T. Koschmann, D. Suthers, & T.W. Chan (Eds.), *Computer Supported Collaborative Learning 2005: The Next 10 Years!*
Mahwah, NJ: Lawrence Erlbaum Associates.

MatrixDesks: Interactive Computing Desks toward One-on-Two Educational Computing Environments

Hercy N.H. Cheng
Department of Computer Science and Information Engineering
National Central University, Taiwan
hercy@cl.ncu.edu.tw

Ben Chang
Research Center for Science and Technology of Learning
National Central University, Taiwan
ben@cl.ncu.edu.tw

Yi-Chan Deng
Department of Computer Science and Information Engineering
National Central University, Taiwan
ycdeng@cl.ncu.edu.tw

Tak-Wai Chan
Graduate Institute of Network Learning Technology
National Central University, Taiwan
chan@cl.ncu.edu.tw

Abstract. The era of 1:1 educational computing environment where each student has one mobile computing device is not far away. When such technology designed for individuals is applied to group learning, several student grouping problems could be encountered. In this paper, three issues are identified to illustrate the vision of the 1:2 educational computing environments. In a 1:2 classroom, besides the mobile devices, students also have their own computing desks, i.e. MatrixDesks, to solve the potential student grouping problems. By putting MatrixDesks together, a small group can form a shared working space with the combined desktops immediately and they can use their own digital pens as the input devices to work on and talk over it. Meanwhile, the students use their mobile devices to handle the related individual tasks. MatrixDesks is a coordination of applying the mobile computing and invisible computing to collaborative learning, which will lead to the accomplishment of 1:2 educational computing environments.

Keywords: student grouping, interactive computing desks, ubiquitous computing, invisible computing, 1:1 educational computing, 1:2 educational computing

BACKGROUND

Computing Desks

A classroom desk provides a working space for learning in the classroom. Students are used to have their own desks in class, and they are familiar with the interaction on the desk, such as reading, writing, painting, talking over the desk, sharing objects on the desk, etc. In the field of human interface interactions, there are several systems using the metaphor of desks, such as DigitalDesk (Wellner, 1993), meatDESK (Ishii & Ullmer, 1997; Ullmer & Ishii, 1997), Sensetable (Patten et al., 2001), InteracTable (Streitz et al., 1999), ConnecTable (Tandler et al, 2001) etc. Ishii and Ullmer (1997) also argue that the graphical user interface (GUI) approach falls short in embracing the rich interface modalities between people and the physical environments, and the desktop metaphor should be pushed back into the real world.

One-on-Two educational Computing

Many researchers have envisioned in a future not too far, a personal computing device for every student in a classroom will be as indispensable as a pencil. These devices could be products evolved from what we commonly see today like notebook, tablet PC, personal digital assistant (PDA), cellular phone, electronic dictionary, visual graphical calculator, gameboy, and so forth. This vision of 1 student 1 computing device classroom is termed as one-on-one (1:1) educational computing environment (www.G1On1.org).

Now, assuming 1:1 educational computing is already practicing in significant percentages of classrooms in the world, and given that the prices of large panel displays are dropping rapidly, *1:2 educational computing*, that is, 1 student 2 computing devices, will bound to happen. We envision one possible 1:2 classroom scenario is that every student will have a personal handy and light device that the student brings along with her everywhere, and in the classroom, her own desk is also a computer, that is, the desktop of her desk is a large computer screen. Such computer desks, which we call MatrixDesks, can facilitate nicely many small group learning activities in a classroom.

THREE STUDENT GROUPING PROBLEMS

Scott et al. (2003) found that sharing a physical display positively influenced the students' collaboration, rather than separate displays (whether in the same room or not). In the shared workspace, it is easy for students to reach a mutual understanding and to collaborate with each other. However, in a 1:1 classroom, it is not easy to construct shared workspaces, because students may bring their personal computing devices which could be different sizes or types. As one may imagine, in a classroom equipped with several computing desks, small groups of students will stand or sit around the desk with their eyes looking at their desks while talking with their neighboring students. Since one student will have her own computing desk in the classroom, the best way is that all students will put their own desks together to form a large desk so that they can sit around the large desk focusing their attention on the desktop, that is to say, the large computer screen composed of individual desktop screen of a computing desk. This student grouping problem we termed as *sharing screen problem*.

