



ADAPTATION OF SCAN AND SLIT-SCAN TECHNIQUES TO COMPUTER ANIMATION

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ABSTRACT - The adaptation and generalization of scan and slit-scan animation stand techniques for use in computer generated animation is discussed. Scan and slit-scan techniques are based on moving artwork, camera, and, for slit-scan, a thin aperture while the camera shutter is open. These processes can be described as selectively sampling an environment over time and recording the result as a single image. Sequences of such images form the animated film. Rather than use mechanical means to accomplish this, it is possible to develop algorithms which mimic this processes but are based on sampling dynamic environment descriptions to generate computer produced images.

The use of computer graphics allows these techniques to be generalized in ways difficult or impossible even with very elaborate animation stands. Use of multiple independent scanning apertures and three-dimensional environments are natural generalizations.

The exact algorithms used depend on the characteristics of the graphics systems used. An approach based on using a real-time shaded graphics system and an approach using frame buffer systems are outlined. The first approach can also be applied to refresh vector graphics systems.

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Introduction

Scan and slit-scan animation techniques have been and continue to be used to produce visually interesting and often spectacular animated sequences [1]. We begin by discussing what the terms scan and slit-scan mean in the context of animation produced using automated animation stand techniques. We then look at how these basic ideas may be adapted for use in computer generated animation.

Scan Animation

In scan animation, each frame is a time lapse photograph of a changing environment [2]. The environment usually consists of some type of flat art (two-dimensional drawing, etc.) positioned on an animation stand. Changes in this environment usually consist of moving the art work and/or moving the camera position. When the artwork or camera position are moved during exposure, this has the effect of leaving a trail or smear along the motion trajectory.

Say we want a scene in which an object appears at point A, then moves to point B, leaving a trail from point A to B and finally the trail catches up to the object at point B. This is accomplished by positioning the object at position A and exposing the first frame of the scene. For the next frame, the object is again positioned at point A and then, with the shutter open, moved an increment toward point B. For the next frame the object is again positioned at point A and with the shutter open moved two increments toward point B. In subsequent frames, the object starts at point A and moves further toward point B until the frame is reached in which the object moves all the way from A to B. In each of these frames the object has the same starting point, A, but a different ending position. Now, to make the trail catch up to the object at point B, the movement on each frame will have the same ending position, B, but a different beginning position between A and B.

This form of animation depends on having a mechanism to precisely control motion within each frame and from frame to frame. This is usually done using rather elaborate automated animation stands.

Slit-Scan Animation

In slit-scan animation, each frame is also a time lapse photograph, but, here the environment is photographed through a narrow slit or aperture which is moved during exposure [2,3]. With this approach, at any instant only a narrow region of the artwork is visible through the slit.

If the slit is moved parallel to the film plane, with the camera and artwork stationary, the slit will 'paint' an exact image of the artwork on the film. But, if either or both the camera or the artwork are also moving, the slit will 'paint' a distorted image on the film.

If the artwork is moving in the same direction as the slit, but at a slower rate, the image will be stretched out. If the artwork and slit move in opposite directions, the image will be compressed. If the artwork moves perpendicular to the slit motion, the image will be slanted or skewed.

Various combinations of camera, slit, and artwork motions produce a wide variety of visual effects. Pseudo-perspective can be added by zooming the camera.

Adaptation to Computer Animation

The essence of the techniques described above is to produce a sequence of images where each image is the result of summing light energy from a carefully controlled dynamic environment. This can be thought of as summing the results of a continuous sampling process.

When we move this idea over into the realm of digital computers and computer graphics we end up with algorithms which are in essence techniques for producing sequences of images where each image is the result of summing discrete samples of a carefully controlled dynamic environment. We in effect substitute computer graphics technology for the mechanical and optical technology of the animation stand.

In this domain, rather than manipulating physical parameters such as camera position, focal length, and artwork motion we are concerned with the manipulation of coordinate systems, clipping window parameters, shading parameters, perspective transformations, etc.

The following sections outline two methods for summing the computed environment samples to form the desired images. The first of these uses film as the sum-

ming or integrating mechanism, the second makes use of an image or frame buffer.

