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Holostereosynthesis: An Improvement to Louis Lumière's Photostereosynthesis Technique

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Abstract: In 1920, Louis Lumière, one of the fathers of Cinématograph, invented photostereosynthesis, a photography technique that could recreate three-dimensional images without a specific artifice. This method involved stacking six to eight photographs of the same subject, usually a portrait, recorded with a progressive shift in focus and observed together through transparency. This invention remained at the laboratory experiment stage, and only a dozen portraits of famous people from the time of Lumière are known. The final device is a complex assembly of glass plates mounted on a wooden frame, and it is fragile, bulky, heavy, and difficult to build and observe. Here, we demonstrate that we can replace the stack of photographic plates with a single reflection hologram. Experiments were successfully conducted using the digital CHIMERA holographic stereogram printing technique. This new method of holostereosynthesis will facilitate the restoration and dissemination of the historical portraits originally recorded by Louis Lumière and may also allow the creation of brand new images.

Keywords: digital holography; display holography; 3D portrait; holographic stereogram

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1. Introduction

Louis and Auguste Lumière, often referred to as the Lumière brothers, are French engineers and industrialists who played a leading role in the history of cinema and photography. Their best-known joint contributions among 196 patents are Cinématographe [1], a motion picture system invented in 1895, and Autochrome [2], a color photographic process in 1903. One of the later inventions of Louis Lumière alone, presented to the French Académie des Sciences on 8 November 1920, was photostereosynthesis—*la Photo-stéréo-synthèse*—an early photography technique that could recreate three-dimensional (3D) images [3].

To obtain 3D images without a specific artifice, Louis Lumière proposed a technique with a concept not based on photographs with a horizontal shift, as is the case for conventional stereoscopy [4], but on the axis. Photostereosynthesis required a series of six to eight photographs of the same subject, usually a portrait, each recorded with a different focal length (Figure 1a) thanks to a unique large-format camera built by Lumière that mechanically narrowed the depth of focus of the image. The photographs were then reassembled, maintaining the same distance as the initial object, affected by a coefficient corresponding to the adopted scale. Each lightly developed positive photographic plate was printed on a glass plate as transparent positive, mounted in a wooden frame, and stacked to produce a translucent 3D image several centimeters thick (Figure 1b) when illuminated by backlighting through frosted glass for an observer placed just in front.

Theoretically, photostereosynthesis requires the recording of an infinite number of images. However, Louis Lumière found that, in practice, a small number of photos with an extremely shallow depth of field of a few millimeters was sufficient to obtain a convincing result. Owing to the complexity of recording images at the time of Louis Lumière, photostereosynthesis remained a laboratory experiment without follow-up. Its implementation was difficult from both the photographer's and the subject's perspectives. To obtain a perfect final 3D image, the model had to remain still during successive exposures. The final device was a complex assembly of glass plates mounted on a wooden frame, and it was fragile, bulky, heavy, and difficult to build and observe. However, Louis Lumière's concept laid the foundation for the current techniques used in medical scanners [5], 3D printers [6], and auto-stereoscopic multi-layer displays [7], and was a precursor to plenoptic cameras [8], also known as light-field cameras, that will soon be available on smartphones [9].

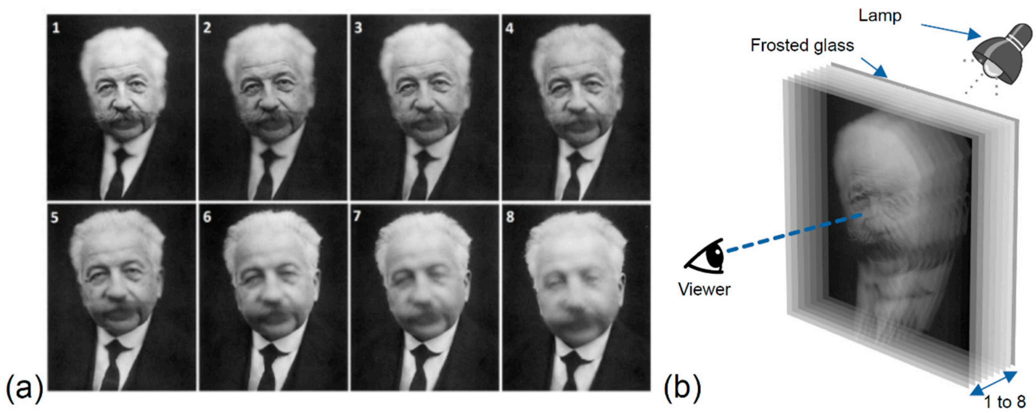

Figure 1. Principle of photostereosynthesis illustrated by the portrait of Auguste, Louis Lumière's brother (circa 1920). A series of photographic glass plates numbered from 1 to 8 and recorded with a progressive shift in focus (**a**) were viewed together through transparency and illuminated by backlighting through the frosted glass to reconstruct a three-dimensional portrait (**b**).