Since there could be plenty different small group activities with various ways of grouping students, combining desks to construct larger working spaces is a natural and reasonable thought for a small group of students. Now, their desks, suppose they can be moved easily around in the classroom, are arranged in different configuration for supporting these activities. For example, in Jigsaw collaboration, at first students split into several focus groups, which focus on different aspects of a common topic, and then they return to their home group to share their "expertise" learned from focus groups to produce a presentation about the topic. When students come back to their home group, their desks should change the grouping automatically. And when a teacher wants to conduct a group learning activity, he has to consider not only how to group the students but also how to make their desks understand the grouping configurations. There are several ways of grouping students with their devices. Typically, teachers have to make a list manually to tell the desks which ones are grouped together. However, this is a time consuming work for teachers, especially when some learning activities need to group students again. To solve this problem, a computing desk should be "aware" which desk is belonged to whom and which desk is currently attached to it and on which side. This is another student grouping problem and we term it is the *desk configuration problem*.

On the other hand, pen-based interfaces are one of the natural input devices for students on the computing desks. Generally speaking, such input devices are designed for a single user and dedicated to one computing desk only. When several computing desks are grouped, the students likely use their digital pens not only on their own desks but also on the entire shared workspace. In other words, the computing desks should have the capability to distinguish the group members' pens without ambiguity. In educational applications, it is crucial to track each student's actions. Such problem is termed as *input identification problem*.

This paper focuses on these three student grouping problems in 1:2 classrooms and intends to discuss possible solution for them. Actually, student grouping is a fundamental issue of collaborative learning, not only for 1:2 classrooms, but for 1:1 classrooms too. In the following sections, after discussion of related works, we present the design of MatrixDesks to support student grouping with tablet PCs or notebooks.

RELATED WORKS

Our original project of using tablet PCs in the classroom is called Digital Classroom Environment (DCE). Under the environment, there are several wireless access points put at different place in the classroom, and also a common display for projecting the screen of the teacher's tablet PC or notebook. Each student has a wireless-enabled tablet PC on which the student can make annotations on their content. DCE also provides both teachers and students to manage devices including broadcasting the materials, sharing annotations, etc. The Puzzle View (Deng et al., 2004) is a prototype that constructs a group display by combining several screens of tablet PCs (Figure 1). It provides shared working spaces among several computing devices and was designed for enhancing group interaction experience. However, it is noticed that Puzzle View is not facile for teachers or students to change grouping immediately. Furthermore, students also have to figure out the proper order of screens when they are grouped. The Puzzle View provides not only a solution to the *sharing screen problem* but a foothold to explore the other problems.

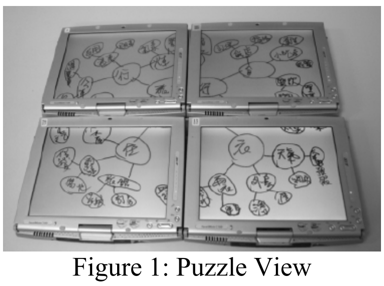

Figure 1: Puzzle View

For the purpose of building a meeting room, several roomware® (Streitz et al., 2001) components are developed in the first generation of i-LAND project, such as DynaWall, InteracTable (Streitz et al., 1999). The InteracTable allows a single user at a time using the pens or his finger for gesture-based interaction with virtual objects, while the DynaWall integrates tightly three interactive touch screens into a wall for a larger presentation area or parallel presentation areas. To enhance the fluidity of the interaction, ConnecTables (Tandler et al., 2001) are designed to dynamically form a homogenous display area. When two ConnecTables are moved close to each other, the workspaces are connected so that their users can work individually in parallel and exchange information. ConnecTable solves the *sharing screen problem* and, to some extent, the *desk configuration problem*.

SOLUTIONS OF THE STUDENT GROUPING PROBLEMS BY MATRIXDESKS

The design of MatrixDesks is to solve the *sharing screen problem*, *desk configuration problem*, and *input identification problem* so that students' experience can be improved in group learning activities. MatrixDesks have wheels to assist students to move their desks easily. Each MatrixDesk is designed for one student with the desktop being a sensing display, which is a large screen of an embedded computer (Figure 2). For writing and painting on the sensing display, every student has a digital pen with its unique electromagnetic identification which can be sensed by the sensing display. Such technique is used to solve the *input identification problem*.

