Techniques of Stereo Photography & Stereo Fractals

S. Rathinagiri, B.Com., FCA., DISA (ICAI) [#1]

[#]*52, N.P.S. Street, Sivakasi-626 123, India.*
[1]`srgiri@dataone.in`

Abstract— **This paper deals with creating stereo images and fractals using latest software technologies. Recent introduction of 3D digital camera by Fuji and Auto-stereo (lenticular) 3D LCD monitors by various companies into the tech-market clearly indicates the fact that the whole world is just rushing towards three dimensional imaging in the near future.**

Out of various concepts and areas available in 3D imaging, this paper covers only the stereo photography in particular. The process explained in this paper would be useful to both an amateur photographer and a corporate/professional image processing unit.

Keywords— **stereo photography, stereogram, lenticular, 3D fractals**

I. INTRODUCTION & HISTORY

Stereo photography has a long history dating back to 1850s. Creating and distributing stereo cards were so popular and commercially sold successfully world wide in those days [1]. These cards were parallel view stereo photographs. They required special devices to view them in 3D (3 Dimension) for those who couldn't view them properly. Now-a-days we can find many other alternate ways of viewing 3D images/movies in practice.
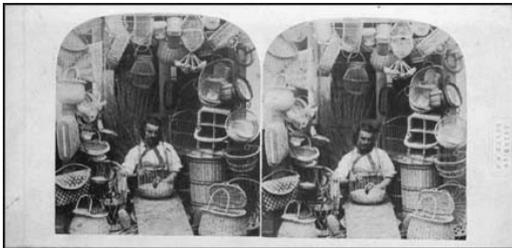

Fig. 1 A stereo card of a Brighton Basket maker by W H Mason Junior (c1862)

Why do we need stereo photography? With stereo photography one can virtually feel the depth in the picture rather than just imagining it. Stereo photography is nothing but mimicking the human vision. In stereo photography there are two different images, one for the left eye and another for the right eye. Each eye sees a different image and then the brain fuses the two images into one and the depth is perceived.

This paper deals with the processing of images in computers using specialised software to create professional stereo pictures/movies in various formats.

II. PROCESSES INVOLVED

Following are the processes involved in creating an effective stereo photo:

A. Finding out parallax/stereo-base

Parallax/stereo-base is the horizontal distance between the camera lenses. Since we have to take two pictures, one for left eye and another for right eye, it would be better if the space between the lenses is also equal to the inter-pupillary distance of human eyes ie., 60~65 mm. However, the stereo-base could not be the same for all the scenes; it depends mainly upon the distance between the camera and the nearest object. The approximate stereo base can be calculated with the help of the 1/30 rule. The rule states that the stereo-base should be equal to 1/30 times the distance of the nearest object. This would mean that the distance between the camera lenses should be increased for outdoors/distant objects and it should be reduced for close up/macro shots. The 1/30 rule comes from the first treatise on stereo photography by Brewster[2] who expressed it as an angular parallax of 2 degrees for an object of 6 feet distance.

Applying this rule, for example a stereo picture of moon was created using two pictures taken from Argentina and Spain at the same time.
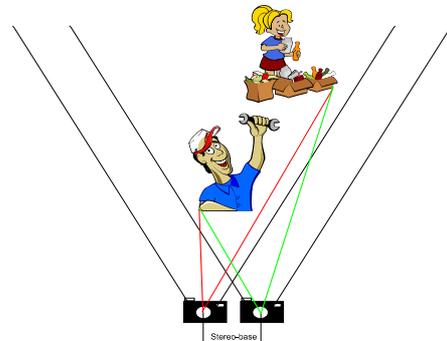

Fig. 2 stereo-base

We can see that the angles of the nearest and the farthest objects in figure 2 are different for both cameras (red for left camera and green for right camera). This is how human eyes see the picture and the brain perceives the depth. Using the same strategy, two cameras are fixed to capture two images to create a stereo photograph.

Fig. 3 shows both pictures taken separately by the two cameras side-by-side. We can observe that when widening the

stereo-base, the difference between the farthest and nearest object is widened more.