Using Film as the Summing Mechanism

If one has access to a graphics system that can generate refresh images (shaded or vector) relatively rapidly and provided there is some provision for photographing these images, then scan animation can be reasonably produced by generating for each frame of the animation a sequence of images, each image being a sample of the changing environment. As these samples are produced for each frame, the camera shutter is left open. The film acts as the mechanism which sums the samples into the desired image for that frame.

The program controlling this process needs precise control over the display refresh mechanism. Each sample contributing to the image is displayed a small integer number of refresh cycles. The camera lens aperture and the number of refresh cycles used determine the amount of light reaching the film for that sample.

Slit-scan images are produced by introducing a scanning aperture or apertures. These apertures change position between samples, in effect painting the desired image on the film. There is usually a fair amount of overlap between successive aperture positions.

A single rectangular slit can be generated by simply specifying appropriate clipping window parameters which change from sample to sample.

Multiple slits can be produced by introducing an obscuring surface (polygon), between the viewer (camera) and the environment, which has 'holes' in it. By changing the positions of these holes between samples, the slits scan over the environment.

Frame Buffer as the Summing Mechanism

Given a frame buffer system, the frame buffer memory may be used as the summing mechanism. For each sample contributing to the desired image, pixel values are computed and written to the frame buffer memory. In normal operation these values are simply written into the memory replacing previous contents. However, for scan and slit-scan modes of operation, values written to the memory are added to previous memory contents. This summing operation creates the desired image.

Since most frame buffer systems have only a few bits, typically 8, to represent each pixel value, care must be taken in choosing the intensity range of the com-