Today, only a dozen works are known, and the original camera used to capture them has disappeared [10]. The portraits recorded by Louis Lumière were limited to his entourage and a few famous people, such as the president of the French Republic at the time, Alexandre Millerand (see Figure 2a), World War I Supreme Allied Commander Ferdinand Foch (Figure 2b), and the French engineer and inventor Jules Carpentier (Figure 2c).

Figure 2. Three historical portraits recorded by Louis Lumière using the photostereosynthesis technique, circa 1920. French President Alexandre Millerand (**a**), World War I Supreme Allied Commander Ferdinand Foch (**b**), and French engineer and inventor Jules Carpentier (**c**).

Modern observers of these historical portraits notice a strong resemblance to holography [11,12], a 3D technique based on the interference and diffraction of light waves invented by Hungarian-British physicist Dennis Gabor in 1948 [13]. For Peter J. Bloom in 2020 [14], this style of assemblage created a holographic illusion, and for Helena Monteiro in 2021 [15], the depth impression was similar to a holographic display. The purpose of this research is to replace the complex assembly of glass plates that comprise Lumière's photostereosynthetic device with a single reflection hologram, thus creating 'holostereosynthesis.'

Experiments were carried out using a set of original black-and-white images composing the photostereosynthetic portrait of Auguste Lumière and were conducted using the digital CHIMERA [16] holographic stereogram printing technique.

2. Materials and Methods

2.1. Set of Images

Experiments were performed using a set of eight black-and-white photographs from the photostereosynthetic portrait of Auguste Lumière, recorded by his brother Louis in 1920. The images available for this study had a limited resolution of 427 × 545 pixels. The different images were realigned using GIMP, which is a free and open-source raster graphics editor.

2.2. Plates and Processing

Digital CHIMERA holographic stereograms were recorded on silver halide holographic Ultimate U04 [17,18] glass plates. The material was specially designed for recording color holograms without any diffusion and was set to be isopanchromatic for all common visible lasers used in full-color holography. Ultimate U04 glass plates were developed through a process involving two chemical baths: developer and bleach baths. These chemicals are safe for both holographers and the environment and are easy to use. The recommended exposure energy is 600 $\mu J/cm^2$ for a monochrome hologram and 200 $\mu J/cm^2$ per color for a full-color hologram.

2.3. Recording Digital CHIMERA Holographic Stereograms

CHIMERA, the last generation of the holographic stereograms printing system [19], is based on three low-power RGB DPSS lasers combined with the silver halide color material Ultimate U04. A half-parallax CHIMERA hologram was first created by recording a series of 768 horizontal images—points of view of the scene—on a 120° arc of a circle. In this research, data were created using a virtual video camera rotating around the scene with a 3D computer graphics program, Autodesk 3ds Max. In-house software was used to generate all of the hogels from the perspective images. Each hogel was recorded sequentially in the U04 holographic material, using an RGB display system made of three spatial light modulators (SLM) and a 120° custom-designed full-color optical printing head in the U04 holographic material. The hogel size was 250 μm and the printing rate was 50 Hz. Three RGB DPSS lasers (power: 20 mW; wavelengths: 640, 532, and 457 nm) were used for the CHIMERA holoprinter.

2.4. Illumination of Holograms

In holography, the reconstructed light must be a point source and should include the wavelengths of the original recording lasers. RGB LEDs are currently the most suitable candidates because their wavelengths are consistent with the laser wavelengths [20].

