Lykta - A Platform for Wireless Handheld Projection Mapping

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ABSTRACT

This paper presents a low-cost way to achieve accurate mobile projection mapping with location-aware projection devices. Interaction is done through the "flashlight metaphor", where users explore digital content by shining a mobile projector along surfaces and discover content which appears to be attached to these surfaces.

A prototype was developed for the context of a virtual art gallery in physical space, as part of the *Kulturhus Backaplan* culture house project in Göteborg, Sweden. The response from the initial demonstration in a public library was overall positive with many users describing it as an interesting and novel experience, though it was observed that some did not appear to notice that the projector was meant to be picked up and interacted with. The prototype indicates that the concept provides an interesting and intuitive way of exploring digital content and that it is viable using commercially available technology. It is set to be developed further for more interactive experiences such as games.

1. GENERAL TERMS

Design, experimentation, human factors.

2. KEYWORDS

Projection mapping, flashlight metaphor, pico projector, prototype, wireless, augmented reality, ubiquitous computing, interaction, exploration, COTS.

3. INTRODUCTION

Projection mapping, casting an image from a projector onto an object with correct perspective on the projected image, has been used in static exhibitions and projections on the sides of buildings for events[3]. By overlaying the physical space with a digital one many new ways of displaying and interacting with digital media are made possible.

Handheld projection mapping, where users explore a virtual world using the "flashlight metaphor", i.e. shining the light from the projector around on surfaces to "discover" content that appears to be attached to the surface, requires location-aware portable projectors with a high degree of position and orientation accuracy. This has previously only been achieved in laboratories with expensive equipment[1, 2, 6, 10, 12, 13, 16], but new consumer technology promises to make this much more accessible.

The municipality of Lundby, Göteborg in the southwest of Sweden is subject for an intense remodeling, where a new central urban district is being built. In order to support their desire to lead the foray into the future of modern cultural experiences in the new culture house, *Kulturhus Backaplan*[5], a prototype for a new kind of gallery, the *Invisible Showroom,* was built. Handheld projection mapping is used to enrich and augment the ordinary art gallery experience.

The prototype system is called the *Lykta Platform* and the purpose of this paper is to present Lykta as a way to achieve handheld projection mapping from a wireless portable unit using off-the-shelf components. *Lykta* is Swedish for *lantern.*

4. PREVIOUS WORK

Over the last decade many projects have focused on creating movable projectors that adjust to the different projection surfaces in the environment. Early work appeared in the 2001 paper *The Everywhere Displays Projector[10]* by Pinhanez et al. A static projector with a motorized mirror was used to project "mobile displays" almost anywhere in the room where the system was mounted. While many other projects following this would use various algorithms for perspective correction of the image, Pinhanez et al. recognized that this could be accomplished using 3D worlds in computer graphics engines. It was noted that this would leverage the graphic processing capabilities of modern computers for fast image updates.

Early portable units were built by Raskar et al, Karitsuka & Sato in their *iLamps* and *Wearable Mixed-Reality* devices[13, 6]. These solved the positioning issue by having a camera in conjunction with the projector to recognize visual tags and RF tags on the projection surfaces, with IR LEDs on fingers for touch interactivity. Other solutions used ultrasonic beacons[16].

Raskar et al. added inertial sensors in later projects to increase orientation stability, but still used sensing of static tags for positioning[12]. These later prototypes added a static cursor in the middle of the projected image to manipulate data by moving the projector.

Cao et al. are the first to our knowledge who achieved accurate positioning and orientation tracking without environment markers or onboard cameras[1, 2]. Their system uses a motion capture system with markers on the handheld unit, detected by a static IR camera. Many types of interactions are explored, including dynamically adding surfaces to the environment. For computing the image the handheld unit is tethered to a stationary computer.

More recently, Molyneaux, Cao et al. have worked on a promising technique using simultaneous localization and mapping (SLAM)[8]. This uses a *Microsoft Kinect[7]* depth camera to construct a textured 3D scene of the environment, while simultaneously calculating the position and posture of the device. Currently, these devices are also tethered.

5. TECHNICAL BACKGROUND

The most important factors for accurate projection mapping is a precise model of the surface to be projected on, combined with accurate positioning and orientation of the projector if it is to be mobile. The projected image not only needs to be adjusted for its orientation relative to the surface, but also for the geometry of the surface itself. In summary, real-time handheld projection mapping requires handheld projection technology, with accurate and fast wireless positioning. Additionally, a 3D model of the surface to be projected on must be present and run on handheld 3D rendering hardware fast enough to adjust the projected image in real-time.

