Room User Interface (RUI) Design for Laser Based Interaction

Amnon Dekel
The School of Engineering and Computer Science
The Hebrew University Jerusalem
amnoid@cs.huji.ac.il

Scott Kirkpatrick
The School of Engineering and Computer Science
The Hebrew University Jerusalem
kirk@cs.huji.ac.il

ABSTRACT
This work is part of our pursuit of paradigms and technical solutions that will take advantage of the rapid advances in computing power that inexpensive tools for presentation and collaborative work are bringing to the world of education. We have developed an interaction model for the "smart classroom," (more generally, for rooms in which people interact and learn together). Using our prototype environment we report on preliminary user testing of some novel ways to exploit the common laser pointer, a device most lecturers now possess. In our environment, users report increased usability of complex presentation devices and ability to focus more effectively on delivering a lecture or holding a class.

Author Keywords
Laser Pointer, Interaction Design, Interaction Models, Pointing Devices, intelligent control.

ACM Classification Keywords
H5.m. Information interfaces and presentation, H.5.2 User Interfaces, I.3.6 Methodology and Techniques (Interaction Techniques),

INTRODUCTION
In recent years high quality presentation devices have become very popular in business and higher education. Many conference rooms or teaching auditoriums are equipped with a presentation podium that at the least enables the projection of the local computer screen for view by the audience. Several research projects have explored the uses of handheld and non-tethered pointers that served the double purpose of *pointing* at something on the projected screen (using a built in laser) and *controlling* the projected presentation using a number of interaction models [2, 5, 6, 7, 8].

Various technologies have been explored to enable these capabilities. These include visually acquiring the position of a pointing device in a room, three dimensional mapping and matching of the location of an object in the room relative to a three dimensional reference model, and electromagnetic transmit and receive localization systems [10]. Most of these projects did not look at the design of the physical environment in which the lecturer would be using their tools. Those who do think about these environments (the architects) did not think very deeply about how to make these environments easier to manage and use by those users who want to present various forms of material in different media formats.

The result of this situation is the generic "Podium", a cabinet that houses the audio and visual elements and their interfaces (see fig. 1)[1]. These usually include a multimedia computer, a VCR, an amplifier, and a document camera. The major drawback of such designs is that the user must either pick up and use a multitude of different remote control devices (one for each of the devices to be controlled), or a complicated universal remote control, or a walk to a podium based touch screen (in the best cases), or (in the worst cases) have to access and control the devices by kneeling and directly manipulating their interfaces (a frustrating example of "direct manipulation").

Figure 1: A classic Podium

Our research focuses on the interaction possibilities that open up when a lecturer is free to move around a meeting room or auditorium and is able to control all aspects of their presentation from wherever they are. This means at least two things to us: a. how does the design and placement of objects inside a room affect the ease of achieving the tasks that are to be completed in that room and b. how do we create a smart central control system that enables this?

[1] Image copyright:
www.marquette.edu/ imc/AV/smartpodium.html

We have developed an interaction model that explores this direction, implemented a proof of concept prototype and have run user testing sessions with it to explore its utility.

THE ROOM AS AN INTERFACE.

The first part of our model explores the use of the physical space of the room as part of the interface to be interacted with. When designing such a room, every part of it, from floor to ceiling, from door to window, from book to computer, from light to projector, from chair to table, are candidates to become interaction hotspots. This means that any object in a room can serve as an interface object for activating various elements and services in the room. Using this method, a user can activate a service (i.e. lights, sound, projector, etc) by pointing at the provider or the controller of the service (a light fixture, an audio speaker, a projector, etc) or some surrogate (i.e. a physical icon or other physical objects placed in the room). But where should the different objects be placed in order to create an easy to use interface? Screen based interface design has generated a standard in the various GUI window systems. In room interface design a number of other things must be taken into consideration.

Line of Sight: the lecturer must have a clear line of sight to the objects at all times if they are to be useful. Thus, objects must be placed in such a way where no matter where the lecturer stands, they will be able to access these interface objects. Lecturers should not have to turn their backs on their audience, thus some interface objects might need to be placed in more than one place in the room.

