A Computer Model For Pinscreen Simulation

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Abstract

This paper presents a computer model that simulates the traditional physical pinscreen image synthesis process. The basic goal is to enhance the artists ability to express themselves. Pinscreen is a very particular and difficult device that enables a "chiaroscuro" approach to image synthesis. In this paper we describe with some detail the traditional pinscreen technique, the way it is operated, results and related difficulties. A first basic computer model to simulate the pinscreen is presented. New important extensions to the basic model are also proposed. Advantages and possibilities of the method when compared with the traditional method and the problems that arise from this technique will also be explained.

1. Introduction

In the early days of computer graphics the hardware capabilities enabled only calligraphic or low resolution raster based image synthesis, most of the time abstract oriented. Today the "de facto" standard for image synthesis is based on high resolution frame buffers with 24 color bit planes enabling the so called real color representation (more than 16 million colors) [Foley84, Jankel84]. This capability, linked to the use of realistic oriented shading and texturing algorithms applied to 3D models, permits photorealistic image synthesis (sometimes one can not clearly state if a given picture is, or is not, a real photograph). The problem with this approach is that computers are too precise and reality is not that precise.

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Some artists think that computer synthesized images are too cold or that the human creative interpretation of reality is lost in the synthesis process. In the photorealistic approach one way to improve human control is by simulating optical and photographic effects like motion blur, focus distance, depth of field, etc., one area where some practical results have already been achieved [Cook87, Magnenat-Thalmann87].

In the 2D area paint programs spread as the tool for 2D image creation and composition. These programs simulate a painter's workbench by providing traditional based tools (brushes, color mixing capabilities, etc.). They also enable the user to access the "digital functionality" (cut, paste, image grabbing, fill area, ...), an almost non ending creative possibilities and solutions. Nevertheless, once more, the basic expressiveness of the traditional tools is not yet completely available: digital brushes pressure and inclination dependent are difficult to achieve in the same way that artists feel and manipulate a real brush and research is being done in this area [Smith82, Fishkin84, Bleser88].

When synthetising motion by computer two basic approaches exist [Magnenat-Thalmann85, Kochanek87]:

- 3D programs, computer modeled animation, that simulate the traditional 3D animation.
- 2D programs, computer assisted animation, that replicate the cel animation technique.

Each have strengths and limitations [Kochabek87, Lopes88a-Lopes88c] and both replicate traditional animation methods. Research in both areas is normally conducted to overcome these limitations with better or new algorithms improving the tools already available [Platt81, Hofmann88, Pintado88].

A quite interesting research paper is [Hofmann88] where the author proposes a method to apply the scene-shifting technique of classical films to computer animation. For a specific frame parts of the preceding frame may be inserted with scaling and shifting transformations but with no need for perspective transformation or rendering, thus speeding up the rendering process in 3D computer animation. Particularly interesting is the way he gets into the problem: a scene from a Fellini's film (*La citta delle donne*) is used to show that if scene-shifting in real films illude the viewer then the same principle can be applied to computer generated scenes.

With todays technology it is possible to create realistic images. It is now time to use knowledge not only from the photographic world but also from traditional animation areas. We follow this trend and, based on the experience in traditional animation of one of the authors [Lopes88c] and also studying traditional animation techniques [Russett76, Laybourne79, Salomon79], we realized that among all available animation techniques very few artists used the pinscreen animation technique. The explanation is that, inspite of the creative possibilities, it is a very time consuming technique and a not very easy one to deal with. We try to overcome these limitations with the computer model explained in this paper.

In the next chapter we describe the traditional pinscreen apparatus and operation techniques. Next we present a basic model for a computer modeled pinscreen and the visualization algorithm. We also propose new important extensions to the basic model. Finally we discuss advantages of this approach over the traditional method.

2. Traditional Pinscreen

History and goals

The pinscreen technique was invented by Alexandre Alexeieff and Claire Parker between 1930 and 1935. Their goals were to build a system where one could produce images that, when animated, could resemble engraved pictures in motion [Salomon79].

