Studies on Holographic Anamorphoses: 500 Years After

Brigitte Burgmer

ABSTRACT

Holographic anamorphosis is based on the geometric theory of optical imaging. Under certain circumstances there is not only a hidden but an obvious relationship between anamorphoses and holograms. Due to the unique storage system of holograms, the author feels that, in studying the nature of holograms, one should take anamorphoses into consideration. While a photograph records a subject point to point, in a hologram the information is spread across the film. An anamorphosis can be represented in a drawing construed on a two-dimensional surface or, as explained in this article, in a hologram of a three-dimensional subject. The author experimented with an anamorphic drawing by Leonardo da Vinci, which is considered the oldest documented anamorphosis.

A Queer Fish of Perspective

Holographic anamorphoses show the essentials of holography through exaggeration; they offer an approach to holography when this medium is not restricted to depictions that are true to nature.

Leonardo da Vinci's Codex Atlanticus, Vol. 35, verso >a< contains the *Anamorphic Sketches of a Child's Head and an Eye* (Fig. 1), which dates back to approximately 1485. This drawing is considered to be the oldest documented anamorphosis [1]. The original, on display at the Biblioteca Ambrosiana in Milan, is much richer in detail than the printed reproduction; using fine lines, Leonardo was able to suggest the hair, a crease in the neck, and the shoulders. This work is best viewed from the right side, with one eye a few centimetres from the paper. This perspective produces a foreshortening; the elongated drawn lines 'shrink' to depict the proportions of a child's head.

My ideas about the relationship between holography and anamorphosis did not arise from abstract theories but from experimenting with the first hologram I held in my hands. My first anamorphosis (Fig. 2) was created in 1981, one year before my first holographic work was completed. The small relievo I created arose from my ambition to explore whether an anamorphosis, which is commonly represented on the plane, functions three-dimensionally. In this relievo the face is smaller than the palm of a hand and relatively flat. It therefore produces an effect similar to the one produced by the Leonardo drawing that served as the model.

In our process of visual perception we learn to account for extreme foreshortenings and diminutions. For example, at a distance of 20 m a person would appear as tall as the reader's thumb, arm outstretched. In the phenomenology of perception, the brain's compensation is called the effect of constancy of height [2]. In perspective drawing, only one important factor of the complex space-perception calculation is conveyed through a simple system using one or two vanishing points so that the image more closely approximates the subject of our perception. This is the dominant system used in computer graphics to portray space; however, a more realistically convincing picture can be achieved using a more moderate system. Many painters did not use the vanishing-point system of perspective strictly.

Anamorphoses are a special case: they represent a deviation from a central projection. From a historical point of view, they could only be created, systemized and applied parallel to the development of the representation of space in drawing and the acceptance of central projection as a norm [3].

During the Renaissance, the term 'anamorphosis' was created out of the Greek words *ana-* and *morphosis*; it means a 'transformation'. Such a transformation occurs when a picture is projected at an extremely oblique angle, rather than at a 90-degree angle, so that the picture is elongated on the wall. The largest documented anamorphosis is a fresco entitled *The Holy Franciscus from Paolo* by the mathematician Emmanuel Maignan from the year 1642; the work is preserved at the SS. Trinità dei Monti Cloister in Rome [4], where Maignan was Doctor of Divinity. This black, white and gray image stretches over 20 m of wall and ceiling in the Cloister passageway. If one views it from the end of the passageway,

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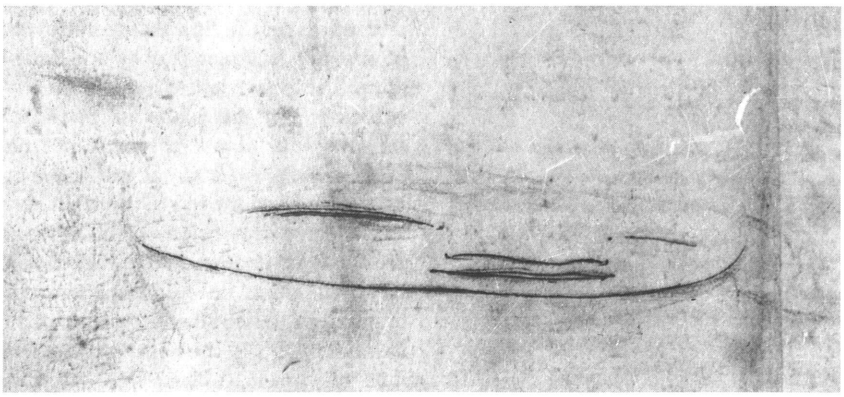

