STEREOGRAPHICS®

The SynthaGram™ Handbook

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1. The SynthaGram System

Introduction

This handbook is aimed at content creators, advanced users, and developers.

SynthaGram™ is the trade name of StereoGraphics™ Corporation's autostereoscopic technology. The SynthaGram has the characteristic stereoscopic image of our CrystalEyes® and ZScreen® products but without the need for wearing special eyewear. CrystalEyes and the ZScreen select the left and right images of the stereo-pair at the eyes; the SynthaGram selects a multiplicity (usually nine) of perspective images at the surface of the screen.

The SynthaGram image offers equalized resolution in the *x* and *y* directions and as importantly, the optical moiré (color banding) and pattern noise that is associated with the combination of a lenticular screen and a flat panel display have been eliminated.

The SynthaGram system consists of monitors, content creation means, playback means, and a software developer's kit (SDK). SynthaGram monitors are offered in a variety of desktop models from modest to super-high resolution, and as large plasma panels for presentation and public space displays. Consult our website, www.StereoGraphics.com, for information and specifications.

StereoGraphics offers plug-ins for 3D Studio and MAYA that enable these slide and animation tools to create Interzigged (see below) or nine-tile format images. Once slide shows or movies have been created with these tools they can be played back using the SynthaGram Player (SynthPlayer) a versatile media player that allows for playback on any SynthaGram monitor.

StereoGraphics offers an SDK for application developers to help them create SynthaGram-ready applications.

Dynamic Digital Depth, of Santa Monica and Perth, offers a service that converts planar videos and movies into SynthaGram format content to be played back though their TriDef™ Player. They also offer a product, Transformer, which allows the user to create SynthaGram content from planar photos and drawings.

Other independent organizations offer on-the-fly *stereo-izing* processes in firmware or software embodiments.

Historical Background

The SynthaGram uses lenticular screen or lens sheet technology (lenslets or miniature lenses arrayed on a flat sheet) that has been under investigation for almost a century. Our technology is an outgrowth of this work and the result of our own investigations.

G. Lippmann invented the first lenticular display of this kind in 1908. He devised what is known as *integral photography* or the *fly's eye* technique, in which a series of semi-spherical lenslets, lying in a plane, are used to photograph and display images. The process is considered to be a precursor of holography.

In a United States patent granted in 1915, W. Hess, a Swiss inventor, described a modification to the Lippmann optics by replacing the spherical lens elements with corduroy-like vertical going lenticules that refract only in the horizontal direction (unlike Lippmann lenslets that refract vertically and horizontally). Hess also described a means to photograph left and right images and to then combine them optically into an interdigitated (slicing into strips and alternating the strips of left and right perspectives) lenticular stereogram. Figure 1 explains how the Hess and similar systems work.

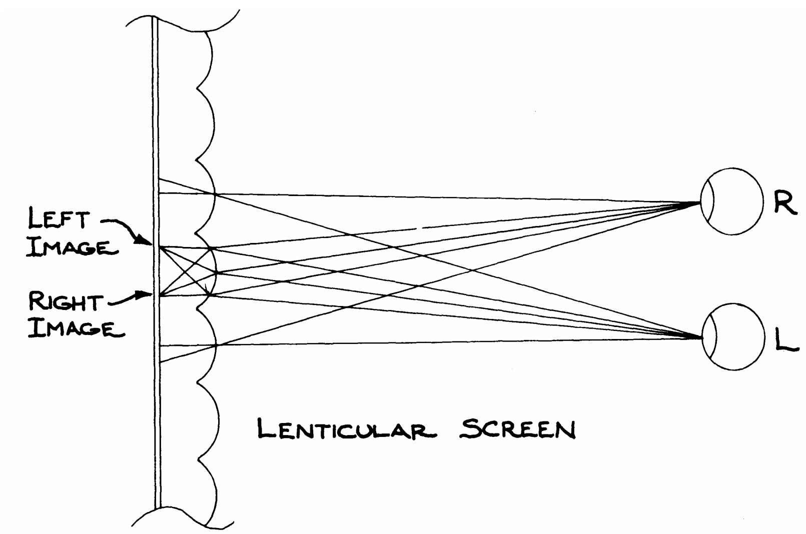

Figure 1. Lenticular Imaging. We show a top cross-sectional view of lenticules with interdigitated images behind them. The eyes of the viewer are indicated at R and L. This drawing illustrates how the optics work, although the SynthaGram is a bit different. Only two image points, one left and one right, are shown, but in the case of the SynthaGram there are more images providing for broad viewing zones. (From *Foundations of the Stereoscopic Cinema* by L. Lipton. Copyright by the author.)

