Stereographic Animation (1951)*

The Synthesis of Stereoscopic Depth from Flat Drawings and Art Work. An outline of the Production Techniques used in Now is the Time and Around is Around

1. Introduction

A year ago, the festival of Britain asked the National Film Board of Canada to contribute two shorts for a program of stereoscopic and stereophonic films being shown at the Telecinema in London, with the specific request that the films be of a cartoon or animated nature to set off the natural or “live” stereo films being made by the British themselves.

To our knowledge, no stereoscopic cartoon-type animated film had been made before. In 1939, Loucks and Norling made most successful use of stereoscopic animation in the sense that solid objects were photographed using a stereo camera and stop motion; and we were familiar with the results of this work presented by Mr. J.A. Norling to the S.M.P.E. in 1939 and 1941.

Our problem, however, was somewhat different, for we were concerned with the making of a stereoscopic film from drawings or art work which in themselves were flat – the problem of synthesizing three-dimensional space from two-dimensional subject matter.

Since the subject matter to be photographed is flat, no special stereoscopic camera is needed, but simply the regular type of animation and optical set-up, the film for each eye being shot in succession.

Many possible technical approaches suggested themselves – the most obvious being that of adapting the standard cartoon technique – by preparing two sets of drawings, a left and right eye version of each cell, with all the necessary parallaxes drawn into each cell.

This technique, however, was discarded, due to limitations of time, staff and budget, in favour of several simpler methods which this paper will describe in detail.

Before doing so, it might be useful to review in simple language the principles behind the animator’s approach to creating depth.

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*N.B. This paper was given as an explanation following the actual screening of these two films.*
2. Control of Depth by the Animator

Principle of convergence, screen, film, and cell-parallax

In essence, this is done by controlling the amount of toe-in or toe-out of the spectator’s eye-balls.

In a normal flat cinema when a spectator looks at the screen, the lines of sight from his left (L) and right (R) eyes are toed-in so as to meet each other at a point (lr) on the surface of the screen, as in diagram No.1:

Throughout the viewing of a normal flat film, the spectator’s eye-ball toe-in remains fixed. In viewing a stereoscopic film, however, this toe-in varies.

If our spectator, instead of looking at the screen, were to let his eyes drift and look away beyond the screen, staring at infinity, the lines of sight from his eyes (L and R) would become parallel, as in diagram No. 2, and these lines would pass through the screen at two separate points (1 and r).

Since the distance between the average spectator’s left and right eyes is 2 ½ inches, and since his lines of sight are parallel, the distance between the two points on the screen (1 and r) will be 2 ½ inches. No matter at what distance from the screen the spectator is sitting, this will always be so.
Now if our spectator were to look at an object located exactly half way between himself and the screen, his lines of sight would cross each other at a point (1r) half way between himself and the screen, as in diagram No.3, and the lines of sight, if projected beyond this point, would fall on the screen at two points, 1 and r.

![Diagram No.3](image)

Again, by simple geometry, we can see that the distance between 1 and r is 2 ½ inches, and that no matter what distance the spectator is from the screen, this will always be so; it is important to note that 1 and r are now switches, so that 1 is to the east and r to the west.

For the stereoscopic animator, these are three basic diagrams on which to anchor all calculations of parallaxes. In designing a stereoscopic scene from flat drawings, the artist, if he wishes, let's say a dot to appear on the surface of the screen, he must have the left and right eye versions of the dot coincide precisely. For the dot to appear at infinity, there must be a 2 ½ inch separation between the left and right eye images on the final screen, the left eye image being on the left hand side of the screen and the right eye image on the right.

For the dot to appear midway between the spectator and the screen, there must be again 2 ½ inches separation between the two images, but this time the left eye image is on the right hand side of the screen, and the right eye image on the left.

If the images are separated by progressively less than 2 ½ inches, the dot will be located progressively nearer to the screen than half way, or nearer to the screen than infinity.

