uPen: A Smart Pen-liked Device for Facilitating Interaction on Large Displays

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Abstract

This paper presents the uPen, a laser pointer combined with a contact-pushed switch, three press buttons and a wireless communication module. This novel interaction device allows users to interact on large displays at a distance or directly on the surface with full-function of mouse. Onboard software enable the uPen system to identify different users and provide personalized services to them, such as associating users with corresponding privileges, giving access to each participant's private content (e.g., home pages, personal calendars). Additionally, with our two-step association method, the uPen system has the ability to distinguish strokes of different uPens working simultaneously and support multi-user simultaneous interaction. A prototype system has been implemented in our Smart Classroom [1]. And user studies show the benefit of using it.

1. Introduction

Large displays are widely used to benefit users nowadays. The most significant affordance of them is allowing user to watch at a distance and the large surface makes it convenient for a group of users working together. However, most of large displays are non-interactive. They just serve as dispensers of canned information without interactive capabilities.

Our core idea is to augment the large display with appropriate interactive capabilities. Equipped with our uPens and auxiliary software, large displays evolve into a Large-scale Information Appliances (LIA), a new kind of information appliance that serves single users and multiple users as well. For a single user, it serves as a general information kiosk to provide personalized services. For multiple users, it identifies different users and allows them to interact simultaneously.

Such new interactive appliance bases on a novel interaction device which we call uPen. uPen is an augmented pen-like device integrated with a laser emitter, three buttons, a contact-pushed switch and a wireless communication module. This device provides users ability for interacting on projected large displays with full-function of mouse at a distance. And if the display is touch sensitive, such as Smart Board [14], it enables users to directly manipulate on the surface to experience all the service. uPen system has the ability to identify the user who is interacting currently and assign him/her corresponding access privilege. Then, the onboard software enables the large display to serve as a general information kiosk for the user. It allows the user to easily access personal content (such as personal home page, calendar, etc.), exchange digital objects between local and remote private stored space (for example copying a beautiful image and emailing it back). When more than one user are working together with one large displays, our system can distinguish users so as to support multi-user simultaneous interaction. In addition, if the environment includes a number of large displays driven by different machines, user can use uPen to move information objects (for example digital documents, digital images) across these screens seamlessly as if they were one large virtual display.

This paper describes the design and implementation of our uPen system, highlights the key interactive features. A prototype has been installed in our Smart Classroom [1], and empirical user studies have been carried out to evaluate it.

2. Related works

There are many large displays projects in research world. Several of them are sufficiently similar to merit attention.

The DynaWall [15] from GMD is a very large display surface that supports multiple people working together. The DynaWall explores the interesting issues in group work and large scale interaction, but does not afford manipulating remotely, user identifying, or easily sharing content.
Similarly, the Interactive Workspace [16] at Stanford emphasizes the large, sophisticated display areas for information rich manipulation. While they have developed various interaction techniques for large displays, they too do not support personalized service or remotely interaction.

BlueBoard [17], which allows identified users at the board to display personal information, and share with others via email is very similar to our system. However, in BlueBoard system, users need to carry additional badges for identification and as this project aims to provide lightweight walk up interaction, people must walk to the display to direct manipulate.

To interact with large displays remotely, several researchers have explored the use of laser pointer as input to large displays [2, 6, 10, 11]. These have the advantages of low cost, direct pointing, and mobility, but have a fundamental limitation in that there are no buttons to augment the single point of tracked input. As such, even standard mouse operations are not possible. To overcome this, Kirstein and Muller [2] used the on/off of the laser pointer and Olsen and Nielsen [6] explored the use of dwell time to replace the button presses.

Chen and Davis [10] described a system that recognizes different laser strokes with multiple cameras, which increase the cost highly. Ji-Yong[11] used different blink patterns to distinguish laser pointers.

Compared with previous projects, our uPen system allows people to freely interact at a distance or directly on the surface. It has the ability for identifying users easily and we have developed onboard software to augment large displays with abundant interactive capabilities. As a result, large displays finally evolve into a kind of Large-scale Information Appliance (LIA).

2. The uPen

Our approach is to bring a special designed pen to the environment with large displays. Figure 1 shows the architecture and the prototype of the uPpen, which has a laser emitter and a contact-pushed switch separately on both ends, 3 buttons on the pole and a wireless communication module inside.

