

Content metamorphosis in synthetic holography.

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Abstract. A synthetic hologram is an optical system made of hundreds of images amalgamated in a structure of holographic cells. Each of these images represents a point of view on a three-dimensional space which makes us consider synthetic holography as a multiple points of view perspective system. In the composition of a computer graphics scene for a synthetic hologram, the field of view of the holographic image can be divided into several viewing zones. We can attribute these divisions to any object or image feature independently and operate different transformations on image content. In computer generated holography, we tend to consider content variations as a continuous animation much like a short movie. However, by composing sequential variations of image features in relation with spatial divisions, we can build new narrative forms distinct from linear cinematographic narration. When observers move freely and change their viewing positions, they travel from one field of view division to another. In synthetic holography, metamorphoses of image content are within the observer's path. In all imaging Medias, the transformation of image features in synchronisation with the observer's position is a rare occurrence. However, this is a predominant characteristic of synthetic holography. This paper describes some of my experimental works in the development of metamorphic holographic images.

1. Introduction

When Étienne-Jules Marey¹ uses chronophotography², he wants to study body movements by dividing it into a series of static images from a fix predetermined point of view. When the Lumière brothers³ start experimenting with their cinematograph, they use the same sort of series of images to reproduce movements also from a static position. When Georges Méliès⁴ compose his movies, there is no visible camera movement. For him, a camera movement is a trick used to produce special effects⁵. The movement is inside the image. The first travelling is initiated by Alexandre Promio⁶ who embarks his camera on a gondola in Venice in 1896 to film the *Panorama of a canal from a boat*. In the beginning of cinema, a camera movement is a rarity. The cinematographic language borrows from photography and theatre. Yet, it took years to develop the cinematographic language in its full capabilities. After more than a century, it is still in development.

Each element composing a visual language has to be experimented, tested in its variations, confronted to the viewer's perceptions and interpretations. Developing the basic elements of a visual language is a process that never ends. It is linked to the graphical and optical characteristics of the imaging technology; it is subjected to the context of production and presentation and it has personal and cultural ramifications.

After a few decencies of experimentation and being at a technological crossroad, we can't expect holography to present itself with a completed and achieved visual language. Working

with analog holography is not the same process than working in photography or sculpture. Working in synthetic holography⁷ is not the same process than working in cinema, computer graphics or even analog holography. Even though we can establish several similarities between these forms of visual representations, their dissemblance and their particularities makes them distinct Medias with their own codes, their own language. The optical, spatial and temporal characteristics of synthetic holography provide particular formal elements, limitations and effects that imply the development of a proper visual language. I have been experimenting with different characteristics of holographic images produced by a limited set of perspective views to investigate its optical, spatial, interactive and narrative possibilities. One of these characteristics is the metamorphosis of content; the transformation of forms attributes that occurs when the observers moves and changes their angles of view.

2. Fragmentation:

*"(...) lumen aliquando diffringi, hoc est partes eius multiplici dissectione separatas (...)"*⁸.
Francesco Maria Grimaldi, 1665.

To consider the specificities of synthetic holography, and subsequently its possibilities for building narrative forms, we have to realise that this imaging process is based on a series of fragmentations. First of all, as Francesco Maria Grimaldi described diffraction, in 1665 for the first time in history, light itself is divided and fragmented⁹. Synthetic holography goes even further in this fragmentation process. To produce the necessary set of image for a synthetic hologram, the computer generated 3D scene is rendered as a series of several hundred perspective images, each one representing an angle of view on three-dimensional space. This is a division of the field of view. In a direct-write holographic imaging system, these images are fragmented, processed and recombined to fit the specific optical needs of the holographic cells structure. Before imaging the hologram, there is also a chromatic fragmentation in three channels, red, green and blue. And finally, the holographic emulsion itself is divided in thousands of holographic cells. These successive fragmentations allow us to setup the necessary requirements for reconstruction of the multiple viewpoints perspective. Then, the holographic display will show the images in all their graphical, chromatic and spatial dimensions. All in all, synthetic holography is fragmentations to metamorphose virtual space into optical space.