Fig. 1. Leonardo da Vinci, *Anamorphic Sketches of a Child's Head and an Eye* (detail), Codex Atlanticus, fol. 35, verso >a<, 1485. (Courtesy of the Biblioteca Ambrosiana, Milan) This is the first documented anamorphosis. It is best viewed from the right side, with only one eye, at a distance of 5 cm from the paper. The child's face will then appear in normal proportions, detached from the level surface of the picture.

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one can recognize the Holy Franciscus in the distance, praying under a tree.

At the beginning of the seventeenth century, cylinder anamorphoses became popular in the Netherlands, Germany, England and Scandinavia; however, it is assumed that they originated in China. They were frequently created as paintings in circular form with a mirrored cylinder at the center where the scene could be deciphered. This particular form of distortion presumably developed as a solution to the problems encountered by fresco painters, such as designing figures and architectural parts in a realistic style on uneven surfaces, i.e. ceilings and domes. In certain structures the image had to be distorted in order to give the viewer a perfect illusion.

In anamorphic constructions, drawn or painted figures seem to detach themselves from the level surface of the painting and appear to be floating free in space. In Leonardo's drawing, the child's face is intended to appear in a frontal view. It is best viewed from the right side, with only one eye, at a distance of 5 cm from the paper; only then do the graphic points move into the axis of deep dimension, side by side on that imaginary level from where they could have been projected, had the drawing been constructed in this manner. It seems, however, to be have been drawn freely by hand. Leonardo's drawing is analogous to the projection of a picture at an extremely oblique angle, discussed earlier.

The viewer forces the anamorphic image onto an imaginary plane. Only there will the image appear normal or recognizable. This impression of floating free in space also occurs in holograms. The holographic film and the holographic image are divided in space. The holographic subject can appear to be behind or in front of the film. The film can even intersect the holographic subject; in this case the hologram is an image-plane hologram.

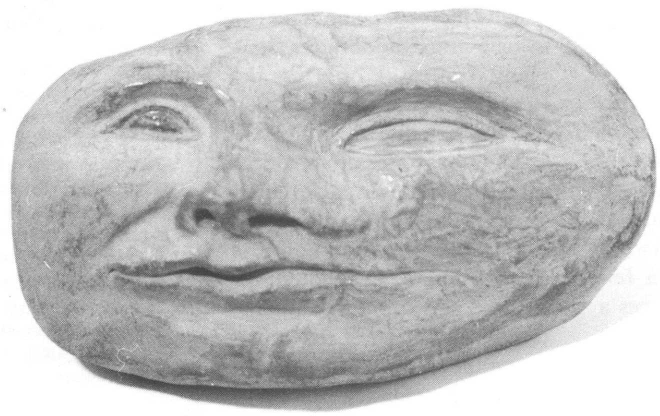


Fig. 2. Brigitte Burgmer, relievo after the drawing *Anamorphic Sketches of a Child's Head and an Eye* by Leonardo da Vinci, plastic modelling material, 5 × 9 × 2.5 cm, 1981. (Photo: Jo Firmenich) This is a three-dimensional anamorphosis (anamorphoses are commonly two-dimensional). The face appears normal when viewed from the left side at a distance of 5 cm from the paper.

Fig. 3. Brigitte Burgmer, *Cartesian Portrait of a Young Painter* (detail), pulsed white-light reflection hologram with gouache on plexiglass, 85 × 100 cm, 1982. Only from the frontal view do the holographic head and the white line painted on the inner side of the plexiglass come together, though they are divided in space. It becomes obvious how large an area around the head must be free of colour to allow all views of the holographic head; otherwise the paint would cover the head when the piece is viewed from other angles.