If the stereo-base is equal to the binocular vision of the eye it is called ortho stereo. If it is more, it is called hyper stereo. If it is less, it is called hypo stereo. In the ortho stereo all the objects in the picture would be in real size and the real depth can be felt. In the hyper stereo objects seem to be smaller than the real size and more depth than the reality can be felt. In the hypo stereo, objects seem to be bigger than the real size and the depth would be lesser. In general, hyper stereos are used for outdoors/landscape for wider coverage. Hypo stereos are used for close up/macro shots for fine details.

For most pictures (ie., objects within 5-9 feet range), normal stereo-base of 65 mm would be nice.
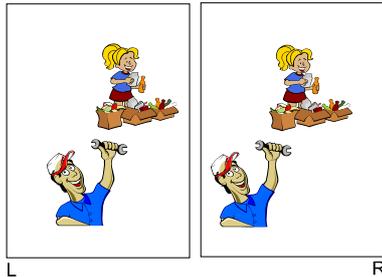

Fig. 3 Pictures shot by two cameras

In Fig. 3, the boy (nearest object) in the right picture (shot with right camera) has moved more to the left, than the girl (farthest object).

This can be proved easily by a real life situation. In a moving train, the nearest objects would move sooner than the farthest objects.

B. Capturing the stereo images:

After finalising the stereo-base either approximately or with accurate measurements, we can capture the images. There are many ways to capture the stereo images. Let us discuss about the commonly used methods here.

1) Cha-cha method: In this method, two pictures were shot with a single camera. First a picture for the left eye is captured. Then the same camera is moved horizontally towards right for a distance equal to the stereo-base and the second picture is captured for the right eye [2].

2) Twin camera rigs: In this method, two cameras of same type are fixed on a rod. (Fig. 4) The cameras can be moved horizontally to increase/decrease the stereo-base. Synchronization is achieved either manually or by triggering an electronic switch [3]. This is the best method for various reasons.

Fig. 4 Twin camera rig

3) 4 mirror rig: It is just like fixing two periscopes in a single camera. 4 mirrors are fixed (two for outboard and two for inboard) in a container as shown in Fig.5 and placed before the lens of a camera [4]. All the mirrors are fixed at an angle of 45 degrees. In this method, single camera can be used to capture both images for left and right eyes simultaneously.
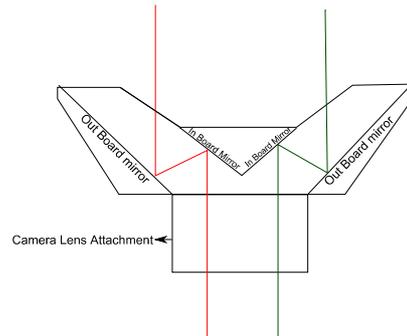

Fig.5 4 Mirror Rig

4) Twin lens 3D camera: Two specially made lenses are fixed in a single camera and stereo pictures are exposed on the same film as shown Fig. 6. In the picture captured, the left half will be for left eye picture and right for right eye.

Fig.6 Horseman 3D camera [5]

The advantages and disadvantages of each method are listed below:

PROS AND CONS OF STEREO CAPTURING METHODS

Method	Pros	Cons
Cha-cha	1. Adjustable stereo-base. 2. No special equipments are required and useful for amateur and entry level shooters.	1. Exposure, focus, light source must be maintained at the same level for both pictures. 2. Human errors are possible which would ruin the quality.

		3. Only suitable for stationary objects.
Twin camera rig	1. Adjustable stereo-base. 2. Post processing is very easy. 3. High quality stereo pictures. 4. Suitable for capturing objects which are moving.	1. Exposure, focus must be maintained at the same level for both cameras. 2. Investment for two identical cameras. 3. Not suitable for hypo stereos since distance between lenses can not be reduced. 4. Synchronization of the cameras is difficult [6]. Even for electronic synchronisation, 100% accuracy could not be achieved.
4 Mirror rig	1. Post processing is very easy. 2. High quality stereo pictures. 3. Suitable for capturing objects which are moving. 4. Need not worry about exposure, focus and light source since the pictures are shot with a single camera.	1. The rig is not commercially available. It is self made. 2. Stereo-base can not be adjusted. Therefore, not suitable for hyper and hypo stereos.
Twin lens camera	Same as 4 mirror rig and the camera is made available in the market and popular now-a-days.	1. Stereo-base can not be adjusted. Therefore, not suitable for hyper/hypo stereos.