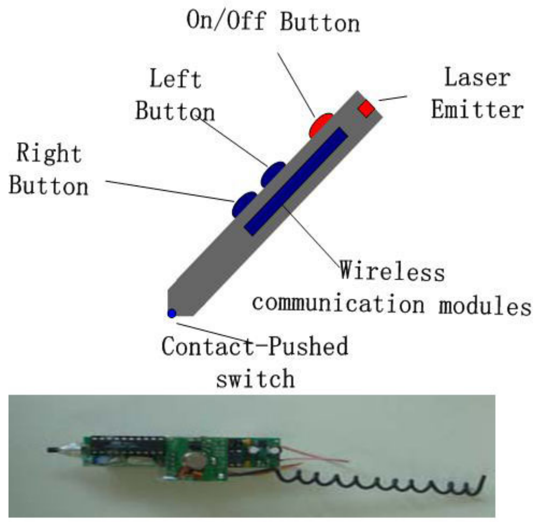

Figure 1. The up is the architecture of the uPen and the below is the inside of it.

Besides a common laser pointer, uPen is designed to be with more functions illustrated in Table1.

Table 1. Functions of additional components on an uPen

BUTTONS	FUNCTIONS
On/Off Button	(1)Emitting a laser beam (2)Emitting the uPen's ID
Right Button	Wirelessly emulating a mouse's right button
Left Button	Wirelessly emulating a mouse's left button
Contact-Pushed Switch	Emitting uPen's ID when being pressed directly on the surface of the display
Wireless communication module	Wirelessly communicate with computer

- **On/Off button.** When it is pressed down, the uPen emits a laser beam and sends the uPen's identity to the computer through radio frequency as well. This function is designed for identifying different uPens in use. Details will be discussed later on.
- **Right Button.** It wirelessly emulates a standard mouse's right button. The state of it is transmitted to the computer through radio frequency.
- **Left Button:** It emulates a mouse's left button.
- **Contact-pushed switch.** It emits the uPen's ID through radio frequency when users are directly writing on the touch sensitive display with uPen.

– **Wireless communication module.** It works as the bridge between the uPen and the computer, which provides wireless communication channel.

3. The Interaction Principles

Based on uPen, users can easily interact with different forms of large displays, from normal projected walls to touch sensitive board (for example, the Smart Board [14]). uPen system makes these large displays serve as Large-scale Information Appliances(LIA), which support not only a single user to take over personalized service, but also serve a group of people working together.

3.1 A single user

For a single user, our uPen system augments a large display to serve as an extended information kiosk, where the user can easily access, share, and exchange personal digital content. Followings are key interactive features.

3.1.1 Augmented mouse. People often stand away to use large displays. For example, at a meeting room, large displays are always placed at high placement where user can't walk-up to touch it. It is necessary to allow the user to interact with the screen at a distance with no cable connected. To meet this requirement, we make uPen masquerade as an augmented mouse.

The red laser spot emitted by the uPen on the large screen is grabbed by a video camera and its position is interpreted as the location of the cursor. The Left and Right buttons on the uPen wirelessly emulate as a standard mouse's left and right buttons respectively. Additionally, as the On/Off button simultaneously emits a laser beam and the uPen's ID, we can add the ID information to the mouse event. As a result, the system has the ability to recognize who is interacting currently, which is the basis of providing personal service. Figure 2 is the scenario of using it.

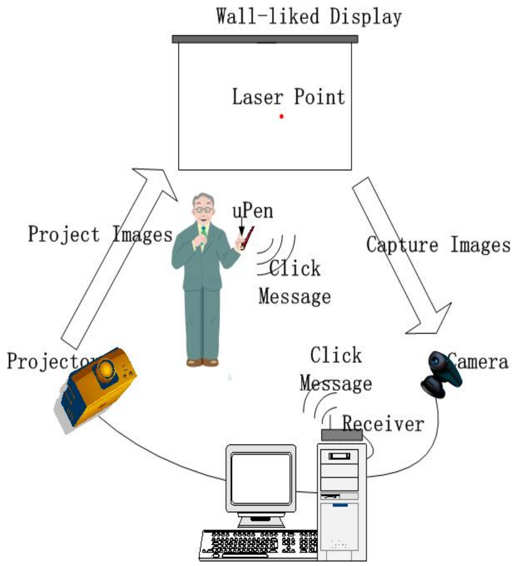

Figure 2. The architecture of the uPen in use for a single user.

A computer-vision-based module called Laser2Cursor was utilized to locate the laser spot's position and mapped it to the position of the cursor. Laser2Cursor embodies a number of ideas not seen in previous work on laser pointer tracking [2, 6, 7, 8, 10, 11]. First, we have developed a training process to improve the system's adaptability. By learning the background of the image captured by the cameras and parameters such as color segmentation and motion detection thresholds, our system automatically adapts to new environments. Second, to improve the system's robustness, we integrate multiple cues such as color, motion, and shape in the laser spot detection. Because most people's hands are unsteady, when a person aims a laser pointer, the spot's exact position usually jitters. We use this characteristic as an additional cue to detect the spot. After it, the coordinates of the laser spot are interpreted as the position of a cursor.