Let us assume a MatrixDesk is a square desk. The *desk configuration problem* can be simplified by calling a function of MatrixDesk for detecting the neighboring desks automatically. This detecting function take the value of an electronic identification (such as RFID, Radio Frequency Identification) labeled on each side of the desk as an input and activate a sensor when the two desks are attached (Figure 3). Similarly, when another MatrixDesk is put together, they can detect each other and tell the computers with whom they are put together and in what shape, such as rectangle, square, or other irregular shapes such as L, T, or U shape. Figure 5 shows an example of the desk configuration if the desktop is a square.

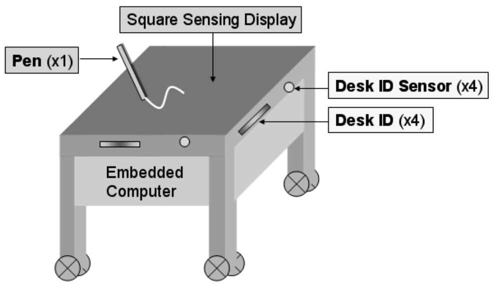

Figure 2: The sketch of a MatrixDesk

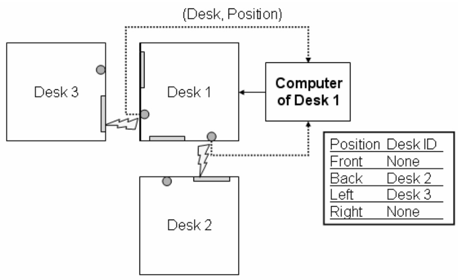

Figure 3: The neighbors detecting function

Figure 4 shows the system architecture of MatrixDesks, which are client/server architecture. MatrixDesks are equipped with wireless communication capabilities so that these desks can transmit data through wireless networks to the server which is either a centralized class server or one of the desks. **Neighbors detecting module** receives the signals of the four desk identification sensors. After detecting the neighboring desks, the module sends the data of the identifications and orientations of neighbor desks to the server. According to the data, **shared workspace analyzer** of the server groups the corresponding desk identifications, and analyzes the layout of shared workspace for the best viewing experience. Then **display generator** dispatches the workspaces to the respective desks, which are to present the workspaces on their screens. The whole process is used to solve the *sharing screen problem*.

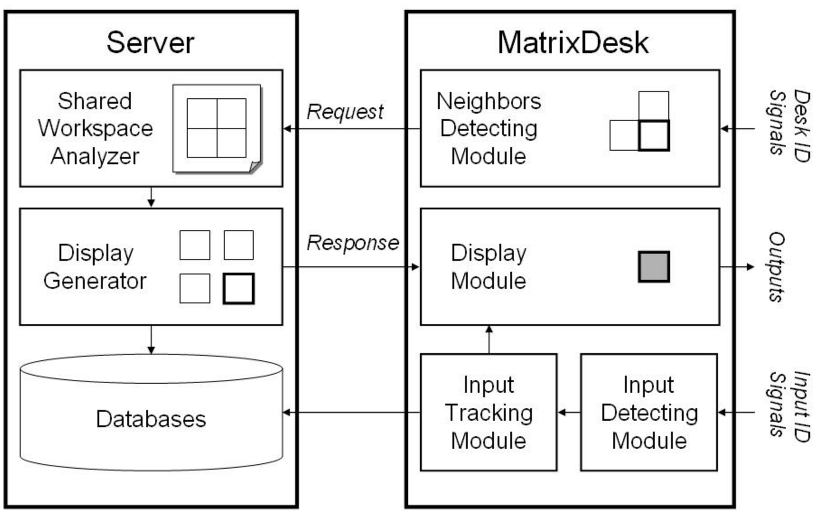

Figure 4: system architecture

Input detecting module receives the identification and position of the digital pen, and then these data are transferred to **input tracking module** which can identify and track which pen is sensed on the desktop. In this version, MatrixDesks are simply designed to allow students writing, drawing, painting and making annotations, so the students' handwriting can be output directly without being processed through the server. In other cases, such as exchanging or connecting virtual objects, the module needs to send the data to the server, so that the actions can be performed correctly. Finally, **display module** presents the adequate workspace as the background and the handwriting as the foreground on the screen. At the same time, both data are logged in databases for future analysis.

