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LumEnActive: A novel presentation tool for interactive installations

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Abstract

We present a novel presentation tool, LumEnActive. LumEnActive is a versatile software/hardware solution for steerable digital projection that can be deployed in museums, at art installations, for dissemination of cultural heritage information and in education. LumEnActive is suitable for a range of application areas with varying degrees of interactivity: from autonomous replay of pre-programmed presentations, to an interactive tool for guided tours, as well as for interactive and mixed-reality installations, where visitors can freely interact with the presentation tool to explore and learn on their own and at their preferred pace. Furthermore, it offers portable data visualization for collaboration on spatially vast data sets such as excavation plans, maps, floor plans, or high resolution images. In the paper we sketch these application areas and provide a discussion of the benefits of the approach, as well as a comparison with alternative solutions.

Categories and Subject Descriptors (according to ACM CCS): B.4.2 [Input/Output Devices]: Image display I.3.8 [Computer Graphics]: Applications J.2 [Physical Sciences and Engineering]: Archaeology

1. Introduction

With the commoditization of computer disseminated information, more and more computer based installations, often highly interactive in nature, are finding their way into our museums. Among the display solutions location aware handheld computers or phones, as well as augmented reality (AR) using head mounted displays (HMD) are popular [AAH*04, PPM*02, VDPI04]. However, these solutions suffer from practical shortcomings:

- Visitors might not want to be wired to HMD and computers when they enter a museum.
- HMDs often interfere with the spectacles worn by so many people.
- HMDs can be a safety risk as a result of the reduced field of view and can induce nausea.
- Visitors might be distracted from the exhibited artifact itself as a result of operating the handheld.
- Visitors may dislike wearing equipment used by other visitors before them.
- A significant quantity of handheld or portable equipment has to be acquired and maintained (recharged, repaired, cleaned, insured against theft or damage).

In this paper, we present LumEnActive, a hardware / software solution for steerable digital projection. Steerable projection offers a means of relating the use context, atmosphere, or way of living between and around exhibited objects. Thus, the effect is similar to HMD based AR but, as the necessary equipment is mounted in a fixed location, the practical shortcomings of handheld or head mounted devices mentioned above can be avoided. Additionally, steerable digital projection can direct the attention of visitors to specific artifacts or highlight interesting details.

In the following section, we report on previous and related work. In the third section, the LumEnActive system is presented. In the fourth section, we sketch some promising application areas for LumEnActive. We compare our approach with alternative solutions in section five before we summarize and present concluding comments.

2. Previous work

Data projectors that can project to different locations using a computer controlled mirror have been described in the literature in the area of ubiquitous computing, [Pin01]. Pinhanez introduces the idea of distorting computer generated graphics in such a way as to make them appear undistorted when projected onto different surfaces in an office space, such as walls, tables, or furniture. He proposes augmenting several reasonably bright and homogeneous surfaces in a room into interaction spaces that work like a touch screen, by combining projection with computer vision techniques using a steerable camera. Once calibrated, it is possible to turn on and off projection in order to switch back and forth between the different interaction spaces.

Raskar et al. as well as Bimber et al. put artifacts into context with computer generated media using non-steerable projection. They augmented artifacts with annotations in a work environment or a museum, [RWLB01, BGW*02, BCK*05].

We propose combining the two approaches into a novel presentation means for cultural heritage dissemination. In contrast to Pinhanez's line of work where a touch screen like operation within the projection space is used, we propose using interaction techniques following a flashlight metaphor, where interaction mainly occurs by steering the light beam itself. These interaction techniques were introduced by Rapp et al. in [RMO*04] for miniature handheld projection devices. Rapp et al. presented an ultra compact projector that allows access to data by moving the projector as a whole in the user's hand. Similar to exploring a dark room with a flashlight, users explore data that is laid out on a potentially huge virtual plane. Given the current orientation of the projector at any instant customized software calculates the portion of the virtual plane that the system has to display. By following the motion of the projector in the user's hand, the appropriate part of the virtual plane is recalculated in real-time allowing the user to move the light beam like a flashlight in order to explore the whole virtual data space. The projection can be directed onto any suitable surface. The approach of Rapp et al. comprises a set of intuitive interaction techniques, such as zooming in and out, and novel methods for writing and drawing sketches on the virtual plane.