Tiny LED projectors (also known as pico projectors) are becoming increasingly common on the market. While these are not as bright as traditional light bulb projectors, their lower power consumption and heat generation mean they can be made more compact and light and are capable of running on batteries for hours at a time.

Likewise, recent advances in smartphone technology mean that the required computing and rendering power is easily available through mobile phones. Many of these provide the possibility of outputting high-quality images to a projector, and smartphones are even starting to appear with built-in LED projectors[14].

If the geometry is simple, a 3D model can be created beforehand. Recently high-resolution depth sensors such as *Microsoft Kinect* have started seeing use in SLAM applications, creating 3D models of small environments in real time without external positioning equipment[8]. Though this is currently outside the scope of the *Lykta* platform, such functionality may be added in the future.

While smartphones are usually outfitted with GPS receivers, these only provide positioning accuracy down to an order of several meters outdoors and are not suitable indoors. Projection mapping requires precision down to centimeter level for results that look pleasing to the eye[16].

5.1 Positioning

To solve the indoor positioning problem, early versions of *Lykta* used an overhead-mounted *Nintendo Wii* controller as a wireless IR camera for tracking the position of IR LEDs on the handheld unit along a plane. However, due to the limited field of view of the Wii controller camera and the limitations of having only two-dimensional tracking, this solution was abandoned.

Seeing the tracking accuracy achieved in *Project Holodeck*[18], a game project using VR glasses, the *PlayStation (PS) Move* controller appeared to be a good match for the positioning needs. However, this limits use of the system to within the area the *PS Eye* camera can track the glowing sphere in the *PS Move* wand - roughly 3,5x4m.

An open source Application Programming Interface (API) for tracking was first investigated[9], which provided accurate positioning. However this was replaced with a proprietary API from Sony to improve orientation tracking accuracy, see below.

5.2 Orientation

The Wiimote-assisted versions of Lykta used the smartphone sensors (compass, accelerometers and gyroscopes) together with a sensor fusion algorithm. However it was still sensitive to magnetic disturbances, which can be common, especially indoors.

When used in retail gaming applications on the *PS 3* console, the *PS Move* system can use computer vision-based position tracking to create a more robust orientation tracking. The open source API implements this, but Sony's proprietary *Move.me* API[15] was considerably more robust and calibrates automatically. There is no access to the source code of the *Move.me* software. However it is assumed the computer vision positioning data is used as state constraints in a Kalman filter together with the compass, accelerometers and gyroscopes of the wand to compute the pose.

5.3 Lykta system overview

A wide-angle *PS Eye* camera connected to a *PS 3* console captures images of the glowing spheres of up to four *PS Move* Wands, and since *Lykta* will use one per portable projector, up to four users are supported at once. This is combined in the proprietary *Move.me* server software on the PS3 with sensor data sent from the controllers over bluetooth. A host computer receives the position and orientation data of the controllers and updates a 3D scene of the exhibition area with all the handheld projectors. This is synced over wireless network with a smartphone client in each handheld projection unit, running its own simulation. The image is then output to the projector through an MHL video adapter. See fig. 1 for an overview. The software on the server and smartphone clients is developed in *Unity3D*[17]with a plugin for Move.me[19].

6. DESIGN CASE

The *Lykta* platform was initially developed as an affordable prototype solution for the *Kulturhus Backaplan* context and use case.

6.1 Context

During a meeting with the municipality of Lundby a possible future of *Kulturhus Backaplan* was presented, along with the problems and issues they face. They wish for a culture house which can affect the preconceived notion of the location as a transport hub, provide a more inner city feel, and show culture in a more contemporary way.

Some requirements imposed by the context are that the technology should not be in the way of usage but be easy

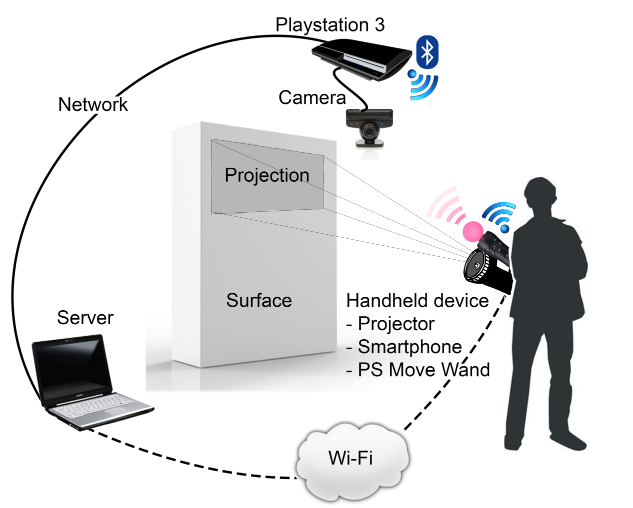

Figure 1: Overview of the parts comprising the *Lykta* platform.

