Animation & Sequential Art Principles for Handheld Projector Interaction

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ABSTRACT
We present a brief history of historic handheld projection devices and introduce design techniques for handheld projector interaction that draw from the principles of traditional animation and sequential art. Our approach is to utilize the movement of the handheld projector to express the motion and physicality of projected foreground objects. Users interact and control the projected image by moving and gesturing with the handheld projector itself. The overall interaction metaphor, *MotionBeam*, is applicable in a wide range of scenarios ranging from the behavior of interface elements to interaction with game characters.

1. INTRODUCTION
The history of cinema spans over a hundred years and has evolved from a technological gimmick to a vastly rich language for communication and artistic expression. While numerous technical innovations have helped shape the language of cinema, one constant has been the fixed size, location, and shape of the image frame during presentation. Handheld projectors represent a radical departure from cinema as the projection frame moves, shakes, and distorts with the users every move (Figure 1). Designing for handheld projectors therefore means creating interaction techniques that work with user movement.

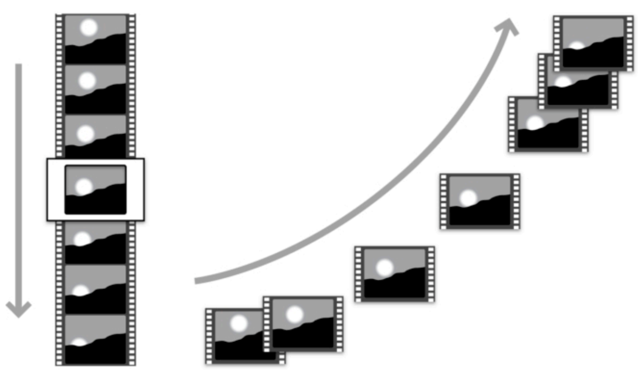

Figure 1. Conventional moving image sequences show a series of images in a static location (left). Handheld projectors set in motion by the user, show each image in a physically separate location (right).

Our research is concerned with how the movement of a handheld projector can contribute to the interactive experience. Rather than attempt to mitigate the effects of projector movement, we seek to encourage movement by using the projector as a gestural input device. Users interact and control the projected image by moving and gesturing with the handheld projector itself.

In this paper we begin by taking a historical look at handheld projection and then move on to examining how the principles of traditional animation and sequential art can be a useful resource when designing for a moving projection frame. Finally we present a number of handheld projector interaction techniques based on our observations.

2. HISTORY
If we look back at the 'pre-history' of cinema we find a number of early projection devices that can give us valuable insight into the possibilities offered by handheld projector interaction. The *Magic Lantern* was an early projection device invented in the 17th century that used a concave mirror, a painted slide, and a light source to project images. With the later development of the *Phantasmagoria*, a pre-cinema projection ghost show, the *Magic Lantern* was mounted on wheels to allow the image to shrink and expand by rolling the device in and away from the screen. The careful juxtaposition of a moving foreground image such as a ghost, over a separate static background image such as a road, would create the impression of the foreground object moving closer and closer to the audience.

Variations of the *Magic Lantern* include a belt-mounted device produced by Phillip Carpenter; like the *Phantasmagoria* this device was designed for linear movement in and away from the screen (Figure 2). By examining the slides used with this device it is clear that the characteristics of the 'handheld projector' have been carefully considered (Figure 3). The animals are drawn on a black background for use as foreground images, meaning the projectionist can freely move the device without drawing attention to the all-but-invisible projection frame. As with the *Phantasmagoria*, the black background also enables other imagery to be projected on to the same surface.

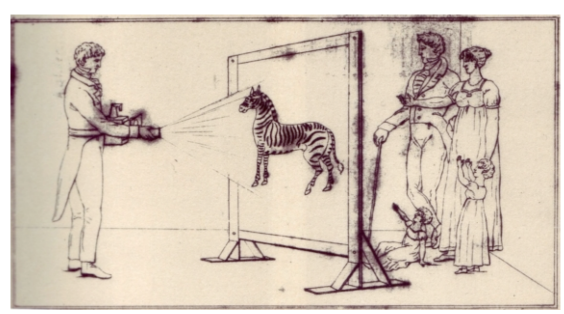

Figure 2. A belt-mounted *Magic Lantern* created by Phillip Carpenter, 1823.

Figure 3. Projection slides from Phillip Carpenter's belt-mounted *Magic Lantern*, 1823, Huhtamo Collection.

