POSITION-INDEPENDENT INTERACTION FOR LARGE HIGH-RESOLUTION DISPLAYS

Werner A. König
University of Konstanz
Werner.Koenig@uni-konstanz.de

Hans-Joachim Bieg
University of Konstanz
Hans-Joachim.Bieg@uni-konstanz.de

Toni Schmidt
University of Konstanz
Toni.Schmidt@uni-konstanz.de

Harald Reiterer
University of Konstanz
Harald.Reiterer@uni-konstanz.de

ABSTRACT

Since large, high-resolution displays (LHRD) are capable of visualizing a large amount of very detailed information, users have to move around in front of these displays to gain either in-depth knowledge or an overview. However, conventional input devices such as mouse and keyboard restrict users' mobility by requiring a stable surface on which to operate. We present a flexible and intuitive interaction technique based on an infrared laserpointer, a technique that allows identical use from any point and distance. In particular, our laserpointer interaction satisfies the demands of LHRD in the areas of mobility, accuracy, and interaction speed. The solution presented is technically designed as a generic interaction library whose flexibility and general applicability was verified by using it on two very different systems – a planar 221″ Powerwall and a curved 360° panoramic display. Furthermore, a comparative evaluation study with 16 participants was conducted on the Powerwall to compare the performances of a conventional mouse and our laserpointer by means of a unidirectional tapping test at varying distances (ISO 9241-9). The statistically significant performance advantage of the mouse (13%) appears marginal considering the intuitive and direct mode of interaction in using the laserpointer and the flexibility gained by its use, both of which are fundamental requirements for LHRDs. In comparison to previous systems and evaluations, we were able to reduce the laserpointer's performance lag by over 50%. This result is achieved mainly by our precise tracking method, the minimized delay, and the effective jitter compensation.

KEYWORDS

Interaction technique, input device, laserpointer, high-resolution display, evaluation, usability.

1. INTRODUCTION

In the case of a typical display size of more than 200 inches and a resolution of more than seven megapixels, large, high-resolution displays (LHRD) offer great opportunities for various industrial and scientific application domains. They are capable of visualizing large and complex information spaces without sacrificing context or detail. LHRDs are therefore widely used for exploration and analysis tasks, whereby one user or a group of users observe detailed information at close range or obtain an overview of the displayed information space from a distant position. Users are not able to perceive both detail and overview simultaneously, since the display capabilities exceed either the limited human visual acuity or the users' field of view, dependent on their distance from the screen. It therefore follows that the ability to move around freely while interacting with the display is an absolute requirement for input devices. Traditional input devices such as the mouse and keyboard are technically unable to fulfill this requirement since they require a stable surface for their proper operation. Wireless air mice with integrated gyroscope, or presentation aids with additional mini joystick or trackball offer more mobility but perform substantially worse than a traditional mouse (MacKenzie & Jusoh, 2001). Due to their relative interaction mode, they are also less suitable for supporting handwritten annotations and drawings.

We therefore propose Laserpointer-Tracking as a more usable interaction technique for large, high-resolution displays because of the flexibility offered and the direct and intuitive manner of interaction. The well-known laserpointer is thus used not merely as a presentation aid for accentuation purposes but additionally to control the cursor or generally the entire user interface. Users typically utilize a laserpointer as a natural extension of their hand, so the cognitive load for interaction is imperceptibly low since pointing is a fundamental human gesture. The mental association of physical laserpointer and virtual cursor movement is easy and is processed subconsciously. In contrast, the use of a conventional mouse is – at least in the beginning – more demanding, since physical and virtual movement take place in different planes (horizontal surface vs. vertical display) and with different speed levels due to the mouse acceleration that is applied and the existing control-display ratio (ratio of operation size).

Mobility is a fundamental requirement for input devices that are to be used with LHRDs, and it is satisfied per se by Laserpointer-Tracking, since it is the reflection of the laser on the display that is tracked and not the position of the laser device itself. Hence, from any position and at any distance, the user can always interact in the same way. Whether the user writes directly on the display or is pointing to an object from afar, there is no need to change the input device or the interaction technique.

