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Proposal for Deviceless Learning Environments Instead of Environments Using Smart Devices

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Abstract: Smart devices such as smartphones and tablets have become indispensable in educational settings in the 21st century. However, to both ensure the educational effect and reduce the cost of using these devices, we should overcome the issues identified by earlier, pioneering studies. Accordingly, this paper proposes a deviceless learning environment called "Followable Learning Environment" (FLE). Although FLE is based on projection mapping techniques that project a user interface (UI) on desks, the UI is dynamically projected on a student's desk or hands according to their behavior by using the area of projection as the student's movable area. Since the UIs of several students are projected by one projector, we need not separately prepare the devices and their management for each student. In addition, using FLE, we can realize new functions that are impossible using smart devices. This paper describes the background of this research and explains the concept of FLE through the development of a prototype system.

Keywords: Learning Environment, Smart Devices, Augmented Reality, Dynamic Projection Mapping, One-to-One Computing

1. Introduction

Today, smart devices such as smartphones and tablets have become indispensable in educational settings. Although many pioneering studies have focused on the pedagogical effects of using smart devices in educational settings, many studies also mention issues such as the preparation and management of these devices. Another consideration pertaining to the use of these devices is the resulting increase in cost of educational services.

This paper proposes a new type of learning environment called the "Followable Learning Environment" (FLE) as a substitute to the use of smart devices in educational settings. Although FLE is based on projection mapping techniques that project a user interface (UI) on a desk, the UI can be dynamically projected on a student's desk or hands according to their behavior by using the area of projection as the student's movable area. In addition, we can realize new functions that are impossible using smart devices, such as a changing display size function that changes the display size from small, for individual students, to large, for collaborative learning, and overlap projection functions to promote students' understanding. Accordingly, this paper describes the background of this research and explains the concept of FLE through the development of a prototype system.

2. Background

Many studies have revealed that the use of tablets enhances the learning motivation and understanding of students. For example, a survey on 6,057 students and 302 teachers in Quebec, Canada, revealed the positive effects of tablet use, such as an increase in student motivation, ease of information access, the quality of presentations, within-classroom collaboration, and creativity (Karsenti et al. 2013). A study by Alvarez et al. (2011) showed that tablets strengthen collective discourse capabilities and facilitate a richer and more natural body language, on collaborative learning in undergraduate course. Many studies have examined the utilization of smart devices in education in Japan, as well. In addition, in 2013, the Japanese government published an IT strategy to provide one smart device to one student (one-to-one computing). Although the utilization of smart devices in educational settings has undisputed benefits, it generates some problems that remain unresolved to date. This study focuses on the problems of utilizing smart devices in school settings as following.

2.1 Initial Costs and Operational Costs

The problems associated with high costs are always a major consideration. Regarding the use of smart devices, both the costs of preparing the devices and costs of software licenses, staff training, provision of services, provision of technical support, and so on should be considered. With respect to the preparation of devices, although some schools request the parents of students to buy devices in some cases, the schools provide their students with devices, such as 1-1 computing initiatives, in some other cases. For successful 1-1 computing, high-quality infrastructure and readily available technical support are necessary (Valiente 2010). As a factor of increasing costs, there might be a problem for 1-1 computing itself. Since the main user of a device is a student, administrators cannot completely control the use of such devices. Although various Mobile Device Management (MDM) tools are currently available, it has limitations for management scope as well, it is difficult problem that to cope with both security and functionality. A similar problem occurs in corporate usage, as well. To manage issues related to both security and functionality, a thin client solution, such as the Virtual Desktop Infrastructure (VDI), is introduced in corporate use. On other hand, in educational settings, particularly the utilization of IT in primary school, the introduction of 1-1 computing using tablets seems to have attained global focus.

2.2 Distraction

Another consideration is the problem of being distracted in class. This problem is an important in improving the cost–benefit relationship. The Quebec survey mentioned in Section 2 reported that the greatest challenge faced by teachers is the provision of tablets as a distraction for students. A survey conducted by Ditzler et al. (2016) also mentioned the problem of distraction.

Because students always want to use a device, they might not be able to concentrate on the learning activity even when the activity does not need such a device. In this case, although we should instruct students to turn off the device, place it in a bag, and so on, teachers might hesitate to use devices depending on the instructional model since these devices impair convenience. Similar problems also be mentioned in the survey by Roblin et al. (2018).

2.3 Problems in Primary and Junior High Schools

In addition, under the assumption that tablet devices are used in primary and junior high schools, this study also focuses problems as follows.