The concept of fragmentation as a mean for representation of space isn't new. You can find it in pre-Renaissance perspective systems in which the pictorial space is divided in horizontal zones, each step showing represented objects in smaller sizes from the bottom of the picture to the top. Such spatial representation system can be seen in many paintings by Hieronymus Bosch¹⁰. Fragmentation of pictorial space is also visible in Oriental paintings that apply Kuo Hsi's theory of three distances¹¹ where spatial divisions are used to represents relative depth¹². Also, oriental horizontal scroll landscape paintings often represent wide spaces by dividing the scroll into multiple viewpoints and accumulating several views to compose a landscape. Each portion of the pictorial space has transition elements that connect the accumulated views as if it was a single panoramic view. To appreciate these compositions, the observer has to move and vary his own points of view. More than spatial representations, these paintings are representations of a path in space¹³.

These fragmentations and this observational movement is an opportunity for the artist to introduce gradual modification of forms, content or spatial appearance itself. An example of such a metamorphosis is found in three etchings by M. C. Escher¹⁴ called *Metamorphosis I, II* and *III*. These complex patterns gradually transform into different forms and even between the flatness of bi-dimensional geometrical compositions to the illusory three-dimensionality of perspective. Escher's Metamorphosis transforms the identity of represented space itself¹⁵.

By fragmenting pictorial space in such ways, artists spread the metamorphosis of content, not only over space, but also over time since the observer has to accumulate **what is seen here** and **what is seen there**. In synthetic holography, we would rather say that the observer accumulates **what is seen from here** and **what is seen from there**. This distinction is fundamental in the composition of a synthetic hologram. Instead of producing fragmentation of the pictorial space, we apply fragmentation to the optical space by dividing the field of view of the hologram. In my *Tractatus Holographis* hologram (2005) (figure 1), I divided the field of view in three zones. When the observer is in the left portion of the field of view, he can see two pages of the book. When he is in the right portion of the viewing zone, he sees two other pages. The center part of the field of view is used for the page to turn. This hologram of a fictitious treatise on holography presents a text written in 16th century French that describes the basic principles of holography. By fragmenting the field of view, I could not only augment the content with a metamorphosis of forms, but also demonstrate visually a spatial and interactive characteristic of synthetic holography.



Figure 1. Jacques Desbiens, *Tractatus Holographis*, 2005.
Three views of the synthetic hologram, 60cm X 4cm.

To go beyond this configuration of two zones with a transition in between, I produced another experimental hologram in which numbers change from 0 to 9 when the observer moves from left to right. The *Numbers* (2009) hologram demonstrates that several transformations can occur in a small hologram. In such a simple configuration, the observers understand easily the purpose of his movement and the necessary orientation.¹⁶

It is the observer's movement that is the main feature of these holograms. It is what generates the modification of content. To produce this effect I had to work spatially and foresee the optical circumstances of the holographic display. The computer graphic animation wasn't the finality. It was just a tool to introduce content variations in a fragmented space. These transformations are possible due to the anisotropic¹⁷ properties of holograms. Content metamorphosis, in synthetic holography, is produced by the angle variations between the light source, the hologram and the viewer.

It would be tempting to associate this kind of metamorphosis of the holographic image to some cinematographic special effects such as morphing. However, in these holograms, the image movement is different than the cinematographic movement. The metamorphosis rhythm and direction is controlled by the observer. His movements can pace or reverse the transformations. He can be selective; stop here to look, move there to compare. Content metamorphosis in synthetic holography is a fragmentation of movement. In that sense, synthetic holography may be closer to chronophotography than cinema.

3. Spatial synchronisation:

“ (...) the change of shape with every step one takes”¹⁸.
Kuo Hsi, 1117.

Anisotropy is a directional property of the transformation of visual appearances. We can imagine several compositions using this property to create content metamorphosis as an aesthetic effect where colors, forms and space itself would transform in synchronization with the observer's movement. Given the fact that synthetic holograms are three-dimensional multiple points of view perspectives and that the observer's two eyes sees different points of view at the same time, these transformations will appear different than what a 2D image would show. This is a field where there has been some experimentation in analog holography. However, synthetic holography offers different effects and controls over the transformations that are particular to the synthetic hologram structure and the computer graphics tools used to compose the images. Beyond the visual effects, the directionality, this link and dependence to the observer's angle of view, can be an asset in the development of narrative tools. To experiment this characteristic, I produced a large hologram in which texts, images, objects and backgrounds transforms in a synchronized composition to build a complex set of relations that the observers can reconstruct at their own rhythm.