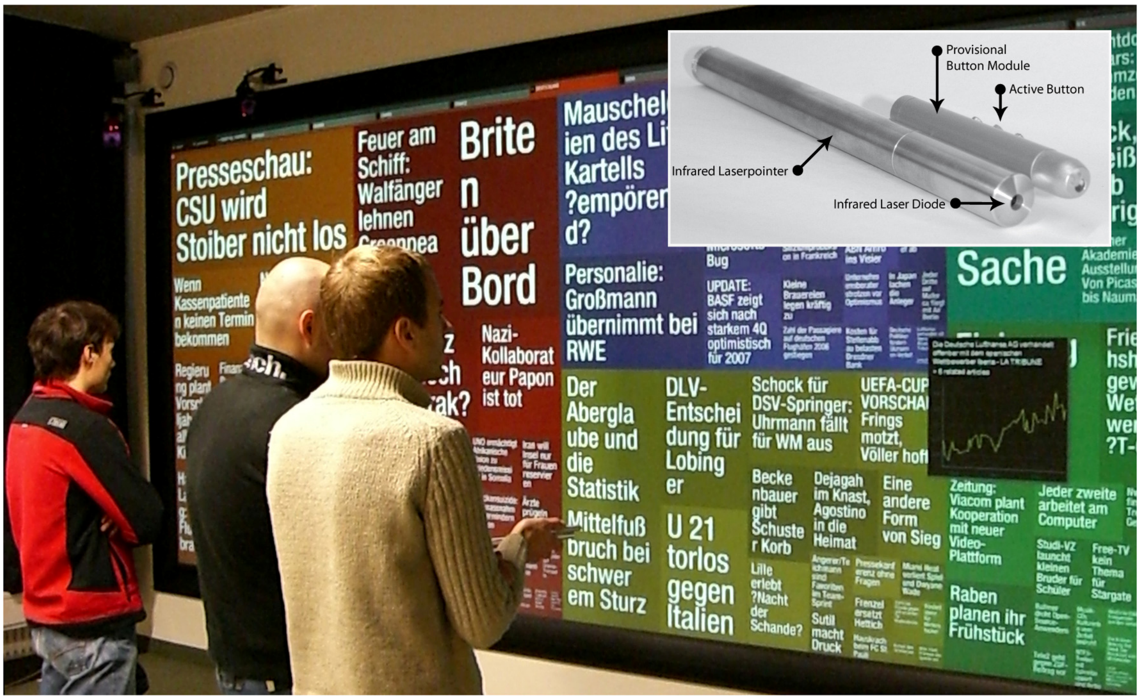

Figure 1: Newsmap visualization on the Powerwall in Konstanz and the infrared Laserpointer being evaluated

Laserpointer-Tracking is already used to some extent for presentation scenarios with a single low-resolution projector or multi-projection systems. However, LHRDs such as the Powerwall in Konstanz (Figure 1) with a display size of over 220 inches and a resolution of almost 9 megapixels, or the PanoramaScreen in the ZKM | Center for Art and Media in Karlsruhe (Figure 2), a 360 degree panoramic display with a diameter of 10 meters and a resolution of almost 8 megapixels, pose as yet unknown challenges in the areas of tracking precision, speed, and interaction technique in general.

In this paper we present a flexible and scalable interaction library that allows direct and almost delay-free input in the form of Laserpointer-Tracking. Besides offering an intuitive interaction technique, and in contrast to previous research, we concentrate especially on satisfying the requirements of usage with large, high-resolution displays with regard to accuracy, speed, and mobility. Subpixel-accurate tracking methods and the possibility of combing any number of cameras to increase overall resolution facilitate high technical accuracy. Furthermore, we effectively compensate for natural hand tremor in real time by applying a combination of dynamic and static Kalman filters. In particular, we propose the use of a laserpointer with an infrared laser diode (Figure 1), which allows interaction without visible reflection on the display. In this way, no displayed information is overlapped by the laser reflection, and the style of the cursor (the visual feedback) can be changed in a very flexible manner. We compared our Laserpointer-Tracking with a conventional mouse in a formal evaluation study on the basis of the ISO standard 9241-9. The 16 participants performed unidirectional tapping tasks with varying distances on the Powerwall in the University of Konstanz. Before we describe the evaluation study in more detail, relevant prior research is discussed in the following chapter. Subsequently, some more detailed information about our Laserpointer-Tracking library is given.

