

# Computer-Generated Stereogram

## – Review on Stereogram and Works of Art –

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Recently, many kinds of computer-generated stereograms (CGSs) as the area of art produced by the use of computer are published for hobby and entertainment. It is said that activation of brain, improvement of visual eye sight, decrease of mental stress, effect of healing, etc. are expected when CGSs are properly appreciated.

There is a lot of information on the internet web site concerning all aspects of stereogram history, science, social organization, and various types of stereogram. Generally, CGS is classified into six types: (a) stereo pair type, (b) anaglyph type, (c) repeated pattern type, (d) random dot type, (e) single type called single image stereogram (SIS), and (f) modified multi-type such as embedded, united, and synthesized stereogram. Each stereogram has advantages and disadvantages when viewing the stereogram with two eyes. In this review, the characteristics of CGS, the role of depth map image (DMI) called hidden image or picture, and that of texture pattern image called wall paper are studied and discussed through the modified CGSs corresponding to the embedded, united, and synthesized stereograms for the parallel viewing method.

### 1. Introduction

Digital stereoscopic display techniques on stereograms and optical holography techniques on holograms have advantage and disadvantages respectively, concerning the demonstration and visualization of 3D virtual images.

**Table 1** shows an example of frequently asked questions (FAQs) on stereogram. In the stereogram, a depth map image (DMI) with gradation in black, gray and white colors and a basic texture pattern must be prepared in advance. Two different types of images correspond to object and reference waves which are necessary for producing an optical hologram. A notion for fabricating the stereogram resembles in that of producing the hologram optically, though the quality of 3D virtual image is different between the two each other. See **Table A** in the appendix with regard to comparison of stereogram and hologram.

Many people are straining their eyes by looking at a computer screen or small mobile telephone monitor for hours every day. A fancy picture or pattern image called stereogram has been in fashion and been used in recent years in order to improve eye fatigue or mental stress by finding hidden objects in the stereogram for hobby with having a good time [1]. Once you perceive the hidden image after training with a little patience, you can look around the 3D virtual image with depth. The farther away you hold the stereogram, the deeper the impression of depth becomes. The 3D virtual depth perception takes place with the function of brain by viewing properly a computer-generated stereogram (CGS). As a result of stereopsis, the brain gives our minds a sense of virtual depth or 3D distance psychophysically.

There is no need of the special viewer or glasses for binocular vision when viewing the CGS by means of ① “parallel viewing method” or ② “crossed viewing method” [2].

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**Table 1 Frequently Asked Questions on Stereogram**

<p>(1) What is a stereogram or CGS ?</p> <p>(2) Why do we have to prepare a DMI and texture pattern in order to fabricate a stereogram in advance ?</p> <p>(3) How is a stereogram fabricated ?</p> <p>(4) How is a stereogram viewed ?</p> <p>(5) What is the main type of stereogram ?</p> <p>(6) What are some applications of stereogram ?</p> <p style="text-align: center;"><b>Stereograms are available to us in daily life: Hobby or Entertainment ! Activation of brain activities ! Eye Therapy !</b></p> <hr/> <p style="text-align: center;"><b>What is the difference between stereogram and hologram ? (See Table A in appendix.)</b></p>
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The visual appearance of CGS, i.e. a sort of illusory images which seems to float in the apparent space for stereoscopic vision is similar to that of the 3D virtual images reconstructed from an optical reflection type hologram. However, there are notable differences between the two in principle. It is possible to view directly the CGS at computer screen or on printed paper in color. On the other hand, we may view a perfect 3D virtual image with depth by using only a broken small part of hologram.

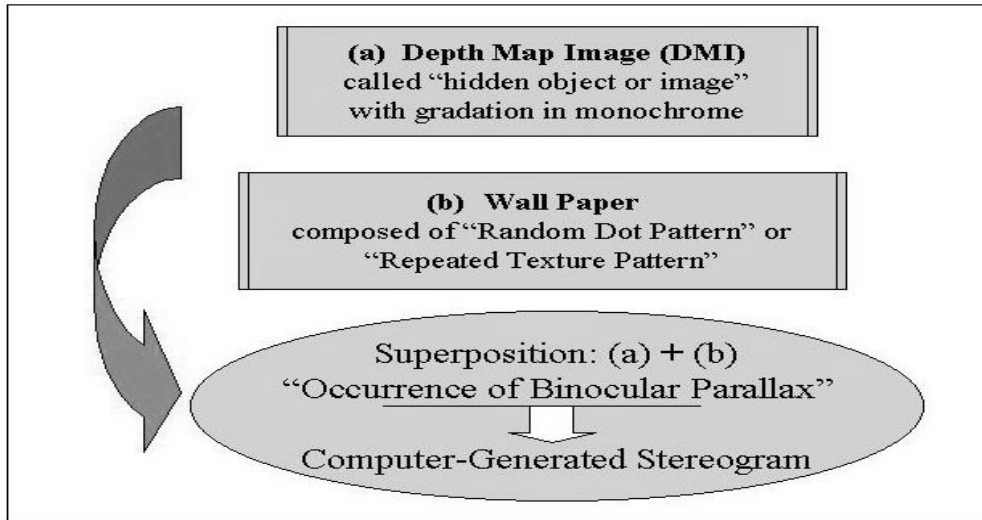
We published the influence of depth perception caused by modifying DMI with gray level for CGS and its subjective estimation [3]-[4]. In this review, the role of DMI called hidden image or picture and that of texture pattern image called wall paper are discussed through the multi-type stereograms such as embedded, united, and synthesized stereograms for the parallel viewing method, respectively [5].