- ✓ *Device Loss/Breakage:* Students often inadvertently lose/break their devices. Although, such accidents can be compensated by the provision of insurance, they do increase the overall cost. A case study of Henderson et al (2012) mentioned that additional costs had also incurred through the purchase of protective gear for devices, such as cases and screen protectors.
- ✓ *Batteries:* Currently, devices have sufficient battery capacity for one-day use. However, students often forget to charge batteries. Moreover, they might use the devices for entertainment during recess hours, which also requires batteries.
- ✓ *Small Desks:* Although it might be a problem unique to Japan, students' desks in classrooms are relatively small in size. In typical Japanese primary schools, a desk has a breadth of approximately 600 mm and length of 400 mm. Since the desk is small in size, students often drop objects placed on the desk; this might be one reason for the breakage of devices.

These problems can be solved by preparing spare devices. However, the problems should be solved smoothly without interrupting the progress of lessons. For this purpose, sufficient numbers of spare devices and well-trained technical staff should be made available, which causes an increase in overall cost.

A major trend that has emerged in recent years is 1-1 computing. However, although this concept has been implemented to solve the aforementioned problems, it seems to that, to date, no study has attempted to fundamentally solve these problems. Accordingly, this study proposes a new concept to solve these problems.

3. Concept of the Followable Learning Environment

The author proposes the application of a new type of UI called Followable User Interface (FUI) (Yamaguchi et al. 2015). In the FUI environment, the UI is projected on a user's hand using sensors placed on the ceiling of a room that detect hand behavior (Figure 1). One UI is projected by using the partial area of one projector. Therefore, the area of the projector is considered the area in which the user can move his or her hands. In addition, several UIs of one user can be projected from one projector at the same time, in theory. Users' experience of this environment is similar to that of using conventional UIs without smart devices. The size of area which the FUI environment can projects UI using two projectors and two sensors in the current experimental system is only about 4m × 3m. In the future, to spread the area until room size by using several sensors and projectors is planned in this study.

In this study, the concept of FUI is applied to a classroom for solving the aforementioned problems, as shown in Figure 2. By using a sensor located on the ceiling, the system detects the desks and gestures of multiple students. One projector projects each student's UI at the same time. By increasing the number of sensors and projectors, it is possible to provide UIs to the entire classroom. This study calls this concept based on FUI as "Followable Learning Environment (FLE)".

Instead of projecting the UI on a user's hand, it is projected on a student's desk. Since the method is deviceless, additional devices need not be prepared for each student. An application instance of UI, which is projected on the desks, is executed on the FLE system similar to a thin client system. It is expected that this method reduces management costs compared to the use of smart devices.

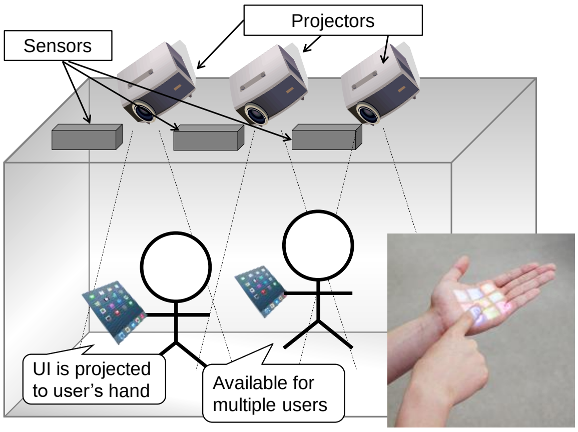


Figure 1. The Concept of the Followable User Interface.

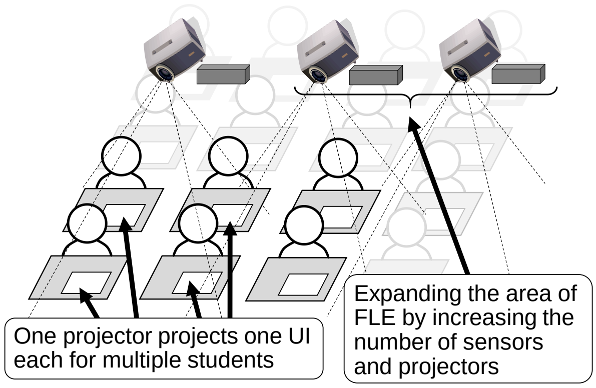


Figure 2. The Concept of Followable Learning Environment.