In addition, several inventors (A. Berthier, 1896, J. Jacobson, 1899, and F. E. Ives, 1902) at the turn of the 19th century conceived of the idea of interdigitating images to form a stereogram. Their selection technique used a *raster barrier*, a ruling or grating of black lines with narrow vertical openings, rather than a lenticular screen.

Scores of inventors have added to or improved upon this work and have devised interesting approaches to lenticular (and the related raster barrier) technology. D. F. Winnek describes one of the most important inventions in the field in a 1968 U.S. patent disclosure. The SynthaGram uses his approach for slanting lenticules allowing us to eliminate optical moiré and to equalize resolution in the *x* and *y* directions.

Techniques have been found to mass-produce lenticular stereograms using web printing processes. The technology has also been taken in another direction using desktop or large format printers. Familiar applications include portraiture, theater lobby cards, book covers, various novelty items, trading cards, and packaging.

Modern work in the field substitutes a computer process, pixel mapping, for optical interdigitation. This advance is a necessary one for electronic displays. It simplifies and improves the process and makes it possible to display computer-generated images. Flat panel displays are another important ingredient for electronic autostereoscopic displays. Unlike cathode ray tube (CRT) monitors, the flat panel image surface lies on the surface of a plane, making it simpler to adhere the lenticular screen. As important, the location of pixels can be determined with great precision.

Lenticular Screens

The SynthaGram monitors use lenticular screens (also called lens sheets as noted), developed in our laboratory and manufactured by StereoGraphics. They have the corduroy-like structure shown in Figure 1. These lenticular sheets are located in front of the surface of a flat panel monitor. The screen and display are integral units and are precisely aligned by means of moiré interferometry. The lens screen is made of a material matching the characteristics of the display screen to insure continued alignment of pixels and optical elements over time even with changes in temperature.

As mentioned above, our lenticular optics are tipped from the vertical to achieve good resolution and to eliminate optical moiré. StereoGraphics has developed our own optical modeling and manufacturing techniques so that we can provide the precision lens sheets for a variety of liquid crystal and even very large plasma panel displays.

The SynthaGram process embedded in two areas: optics, discussed above, and software manipulation of picture elements. Mapping of the pixels is accomplished at the subpixel (red, green, and blue) level. The proper combination of these two disciplines is required for the creation of SynthaGram technology and the creation of images. The SynthaGram screen has the ability to direct image pixels of the appropriate perspective to each eye over a wide viewing angle.

The geometrical/optical constraints of the process demand a digital pipeline (rather than analog to digital conversion) from computer to monitor in order to preserve the precise mapping of the pixels and their association with the optical elements. Therefore the SynthaGram Monitor may be supplied with a video accelerator board (to be added to your PC) that offers a digital video interface (DVI).

Viewing Zones and Look-around

A SynthaGram image is made up of a number of perspective views whose pixels are mapped so that they will be precisely juxtaposed with the appropriate optical elements. The views fan out into space (like wedges of cheese) over the primary and additional viewing zones (see Figure 2). As you move your head to the left or right you see a good stereo view within a viewing zone and then traverse regions of only a few degrees in which, although the image can be seen, there is no proper stereo information. Move farther and your eyes move into another viewing zone of the same angular extent and as good to look at as the central zone. The process repeats for secondary and tertiary zones, and so on.

Thus there are many viewing zones symmetrically located in front of the display. That means that group viewing of a stereoscopic image is effortless. Although we recommend that the optimum number of images required for our display is nine perspective views, any number of views, two or greater, may be used. If a low number, such as two or three is used, the viewing zone angle of view is reduced. If a number greater than nine perspective views is used there is no attendant benefit.