## 2. Three different types of Computer-Generated Stereograms

The main role and characteristics of DMI and texture pattern which are necessary for fabricate CGS are shown in **Figure 1**. It is important to use an idea of superposition of DMI and basic texture pattern in order to fabricate a binocular parallax image, i.e. a stereogram.

As an application technique of single image stereogram (SIS), there are three different types of stereograms called (a) embedded, (b) united, and (c) synthesized stereograms, respectively. These three stereograms have merits and demerits in contrast to the general SIS.

**Figure 2 (a) and (b)** shows the simple procedure for fabricating CGS. In Fig.2 (a), a hidden object or image often with gradation called DMI may be prepared from the digital color photograph or by using computer graphics (CG) technique in advance. In the next step as shown in Fig.2 (b), it is necessary to prepare the DMI with gradation in monochrome. The basic texture pattern image called wall paper is demonstrated at the left lower part. By using a kind of free software, we can simply fabricate a variety of CGSs by altering the original texture size or pattern type. Many works of art and the free software are widely released at the internet website [6].



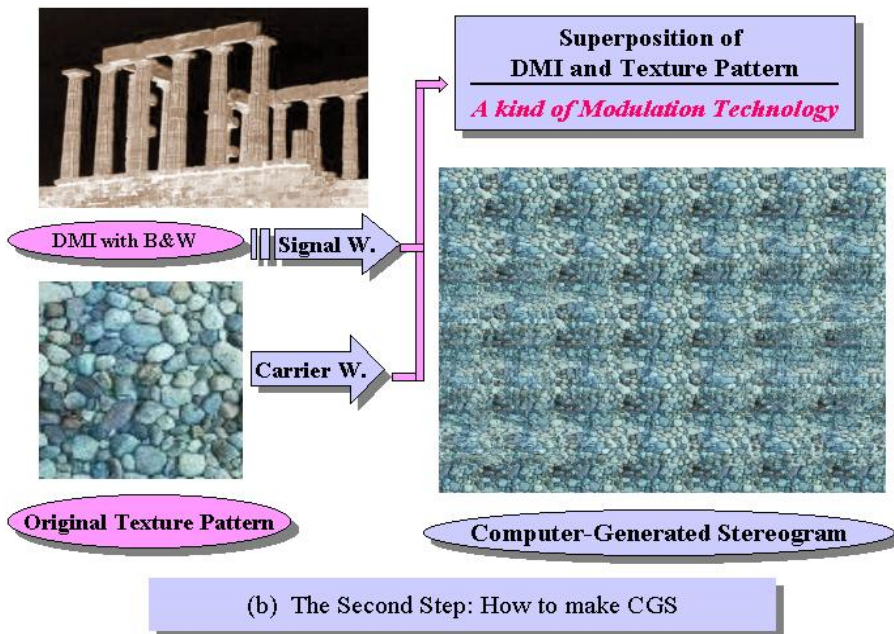
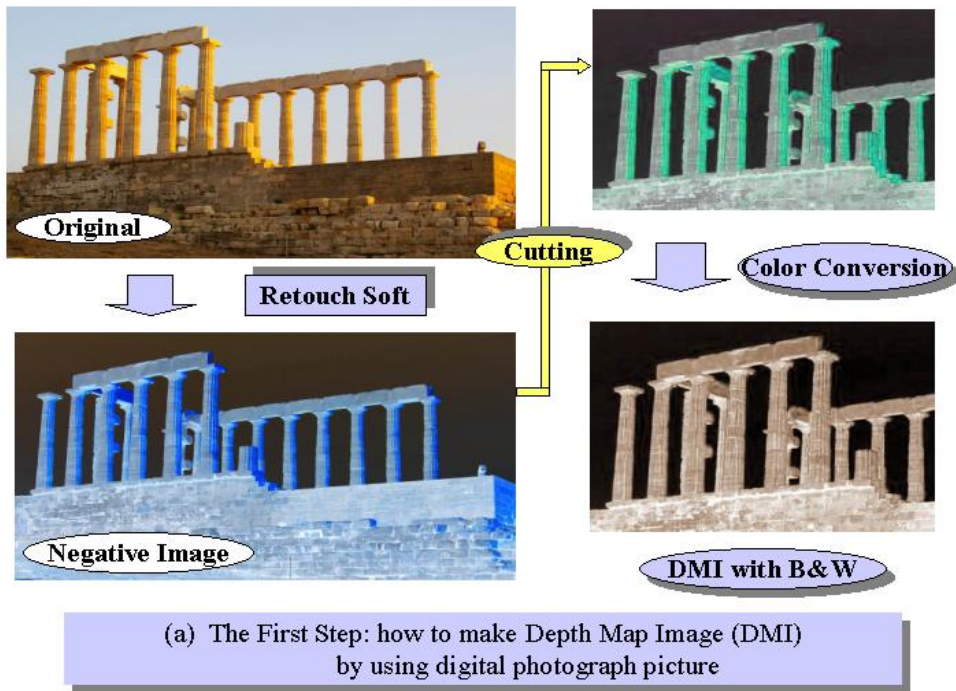
**Figure 1 Composition of Computer-Generated Stereogram (CGS)**

In the case of the embedded stereogram, the border between an original background image and special SIS is very clear and a little unusual. It is important to take account of the choice of the basic texture which is cut off from an original image or picture.