HOLOGRAPHY—EXTRAORDINARY

The second time I came across the phenomenon of anamorphosis was in my first holographic work, *Cartesian Portrait of a Young Painter* (Fig. 3) from 1983. When I was outlining the pulsed portrait of the painter George Stockinger in this holographic collage, I realized I could not come as near to the outline of the head with my paint as I could on a photographic portrait because the head would not be viewable from all possible perspectives. In my book *Holographic Art—Perception, Evolution, Future,* I wrote about this significant experience in detail [5]. What became clearly visible by painting on the surface of the picture was not the punctual—like in photography—but the 'scattered' storage mechanism of the holograms. The complete head, that is, the infinite number of heads visible at other angles, cannot be seen simultaneously but rather must be viewed successively. One essential fact becomes visible only when one marks on the film all the contours of the heads generated by the hologram: the holographic head is greatly expanded on the plane of the film. Anyone who wants to measure the width of the painter's head will find that it is 30 cm from the left to the right ear. The bizarre dimensions of holograms are hard to imagine. In those days I called the many potential heads, accumulated in the emulsion, 'monstrous'. In anamorphosis, the figures in a painting—two lovers, for example—are dis-

Fig. 5. Brigitte Burgmer, *Holographic Anamorphosis for L. d. V.*, collage composed of a white-light reflection hologram, 24.5 × 39.0 cm, 1987. (Photo: Jo Firmenich) Viewed from the right side, the right face turns into pure profile while the left face stretches to two or three times its original size. This effect is reversed when the piece is viewed from the left side. It is difficult to take a picture of this anamorphosis because the elongated part of the face is out of focus.

Causal Reflections

Several factors are involved in the production of a holographic anamorphosis.

1. The model must have a slight anamorphic distortion. As experimentation with other models has taught me, the distortion must not be too great.

2. A slanted position for the faces is advantageous for a wide viewing angle; in the hologram, the faces go into a pure profile.

3. In producing the white-light reflection hologram, one needs to place the object in a position such that the reference wave, coming from above, illuminates the chin. This arrangement later allows for the reconstruction of the hologram using a light from above.

4. The film (Agfa-Gevaert Holotest 8EH75) was placed on a glass plate and fixed with plate holders directly over the model in order to obtain a wide viewing angle.

5. The laser, optical elements and their alignment play important roles in the creation of a holographic anamorphosis. The distance from the lens (capable of a 20-fold magnification) over the mirror to the film was less than 2 m. Therefore, the ray cannot be called collimated or parallel, especially since the subjacent parts of each face become increasingly longer and blurred.

6. Optical distortion can be achieved by applying the Denisyuk technique, used in all the holograms discussed here, because the wave fronts of the reference beam and the wave fronts sent out by the object reach the holographic emulsion from different sides. These 'micro-holes' in the abstract recording pattern act as convex or concave lenses or mirrors. When one reconstructs the real pseudoscopic faces, the zone plates—the smallest units of the emulsion—act as convex mirrors so that the diffracted rays are focused on the object points in front of the plate and are then diverted. This is the physical-optical reason for the elongation of the faces.

7. When the real pseudoscopic hologram is reconstructed from a distance of 3 m and at an angle of 62 degrees, the abstract plastic parts of the upper and lower film pieces alter: when the elliptical form is viewed from below, for example, it changes into a reddish cone-like shape. This occurs particularly when a more divergent light is used, e.g. a halogen light of 10-degree, rather than 6-degree, dilation.

All these factors seem to potentialize one another. The holographic anamorphosis is generally based on the geometric theory of optical imaging. The hologram therefore generates the anamorphosis. This is, literally and functionally, the union of holography and anamorphosis.

Holograms and cylinder anamorphoses operate under similar laws. The rays coming out of the circular distortion are converged by the convex surface of the mirror so that the 'scattered' parts of the picture move together in the mirror to normal dimensions in width and height.

A fundamental difference nevertheless still exists between holographic anamorphoses and anamorphic drawings: unlike anamorphic drawings, a hologram can be considered a 'lens system', for the laws of optics as well as the rules of central projection have an effect on the hologram.

Acknowledgments

I would like to thank all those who, for some years now, have been involved with my work: Peter Heiss, who holographed the first model of Leonardo's child (it was this hologram that captured me); Andreas Neusser, in whose lab in Cologne the first anamorphic edition of *Leonardo's Baby* was created and who never avoided any of my persistent questions; Daniel Weiss of La Coruña, Spain, who holographed *Holographic Anamorphosis for L. d. V.*; and Jörg Gutjahr from the Department of Photo Engineering/Optics of the Technical College in Cologne, who, at the end of a long discourse, reduced all our words to a single formula.