Target Size: Fitt's law [3] is applicable here too, but to a stronger extent since a wireless laser pointer has many more degrees of freedom than a mouse. Add to that the human physique which finds it close to impossible to aim in a steady fashion without wiggling, and you conclude that targets must be relatively large and far apart.

Statelessness and Accidental Operation: Because of the laser pointer's characteristics, a room interface must take into account a larger amount of accidental operation when compared to a computer interface. Since the pointer is stateless, various interaction methods have been developed to pass state information to the system. These have taken on the forms of dwelling over an area (time based) or moving the dot in a pre-specified way (gesture based)[2] [7].

Context: Physical interface objects should be placed in the room according to their usage contexts. Thus, a lighting control should be where one would expect to find it: higher up than other elements. A door control should be placed near the door it controls, and VCR controls should be grouped, etc.

[2] Some projects have created state-full laser pointers by adding hardware and wireless capabilities to pass the state to the control system [2].

INTELLIGENT PRESENTATION MANAGEMENT.

The second part of our model implements intelligent central control over the multiple devices that are used in an auditorium or conference room. We feel that it is not enough to be able to track what a person is pointing at in the room, if the room does not also include a system that can carry out all the necessary actions needed for the task represented by the object.

Most existing environments force the presenter to do the system management by themselves: to click on the play button on the DVD (or on the DVD remote control), change the video source input accordingly (on the projector itself, or using yet another device, the projector remote control), and turn the lights down or off using the wall based or podium based switches. To anyone with any experience teaching in large auditoriums and their "interfaces", this can become an annoying process, especially since every part uses a different interface, and every remote control must be aimed in different directions, then returned to the table for use later on (when it is usually difficult to find)[3].

Using real world knowledge of the structure of presentations, our system turns services on or off, or changes inputs, as deemed necessary by the logic of a presentation. Thus, when a presenter wants to switch from one media form (i.e. a PowerPoint presentation) to another form (i.e. a DVD movie), they only need to point at the appropriate service icon for the function they want to enact in the room (i.e. Play DVD), and all the accompanying system management actions are activated automatically: the projector input source is set to project input from the DVD (i.e. Video 1 or 2), the lights are turned down or off, and the PowerPoint presentation is frozen in place. When the presenter later points at STOP, the projector input source is returned to its previous state (i.e. computer 1), and the PowerPoint presentation comes up again, and the lighting is returned to its previous state. This auto-switching feature of the system was received with great enthusiasm by everyone taking part in the user tests.

SYSTEM ARCHITECTURE:

Setup

The system utilizes a number of elements in parallel, with a central control application receiving inputs and sending outputs according to the various systems it controls. A simple web cam ($20, 640x480 @ 15 frames per second) provided the tracking data for the "red dot" of the laser pointer. The data was returned as the coordinates of the dot that exhibits the RGB values we were interested in. These RGB values changed whenever we placed the test system

[3] A number of centralized control systems have been developed using touch screens or specialized remote controls, but these too force the user to walk towards a central control station, or use a relatively complicated remote control device

in different environments, and a calibration process was carried out in order to discover the RGB values of our laser's red dot in that environment. Once set, these values do not need to be changed until and if the lighting in the room was changed significantly. The camera needs to be placed so that its field of view contained all the hot spots to be tracked. In our tests, one camera was enough, but more than one camera will be needed if we wanted to place physical hotspots in a wider dispersal throughout the room.