As the uPen allows the user to interact at the level of mouse inputs, people can control all applications with it. With the additional ID information, our system identifies who is interacting currently and provide personalized service for him.

3.1.2 Personalized service. After receiving the ID, our system identifies the user via a server database which stores the user's personal information such as ID, access privilege, URL to home page, email address, etc. By recognizing the user's identity, different users are associated with different privileges. For example, a teacher has the privilege to access all documents stored on the computer while the student can just view his own files.

Several special interactive behaviors are defined to provide personalized services.

- **Blinking.** When the laser emitter on uPen blinks, this behavior is interpreted as bringing up personal content. The system automatically open the user's personal content (such as personal home page) through URL.
- **Circling.** If the user finds something (such as a file or an image) is interesting and want to have a copy of it, he can just draw a circle around it with the laser beam and press down the Left Button on uPen. This behavior is interpreted as Circling command and a copy of the selected object will be automatically transferred to the user through email.

3.1.2 Interaction on touch sensitive board. With the help of the laser beam, users can manipulate freely at a distance. However, the limitation is that an additional camera needed to be settled to locate the red laser spot, although the camera is a common, inexpensive one which only cost 20$.

The touch sensitive board such as Smart Board [14] can detect the position of the touch and interpret it as the cursor position. We added a contact-pushed switch on the tip of the uPen which allows users to directly experience our services on such touch sensitive surfaces. When uPen is pressed on the surface, the contact-pushed button on the tip is pressed down and the transmission of the ID is trigged as well. Differently with interacting on projected display wall where the cursor position is located by laser spot, the mouse's position is determined by the contact position between the uPen and the board. The rest work is the same with interacting by laser beam. As a result, interactive capabilities achieved with laser beam were totally implemented on touch sensitive board with uPen. And the main advantage is that users can walk to the board and directly manipulate on it. In our Smart Classroom [1], we have built an InteracTable to implement all the ideas (Figure 3). InteracTable is a normal touch sensitive board produced by SmartTech[14]. Augmented with uPen and auxiliary softeare, it serves as a Large-scale Information Appliance to provide personalized service.

Figure 3**. A single user is interacting on InteracTable**

3.1.3 Multiple displays. Smart Space usually includes various large displays driven by different machines. We have developed "easy-trans" mechanism to support collaborative interaction across multiple displays. Our "easy-trans" feature allows the user to seamlessly move information objects across screens with an uPen as if all of the screens were a virtual large desktop. Firstly, user accomplishes the selection by uPen (emitting the laser beam onto the objective information object and pressing down the Left Button). The selected object will move along with the laser spot on screen. When the laser spot reaches the edge of the screen, it continues its motion onto the edge of the adjacent screen in that direction. The selected object is also transited onto the machine connected to the adjacent screen and continues motion along with the laser spot.

In our Smart Classroom, setup about screens is shown in Figure 4(a).

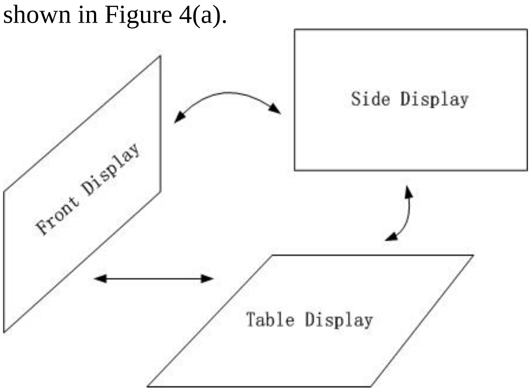

Figure 4(a)**. Setup of screens in Smart Classroom**

Figure 4(b) **"Easy Trans" works well in Smart Classroom.**

There are totally three large displays in Smart Classroom [1]. The left edge of the table display connects to the bottom edge of our front display while the top edge connects to the bottom of the side display. The right edge of the front display connects to the left edge of the side display. The "easy-trans" enables the user to move information object seamlessly across all the three screens in our Smart Classroom with an uPen (Figure 4(b)). This function is useful in the scenario of the discussion. When people were discussing about a document on the front display, a few minutes later, the author wanted to modify it. He can seamlessly move it onto the table display and make the modification.