Device Description

The pinscreen technique is based on a white plate standing upright in a frame, with approximate A3 format or bigger. The plate is uniformly perforated perpendicularly to the surface by small holes where headless metal pins are inserted, one per hole, sliding easily through them. Depending on the size a pinscreen may be composed from 80 thousand to one million pins. The pins are longer than the thickness of the plate. This means that each pin, or group of pins, can be pushed in the back surface of the plate emerging in the front surface. The reverse operation is also possible. Both surfaces are lighted at an angle by spotlights, one per surface.

Image Synthesis Basis

The image creation in the pin screen is based in the shadow casting principle explained next. Let's assume that we are looking at the front surface. When the pins are not emerging from a surface no shadows are cast and the surface appears white. If one of the pins is pushed from behind its shadow will be cast on the white surface. The further the pin is pushed the longer the shadow. Instead of a pin one can push a group of pins. Suppose we did it only halfway. The shadows cast will appear with white spaces between them and a medium gray tone will be obtained. If the pins are fully pushed each pin's shadow will overlap that of its neighbour. No light will reach the white surface and a black tone is formed. The back surface shows the reverse effect acting as a negative.

Animation

To animate images on the pinscreen one image is synthesized using several tools to manipulate groups of pins, in both surfaces, until the desired gray tones are achieved to form the picture. This picture is photographed into a film frame. The next frame is obtained by slight modifications on the first image on the same pinscreen according to the desired motion.The complete animated film is a collection of images that were gradually and incrementaly produced, each one based on the previews one.

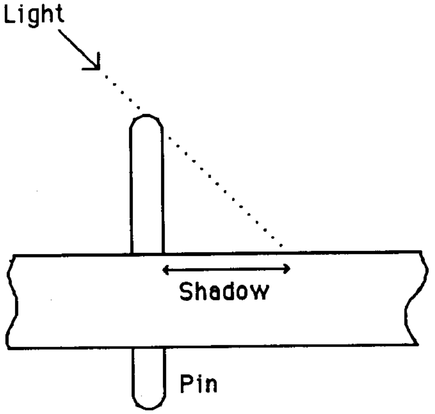

Figure 1 Detail of a pinscreen transverse cut showing its geometry.

Results

According to Claire Parker the modeling and shading capabilities of the system "makes it possible to work the entire film in chiaroscuro, and thus to escape from the comic or satiric into the poetic and dramatic" [Russel76, pp. 95]. Few persons used the technique and few films were produced with it. Alexeieff and Parker made a total of six films with this technique [Salomon79]. There are few pinscreens in the world and one of them is at the National Film Board of Canada, Montreal, used by Jacques Drouin. One of his films, *Mindscape*, is considered an "example of the expressiveness of the medium" [Kochanek87].

Why are so few pinscreens and persons using the technique? Doesn't the poetic and dramatic effect attract artists? One of the problems is related with the frame construction. The underlaying technique is simple and one pin is no source for alarm: it's small, light and almost inexpensive. But multiply it by one million and it becomes a huge, heavy and not so cheap collection.[1]

Another problem is that it's not an easy task to work with. Apart from the way pins are manipulated to produce a specific image, the major difficulty arises from the fact that it is

1 While doing experiments with traditional animation one of the authors tried to build a pinscreen with spagetti bars as pins. To avoid frustration to others he states that it doesn't work: spagetti is too fragile and not opaque enough, inspite of being lighter than metal pins.

almost impossible to exactly reproduce a given frame of an animated sequence. This means that an error in one frame can easily throw away all the work involved in a complete animation sequence. Great amount of scene preparation, care and dedication are needed to produce a complete film.

Even if errors are avoided the animation in itself is a tremendous task. Imagine the animation of an animal moving in a landscape. Each time the animal is moved the portion of landscape that shows up has to be redrawn as much accurate as possible, because the scenario is supposed to be frozen during the action.

One way to avoid the full animation of a character and hence diminish the amount of work involved is achieved with the use of dissolves (incamera or with future laboratory work). A dissolve is an effect where an image disappears (fade-out) while at the same time the next one appears (fade-in). A half second dissolve requires only two images while full animation in the same period would require at least six images, each filmed twice.

Until now we saw how traditional pinscreen animation worked, the kind of results achieved with it and why there are so few artists using this technique. In the next chapter the model of a virtual pinscreen is presented.

3. Computer Modeled Pinscreen

The basic questions we are facing are:

- Is it possible to model a pinscreen by computer?
- What kind of final image quality can be expected? Better, equal or worse than that obtained by the traditional method?
- Are there any real advantages in the computer approach?

