Spatial Correspondence in Motion Picture Display

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Abstract

This paper reflects upon the fact that movie cameras move and movie projectors do not. When a movie projector duplicates the angular movements of the camera, directionality is retained. Spatial correspondence between record and playback environments is achieved. Two different systems for making "moving movies" are described, as well as a large-scale environmental artwork incorporating this technique.

Introduction

Legend has it that a gentleman once approached Picasso on the street and criticized his paintings as distorting reality. Seeming to change the subject, the artist asked the gentleman if he had a girlfriend. He did, and produced a small picture of her from his wallet. "She's beautiful," replied Picasso, "but she's so tiny."

What makes an image look real is a function of both the imaging technology and the perceptions of the viewer. Both functions are dependent on each other and co-evolutionary.

The first moving pictures were shot with a static camera. To their audiences, these movies looked REAL. It is reported that when the Lumiere brothers first showed a scene of an oncoming train, the audience would duck.[1] Sometime, most probably within the first few years of moviemaking, camera movement was introduced. Imagine the initial reaction of the audience as their "piped in" world turned around while they sat still. This undoubtedly took some getting used to. One of the most extensive early uses of panning and tracking shots was in the 1914 epic Italian film "Cabiria." Wrote the "New York Dramatic Mirror:"

> Scenes are slowly brought to the foreground (tracks) or moved from side to side (pans), quite as though they were played on a movable stage. By this method full value is given to the deep sets, and without any break the characters are brought close to the audience.[2]

As motion picture technology evolved and as audiences became more visually sophisticated, camera movement became more commonplace. One may speculate that the introduction of television with its small low resolution screen necessitated even greater use of camera motion, since not everything could "fit" in the frame at the same time. Today, we think nothing of camera movement: we have habituated.

Camera movement, like edits and other special visual effects, allow movies to offer experiences that everyday reality cannot. However, something is lost. The security of knowing that stationary objects stay put, that people don't shrink and expand, and that if we walk toward something we get closer to it are all part of how we relate to our environment. What is lost is a sense of spatiality.

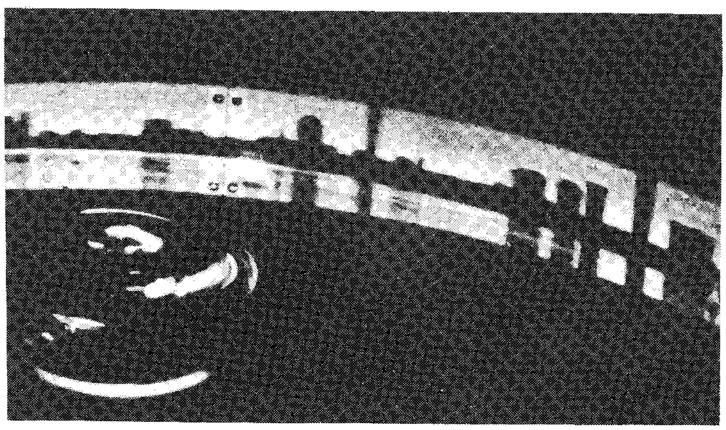

Figure 1. Rotating movie projection onto a cylindrical screen shot with a rotating camera.

Spatial Correspondence

Concept. The concept is simple: it is to move a movie projector the same way the movie camera moves. Camera pans left ninety degrees; projector pans left ninety degrees in sync. Now, imagine what happens. The projected image MOVES around the playback space. The entire playback space becomes fair game, just as the record space is.

Images of stationary objects STAY PUT on the walls of the playback space. Imagine a pan of a stationary object, say a building. On a conventional movie screen, we would see the image of the building enter on one side of the frame and move across to the other side. It follows that if the projected image is physically panned the same way as the camera panned, the image of the building would remain stationary on the screen; only the frame itself would move.

The effect is exactly equivalent to viewing a dark space with a flashlight. (More on this later.)

What is occurring is a SPATIAL CORRESPONDENCE between the record space and the playback space. If an image of the east is projected east in the playback space, then images of west, north, and south will correspond to west, north, and south in the playback space.

When the temporal interval between frames correspond between record and playback, we have temporal correspondence or REAL TIME. Real time is intuitively obvious: when a movie speed is "not too slow" and "not too fast," then it is in real time. When the spatial interval between frames correspond between record and playback, we have spatial correspondence or REAL SPACE. If an image is "not too left" and "not too high," then it is in real space.