References and Notes

1. Joost Elffers, *Anamorphosen: Ein Spiel mit der Wahrnehmung und der Wirklichkeit* (Cologne: DuMont, 1981) pp. 10–12.

2. Maurice Merleau-Ponty, *Phänomenologie der Wahrnehmung* (Berlin: Walter de Gruyter, 1966) pp. 347–352.

3. Elffers [1] pp. 100–109. Daniele Barbaro provided an early a good description of anamorphic design in his book *Practica della Prospettiva* from 1569. The empirical method starts with a normal drawing—for instance, a face—placed at a right angle to a wall. When one views the final painting from the place where the light source originated during the projection of the drawing, the face appears exactly as it was on the paper. In 1584, Giovanni Paolo Lomazzo described a similar set-up but with the following modifications: a raster of vertical and horizontal lines covers the drawing, which has been placed at a right angle to a wall, and one has to use a string to project each part of the drawing onto the wall. In 1638 the French friar Jean-François Niceron explained a simpler geometric method in his book *La Perspective curieuse.*

4. Elffers [1] pp. 109–115.

5. Brigitte Burgmer, *Holographic Art—Perception, Evolution, Future* (La Coruña, Spain: Daniel Weiss, 1987) Fig. I and pp. 11–24.

6. Burgmer [5] Fig. III. The convex model of this face and the surrounding rocky structure were cast in plaster in order to get a concave relievo. For the reproduction of the hologram, the model was illuminated from below with the holographic emulsion facing upwards. The hologram has to be reconstructed upside down. The distortion of the faces was not as large as expected and the viewing angle not wide enough to achieve the anamorphic effect. Later analysis with the holographer Andreas Neusser revealed that the problem was caused by the long distance between concave relievo and film.

7. Edi Lanners, *Illusionen* (Lucerne and Frankfurt am Main: C. J. Bucher, 1973) pp. 102–106.

8. E. H. Gombrich, *Kunst und Illusion* (Cologne: Kiepenheuer & Witsch, 1967) pp. 296–299.

torted into monstrosities. Only from the correct angle do the figures appear normal and correctly posed.

This indicates the hidden relationship between the totally invisible storage mechanism of holograms and the visible code of anamorphoses: the information system and the intended image are not identical and the information is distributed widely. A completely different relationship arises through the real pseudoscopic holographic subject. The pseudoscopic reconstruction becomes a subject of wonder when optical distortion alters the abstract form. It is difficult, however, to calculate in advance the distortion needed in the model.

Over the years, I have experimented with different models fashioned after the drawing by Leonardo. The first model was holographed at the Museum of Holography and New Visual Media in Pulheim, near Cologne. Studying this small film I discovered that the hologram itself created the anamorphic phenomenon. In 1985, I made the first holographic edition of *Leonardo's Baby* (Fig. 4) [6]. In this case the anamorphic effect is caused more by the model than by the holographic technique. Through experimentation, I learned which of the conditions affecting the model, the holographic technique and reconstruction produced the most successful anamorphosis.