3. Results

3.1. Reconstruction of a Portrait by Photostereosynthesis

The first step of this research was to reconstruct a device imagined by Louis Lumière using the eight original black-and-white photographs composing the portrait of Auguste to serve as a reference. Because of the very long time between shots in 1920, Auguste did not remain still during successive exposures. Analysis of the merged photographs revealed that they were not well positioned with respect to each other (Figure 3a). Therefore, they were realigned using a graphics editor (Figure 3b). The eight images were then lightened (Figure 3c), printed on 10 × 15 cm overhead projector (OHP) transparent films, cut, laminated on glass plates, and mounted. Each image was separated by two millimeters in a wooden frame with frosted glass, according to the original design. As described in the literature, when this display was backlit, a dim translucent black-and-white 3D image several centimeters thick was visible (Figure 3d) to an observer placed in front. This effect was only visible from one point of view, and the different image planes began to separate as soon as the observer moved vertically or horizontally. This visual depth perception is difficult to imagine and cannot be transmitted using simple photographs or video.

Figure 3. Reconstruction of a portrait by photostereosynthesis. The original images (**a**) were realigned with a graphic editor (**b**) and then lightened (**c**) to reconstruct a photostereosynthetic portrait according to Lumiere's design. When this display was backlit, a translucent 3D image several centimeters thick was visible to an observer placed exactly in front (**d**).

3.2. Holostereosynthesis with CHIMERA Holographic Stereograms

To realize holostereosynthesis using the CHIMERA holographic technique, we imported the eight photos into a 3D computer graphics program by positioning them on either side of the rotation axis (Figure 4a): four images in front and four behind. The photos maintained the same distance affected by a coefficient corresponding to the adopted scale in the 3D program. A series of 768 horizontal perspective images of the scene on a 120-degree arc of a circle (Figure 4b) was then generated for Photo 1 (Figure 4c), thanks to a virtual video camera rotating around the image. This operation was repeated for each of the other photos to obtain eight different sets of images. All images were then merged using in-house software to obtain a single file of 768 perspective images (Figure 4d and Supplementary Video S1).

Hogels were generated from the perspective images and recorded sequentially into a 30 × 40 cm U04 holographic plate with a CHIMERA holoprinter. When the CHIMERA hologram was illuminated by the RGB LED lamp, a fine black-and-white 3D reconstruction of Auguste Lumiere's head was obtained. Holostereosynthesis of the eight original photos was performed using a single hologram recording. The final 3D image was bright and protruded out of the frame, resembling a pulsed holographic portrait [21] (Figure 5a). With a resolution of 250 μm, the hogel grid was invisible to the naked eye. The hologram had a narrow horizontal field of view of approximately 5°, which allowed the 3D effect to be observed before the images separated and blurred (Figure 5b). Because the hologram was half parallax, the images did not shift when moving vertically, and observation of the 3D effect was easier. Furthermore, this CHIMERA hologram has a mastering quality and can be copied with the same RGB lasers to produce copies on both silver halide and photopolymer materials.