4. Development of a Prototype System and Experimental Results

Realizing a system based on the FLE concept is a challenging task. For this purpose, we should develop elemental technologies for instance, to integrate sensor data, detect desk positions and shapes, detect gestures, and perform high-precision projection mapping, as well as applications that utilize these technologies. Accordingly, as the first step, this study developed a prototype system that performs desk detection and UI projection using one sensor and one projector to explore the feasibility of FLE.

Figure 3 depicts the abstract of the prototype system. The system uses a depth sensor, which is located near the ceiling such that it is directed toward the floor. The captured depth data are sent to a workstation. In the workstation, the system program detects desks, decides UI positions, and creates UIs. The UIs are projected from a projector connected to the workstation. Similar to the sensor, the projector is placed near the ceiling such that it is directed toward the floor.

The prototype system was evaluated using actual desks. Figure 3 depicts the arrangement image of the overall system. Figure 4 depicts the arrangement image of the overall system. Since the projected UIs are pseudo UIs, we cannot operate them. The experiment used prepared desks of dimensions 600 mm × 500 mm which are nearly size of used in primary schools. The top plate height from the floor was 700 mm. The sensor and projector were placed at a height of 2500 mm and 2200 mm from the floor. Figure 5 depicts some UI projection examples of different cases of using several desks: (a) arrangement in the vertical direction, (b) arrangement of four desks, and (c, d) arrangement for group work. Since UIs were projected using a part of the projection area of one projector according to the FLE concept, UIs could be projected on each desk even after changing the arrangement of desks.

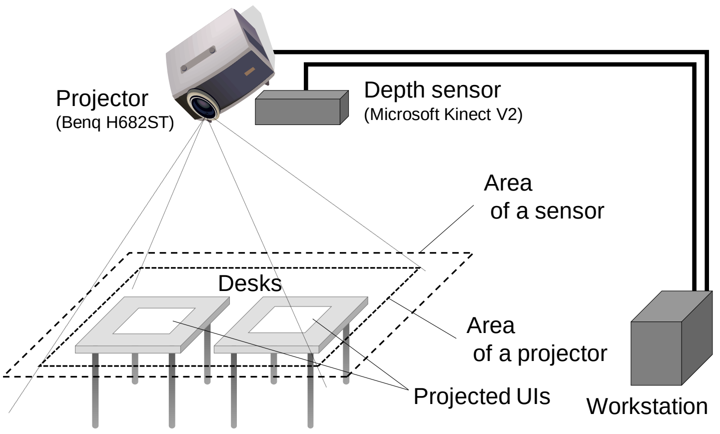
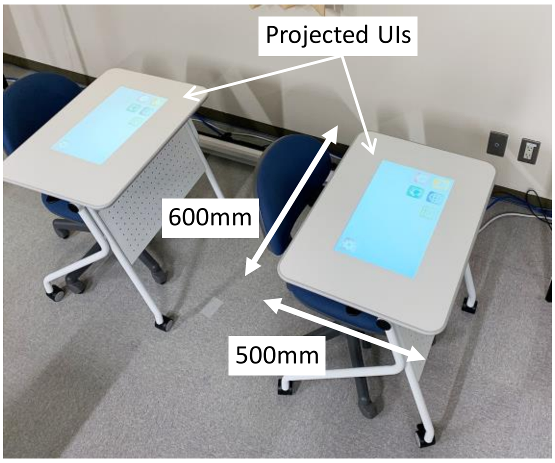


Figure 3. Abstract of the Prototype System.

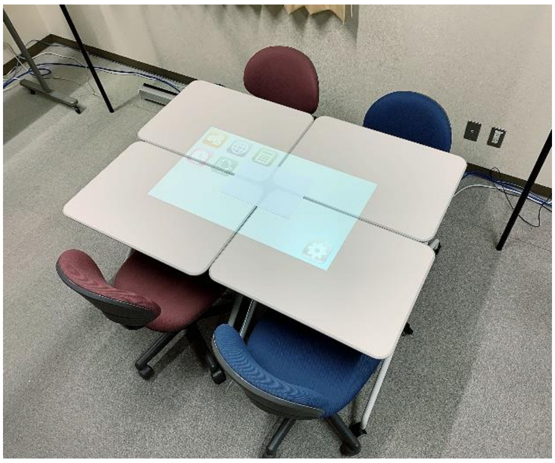
Figure 4. Arrangement of the Overall System.



(a) An arrangement of two desks

(b) An arrangement of four desks

(c) Two desks and two groups



(d) Four desks and one groups

Figure 5. Examples of the UI Projections Provided by the Prototype System.

5. Consideration

Since the prototype system performs desk detection and pseudo UI projection alone, we cannot evaluate the extent to which the aforementioned problems could be overcome by the prototype system based on the results of our experiment; however, this study considers the FLE concept from different perspectives.