This experimental hologram is titled *Graphis*¹⁹ (2009) (figure 2, 3 and 4). It is a panoramic 3D scene produced from 2537 computer generated images showing books, drawings, calligraphy and objects that transforms when the observer walks and change his angle of view on the horizontal axis²⁰. All the elements composing this holographic image are references to the history of optics, perspective and research methodology. Superposed to the 3D scene are several historical quotations of Zangzhi²¹, Zhang Huaiguan²² (8th century), Ibn Al-Haytham²³ (965-1039), Kuo Hsi²⁴ (11th century), Su Shih²⁵ (1036-1101), Roger Bacon²⁶ (1214-1294), Leonardo da Vinci²⁷ (1452-1519), Jean Pélerin Viator²⁸ (1445-1524) and Francesco Maria Grimaldi²⁹ (1618-1663). The field of view of this holographic image is divided in several portions but three main zones prevail. From the left portion of the field of view, the observer sees a blurry landscape with a few calligraphic texts floating above (figure 2). The center of the field of view shows a pack of books and papers, five polyhedrons and a mirror. Calligraphic texts are also visible from this center part (figure 3). From the right side of the field of view, the space is filled by a horizontal plane of water and a few images and calligraphy appears (figure 4). The texts are in Latin, Chinese, Renaissance French, Greek, Italian and Arabic.

Therefore, with such a mix of sources and languages, I don't expect that the observer will understand and reconstruct the whole references and significations brought in this hologram without some extensive research. Besides, I didn't include any linear story or discourse in this holographic scene. There is no progression and no predominant point of view. *Graphis* is a chaotic composition from which the observer can take the elements of information according to his wishes or abilities.

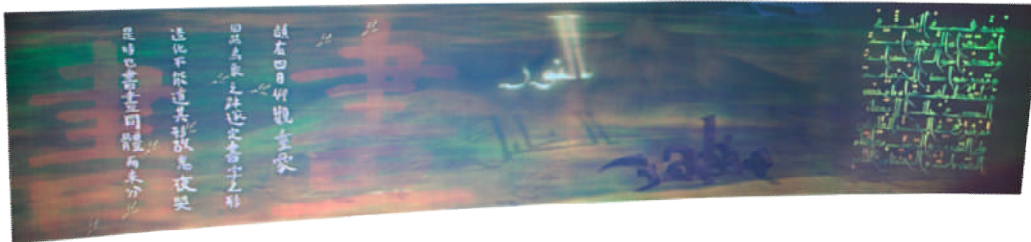


Figure 2. Jacques Desbiens, *Graphis*, 2009,
Synthetic hologram, 1.5m X 30cm.
View from the left.



Figure 3. *Graphis*, 2009. View from the center.

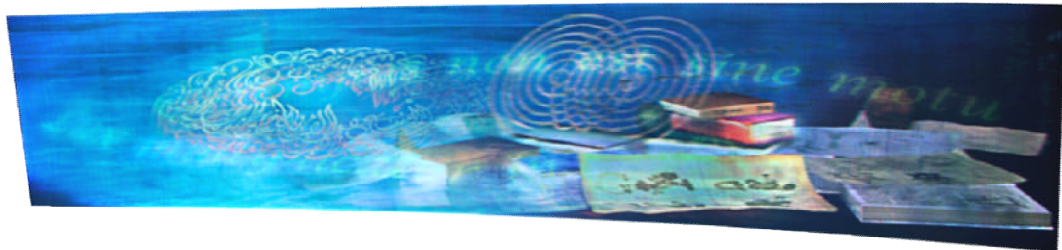


Figure 4. *Graphis*, 2009. View from the right.

