Facilitating Interaction with Large Displays in Smart Spaces

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Abstract

Large displays are widely equipped in Smart Spaces these days. However, traditional interaction devices which are designed to suit desktop screen, such as mice, keyboards, have various limitations in such environments. In this paper, we present a novel human-computer interaction system, known as *the CollabPointer*, for facilitating interaction with large displays in Smart Spaces. A laser pointer integrated with three additional buttons and wireless communication modules is induced as input device in our system and three features distinguish *the CollabPointer* from other interaction technologies.

First, the coordinates of the red laser point on the screen emitted by the laser pointer are interpreted as the cursor's position and the additional buttons on it wirelessly emulate a mouse's buttons through radio frequency. It enables remote interaction at any distance.

Second, when multiple users are interacting, with two-steps associating methods described in this paper, our system can identify different laser pointers and support multi-user collaboration.

Last but not least, the laser pointer emits its identity through radio frequency during interaction. The system receives it and treats different users separately.

In the end, *the CollabPointer* has been implemented in the Smart Classroom [1]- a prototype of Smart Space, and the results of user studies show the benefit of it.

1. Introduction

Smart Spaces are work environments full filed with embedded computing devices allowing people to perform tasks efficiently. The size of displays of these devices can range from very small to very large. In this paper, we addressed at the issue of facilitating interaction with large displays in Smart Spaces.

To enables the detailed display and exploration of complex data sets, large tiled displays are well-suited in Smart Spaces [15] for visualization applications. However, as traditional interaction technology addressed at desk computers, large wall-sized display configuration presents a number of challenges.

Consider a class room equipped with a large projected display. A teacher is giving a lecture to several students with slides projected on the large screen. Transitional interaction devices such as mouse and keyboards require the teacher to walk to the computer to manipulate it, which always interrupt the process of lecture. A novel interaction device which allows interaction at any distance is desirable in this situation.

Another example involves a planning session for rescue efforts with a number of participants scattered around a room with a shared large display. If there is only one interaction device that is wired to the computer, the device can only be used in a limited range. If participants in the back of the room want to contribute, they have to come to the front to use the interaction device. Even worse, since there is only one input device available, users are forced to go through the process of acquiring the device before they can contribute their ideas. To facilitate this kind of collaborative work, a system supporting multiple users interacting simultaneously is desired.

We wanted a solution reflects the characteristic of Smart Spaces integrated with large wall-sized displays. This led us to the following design principles

- *Remote interaction* - Users can interact at any distance without wires connected to the computer. It allows users to move freely during the interaction.
- *Supporting collaboration* - The system distinguishes a various users and supports them interacting simultaneously.
- *User reorganization* - The system has the ability to recognize the user's identity wherever he is interacting. Individual service is provided for him and it is beneficial that different users are treated separately.

To meet these goals, we designed and implemented a interaction system called *the CollaPointer*

2. Related work

Many researchers consider interaction from a large display at a distance.

Kirstein and Muller [2] presented a system that uses a laser pointer as a pointing device. Their system acquires video frames at 20 fps. They report that they are able to detect the laser spot in only 50% of the frames.

Olsen [6] proposed an inexpensive interaction technique by introducing a set of window events for the laser pointer such as laser-on/off, and laser-move/dwell.

Winograd and Guimbretiere [14] proposed a new kind of interaction techniques for large displays, which are based on "gesture and sweep" paradigm instead of the usual "point and click".

Chen and Davis [12] described a system that can provide multiple laser pointer inputs with multiple cameras. Ji-Yong[13] used different blink patterns to distinguish laser pointers

None of the previously mentioned approaches can reliably support multiple users interacting with the system and no one provides individual service.

3. The CollabPointer

3.1 Overview

In our system, a laser pointer integrated with three additional buttons and wireless communication modules is introduced as the interaction device. A new hardware named *Receiver* serves as a bridge between the laser pointer and the computer. Its function is to receive the radio frequency emitted by the laser pointer and transmit it to the computer through USB interface. Figure 1 shows the application scenario and the components of the *CollabPointer*.