First Steps

The pinscreen underlaying technique is a typical problem of casting shadows over a surface. With the first tests we tried to simulate the physical model of a pinscreen and apply raytracing to produce the shadows. We used a general purpose public domain raytracer [MTV] enabling the specification of several kinds of primitives (spheres, cones, cylinders and mesh polygons). The pins were modeled as opaque cylinders placed vertically on a white polygon. The raytracer produced the expected shadows but, as we expected from the beginning, this approach is limited and only suitable for tests.

One problem is the time spent to render the image even when the number of pins amount to ten or twenty. The number of primitives supported by the raytracer is also a problem. A pinscreen is formed by hundreds of thousands of pins and the raytracer doesn't support this number of primitives. The software could be modified to extend this limit but the time spent for rendering would be prohibitively high.

Next we present a model for the pinscreen and propose a visualization algorithm.

Pinscreen Model

The traditional pinscreen is really a simple device: pins in holes. The computer model should match the original simplicity and the time spent to compute the shadows should be inexpensive to enable interactive use like in the real pinscreen.

In [Kochanek87] the pinscreen is considered the first analog framebuffer with a "resolution" (number of pins) similar to the pixel resolution found in modern 512 * 384 framebuffers. From one side we have an analog buffer and in the other side a digital buffer. The question is how can they be matched.

What are the fundamental items in the pinscreen to form the image? The spot light, the pins and the white surface serve to produce the elements responsible for the image synthesis: the shadows and the white spaces inbetween. This means that the computer model only has to consider the minimum set of items that will simulate shadows.

As a consequence we can identify the light and the white surface as elements to be supported in the model. The light can be modeled as a parallel ray light source with a specified direction.

What about the pins? In the real pinscreen, physical opaque pins interfere with light producing the shadows. In the computer model there is no need for a physical simulation. We only need each pins' position, high and thickness to calculate the cast shadow.

Another important question is how are the pins' position distributed over the surface. One thing is for sure: there are moments when white spaces must be seen among the shadows so that intermediate tones of gray can be synthesized. This means that for a particular image, the denser the pins' position the darker the image and vice-versa. In the computer model density is controlled through the distance between pins measured in multiples of pin thickness.

Thus, the basic computer model supports:

- a light source (direction)
- a white surface
- a number of pins (position, high, thickness, distribution)

Visualization of the Pinscreen Model

In the first version of the pinscreen model the thickness of a pin, the picture element in the analog framebuffer, is approximated to the size of a pixel, the picture element in the digital framebuffer. This approach enables the matching between the analog and the digital framebuffers.

We followed a very simple procedure to visualize the model that will enable in the near future a real time interaction. Providing that the framebuffer is initialized to white (simulation of the white surface) the following algorithm is applied:

For each virtual pin
- read pin's position and high
- compute direction and length of shadow according to light position
- draw a black line starting in the pin's position with the shadow's direction and length.

Pinscreen Model Test

Tests were made with a black & white digitised image with 512 * 512 pixel resolution. For each pixel of the source image a virtual pin was assigned, its high being inversely proportional to the gray value of the pixel (dark pixels were assigned long pin values and vice versa).

Different virtual pin densities were tried, from one to three pixel intervals. The resulting images, if compared with the original digitesed one, lost definition and contrast, as it was easily predictable. The point is that they aren't comparable because the reproducing medias are different and the final goals are opposite: pinscreen is really intended to reproduce "chiaroscuro" images, not precise reproductions.

Nevertheless computer modeled pinscreen resolution is a problem with today's digital framebuffers. A 1024 * 768 pixel resolution digital framebuffer enables a pinscreen with 512 * 384 pin resolution, considering one pin interval between virtual pins. This gives a total of less than two hundred thousand pins, still a low resolution. To model the best traditional pinscreen available (one million pins) it would require a digital framebuffer with 2300 * 1740 pixel resolution. There are already digital film recorders that can record images up to 4000 * 4000 resolution but, for interactive use, this resolution is not yet available.

The results achieved till now show that the proposed model works but, inspite of the the good results, the best test possible would be to let a skilled artist synthesize an image using a digital pinscreen and a traditional one, both with similar resolutions and tools (interactive virtual tools are under development). It's a difficult task, but not an impossible one.