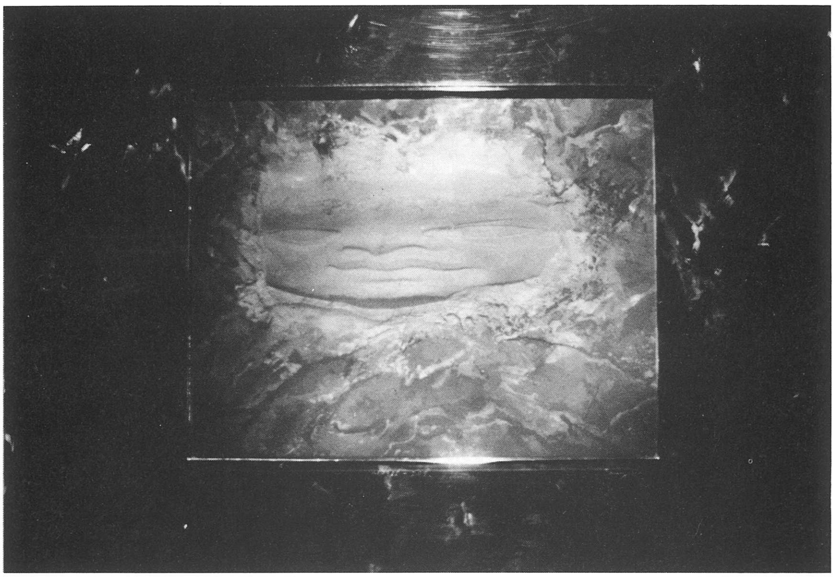


Fig. 4. Brigitte Burgmer, *Leonardo's Baby*, white-light reflection hologram in a plexiglass frame with acrylic paint, 60 × 60 × 3 cm, edition no. 2/5, 1985. The concave face was fashioned after the drawing by Leonardo da Vinci. A convex relievo served for the hologram. The three-dimensional, rock-like effect seen in parts of the hologram was caused by painting in black and white on the model. The hologram was made with a single beam technique on 20 × 25 cm Holotest glass 8E75 by Agfa Gevaert. The face is reconstructed real pseudoscopic. The anamorphic effect is caused more by the model than by the holographic technique.

HOLOGRAPHIC ANAMORPHOSIS FOR L. D. V.

The holographic collage *Holographic Anamorphosis for L. d. V.* (Fig. 5 and Color Plate C No. 3) consists of three rearranged parts of one single film.

The Model

The middle part of the model for this work shows the two modelled children's faces mirrored symmetrically with each facial plane at a certain angle, slanting away from the plane of the film. The faces have only slight anamorphic elongations. The plastic form around the faces has also been set up in a symmetrical way and rolls away from the outer edges into structural depressions; in the middle between the two faces, an elevated flat bar is formed. The heads are joined together by a capital in the shape of an ellipse.

The Hologram

When one reconstructs the orthoscopic faces by illuminating the hologram in a conventional way, the normal rules of perspective apply. The slight elongation of the face on the right is cancelled by perspective foreshortening when viewed from the left side. The holographic image responds in the same way as the model that was holographed.

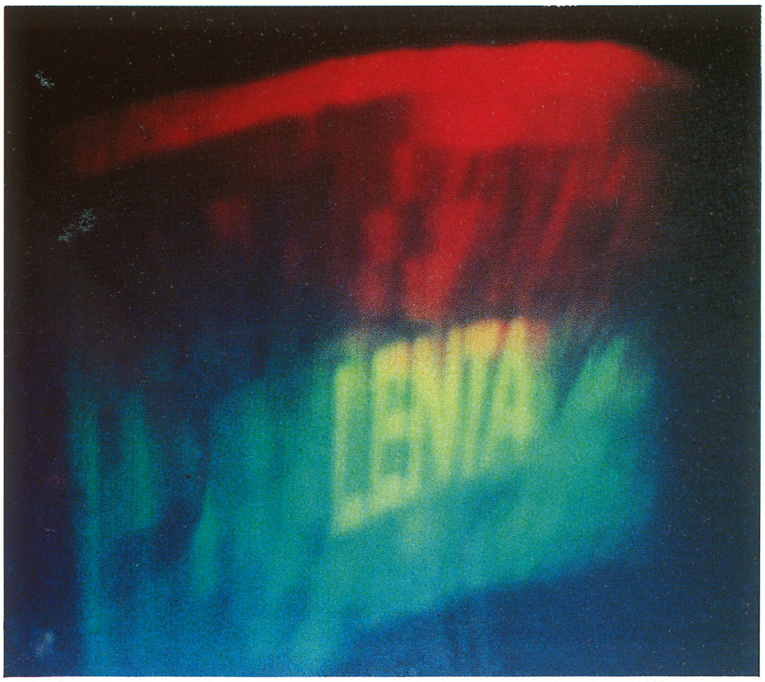
The reconstruction of the real pseudoscopic faces responds completely differently. When viewed from the right side, the right face is seen in profile, although we should see it frontally, and the left face becomes longer, although we expect to see it in profile (see Fig. 4). The elongation of the faces in the hologram is enormous. At a visual angle of 130 degrees in the horizontal axis, each face expands to two or three times its original width of 12 cm.

