Attjector: An Attention Following Wearable Micro-Projector

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ABSTRACT

Mobile handheld projectors in small form factors, e.g., integrated into mobile phones, are getting more common. However, managing the projection puts a burden on the user as it requires holding the hand steady over an extended period of time and draws attention away from the actual task to solve. To address this problem, we propose a body worn projector that follows the user's locus of attention. The idea is to take the user's hand and dominant fingers as an indication of the current locus of attention and focus the projection on that area. Technically, a wearable and steerable camera–projector system positioned above the shoulder tracks the fingers and follows their movement. In this paper, we justify our approach and explore further ideas on how to apply steerable projection for wearable interfaces. Additionally, we describe a Kinect-based prototype of the wearable and steerable projector system we developed.

Categories and Subject Descriptors

H.5.2 [**User Interfaces**]: Input devices and strategies, Interaction Styles

General Terms

Human Factors, Design

Keywords

Mobile interaction, pico projector, dynamic peephole, wearable computing

1. INTRODUCTION

Mobile projection technology is rapidly developing in terms of miniaturization, brightness, resolution and power consumption. Miniature projectors are available for sale as stand-alone devices or built into devices such as mobile phones or digital cameras. Apart from static applications such as picture or video display, mobile projectors offer interesting possibilities for interaction. This has in the past been demonstrated by handheld projector applications such as [1] as well as body-worn applications such as Sixth Sense [6]. Picoprojectors integrated in mobile phones are becoming more common [11]. Harrison et al. [4] present a system that detects input on the skin and uses a pico-projector mounted on the upper arm for generating graphical output. Sakata et al. present a belt mounted projector that projects information into the user's hand [12]. Tamaki et al. present the concept of a personal projector that is integrated into an earphone [13]. In the following, we discuss the need to control the mobile projection as a critical interaction problem with such systems and propose a solution based on steerable projectors. We discuss a prototype system and the advantages such a system can provide for user interfaces.

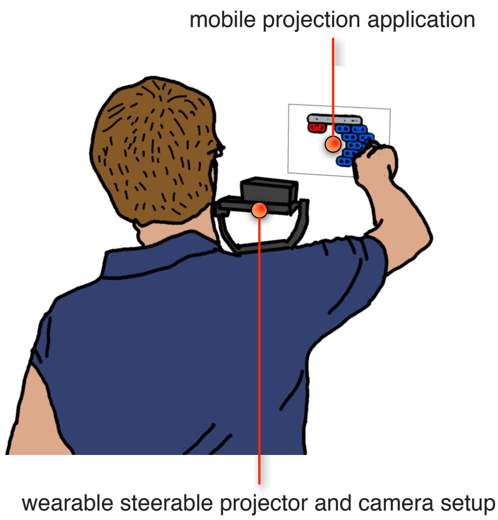

Figure 1: Using a stabilized mobile steerable projector allows the projected image to follow the user's locus of attention. This Figure conceptually shows a shoulder-worn projector and camera setup that tracks the user's right hand.

2. WHY TO CONSIDER STEERABLE AND MOBILE PROJECTION

We believe that a fundamental weakness of existing and past mobile projection interfaces is that the user is required to focus on managing the actual projector to an unacceptable extent. In a worn projection system, for example, the users must, for any interaction, ensure that they keep their body steady and if any external objects are supposed to be augmented by the projection, they must ensure that the object stays within the projector's field of projection. In the case of handheld mobile projectors, users are faced with the similar problem of keeping the projection steady or aiming the projections towards some target that is meaningful for the application they are currently using.

We feel that the task of managing the projection diverts too much of the users' attention away from the tasks that they are trying to accomplish. This is an undesired feature of mobile projection applications. Cauchard et al. [3] suggest that typical configurations of handheld pico projectors are unsuited to many projection tasks, because they couple the device orientation to projector orientation in a fixed way and argue for steerable handheld projection. They show a prototype that contains a mirror in front of the projector that can be controlled by a servomotor in order to allow for wall, desk, or floor projection. We focus on body-worn rather than handheld projectors to further alleviate the user from managing the projection and aim to follow the user's manual activities and locus of attention.

