. Remote collaborative work is possible if we use a pair of tables.

A grouping operation in the KJ method can be realized by introducing special folding cards. The folding card, which represents a more advanced concept than an original card, is twice the size of an original card, and a visual marker is printed on its front. The user can fold the card in half and place the original cards

---

[2] The KJ method is a registered trademark of the Kawakita research institute.

between the folds of the card. Then, the user can continue the organizational tasks in the normal way as per the KJ method.

Drawing line operations, at the visualization stage of the KJ method, is not supported. However, once the card structure is obtained, the system may project the surrounding lines automatically.

2.4 Advantages

Controlling the transparency of the tabletop screen material is helpful in capturing small visual markers. Since the configuration of AwareTable is relatively simple, we can easily extend the size of the tabletop screen. Also, the resolutions of both the scanning image and projection data can be increased by adding cameras and data projectors. The resolution of the scanned image determines the size of the visual marker. Using a large tabletop screen and high-resolution images, the system can handle more paper cards. Thus, our framework is suitable for handling many cards simultaneously.

As mentioned in section 2.1, the frosted mode of the screen surely improves the visibility of the projected data. By increasing screen resolution, the user can obtain precise and detailed images of background knowledge.

3 Related Work

The concepts of extending paperwork on the table using computation emerged in the 1990s. DigitalDesk [1, 2] by Wellner et al. and EnhancedDesk [3] by Koike et al. are representative examples. DigitalDesk captures finger operations and paper documents, and integrates them. Wellner et. al. explained that, using the DigitalDesk Calculator, the user can enter numbers and operators by pointing at items printed on a paper sheet. EnhancedDesk realized the linkage of real-world objects to virtual ones by recognizing fingers and a two-dimensional matrix code printed on books.

The designers' outpost [4] is a wall-sized tangible display that recognizes the locations of physical Post-it notes through computer vision. The outpost requires an environmental camera to capture the foreground image. Although the type of collaborative task is similar, we focus on the simplicity and mobility of the table configuration by encapsulating all the required devices in it. Interactive Station, developed by Ricoh, is a tabletop system that stores hand-written text or drawings composed using conventional white board markers on a screen. The stored hand-written text or drawings can be overlaid on electronic documents displayed on the surface. The concept and configuration of the Interactive Station are similar to those of AwareTable, because both a camera and a data projector are installed in the table. However, we focus on the card-handling activity. Döring and Beckhaus proposed to apply the cards in a study on art history [5].

Some systems employ special devices to interact with digital objects in the virtual world. metaDESK [6] and Sensetable [7] are significant systems in this regard. These technologies have been applied to network management [8] and

Fig. 2. AwareTable appearance

disaster simulation [9]. SnapTable [10] and PaperButtons [11] augment paper with electronic devices. SnapTable introduces electronic paper and a collaborative workspace to provide intuitive browsing of electronic documents.

Research has also been performed on screen devices using a liquid crystal shutter. Shiwa developed a large-screen telecommunication device that allows eye contact in remote conferences [12]. Kakehi et al. proposed Lumisight Table [13, 14], which provides personalized projection images for four users. Lumisight Table employs Lumisty films to control the visibility of different users, and detects objects placed on the table using its inner camera. TouchLight [15] also employs a similar material for a screen. The Lumisight table uses four Lumisty films and a Fresnel lens to improve image quality. Even though the Lumisight Table provides significant functionality, it is not suitable for a large tabletop. The simplicity of the AwareTable configuration suits a large tabletop, and allows the handling of many paper cards.

4 Implementation

In this section, we describe implementation of the AwareTable prototype. **Figure 2** shows the table. We employed UMU Smart Screen for the tabletop material. The size of the tabletop is 60 inches diagonally (1219×914mm). The table size is determined by considering the simultaneous placement of 100 paper cards, with up to six users collaborating. To control tabletop transparency, we used a solid-state relay (Phototriac BTA24-600CWRG) for switching 100 volts power supply. The solid-state relay is controlled by a Phidgets Interface Kit[3]. For image capturing, we chose an IEEE1394 high-resolution camera (PGR Scorpion SCOR-20SOC-KT, 1600×1200 pixels). For data projection, we selected a short-throw projector (SANYO LP-XL40(S)). **Figure 3** shows the image of a projection in the frosted mode.