Separation of more than 2 ½ inches for back-of-screen images has generally to be avoided as it places the object ‘beyond infinity’, a condition which, due to the spectators’ having to wall-eye, is almost as awkward to perceive as conceive. Separations of much more than 2 ½ inches to bring the image closer to the spectator than midway can be used, but sparingly, in order to avoid eye strain for a certain percentage of the spectators.
The animation artist therefore is not troubled by the major limitations which afflict the regular cameraman in stereoscopy. The stereoscopic world created by him is so calculated that no part of it will exceed the tolerable limits of parallax when projected on the screen, that is, so long as he knows the maximum size of screen on which his film is to appear. Knowing this size of screen, the amounts of parallax on the surface can be mathematically translated into amounts of parallax on the surface of the 35 mm film, and that, in turn, can be converted into amounts of parallax on the surface of the cell, cards or other art work.

The size of screen for which these Canadian films were designed was fifteen feet wide, this being the requirements for the Telecinema in London, England, where two interlock 35 mm projectors were lined up with their optical axes converging at the surface of the screen.

A paper entitled “The Determination of Stereoscopic Parallaxes in Animation” by Mr R.J. Spottiswoode, Technical Director of the Festival of Britain’s stereoscopic program, was used as a basis for calculating all parallaxes.

I will now give a detailed account of the various production techniques used in the two films entitled *Now is the Time* and *Around is Around*.

### 3. Techniques used in *Now is the Time*

**Parallax by Moveable Cut-outs in the Art Work**

The opening scene of *Now is the Time* is progressively built up of twelve planes of clouds, each flat in themselves, starting from the most distant and working forwards.

The most distant plane was to be located at stereoscopic infinity. The nearest plane was located approximately half way between the spectator and the screen.

The material prepared for shooting consisted of one basic black card 10" by 14". Clouds, varying in size from ¼" to 3" wide, were painted with white paint on small bits of black card. These were then stuck to the black card with double-sized tape in a series of horizontal rows varying in size from the smallest row in the center of the card to the largest at the bottom. The card was then placed under a standard animation camera and photographed on high contrast stock in such a way that the various row of clouds were revealed in turn by a series of cross fades. This shooting was for the right eye viewpoint; the card was then kept in the same position under the camera, but the lateral position of all the clouds on the card was changed. The cloud cut-outs were moved in varying amount either to the east or to the west to allow for the desired amount of parallax. Only one plane of clouds was left untouched, the one located on the surface of the screen. The parallactic shift was mathematically calculated for only the farthest and
nearest planes, the rest being adjusted by eye – a relatively simple matter. The card with clouds was then shot again, following the same footage dope-sheet as before, to obtain the left-eye footage.

The sequence of appearing suns which follows the cloud sequence was done in the same way as the clouds.

**Parallax by Lens-shift in the Optical Camera**

The little dancing man and the animation that grows out of it was done by a different method. With an ordinary writing pen and India ink, the action was drawn frame by frame directly on clear 35 mm machine leader (the usual animation stages of pencil sketches, inking, shooting and developing being short-circuited in the process of making the original negative).

The drawing was done from a mid-interocular viewpoint, that is, it was designed on the assumption that it would be representing a viewpoint midway between the final left and right eye viewpoints. The animated image itself was designed to remain at all times within a plane parallel to the cinema screen.

From this original hand-drawn negative, an optical print was made and loaded into the projector of a standard optical printer. A left and right eye optical negative was produced in turn, the transverse action of the camera lens being used to create the required parallaxes. The amounts of parallaxes for the nearest and farthest planes were calculated mathematically. These amounts, split in half for each eye, were marked on the indicator controlling the transverse action of the lens on the optical camera, as movements to the left or right of zero position. The zero position itself represented the plane located on the cinema screen. A dope sheet indicating the amounts of parallax required at key points in the animation was prepared. The dope sheet for the right eye being the same as for the left except that, in shooting, the direction of transverse movement was reversed. The optical print was projected continuously at a speed of 160 frames per minute, during which the artist by glancing at the dope sheet and watching the animation, turned the transverse control and created variable parallax in sympathy with the size perspective of the flat drawing.