Mobile Projectors and The User's Locus of Attention

When working on a complex task, users tend to focus exclusively on the current subtask they are performing. This is what Raskin refers to as the *locus of attention* [8]. Any feature of the user interface that is not within the user's locus of attention tends to be ignored. Thus, when users use existing mobile projection systems, their attention is split between managing the projection and the actual task accomplishment in a significant way.

How, then, can we make a mobile projection system aware of the user's locus of attention? In an attempt to generalize interaction with mobile projection systems, it becomes apparent (at least in systems that use touch or bodily gestures for input) that the user usually interacts with her hands and fingers over or on a surface that is augmented by the projection system and is, during interaction, looking at the area in the vicinity of her hands or fingers. We can thus assume that the user's locus of attention follows the position of the user's visual attention, which, in precise manipulation tasks, can be approximated by the position of his hands or dominant fingers (index finger and thumb). This observation gives us an estimate of where the user is looking at when interacting with mobile projection systems that use a touch or gesture-based input technique. We realize that current systems, in addition to burdening the user with the task of controlling the projected image, waste a lot of projection space by projecting to areas the user is not attending to. Conversely, the projection could be directed explicitly towards the area the user is actually interacting on, thus increasing the effective "screen" resolution and brightness of that area.

Following the User's Attention

Full-scale steerable projectors on gimbaled mounts have in the past been used to augment interactive rooms [7] or in desktop settings [11]. We propose that stabilized, steerable micro projectors in combination with appropriate computer vision techniques for the tracking of hands, fingers and augmentable objects can be used to realize attention following in interfaces using mobile projection. Such systems have the advantage of providing a stabilized image at all times, as well as providing increased localized resolution to the user. Moreover, user interface elements can, for example, be projected such that they appear at a fixed distance from the user's hand, even if she moves it around on the interactive surface. This allows instant access to commonly used commands. If equipped with automatic zooming capabilities, the projector could project content at a wider angle if no hand (and thus user) input is detected, allowing the user to gain an overview of the interaction area. Using a steerable projector, augmentable objects could be perfectly tracked and augmented with a high-resolution projection.

3. PROTOTYPE HARDWARE

To evaluate our ideas about attention following for mobile projection, we are currently developing a wearable steerable projector system. A projector and a camera on a fully gimbaled mount are positioned above the users shoulder (Figure 2). We believe that the shoulder is an optimal placement location that doesn't constrain the user's arm movements while at the same time providing a good field of projection due to the elevated position.

Because commercial pan/tilt mounts for cameras are generally not meant for use in wearable settings and are relatively expensive when they are designed to support rotation on three axes, we decided to build our own hardware. The design requirements for our wearable, steerable projector system were the following:

- The Kinect/projector mount needs to support rotation in all 3 axes (pitch, roll, yaw), in order for the system to compensate for movements of the user's upper body and also to be able to track the user's hand over a wide range of motion.
- The mount needs to be actively stabilized and react quickly to sudden user movements, in order for the projected image to remain at a stable position and to minimize image jitter.
- The entire system should be wearable and self-contained, so that it can be used in mobile settings.
- The system should be relatively easy to reproduce by other research labs equipped with basic FabLab equipment.

Our prototype consists of an actively stabilized gimbaled mount with three freedoms of rotation, a truss system for positioning the gimbaled mount above the user's shoulder and a hard-shell backpack that acts as a fixation point for the truss as well as a storage space for the battery and a laptop computer.

The gimbaled mount holds a Kinect and an Optoma PK 201 pico projector. The Kinect's depth image is used to track the position of the user's hand, and monitor the scene for touch events. Marker recognition or OCR can be accomplished by using the Kinect's RGB Camera.

The gimbal mount is equipped with an accelerometer and a gyroscope[1] that is used to maintain level orientation at all

[1]We use a "Sparkfun IMU Digital Combo Board" `http://www.sparkfun.com/products/10121` containing an ITG3200 3-axis gyroscope and an ADXL345 3-axis Accelerometer, that are readable via an I2C bus.

