Enhancing Interaction in Architectural Presentations with Laser Pointers
Siu-Pan Li, Thomas Kvan
Enhancing Interaction in Architectural Presentations with Laser Pointers
Siu-Pan Li, Thomas Kvan

In a common meeting environment with projector-and-screen settings, the discussion may be dominated by a presenter who has the control of the content displayed. Although frequently used for architectural discussions, this digitally-engaged setting may not be optimal in its support of participation and discussion of design ideas. This paper presents a novel use of laser pointers to enhance the interaction in architectural presentations. A laser pointing system designed for a projector-and-screen environment was developed. To compare the performance of the laser pointer with other interaction devices, a controlled user study was carried out to test the efficiency of different devices in point-and-selection interactions. The usability of the system was also tested in a design critique. These two tests show that laser pointer is useful and able to encourage participation in group discussions. Details of the laser pointing system, the experiments and the results are reported in this paper.
1. INTRODUCTION

Images projected on screens have become common in educational and commercial presentations in recent years. The projection of an image or data on a large screen provides a shared context in which many participants can see the information; in such a setting, the content on the projection screen is the focus of the discussion. A screen projection setting is particularly good for one-way dissemination of information and the flow controlled by the presenter. Thus the discussion may be dominated by the presenter who has the control of the computer and hence reducing opportunities for active participation from others in the room. Where participation is desired, control has to be passed formally by handing over the remote or keyboard, slowing down interaction and stifling discussion. With potential difficulty in controlling the projected image, some participants may choose to engage in discussion without coordinating the visual image. To overcome this, a means of more easily sharing control is needed.

Laser pointers are commonly used in presentations. It is natural and convenient to point to things across a room using a laser pointer [1]. It is feasible to use laser pointers as interactive devices in computer interactions; this capacity can facilitate group discussions in which interaction with a computer is required. While technical issues of implementing laser pointing systems have been broadly examined [2-4], the benefits and problems of using laser pointers in group design discussion have not been explored.

Architectural juries are a common example of meetings in which interactive discussion with the presented information is needed. Design juries and the nature of participation in these juries have been extensively reviewed elsewhere [5-7]; this paper will not address the nature of interactions and the role of particular tools in such interaction. Instead, we work from a presumption that there is a need for a pointing device in co-located juries using digitally projected images and that multiple users may wish to interact with the projected image. Broad engagement and control of the projected information will promote more interactive discussion.

This paper examines the feasibility of using laser pointers to achieve such purpose. A laser pointing system for large screen interaction was developed and tested in design discussions. With this system, each participant with a laser pointer has an equal chance to control the projection display and thus to lead the presentation. In developing the system, it was anticipated that a laser pointing system would enhance the engagement of students in presentation and discussion in architectural schools. In order to test this hypothesis, two experiments were carried out. Details of the system and the experiment results are reported.
2. LITERATURE REVIEW

Laser pointer interaction has attracted a great deal of attention in recent years. A large number of laser pointer enabled wireless mice are commercially available. The wireless mice interact with the computers through radio frequency or infra-red signals and the laser pointer is simply an add-on feature to enhance a presenter’s ability to indicate onscreen. Thus, these tools offer the same capabilities and difficulties of using a mouse and a laser pointer independently.

At least one company has removed the need for a mouse; since 1995 Proxima have incorporated a camera for tracking a laser dot as a mouse input device in their commercial data projectors [8]. Kirstein and Muller [2] describe a system for direct interaction with a video projection screen using only a laser pointer. The behaviour of the laser point is translated into mouse signals and the device is directly analogous to a single user wired mouse. Eckert and Moore [9] used laser pointers in a large classroom to increase interactivity between instructor and students. Employing a laser pointer that emulates mouse actions on a computer projection screen, the instructor moves about the classroom as he/she controls the presentation. The system increases interactivity between instructor and students by freeing the speaker to walk around and change socio-spatial dynamics during the presentation. Olsen and Nielsen [10] developed an interaction interface which incorporated a laser pointer with pop-up menus on the screen to provide similar results.

