Designing mobile projectors to support interactivity

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ABSTRACT
Current commercial pico-projector systems are mainly designed as a principal or secondary output for which very few systems have interaction capabilities. Recent research, however, has created pico-projection prototypes with user interfaces tailored to device or application uses. This paper explores different design possibilities for mobile and embedded pico-projectors and identifies how those designs influence the choice of interaction techniques.

INTRODUCTION
With progress in miniaturisation of projection technologies, a wide range of devices equipped with a pico-projector as main or secondary output is becoming available. This includes handheld projectors, phones, still cameras and video-cameras. Pico-projection devices have typically been designed as a smaller version of existing projection systems with some further regard given to mobility such as the battery life, weight or form. Nonetheless, the design of such devices and the available interaction techniques do not correspond to all uses of a portable solution. The user can effortlessly point the device at a suitable surface when projecting for a small amount of time, for example to show a specific screenshot or for entertainment purposes. However, if the projection lasts longer, such as when watching a movie or playing a game, the user will quickly tire of holding the projector and prefer to put it down on a surface. Typically, the user will place it on a table that often may not be at the right height or distance from the projection space. Moving the projector further away from the border of a table can lead to some of the image being partially obscured by the table itself. This usually leads users to sit the projector on a tripod (Figure 1a) or on a pile of books and boxes (Figure 1b) until they reach the right height and angle to project.

Some devices benefit from newer designs that try to resolve this issue. Some pico-projectors are, for example, designed in order to stand vertically moving the lens away from the table; some others are mounted on a hinge [9] or on an axle [8] so the user can choose an inclination that is adapted to the situation (Figure 2). Additionally Cauchard et al. [2] show that different projection angles are more suited for different applications using the same device. All of the above demonstrate that the design of portable projectors is key to how easily people will be able to use them to project

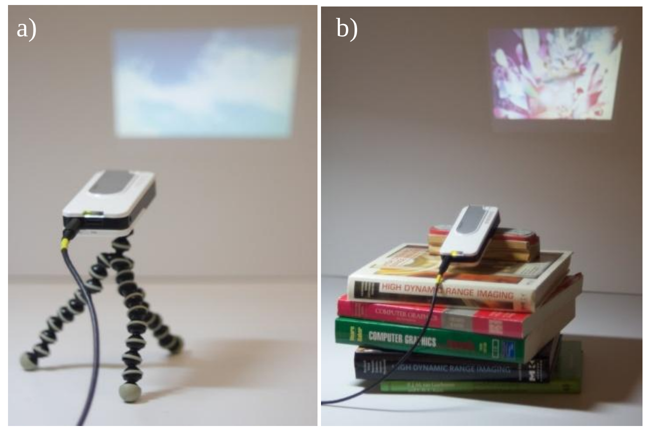

Figure 1. Pico-projector on (a) a tripod (b) a pile of books

where they want as well as potentially interact with the projection itself. In the following section, we present this design space for mobile projectors and discuss how interaction techniques depend on these design constraints.

DESIGN SPACE
There are two main types of interaction challenge when working with mobile projectors. The first one concerns interaction with the content of the projection while the second relates to interacting with the projection space itself. In this position paper, we briefly describe interaction with content and then focus on interaction with mobile projectors in terms of positioning the projection space.

Figure 2 - Video camera with pico-projector on hinge [9]

Interaction with projected content
There are many ways in which to interact with mobile projectors that relate to techniques available for non-mobile projectors including: “in-the-air” interaction [5] or more generally gesture recognition; touch screen or control buttons such as on a projector phone or video camera; and “direct touch” of the projection. Such interactions can be combined as in Spotlight Navigation [7] where the content

can be interacted with using control buttons, laser pointer and by moving the prototype itself. The main difference between interacting with a mobile projector and a non-mobile one depends on whether the device is being held. If the device is being held, then one hand will normally be occupied holding the device and the interaction will be realised using the second hand. In some cases, such as a projector phone, the user might use the thumb of the first hand to use the touch screen, leaving one hand free to move. When the projector is being worn, around the neck for example, then both hands are free which allows the use of a wider range of gestures. Also, depending on the direction of the projection, other body parts can be used, such as the foot in the case of a floor projection (Figure 4a) or skin in the case of skin projection [4]. Yet, in some cases of mobile projectors, the device is specifically designed to not be held while in use as the Light Touch [1] (Figure 3). In that case, the available interaction techniques are similar to the ones for non-mobile projections.

Figure 3 - Direct touch on the projected image [1]

Interaction with projection spaces

In the following sections we describe a range of possible designs for mobile projectors taken from the existing literature. For each potential design, we discuss different challenges that emerge when choosing techniques to interact with the projection space.