2. RELATED WORK

In recent years, laserpointers have been widely used as presentation aids and have been integrated in remote controls, USB sticks, pens, and various other common devices. It has thus become a well-known device, and the idea of additionally using it as an input device dates back to the end of the 1990s.

2.1. Technical Solutions

In 1998, Kirstein and Müller presented a video-based tracking system that was able to detect a single laser point on a projection surface. Although their hit rate of 50% was rather low, the basic idea seemed promising. They also proposed dwelling as an interaction technique for laserpointers; an action is triggered whenever the user keeps the laser reflection in an active area for a defined time. Olsen and Nielsen (2001) introduced enhanced actions with dwelling and the laser state, depending on the currently focused UI-widget. They also compared a conventional mouse with their tracking system in an evaluation with eight participants. The movement time (MT) with the laserpointer was more than twice as long as the measured MT of the standard mouse. Clearly, the low frame rate of 7 fps (frames per second) and the remarkable delay of approximately 200ms had a noticeable effect on the evaluation results. Chen and Davis (2001) combined eight interlinked cameras to track laser reflections on a back-projection system named “Interactive Mural” with a display area of 1.8 x 0.6 meters and a resolution of 3796 x 1436 pixels. They detected multiple laserpointers in parallel with an interlaced frame rate of 60 Hz and distinguished different strokes by separate Kalman filters. Likewise, Ahlborn et al. (2005) also focused mainly on the practical issues of laserpointer tracking and described a robust and efficient dot detection method.

2.2. Empirical Studies

Cavens et al. (2002) compared a laserpointer emitting red light with a traditional mouse, and in a further study they compared the red laserpointer with one emitting invisible infrared light. The mouse and red laserpointer showed similarly good movement times, whereas the infrared laserpointer performed significantly worse. Only four and six persons respectively participated in these studies; in view of these small numbers and the remarkable tracking delay, the results should be interpreted carefully. In a study with 10 participants, Peck (2001) examined usage parameters for the design of laserpointer interaction techniques and found that a user needs between 0.9 and 1.4 seconds to acquire a target after turning on the laser. Furthermore, an additional time of at least one second is required to determine a dwell on a target. Peck also showed that the dwell area, and therefore the jittering, measures about 0.4° vertically and between 0.4° and 0.6° horizontally depending on the distance to screen. In a comparable evaluation, Myers et al. (2002) showed that, in contrast to Peck, the jittering is horizontally stable but vertically distance-dependent. In a second study, Myers et al. compared a traditional mouse with a laserpointer and a touch-sensitive SmartBoard. As expected, the direct interaction on the SmartBoard led to a significantly better performance rate with 11.80 Bits/s (index of performance in bits per second according to ISO 9241-9), followed by the mouse with 6.98 Bits/s and the laserpointer with 5.08 Bits/s. Oh and Stürzlinger (2002) presented a similar result. They also compared a mouse with a visible laserpointer and identified an index of performance of 3.98 Bits/s for the mouse and 3.04 Bits/s for the laserpointer. Since their authors used different calculation methods, the absolute performance values of these two studies are not directly comparable. Nevertheless, a relative performance advantage of at least 30% for the mouse versus the laserpointer is generally observable.

The cited studies and systems were employed in conjunction with conventional projection screens (e.g. 1.8 x 1.2 m, Oh & Stürzlinger 2002) with small amplitudes (distance between targets: e.g. 60cm, Myers et al. 2002) and short distances to display (e.g. 1.5 m, Myers et al. 2002). We wondered if these empirical findings were also transferable to large, high-resolution displays such as the Powerwall in Konstanz, with its display area of 5.20 x 2.15 m and resolution of 4640 x 1920 pixels. Here, the distance between targets can amount to more than 5 meters and users are not always able to survey the entire display because of their limited field of view. Hence, users have to turn their heads to switch between targets. To answer this question, a formal evaluation was undertaken and is described in Chapter 5. First, however, we describe our Laserpointer-Tracking library, which we used for the following experiment.