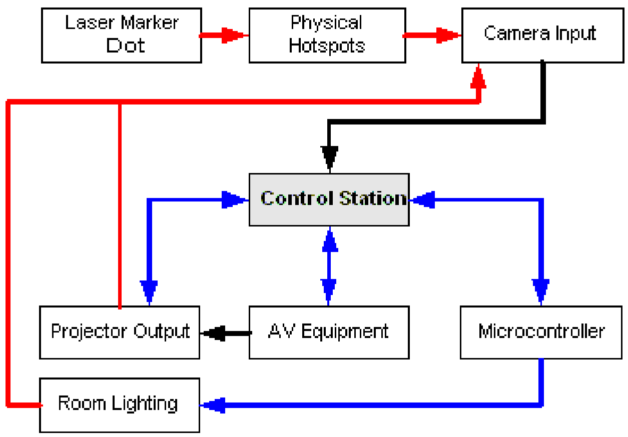

Figure 2. System Architecture

Red: I/O, **Black**: Data Communication, **Blue**: Control Communication

Control

Once the laser dot is tracked, our control program uses the tracking data to asses whether a hot spot was pointed at by comparing the dot coordinates against a mapping of hot spot locations. Once a hotspot is touched, the appropriate actions for that hotspot are enacted. For LIGHT ON this takes the form of sending a control character over a serial cable to a Parallax BS-1 Rev D microcontroller (PIC based), which then interprets this control code and sends current to a relay that closes a 220V circuit which turns the lights on. LIGHT OFF entails the same process, except for a different control code, and the relay disconnecting the 220V circuit.[4]

For Video the control application sends device control statements (Play, Pause, Rewind and Stop) over an IEEE-1394 (i.e. Fire wire) cable to a mini-DV video Deck.[5] The projector is controlled in a similar fashion by sending control statements over an RS232c serial cable to switch inputs. Lastly, the on screen presentations are implemented as simulations of a PowerPoint presentation. This is because the software needed to run a real PowerPoint window with our control program is still under development. The PowerPoint simulation in our system contained tracking hotspots for *opening* a presentation, moving to the *next* and *previous* slides, and returning to the *first* slide.

USER TESTING:

In order to learn if this model has succeeded, we ran a number of user tests. Ten subjects were tested (ages 26-46, 50% male, 50% female). Subjects were first given a short explanation of the system and its uses, then a short demo showing the system in use, and then 2-3 minutes to get acquainted with the laser pointer and the system itself (see figure3). After training, users were given specific tasks scripts to do (such as "play a video, pause it, and then return to the main screen" or "open a presentation, flip through to the 4th slide, flip back to the 2nd slide, then show a video, and return to the main window" among others). While carrying out their tasks, subjects were asked to speak their thoughts out loud. After the session was over, the subjects were asked how they felt they did, how well they felt that they could control the system, where they felt the system could be improved, how they felt the system reacted when compared to a standard mouse based system, and how they felt the system performed relative to a regular auditorium setup (computer, mouse, light switches, VCR, Projector).

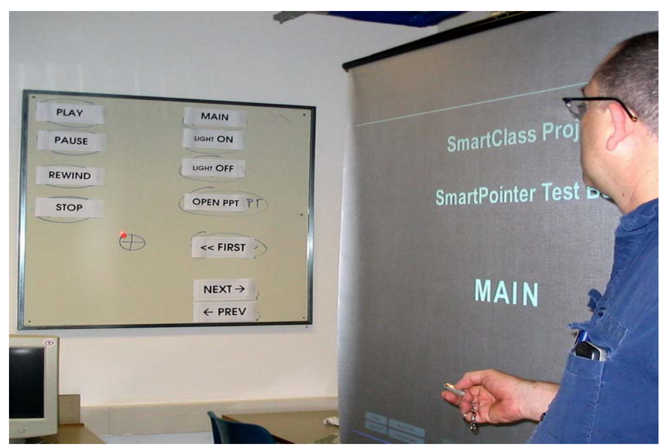

Figure 3: A subject practicing to point the laser at some off screen hotspots

As a control, we ran the exact same tasks using a standard conference room setup. In this room they had access to a podium which houses a computer and VCR. During their presentations, the subjects had to manually control and manage all the services in the presentation: turning lights on and off, switching inputs on the video projector using its remote control, navigating between PowerPoint slides using the keyboard or mouse, and controlling the VCR through it's physical buttons.

---

[4] For implementation in large existing locations, the use of X-10 protocol based equipment would probably be easier.

[5] We used a miniDV player because it enabled us to get up and running with device control very quickly. We view it as representing the family of AV equipment which would include normal VCR's and DVD players which can be controlled either via a serial cable or infrared.