**Figure 3 (a) and (b)** shows comparatively the main procedure and its characteristics between the two modified stereograms. In the united stereogram, multiple hidden images composed of a set of DMIs must be prepared in advance when fabricating the CGS. On the other hand, a set of SISs must be arranged up and down or side by side for fabricating the synthesized stereogram. In the case of the synthesized stereogram, two different SISs are generally arranged side by side. As a result, it should be noted that the vertical border part between two SISs affects psychophysically image degradation of a sort as regards the subjective estimation of visual depth perception. It is possible to view simultaneously multiple hidden object or image in the united and synthesized stereograms in contrast to a general SIS or embedded stereogram.

### 3. Art Works of Computer-Generated Stereogram and Discussions

**Table 2 and Table 3** show the main role and characteristics of DMI and texture pattern, respectively. The topics which are described in Table 1 and **Table A** (See Appendix.) should serve as a brief summary for readers not well-versed in an idea of CGS. It is necessary to prepare DMI and texture pattern in advance when fabricating three different types of stereograms, i.e. (a) embedded, (b) united and (c) synthesized stereograms, respectively. The visual appearance of image with 3D virtual depth is noticeably affected by the quality of DMI with gradation. To our regret, it is impossible to take a photo of 3D virtual image which seems to float in the virtual space between the stereogram plane and eye position of viewer or observer in contrast to the optically reconstructed hologram image. As a result, it is very difficult to quantitatively estimate the visual appearance of CGS. But, it is possible to make a subjective estimation as regards the relative degree of depth perception or quality of 3D virtual image when viewing simultaneously the similar CGS as demonstrated in Fig.3.



**Figure 2 Simple Procedure for Fabricating Computer-Generated Stereogram (CGS)**

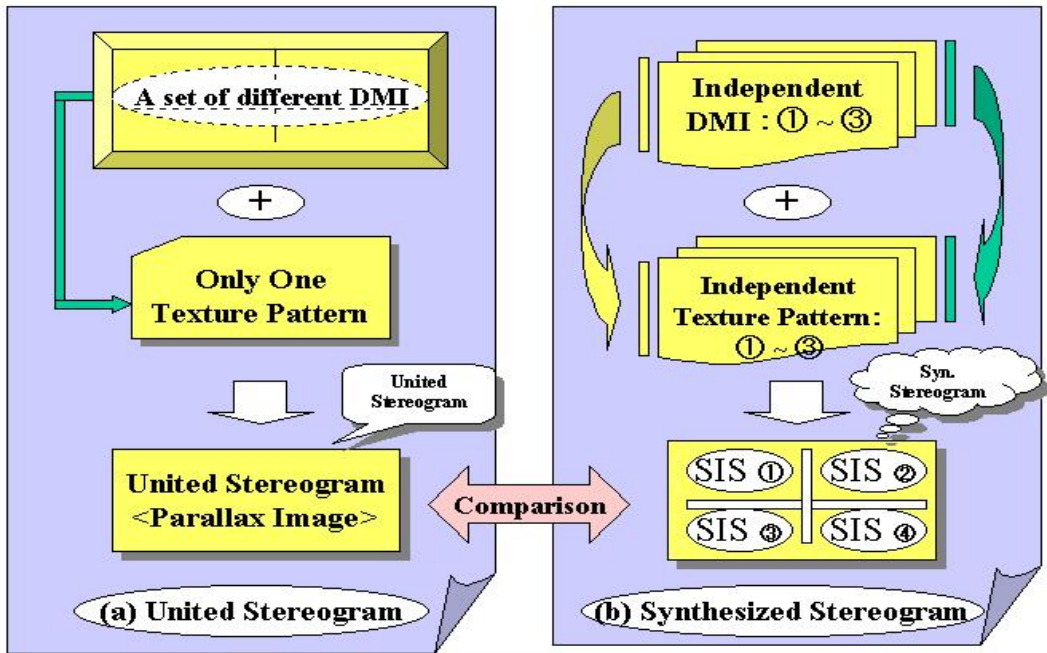
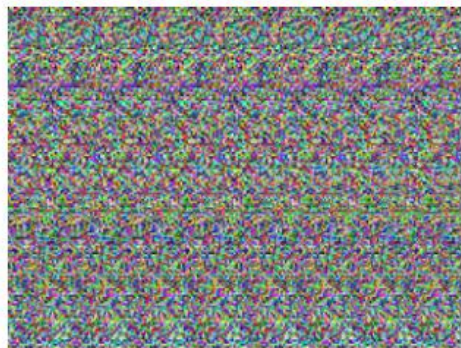


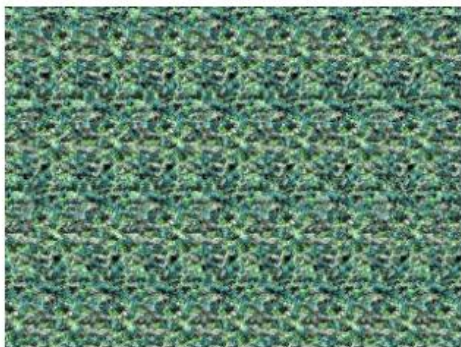
Figure 3 United and Synthesized Stereograms