Researchers have reported various problems in the use of a laser pointer for interaction. By measuring the performance of laser pointers and other devices, Myers, et. al. [1] revealed that conventional interaction techniques designed for a mouse or a stylus fail when used with a laser pointer due to hand jitter and difficulties in turning the beam on or off at the right position. Olsen and Nielsen [10] found that the laser pointer was half the speed of mouse-based interaction. Addressing usability problems, Matveyev and Gobel [4] developed a three-beam laser pointer for their “optical tweezers” to increase the accuracy of the laser pointing device.

Some researchers have attempted to extend pointing systems to support multiple pointers for collaborative engagement on screen. Oh and Stuerzlinger [3] and Vogt, et. al. [11] tracks multiple laser pointers using an asynchronous “blink-off” approach while Pavlovych and Stuerzlinger [12] use synchronous multiplexing techniques. It has been demonstrated that using multiple laser pointers is useful in a specifically designed problem-solving task such as finding the shortest path in a maze [13]. However the interaction of concurrent multiple pointers has not been explained in any literature.

These research findings demonstrate the possibility of using laser pointers as computer interaction devices and reveal some physical limitations in manipulating with laser pointers. The use of laser pointers in...
specially designed collaborative activities has also been examined; while research has been carried out on the assumption that laser pointers could help in presentation, the actual performance of systems employing laser pointers in real applications has not been reported. This research investigates the application of laser pointers in the particular context of an architectural presentation.

3. THE LASER POINTING SYSTEM

To provide tools for interaction in a presentation, a Laser Pointing System (LPS) is developed as a flexible building block for specific interactive applications. The system fulfills three functions: it allows the user to direct attention by pointing a bright red spot on the screen (the traditional use for laser pointers); identify and then manipulate an object displayed directly on the screen (e.g. move or changing its attributes), and to instruct the computer to invoke a series of more complicated actions (e.g. shut down a computer).

No specific type of usage is assumed during the development; the system is designed to be context and hardware independent, thus useful in a variety of situations with different projectors and cameras. Composed of two major parts, it is implemented in a client-server architecture (see Figure 1) which allows transparent integration of different devices independent of platform.

A LPS server program running on a computer which is connected to a camera is responsible for detecting laser spots and sending the laser ON/OFF signals and the coordinates of the laser point to the client side. A client of the system, which is a program executed on a participant’s computer, is responsible for receiving message from the servers, decoding the message, and interpreting the movement of the laser point into interaction commands, and sending the commands/events to the operating system. A client can be connected through a local area network (LAN) to one or two LPS servers. Therefore the system is able to handle multiple screen projection, a distinctive requirement of architectural presentations.

3.1. Hardware set-up

Low cost video cameras, typically used for video conferencing and surveillance video, are used to monitor front-projection screens. A camera captures a projection screen at 800x600 pixel resolution at a rate up to 30 frames per second. It is connected to a normal PC through a high-speed USB2.0 cable. A display resolution of 1024x768 for each screen is used in this project. Since the camera resolution is lower than the resolution of the display, a camera must be placed close to the screen so as to better utilize the capture area. The brightness of a laser spot is sufficiently high that the camera sensor is always saturated at a normal setting.

Through experimentation we found it necessary to reduce the exposure time of the camera. Even then, the laser spot is consistently too bright and...
the captured image of a red laser spot rendered pale orange, reducing recognition. In order to increase the accuracy of the laser spot detection, a red filter is attached in front of the camera lens.

3.2. Software

In this project, one server program and two client programs were developed.

Detecting the laser point

Although using multiple laser pointers in computer interaction has been demonstrated elsewhere [3, 12-13], use of multiple pointers has not been made by participants in a discussion. In earlier experiments, concurrent multiple pointers have been used solely for specifically designed interactions. Multiple pointers may lead to interaction conflicts when multiple users attempt to control a computer at the same time; for example, a conflict will occur when a participant wants to go to the next slide in a PowerPoint presentation while another attempts to go to a previous slide. A parallel may be drawn with mouse interaction; no general-purpose computer supports multiple mouse pointers within a same display session. Since the LPS was designed as a general building block for various applications, a single-pointer-interaction is assumed in the system in order to prevent any conflicts which may arise when multiple users attempt to control a computer at the same time. In spite of this, the LPS can still provide a
virtually 1-to-many interaction where multiple users can interact with the system provided that they collaborate properly. The concept is similar to “time-slicing”. A user holding a laser pointer can interact with the system immediately after the other finishes his action.