Even though the field of view of this hologram is divided in three zones, objects appear and disappear independently and at their own rhythm. This procedure creates more alignments and associations between objects and texts. It also allows transitions that include links between the content of each zones. For example, this kind of transition is visible when the mountain in the left zones dissolves into a Chinese text shaped like the mountain's topography (figure 5). This text is a quotation from Kuo Hsi's painting treatise that can be translated as follow:

“A mountain viewed at a close range has one appearance; a mountain viewed at a distance of several miles has another. When viewed from a distance of scores of miles, it has still another. The change of appearance caused by the varying degree of distance from the object is figuratively known as “the change of shape with every step one takes.” The front view of a mountain has one aspect; the side view another; the back view still another. The ever changing view from whatever side one looks is described as “different shapes of a mountain as seen from every side.” Thus a single mountain combines in itself several thousand appearances. Should we not realize this fact?”³⁰

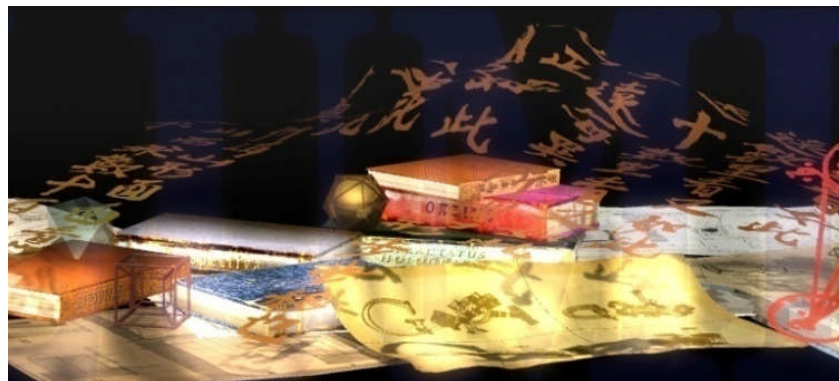


Figure 5. Jacques Desbiens, *Graphis*, 2009.
Kuo Hsi's calligraphic mountain, detail of a source image.

Obviously, such a transformation is charged with symbolism. Content metamorphosis and spatial synchronisation are tools that can be used in different ways to produce meanings and relationships between the elements occupying a composition. In synthetic holography, animation isn't just movements, it is transformations, alignments, superpositions, juxtapositions, contrasts, transparencies, occlusions and all sorts of variations and attributes that we can apply to elements in momentarily synchronisation with each other and with the observers position. *Graphis* is filled with such configurations to introduce meaningful associations. For another example, the Chinese text visible from the left part of the field of view (figure 6) is a quotation from Zhang Huaiguan's description of the mythological creation of writing by Canjie, a mythical character who develops ideograms from his observation of animal tracks. When the observer starts to move toward the right of the field of view, he will see bird tracks gradually appearing on the plane of the hologram, just behind the calligraphy. In the same way, a graph made by Ibn Al-Haytham is superposed on his text commenting on research methodology³¹ (figure 7). This drawing is the first correct depiction of stereopsis in history. These two examples use superposition to create meaning. It is one of the most obvious narrative tools that we can use in the composition of a hologram. Besides, this positioning enhances the three-dimensional effect of the hologram.

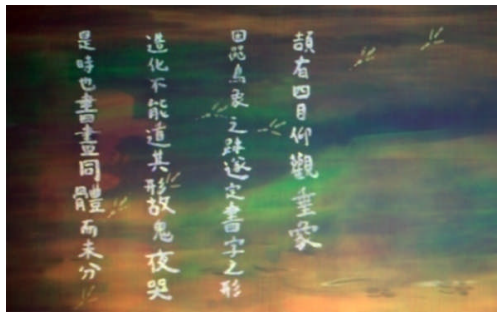


Figure 6. *Graphis*, 2009. Detail.
Calligraphy : Yunjeung Yang.

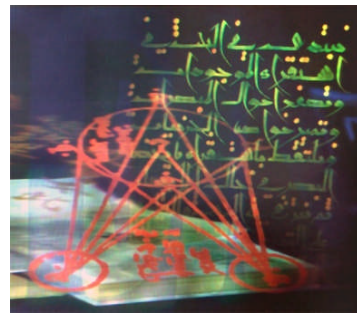


Figure 7. *Graphis*, 2009. Detail.
Calligraphy : Joseph El Hourani.