C. Stereo processing:

Stereo pictures shot by using any of the methods mentioned above have to be processed further using special software to avoid window violations and vertical/rotational misalignments. Cropping of images is also required. Fortunately, a software, Stereo Photo Maker shortly known as SPM for processing stereo pictures is available as a freeware. It is even useful for professional/commercial 3D photographers. The software can be downloaded from http://stereo.jpn.org/eng/stphmkr/. This software is designed to handle even a batch of stereo pictures automatically.

Most of the people can see 3D pictures using cross-eye method . Hence, we can use that method for the various steps involved in stereo processing. This means that the image for the left eye is placed in the right side and the image for the right eye is placed in the left side.

First of all, any misalignments because of vertical/rotational errors should be removed. These errors will be more in cha-cha method since the camera is moved in between shooting the left image and the right image. Any tilt in the camera by y axis or z axis during the process of image

capture will cause misalignments. SPM can remove such misalignments automatically using auto adjustment. This can also be done manually using Adjustment -> Easy Adjustment in SPM.

In the next step, both left and right images should be aligned properly. In the stereo photography, the viewer feels like seeing the scene through a virtual window. This window is called stereo window which can be placed anywhere in the z axis.

If we place the stereo window in line with the nearest object, all other objects will be felt like seen behind the window (which are farther to the viewer). If we place the stereo window in line with the farthest object, all other objects (which are nearer to the viewer) will be seen like popping through the window. The stereo window can be placed in between the farthest and nearest objects also. In that case, part of the scene will be seen in depth and part of the scene will be seen before the window. This is shown in the Fig. 7.
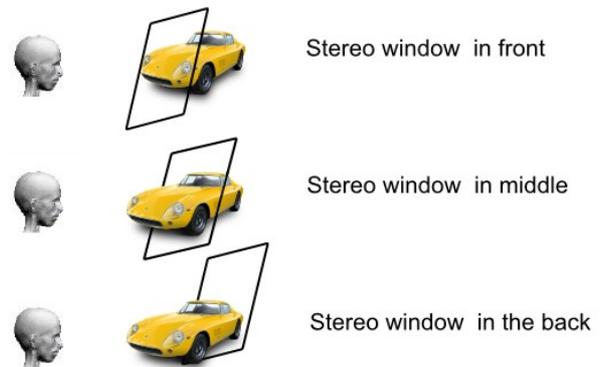

Fig. 7 Placement of Stereo window

The placement of the stereo window depends upon the left and right images available. The stereo window should be properly fixed. Otherwise, there will be a defect called window violation. A stereo window violation occurs when an object appears in front of the stereo window and is cut off by the window [7]. It is a physical impossibility that a window frame, seemingly appearing behind the object, is able to obscure it. Usually, this paradox cannot be well processed by our brains and such an image hurts our eyes.

To avoid window violation, the stereo window should be brought to the front. Better effects can be achieved if the stereo window is placed either in between the front and the back or in the back. However, utmost care should be taken to avoid the window violation. The trick is called 3L Rule. You should see "Less to the Left in the Left eye view" [7]. It means that if some area is cut in the left side of the left eye image, it will not affect the 3D effect.
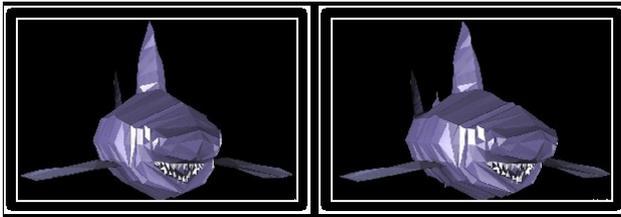
Fig. 8 Stereo window in the middle