Theory. TRUE spatial correspondence occurs when the angular movements of the camera and projector are equal. Focal lengths of the camera and projector must also be equal. Angular movement is measured in degrees per frame. Focal length translates to angle of view.

Let

R = rotational speed (degrees per second)
F = fps rate (frames per second)
θ = angle of view (degrees)

and let the subscript "r" denote record mode and the subscript "p" denote playback mode.

True spatial correspondence occurs when:

$$\frac{R_r}{F_r} = \frac{R_p}{F_p} \quad \text{and} \quad \theta_r = \theta_p$$

When the focal lengths of the camera and projector are not equal, spatial correspondence is possible by altering the angular movements by the ratio of focal lengths:

$$\frac{R_r}{F_r}\,\frac{\theta_p}{\theta_r} = \frac{R_p}{F_p}$$

When the ratio of focal lengths equals one, we have true spatial correspondence where the camera's and projector's angular movements are equal. When the ratio of focal lengths does not equal one, we have spatial corresponence in that images of stationary objects will "stay put" on the walls of the playback space, but a "warping" of sorts will occur.

Suppose we film a 360° pan where the camera's focal length is half that of the projector's. The ratio of angles of view, which we'll call the warp factor, equals 1/2. If we record with an angular movement of 2° per frame, we must play back with an angular movement of 1° per frame to achieve spatial correspondence. To record a 360° pan will require 180 frames, but 180 frames will play back as only 180°. If north is set at north in the playback space, then west becomes northwest, south becomes west, east becomes southwest, north becomes south, and the process repeats. And THAT is only dealing with one dimension of movement and fixed focal lengths.

It should be noted that spatial correspondence addresses only angular motion, not lateral motion. Lateral motion creates parallax, where objects in the foreground move across the frame faster than objects in the background. This differential motion prevents spatial correspondence, since not everything in the frame can "stay put."

It should also be noted that spatial correspondence isolates camera motion from object motion, both which cause change within the frame. Camera motion becomes projector motion, while object motion remains object motion. Spatially correspondent movies are therefore always stable, with only the frame itself exhibiting shakiness.

Designing a Moving Movie System

A Simple Experiment. I began work on producing moving movies in the fall of 1977 at MIT. The simplest, cheapest thing I could do to at least SEE what spatial correspondence looked like was to film a series of 360° panoramas using a motor to rotate the camera on its tripod. The processed film would be loaded into an endless loop cartridge and played back with a projector rotated on a turntable by the same motor used for shooting.

I chose a one rpm AC synchronous motor, a super 8 camera that shot at about 18 frames per second, and a small super 8 loop cartridge projector which also ran at 18 fps.

Most shooting was done with the camera's focal length equal to the widest focal length possible with the projector, 20mm (15° horizontal angle of view). Spatial correspondence did occur during playback, in that you could stand by the wall and put your finger on, say, the image of Boston's Prudential Building as it was being panned and the building would "stay put" as the frame moved by.

The major problems were ones of blurriness and wobbliness of the image due to the system's relatively slow fps rate. At 18 fps, a one rpm rotation results in a 1/6° pan per frame (with a 180° shutter). Played back at the center of a 20 by 20 foot room, each frame would move over 1/3 inch while it is being projected on the wall. Of course, the actual degree of motion aliasing is no worse with a moving movie than with a conventional movie, but it is apparently more obvious.

Another problem inherent in a moving movie system is the shape of the playback space. In a square playback space, problems occur with focus and shape distortion. Neither were intolerable. The blur and wobble were worse than that caused by poor focus. The shape distortion went surprisingly unnoticed; my guess is that this illusion is largely perceptual. Most of us are unaware, for example, that when we view a movie from the side that we are looking at a trapezoid.

Many viewers, myself included, found the rectangular shaped frame itself disturbing. Perhaps a circular frame would look more "natural," as it is reminiscent of a spotlight, whose properties are more spatially equivalent to a moving movie. An equally interesting alternative may be to eliminate the frame edge itself, possibly by diffusion.