To construct a shared workspace, the server allocates a working space and, according to the desk configuration, maintains the relations between desks. When students change the configuration, computers only need to change these relations rather than to create a new shared display again. After putting several MatrixDesks together, students can sit or stand around the desks to share the workspaces with their digital pens. Figure 6 shows several possible ways to use MatrixDesks when two desks are attached, including facing each other or side by side, which depend on the learning activities and materials. For example, if the students try to compare two diagrams shown on MatrixDesks separately, they can share the workspace side by side.

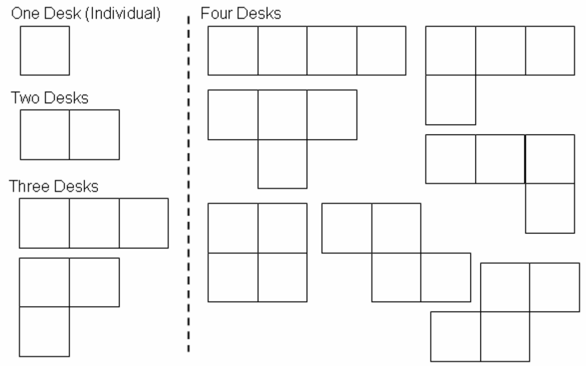

Figure 5: Possible combinations of MatrixDesks

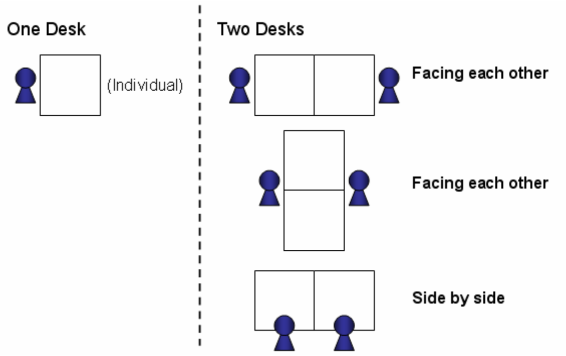

Figure 6: Possible ways of sharing working spaces

When comparing to students using the screens of MatrixDesks for individual works, how frequent a small group of students would need such a large shared screen in a class is not known. Therefore, it is important to be able to switch between individual work spaces and shared work space. Note that when students work individually, they can still exchange data or communicate through verbal or online chatting. Also, we do not plan to ask computer manufacturers to produce machines with screens as complete desktops. Instead, we embed tablet computers with their screens large enough into usual desktops. RFID is used to attach to the desks to identify the mutual locations and orientations of the sides of the simulated MatrixDesks.

Another design challenge is how to support learning activities with the mobile devices and the computing desks in 1:2 classroom scenarios. Remember that 1:2 classroom is an enrichment of 1:1 classroom where every student has already had her own device of which we anticipate that its size will be about that of a handheld or an electronic English dictionary. In 1:2 classroom scenarios, a learning activity ought to be divided into two parts, the individual tasks and group tasks. The individual tasks are performed on the mobile devices, while the group tasks are supposed to be done on the computing desks. For example, when students work as groups with the shared workspace, their individually owned devices may serve as interactive books for reading and taking notes which can be transferred to the shared workspace if needed. When students work individually, these mobile devices will become communication tools with their desks.

SUMMARY AND FUTURE WORKS

In a classroom of future, besides having a personally owned portable small-size screen handheld, every student is provided with a personal computing desk. Furthermore, while researchers talk about wireless and mobile technologies in CSCL today, the genuine mobile learning is merely about the use of the portable computing device that the student brings along with her all the time, at home, at school, as well as outside classroom. But at home and in classroom, she may largely works on a computing desk, one at home and one in every classroom she goes in, complemented with her portable computing device. This is the most feasible and practical scenario we envision in the era of ubiquitous computing (Weiser, 1998), that is, seamless computing, or simply everyday life computing. In a word, the 1:2 educational computing links the research areas of mobile computing (Gay et al., 2001) and invisible computing (Norman, 1998) applied to teaching and learning.