For example, in Fig. 8 the stereo window is placed in the trunk. The head of the shark is peeping through the window and the tail is behind the stereo window.
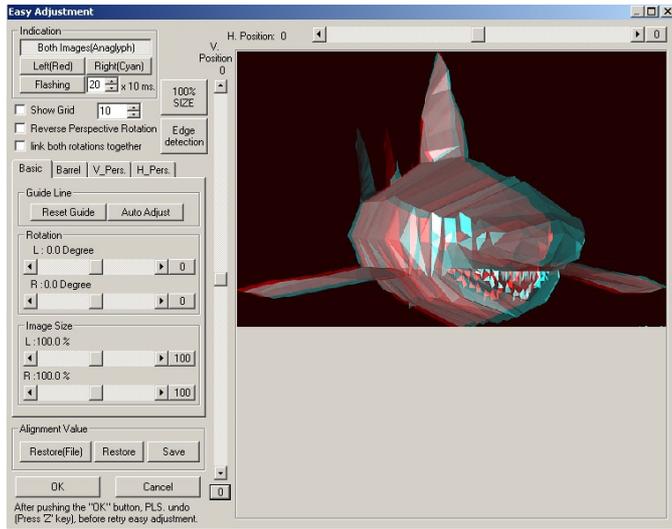

Fig. 9 Adjustment of Stereo window

This is the easy adjustment dialog of SPM with the stereo image seen in Fig. 8. In this picture we can observe that the head of the right shark is (cyan colour) moved more towards the right and the tail of the right shark is moved more towards the left. The trunk is on the same place in both images.
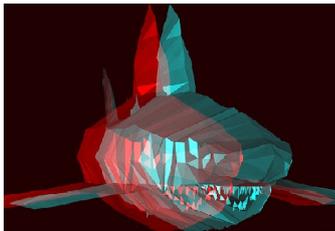

Fig. 10 Window violation

If we take the tail as the base and move the stereo window to the back, then we can see that some area of shark's fin is cut in both sides. This causes window violation.

Stereo window can be moved towards the front and the back using the horizontal position slider of easy adjustment dialog. (Fig. 9)

After aligning the left and the right images and fixing the stereo window, the main part of stereo processing is done.

D. Post processing:

Post processing of stereo images consists of cropping, drawing borders/watermarks/logos, framing and exporting the stereo pictures in various formats. Except framing, all the post processing can be done using the SPM software. The main advantage of using SPM for these processes is that the effect is applied on both source images simultaneously.

Cropping the stereo image should be done in such a way that the nearest object in line with stereo window should be available in both images.

Bordering in stereo picture is not just decorative. It has a special purpose. It depicts the virtual stereo window while viewing in 3D. SPM has bordering facility along with designing of borders. A maximum of three borders can be used. Width and colour adjustments are available for each border.

Watermark/logo can be placed in the stereo window in any depth. This can be done in SPM using edit->add text and edit-> add logo image function. Position, font, colour, depth can be adjusted.

Framing or Out Of Bounds effect (OOB) is a modern concept of avoiding the window violation. In framing, area available in both left and right images only are retained. The excess area in left image which is not in right image and the area in right image which is not in left image will be masked with single colour.

Fig. 11 OOB effect/Framing

In the above figure, unnecessary area is masked with white colour, there by avoiding window violation. Even though the farthest object (cloud) and the nearest object (floor) seem to be placed in the same stereo window, it is imaginary. When viewed in 3D, we can observe that the stereo window is placed well behind the scene and the aircraft is popping through the window naturally without any window violation.

For framing we have stereomasken software which is available as a freeware. It can be downloaded from http://www.stereomasken.de. This software is exclusive for framing and no other processing can be done. It has excellent options for designing frames in any shape, any size. A single point or a selected area can be moved in any axis. With the available tools, it is a patient art work to create a frame without any window violation.
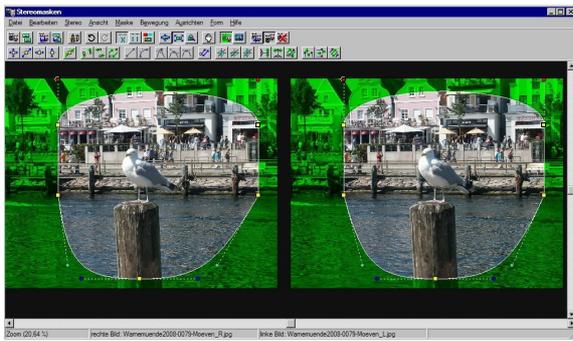
Fig. 12 Stereomasken application