In [EHH04] Ehnes showed how to overcome a limitation of commercial steerable data projectors (and, by analogy, also mirrors as used in [Pin01]): namely, the limitation that the actual projection direction can deviate from the direction command sent to the projector. By modeling the actuator timing parameters in software Ehnes showed that it is possible to display a stable image even during movement of the projector (or mirror). With this improvement the interaction techniques that were developed in [RMO*04] for a mobile handheld projector also become feasible with a stationary steerable projector.

3. LumEnActive

LumEnActive is a hardware/software solution for steerable digital projection. It consists of a standard off-the-shelf digital projector, a custom made, computer controlled, steerable mirror (see Figure 1) and a software library running on a standard PC with a 3D-graphics card. With [Pin01], it shares the principal hardware setup of a projector / steerable mirror system. However, in order to allow for stable content even during movement phases (as is also shown by [RMO*04, EHH04]), we developed a novel deflection system that is directly controlled via the parallel port of the PC and not via a DMX interface. Thus, explicit modeling of the actuator timing parameters as in [EHH04] is not needed with LumEnActive. The software drives the actuators of the mirror, selects the appropriate content to show, and calculates the correct image for projection. Our software basically follows the approach of [Pin01] in that it distorts the image based on the orientation of the mirror in such a way that it appears correctly on the surface it is projected on to.

3.1. Mirror unit

We have experimented with different actuators and gears for the construction of the steerable mirror as depicted in Figure 1. In order to achieve a smooth image while the mirror is moving, sufficiently fine movements must be addressable and detectable by the software. To illustrate this fact with figures: for an XGA projector with an opening angle of 30 degrees (that is, with a throw ratio of 1.86:1), the angle between two neighboring pixels is about 0.03 degrees. Consequently, if we tolerate deviations of up to a single pixel during movement, the mirror must be set accurately to within a tolerance of between 0.015 and 0.03 degrees. A typical stepper motor has a step width of about 1.8 degrees. As the mirror will typically change its direction of movement, the gear must be free from play to ensure reliable positioning. We finally settled on a solution involving wire gears and a gear ratio of about 20:1. This setup achieves, as we found, a good compromise between smoothness of movement and motion speed.

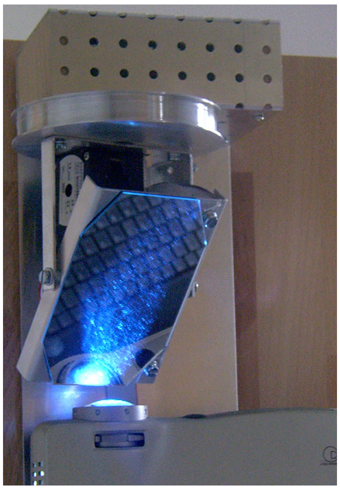

Figure 1: *The computer controlled mirror for steering the projector light beam.*

3.2. Software

At the core of LumEnActive is its software library. It is implemented in C++ and OpenGL. Thus, it can take advantage of the sophisticated hardware acceleration present in modern graphics cards for calculating the distortion that is required by the current setting of the mirror in relation to the orientation of the projection surface. It can be easily adapted to different projector properties such as throw ratio and offset. The content to be rendered may be any portion of a scene modeled within OpenGL. The system currently supports several frequent content types such as images or interactive classes like hotspot sensitive images. It is also possible to render video or flash animations [GOR03].

The software architecture comprises different modules for various tasks that communicate via so-called VIDStates. These VIDStates describe orientation and position data. The main module consumes VIDStates, calculates the correct mirror orientation and steers it into the correct position. The main module also generates the graphical information for the projector and does the geometrical calculations described previously. Further modules are responsible for producing VIDState streams. One module produces orientation data as captured by a commercial inertial navigation sensor. The inertial navigation sensor measures the orientation by means of accelerometers, gyroscopes, and magnetic field sensors. A second module assembles VIDStates from a traditional GUI, with sliders or other UI elements for each of the VIDState parameters. It is straightforward to attach other input devices to this architecture, such as joysticks, trackballs, or switches, as well as more sophisticated components like vision based tracking systems. Additionally, the system comprises a module for recording and a module for playback of VIDState streams. Finally, there is a module that accepts VIDStates and steers a pan-and-tilt camera using the supplied information.