Fixed projector

A fixed projector consists of a lens which is immobile compared to the body of the device. This means that the device itself needs to be moved to position the projection. This is the case for most pico- and even wearable projectors. For instance, a wearable projector attached to a body part (i.e. neck, wrist, shoulder) will move with the limb. The choice of projection space will therefore be limited to how much the limb moves. The wrist, for example, has 6 Degrees of Freedom (DoF). When hindered by a large device (such as a projecting watch), the number of DoF reduces, therefore limiting the possible projection opportunities. In the case of a fixed projector, the interaction with the projection space is therefore limited to the design of the shell of the device or the way it is being carried.

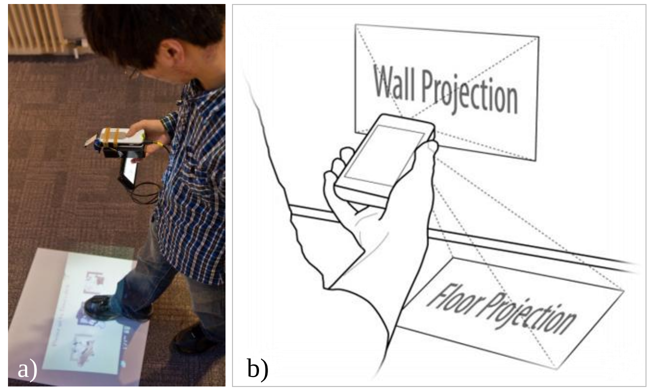

Figure 4 - (a) Foot interaction for floor projection - (b) "Everywhere" projection from a mobile multi-display system

Multiple projectors

One way to increase the possibilities in terms of projection space is to fit the device with multiple projectors, as some mobile phones are equipped with multiple cameras for applications such as video-conferencing. A device could be fitted with a projector at the top and one at the bottom, or even one on multiple sides of the device to allow "everywhere" projection, as illustrated in Figure 4b.

This design allows the user to decide where to project by choosing which projector to use or by using the projectors simultaneously (Figure 5a). Both projectors could also co-exist as a way to layer information; this is already the case in a device such as the Discovery Space Projection alarm clock (Figure 5b) that overlays two separate information layers on the same projection space [3].

Figure 5 - (a) Everywhere projection on a dual pico-projector phone [6] - (b) Discovery alarm clock with dual pico-projector mounted on a hinge [3]

Having multiple projectors can improve the capabilities of the device but it may also lead to new design and interaction challenges in comparison to single projectors. As a matter of fact, an interface needs to be provided that allows the user to select which projector(s) they want to employ. Moreover, if multiple projectors display at different locations, a direct manipulation will require an interaction system for each projector. This is the case of the Mozilla Seabird [6] that, fitted with dual pico-projection (Figure 5a), requires a recognition system for each pico-projector. An indirect manipulation such as using a touchpad could potentially support simultaneous interaction with more than one projector.

Steerable projection

Another way to project at different locations without having to move the device or having to hold it still in different positions is to have a swivelling lens. This can then be controlled in two ways: manual steering or automated steering.

- Manual steering

One way to design the steering mechanism is to create a mechanical system that the user can easily reconfigure. A manual steering technique has the advantage that the user can directly operate a simple mechanical system, such as a hinge [9] (Figure 2), a rotation axle [3] (Figure 5b) or even a multi-degree rotation ball. In terms of interacting with the projection itself, a steerable system offers more possibilities than traditional mobile projectors since the device can either be carried around while projecting at a comfortable height or put down on a surface while still projecting on the desired surface.

- Automated Steering

Automated steering may provide additional advantages over manual steering, since the device can steer the projection on its own. For example, a system may use vision-based techniques to decide where to project depending on contextual information. The device can recognise which projection space is the most appropriate to display on depending on notions such as: colour, size, distance or environmental settings, such as number of people around and level of privacy.

When the steering is visible, with the control on the outside of the device or inside but in a transparent shell, the user can instantly see the result of their actions of moving the lens. For example, there could be a mirror just in front of the lens that reflects the projection. When the user modifies the steering angle, they can directly observe the effects of their actions on the device; so whether the mechanism is controlled by a menu, a button or a touch screen, the user can immediately see the result.

When the steering is invisible, such as when the lens is mounted on an axle or curved ball for multiple DoF inside the device, it needs to be very clear how to steer and feedback the progress of the steering process. For example, the user may need to see a virtual representation on a screen to see the effects of the moving projection. Similarly, it may be easier to use a joystick system rather than a set of buttons in the case of multiple DoF. This is the most difficult case to interact with since the user cannot observe the direct effect of their interaction upon the mechanism.

CONCLUSION

There are many advances that we expect to see with new designs of mobile projectors. We have proposed and categorised possible designs and explored their advantages and drawbacks in terms of finding suitable interaction techniques for positioning mobile projection spaces.

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