3. LASERPOINTER-TRACKING

Although some research regarding Laserpointer-Tracking has already been done in the past few years, so far there has been no reference system that combined the partial solutions of multiple works in one flexible yet robust interaction library. The Laserpointer-Tracking library presented here represents such a combination and, in addition, claims to be especially suited to interaction with large, high-resolution displays. Besides the much larger display size of LHRDs, the higher resolution as well as the users' mobility and their typical behavior also have to be considered. To achieve an adequately high tracking resolution, our library allows the interlinking of any number of cameras in a flexible client-server architecture and therefore scales almost linearly. As well as increasing the overall resolution, the interaction precision is enhanced by applying adapted band-pass filters in combination with independent static and dynamic Kalman filters. We were therefore able to compensate for natural hand tremor and the associated jittering of the cursor, no matter whether the user moves quickly or slowly, scribbles on the surface, or activates buttons.

Further main issues relating to our Laserpointer-Tracking are minimizing the interaction delay and supporting high interaction speed. With increasing distance from the display, even small laserpointer movements of only a few degrees already cause rapid cursor motion. To control that extremely responsive cursor effectively, users need an instant and correct visual feedback of their interaction. By the use of industrial cameras and optimized detection algorithms, we can track the laser with a frame rate of over 80 fps and a tracking and transmission delay of less than 10 ms in total. The result is that users receive a natural and direct feeling of interaction and are able to control the cursor from any point and distance.

Technically, the cameras are positioned behind (back-projection) or in front of the display in such a way that each camera looks onto a particular, predefined area of the display, and in combination they cover the entire screen. Automatic calibration allows the cameras to be freely positioned either in the center of, or at an angle to, the specified display area. In addition to the camera’s extrinsic parameters, which derive from the display segmentation and the camera alignment, intrinsic parameters such as radial and tangential distortion are also acquired through the calibration. If the environment is stable, it is sufficient to calibrate the system once only, and thereafter simply to load the parameters determined earlier.

A further feature of our Laserpointer-Tracking library is the support for visible (red, green, blue) and infrared laser-rays. Existing systems work in the main with red laserpointers, in which only the laser point or the laser point in addition to the cursor is visible on the display. In consequence of tracking delay and inaccuracy, laser point and cursor neither act identically nor match exactly and these facts can irritate the user. We propose the primary use of infrared laserpointers. Infrared rays are not visible to the human eye and therefore allow visualization of just the virtual cursor, which can also be varied according to the system’s state, thus matching the user’s expectations. Moreover, in the case of a visible laser the natural trembling of the user's hand is clearly evident to everyone, for instance, the audience in a presentation situation. When using an infrared laser, the laser point trembles but is invisible while the jitter compensation reduces the trembling of the visible cursor. So the virtual cursor remains largely steady even in situations with a higher stress level.

3.1. Cameras & Pointers

Basically, the design of the interaction library is hardware-independent with regard to display, cameras, and laser pointer. Single- as well as multi-projector systems of any size and resolution are supported. For the following study, and as a reference environment, the Powerwall in Konstanz – a back-projection display driven by eight high-performance projectors and featuring a homogenous overall view – is used.

For image recording, standard web- or video-cameras can be connected using USB or Firewire. However, a precise and almost delay-free interaction is only made possible by the use of industrial cameras with high resolution and frame rate. The importance of a preferably delay-free tracking process is corroborated by MacKenzie and Ware (1993), who have determined a direct correlation between the measured performance of a device and the interaction delay – the time between input action and output response. It turned out that below a delay of 25 ms the negative influence on performance was negligibly small. Starting with an average delay of 8.3 ms as a result of the display rate (60 Hz), and a maximum calculation and transmission time of 10 ms for image analysis, the camera's refresh rate should not cause a delay of more than 6.7 ms on average. Thus, the total system delay stays below 25 ms (8.3+10+6.7 = 25). To satisfy this requirement, three identical industrial cameras (model IDS 1540-C, cost about EUR 650) with 80 fps (6.25 ms average delay) at a resolution of 640 x 512 pixels and a 4.8 mm wide-angle-lens were chosen. These cameras were positioned vertically centered behind the Powerwall, each covering 1/3 of the display. Thanks to the interaction library's client-server architecture, the cameras can be connected to different computers. Hence, the image analysis is also distributed to several concurrent computers, which results in higher scalability and flexibility.