Some quotations, words and images in *Graphis* refer to the optical properties of synthetic holograms. For example, when viewing the hologram while moving horizontally, the observers may notice that most transformations appear as a wavy movement. This is not an effect produced by computer graphics but rather by the holographic cells structure itself. These waves are in fact a form of time-smear³² in which shapes appear to be distorted. The introduction of water in the third zone is obviously an analogy to this effect. To push further this theme, I added Leonardo da Vinci's drawing of interferences (figure 4). Francesco Maria Grimaldi's description of diffraction³³, from his 1665 treatise on light, can also be seen floating on the water³⁴.

With the attribution of specific effects to particular elements, in connection with the optical properties of the hologram, a hologram such as *Graphis* becomes a set of spatial relationships between words and objects, space and kinetics, between what is visible here now, what was seen there before and what will be seen later elsewhere. The metamorphic composition of forms, zones and content establish the multiple views in an observation time defined by the observer's free movements. "*Tempus non est sine motu*"³⁵ as it is quoted in *Graphis: Time isn't without movement*.

To build this kind of metamorphosis, where each form, each volume, each object, each graphic element, appear and disappear independently from each other, linked to the observer's

displacements, the rendering process and the optical structure of the hologram needs to provide continuous variations over the whole field of view. The anisotropic properties of the synthetic hologram optical system is giving us a clue for developing narrative forms that uses spatial synchronisation with the observers angle of view. *Tractatus Holographis* presented a narrative composition that was oriented by the subject, an open book. It suggested a chronology. *Graphis* is an attempt in an adaptation of the narrative structure to the disorder of the observation movements. The narration is fragmented but reconstructed in the synchronisation of presences and in random successions of spatial relationships. We may try to order and structure images and optical systems, but these very structures deprive us from controlling the sequence of observation. In synthetic holography, the movement of the gaze is the transformation of forms.

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- [1] Marey, Étienne-Jules (1830-1904), French scientist and physiologist.
 - [2] Chronophotography is a technique using sequential photography to register a movement decomposed in a serie of successive images. See the work of Étienne-Jules Marey (1830-1904), Eadweard Muybridge (1830-1904) and Georges Demenÿ (1850-1917) among others.
 - [3] Lumière, Auguste (1862-1954) and Louis (1864-1948), French scientists and inventors.
 - [4] Méliès, Georges (1861-1938), french illusionist and filmmaker.
 - [5] In *The man with the rubber head* (1902), Méliès use a camera on wheels to move closer or farther to the man's head to produce an illusion of stretching when the head gets bigger or smaller.
 - [6] Promio, Alexandre (1868-1926), cameraman for the Lumière brothers.
 - [7] Synthetic holography is a process that register on a photosensible emulsion a large number of images (usually computer generated) representing a succession of points of view on a 3D scene.
 - [8] "(...) at times light is divided, to be partitioned, multiplied, severed and separated (...)". Francesco Maria Grimaldi, 1665, *Physico-mathesis de lumine, coloribus et iridi*, proposition I, num. 5.
 - [9] *Ibid.*
 - [10] Bosch, Hieronymus (c. 1450-1516), Dutch Painter.
 - [11] High distance (*gaoyuan*), deep distance (*shenyuan*) and level distance (*pinyuan*).
 - [12] See: Hsi, Kuo (1117), *Lofty Messages of Forests and Springs (Lin Ch'üan Kao Chih)*, in : *An Essay on Landscape Painting*, translated and commented by Shio Sakanishi, London, John Murray, 1935, 70 p.
 - [13] See my articles: "Nomadic Perspectives: Spatial representation in oriental scroll painting and holographic panoramagrams." In: *Proceedings of the 12th International Conference on Virtual Systems and Multimedia (VSMM)*, Xi'an, China, October 2006, Springer-Verlag Berlin 2006, p. 504-513. And: "The perspectives of synthetic holography", in: *Proceedings of the 9th International Symposium on Display Holography (ISDH)*, Shenzhen, China, July 2009.
 - [14] Escher, Maurits Cornelis (1898-1972), Dutch graphic artist.
 - [15] Another example of this kind of graphical transformations can be seen in Saul Steinberg drawing *The Line* (1954). This drawing shows a horizontal line where different elements modify the identity of the line by refereeing to different angles of view. Steinberg made this very long drawing on the wall of a maze in Milan. It was an image of spatial metamorphosis that you observe by walking.
 - [16] On t h e s e experiments see my article in the ISDH 2009 proceedings: *Experiments in image composition for synthetic holography*, Jacques Desbiens, ISDH 2009.
 - [17] Anisotropy describes "a substance that exhibits different properties along different axes of propagation" (Photonics dictionary, www.photonics.com). I use this term in the context of a whole hologram to describe the properties of a hologram to show different aspects and content depending on the angle of view or the angle of lighting, in opposition to "isotropic" which would be the property of 2D graphical images to remain unchanged even with variations of angle of view.
 - [18] *Op. Cit.* p. 37.