(a) DMI with gradation



(b) RDS



(c) SIS

Figure 4 DMI and Two Types of Stereograms

**Table 2 Outline on Depth Map Image (DMI)**

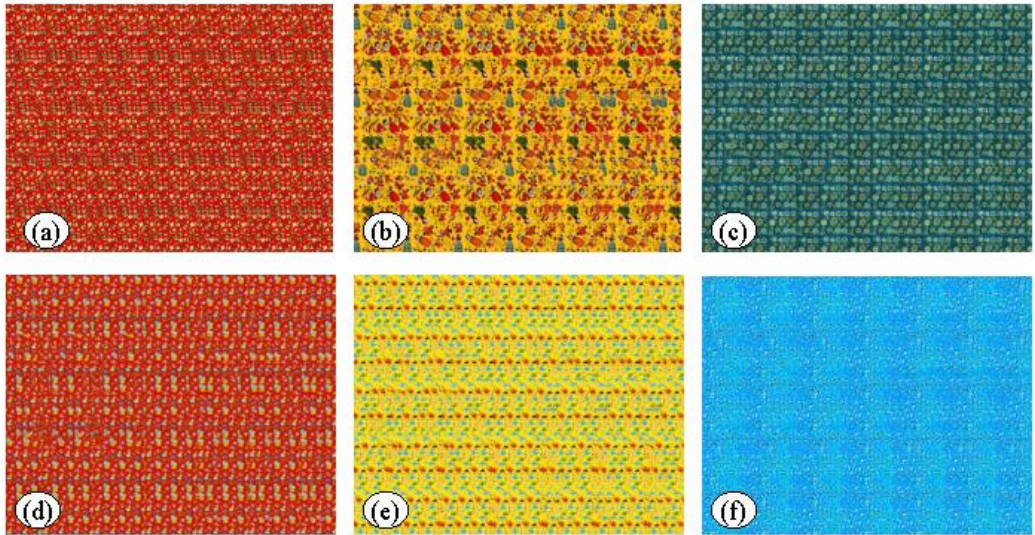
- (a) It is necessary to prepare a hidden image called DMI in advance, when fabricating a computer-generated stereogram such as RDS SIS, and embedded, united, and synthesized stereograms.
- (b) Generally, the DMI corresponds to a specified 2D object or image with gradation of gray level.
- (c) By printing out the DMI with gray level on a color paper, we can simply modify the degree of 3D virtual depth on stereogram.
- (d) A variety of DMIs have been demonstrated in order to fabricate a CGS together with texture pattern on web site.
- (e) By means of Computer Graphics (CG) techniques or special software, we may produce a DMI.

**Table 3 Outline on Texture Pattern**

- (a) It is necessary to prepare a texture pattern called wall paper, when making a computer-generated stereogram such as SIS.
- (b) Generally, the texture pattern corresponds to a kind of 2D scene or image displayed in color.
- (c) We may think out a unique scene or graphical pattern as an original image to order to modify the image quality of 3D virtual depth, i.e. visual impression on stereogram.
- (d) A variety of texture patterns have been demonstrated for fabricating a SIS together with DMI on web site.
- (e) By means of Computer Graphics (CG) techniques or special software, we may produce a fancy pattern.

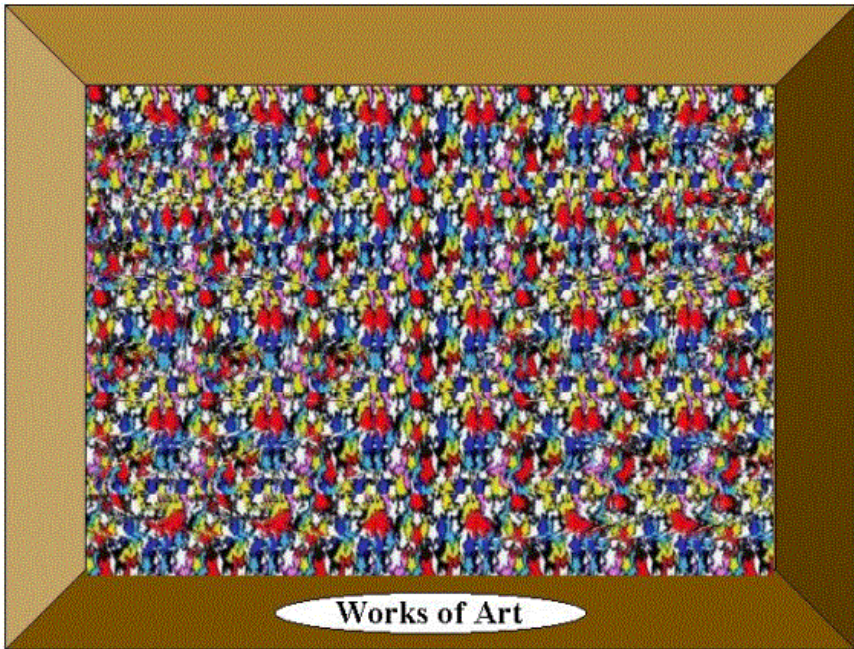
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***[Note] The horizontal scene or pattern has a repeated texture. As a result, the parallax image for stereoscopic vision must be used in place of using a set of random dot in the SIS.***



What is a hidden object called DMI ?  
Which type of SIS is a good and clear image ?