In the early 19th century the *Magic Lantern* was adapted in Japan from a heavy metal case to a lighter, more mobile, wooden one. In the tradition of Japanese storytelling, such as *Kabuki* or *Bunraku*, this lightweight projector was used to act out a story by rear-projecting images onto a rice paper screen. The art form came to be known as *Utsushi-e*, and was popular during the Edo and Meiji periods. Unlike *Phantasmagoria*, *Utushi-e* performers directly held and manipulated the device to change the size and location of the projected image and create simple effects such as fading in and out. Slides on the projector could be changed during the performance and combined with physical movement of the device to produce relatively complex animated sequences. A typical production involved the coordination of multiple projectors, with each performer controlling one part of the scene (Figure 4).

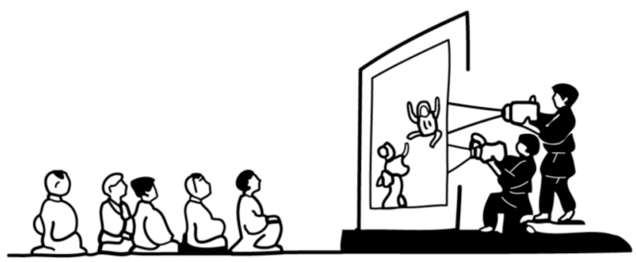

Figure 4. The stage layout of an *Utsushi-e* performance.

Although technologically primitive by today's standards, the illusions and performances created by these early devices were extremely popular in the pre-cinema era. They establish a historical precedent for interacting directly and physically with a handheld projector.

3. CURRENT RESEARCH

Research exploring the use of modern handheld projectors focused firstly on addressing the problems of image stabilization and distortion correction [7, 8]. By dynamically correcting the image as the projector moves, conventional content can be viewed in a regular fashion. Despite the natural mobility of handheld projectors, research to date has focused on scenarios where the projector is either predominantly stationary or not actively moved throughout the environment. While a static projected image is well suited to numerous applications, we believe it is important to investigate interaction techniques for a moving projection frame.

Research exploring the gestural movement of handheld projectors for user interaction has focused predominantly on the *spotlight metaphor* [1, 2, 6], where a projected image reveals a small section of a larger virtual image. The underlying virtual image is fixed to the physical environment making the metaphor less suitable for interaction with a single object or when actively moving from one space to another.

A different approach to the moving projection frame is evident in the work of artist Karolina Sobecka. Using a car-mounted projector, her *Wildlife* [9] artwork projects imagery of running animals on to nearby buildings. The speed of the car is directly linked to the speed that the animal runs, blending the projected image into the physical environment. Sobecka's work relies on a car-mounted projector, greatly limiting interactivity to the physical movement of the vehicle.

4. DESIGNING FOR MOVEMENT

Like the early handheld *Utsushi-e* devices, our aim is utilize the movement of the projector to express the motion and physicality of projected objects. By embedding orientation and acceleration sensors in the projection device we can couple the movement of the projector (input) to the projected image (output). What results is a unified interaction style where the system responds directly to user movement by changing the projected image.

4.1 MotionBeam

Our design approach focuses on the perceived movement of a projected foreground object across a physical background. An example of this is a car driving along a road; in 2D animation terminology the foreground object (the car) is known as a sprite, and the background (the road) is called the stage (Figure 5, left). Our *foremost* consideration is the interactive behavior of the sprite objects, with the role of the stage secondary. We label the overall interaction metaphor *MotionBeam* [10], as the sprite object behaves as if it is tied to the middle of the projection frame by a virtual 'beam' (Figure 5, right). The sprite object remains relatively static with the primary motion being that of the projection frame across the physical background.

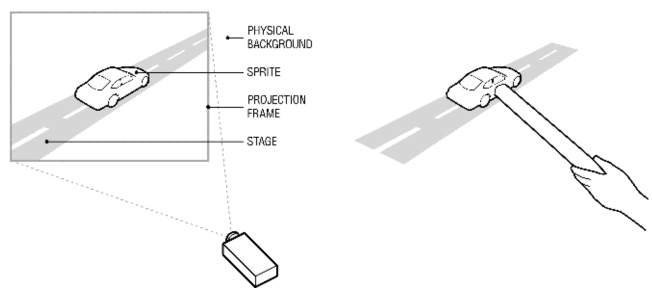

Figure 5. Our design approach draws upon animation techniques and terminology (left). Using the *MotionBeam* metaphor, sprite objects behave as if they are attached to a user-controlled 'beam' (right).

4.2 Design Techniques

The following design techniques draw from the principles of traditional animation and sequential art to explore interaction with handheld projectors. They represent an initial list that we are continuing to expand upon; the techniques are not mutually exclusive and may be combined appropriately for each design scenario.