[3] http://www.phidgets.com/

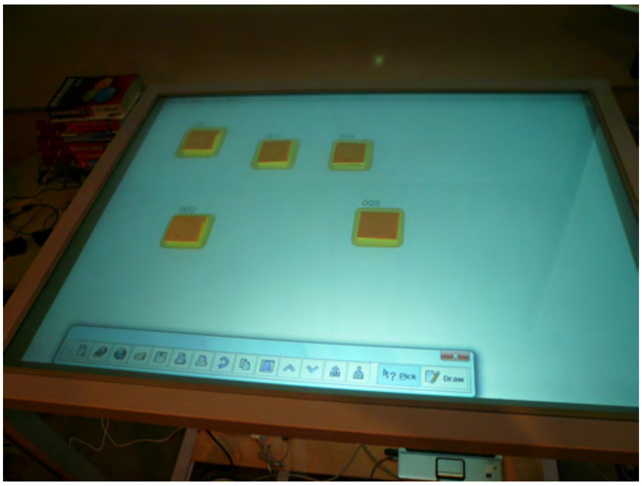

Fig. 3. Projection in frosted screen mode

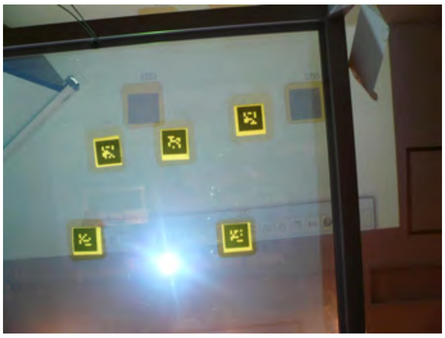

Fig. 4. Sample Captured Image (transparent/capture mode)

Fig. 5. Sample Captured Image (frosted/screen mode)

To identify and obtain the location of each paper card, we utilized ARToolkitPlus [16] and its visual markers. ARToolkitPlus has the advantage of recognizing many visual markers with little computation. The recognition module that processes captured images from the IEEE1394 camera is constructed in Visual C++. The recognition module uses a graphic interface module written in Java, connected through Java Native Interface (JNI). A transparency control module was also developed in Visual C++, and is connected via JNI. When the graphical interface module requests scanning, the recognition module calls back with coordinates (or a translation matrix for 3D application). Then, the graphical interface module can overlay rectangles where the visual markers are placed, or show additional data on the tabletop screen.

Figure 4 and **Figure 5** show sample captured images of the transparent and frosted states, respectively. Here, we used relatively large visual markers (66mm × 66mm), and the distance from the camera to the tabletop screen was 90 cm. The former image is clearer than the latter. Thus, the system has a potential of recognizing small visual tags. We have already succeeded in recognizing smaller markers (33mm × 33mm) in the transparent mode, thus proving that our tabletop framework can handle many paper cards effectively.

5 Conclusion and Future Work

In this paper, we proposed AwareTable, which uses transparency controllable glass as a tabletop surface. We discussed the configuration and its merits for collaborative card-handling activities, since its scalability allows application to card-handling tasks with as much as hundred paper cards. The concept of gradually extending refers to moving physical tasks into the virtual world, with full interoperability or interactivity between these two worlds. However, even the limited time-sharing approach can extend conventional paper-based tasks without any migration to the virtual world. We consider this approach promising because some people are not willing to abandon the conventional methods that are still natural and intuitive for almost all users.

In future, we will attempt to recognize finger taps on the screen in AwareTable, to provide better interaction with additional data or other virtual objects.

Acknowledgment

Our research is partly supported by a grant-in-aid for Scientific Research (18700117) and a fund from the Ministry of Education, Culture, Sports, Science, and Technology of Japan, under the name of "Cluster for Promotion of Science and Technology in Regional Areas."