Detection of the laser spot is handled by the server program which scans through each individual frame to check if there is any instance of pixel brighter than a certain threshold. If more than one bright pixel is detected, the mid-point of these bright pixels is computed. Therefore the server will only report one laser spot at a time.

Calibrating the camera

Since the resolution of a display produced by a projector is higher than the resolution of a camera, it is impossible to directly relay the projection area with the captured area. A transformation is needed to convert a captured display to its corresponding area on the projection screen. As a result, the software must be able to handle this transformation. Eckert and Moore [9] assumed that the captured projection area is trapezoidal and did a linear mapping from a trapezoidal area to its original rectangular area. However this assumption is only valid for few expensive cameras without any optical distortion. The non-linear pin cushioning effect of most cameras and the keystoning effect of projectors [10] make the linear mapping approach inappropriate. And thus a non-linear transformation is used in this system.

The transformation equations are two polynomials of second order degree in x and y:

\[
x' = r_0 + r_1x + r_2y + r_3x^2 + r_4y^2 + r_5xy + r_6x^2y + r_7xy^2 + r_8x^2y^2 \quad (1)
\]
\[
y' = s_0 + s_1x + s_2y + s_3x^2 + s_4y^2 + s_5xy + s_6x^2y + s_7xy^2 + s_8x^2y^2 \quad (2)
\]

where \( r_i \) and \( s_i \) are coefficient constants determined in the initialization; \( (x, y) \) are coordinates of a point on the captured image; and \( (x', y') \) are coordinates of the point on the projection screen.

The 9 pairs of coefficient constants can be found using a series of 9 distinct points with known coordinates both on the projection screen and on the captured area. These learned polynomials are then used by the server program to map detected points onto coordinates on the projection screen.

In order to determine the coordinates of 9 distinct points, a calibration step is initialized when the server starts. A user targets the laser pointer to a series of 9 points on the screen with known coordinates. The corresponding coordinates on the captured image are recorded by the server program. After computing the coefficient constants, an accurate mapping model is obtained.

Interaction

The server program detects the ON/OFF events of the laser points,
computes the coordinates of laser spots on the screen, and sends these information to the client programs through a LAN using a stream of UDP packets. The meaning of this information is subject to interpretation in the client program; therefore different interaction behaviour can be programmed in the client program to suit different needs. For instance, the interaction of a computer game can be completely different from the interaction of a presentation.

In this project, two client programs were implemented. One client simply mimics the movement of the mouse cursor and invokes a mouse click when the laser spot goes off. The other client provides a set of interactive behaviours for the general use of a computer, such as single mouse click, double mouse click, right click, drag and drop, up cursor key and down cursor key. These complicated interactions were made possible by a stroke recognition function. The locus of a laser point is first interpreted as a command. Consequent action will be taken when the system recognizes a predefined stroke.

Stroke recognition

A stroke recognition function was implemented in one of the client programs using the neural network approach. The recognition function was developed based on Boukreev’s Mouse Gestures Recognition program [14]. A 3-layer feed-forward neural network with standard back-propagation algorithm was used. The neural network was trained to recognize a number of predefined stroke patterns. Eight strokes were used in this client program (see Table 1), for example. The training result is stored in a file which is recalled when the client program is executed. Since noise was introduced in the training process, the neural network was able to recognize strokes by different users.

After receiving a series of laser spot coordinates from the server, the client feeds the coordinates sequence into the recognition function. When a predefined stroke is detected, the behaviour of the next laser point interaction is changed accordingly. If an unknown stroke is detected, the sequence of spot coordinates is simply discarded.

With the stroke recognition function, the laser pointer not only can emulate a mouse cursor, but also can mimic more difficult actions, such as right mouse click, double mouse click and keyboard events, without any auxiliary devices [15].