**Figure 5 Six Types of SISs with different texture pattern**



**Figure 6 Computer-Generated Stereogram**

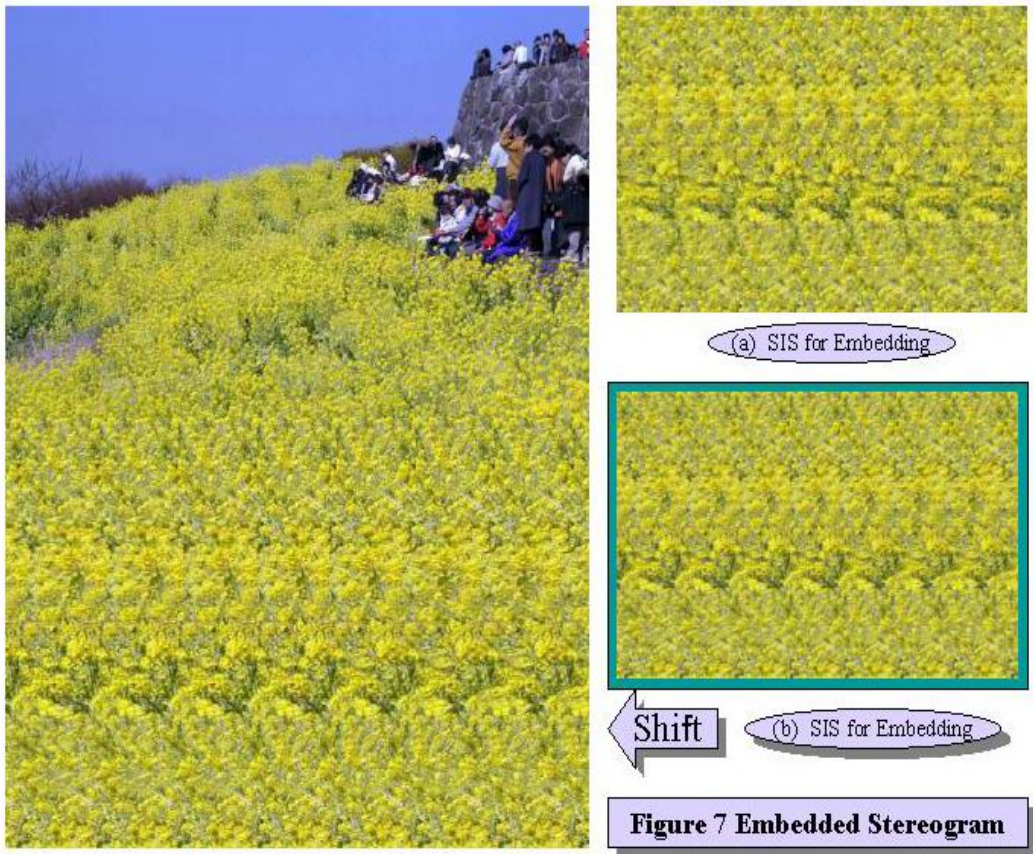
**Figure 4** shows the original DMI and two types of stereograms such as RDS and SIS. Two CGSs have the same depth perception, when viewing simultaneously the upper and lower stereograms as demonstrated in Fig.4.

**Figure 5** shows six different SISs with the same DMI. It is possible to discern the difference of image quality each other as regards 3D virtual depth.

In **Figure 6**, the special characters such as “Works of Art “ composed of three lines are used as the DMI. We may subjectively discern the degree of depth perception when viewing properly the CGS, because the DMI with three levels of gradation is prepared in advance.

**Figure 7 and Figure 8** show the works of embedded stereogram. As the background image, two kinds of digital photo and color picture for leaflet are applied for fabricating CGS. In Fig.7, type (b) SIS at lower right is used for embedded stereogram. On the other hand, the original image and embedded stereogram are demonstrated in pair in Fig.8. The hidden object, i.e. DMI is embedded at the lower part in Fig.8 (b).

**Figure 9** shows original image composed of a set of four types of DMIs and united stereogram corresponding to a general SIS. In the restricted size, four different SISs are mixed and fabricated simultaneously though we may seem to only one stereogram at glance. It is impossible to divide the united stereogram into the four separated and isolated SISs directly. Note that we can separate each SIS from the synthesized stereogram which is composed of four SISs and demonstrated in Fig.10.







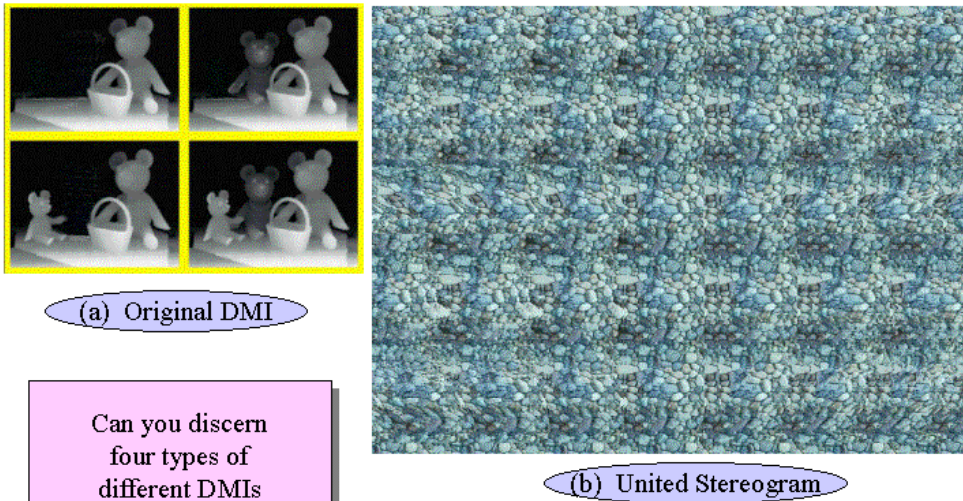
**Figure 8 Original Image and Embedded Stereogram**

**Figure 10** shows an example of synthesized stereogram. As shown in Fig.3, the united stereogram and synthesized stereogram are different as regard to the main procedure for fabricating stereogram each other. It should be noted that two stereograms arranged side by side affect degradation of quality of image with 3D virtual depth in comparison with stereogram arranged at upper and low parts. The latter does not affect the binocular parallax in contrast to the former. In this stereogram, a quarter of the upper right is a little separated intentionally in order to demonstrate an idea of synthesized stereogram.