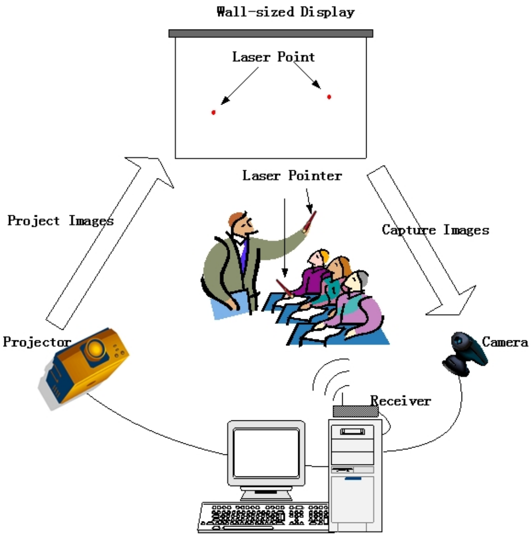

Figure 1: Application scenario and components of the system

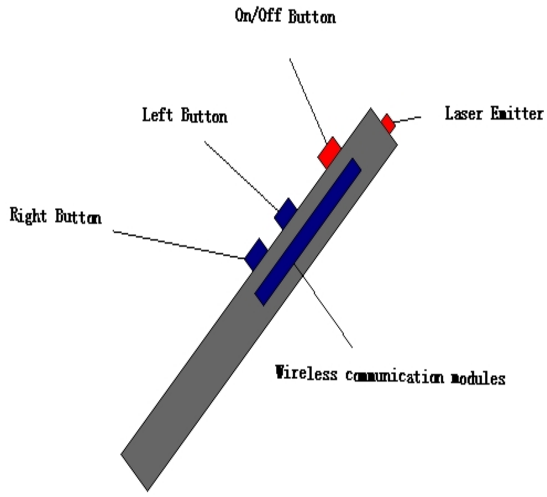

Figure 2: Architecture of the laser pointer

When a single user is interacting, the point induced by the laser pointer on the large projection screen is grabbed by a video camera and the digitizing computer hardware. The images are analyzed to detect the location of the red laser spot. The coordinates of it are interpreted as the position of a cursor. On the other hand, the addition buttons integrated on the laser pointer emulate a standard mouse's buttons wirelessly. As a result, the laser pointer totally emulates a mouse and can be utilized wirelessly at a distance. If multiple users are interacting simultaneously, with *STC (Start Time Coherence) principle*, which is firstly brought forward by us in this paper, the system can distinguish a various laser pointers correctly and support multi-user collaboration. In addition, the system obtains each user's identity while he is interacting. For different users, the service provide by the system is also different.

3.2 Interaction Device

A common laser pointer integrated with three additional buttons and wireless communication modules is introduced as the interaction device in our system. In addition, to receive the RF signal emitted by the laser pointer and transmit it to the computer, a new hardware called the Receiver is also introduced.

3.2.1 The laser pointer

Figure 2 shows the architecture of it.
There are totally three additional buttons on the laser pointer, On/Off button, Right button and Left Button. Their functions are described as table 1.

BUTTONS	FUNCTIONS
On/Off Button	(1)Emitting a laser beam (2)Broadcasting the user's ID
Right Button	Wirelessly emulating a mouse's right button
Left Button	Wirelessly emulating a mouse's left button

Table 1: Functions of Buttons

On/Off button: This button is a switch, not only for turning on the laser pointer but also for broadcasting the user's identity through wireless communication modules. If the button is down, the laser beam is emitted and the ID of the laser pointer is broadcasted through radio frequency at the same time. The system receives the ID through the *Receiver*. According to its ID, we assign different users with different access priorities. For example, an administrator has more power than a guest.

Right Button: This button wirelessly emulates a standard mouse's right button. The state of it is transmitted to the computer through radio frequency. The computer receives it via the *Receiver* and matches it to a standard mouse's right button. When multiple users are interacting simultaneously, users are ranked according their identities and the computer is controlled by the user who has the highest access priorities. For example, when a teacher and a student are pressing the Right Button simultaneously, the system responds to the teacher's action while ignores the student's.

Left Button: It is nearly the same as the Right Button. The only difference is that it emulates a mouse's left button.

3.2.2 The Receiver

It receives the radio frequency emitted by the laser pointer, decodes it, and then transfers it to the computer through USB interface. According to the three buttons integrated on laser pointer, the computer explains the received signal as the laser pointer's ID, the Right Button's state or the Left Button's state. Figure 3 is the prototype of the *Receiver*

Figure 3: the prototype of the Receiver

First, it decodes the radio frequency emitted by the laser pointer. Next, the IC 74LS00 is used to transit the electrical signal to logical zero, which serves as an interrupt input for the microcontroller. Finally, and also the most important, the microcontroller is programmed to communicate with the computer through USB interface. Phillip's PDIUSBD12 IC servers as a bridge between the microcontroller and the computer.