RESULTS

	Action Errors *	Feeling of Control	Ease of Use rating	Ease of Use Relative to the other system (equal =1)
Test (N=5)	1.4	7.8	9.2	1.8
Control (N=5)	0.4	9.4	6.8	0.59
H1: Test will not be different from control	P<0.05	P<0.072 Not Significant	P<0.05	P<0.01

Table 1: Results of User Testing

***: Action errors:** A user causing the system to put into action something that the user did not mean to do.

Ease of Use:

Our results give us a very clear indication that our system was seen as easier to use than the regular podium based lecture room. The ease of use ratings of the test group were significantly higher than those of the control group (9.2 versus 6.9 ($F(1,8)=32$, $p<0.01$ [9]). In order to test this further, subjects were called back to perform the scenario they originally did not perform (test group subjects performed the control task, and vice versa). They were then asked to rate the ease of use of our system relative to the regular podium based system. Their feelings were clear: our system was deemed to be almost twice as easy to use in comparison with the podium scenario (mean relative ease of use rating = 1.8, where 1 represents equal ease of use), and the podium task was seen as being almost half as easy to use (or in other words close to twice as *hard* to use) in comparison with our system (mean relative ease of use rating for the podium task = 0.59).

Upon further exploration it became clear that the greater ease of use reported was in many ways the effect of the intelligent management system we had implemented. When comparing the laser pointer to a normal mouse based system used in the podium scenario, we found that the laser pointer users exhibited more usage errors (an average of 1.4 errors in our system versus 0.4 errors in the podium scenario, $F(1,8)=8.3$, $p<0.05$)), and described themselves as having somewhat less feelings of control (an average rating of 7.8 with our system versus 9.4 in the podium scenario - although this was not statistically significant: ($F(1,8)=4.266$, $p<0.072$)). This is indicative of the test groups verbal responses during the tests in which they voiced the feeling that the point and shoot part of their task was more difficult then using a regular mouse. On the other hand, they all made it very clear that the automatic control system made their life much easier. Not having to personally manage the switching of inputs, the pressing of buttons, or the control of the lighting enabled them to stay focused on the task at hand: presenting the material and focusing on their viewers.

The one exception to the rule that pointing and clicking with the mouse is easier was in the *next* and *previous* buttons which were implemented on the screen area itself within the PowerPoint mode. In addition to the off screen physical button hotspots, pointing anywhere in the bottom right quadrant of the presentation screen would perform a *go to next slide* action, pointing anywhere in the bottom left quadrant of the screen would perform a *go to previous slide* action. This solution enabled the users to feel very confident that the laser pointer would fall in the correct place when they pressed its activation button, while at the same time enabling them to stay focused on the presentation screen itself. Using the off screen hotspots in this case forced them to take their eyes of the screen itself, making them feel unsure that the actions were in fact registered. Both of these features made the subjects report that they found this very easy to use, and also very entertaining.

Hotspot Placement

We also evaluated the physical placement of the hotspots in the room. Since this was a proof of concept prototype, we worked with one camera which severely limited our placement options. As seen in figure 3, the hotspots were physical two dimensional textual “buttons” which were pasted to a small white board next to the video screening area. This placement worked well until our subjects wanted to walk to the other side of the screen, either to point something out, or in order to view the other side of the room. In these cases the subjects would physically get in between the camera and the hotspots, making them useless until they moved, or they would have to turn their backs on the audience in order to point at the hotspots they were standing near. By the end of their session, all subjects moved back to their starting position on the other side of the screen and stayed there, reporting that they preferred to be farther from the hotspots so that they could face the audience while not causing any performance problems to the system. All subjects stated that they would prefer to have redundant hotspots located on both sides of the room so that they would be able to freely walk around.

CONCLUSIONS

The results show us that although the laser pointer is not seen as the best pointing device by most people, when the interaction scenario is designed around its limitations it can become part of an easy to use system for lecture room based presentations.

Although users reported feeling that the task of pointing at physical hotspots in the room is somewhat harder than pointing at a screen widget with a mouse, these feelings were washed away when the pointing system was coupled with an intelligent management system in the background that took care of many of the management tasks they usually had to handle by themselves. And this with a first generation prototype which can be much improved not only in the sizes and placement of the physical hotspots, but also in the careful analysis of where to put the different types of hotspots.