The SISs consist of almost identically repeated or random patterns in the horizontal direction. The texture pattern is also repeated in the vertical direction, but that is not necessary for fabricating the CGS. For purely aesthetic reasons, we will not consider RDS, but the principles are almost the same.

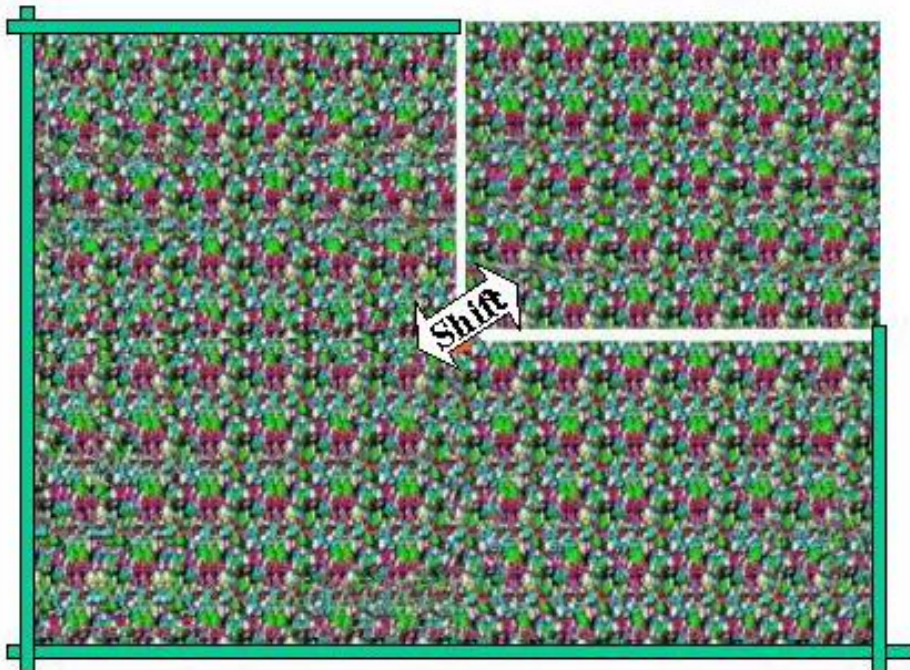
A 2D fancy picture or pattern image called stereogram will be widely used from now on. To find unknown objects or images hidden from CGS has a relation to the function of brain. The improvement of eye fatigue or eye sight, and the decrease of mental stress is considerably expected by viewing a variety of stereograms properly for hobby or entertainment by having a good time from the psychophysical viewpoint.

The binocular parallax and convergence arise in our brain. As a result of psychophysical effect, the magnitude of 3D virtual depth increases quantitatively together with that of the binocular parallax as shown in Appendix **Fig.A**, assuming that the pupil distance and viewing distance are constant.



Can you discern four types of different DMIs from only one "united stereogram" ?

**Figure 9 United Stereogram using Four Different Types of DMIs**



**Figure 10 Synthesized Stereogram using Four Different Types of DMIs**

#### 4. Conclusions

Three types of stereograms, i.e. embedded, united, and synthesized types have distinctive merits and demerits among others. An embedded stereogram has characteristic feature, i.e. a texture pattern corresponding to a special figure or photo. A united stereogram is available for psychophysical estimation of 3D depth perception in the case of the simultaneous observation. A subtle vertical strip pattern caused by the effect of unusual parallax may be unexpectedly discerned between two stereograms side by side in a synthesized stereogram. It is impossible to take a photo of 3D virtual image in order to estimate the magnitude of depth in the case of stereogram.

#### References

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**Table a : List of original words & abbreviation**

Depth Map Image ( <b>DMI</b> )
Computer-Generated Stereogram ( <b>CGS</b> )
Random Dot Stereogram ( <b>RDS</b> )
Single Image Stereogram ( <b>SIS</b> )

#### <Appendix>

There is a special skill or way that allows you to view a stereogram by means of the parallel view method. The secret is not to focus on the flat stereogram, but to relax your eyes and try to make it turn fuzzy. At first, you have to be a little patient and exercise. Once you find the proper way to look at it, everything becomes really simple. The 3D virtual image will appear between the eye position and stereogram plane.

In order to estimate quantitatively depth perception between two different objects, two kinds of illustrated diagrams together with simple expressions are shown in **Fig.A** and **Fig.B**. In Fig.B, binocular parallax does not occur on two points: A and A' of the circumference.

**Fig.C** shows two kinds of SISs by modifying the size of basic pattern, i.e. horizontal width of texture pattern. It is possible to simply alter the degree of depth perception. The binocular parallax happens in the brain when viewing the SIS. As a result, we may psychophysically evaluate the visual difference of 3D virtual image with depth. **Fig.D** as well as Fig.2 (b) shows an example of DMI, texture pattern, and SIS.