In cases where the parallax changed rapidly and in a varied fashion, the shooting was stopped periodically, or the process run slowly to secure greater control.

**Combining Material for Release Printing**

The left and right eye negatives from the optical camera bearing the animated images, and the left and right eye negatives from the animation camera bearing the static backgrounds were then used as material for building up six
parallel picture separation negatives (a yellow, cyan and magenta record for the left eye, and a yellow, cyan and magenta record for the right eye), for release colour printing in English Technicolor.

Stereophonic Animated Soundtrack

Strictly speaking, the music of the film *Now is the Time* should be classed as animation. This synthetic sound was produced by photographing patterns of black and white sound wave forms on to the soundtrack area of 35 mm film, using standard animation equipment and techniques.

The stereophonic system used in the Telecinema at the Festival of Britain employed four channels. To make the animated sound stereophonic, four identical prints were lined up parallel in a four-way, each representing one of the channels. Various notes were then blooped out of certain of the tracks, depending on which channel or channels the sound was desired to come from. This was possible because the animated sound was built out of small units each separated by small sections of unmodulated track.

4. Techniques Used in the Film *Around is Around*

Parallax by Double Punch-Holes on Art Work

The opening build-up of eight planes of stars was produced as follows:

The stereoscopic location of the eight planes was decided upon, and from this in turn was calculated the amounts of screen parallax, the amounts of parallax on the surface of 35 mm film, and the amounts of parallax for art work with a field 12 inches wide.

Eight standard animation cells (10” by 14”) were then punched with two sets of registration perforations; the distance between the two sets of punch holes varied for each cell and depended on the amount of parallax required for the plane represented by each cell.

The plane representing the surface of the screen had only one set of punch holes, there being an absence of parallax for that particular plane.

The art work (stars in this case, and representing no depth in themselves) was then painted on the eight cells. In order to prevent the final stereo scene from being asymmetrical, during the painting, the cells, when placed on top of each other, were registered for a mid-interocular viewpoint, that is, the midway points between the two sets of punch-holes were registered with each other.
In shooting, a standard animation camera and stand with registration pins and glass platen were used. The eight cells were not separated physically in space, but pressed close together under the glass platen. They were registered by the set of punch-holes for the right eye and shot once, then registered by the other set of punch-holes and shot a second time, for the left eye.

All static background material for the film *Around is Around* was shot in this fashion.

**Parallax by Frame-stagger on the Negative**

The horizontal panning background of clouds and stars were cases in which the speed of travel of the various planes was so calculated that the dynamic parallaxes of a monocular panning shot gave rise automatically, when two identical prints were staggered by a certain number of frames, to the required binocular parallaxes for a stereo pair.

The monocular cloud and star panning shots were made by multiple exposures, the various planes, each with a different travel speed, being superimposed in the animation camera.

Assuming a one-frame stagger, the travel speeds for various planes were calculated. For example, for the infinity plane: the amount of parallax needed on the surface of the 35 mm film to locate a plane at infinity is known, therefore, the corresponding amount of parallax needed on art work of a given field width can be calculated. This amount is the same as the amount of travel per frame required to locate this plane of the art work at infinity. Speeds progressively less than this will locate planes progressively closer than infinity, until an absence of any movement will locate the plane on the surface of the screen.

The locate subject matter behind the screen in a horizontal panning shot in which the subject matter is traveling eastward, frame #1 for the left eye should be placed opposite frame #2 for the right eye (L1 = R2). For westward traveling subject matter, R1 = L2.