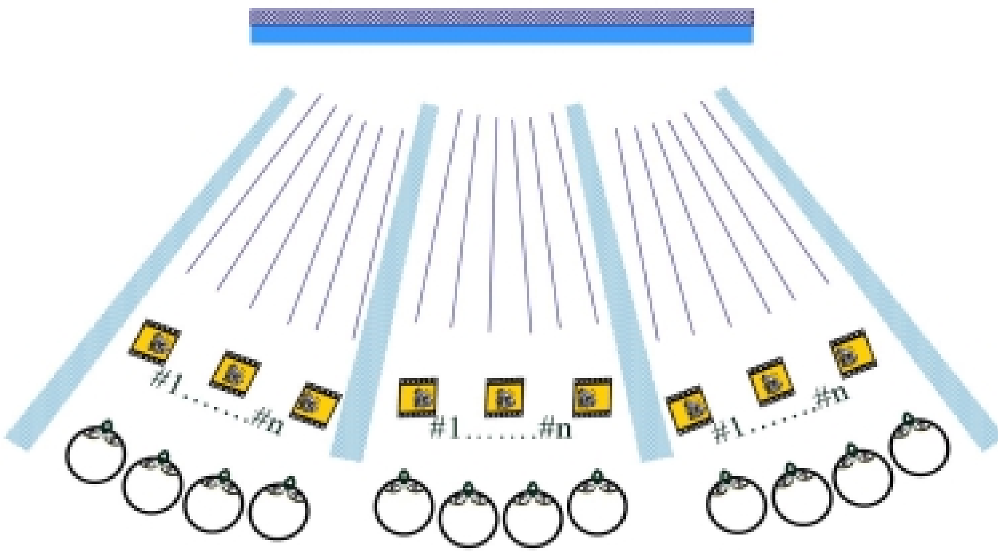

Figure 2. Viewing Zones. Moving laterally across a viewing zone produces the *look-around effect* because the observer is seeing different sets of stereo pairs. Moving out of one viewing zone into the next zone repeats the exact same perspective progression. Within a viewing zone you may see any two of nine views depending upon where you are located. Two views (say views 1 and 4 or views 6 and 8) make a stereo pair.

We chose nine perspective views as appropriate after extensive experimentation. Reduce the number of views by one or two and the display's effectiveness may be slightly diminished. Add more views and there is no perceptual advantage. We also like nine views because the aspect ratio of the image can be maintained as described below in the section *Nine-Tile Format.*

The exact image you see depends on where you stand in front of the display (see Figure 2). Any two of the nine views is a stereo-pair. For example, views 2 and 6 are a stereo pair, as are views 1 and 9. Thus if you are at one edge of a viewing zone you may see views 2 and 4, and from another you may see views 6 and 9. Move closer and you may see views 1 and 9, and further away you may see views 4 and 5. As you move sideways the perspective of the image, or rejuxtaposition of foreground and background, changes. This is sometimes called the *look-around effect* and is why the process was dubbed the *panoramagram*. The look-around effect and the ability to view the image from different viewpoints derive from the multiple perspective views. Interestingly this kind of display is one that can be enjoyed by stereo-blind people because they can move their heads side-to-side to observe changes of perspective thereby substituting motion parallax for stereo parallax.

Nine-tile Format

Please refer to Figure 3 for our discussion of how images are created for the SynthaGram process.