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- [19] *Graphis* : latin word meaning “pencil” or other instruments used for drawing and writing. The hologram exhibited in the MIT Museum (June 2012 to September 2013) is a smaller version (1.5m X 30cm) of a large panoramic hologram (3m X 60cm).
- [20] This synthetic hologram has horizontal parallax only.
- [21] Zangzhi, (4th century B.C.), Chinese philosopher.
- [22] Huaiguan, Zhang (8th century), calligraphy theoretician and historian. Author of several books on painting and calligraphy.
- [23] Ibn Al-Haytham (Alhazen) (965-1040), Persian scientist. Author of the treatise *Kitâb fi'l Manazir (Book of Optics)* 1021.
- [24] Hsi, Kuo (c.1020 - c.1090), Chinese painter and theoretician. Author of a treatise on landscape painting: *Lofty Messages of Forests and Springs (Lin Ch'üan Kao Chih)*, 1117.
- [25] Su Shih (Su Dongpo) (1037-1101), Chinese poet, calligrapher and scientist.
- [26] Bacon, Roger (1214-1294), English philosopher and scientist. Author of the optics treatise: *Opus Magus*, 1267.
- [27] Vinci, Leonardo da (1452-1519), Italian drafter, painter and scientist.
- [28] Viator, Jean Pélerin (1445-1524), French artist and diplomat. Author of a perspective treatise: *De Artificiali Perspectiva*, 1505.
- [29] Grimaldi, Francesco Maria (1618-1663), Italian astronomer and physicist. Author of the optics treatise: *Physico-mathesis de lumine, coloribus et iridi*, 1665, in which he describe diffraction.
- [30] Hsi, Kuo (1117), *Op. Cit.* p. 89.
- [31] “ *Research begins with observation of present things, examination of optical circumstances and discernment of the specificities of their components. Thus, we observe what concern vision and we progress in research by measures and classification while criticising hypothesis and tackle results with circumspection.*” Ibn Al-Haytham, *Kitâb fi'l Manazir*, 1021.
- [32] On time-smear see my article in ISDH2009 proceedings: *Experiments in image composition for synthetic holography*, and Teitel, Michael A. (1989), “Animation in holographic stereograms: the time depth paradox”, *Practical Holography III*, SPIE Vol. 1951, 205-215.
- [33] “*Nobis alius Quartus modus illuxit, quem nunc proponimus, vocamusq ; Diffractionem, quia advertimus lumen aliquando diffringi, hoc est partes eius multiplici dissectione separatas per idem tamen medium in diversa ulterius procedere, eo modo, quem mox declarabimus.*” I translate: “A fourth lighting method is known, here now how I propose to name it : diffraction. I bring attention that at certain moments light is divided, being partitioned, multiplied, sectioned and separated, this however by the same medium in diverse ulterior procedures. Because of this, this is how I conclude.” Francesco Maria Grimaldi, “*Physico-Mathesis de Lumine Coloribus et Iride* ”, (1665).
- [34] Unfortunately, when the light source isn't precisely positioned and strong, this text is quite faint.
- [35] Bacon, Roger, (1267), *Opus Magus*.