If in the above shot with eastward traveling material the stagger is reversed, or the left and right eye films are switched (R1=L2), then the planes are located stereoscopically between the surface of the screen (for the plane with no movement) and a point midway between the spectator and the screen (for the plane with maximum speed); similarly with westward traveling subject matter when R2 = L1. To state this more briefly:

To locate planes in back of screen,
   with eastward traveling subject matter – L1 = R2
   with westward traveling subject matter – R1 = L2
To locate planes in front of screen,  
with eastward traveling subject matter – R1 = L2  
with westward traveling subject matter – R2 = L1

In the latter two cases, faster travel can be used for locating planes closer than halfway between the spectator and the screen; but in the former two cases, if faster travel is used the planes will be located beyond binocular infinity.

If a two-frame stagger is used and the same stereoscopic effect desired, the speed of travel of each plane has to be halved; if not, the total gamut of depth will be doubled.

A three-frame stagger will triple the depth gamut, unless the speeds of travel are divided by three, and so on.

In *Around is Around* a seven-frame stagger was used for the white on magenta horizontal panning clouds, and a two-frame stagger in the last sequence of the film for the cyan stars on a blue background.

The frame-stagger technique was also used to create the stereo depth of all the linear animated images in *Around is Around*.

These revolving images, lissagous figures and other patterns were produced on an oscillograph, and a brief description of their means of production is given in an appendix to this paper.

A standard Bell & Howell camera was trained on an oscillograph, and the patterns photographed while in motion. The growth and change of the patterns was controlled by manually operating the control knobs on the oscillographic set-up. The camera was run at 12 and also 8 frames per second, rather than normal speed, to permit greater control of pattern modulation.

The movement of the patterns was kept predominantly horizontal, so that the monocular dynamic parallax would produce binocular parallax, when two identical prints were staggered as a stereo pair. The movement had to be slow enough to prevent the parallax between two adjacent frames from exceeding the tolerable limits of parallax infinity. On the slower patterns a two-frame stagger was possible; on the quicker, a one-frame. Any vigorous vertical movement within the patterns was avoided, for this, due to the frame-stagger, would have created undesirable vertical parallax in stereo-viewing.

**Parallax by Frame-stagger Plus Lens-shift**

Rotating patterns which traveled to and from the audience achieved their depth by combining stagger frame and lens-shift techniques.
An optical print from the original negative was shot twice on the optical camera, once for each eye, the parallax relating to the eventual to-and-fro movement of the pattern being introduced by camera lens-shift while shooting; the two resulting negatives were then staggered to produce the parallax relating to the rotational movement.

5. Conclusion

The above covers the various techniques used in the two films under review, and leaves untouched a number of others which were considered but not tried out.

Our particular choice of techniques was dictated by the set-up at the National Film Board of Canada, and by our desire not to stimulate reality (a thing which natural stereo photography can do most ably) but to create a new kind of reality more in keeping with the graphic method by which the films were produced. We were also interested in dispensing with some of the non-stereoscopic depth-assessing factors normally present in stereo films, such as interruption by opacity, light and shade, chromatic hue, and tonal perspective, and to some extent diminishment (in the oscillographic patterns – which, however, have dynamic fore-shortening) in order to discover to what extent and in what order the human mind relies upon these factors for depth information.

To sum up, our production experience would suggest that the major methods of introducing parallax into flat drawing and animation are probably:

1. Stereo pairs of cards or cells, the parallax being drawn into the images.
2. Double punching of single cards or cells.
4. Movements of the horizontal panner under the animation camera.
5. Horizontal panning or lens-shifting in the optical printer.
6. Frame-stagger on horizontal action shots.

Each method would seem to be effective for different purposes; obviously Method #1 has the greatest flexibility, and would recommend itself for cartoon work, particularly when combined with #2 for static backgrounds. On the other hand, for diagrammatic and cartographic animation some of the other methods may well be more suitable and economical, especially when the final visual is built out of several superimposed elements. At all events, it is quite safe to
predict that the combinations of all these methods will be useful for stereo animation, and that they will, in the future, become part of the technical ammunition with which the animated film will meet the challenge of stereoscopy.