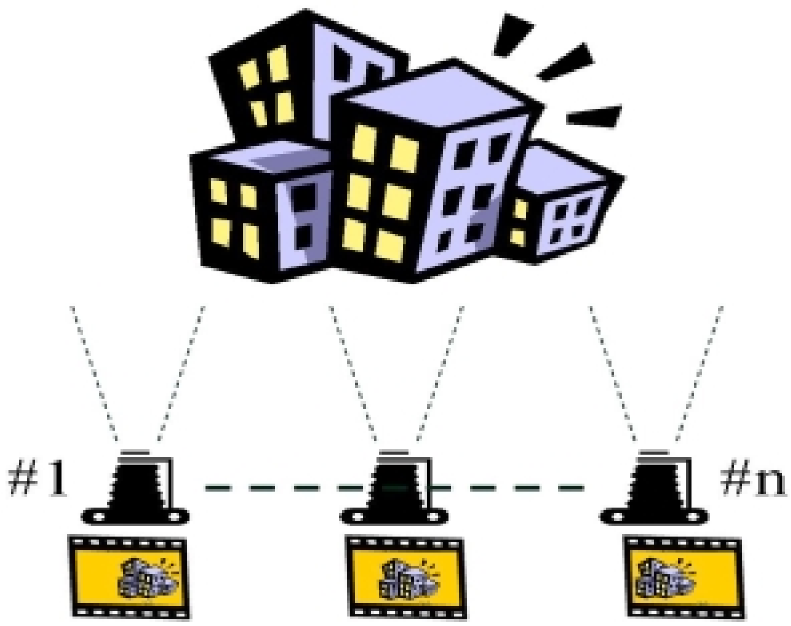

Figure 3. Image Creation. Multiple cameras, virtual cameras in computer space, or cameras in the visual world, are equally spaced along a straight-line, look at the scene or objects to be captured. These individual images, or tiles, are then Interzigged (see below) to produce the pixel map required by the SynthaGram lens sheet. The map contains the multiple perspective views.

The images may be taken from the visual world or from a computer graphics virtual world. Still images can be photographed with an array of nine cameras or with a single camera moved along a straight line (for still subjects). Images may also be generated from the appropriate computer application. This can be accomplished with a plug-in (like our 3D Studio MAX or MAYA plug-in) working with its designated application. Or it can also be accomplished if an application is SynthaGram-ready.

Our plug-in for 3D Studio MAX and Viz, for example, prepares nine images in memory for processing (*Interzigging*) to be displayed directly on the SynthaGram monitor. The images can be slides or still images, or movies using any one of various standard compression techniques. Preferably, the nine-tile format is used (see Figure 4) because it is monitor-invariant when played back through the SynthaGram Player (see below). As an alterative the images can be rendered as interzigged but this restricts their use to a specific monitor model and interzigged images do not withstand compression.

Interzigging refers to the image mapping process performed by our Interzig™ software. This process is an outgrowth of the interdigitation techniques used in the past for producing parallax panoramagrams. Interzigging requires the nine perspective images and operates at a precise subpixel level to map appropriate subpixels in juxtaposition with the optical elements of the lenticular screen. The subpixels are optically directed into space in front of the monitor so that the observer will see a good stereo image (see Figure 2).

As a precursor step we arrange the views in a tiled pattern of rectangles three by three for a total of nine images. These tiles serve as an intermediate step and are not displayed as such. For example, assuming a 1280 by 1024 system, each image in the nine-tile pattern has 426 by 341 pixels. (In this particular case there are two unused columns on the right and one unused row on the bottom.) Each image has one-ninth the resolution of the total resolution.
There is no benefit to having more than one-ninth of the total screen resolution for these tiles. If one were to use images tiles far bigger than 426 by 341 pixels for our 1280 by 1024 display screen the resultant autostereoscopic image would not be improved.

The nine-tile format is important because it is invariant in terms of content and monitor match. Once an image has been interzigged it can only be displayed properly on one model of monitor. Therefore images may be saved in the nine-tile format for use with other resolution monitors. In addition, the nine-tile format is useful for movie files.

1 (Leftmost)	2	3
4	5	6
7	8	9 (Rightmost)

Figure 4. Nine-tile format. Nine views arranged in a 3 X 3 progression of perspectives.

The Plug-ins

We offer content creation plug-ins for 3D Studio MAX and VIZ, and MAYA. All of the functionality of these image and movie creation programs remains in tact.
The plug-in interface has been designed so that the user will be able to successfully create compelling autostereoscopic content. The user views the relationship between the stereo camera (made up of nine camera heads or nine virtual cameras in a computer universe) and subject. This allows the user to control the stereo effect by changing the distance between the camera heads, the distance between camera and subject, and the angle of view of the camera lenses

The plug-in prepares images directly for the SynthaGram monitor in one of two ways. First it can produce Interzigged images by rendering nine perspective images in memory and then extracting and reordering their pixels by means of our Interzig algorithm. It does this for a specific monitor model. Once this has been accomplished it is not possible to playback this image with a stereoscopic effect on other SynthaGram model monitors. Still images or movies that are Interzigged cannot be compressed and played back successfully because compression algorithms reorder the precisely mapped Interzigged image so that the subpixel ordering no longer matches the lens sheet optics. PC's require compression for movie playback especially at higher resolution. Thus the pre-Interzigged method is suitable only for slide shows for a specific model monitor.