In principle, the interaction library supports laser pointers of variable wavelength and intensity as input devices. The laser pointer used here is similar to a standard laser pointer in structure but contains a class 1 laser diode that emits infrared light with an intensity of 0.55 mW and a wavelength of 785 nm. Due to the low radiance intensity, the infrared laser pointer is, in contrast to commonly used class 3 red laser pointers, absolutely harmless to the human eye and can be used without any fears over safety. To emulate the mouse buttons in the evaluation study, a standard presentation laser was put on top of the infrared laser's case (Figure 1). Future design iterations include integration of these buttons directly into the case and transmission of their state changes via radio.

3.2. Calibration, Detection and Compensation

Due to the variety of possible configurations with regard to display, cameras, and their positioning, a calibration is done once only prior to the actual tracking. During this process, the cameras' intrinsic parameters, their positioning relative to the display, and the corresponding tracking areas are determined automatically by sequentially visualizing a regular pattern on each display segment. Furthermore, disturbing reflections caused by projectors, lights, or the sun are registered and removed from the image that is recorded for further processing. The calibration parameters are saved and then loaded automatically at the next start, which enables a very fast startup procedure.

In the tracking process, the camera's exposure time is reduced, which results in a clear contrast between the high-intensity laser point and the low-intensity ambient light. When using an infrared laser, an optical filter is placed in front of the camera; this only allows light with a wavelength of above 750 nm to pass and so filters out virtually all visible light. Thus, even very weak class 1 laser diodes can be detected reliably. For the point identification, the RGB image is converted into a grayscale image. In this process the highest color value is adopted and can be amplified. Afterwards, bright patterns are identified and their center is determined by a process based on the work of Oh and Stürzlinger (2002). The center is calculated by weighted intensity values. In this way, the accuracy of this center is not limited by the camera's resolution.

Although the system has the potential for localization with subpixel accuracy, users are unable to hold the laserpointer steadily because of natural hand tremor. Peck (2001) identified an average deviation of 0.4° while remaining on one point for 3 seconds. Applying this date to the Powerwall, users would find it difficult to hit targets smaller than 18 pixels (2.09 cm) in height and width. This limitation would seriously impair the use of laserpointers for LHRDs, whose main application is the visualization of complex information spaces. For this reason we increased the interaction accuracy by compensating the jittering with a combination of band-pass filters and several Kalman filters. The Kalman filter models the behavior and predicts the next position based on previously measured deviations and movement speed. This prediction is compared with the measured data resulting in an iterative update of the movement model. This enabled us to reduce both human-originating as well as technically caused noise. In order to support fast movements as well as precise hovering, a static, dynamic or weighted combination of both is used for the prediction based on a multi-model approach. For the cursor's final position, the library does not use the measured coordinates but rather the smoothed predictions; this enables steady hovering in one position as well as smooth movements with different speeds.

4. APPLICABILITY STUDY

Our Laserpointer-Tracking is implemented and designed as a flexible interaction library and it can therefore be applied with some versatility on diverse domains. To confirm this, we installed it not only on the Powerwall in Konstanz – our reference and evaluation environment – but also on the PanoramaScreen of the ZKM | Center for Art and Media Karlsruhe, Institute for Visual Media (Figure 2). The latter is a 360-degree, large, high-resolution panoramic display with a diameter of 10 meters and a resolution of 8192 x 928 pixels. It is driven by 6 SXGA+ projectors. Since the projection surface of the PanoramaScreen is curved both horizontally and also vertically, we were able to demonstrate that our calibration works for almost any shape of screen surface. At the ZKM, the Laserpointer-Tracking is used in an artistic installation in which the user can navigate on a geographic map or in panoramic pictures (Figure 2 left) with the aid of the laserpointer. A crosshair is displayed as the cursor, and the user specifies the panning and zooming direction by moving the crosshair. At the Powerwall in Konstanz, the Laserpointer-Tracking is variously used for presentation issues, creativity sessions, and explorative analysis of large information spaces.