4.2.1.1 Staging

The animation principle of staging aims to focus the attention of the audience by minimizing other distractions in the frame [3]. One important aspect of staging is the use of silhouette to highlight the main point of focus [4]. This is particularly important for handheld projectors that have limited image brightness and contrast, as a strong silhouette will still be visible in high ambient light.

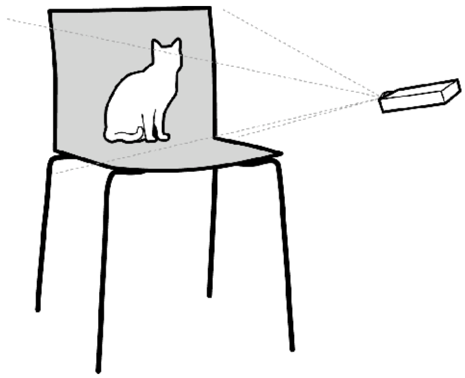

Figure 6. An outline drawing of a cat on a black background is projected onto a chair, aiding the illusion of the sprite object existing unframed in the physical environment.

As with the *Phantasmagoria*, the staging principle can be applied by rendering the sprite alone on a black background. This creates the illusion of the sprite existing unframed in the physical environment and blends the real and projected worlds together (Figure 6). This technique becomes even more convincing using laser-based handheld projectors, which do not project light from black areas of the image, allowing the projection frame to disappear.

4.2.1.2 Movement

Movement can be emphasized using variations of the sequential art techniques described by McCloud [5]. These include zip ribbons showing a path traveled, multiple images depicting past object locations, and streaking/blurring akin to long exposure photography. When dealing with a moving projection frame the sprite object is fixed to the middle of the frame and trails depicting movement are created on the opposite side from the direction of movement. Moving the projection frame from left to right creates a trail of images seeming 'left behind' from the previous position (Figure 7, left), or a stylized representation of the path travelled (Figure 7, right).

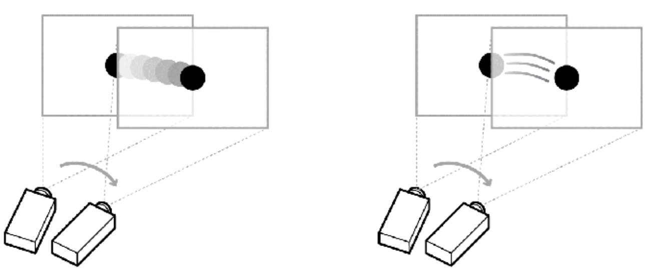

Figure 7. Movement of a sprite can emphasized using sequential art techniques such as *motion trails* (left) and *motion lines* (right).

4.2.1.3 Animation

Sprite objects can be animated according to the heading and speed of the handheld projectors movement. For example, the individual frames of Eadweard Muybridge's *The Horse in Motion* can be animated with a left to right motion, leaving the impression of the horse galloping across the physical background.

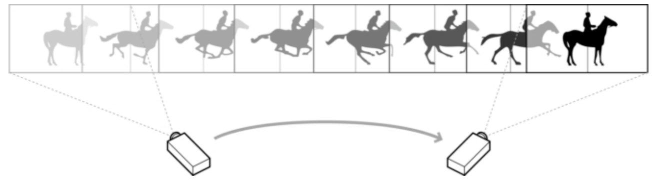

Figure 8. Frames from Eadweard Muybridge's *The Horse in Motion* are animated with left to right motion of the projector.

The classic animation principle of squash and stretch [3] can be used to deform a sprite object in a convincing way according to heading and speed (Figure 9).

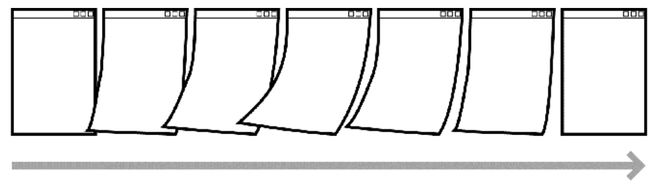

Figure 9. An interface window stretches and deforms as the projection frame is moved from left to right.

4.2.1.4 Physics

Physical properties such as friction, springiness, and gravity can be depicted by temporarily moving the sprite away from the middle of the projection frame. For example, sprite objects can create a feeling of resistance by moving in the opposite direction from the projection frame (Figure 10).