As the transmission of the VIDStates is done over the network, it is possible to deploy the modules in any configuration on any number of networked computers. The modules may all run on the same or on different computers, either on a local network or far apart and connected via the internet. In chapter 4, we give some example configurations alongside the description of application scenarios that are appropriate to a museum or cultural heritage collaboration setting.

3.3. Interaction techniques

The LumEnActive approach comprises a set of interaction techniques that are suitable for interactive installations and that are sufficiently natural and simple for first time users.

Panning, the most prominent interaction technique, comes as a direct consequence of the flashlight metaphor: access to different spatially encoded information chunks may be achieved by steering the light beam in the respective direction. This way of panning is intuitive for selecting (virtual) information related to physical objects that are laid out in space. It also works well for selecting virtual information in absence of real world cues, if the virtual content provides sufficient inherent structure (such as days in a calendar), taxonomy- or tree-like structure, or direct spatial reference (as in maps).

Zooming may be combined with panning, if the virtual content is not aligned with real world artifacts, [RMO*04]. A combination of panning and zooming seems to be an effective and natural way to access large spatially encoded information items such as floor plans, excavation plans, high resolution images or 3D scans.

Point-and-click operations allow users to activate or start and stop active elements in an interactive installation. If needed, LumEnActive can overlay a cursor-like moveable marker over the displayed content as a pointing aid. Point-and-click interactions are a well-established technique. In the LumEnActive approach, with the handheld inertial navigation device as a pointing device, the interaction bears great similarity to casual point-and-shoot operations. Therefore, we consider this interaction operation feasible and fun to use in interactive installations, even for novice users.

4. Application areas

Autonomous replay of pre-programmed presentations. The setup for an automatically playing guided tour is as follows: A PC and the projector with the steerable mirror are installed on the ceiling or on a wall, such that the relevant part of the exhibition space may be illuminated by the steerable light beam of the projector. The content that will be displayed, such as annotations, arrows, animations or images, are stored on the PC. The PC runs two LumEnActive modules: firstly, the main module that generates the graphics output from the stored content, and secondly, the VIDState player that plays back the sequence of VIDStates that the projector beam has to follow.

The presentation is recorded in two steps using the inertial navigation module and the record module. In a first positioning phase, the handheld inertial navigation device allows interactive positioning of the graphical elements of the presentation and matching them with the placement of the real-world artifacts while the LumEnActive main module simultaneously drives the steerable projector.

In the second highlighting stage, the handheld inertial navigation device facilitates experimentation using different traces of the light beam over the correctly positioned graphical content. When the best presentation sequence is found, the movement of the light beam as well as triggers for interactive presentation elements are recorded with the LumEnActive record module.

Interactive tool to be used for a guided tour. LumEnActive is also suited as a means to enrich a guided tour through an exhibition. Various degrees of adaptability with regard to the individual interests of visitors are possible. The application setup is similar to autonomous replay as described above, the difference being that a (human) tour guide triggers the progress of the presentation, starts active presentation elements and selects from different pre-recorded illumination sequences. To that end, the guide may either use a switch or button that is installed in the exhibition area or carry along a device that connects wirelessly to the presentation system. If provided with a handheld inertial navigation device, the tour guide may also direct the projector beam interactively to the exhibits as with a laser pointer, thereby guiding the attention of visitors and providing additional information on the exhibits.

Interactive installations. In this scenario, LumEnActive allows for more visitor involvement and activity. The visitors steer the light beam. For example, a wall mounted trackball or a joystick can serve as a steering device. The movements of the steering device are translated into corresponding VID-States and input into the LumEnActive main module which steers the light beam accordingly. Thus, a visitor can actively direct the beam around the exhibition space in order to obtain additional information on the exhibits that are illuminated by the light cone, see Figure 2. An interactive installation may also start animations or audio playback, either upon entering a certain area or hotspot of the exhibition space, or upon explicit request of the visitor, for instance, by button press.