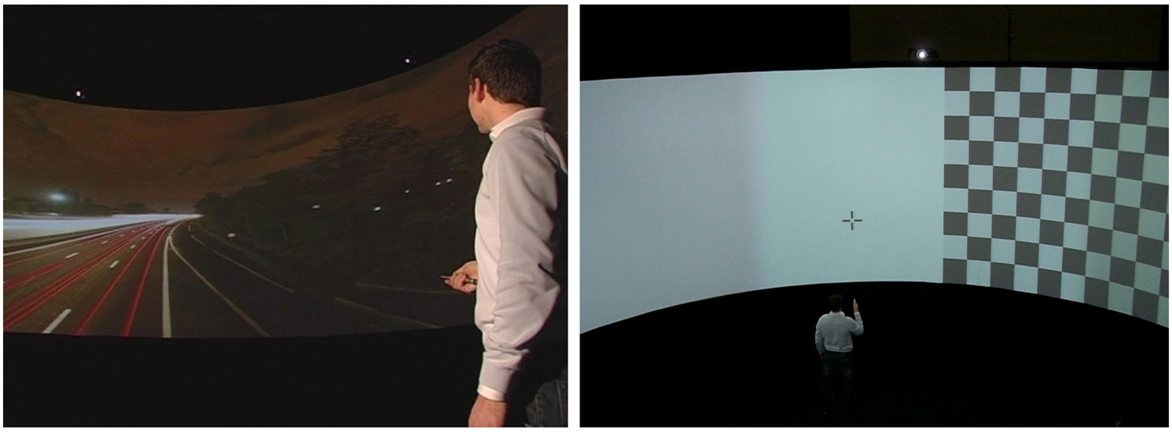

Figure 2: Laserpointer interaction on the ZKM 360° PanoramaScreen in Karlsruhe, including calibration pattern (right)

5. EXPERIMENT

In order to assess the feasibility of the interaction library for LHRDs, an experiment on the basis of the ISO standard 9241-9 was conducted on the Powerwall in Konstanz. The primary goal of this study was to compare the laserpointer system to the mouse as the standard input device. Existing studies that have been carried out with normal projection displays suggest that interaction with the mouse is more precise and faster – with the drawback that a stationary surface is needed for its use. With the laserpointer, however, participants can move freely in front of the display. Apart from comparing the two devices, the effect of eye-to-display distance was also under scrutiny. Peck (2001) examined the deviation when pointing at a fixed target with a regular red laserpointer from a distance of 1.5 m and 3 m. Similarly, Myers et al. (2002) examined 1.5 m, 3 m, and 4.5 m. The results of both studies underline the intuitive assumption that the laserpointer's performance deteriorates at larger distances due to the effects of natural hand tremor.

The experiment was based on the unidirectional tapping task (Fitts' tapping task) for evaluating the "efficiency and effectiveness of existing or new input devices" as described in ISO 9241-9 (cp. Douglas et al.

1999). The unidirectional tapping task is a serial point-and-select task with users controlling the on-screen pointer to alternately click on two targets of width W that are aligned horizontally at a distance (amplitude) A. Participants were asked to alternately select the targets as quickly and precisely as possible (Figure 3). These types of tests were pioneered by Fitts (1954, 1964) and were applied in several evaluation studies concerning input devices (cp. MacKenzie, 1991).