4. Interaction with the CollabPointer

For a single user, the laser pointer emulates a standard mouse and can be utilized to interact at a distance. For multiple users, the system can identify a various laser pointers and afford seamless and parallel collaboration among several users. In addition, we can obtain each user's identity while he is interacting. According to it, different people are treated differently.

4.1 Single-user

In this mode, the coordinates of the laser spot on the display are mapped to the position of the cursor, which means that the user can directly utilize the laser pointer to manipulate the cursor. The Right/Left button on the laser pointer wirelessly emulates a mouse's right/left button. Using this new interaction device, people can "point and click" wirelessly at any distance.

A computer-vision-based module called Laser2Cursor was utilized to locate the laser point'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. 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 per son aims a laser pointer, the spot's exact position usually jitters. We use this characteristic as an additional cue to detect the spot. Next, a Kalman filter smoothes the spot's trajectory, which tends to be irregular and rough.

In addition, the laser pointer broadcasted the user's ID via radio frequency while it is working. The system receives it through the *Receiver* and treats users separately. For example, we assign different users with different accessing priorities. In Smart Classroom [1], where the system has been implemented, teachers and students are assigned different accessing priorities. With teachers' laser pointer, the user can view all files on the computer; while with students' one, he can just view his own document.

4.2 Multi-user.

When multiple users are interacting simultaneously, associating laser spots on the screen with corresponding laser pointers is the basis for collaboration. As shown in figure4, we achieve this aim by two steps. The first is to associate laser strokes with corresponding laser pointers and the second is to associate laser spots with laser strokes.

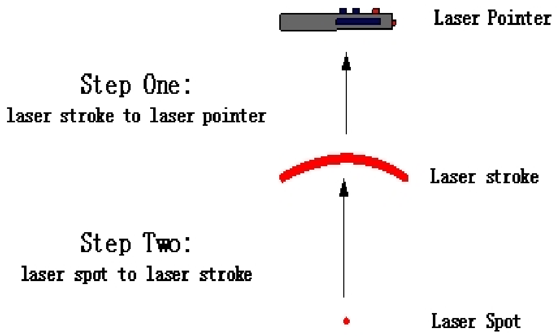

Figure4: associating laser spots to laser pointers

4.2.1 Step One: Laser strokes to Laser pointers

When the laser pointer L is being utilized, the laser beam will generate a laser stroke l on the screen and the laser pointer's identity L will be transmitted to the computer via radio frequency at the same time. If multiple ones are being used simultaneously, associating laser stroke lx with corresponding laser pointer Lx is the aim of this step.
Initially, several symbols are introduced.

P_l: The starting point of the laser stroke l.

T_l : The time when the computer recognizes P_l through image processing.

t_L : The time when the computer receives the laser pointer L's identity.

STC (Start Time Coherence) Principle: Ideally, if no latency, because the On/Off button on the laser pointer is the switch not only for emitting laser beam but also for sending out the user's identity via radio frequency, we can draw a conclusion: $T_l = t_L$. This equation means that when the computer just recognizes the starting point of stroke l, at the same time, it will receive the laser pointer's identity L. However, in practice, due to the latency in signal transmission and data processing, T_l is not equal to t_L but a little later than it. Experiment 1 is designed to measure this time interval $\Delta t(\Delta t = T_l - t_L)$.

Experiment 1: Five people interacted with computers using laser pointers. Every one draw ten laser stokes on the display.

T_l , t_L were recorded for each person and the average/maximum values for $\Delta t(\Delta t = T_l - t_L)$ were worked out.

Person	1	2	3	4	5
Average (Δt) (ms)	50	51	50	52	50
Maximum(Δt) (ms)	55	54	55	54	55

Table 2: Results of Experiment 1

Analyzing the results, we come to the conclusion that the average value of T_l - t_L is nearly 50ms and the maximum value of this interval is 55ms. (0ms < T_l - t_L <55ms).

Take two laser pointers Lx and Ly for example. When Lx and Ly are being used simultaneously, two laser strokes lx and ly will be generated on the screen. Firstly, we can get two formulas as below:

$$0ms < T_{lx} - t_{Lx} < 55ms \quad (1)$$

$$0ms < T_{ly} - t_{Ly} < 55ms. \quad (2)$$

On the other hand, during collaboration, it is almost impossible that any two users press down the On/Off buttons exactly at the same time. There is certainly a time interval between two people's actions. We have designed experiments 2 to measure this time interval.