4. LASER POINTER PERFORMANCE EXPERIMENT

It has been shown that applications using hand-held laser pointers are constrained by some physical limitations [1, 3-4]. Some measures, such as adding a colour filter to a camera as mentioned above, providing more accurate mapping for the laser point coordinates, and minimizing feedback delay, were taken to improve the performance of the LPS. Before using our
tool in a presentation, however, a usability study was carried out to compare the performance of the LPS to other modes of interaction. A modified version of the Fitts’ experiment [16] was used.

4.1. Experimental setup

A computer program implementing a modified version of the Fitts’ experiment was developed. In each test, a subject was asked to click on 100 circles, including 50 “parked” circles and 50 “random” circles appearing in alternation. A parked circle is a circle of a fixed size of 30 pixels in diameter and located at the centre point of the window. A random circle is a circle of a random size, ranging from 20 pixels to 100 pixels in diameters and appearing at a random position, the edges of any two consecutive circles being at least 20 pixels apart.

Thirteen participants, nine male and four female, took part in this experiment. Each participant had to undertake five tests with a projection screen. Each subject tested the following devices: a laser pointer, a Track Point, a mouse and a stylus. For a comparison purpose, the participants were also asked to test with a stylus with the LCD display of a Tablet-PC. The tests were randomly assigned in a random order for each participant.

<table>
<thead>
<tr>
<th>Stroke</th>
<th>Subsequent actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
<td>Send a UP cursor key event</td>
</tr>
<tr>
<td>b</td>
<td>Send a DOWN cursor key event</td>
</tr>
<tr>
<td>C</td>
<td>Point the laser spot to the right position and switch OFF to invoke a mouse left-click</td>
</tr>
<tr>
<td>R</td>
<td>Point the laser spot to the right position and switch OFF to invoke a mouse right-click</td>
</tr>
<tr>
<td>D</td>
<td>Point the laser spot to the right position and switch OFF to invoke a double mouse left-clicks</td>
</tr>
<tr>
<td>M</td>
<td>Point the laser spot to the right position and switch OFF to select an object. Move the spot to another place (drag) and switch OFF to the object (drop)</td>
</tr>
<tr>
<td>P</td>
<td>Switch to laser pointer mode (for simple pointing purpose without interaction)</td>
</tr>
<tr>
<td>(at the bottom of the screen)</td>
<td>Restore to laser interaction mode (with stroke detecting)</td>
</tr>
</tbody>
</table>

Table 1: Command strokes.

Enhancing Interaction in Architectural Presentations with Laser Pointers
The sizes of each circle, distances between each pair of consecutive circles, and the time spent in each click were logged in a text file.

4.2. Results

According to Fitts’ model [17], the time to move a pointer (MT) to select a target of width W at distance A is

$$MT = a + b \log_2(2A/W)$$  \hspace{1cm} (3)

where a and b are constants determined through linear regression. The log term is the index of difficulty (ID) and carries the unit “bits”. If MT is measured in “seconds”, then the unit for a is “seconds” and the unit for b is “seconds/bit”. The reciprocal of b is the index of performance (IP) in “bits/second” and measures the human rate of processing for the movement task under investigation. Although Fitts’ model is inherently one-dimensional and our experiment is two-dimensional, the model remains intact as our targets are circles [18]. It is appropriate for evaluating the performance of different devices.

The data for each test of each participant were applied in the Fitts’ model separately (Table 2). The coefficients a and b of each test were computed using linear regression. The average value of the coefficients a and b for each device were calculated and compared.

<table>
<thead>
<tr>
<th>Device</th>
<th>Mean a (ms)</th>
<th>Mean b (ms/\text{bit})</th>
<th>Average MT (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tablet-PC*</td>
<td>275.2</td>
<td>158.3</td>
<td>822</td>
</tr>
<tr>
<td>Mouse</td>
<td>380.4</td>
<td>153.3</td>
<td>917</td>
</tr>
<tr>
<td>Laser pointer</td>
<td>338.2</td>
<td>223.4</td>
<td>1102</td>
</tr>
<tr>
<td>Stylus</td>
<td>422.3</td>
<td>247.7</td>
<td>1264</td>
</tr>
<tr>
<td>Track Point</td>
<td>405.5</td>
<td>331.2</td>
<td>1555</td>
</tr>
</tbody>
</table>

* A projector is not used.