Next important and final step is exporting to the format we require. Following are the formats available [8]:

1) Cross-eye format: In this format both images are placed side-by-side after swapping. The left eye image is placed on the right side and the right eye image is placed on the left side of the stereo picture. More than 70% of the people find it easy to view 3D pictures in this format. This is also called as X-View method. The viewer has to cross his/her eyes and focus in between the image and eyes. The two images will be fused together and a third image will be emerged in between, which is the 3D image.

2) Parallel view format: The left eye image is placed in left side and right eye image is placed in right side of the stereo picture in this format. The viewer has to focus through the image.

3) Anaglyph format: This is a popular format of 3D effect which is viewed with 2 colour glasses in which each lens is a chromatically opposite colour, usually red and cyan (red for left eye). Both grey and colour anaglyphs are available.

4) Interlaced format: This is useful for 3D lenticular printing and 3D LCD TVs wherein both images are interlaced together and while viewing from a particular angle, the left eye sees the left image and right eye sees the right image to view the scene in 3D.

Stereo photo maker is capable of exporting in any of the above mentioned formats.

III. 3D STEREO MOVIES/ANIMATION

For 3D stereo movies we require two video cameras and all other settings are the same as above. The movie files can be processed just like two photos and saved in a single movie file in any of the above mentioned format. The software for processing stereo video is also available free. It is called Stereo Movie Maker. It can be downloaded from http://stereo.jpn.org/eng/stvmkr/index.html.

Animation software like Blender, 3D Studio Max, Maya are capable of rendering the animation movies for left and right eye separately if two cameras are defined. These movie files can also be processed using stereo movie maker.

IV. STEREO FRACTALS

Another area of interest in 3D is stereo fractals. Fractals are creative, interesting images with eye catching random colours created using various mathematical functions. There are softwares available for creating various types of fractals called flames, Mandelbrot fractals, Julia set etc. Creating stereoscopic images from these fractals are possible. Since these images are fully rendered using computers, high quality stereo images with nice 3D effects can be created.

For stereo fractals also, we have to render two images (one for the left eye and another one for the right eye) of the same fractal. Then we can use SPM for further processing as discussed above.

Apophysis software is one of the best fractal softwares which can be used for rendering 3D fractals also. The software is open source and available under General Public License. This can be downloaded from http://www.apophysis.org/. There are two versions available. 3D hack version is useful for rendering 3D fractals. There are many plug-ins available in the internet for various effects.

There are so many options in the software for creating wonderful fractals. They are beyond the scope of this paper. We can restrict ourselves in rendering two images of a fractal as seen from different angles (remember moving the camera horizontally in cha-cha method).

Let us discuss about creating a stereo fractal using Apophysis software.

First of all, we have to select a fractal. Apophysis software is capable of creating random fractals.
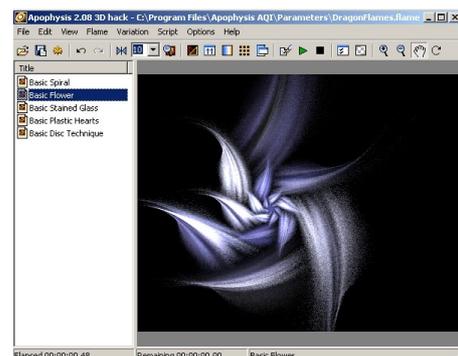

Fig. 13 Apophysis main window

After selecting a fractal, we have to select adjustment options by pressing F5 or selecting from the tool bar. In adjustment window we shall make the value of pitch as 90. This is the view of the fractal if we see it in z axis (Fig. 14). We can see that the above flower is in 2D. However, we can add 3D effect using 3D variations available in Apophysis.
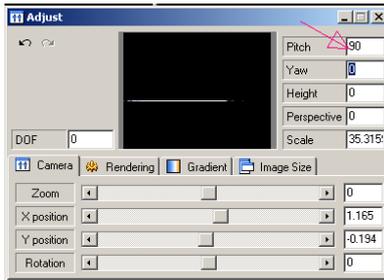
Fig 14 Z axis view