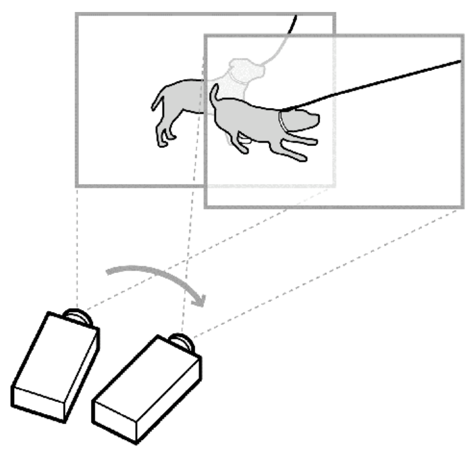

Figure 10. Physical properties can be accentuated by utilizing the entire projection frame. In this case a dog resists being led by moving in the opposite direction.

Sprite objects can also be influenced by gravity; an upward flick motion can throw an object outside the frame, only for the object to return back to the middle of the frame with gravity.

4.2.1.5 *Perspective*

Real-world perspective can be linked to sprite perspective by changing the viewing angle of the sprite to match the angle of projection. For example when projecting a 3D cube, pointing the projector to the ground displays the top of the cube; pointing the projector to the ceiling displays the bottom (Figure 11, left). Keystone distortion, caused by projecting at an angle, can be combined with changes in perspective to stretch out sprite objects with the appearance of a widening field of view (Figure 11, right).

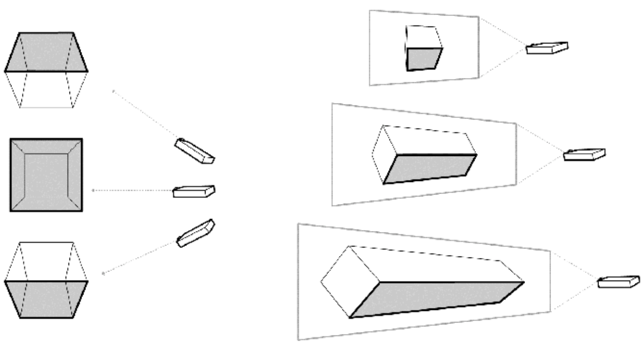

Figure 11. Real-world perspective can be used to change the viewing angle of sprite objects (left). Keystone distortion can be combined with changes in perspective to give the appearance of a widening field of view (right).

4.2.1.6 *Closure*

The concept of *closure* is used in sequential art to infer meaning from a sequence of image panels [5]. By viewing one panel followed by another a single meaning emerges, for example, a panel of a shooting gun beside another of a speeding ambulance infers that someone has been shot. This same principle can be applied to interaction with multiple projection frames where only parts of a larger scene are revealed. Actions are shown sequentially in each frame to infer an overall meaning.

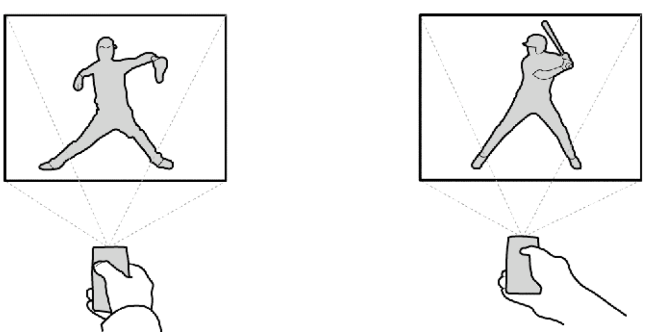

Figure 12. The sequential art concept of *closure*, can be used to infer meaning between separate projection frames. A baseball leaving the left projection frame and entering the right projection frame is perceived as the same object.

For example, depicting a pitcher throwing a baseball from one frame, followed by a baseball entering a separate frame, infers that the ball has passed from one frame to the other (Figure 12). The baseball may not have followed a perfect path or transitioned with perfect timing, but *closure* leads us to perceive it as the same object.

5. SUMMARY

In this paper we have presented a brief history of early handheld projection devices and used the language of animation and sequential art to inform the design of handheld projector interaction techniques. The overall interaction metaphor, *MotionBeam*, is applicable in a wide range of design scenarios ranging from the movement of interface elements to interaction with game characters.

Although the problem of designing for a moving projection frame is new, we have found there are noteworthy historical precedents such as early *Magic Lantern* projection devices, and numerous commonalities with the language of animation and sequential art. These provide a useful starting point to develop a 'native' language of interaction for handheld projectors. The important role for designers and developers will be to design with careful consideration to the innate qualities of the medium. We have begun to address one of these qualities, motion, but there are numerous others. We hope our findings will provide a useful starting point for further exploration in this field.

6. ACKNOWLEDGMENTS

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