Figure 2: The *Invisible Showroom* prototype in use. The *PS Eye* camera is placed on the table to the side of the exhibition.

to pick up, require no explanation, and provide a seamless experience.

The aim was thus to present a concept of a curiosity-inducing, out of the ordinary experience of art and culture, achieved by combining physical and virtual space using projection mapping. If the experience is easy to modify and visitors themselves can affect the content then the installation can become more of a living space.

6.2 Concept

The *Invisible Showroom* is a concept of a virtual multimedia art exhibition displayed in the physical world using the *Lykta* platform to show location based content with projection mapping. The label "art" refers to a wider range of media; images, video, audio and text, which can then be enhanced by the interactivity and movement of the user. The term *showroom* is used instead of *gallery* to indicate a wider range of future uses of the culture house space than just displaying artwork, e.g. games and education.

The aim is to function as a bridge between the virtual and the physical world. Further, it introduces the possibility for visitors to contribute and affect the physical space by uploading their artwork and other contributions through a website. For example, unknown artists who are easily given space in the virtual world in online galleries where the space seems endless, can now be empowered to show their work in a "real" gallery which may affect how the art is perceived. Additionally, when actively searching for hidden art by walking around, holding and utilizing the projection device, an entirely new aspect of the conventional gallery experience is opened up.

6.3 Demonstration of prototype

After the early *Lykta* platform prototype had been developed and tested internally, the municipality of Lundby desired a public test exhibition of the *Invisible Showroom*. A spot at the Älvstranden library at Lindholmen in Gothenburg was offered. This was also seen as an opportunity for a first public test of the new *Lykta* platform, with focus on how visitors would react on initial contact with the handheld portable projector. The two-day demonstration was carried out as an informal test, backed up by observations and some talk-aloud sessions.

Due to budget constraints and time limitation only one prototype of the projection device was created. The system was originally designed to provide the possibility to update the media displayed in the exhibition through an online web portal. This feature was skipped due to the down-scaled nature of the prototype. The sum cost of the components of the current system is less than €1000.

The *Lykta* platform was set up to display paintings from two young artists on the three walls on one side of the installation. The display canvas was a 1.8 meter tall white display wall made of cardboard, with two 90 degree angles (one convex and one concave). See fig. 2 for an overview of the display area.

Two approaches to engaging visitors were tested in order to observe user engagement thereafter. In the first case the projector stood on its own accompanied by promoting signs. In the other case visitors were approached and encouraged to try it out.

7. RESULTS

In the case where merely signs encouraged visitors to pick up the projector, they seemed hesitant to do this. When visitors were approached or saw others interacting, they were more inclined to indulge in the experience.

Most of the visitors who were asked for feedback said that the experience was novel and interesting. It was also observed that some brought the unit to the attention of their peers for them to try. Most visitors observed seemed to quickly grasp how to explore the digital content using the flashlight metaphor. One visitor remarked that just hanging up pictures would be much simpler.

Some visitors inadvertently moved outside the space covered by the *PS Move* camera, which made the position readings stop updating and the image move out of alignment with the surface.

8. DISCUSSION

In hindsight, a public library may not have been the most suitable location to demonstrate the system as visitors may have a mindset to be passive and discrete. In e.g. an art gallery, culture house or a more inviting public space visitors may be more inclined to try something new. However, as an initial public demonstration the library exhibition was successful in providing information on how visitors would react on initial contact with the portable projector. Their reactions indicate that the Lykta platform can provide a novel and interesting experience, but also that users may miss engaging with the device if it is not presented in a clear and compelling way. This may be because projectors are not perceived as being portable devices, but rather as expensive and finely tuned static equipment. Additionally the physical design of the prototype may not have been inviting enough. This should have been investigated further during the exhibition, but was not reflected upon in time. Once picked up, it was observed that exploration using the flashlight metaphor seemed intuitive even for new users.

More dynamic elements, such as sound and video, could have been included in the gallery to show off the possibilities of the system in blending physical and digital space. This would also clarify that the Lykta platform has capabilities beyond hanging up pictures on a wall.

The device's battery life of only 90-120 minutes was a concern and it required light disassembly for charging. This meant that it could not be left on display for long, and that visitors may have been discouraged from interacting with the device when they saw it being disassembled and charged. Ideally the device would easily slot into a charging stand while not in use.