Experiments 2: Two participants tried to push down the On/Off buttons on their own laser pointers (Lx and Ly) at the same time. T_{lx} , T_{ly} are recorded for further study. The two participants repeated the action for ten times and we found out the minimum value of time interval $\Delta T = | T_{lx} - T_{ly} |$ for them.

This experiment is repeated by five groups of people. Each group consisted of two participants.

Group	1	2	3	4	5
Minimum (ΔT) (ms)	300	310	320	305	306

Table 3: Results of Experiment 2.

After analyzing the results, we can draw the conclusion that the time interval between T_{lx} and T_{ly} is at least 300ms. It means that for laser stokes lx and ly ,

$$|T_{lx} - T_{ly}| > 300ms. \quad (3)$$

With (1), (2) and (3), we come to the conclusion that for T_{lx} ,

$$\begin{cases} 0ms < T_{lx} - t_{Lx} < 55ms \\ T_{lx} - t_{Ly} < 0ms \quad or \quad T_{lx} - t_{ly} > 300ms \end{cases} \quad (4)$$

For T_{ly} , it is the same that

$$\begin{cases} 0ms < T_{ly} - t_{Ly} < 55ms \\ T_{ly} - t_{Lx} < 0ms \quad or \quad T_{ly} - t_{Lx} > 300ms \end{cases} \quad (5)$$

According to (4) and (5), T_{lx} , T_{ly} can be associated with corresponding t_{Lx} , t_{Ly} .

For T_{lx} , it has a unique corresponding laser stroke lx , and for t_{Lx} , it can be mapped to a unique corresponding, laser pointer Lx. So, the aim of the first step is achieved that we finally associate lx , ly (laser strokes) with corresponding Lx and Ly (laser pointers).

Take more laser pointers for example. If $L1$, $L2$, $L3$… are being used simultaneously, strokes $l1$, $l2$, $l3$ … will be generated on the screen. During the interaction, the computer will receive laser pointers' identities $L1$, $L2$, $L3$… Figure5 shows the relationship between T_{l1} , T_{l2} , T_{l3} …and t_{L1}, t_{L2}, t_{L3}.

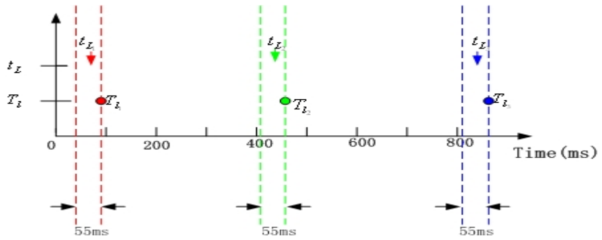

Figure 5: Timing relation between t_{Lx} and T_{lx} (x=1,2,…).

It clearly illustrates that for each T_{lx} , (x=1, 2, 3…), the corresponding t_{Lx} (x=1, 2, 3) locates in the region $[T_{lx} - 55ms, T_{lx}]$ and other t_{Ly} $(y \neq x)$ locates out of it. According to this relationship, it is easy for us to find out corresponding t_{Lx} for T_{lx} . Furthermore, T_{lx} and t_{Lx} were separately mapped to lx (the laser stroke) and Lx (the laser pointer), so in the end, we achieve the goal to associate lx with corresponding Lx.

4.2.2 *Laser spots to Laser strokes*

Based on *STC principle*, laser stroke lx is assigned to its corresponding laser pointer Lx. The rest work we need to do is to associate each observed point with its corresponding 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. We defined valid region for every stroke. This region is the validation region that is standard in many Kalman filter based tracking applications.

Secondly, as in [12], we find out which is the closest valid region for each observed point, and associate the observed point 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.

Depending on the circumstances, at the end of this per-frame process there may be laser spots that cannot be associated with a laser pointer and laser pointers that cannot find a laser spot close to the predicted position. We deal them as in [13]. Unassociated laser spots are classified as starting points for a new laser pointer. If there is a laser pointer where no close enough laser spot exists, we assume that it has been turned off.

After these two steps- *laser strokes to laser pointers* and *laser spots to laser strokes*, multiple laser pointers are successfully identified by the system. It is the basis for multi-user collaboration.

4.2.3 Application:

We have utilized VC++6.0 to develop an application named M-Drawing to enhance collaboration for a number of users. When it runs, a totally transparent window covers the screen. Multiple users can draw on it with laser pointers simultaneously and strokes appear different colors according to different users. Figure 6 is the scenario that two people are discussing about a presentation slide.