5.1 Feasibility

The prototype system used only one sensor and one projector. However, to practically realize FLE, functions such as the recognition of gestures for UI operation, application software for educational use, an integration mechanism to integrate multiple sensors and projectors, system management tools, and so on, should be implemented. These are challenging tasks because the realization of each function requires the consideration of various factors.

In the experiments, the sensor covered an area of approximately 2560 mm × 2030 mm, and the projector covered approximately 2000 mm × 1120 mm (when zooming to a small size). Within a classroom, it is not realistic to place many projectors on the ceiling. However, projector venders have proposed products which are integrated with the functions of both a ceiling light and a projector. By popularizing such products, instead of utilizing ceiling lights by themselves, the feasibility of FLE implementation can be increased.

In the experiment, the size of a UI projected on a desk was 350 mm × 215 mm, and the resolution is 369 pixels × 208 pixels, which is not sufficient for reading e-textbooks, web pages, and so on. In FLE, the resolution of each UI is depended to the resolution and projection angle of the projector. A simple method to increase the resolution of each UI is to apply high resolutions; however, it depends on the number of desks covered by the projector. If a projector with high resolution and a wide projection angle is used, it is possible to increase the resolution of each UI and the number of desks simultaneously. Although the projector's resolution is increased to mainly improve image reproducibility, such as in recent movie appreciation use, the implementation of FLE gives projector technologies new needs.

5.2 Effect of Solving Problems

The results of the experiment cannot explain the effect of improving all the problems described in section 2. However, since the system's architecture is similar to that of a thin client system, it is expected to reduce operational costs. There is no need to worry about charging the batteries or loss of devices, as well. Although there is the risk that projectors might break down, students can use FLE by temporarily moving their desks to the areas of other projectors until the faulty projector is replaced.

Regarding the distraction of students, the condition will be improved using an FLE because a teacher can completely control his or her students' UIs similar to a thin client system. It is easy to turn each UI on/off. When they do not need UIs, the students can use their desks effectively since no devices to take up desk space, unlike in non-FLE settings.

5.3 Future Potential

As mentioned in the Feasibility section, realizing FLE is a challenging task, particularly since we have to wait for the implementation of products that can integrate high-resolution, wide-angle projectors and a ceiling light. However, if the concept of FLE is realized, it is expected to provide functions that cannot be realized using 1-1 computing, such as the following:

- ✓ Optimization of the Arrangement of Items on a Desk:
  Since the position and size of UIs can be adjusted, students can optimize the arrangement of items on their desks. Theoretically, since FLE can project non-square UIs, it might be able to use the top of a desk more efficiently. These functions are not possible with the use of today's smart devices.

- ✓ Collaborative Learning:

  In collaborative learning, large display tools, such as interactive whiteboards, are often used. In 1-1 computing initiatives, these displays are generally prepared in addition to the devices required by each student. However, this causes a rise in costs. Further, when preparing such displays for different groups (since small displays reduce the efficiency of collaboration tasks), it is desirable to change the size of displays according to the number of members in each group. However, this is impossible when using conventional techniques. As shown in Figure 5, FLE can provide UIs optimized for group work without additional investment. Theoretically, using FLE, several large UIs and personal UIs can be projected at the same time on the area provided by adjoining desks. Hence, FLE is expected to easily realize collaborative environments.

- ✓ Application of Projection-Based Augmented Reality and Learning Analytics:

  Since FLE uses projectors, it can incorporate the concept of projection-based augmented reality (AR). Many studies apply AR to learning experiences, which is an advantage of AR, and report effects such as improvements in learning gains, enhancement of motivation, facilitation of interaction, and so on (Bacca et al. 2014). FLE enables the augmentation of several desks at the same time by projecting visual effects using a part of the projection area of one projector.

  Moreover, since FLE uses sensors, we can capture the behavior of each student for learning analytics. It is expected to realize applications such as encouraging students by detecting a lazy attitude, making a group working be actively by detecting discussion stagnation and so on.

6. Conclusion

This study proposed a new learning environment concept as a substitute to using smart devices called FLE. In this concept, by using the projection area of a projector as the movable area of a student, a UI is projected dynamically on the student's desk or hands according to their behavior. This study discussed the design of a prototype system based on the FLE concept, which used one projector and one RGB-D sensor and showed how UIs can be projected on each student's desks according to the desk arrangement. Although many issues remain to be solved to practically implement FLE, the study showed that FLE has many advantages in educational settings.

Acknowledgements

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