Norman McLaren (1951)
National Film Board of Canada, Ottawa, Canada

6. Appendix by Chester Beachell

The Generation of oscillographic patterns in *Around is Around* by Chester Beachell, National Film Board of Canada.

There is no limit to the patterns obtainable on an oscillograph. This is easy to understand when we remember that a picture tube in a television receiver is a glorified oscillograph.

However, it was decided to keep the patterns relatively simple for two reasons:

1) the difficulty of photographing an extremely complicated trace due to the low actinity of the fluorescent screen at high trace speeds, and

2) the presence of vertical movement in the more complicated patterns.

The patterns themselves are mostly complete cycles – that is the sweep was sinusoidal – except for one or two patterns, notably the pillars. With a sinusoidal sweep the return trace is the same rate as the forward trace, and hence is visible, giving a closed loop.

There were never more than four component signals used to form any of the patterns in this film. The wave forms used were (a) sinusoidal, (b) square wave, (c) saw tooth wave, including varying shapes and distortions of the original wave forms. In some patterns varying degrees of phase shift were employed between vertical and horizontal deflection in order to produce such things as the revolving spring pattern.

The signal sources were two audio frequency signal generators, range 20 to 20,000 cycles per second. One audio frequency signal generator, range 7 to 70,000 cycles per second. One square wave generator, range 7 to 70,000 pulses per second and 60 cycle line frequency.

A number of external and separate controls were set up in order that the size, movement, brightness and shape of the patterns could be changed and accurately controlled during any one shot. These controls were: (1) vertical micro gain, (2) horizontal micro gain, (3) mixing controls for the various wave forms so that they could be mixed on either or both sets of the deflection plates, (4) phase shift controls were set up so that they could be inserted in any signal source to
either deflection system, and (5) a switch to rotate the pattern through 90
degrees on the screen. This was necessary in order to keep the movement
largely in the horizontal plane.

As the revolving movement in the patterns is a graphical presentation of the
beat between two frequencies, it was necessary that all signal sources be as
stable as possible. Instability caused varying rates of movement on the screen
and if a pattern moved too fast, then the optical parallax, in final stereoscopic
viewing, became too great. This was our biggest difficulty in that regulation had
to be absolute in the power source, as any change in voltage in the oscillators or
in the scope itself brought on unwanted movement. It was found that saturable
core regulation transformers were a partial answer to the supply regulation
problem, but, even with this, most of the shooting was done at night when there
was no heavy intermittent loads on the AC power.

Due to the low actinity of the phosphor used – the oscillograph tube was a
5LPI – it was necessary to shoot at varying frame rates depending on the
complexity of the pattern. This was also an advantage as it permitted greater
manual control of the figure during shooting. This brought on another difficulty, to
slow the movement of the pattern so that the movement would be within reason
when projected at twenty-four frames per second. As an example – the base
frequency is 60 cycles per second. The beating frequency is the one-thousandth
harmonic which is 60,000 cycles per second. In order that the pattern will move,
it is necessary to charge one of the frequencies so that the beat frequency
between them is 0.05 cycles per second. This would mean absolute stabilization
of the 60 c.p.s. signal and absolute stabilization of the second frequency at either
59,999.95 cycles per second for clockwise rotation, or 60,000.05 for counter
clockwise rotation. This meant that differences in frequency from one signal
source to the harmonics of that frequency obtained from another signal source
were as little as one-twentieth of a cycle per second. Crystal oscillators were
impractical because a room full of crystals would have been required.

The fireworks effect was achieved by charging the capacitor on the vertical
positioning supply through a high resistance to a voltage greater than that
required to centre the beam and then bleeding it down to centre positioning
through another large resistance.

The most simple description of these patterns is that they are graphical
preservations of the sums of the equations of various wave forms at any given
instant in time.

Chester Beachell