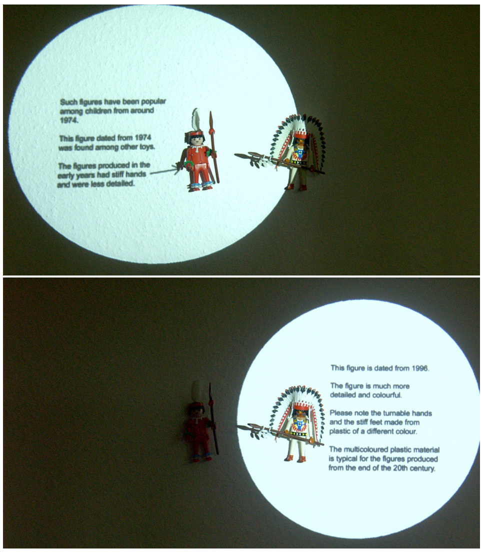

Figure 2: *Highlighting exhibits in a sample toy exhibition.*

Mixed reality. LumEnActive's modular architecture can exploit the bandwidth of current wide area networks (WAN) for interesting mixed reality installations that bridge the distance between in-house presentation and, e.g., excavation field work. Imagine, for instance, an in-house exhibition of artifacts taken from an excavation site where work is still going on. A LumEnActive steerable projector can project the live video stream from the location the artifact was discovered to the area where the artifact is now on exhibit. With the help of a suitable LumEnActive steering device (e.g., a joystick or trackball), visitors at the exhibition site can simultaneously steer both the projector in the exhibition and, via WAN, a pan-and-tilt camera that is installed at the excavation site. The camera's video stream is sent back to the exhibition site via WAN. The pictures from the different locations of the excavation site that are recorded by the camera are projected onto corresponding positions in the area surrounding the artifact in the exhibition site. Thus, visitors are able to relate a restored artifact with the current status of an excavation, or, if past images of the excavation were recorded, with the process of the excavation of the object itself.

Working with spatially extensive data. LumEnActive also offers an attractive way to visualize and handle a large data set where users have to work on detailed local information while maintaining a global awareness of the position of the information pieces within the overall data set. Large data sets of this kind are, e.g., excavation plans, stitched 3D scans, high resolution images, maps, floor plans and the like. LumEnActive represents a natural and intuitive visualization and data exploration tool for tasks of this type. Steering a light beam to the area of interest within the data allows for high visual resolution of the data and, at the same time, provides spatially encoded feedback on the area of interest within the total data space. Panning within the data space is more intuitive as compared to navigation via scrollbars, as it also relies on the user's locomotion or 'muscle memory' and not only on visual cues, see Figure 3.

5. Discussion

The steerable light beam of the projector combines several properties that are useful in cultural heritage dissemination. Firstly, the moving spotlight catches the attention of viewers and directs it towards specific locations, similar to a laser pointer or the hand gestures of a human guide. Secondly, projection offers an unobtrusive way to augment physical artifacts with computer generated information, such as highlighting details with arrows or annotations, surrounding the artifact with illustrations that show its usage or dynamically put it into different contexts, see Figure 4. Thirdly, the steering of the light beam can offer visitors an intuitive way to select objects of an exhibition and trigger the provision of additional information. Thus, visitors can explore and learn at their preferred pace and follow their specific interests.

On the other hand, for successful implementation there are some prerequisites for the technology as well. The most prominent requirements for projection concern the lighting

Figure 3: *Working with a large excavation plan.*

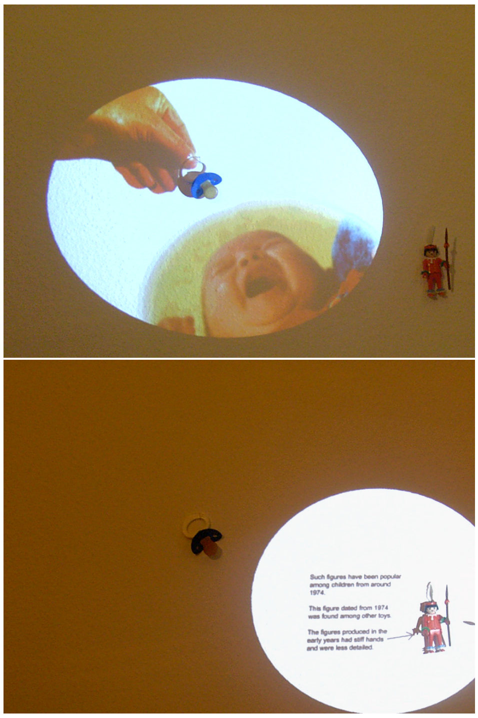

Figure 4: *Use context and space reuse by projection.*

conditions of the exhibition space as well as the surfaces that will be projected onto. Projected content will be most visible if the projection surface is of homogeneous, bright color, and if there is low ambient light emission which might otherwise reduce the contrast of the projected information. As current projectors are bright enough to work well in a wide range of lighting conditions, the main things to avoid are outdoor usage in direct sunlight, dark surfaces, and textures with a high contrast.