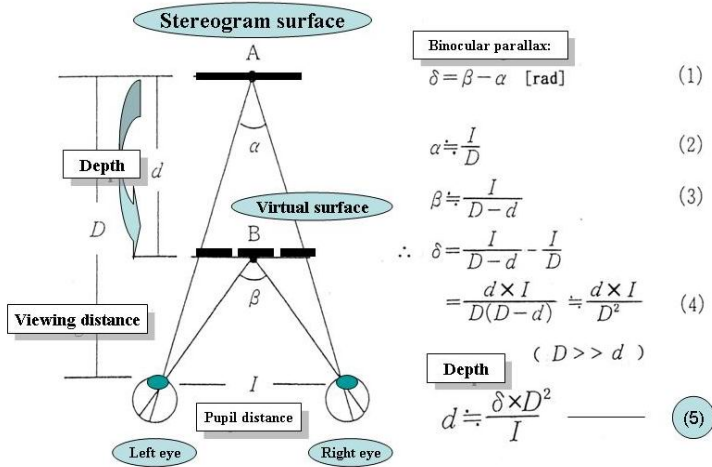


Fig.A Depth and Binocular Parallax in the Case of Binocular Vision

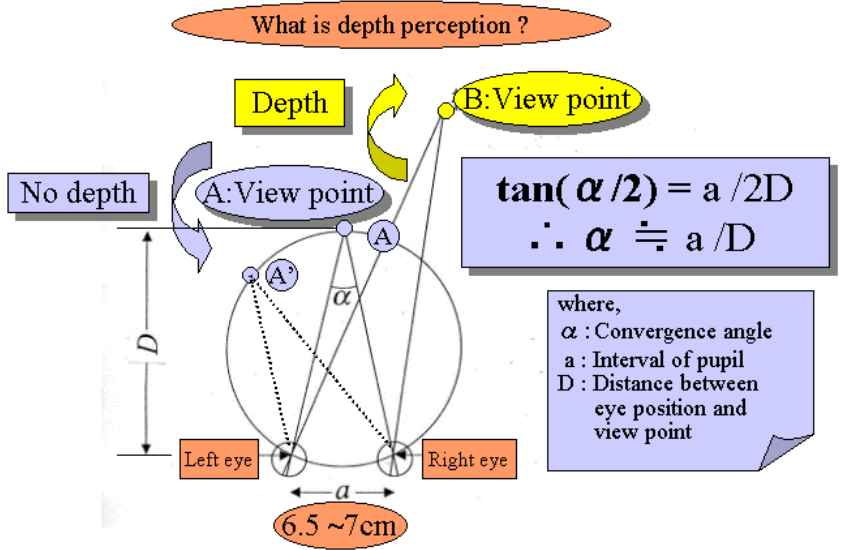


Fig.B Binocular Parallax and Convergence Angle



(a) What is DMI ? ; Is there depth perception between two ?



(b) Are two SISs the above same DMI ?