Secondly, the plug-in can produce the nine-tile format to allow for the playback of slides and moving images. Once slides or movies are rendered in the nine-tile format they may be played back on any SynthaGram model monitor. Moreover the nine-tile format allows for stills or movies to be compressed using any one of a number of off-the-shelf products. These still or movie files may be successfully played back on any SynthaGram model monitor. As a rule of thumb the images should be assembled so that the size of the three by three nine-tile array equal the monitor models resolution specification, as given in the example above for the 1280 by 1024 monitor. However, this is only a rule of thumb and the content creator should experiment taking into account that the results will vary with the type of content and the viewing distance of the observer, and other factors.

Full motion may be played back on a suitable PC using the nine-tile format when using the SynthaGram Player -- a multi-media player with extensive capabilities as will be explained below.

SynthaGram Player

StereoGraphics has developed the SynthaGram Player, a dedicated media player for autostereo movie and still image content. The Player is a Windows™ desktop application and supports the nine-tile format as well as previously Interzigged content.

The SynthaGram Player allows you to choose the appropriate SynthaGram monitor model so that any nine-tile still or movie content may be played back. Slides may be played back with user selectable transitional effects.

The Player supports synchronized sound, provides a movie or slide file list for playing back shows in a pre-set order, and allows for mixing movies and slides. It offers an optional viewer alignment strip at the bottom of a SynthaGram image that allows a user to easily position herself or himself within a viewing zone.

It has a sharpness control that effectively extends the parallax budget (see below), means for setting the image backward or forward with greater or lesser parallax, and an observer distance setting feature. This latter feature allows for optimization of the image quality for a given viewing distance. For example, one of our plasma panels might be used for a virtual reality immersive effect at 4 to 7 feet, or for a shop window at 8 to 15 feet, or for a display hanging high on a wall in an airport lounge at greater than 15 feet.

The Software Developers Kit

As part of the SynthaGram release, StereoGraphics offers a Software Developers' Kit (SDK) that includes various tools for creating and viewing SynthaGram content. A major part of the SDK is the definition of an API that developers can use to create applications to manage the interzigging of source images.

The SDK also provides some utility programs, sample source code, a SynthaGram library file (DLL), the SynthaGram Player to display SynthaGram content, and versions of our 3D Studio and Maya plug-ins to create SynthaGram slides and movies.

We also include sample still and movie images to validate the functionality of your setup and to offer our opinion on what we think are good looking images.

Digital Video Board

A video board capable of a digital output to the SynthaGram monitor may be supplied with the monitor. Whether or not it is supplied you must use a video accelerator board that outputs a DVI signal. You must run the SynthaGram monitor in the digital mode or it will not perform to specification; only in this mode can we guarantee the exact juxtaposition of pixels and optical elements.

In addition, the ability to set the geometry using a flat panel display in the analogue mode leaves calibration in the hands of the user. Recommendations for compatible boards can be found on our website at www.StereoGraphics.com.

Monitor Setup

For information on using and setting up your monitor (cabling, brightness and contrast settings, and trouble shooting issues), please consult your monitor's manual. You must use the DVI cable between the monitor and the video board.

Dual Monitors

While producing content or writing code with the SynthaGram monitors on the desktop, it's best to use a dual monitor configuration; small fonts and dialog boxes may be hard to read through the lenticular screen. Supporting two monitors is a powerful operating system feature found in Windows 98, 2000, and XP, allowing you to extend your Windows workspace across two screens. We have found that there are substantial benefits to using the SynthaGram monitor in a dual monitor configuration. For example, a second monitor can be used to run programs that output to the SynthaGram monitor

2. Autostereoscopic Composition

Introduction

The SynthaGram image is subject to rules of composition just like content created for any other display technology from cave painting to movie making. For example, add color to display capability and the user becomes aware of the importance of color. The same is true for a display when depth content is added. The perceptual basis and the rules of composition for the SynthaGram closely resemble those for the creation of images for our other products -- CrystalEyes, StereoEyes and the ZScreens for projection and monitor viewing. Please consult the *StereoGraphics Developers' Handbook* for a background on stereopsis and stereography. It can be read or downloaded from http://www.stereographics.com/html/whtpaprs.html).