5.1. Participants and Design

Sixteen participants (8 female, 8 male) aged 19-30 were recruited via different mailing lists at the University of Konstanz. Most of the participants were students at the university; none were students from the computer science department. The test was designed as a 2×2 within-subjects design with the factors *device* (mouse and laserpointer) and *distance* (3 m and 6 m) appearing in combination in the different conditions. The order of these four conditions was counterbalanced across participants, using a Latin square design. The dependent measures included movement time MT in seconds, error rate Err, as well as the effective throughput or effective index of performance IP_e in Bits/s. The latter represents one of the benchmarks for comparing input devices and is one of the most widely used measures for the appraisal of input device performance (a detailed discussion can be found in MacKenzie, 1991). The calculations of effective width (W_e), effective index of difficulty (ID_e), and effective throughput were done as suggested by ISO 9241-9 or Soukoreff & MacKenzie (2004) respectively. In the experiment, targets of width W of either 80 px (9 cm) or 140 px (15 cm) and a centre-to-centre distance A of 550 px (62 cm), 1350 px (151 cm) or 3800 px (426 cm) were used, corresponding to levels of difficulty (index of difficulty, ID) between 2.3 Bits (easy), and 5.6 Bits (hard). The index represents both the width W and distance A in a single value. The configurations provided target stimuli that covered the central, proximal, and peripheral space of the Powerwall display. 15 trials had to be performed for each of the 2 (A) x 3 (W) target configurations. A trial was considered to consist of the movement towards the target, and its subsequent selection via a click. Hence, a block was complete after 2 x 3 x 15 clicks (as a minimum) plus one additional click for each configuration to select the first target (96 clicks in total). The order of the W-A configurations was random for every block and participant.

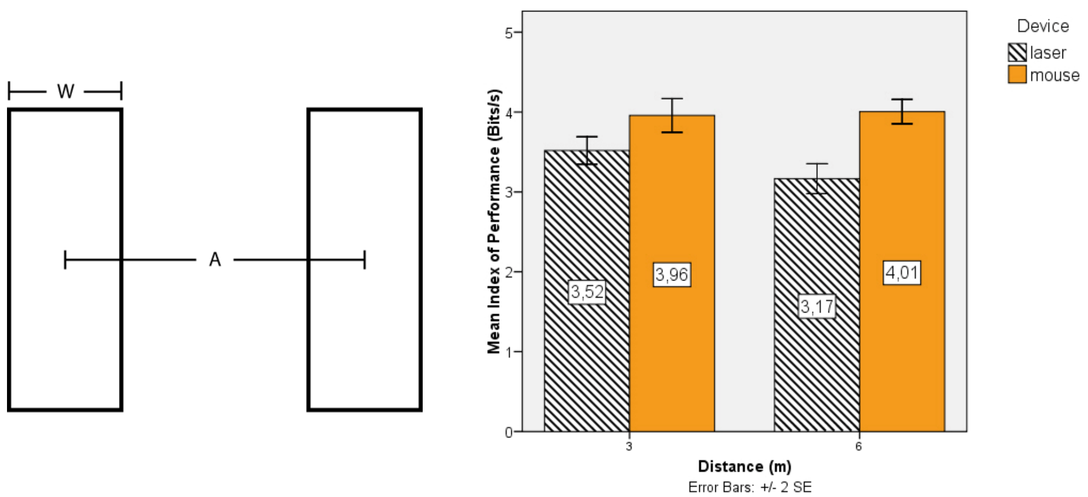

Figure 3: Unidirectional Tapping Task (left) Resulting Mean Effective Throughput (right)

5.2. Apparatus & Procedure

The experiments were conducted in the premises of the Powerwall facility in the University of Konstanz. Participants were standing in front of the 5.20 × 2.15 m display during all of the experimental conditions. A Logitech MX Laser Cordless Mouse was employed for the mouse conditions. The pointer speed was kept at a medium level to let the movement range cover the complete screen area without clutching. The level remained constant throughout the experiment. A 1.10 m high lecture desk provided the stationary rest for the mouse – this is the standard practice at the moment for interacting with the display. The custom-built laserpointer could be handled freely. The interaction (click events and pointer movement) was recorded by a software suite specifically developed for this evaluation and that also provided all the task stimuli (targets to click). It ran on the main computer connected to the Powerwall display with the maximum resolution of 4640 × 1920 pixels. The standard pointer of Microsoft Windows Server 2003 was used. Demographic data and preference ratings (for device choice) were obtained with the help of pre- and post-test questionnaires respectively. At the beginning of each session the participant was welcomed in the reception area of the facility and given a short overview of the procedure. After reading a short written introduction and filling out the pre-test questionnaire, the participant was given a description and concurrent demonstration of the test. It was emphasized that the targets had to be selected "as quickly and accurately as possible". The participant was then asked to stand at a distance of 3 m or 6 m centrally in front of the display. In order to allow her/him to become accustomed to the device and distance, every test condition began with five blocks of a 64-click task that was not considered for analysis. Hence, in total each participant had to perform at least 1664 clicks: for each of the four conditions 64 x 5 clicks for training plus 96 clicks for the task.