References

1. Pierre Wellner. The DigitalDesk Calculator: Tangible Manipulation on a Desk Top Display. In *Proceedings of UIST'91*, pages 27–33, 1991.
2. William Newman and Pierre Wellner. A Desk Supporting Computer-based Interaction with Paper Documents. In *Proceedings of CHI'92*, pages 587–592, 1992.
3. Hideki Koike, Yoichi Sato, and Yoshinori Kobayashi. Integrating Paper and Digital Information on EnhancedDesk: A Method for Realtime Finger Tracking on an Augmented Desk System. *ACM Transactions on Computer-Human Interaction*, 8(4):307–322, 2001.
4. Scott R. Klemmer, Mark W. Newman, Ryan Farrell, Mark Bilezikjian, and James A. Landay. The Designers' Outpost: A Tangible Interface for Collaborative Web Site Design. In *Proceedings of UIST'01*, pages 1–10, 2001.
5. Tanja Döring and Steffi Beckhaus. The Card Box at Hand: Exploring the Potentials of a Paper-Based Tangible Interface for Education and Research in Art History. In *Proceedings of the 1st international conference on Tangible and embedded interaction*, pages 87–90, 2007.

6. Brygg Ullmer and Hiroshi Ishii. The metaDESK: Models and Prototype for Tangible User Interfaces. In *Proceedings of UIST'97*, pages 223–232, 1997.
7. James Patten and Hiroshi Ishii and Jim Hines and Gian Pangaro. Sensetable: A Wireless Object Tracking Platform for Tangible User Interfaces. In *Proceedings of CHI'01*, pages 253–260, 2001.
8. Kazue Kobayashi, Mitsunori Hirano, Atsunobu Narita, and Hiroshi Ishii. A Tangible Interface for IP Network Simulation. In *CHI'03 extended abstracts*, pages 800–801, 2003.
9. Kazue Kobayashi, Atsunobu Narita, Mitsunori Hirano, Ichiro Kase, Shinetsu Tsuchida, Takaharu Omi, Tatsuhito Kakizaki, and Takuma Hosokawa. Collaborative Simulation Interface for Planning Disaster Measures. In *CHI '06 extended abstracts (Work-in-progress)*, pages 977–982, 2006.
10. Minoru Koshimizu, Naoki Hayashi, and Yoshitsugu Hirose. SnapTable : Physical Handling for Digital Documents with Electronic Paper. In *Proceedings of NordiCHI'04*, pages 401–404, 2004.
11. Elin Rønby Pedersen, Tomas Sokoler, and Les Nelson. Paperbuttons: Expanding a tangible user interface. In *Proceedings of the conference on Designing interactive systems (DIS'00)*, pages 216–223, 2000.
12. Shinichi Shiwa. A large-screen visual telecommunications device using a liquid-crystal screen to provide eye contact. *Journal of the SID*, pages 37–41, 1993.
13. Yasuaki Kakehi, Makoto Iida, Takeshi Naemura, Yoshinari Shirai, Mitsunori Matsushita, and Takeshi Ohguro. Lumisight Table: An Interactive View-Dependent Tabletop Display. *IEEE Computer Graphics and Applications*, 25(1):48–53, 2005.
14. Yasuaki Kakehi, Takero Hosomi, Makoto Iida, Takeshi Naemura, and Mitsunori Matsushita. Transparent Tabletop Interface for Multiple Users on Lumisight Table. In *Proceedings of the First IEEE International Workshop on Horizontal Interactive Human-Computer Systems (TABLETOP' 06)*, 2006.
15. Andrew D. Wilson. TouchLight: An Imaging Touch Screen and Display for Gesture-Based Interaction. In *Proceedings of ICMI'04*, pages 69–76, 2004.
16. Daniel Wagner and Dieter Schmalstieg. ARToolKitPlus for Pose Tracking on Mobile Devices. In *Proceedings of 12th Computer Vision Winter Workshop (CVWW'07)*, 2007.