3.2 Multiple users

A large shared surface makes it convenient for a group of users working together. In a meeting room, we can always see that several people standing in front of a large display discuss about their working plane. Beyond serving a single user, our uPen system can associate each laser spot with corresponding uPen so as to support multiple users' simultaneous interaction. When interacting on touch sensitive board, the same method is implemented to associate different contact events with corresponding uPens.

We achieve the association by *two-step method*, which is illustrated in figure 5. The first step is to associate laser strokes with corresponding uPens and the second is to associate laser spots with laser strokes.

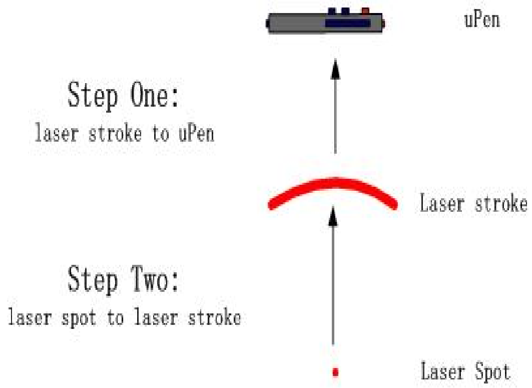

Figure 5**. two-step method**

3.2.1 Step One: Laser stroke to uPen. As the On/Off Button is the switch not only for emitting the laser beam but also for emitting radio frequency which carries the uPen's ID, it is true that the corresponding laser stroke starts to appears on the large screen as well as this uPen's ID is received by the computer at the same time. If multiple uPens are working simultaneously, the computer receives the identities of these uPens in the same order as that in which corresponding laser strokes start to appear. For example, three uPens (L_1 , L_2 , L_3) start to work in the order L_1 , L_2 , L_3 . We identify laser strokes in the way that the laser stroke which appears firstly on the screen is generated by L_1 , the secondly appearing one is generated by L_2 , and the last one's ID is L_3 . Figure 6 clearly illustrates this relationship.

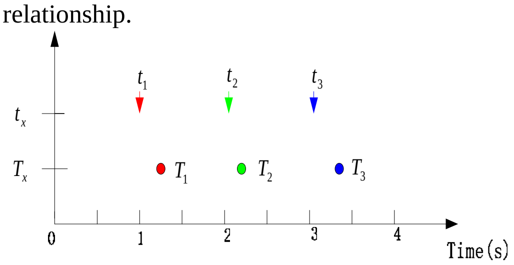

Figure 6. t_x **is the moment when the laser stroke generated by uPen** L_x **began to appear on the screen and** T_x **is the moment when the computer received the uPen'** L_x **ID. (x=1, 2, 3…)**

Thus, the rest work we need to do is to assign observed laser spots to corresponding laser strokes, which is the aim of step two.

3.2.2 Step Two: Laser spot to Laser stroke. Firstly, we predict the expected position of each active laser stroke based on its previous position and velocity, and compare these to each observed position. Valid region is defined for every stroke. This region is the validation region that is standard in many Kalman filter based tracking applications.

Secondly, as in [10], we find out which is the closest valid region for each observed laser spot, and associate the observed spot with the closest stork. After finding associations we update the state of each Kalman system (stroke) that was observed by the current camera. We have found that this data association technique works well in practice.

Two-step method enables the uPen system to support multi-user interaction to some degree. In practice, we found that it suffers from two shortages. First, to identify users correctly, uPens can not start to work exactly at the same moment. In our user study, when number of users increase to four, our system will sometimes get confused. However, when the number of simultaneous users is less than four, our *two-step method* works well in practice. Second, if users are moving laser spot rapidly, it is difficult for system to follow its speed. To correctly associate each laser spot with corresponding uPen, we suggest the user move laser spot less than the speed 1cm per second.

Although these two disadvantages limit the use of our system, as a simple and easily implemented method, two-step association method solves the multi-user interaction problem to some degree. Based on it, we have developed an application named M-Drawing which allows multiple users to simultaneously draw on a public large screen with a various uPens and strokes are rendered with different colors according to different uPens (Figure 7).

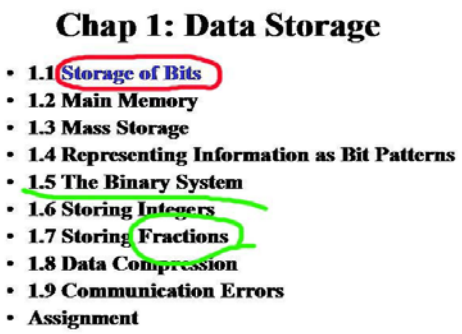

Figure7. Two uPens are being used simultaneously. The laser stroke generated by the first one is rendered with red color while the other is rendered with green.