The fact that test subjects reported that the next and previous actions were easier to enact with the laser pointer using the bottom two screen quadrants as large hotspots, shows us that the laser pointer, with all its limitations, can be a better pointing device than a mouse in specific scenarios. What are these scenarios? We think that these scenarios are characterized by having a limited set of options that can be mapped to the screen in a simple symmetric layout. Thus next and previous could succeed.

Additionally, we saw that an important element in the success of such a system is in designing it against a context of the tasks that must be achieved with it. The moment we understood that this is a severe deficiency in most current designs, we put effort into solving it. Because of this, our system was built to have centralized control of most of the presentation services in the room (lighting, video projection, video player, presentation viewer). We view this as part and parcel of the interface design of the room – not only focusing on the visual design and placement of objects, but on the effects they have on the whole interaction experience of those using them. Our study has shown that much benefit can be gained by designing the whole usage environment around a goal oriented theme, allowing us to use cheap off the shelf elements in ways that create a more successful experience.

As for the physical placement of hotspots around the room, this study made it clear to us that they must be placed in a way that will not hinder the lecturer from moving around the room. This means that wherever the lecturer stands, at least one set of hot spots must be available with a direct line of site, enabling the comfortable use of them without having to turn their backs on their audience. This conclusion is simple enough, but it is clear to us that this layer of room based interaction has a need for much additional enquiry before clear and tested guidelines will emerge.

FUTURE WORK:

A number of issues came up during the testing of the system which impact on future work. First we are interested in creating a clearer vocabulary of interface objects for on screen and off screen actions. Are on screen objects for on screen actions always preferable, or are there cases where off screen objects can perform just as well, or maybe even better? For off screen objects we are interested in exploring different symbolic forms (i.e. physical objects and icons, versus physical two dimensional “buttons”), as well as the impact that their placement in the room will have on ease of targeting by the user. Lastly, we will be working to integrate our system into a larger learning technology infrastructure that will include tools for before, during, and after lecture management of materials and their publication.

ACKNOWLEDGMENTS

We would like to thank Microsoft for its generous support and travel grant. We would also like to thank Doron First, digital systems lab manager at the school of engineering and computer science at the Hebrew university. His hands on assistance shortened our way from idea to reality.

REFERENCES

1. Michel Beaudouin-Lafon: Designing interaction, not interfaces. Proceedings of the working conference on Advanced visual interfaces, Gallipoli, Italy , 2004, 15-22
2. Cavens, D., Vogt, F., Fels, S., and Meitner, M. (2002): “Interacting with the big screen: pointers to ponder”, *ACM SIGCHI '02 Conference on Human Factors in Computing System, Companion Proceedings*,p.181-182.
3. Fitts, P. M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. Journal of Experimental Psychology, 47, 381-391.
4. Kirstein, C. and Muller, H. (1998): "Interaction with a projection screen using a camera-tracked laser pointer", in *Multimedia Modeling; MMM '98 Proceedings*, p.191-192
5. MacKenzie S. , Tatu Kauppinen , Miika Silfverberg, Accuracy measures for evaluating computer pointing devices, Proceedings of the SIGCHI conference on Human factors in computing systems, p.9-16, March 2001, Seattle, Washington, United States
6. Myers, B.A., Bhatnagar, R., Nichols, J., Peck, C.H., Kong, D., Miller, R., and Long, A. C. (2002): "Interacting At a Distance: Measuring the Performance of Laser Pointers and Other Devices", *ACM CHI 2002 Conference on Human Factors in Computing Systems*, p.33-40.
7. Olsen, D. Jr. , Nielsen, T., Laser pointer interaction, Proceedings of the SIGCHI conference on Human factors in computing systems, p.17-22, March 2001, Seattle, Washington, United States
8. Peck, C. (2001): “Useful Parameters for the Design of Laser Pointer Interaction Techniques”, in *Proceedings of CHI 2001*, p.461-462
9. Stevens, J., Applied multivariate statistics for the social sciences, Lawrence Erlbaum Associates, Inc., Mahwah, NJ, 1986
10. Xiang Cao , Ravin Balakrishnan, VisionWand: interaction techniques for large displays using a passive wand tracked in 3D, Proceedings of the 16th annual ACM symposium on User interface software and technology, p.173-182, November 02-05, 2003, Vancouver, Canada