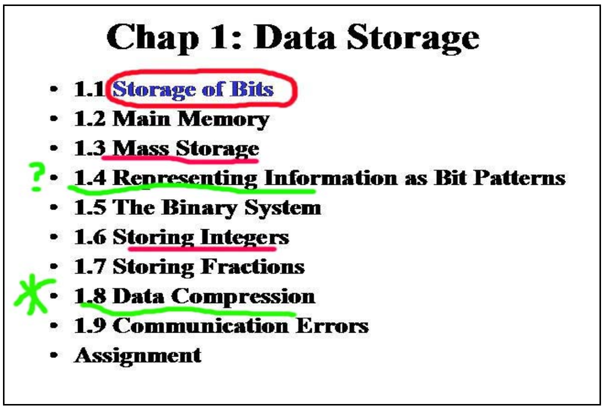

Figure 6: Two users are discussing.

5. Implementation and Evaluation

5.1 Implemented

To evaluate the performance of *the CollabPointer*, a prototype of it has been implemented in our Smart Classroom [1]-a prototype of Smart Space which aims at facilitating a teacher to give a class. The involved technologies include human and hand tracking, face recognition, speaker recognition, CSCW and so on. The software infrastructure of the Smart Classroom is Smart Platform[5], which is based on Multi Agent System(MAS). It means that modules are running as collaborative agents in it. Of course, *the CollabPointer* is encapsulated as an agent, which serves to facilitate interaction with the computer through large displays.

5.2 Evaluation

We took a brief survey of the performance of *the CollabPointer* and recruited 8 subjects (6male and 2 female). All were right hand between the ages of 20 and 30 and were experienced computer users. Each participate utilizes *the CollabPointer* to present a presentation in Smart Classroom. After it, they compared *the CollabPointer* with the mouse and gave scores for them separately.

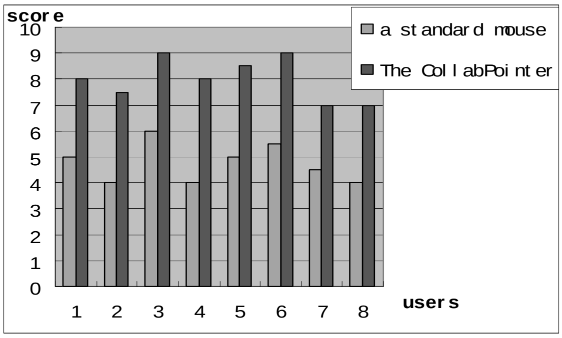

Figure 7: results of the survey

Figure 7 is the result of this survey. It clearly illustrates that every one marked *the CollabPointer* a higher score than the mouse. The average score for *the CollabPointer* is 8 with the full is 10, while that for the mouse is only 5. According to it, we came to the conclusion that *the CollabPointer* is preferred over mouse in the case of interacting through large displays. Additionally, 5 participants commented that *the Collabpointer* allowed them to move freely during the lecture and another 3 participants pointed out that the main advantages of it are mobility and accessibility form remote distances. Of course this survey is definitely insufficient for too few samples, and continuance of this survey in more precise condition definition should be needed

6. Conclusion

In this paper, we proposed *the CollabPointer* which aims at facilitating interaction through large displays in Smart Spaces. This system is designed and implemented based on three principles-interacting at a distance, supporting collaboration, and user recognition. To meet these goals, a laser pointer integrated with three additional buttons and wireless communication modules is introduced as the interaction device in our system.

Three features distinguished *the CollabPointer* from conventional interaction system.

First, by adding additional buttons to a standard laser pointer, a highly effective input device can be created quite inexpensively. The fact that a laser pointer is by definition a pointing device, and additional buttons makes communication with the computer easily, makes it a natural, direct and intuitive apparatus for interacting with a computer remotely. Its effectiveness is similar to that of a desktop mouse, while still allowing the user to interact from large screens wirelessly at any distance

Second, different from other researchers [12], [13], we use wireless communication modules for distinguishing between different laser pointers. With the *STC principle* which was firstly brought forward by us in this paper, we can successfully associate different laser spots with corresponding laser pointers.

Based on it, *the CollabPointer* support multiple users interacting simultaneously and the application M-Drawing has been developed to allow multiple people to draw simultaneously with different colors.

Last but not least, *the CollabPointer* obtains the user's identity during the interaction and assign them with different priorities. . For example, in our Smart Classroom [1], teachers and students are assigned different accessing priorities. With teachers' laser pointers, users can view all files on the computer, while with students' ones, users can just view his own document.

Finally, with the results of our experiments, we are convinced that *the CollabPointer* facilitates interaction with computers through large displays to some degree.

7. References

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