Compared to other display solutions, steerable projection has a number of advantages. As considerable computing power is required to achieve AR with head mounted displays (HMD), current prototypes require wearing a back pack with a computer in addition to the HMD, or to connect the HMD with stationary computers, e.g., by hanging cables from the ceiling. Both solutions are uncomfortable for the user and can even pose a safety risk. One drawback of steerable projection compared to HMD and projection caves is that it delivers a smaller amount of immersion. However this may also be viewed as an advantage in that it poses a smaller risk of related issues such as nausea and/or seasickness. By allowing visitors to steer the projection according to their needs and likes, a similar degree of involvement can be achieved as with other VR or AR solutions, but at lower cost and without the need to expose hardware to visitors, avoiding the problems of donning equipment and dangling wires. A further point in favor for projection based presentation compared to HMDs is that groups of visitors can follow a steerable projector presentation and share in the experience.

Embedded displays are also popular for enriching exhibitions. However, it is not always easy to establish the relationships between the embedded displays and the exhibits. Moreover, there is a risk that such media does not integrate well with the exhibition concept and often appear as if they could just as easily be viewed outside the exhibition context.

Advantages of projection over physically attached information, such as posters and signs, are that the projection space can be shared by the exhibits surrounding it and that information can be dynamically animated and replaced, since several pages of information can be projected onto the same spot over time, either following a fixed regime or under the spectators' control, as is illustrated by Figure 4. This is also very useful when offering explanations in several languages as it saves the space for explanations that individual viewers may not need.

If mobile display solutions, either smart-phone based, PDA-based, or Tablet-PC based, are used as display media, respective infrastructure must be provided to either manage the lending, charging, and maintenance of a set of devices or to establish a way to publish the content for a range of visitor owned equipment and make sure that the location based service works for many, if not all, of these devices.

Depending on the museum size and the specific display needs, steerable projectors can give a real cost benefit saving as compared to other display solutions. In particular, caves or multi-sided projection based solutions are often too expensive and require a lot of space. The projection unit and driving PC hardware of a steerable projector can easily be mounted in the ceiling or hanging on a wall. In most cases only power is required so there are no installation issues that could hinder adoption. Compared to a single, non-steerable projector setup with a wide projection area, the resolution that can be achieved with a steerable projector can be much higher, and compared to a multi-projector setup, the cost issues speak for a single steerable projector solution.

6. Summary and conclusion

The flashlight metaphor as an interaction paradigm is well suited for adoption in museums. LumEnActive's contribution is to make this intuitive interaction available with steerable projectors through custom made hardware and a corresponding software library. The modular architecture of LumEnActive is reconfigurable and flexible enough to realize a variety of presentation tasks, ranging from pre-recorded information playback where the light beam highlights specific exhibits one-by-one, to an interactive presentation tool for tour guides, to interactive AR and MR installations. The system can augment exhibits by projecting content in a safe manner, allowing visitors to interact with artifacts while keeping them at a distance and thus protecting the artifacts themselves against damage. Through computer controlled movements the moving light beam can draw attention to the installation. Furthermore, it can focus the attention of visitors on specific artifacts one at a time, following a computer controlled or tour guide's presentation. The effective use of the viewer's spatial memory supports learning and discerning of information chunks.

As a steerable projector can reach a considerable portion of an exhibition space and can enable augmentation of multiple exhibits within a room, it makes effective use of all available resources. With a few off-the-shelf projectors and the LumEnActive system, it is possible to attractively present exhibits to the public, and tell the story of their usage. Also, with a fixed rather than a portable augmentation, the logistical difficulties associated with handing out equipment to visitors are eliminated. Our experience is that even for first time users the technique is fun to use and interesting in itself. If provided with the inertial navigation sensor it also stimulates them to reflect about how the "magic torch" itself actually works.

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