Fig.C Two types of SISs by modifying period of basic texture pattern

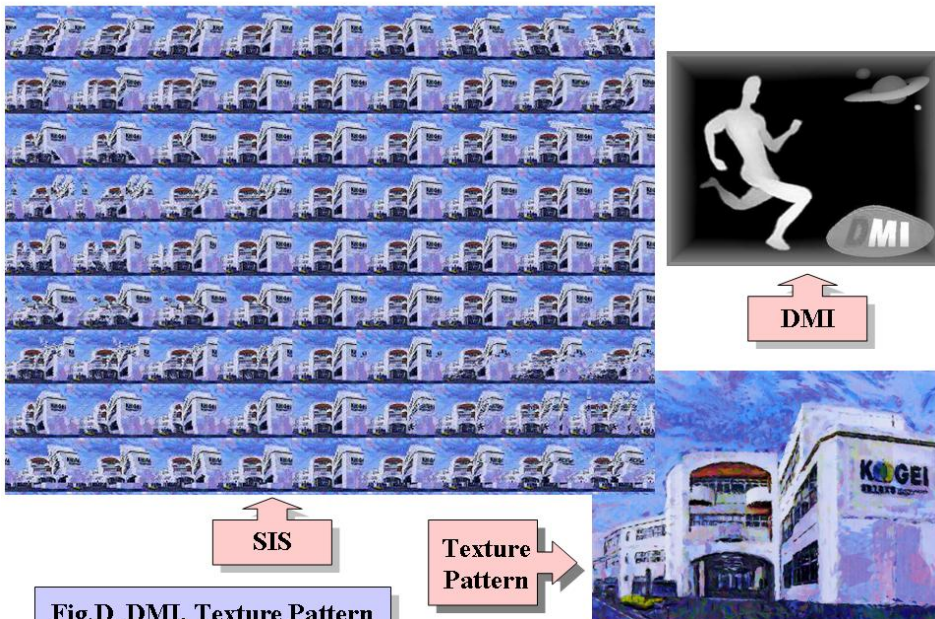
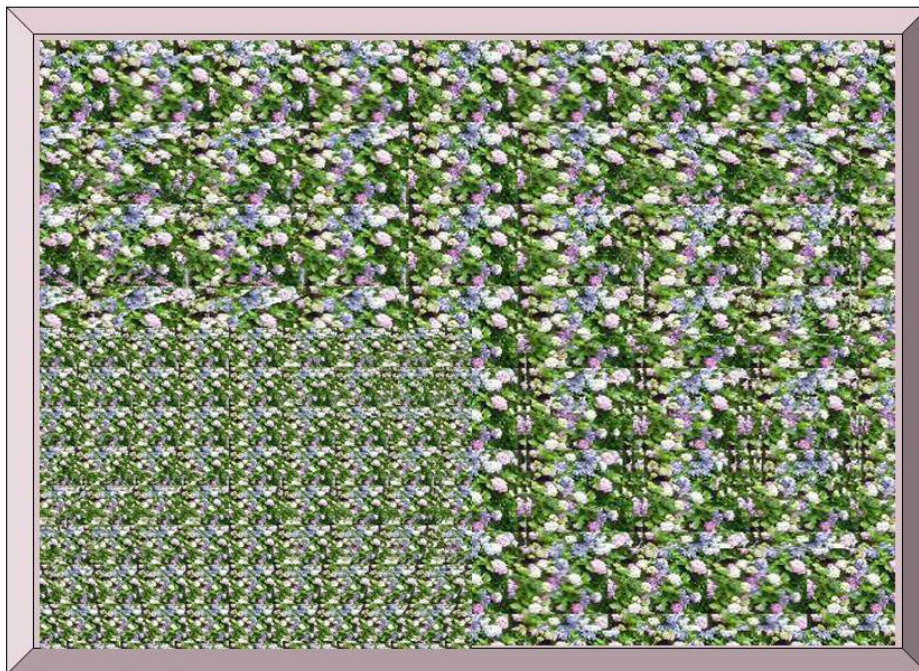
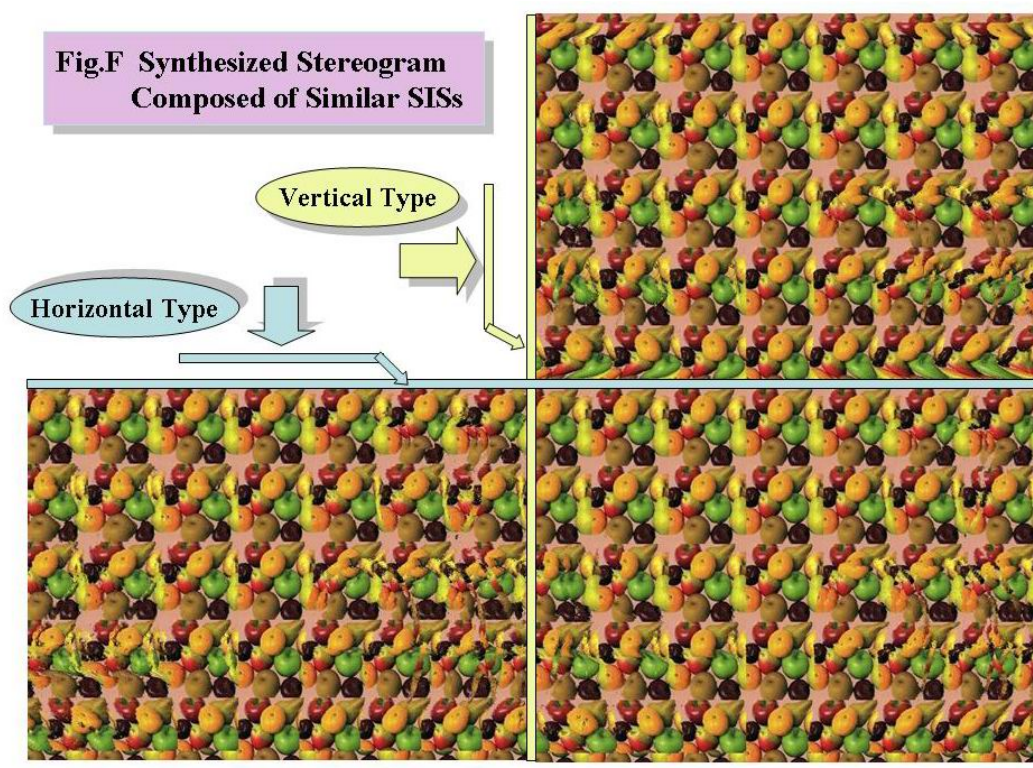


Fig.D DMI, Texture Pattern and SIS

Art work of CG produced by Associate Prof. KASAO  
Bulletin of Faculty of Arts, Tokyo Polytechnic University, Vol.12 (2006)



**Fig.E Mixed Type Stereogram composed of SIS and United Stereogram**



**Table A** shows a simple comparison of stereogram and hologram. A stereogram can be fabricated by using a computer soft ware such as “3D Miracle”. On the other hand, a hologram can be fabricated using a photographic film and laser light.

**Table A Comparison of Stereogram and Hologram**

**(a) Stereogram**

- (1) A stereogram, i.e. 2D plane image may be fabricated from a superposition of depth map image (DMI) called “hidden image” with gradation in black, gray and white colors, and random dot or repeated texture pattern called “wall paper”.
  - (2) A variety of stereograms called computer-generated stereogram (CGS) have been fabricated by a computer.
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**(b) Hologram**

- (1) A hologram as well as a stereogram is a record of 2D photographic image, i.e. interference pattern based on “reference and object waves” produced by a laser light.
- (2) Its principle was discovered by D.Gabor.
- (3) The term “hologram” was coined from the Greek word: holos, meaning “whole”, and the Greek word: gramma, meaning “message or record”.
- (4) A 3D real object is recorded on the special holographic film or plate as a kind of interference pattern, and then reconstructed with a laser light.
- (5) The main process is called “holography or holographic technology”.
- (6) The hologram contains lots of information about the size, shape, brightness, and contrast of 3D real object.