Coefficient a represents the initial response time and the time required to confirm the acquisition of the target. By comparing the constant coefficient (a) of all devices in Table 3, it is found that coefficient for a Tablet-PC (interacting directly on the LCD panel) is significantly different from other tests using a projection screen. This difference may be due to the fact that interacting directly on the LCD panel is “direct manipulation” and thus the response time can significantly reduced. However there is no significant difference among different devices on a projection screen. This
shows that the movement time (MT) depends mainly on the performance of these devices.

<table>
<thead>
<tr>
<th>Table 3. A comparison of constants a for different devices (probability of paired 2-tail t-test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser pointer</td>
</tr>
<tr>
<td>Stylus</td>
</tr>
<tr>
<td>Track Point</td>
</tr>
<tr>
<td>Mouse</td>
</tr>
</tbody>
</table>

* A projector is not used

From Table 4, we see that using a mouse with a projection screen has also no significant difference compared to the direct manipulation on a Tablet-PC which is the fastest in speed. Furthermore, the efficiency of the laser pointer and a stylus has no significant difference. From this experiment, we conclude that although the laser pointing system is not as efficient as a conventional mouse in point-and-select actions, its performance is still as good as, or even better than, other common input devices, such as stylus and Track Point. Therefore the laser pointing system has the potential to be a useful input device in real applications.

<table>
<thead>
<tr>
<th>Table 4. A comparison of constants b for different devices (probability of paired 2-tail t-test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser pointer</td>
</tr>
<tr>
<td>Stylus</td>
</tr>
<tr>
<td>Track Point</td>
</tr>
<tr>
<td>Mouse</td>
</tr>
</tbody>
</table>

* A projector is not used

5. APPLICATION IN A DESIGN REVIEW

From the performance experiment, we see that the LPS performs well in human computer interaction. In order to further test the usability of the LPS in group discussion, a user study experiment with an architectural critique exercise was carried out.

A group of first year architectural students were invited to use the LPS in their interim critique. Seven students and two instructors participated in the critique. Four students presented their projects whilst all students who were not presenting did participate in the discussion. Before the critique, all participants were given a brief on the use of the LPS for about 2 minutes. Students were asked to present their design projects using the LPS system.
A single projection screen was used in the presentation. An LPS server program was running on a desktop computer connected with a video camera capturing at 800x600 resolution and 25 frames per second. The LPS client program and PowerPoint were executed on a laptop computer. The display of the laptop computer was projected on the screen. Students made PowerPoint presentations to explain their architectural designs, including conceptual ideas, design models, and results of sun shading and solar heating experiments. Text, graphs, pictures of models and digital videos were used. These rich media presentations enabled the audience to understand the presenters’ ideas and the work carried out, forming the basis for discussion.

A student, standing in front of the projection screen, made a 15-minute presentation followed by an extensive discussion for about 30 minutes. Throughout the presentation and discussion stages, the LPS was the only way for participants to interact with the presentation materials. Five laser pointers were used in this experiment. The two instructors and the presenter held one laser pointer each; the remaining two laser pointers were shared by the students. Since the system reports only one laser point at a time, the participants must use their pointers following normal conventions of a group discussion in only one person holds the floor and speaks or gestures at a time.

After the experiment, opinions of all participants were immediately collected in the form of questionnaire. Some questions were in a 5-point Likert’s scale: 1 indicating strongly disagreement, 3 for neutral and 5 strong agreement. Subjects were also free to express their opinions in open-ended questions. One of the authors also participated in the critique to observe the experiment in-situ.
5.1. Results and discussions

Students made presentations of their projects using architectural images, supplemented with tables, charts, and videos, composed into PowerPoint presentations. The critique exercise lasted for 3 hours for four projects.