Visitors were prone to move out of range of the *PS Move* Camera. Either a better placement of the camera will have to be worked out, or there should be an indication, e.g. on the floor, for which area is part of the exhibition. With a more open *PS Move* API or new technology for indoor positioning the currently limited area of tracking could be extended.

9. FUTURE WORK

There are many different fields where the *Lykta* platform could possibly be applied. The native input controls on the *PS Move* wand could be used to interact with the virtual world for gaming or productivity applications. Using a cursor in the middle of the projection the user may move, scale, rotate and modify digital content[1, 11]. It is currently being adapted for a horror game experience as part of a master thesis, where more thorough user testing will be carried out.

An additional possibility would be to mount the projector and *PS Move* wand closer to the eye of the user for a CAVE-like system[4], thereby tracking the movements of the head and providing perspective correct parallaxing for one user.

If a whole room could to be covered by the tracking system, *Lykta* could be used for more than just exhibitions and small games. Immersive exploration experiences in large spaces would also be possible, such as exploring a jungle with the flashlight metaphor.

10. REFERENCES

[1] Cao, X., and Balakrishnan, R. Interacting with dynamically defined information spaces using a handheld projector and pen. In *Proc. of ACM UIST '06* (2006), pp. 225–234.

[2] Cao, X., Forlines, C., and Balakrishnan, R. Multi-user interaction using handheld projectors. In *ACM UIST* (2007).

[3] Clarionpost. Clarion Hotel Post opening ceremony. `http://www.clarionpost.se/invigningsfest`.

[4] Cruz-Neira, C. e. a. The cave: audio visual experience automatic virtual environment. *Communications of the ACM 35* (1992).

[5] Göteborg & Co. Göteborg 2021- kulturhus backaplan. `http://www.goteborg2021.com/ideer/kulturhus-backaplan/`.

[6] Karitsuka, T., and Sato, K. A wearable mixed reality with an on-board projector. In *Proceedings of the 2nd international symposium on mixed and augmented reality* (2003), IEEE Computer Society, p. 321.

[7] Microsoft Corporation. Kinect for windows | voice, movement and gesture recognition technology. `http://www.microsoft.com/en-us/kinectforwindows/`.

[8] Molyneaux, D., Izadi, S., Kim, D., Hilliges, O., Hodges, S., Cao1, X., Butler, A., and Gellersen, H. Interactive environment-aware handheld projectors for pervasive computing spaces. Tech. rep., Microsoft Research, Cambridge, UK, 2012.

[9] Pearl, T. Cross-platform tracking of a 6dof motion controller. Master's thesis, TU Wien, Fakultät für Informatik, 2012.

[10] Pinhanez, C. S. The everywhere displays projector: A device to create ubiquitous graphical interfaces. In *Proc. UbiComp '01* (2001), pp. 315–331.

[11] Rapp, S., Michelitsch, G., Osen, M., Williams, J., Barbisch, M., Bohan, R., Valsan, Z., and Emele, M. Spotlight navigation: Interaction with a handheld projection device. *Pervasive* (2004).

[12] Raskar, R., Beardsley, P., van Baar, J., Wang, Y., Dietz, P., Lee, J., Leigh, D., and Willwacher, T. RFIG Lamps: Interacting with a self-describing world via photosensing wireless tags and projectors. Tech. rep., Mitsubishi Electric Research Labs, Cambridge, MA, 2004.

[13] Raskar, R., van Baar, J., Beardsley, P., Willwacher, T., Rao, S., and Forlines, C. iLamps: geometrically aware and self-configuring projectors. *ACM Transactions on Graphics 22* (2003), 809–818.

[14] Samsung. Samsung Galaxy Beam overview. `http://www.samsung.com/uk/consumer/mobile-devices/smartphones/android/GT-I8530BAABTU`.

[15] Sony Computer Entertainment America. Move.me - Software tool for PS3 system that uses Playstation Move Technology. `https://us.playstation.com/ps3/playstation-move/move-me/`.

[16] Teller, S., Chen, J., and Balakrishnan, H. Pervasive pose- aware applications and infrastructure. *IEEE Computer Graphics and Applications* (2003).

[17] Unity Technologies. Unity - game engine. `http://unity3d.com/`.

[18] University of Southern California Interactive Media Division. Project holodeck website. `http://www.projectholodeck.com/`.

[19] Xun Zhang. Move.me plugin for unity. `https://us.playstation.com/ps3/playstation-move/move-me/`.