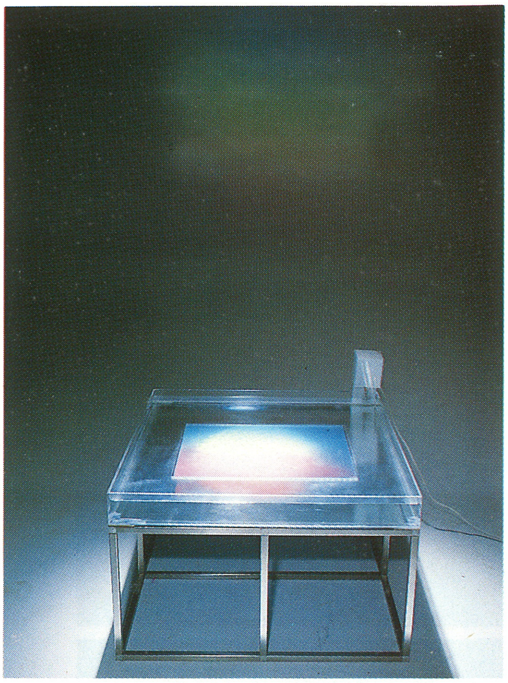
The faces in the hologram also seem to be moving with us. Viewing the model itself from right to left, we gradually experience how the faces are correctly represented in three-quarter profile, but we do not experience the kind of spontaneous movement that is characteristic of holograms. These holographic faces in particular seem to 'persecute' the viewer.

The holographic subject is twisted in yet another way. In pseudoscopic holograms, the spatial relations of convex and concave forms are always reversed. According to the principle of space reversal in real pseudoscopic holograms, the face and the capital should curve inward; however, that is not the case. Some viewers see the faces as concave; I almost always see them as convex. The capital sometimes appears to viewers to be concave and at other times, in relation to the faces, convex. This interplay is well known outside the realm of holography and can be observed when, for example, a picture of a mask, photographed from the inside, is viewed with one eye. The inner curves go out through a reversal of light and shadow [7,8]. The three-dimensionality of the hologram clearly strengthens this illusion.

The Collage

The film, which measured 30 × 40 cm, was cut into three pieces. The faces were kept in the center. The two other parts of the film were exchanged and turned; part of the real pseudoscopic capital was placed below, and the lower part of the relievo, placed above upside down, became a 'virtual orthoscopic' image. Through these turns, leading to a 'double reversal', new plastic forms and different colors developed. The visual angle of this collage, viewed vertically, reaches 150 degrees.





COLOR PLATE C

No. 1. Top left. Eduardo Kac and Ormeo Botelho, *Quando?*, computer-generated hologram, 25 × 40 × 40 cm, 1987–1988. (Photo: Sergio Zalis. Facility: Jason Sapan Holographic Studio, New York.) In this 360° holopoem, a fractal shape rotates around its own axis, alternately disclosing and concealing words. The viewer reads: A LUZ / ILUDE / A LENTE / LENTA (shown here) / MENTE (the light/ deceives/the lens/slow/ly) (see also Fig. 4 in article by Kac and Botelho). Different readings, just as valid as these, may also arise.

No. 2. Top right. Shunsuke Mitamura, *Heliostat in Aqua 17113, re-fraction series*, holographic installation with rainbow hologram, 30 × 40 cm; water tub with wave-motion instrument attached, 60 × 60 × 50 cm; 1984. (Photo: Sadamu Saitoh) A single-exposure rainbow hologram, wrapped with transparent vinyl, was placed over a plate mirror to change it into a reflection-type hologram; the ensemble was laid at the bottom of a water tub to which a wave-motion mechanism was attached.

No. 3. Right center. Brigitte Burgmer, *Holographic Anamorphosis for L. d. V.*, collage composed of a cut white-light reflection hologram, 24.5 × 39.0 cm, 1987. (Photo: Jo Firmenich) The model was holographed by Daniel Weiss in La Coruña, Spain. The hologram was made with a single-beam technique on Agfa-Gevaert Holotest 8E75 film.

No. 4. Bottom right. Doris Vila, *Diagnosis of an existential headache*, white-light transmission hologram, 17½ × 40 in, 1987. From the *explication* series. With graphic use of words and hand-drawn chart notation, the hologram points beyond the visible to render a web of ideas and emotions, caught in large volumes of color.