As current touch sensitive boards (such as Smart Board [14]) can detect multiple contact events which occur simultaneously, *two-step method* is implemented to associate each stroke and contact event with corresponding uPens. Figure 8 shows that two people are writing simultaneously on our InteracTable.

Figure 8. Two users are writing simultaneously on InteracTable.

4. Implementation and Evaluation

4.1 Implementation

A prototype of uPen system has been implemented in our Smart Space system: Smart Classroom [1]. The figure 9 shows the overview of it.

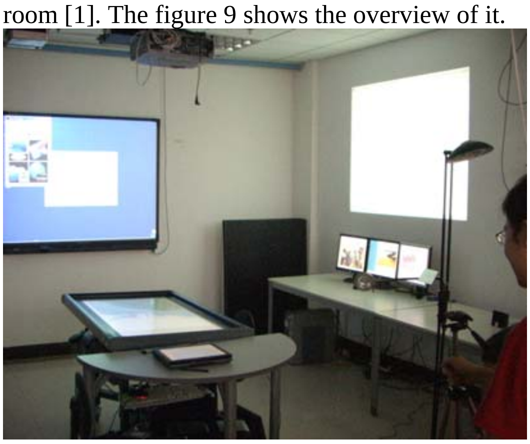

Figure 9. Overview of our Smart Classroom.

It totally contains three large displays. A Smart Board is set up on the front wall and a large projected screen is put on the side wall. A table integrated with touch sensitive screen which we call IntracTable is located in the center of the room.

Software to support the uPen system is based on Smart Platform [5], a multi-agent software infrastructure to support Smart Space. Smart Platform serves to provide necessary communication and coordination method. Based on it, we develop the applications necessary such as detecting laser spots, emulating a wireless mouse, identifying different uPens, etc.

4.2 Evaluation

To evaluate the performance of our system, we assembled a group of 8 subjects (6 male and 2 female) to take a brief survey. All of the subjects were right hand between the ages of 20 and 30 and were experienced computer users. Firstly, each participate utilized the uPen system as an augmented information kiosk, where he viewed his personal calendar, transferred information objects back. Secondly, the subjects are divided into 2 groups, each of which contains 4 persons. They discussed about a plan using our system.

After testing, they compared the uPen with traditional mouse. Scores are given for them respectively.

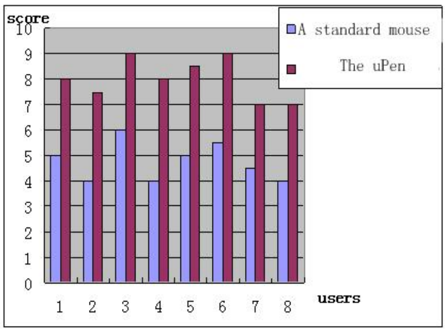

Figure 10. Results of the survey

Figure10 is the result of this survey. It clearly illustrates that every one marked the uPen a higher score than a standard mouse. The average score for the uPen is 8 on a 10-point scale, while that for a standard mouse is only 5.

According to it, we can observe the tendency that the uPen augment the interaction on large displays to some degree. Additionally, 5 participants commented that the uPen allowed them to move freely during the lecture and another 3 participants pointed out that the main advantage of it is various personalized service.

To carry out a large-scale evaluation, a prototype of Smart Classroom has been built in Tsinghua University's Continue Education School. The uPen as the interactive device in Smart Classroom works effectively, and teachers using it have been very positive in their assessment of its utility and usability.

6. Conclusion

In this paper, we presented the uPen system which aims at augmenting large displays to become a new kind of things, Large-scale Information Appliance (LIA). A laser pointer integrated with three additional buttons, a contact-push button switch, and a wireless communication module is introduced as the interaction device in our system, which we call uPen. With this novel interaction device, a number of interaction mechanisms are developed.

- **Augmented mouse.** It allows the user to interact at any distance and provide ID information.
- **Personalized service.** The system has the ability to identify the user and assign him corresponding access privilege. Further more, the LIA allows the user to easily access and exchange personal digital content.
- **Interaction on touch sensitive board.** All of the functionalities have been implemented both on normal projected wall and on touch sensitive board.
- **Interaction across various screens.** "easy-trans" feature allows the user to seamlessly move information objects across screens driven by different machines as if all of the screens were a virtual large desktop.
- **Multi-user interaction.** With two-step association method, the LIA supports multiple users interacting simultaneously.

In the end, the uPen system is implemented in our Smart Classroom [1] and user studies illustrate that it facilitates interaction on large displays greatly. To completely evaluate it, a large scale user study is ongoing.

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