5.3. Results

Of the 5760 unidirectional trials, 18 were identified as outliers due to accidental double clicks or other disturbances in a regular trial and were removed from the analysis.

As expected, the performance of the mouse was generally better than the performance of the laserpointer (Figure 3). At a distance of 3 m, a mean IP_e of 3.52 Bits/s for the laserpointer and 3.96 Bits/s for the mouse was measured. The error rate (Err) at 3 m was 8% for the mouse and 15% for the laserpointer. Average movement times of 954 ms for the mouse and 1086 ms for the laserpointer were obtained. Significant effects of the factor *device* were found for all measures IP_e ($F_{1,15} = 30.570$, $p < 0.001$), Err ($F_{1,15} = 57.767$ $p < 0.001$), and MT ($F_{1,15} = 21.487$ $p < 0,001$).

Compared to the mouse, it was expected that the laserpointer's performance would be worse at the greater distance. The results confirmed this assumption. Distance-device interaction effects could be found for IP_e ($F_{1,15} = 8.627$ $p = 0.010$) and Err ($F_{1,15} = 6.489$, $p = 0.022$). Analysis of the simple effects of distance show that laserpointer performance is significantly ($F_{1,15} = 11.59$, $p = 0.004$) better at a distance of 3 m (3.52 Bits/s) compared to the performance at 6 m (3.17 Bits/s), whereas no significant difference could be observed for the mouse. Moreover, the laserpointer's accuracy deteriorates significantly with increasing distance ($F_{1,15} = 19.76$, $p < 0.001$), from 15% at a distance of 3 m to 20% at a distance of 6 m. Again, no significant difference could be observed for the mouse. The laserpointer's movement time increased slightly from 1086 ms to 1133 ms, but this difference was not found to be significant.

After the session, participants were given the post-test questionnaire so that they could report their impressions about which device enabled them to work faster and which was less error-prone. The participants' assessments correspond to the quantitative results reported earlier in view of the fact that only one participant claimed to have worked equally quickly and accurately with both devices. Ten participants generally favored the mouse, five the laserpointer, with one participant undecided. Reasons given in favor of the mouse were the greater confidence when using this common pointing device, in contrast to the novelty and unfamiliarity of the laserpointer. However, some participants would greatly favor the laserpointer for use in presentations, for example, due to the gain in flexibility.

6. CONCLUSION

We have presented a novel interaction technique based on Laserpointer-Tracking, a technique that is provided as a generic library with very versatile application. In contrast to previous research, our solution caters in particular for the demanding requirements of large, high-resolution displays in the areas of overall accuracy, interaction speed, and user mobility. Thus, in addition to providing good scalability in resolution and tracking speed, the library also allows the user to interact freely from any position and at any distance from the display. We verified the technical applicability by using it on two existing examples of LHRDs, a curved 360° panoramic display at the ZKM | Center for Art and Media Karlsruhe and a planar 221″ Powerwall with a resolution of almost 9 megapixels at the University of Konstanz. The latter also provided the environment for a comparative evaluation study conducted with 16 participants to assess the general usability of the laserpointer interaction by comparing it with a conventional mouse – the current standard input device. In total, the participants accomplished 5760 trials of the unidirectional tapping tasks (ISO standard 9241-9) with two devices (laserpointer and mouse) and at two distances (3m and 6m). As in previous studies, the results reveal that the laserpointer‘s performance in terms of selection speed and precision is close to that of the mouse (around 89 % at a distance of 3 m). This difference seems small in comparison to the gain in mobility when using the laserpointer system. However, other results from the experiment suggest that, due to trembling of the user's hand, the laserpointer's performance deteriorates with distance. This could be compensated by employing a distance-dependent Kalman filtering system. This filtering system requires additional research that appears justified by the current promising results.

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