Now, we have to select Transform editor by pressing F4. In this dialog, we see some triangles which act as the basic foundation in forming part of the fractal. In the right side of the dialog, we have many variables to adjust. In the variations tab, we shall enter zcone value as 1 (Fig. 15). Instead of selecting zcone, other 3D effect variations can also be selected. Here we have selected zcone as our 3D variation. Value can also be any number (positive or negative).
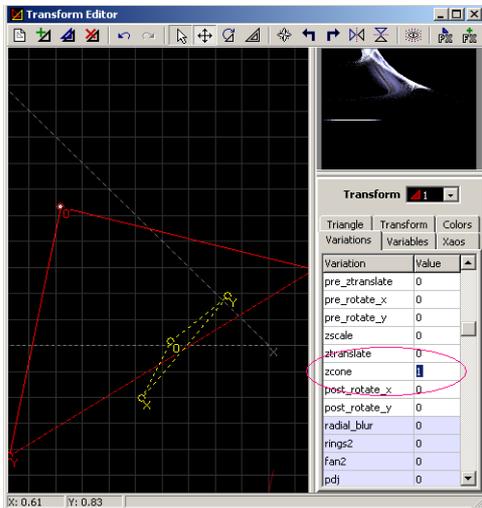

Fig. 15 Transform editor

Now, we can see that the flower has got some 3D shape. After assuring that this fractal has some 3D shape, we can revert back the pitch value to 0. We can observe by entering various angles in pitch (from 0 to 360) that it is rotation of the fractal in x axis.

To imitate the human eyes, we have to rotate the fractal in y axis. To switch from x axis to y axis, in adjustment dialog, we have to enter 90 in rotation (Fig. 16).
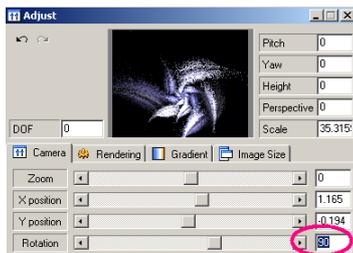

Fig. 16 Switching rotational axis

After rotation, the pitch axis would be switched to y axis. We can change the pitch value for vertical rotation. We shall enter -5 for the left eye and +5 for the right eye. This can be any two numbers from -180 to + 180. The lower value is for the left eye and the higher value is for the right eye. However, in 3D stereo window, we would see the mid point pitch. We have to render two images, one with a lower pitch and one with a higher pitch. The difference between the two will be the stereo-base of the stereo fractal. This should be maintained in optimum level. Higher stereo-base would irritate the eyes with too much depth. Lower stereo-base will not give any 3D stereo effect.

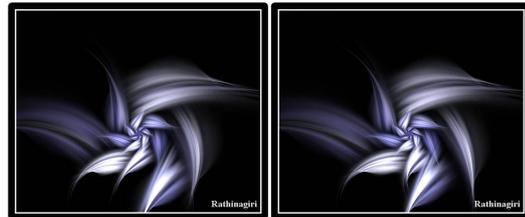In Fig. 17, we can see the cross-eyed stereo fractal with watermark and bordering.

Fig. 17 3D stereo fractal

V. CONCLUSION

Stereo photographs, movies and fractals are gaining more popularity recently. There are huge resources and information available in the internet. Many 3D movies in cross view format and parallel view format can be viewed in youtube [9] and other online video streaming servers. Server side web applications are also available to convert from one format to another online, making a common platform for 3D imaging. Hardware requirements for 3D image processing are also getting fulfilled.

Stereo technology is not only used for entertainment purposes but also used in high end technologies. Robots can move around precisely in the real environment only if they are equipped to recognize the difference between the nearest objects and the farthest objects. With two cameras acting as eyes for the robots, stereo technology helps to determine the distance between the objects using depth maps [10].

Hence, the future for 3D is wide open. Soon, 3D imaging may be the standard image processing method to rule the world and 2D imaging may be seen only in museums.

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