Computer Model Possibilities

Based in the model described above we are currently developing a computer pinscreen system. The model advantages over the traditional pinscreen and new important extensions to the basic pinscreen model are now presented.

When compared to the traditional pinscreen the digital approach offers several advantages manly related to automation, an area where computers are so good at.

Image synthesis and animation

As in the first tests we made, the user could begin an image synthesis session with any kind of digital image already in mass storage. Any subsequent changes can be easily recorded so that, at any time, any of the intermediate image states can be recovered. This approach can be generalized and the way traditional pinscreen animation is done, image by image synthesis, has much to gain from it. Any image of a given animation sequence can be recovered and manipulated, saving time and, most of all, avoiding the loss of the entire animated sequence, as it happened in the traditional method when an error occurred in the animation.

Real time playback

Using the right hardware pipeline it should be possible to show any sequence of images in real time for playback purposes, a feature absolutely impossible in the traditional method.

Automatic recording

Each image doesn't need to be recorded just after completion. It can be done later under computer control. This means time saving because it can be done without the animator being present and also because, if needed, it can be repeated in an error free manner.

Model Extensions

Now we present some important extensions to the basic computer model proposed above.

Light

In the basic model only the light's position is supported. The general model supports also a light color specification. This means that instead of gray levels from white to black the images can be synthesized with shades of a given color as a result of the interaction between the white surface and the colored light. This is similar to experiments Jacques Drouin is doing at National Film Board of Canada when he interposes colored filters between the light source and the pinscreen.

Surface

In the basic model only a white surface is supported. The general model supports also a colored surface, as it was the case for the light. This means that the shades result now from the interaction between a colored light and a colored surface. The model can be still more general.. The surface can be mapped with any given image. Instead of white (or colored) spaces between the pins' shadows we have now "image spaces", the image mapped onto the surface. These are results very difficult to obtain in the traditional method but we can imagine a method to do it. Suppose a device that projects with parallel rays, vertically to the white surface's plate, a slide. The image in the slide will appear in the surface and no shadows will be cast by the pins because the light rays are parallel to them. The final image will be the result of the interaction between the light responsible for the shadows and the one that produces the image. Because now there are two light sources the equilibrium of the shadows intensity and the image contrast in the surface must be well defined through the lights intensity control. As far as we can imagine, this is not a very easy task. In the digital approach this is simple and clean to achieve.

Time Extensions

When taking into account the time component several new extensions are added to the basic model.

Light

Color and position can smoothly change in time. Difficult to achieve in the traditional method but used in other computer animation approaches.

Surface

Color and image mapping can change in time. The mapped image can change like in a traditional image dissolve while, at the same time, the image formed by the pins' shadows change also. This is a very difficult effect to achieve in the traditional method, if not impossible.

Pin interpolation

This is a concept specific to computer modeled pinscreen. It enlarges the animation algorithms available till now. In a standard pinscreen pins are manipulated as groups and there is not the concept of individual manipulation of pins. Even if it were tried it would be almost impossible to get any significant results due to device limitations. However single virtual pin manipulation is possible because it is done under program control. It doesn't necessarily mean that the user is going to use this feature because, as in the traditional pinscreen, the significance of a single pin in the overall image is low. But this is important when considering an algorithmic approach.

Pin interpolation works with the following principle: given any two different sets of virtual pin highs the system can calculate any intermediate set, or sequence of sets, by pin to pin hight interpolation. This effect would be possible in a traditional pinscreen if the pins were controlled electromagneticaly.

Now we finally can present the general animation methodology in the digital pinscreen: given any number of digital pinscreen images (set of pin highs, lights position and color, surfaces color or image mapings) the system should calculate all the intermediate sets through any kind of interpolation (spline, linear, kinematic...) of the parameters that define a set.

4. Conclusions

In the present paper we described the traditional pinscreen technique, its possibilities and difficulties. We proposed a computer model for pin screen simulation witch is intended to enlarge the artists choice for expressiveness when using computer based tools. The results achieved so far show that the proposed model works. Based on these results we also proposed new extensions to the basic pinscreen model.

The advantages of the digital pinscreen are enormous when compared with the traditional one, but the resolution of current digital framebuffers is a limitation to obtain top quality high resolution pinscreen.

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