Although the students were excited to use the LPS in their presentations, most participants expressed a neutral feeling towards the negative questions in the post-exercise questionnaire survey, such as “the LPS caused interruption to my presentation” (average rating of 3.2) and “the LPS distracted my presentation” (average rating of 2.8). This indicates that there may have been usability problems with the systems. This may be due to the fact that some participants were not familiar with the stroke recognition behaviour of the LPS. For example, some participants forgot to write a “’” before using a laser pointer for simple pointing without any interaction and pointed randomly while talking. Some unintended strokes were recognized and some erroneous interaction was invoked. In spite of this problem, the presenters thought that the LPS allowed them to present their ideas more clearly (average rating of 3.5) and that the LPS allowed them to attract people’s attention more easily (average rating of 3.8). This may be due to two reasons. First, without the limitation of computer wiring, presenters are free to move around in the room, as noted earlier by Eckert and Moore [9], permitting more direct interaction between the presenter and the audience. Second, the laser pointer also serves as a pointing device besides being used as an input device. The red bright spot helps to guide audience’s attention to the right position on the projection screen.

Opinions of the audience were also collected in addition to the opinions of the presenters. All those who presented were also members of the audience during the presentations by others, hence all the participants responded to questions posed to the audience. The data indicate a neutral response to the statement that the LPS allowed them to better understand the presentations (average rating of 3.3) but some agreement that the LPS allowed them to engage more actively in the discussion (average rating of 3.8). With the LPS, the audience was able to take control proactively of the content on the screen, scrolling the slides up and down to search for the relevant part for further discussion.

Summary opinions were also sought. Participants reported that they found the LPS easy to learn (average rating of 3.9). They just needed 2 minutes to learn the system and a few minutes to become comfortable with it. However, because participants had to remember to switch between pointing mode and interactive mode, the participants responded with neutrality on the ease of use (average rating of 3.1) with some participants suggesting that the stroke-based control interface was not intuitive. Although the camera captured the projection screen at about 25 frames per second, there was a small delay in the response of the system but participants did not appear to be affected by this, responding neutrally to
the statement that the LPS was fast (average rating of 2.7). In general, the participants felt that the interaction of the LPS was interesting and attractive (average rating of 4.1), and that the LPS is useful for architectural presentation (average rating of 3.9), teaching (average rating of 4) and other kinds of presentation (average rating of 4.1).

6. CONCLUSION

In this research, the use of laser pointer interaction in a digital-projection based architectural presentation is studied. As a part of the research, a general-purpose laser pointing system for projection systems was developed.

It has been shown that some physical limitations present in applications using hand-held laser pointers. Some measures were taken to tackle these problems. In order to investigate the performance of the LPS developed, a controlled user study was carried out to compare the efficiency of a laser pointer and other input devices in point-and-select interactions. Compared to Olsen and Nielsen’s experiment [10], performance of our laser pointing system is better. A mouse-based interaction is only 1.4 times faster than the laser pointer interaction in terms of the IP in the Fitts’ model. The laser pointer is even more efficient than a Track Pointer. This shows that a laser pointer has the potential to be a useful device in human computer interaction for remote pointing and group interaction during presentations.

Another user study was carried out to test the usability and helpfulness of the pointing system in architectural presentation where interactive discussion of the presentation content is needed. A students’ design critique was taken as an example in this study. Using the laser pointers, movement of the presenter is no longer restricted by computer wire. Presenters can present their ideas more clearly and attract audience’s attention more easily with the help of laser pointers.

It is found that the laser pointer interaction encourages audience participation. As there is neither a predefined privilege for different users nor a locking mechanism to block out individual devices, each participant has an equal right to control the computer projection and thus to lead the presentation. Besides being used for architectural presentations, the subjects in the studies perceived that the laser pointing system is also useful for teaching and suitable for other kinds of presentation where digital projection is used, such as business meetings.

Acknowledgements

The authors would like to thank Mr. Patrick Luk and his students at Department of Architecture of Chu Hai College of Higher Education in participating in the design review. We would also like to thank students and colleagues at the Department of Architecture of the University of Hong Kong who participated in the laser pointer performance experiment.
References


Siu-Pan Li, Thomas Kvan
University of Hong Kong
Department of Architecture
Pokfulam Road, Hong Kong
thomas@arch.hku.hk