Camera Settings

Nine equally spaced cameras or camera heads (actual or computer space *virtual camera heads*) are set out along a straight line to make up the SynthaGram camera (see Figure 3). The camera heads use the *parallel lens axis* technique The camera sensors are in the same plane, their lens axes are perpendicular to each sensor's plane and bisect the center of each sensor, and a straight line can be drawn through each sensor where it is bisected by the axes. Our plug-ins use this method. (See the *StereoGraphics Developers' Handbook* for more.)

Images that are a great distance from the stereo camera require that the span between cameras 1 and 9 (the *major interaxial distance*) be increased. Conversely, the major interaxial is reduced for objects close to the camera. This advice can be applied when using our plug-ins, SynthaGram-ready applications, and to photography as well.

The major interaxial is usually a few times that required for conventional stereo-pair creation. As a rule of thumb try making the major interaxial 3 to 5 per cent of the distance from the camera to the subject.

Tricks of the trade

The robust appearance of depth in a stereoscopic image is based on more than the two-eyed depth sense stereopsis. Strong monocular depth cues will help make the picture look even deeper. These cues include interposition, shading, aerial perspective, the textural gradient, and geometric perspective.

Perspective: The strongest monocular depth cue greatly influences the appearance of depth of the image. You can think of perspective as having two aspects: Juxtaposition of foreground and background, and geometric perspective.

Juxtaposition of foreground and background: You can emphasize the depth of a scene by using wide-angle lenses and getting close to the important object. This will make the distant object(s) look even more distant because they appear to be smaller, hence further away.

Geometric perspective: Examples of this are the well-known effect seen when parallel railroad tracks recede and seem to meet at the horizon. Other examples are receding straight lines in interiors where walls meet floors or ceiling, or receding edges of furniture and the like. Strong geometric perspective cues greatly heighten the stereoscopic depth sense.

Textural gradient: Elements of texture are more visible closer to the eye than further away. The nap of a carpet can't be perceived as clearly as it diminishes with distance. This depth cue helps the carpet/floor appear to recede. In this case the gradient can also produce a contrast between the object resting on the carpet and the carpet itself. It also heightens the appearance of depth of near and far objects resting on the carpet.

Interposition: An object cutting off another object or the background appears to be closer than that which it occludes. Objects floating against a neutral background won't look as deep as those set against a background of clouds or a distant vista, for example.

Parallax Budget

People who are used to composing images for our other product, like CrystalEyes or the ZScreen, often follow one of these two the approaches:

Method A: For individual objects, such as a machine part or a molecules, content creators tend to place half of the image within the screen and half out of the screen. Therefore they split the parallax budget equally between negative (out) and positive (in) parallax.

Method B: People who are composing scenes of some complexity, like a landscape, often prefer to restrict the budget from zero parallax (the plane of the screen) to positive parallax. In such cases off the screen or negative parallax effects are used for dramatic effects. If they might touch the screen edges out of screen effects are avoided because of the conflict of the depth cues of stereopsis and interposition.

SynthaGram Method: The SynthaGram has a limited parallax budget compared to CrystalEyes imaging. (The budget can be increased by using the sharpening control in the SynthaGram Player) Therefore we recommend splitting the difference between negative and positive parallax to make the most of what we have despite the fact that there might a conflict of cues at the screen surround. In other words we recommend preparing images having half the content with positive and half with negative parallax with the absolute value of parallax approximately the same for closest and furthest object points.

As noted we recommend this approach even if the subject matter "breaks the frame" and the screen surround occludes material with negative or off the screen parallax.

This methodology for image preparation resembles Method A, above. It is an approach that will be resisted by some practitioners because of their desire not to break the "stereo window" with off the screen effects. We give our advice for what it is worth. Take it or leave it, but we recommend the reader follow the teachings of the Cole Porter song and *experiment* before making up your mind about how to spend your parallax budget.

Practice Makes Perfect

We learned the techniques enumerated above work by using our 3D Studio plug-in. We advise the user to do the same. Play around with the image and learn how to produce a pleasing effect. The creation of good-looking autostereoscopic images is an art. Sometimes seemingly small variations make
the difference between a so-so and a good image. Our plug-ins lets you change lens angles, camera separation, distance to the objects from the camera, and the geometry of the universe. There is no excuse why a computer generated SynthaGram image shouldn't look simply splendid.