Recording Camera Motion. Cameras are often small and lightweight, projectors rarely are either. In designing a user-controlled recording system, I began with a simple premise: it is easier to move a mirror in front of a projector than it is to move the projector. A second premise naturally follows: use the SAME mirror system for recording. From here on the design algorhythm is straightforward.

A mirror mount is constructed such that the mirror can be moved and knows its position. Record by aiming a stationary camera at the mirror and moving the mirror in front of the camera to achieve "camera motion." Record the position of the mirror in sync with the film. Playback is achieved by placing the projector in the same place as the camera relative to the mirror and controlling the mirror's position by the recorded position signal.

The symmetry of such a system eliminates an entire class of problems because they cancel themselves out: image reversal, non-linear motion due to mechanical limitations, tricky transformations, etc. Theoretically, the mirror need not be flat; it could even be cracked.

There are some problems inherent in using a mirror. Blind spots are inevitable. Also, like a periscope with one rotating mirror, the user will see image roll, which can be disorienting during shooting. Though the roll cancels itself out during playback, the rectangular frame itself will appear rolled.

Another problem with using a mirror is that a lateral component is introduced since the virtual image of the camera and projector arc around the mirror. This lateral component will result in some parallax and therefore spatial correspondence is not completely possible.

The system designed was a programmable pan-tilt mount with a mirror mounted in it and a camera or projector mounted above it via a small stationary mirror. A joystick controlled the mirror movement in record mode and modulated a two band audio signal that was recorded on the film's soundtrack. During playback, the soundtrack was used to slave the servo motors to replicate the movements of the mirror.

The medium used was magnetic striped super 8 film. All audio processing was analog. The mirror was positioned using two model airplane servo motors. Even with such a "low budget" system, it was clearly demonstrated what an operator-controlled moving movie can do. The worst problem encountered was caused by wow and flutter in the super 8 projector, which translates into the image swaying when it shouldn't.

An Environmental Art Installation

The concept of spatial correspondence was incorporated into an art piece that attempts to address the distinction between "real" and "movie" in a most direct way. It involves the creation of a livingroom space, complete with sofa, tables, television, wall hangings, etc. From the center of the space, a 16mm camera is panned on a one rpm turntable, shooting the space and people interacting with it. After shooting all objects in the room are secured in place.

Then, the entire contents of the room are spray-painted white. Everything.

The result is a moving movie projection, where everything is projected back onto itself, now white, acting as its own screen. Such projection, sometimes called "relief projection," is truly 3D. All objects appear astoundingly real. (All people appear equally unreal, as their images wrap flatly around the objects in the room.)

This installation has been produced twice so far, at the Aspen Center for the Visual Arts and at MIT's Center for Advanced Visual Studies, both in 1980. Funding was provided by grants from the MIT Council for the Arts and the National Endowment for the Arts Media Arts Program.

Figure 2. This is a still image of a movie projection of a scene projected back on itself. All objects are present, but painted white to become relief screens. Projector rotates. From "Movie Room," an installation by the author, Center for Advanced Visual Studies, MIT, 1980. (photo by Michael Moser)

Media Rooms: Display and Interactivity

The ultimate media room will be indistinguishable from "reality." All sensors will be effected; all effectors will be sensed. We may define a media room user's sense-ability as DISPLAY: it is the degree of information from the system to the user. We may define the user's effect-ability as INTERACTIVITY: the degree of information from the user to the system.

All of my research so far with moving movies has been in the film domain. When video projectors achieve the quality and elegance of film projectors, some interesting possibilities emerge.

Imagine a realtime "video flashlight." The viewer holds a position-sensitive device which controls a projected image, always in front of the device. The image source may be a remote video camera or it may be from a computer database. The viewer IS the camera operator: it is an interactive system.

A relationship exists between display and interactivity. Consider filling all surfaces of a media room with imagery. The viewer can see anything merely by eye movement: display bandwidth is high, interactivity bandwidth is zero. Now compare to a video flashlight: display bandwidth is much lower, interactivity bandwidth is non-zero. In both cases, the user decides what to see. The real-world analog is the difference between turning on an overhead light and using a flashlight. This difference is the heart of my current research.

References

1. Gerald Mast, A Short History of the Movies (Indianapolis: Bobbs-Merrill, 1976), p. 19.
2. George C. Pratt, Spellbound in Darkness (Greenwich, CT: New York Graphic Society, 1973), p. 126.