If desks are regarded as bridges between individual and group learning in classrooms, then MatrixDesks provide personal computing working spaces as well as a cooperative working space for a small group and are able to switch from individual to group environments and vice versa at ease. This project is currently a work in progress and our next step of MatrixDesks is to finish the implementation of our prototype. At present, MatrixDesks is only a frame in which learning activities and materials should and will be placed. Hence, there will be further experiments and investigations that can support the improvements of our design. For example, we would like to know how the students interact with the desks, including the positions of students, the handwriting they make, the ways to share the displays, to talk over the desks, to walk around the desks, and to move the desks, and so forth. Furthermore, this paper also raises a few design issues, in particular, three student grouping problems, of such a future 1:2 classroom to initiate the exploration of the related issues. The researches of collaborative learning with mobile devices and with invisible computers are somehow divergent and need to be accommodated. If we continue studying the 1:2 educational computing environments, more CSCL issues hidden between the two researches will be discovered in the future.

REFERENCES

Deng, Y. C., Do, M. Z., Chang, L. J., and Chan T. W. (2004) PuzzleView: Enhanced Workspace Displaying for Group Interaction with Tablet PCs. Proceedings of the 2nd IEEE International Workshop on Wireless and Mobile Technologies in Education WMTE’04 (Jhong-li, Taiwan, 2004), IEEE Computer Society Press, 205-206.

Gay, G., Stefanone, M., Grace-Martin, M., and Hembrook, H. (2001) The Effects of Wireless Computing in Collaborative Learning Environments. *International Journal of Human-Computer Interaction*, **13**, 2, 257-276.

Ishii, H., and Ullmer, B. (1997) Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms. Proceedings of Conference on Human Factors in Computing systems CHI '97 (Atlanta, Georgia, USA, March 1997), ACM Press, 234-241.

Norman, D. (1998) *The Invisible Computers*. Cambridge, MA: MIT Press.

Patten, J., Ishii, H., Hines, J., and Pangaro, G. (2001) Sensetable: A Wireless Object Tracking Platform for Tangible User Interfaces. Proceedings of Conference on Human Factors in Computing Systems CHI '01 (Seattle, Washington, USA, March 31 - April 5, 2001), ACM Press, 253-260

Scott, S.D., Mandryk, R. L., and Inkpen, K. M. (2003) Understanding Children’s Collaborative Interactions in Shared Environments. *Journal of Computer Assisted Learning*, **19**, 2, 220-228.

Streitz, N.A., Geißler, J., Holmer, T., Konomi, S., Müller-Tomfelde, C., Reischl, W., Rexroth, P., Seitz, P., and Steinmetz, R. (1999) i-LAND: An Interactive Landscape for Creativitiy and Innovation. ACM Conference on Human Factors in Computing Systems CHI '99 (Pittsburgh, Pennsylvania, U.S.A., May 15-20, 1999), ACM Press, 120-127.

Streitz, N.A., Tandler, P., Müller-Tomfelde, C., and Konomi, S. (2001) Roomware: Toward the Next Generation of Human-Computer Interaction Based on an Integrated Design of Real and Virtual Worlds. In Carnoll, J.M. (Ed.), *Human Computer Interaction in the New Millennium*, Addison-Wesley, US, 553-578.

Tandler, P., Prante, Th., Müller-Tomfelde, C., Streitz, N.A., and Steinmetz, R. (2001) ConnecTables: Dynamic Coupling of Displays for the Flexible Creation of Shared Workspaces. Proceedings of the 14. Annual ACM Symposium on User Interface Software and Technology UIST'01, ACM Press, 11-20.

Ullmer, B., and Ishii, H. (1997) The metaDESK: Models and Prototypes for Tangible User Interfaces. Proceedings of Symposium on User Interface Software and Technology UIST’97 (Banff, Alberta, Canada, October 1997), ACM Press, 223-232.

Weiser, M. (1998) The future of ubiquitous computing on campus. *Communications of the ACM*, **41**, 1, 42-43.

Wellner, P. (1993) Interacting with Paper on the DigitalDesk. *Communications of the ACM*, **36**, 7, 87-96.