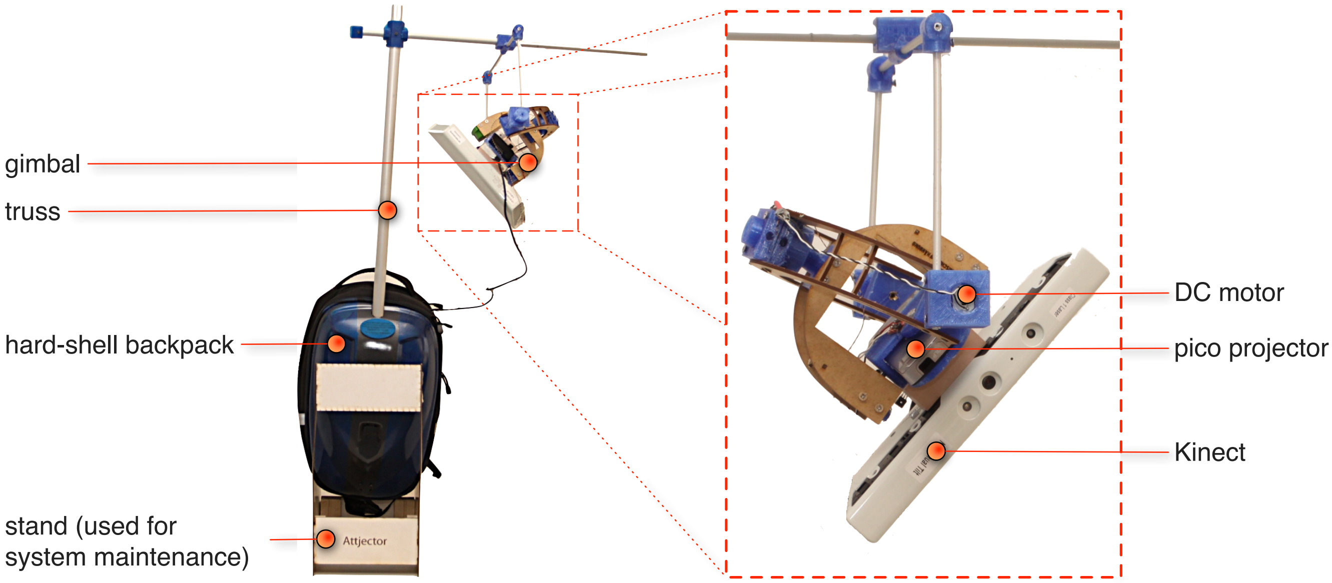

Figure 2: Our prototype consists of a hard-shell backpack, truss system and attached gimbal with the Kinect/projector combination *(Left)*. To ensure the maximum range of motion, the Kinect is mounted below the projector. The gimbal is actuated by three servo motors *(Right)*.

times. To actuate the gimbal, we use three standard size servo motors[2]. The servo motors have a torque of 0.35 Nm and an actuation speed of about 353° per second, which is adequate for our needs. The truss assembly which holds the gimbal is mounted on a hard shell backpack. The hard shell provides excellent rigidity and stability while wearing Attjector.

For easy replication, the gimbal, motor mounts and truss connectors can be constructed entirely from laser cut and 3D printed parts. Construction of the truss system requires 6mm, 16mm and 26mm aluminum tubing.

We use an Arduino microcontroller to read out the sensor values and to control the servo motors via pulse width modulation (PWM). A PC-based application closes the control loop and controls the servo motors via commands to the Arduino, such that the gimbal remains at a steady orientation.

4. RESEARCH QUESTIONS

Using Attjector, we aim to address a number of research questions that were previously not possible to answer due to the lack of a system comparable to Attjector.

Fitts' Law Study for Peephole Pointing

Peephole pointing [14] allows interaction with large workspaces that contain more information than can be displayed on a single screen. This technique provides a movable window that reveals a portion of the larger content the user is working with. Peephole pointing is thus a suitable technique for use with mobile projectors due to their rather limited projection throw angle. For peephole pointing, we hypothesize that systems such as Attjector will lead to a higher throughput compared to solutions where the mobile projector is controlled by hand. Our intuition here is that pointing with the finger is likely to be faster than pointing through a proxy such a mobile projector. Of course, a prerequisite for good performance in a Fitts' Law evaluation is a well-functioning gimbal with sufficient speed to track fast hand movements. Peephole interfaces have been previously evaluated in a Fitts' Law context by [2, 10], but mobile projection has not been covered yet.