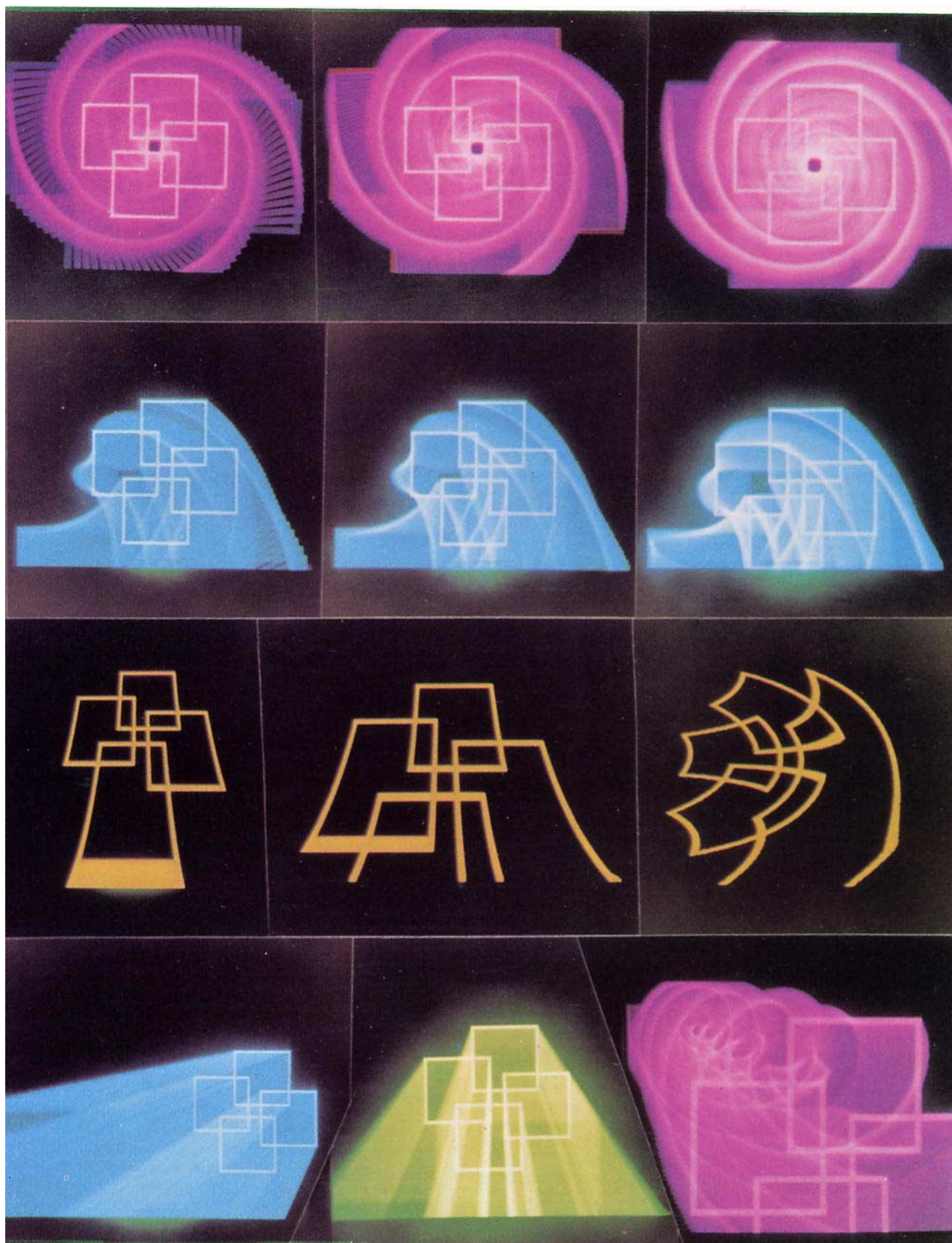


Figure 1 - Example Scan and Slit-Scan Images

puted sample pixels. Since it is quite likely that a given pixel will be written into for successive samples in a single frame, the summed pixel value may saturate (reach the maximum pixel value). This saturation is not necessarily bad since it corresponds to the analogous saturation which occurs in film. The saturation for the film case is controlled by lens aperture and refresh cycles. Saturation for the frame buffer case is controlled by choosing the computed pixel intensity range.

Sampling

Since we have substituted computer graphic techniques, which are inherently discrete, for the continuous optical and mechanical properties of the animation stand, we are bound to have discrete sampling artifacts in the images produced. Whether this is good or bad depends on the type of effect that is desired in the images generated. If one is interested in mimicing the smooth, fluid images produced by conventional scan and slit-scan techniques this will likely require computing a large number of closely spaced samples for each image. The number of samples required for a given effect requires experimentation and depends on the composition of the environment and the range of change within each frame.

Generalizations

The use of computer graphics rather than animation stand technology allows these techniques to be generalized in ways difficult or impossible with even very complex mechanical animation mechanisms. The constraints of two-dimensional artwork are immediately disposed of. The image environment then becomes a space of any or even mixed dimension containing collections of objects limited only by the imagination. The objects may move in multiple independent coordinate systems or might perhaps be moving relative to each other in very subtle, complex relationships. In addition to complete control over object motions, there is complete control over viewer (camera) position, orientation, and field of view. For shaded images, one also has control over lighting, shading, texture, etc.

The slit-scan concept easily generalizes to multiple slits or apertures moving in concert or independently. These apertures may be dynamic, changing in shape or size throughout a scan. Also, the reader, I am sure, will discover additional ways to generalize these techniques.

Example Images

Figure 1 shows scan and slit scan images produced using the Case Shaded Graphics System [4] with film as the summing mechanism. These images are all variations on the four interlocking squares which form the basis of this year's SIGGRAPH logo.

The top row of scan images were produced by rotating while widening the field of view (zooming back). The left image has 50 samples, the center image has 100 samples, and the right image has 200 samples.

The second row of scan images were produced by moving the interlocked squares toward the top of the image while rotating and zooming back. The left image has 50 samples, the center image 100 samples, and the right image 200 samples.

The third row of images were produced using the slit-scan technique. The left and center images are the result of moving a narrow horizontal aperture from the bottom to the top of the image while zooming back. The right image is similar except that the squares were rotated while scanning. Notice the introduction of nice curves into the rendering of objects defined as sets of polygons.

The bottom row of images are scan images. The left and center ones were done by moving the squares from left to right and from bottom to top while zooming back. The bottom right image is the result of translation, rotation, and zooming in (narrowing the field of view).

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