Improved Usability for Focus-In-Context and Peephole Pointing Tasks

Focus-in-context interfaces usually consist of a large scale, low resolution (or low detail) representation of the scene with a smaller, higher-resolution window that is movable across the low-resolution content to reveal in high resolution and high detail content in a local scope. A possible focus-in-context interface scenario for Attjector could be the use of our system in conjunction with a large projected image created by a full-size projector in a room. Again, because the users don't need to control the projector explicitly, it is likely they will be able to focus better on their tasks. We thus expect ISO9241-9-based [5] usability ratings to increase in general and an increased user performance for specific application scenarios, such as peephole-based search tasks (i.e. as in [9]).

5. EXAMPLE APPLICATION SCENARIOS

There are numerous application scenarios for Attjector which go beyond those presented in previous work (i.e. [6, 4]). In the following we present two possible application scenarios for Attjector:

Augmented Environment

Attjector can be used to display contextual information on objects in the environment. Since, at close range, the field of vision of the Kinect is usually larger than the projected

[2]Specifically, we used Modelcraft RS 2 servos `http://www.servodatabase.com/servo/modelcraft/rs-2`.

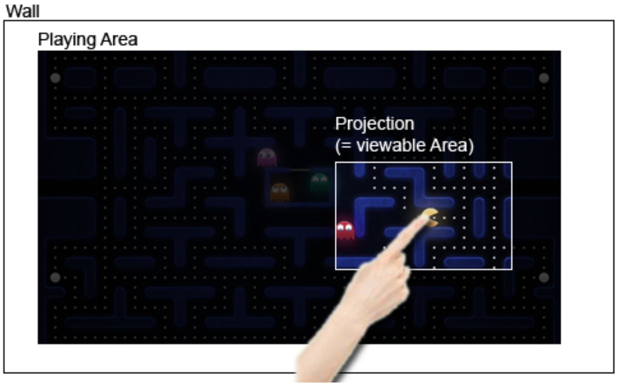

Figure 3: An example gaming application for Attjector, *Peephole PacMan*. By using a steerable projector which follows the user's hand, a playing area much larger than the actual projection is realized.

size of the mobile projector, the Kinect's RGB image can be used to acquire interesting targets which can be augmented by steering the projected image towards them.

For example, indoor navigation applications using Attjector could augment objects such as elevator panels to indicate the floor to choose to reach the desired destination, or display information about rooms (e.g. given a room number displayed at the door, that could be recognized through OCR when in view of the Kinect's RGB camera).

Projecting Large UIs for Mobile Applications

With Attjector, the peephole metaphor can be used to create very large ad-hoc interactive surfaces in a mobile setting. An example could be viewing high-resolution content such as maps on the go. The possibilities for gaming using are also interesting. Figure 3 shows an interface mock-up of an idea for a *Peephole PacMan* game. A game area that is much larger than the actual projection size can be used. Navigation through the game area is effortless since the Attjector automatically tracks the user's hand position.

6. CONCLUSION

In this position paper, we propose a wearable and steerable mobile projector that uses a Kinect to enable user input. We argue that a steerable projector is beneficial, because the user is not distracted by controlling the projection, and the projection itself can be set up so that it follows the user's locus of attention. Additionally, a steerable system allows a large display area when using the peephole metaphor. We go on to describe the hardware implementation of our current prototype as well as several concrete research hypotheses which we would like to evaluate using our system. In future research, we intend to show that Attjector can be used to implement novel mobile applications in the areas of augmented environments, navigation and gaming.

Our future work will also address the question of how much additional benefit can be gained from tracking the users eye gaze for estimating the locus of attention. The main question is whether the increased accuracy of eye tracking really helps in the kinds of applications we outlined in this position paper, given that it requires more sophisticated hardware.

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