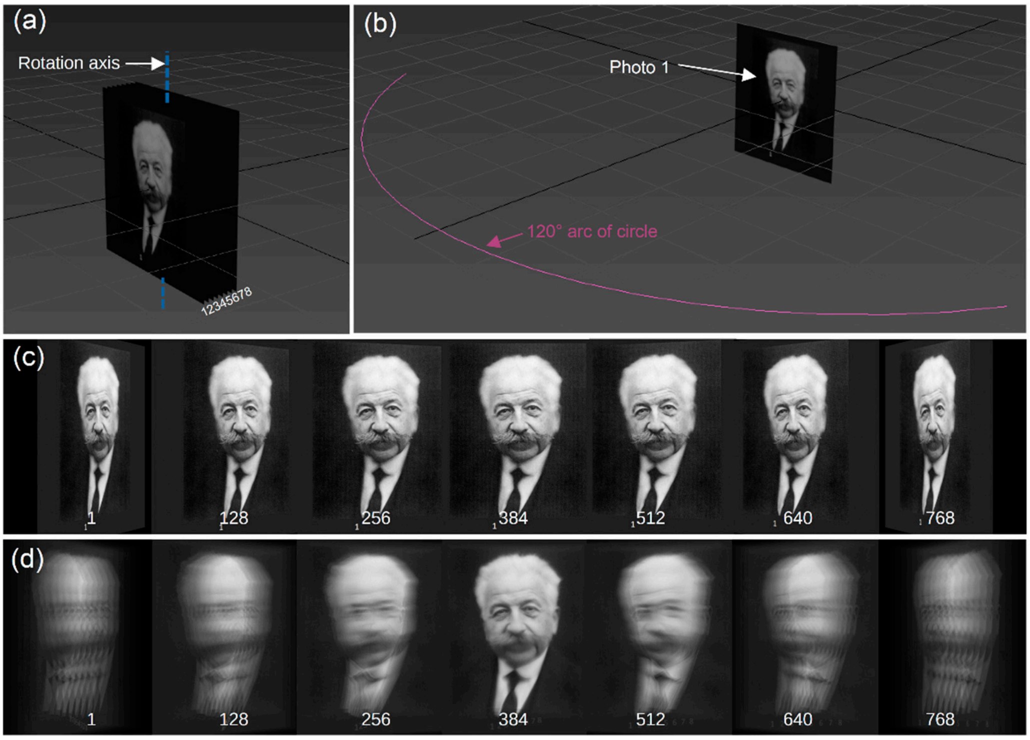

Figure 4. Perspective image generation from the set of the eight original photos using a 3D computer graphics program. Eight photographs were positioned on either side of the rotational axis (**a**). A series of 768 horizontal perspective images on a 120-degree arc of a circle (**b**) were then generated for Photo 1 (**c**) using a virtual camera. This operation was repeated for each photo, and all images were merged into a single file of 768 images (**d**).

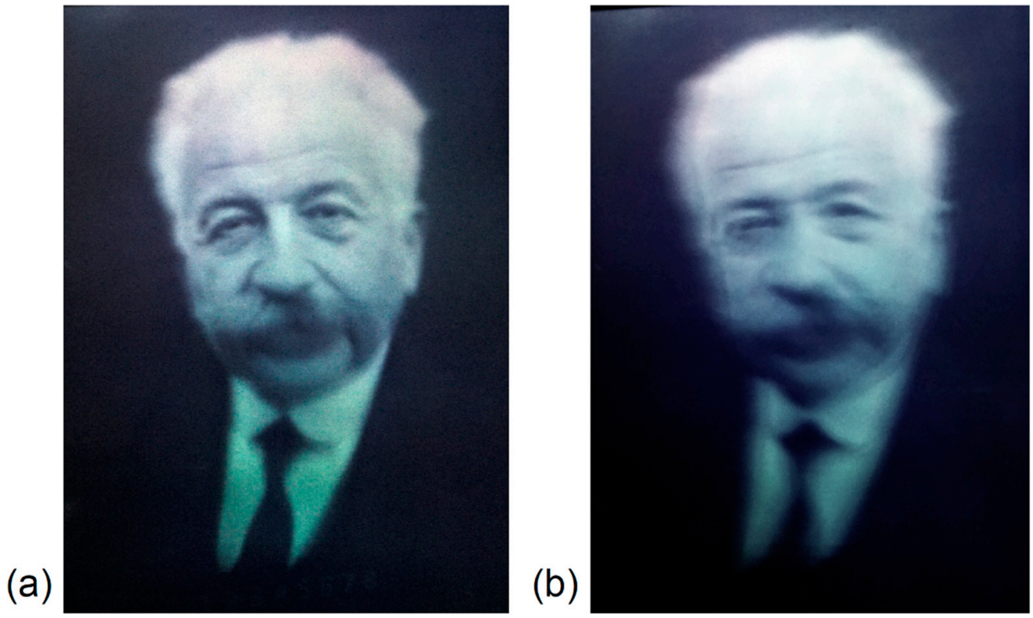

Figure 5. Holostereosynthesis with a CHIMERA hologram. The eight original photos were merged using holostereosynthesis in a single 30 × 40 cm CHIMERA hologram. When illuminated by the RGB LED lamp, a fine black-and-white 3D reconstruction of Auguste Lumiere's head appeared (**a**). Upon moving horizontally by a few degrees, the different planes were separated (**b**).

4. Discussion

The results confirmed the initial hypothesis. It is possible to replace the complex stack of photographic glass plates for photostereosynthesis with a hologram. Holostereosynthesis was successfully performed using the digital CHIMERA holographic stereogram printing technique. The eight different photos were combined using software and printed in full color on a single digital CHIMERA hologram, with a final image that resembled a pulsed portrait.

This method formed a half-parallax hologram, which facilitated visible observation of the 3D effect, in contrast to traditional photostereosynthesis, which offers a unique perspective for a single observer. Furthermore, digital CHIMERA holograms can be easily printed in various formats, up to 60 × 80 cm, and can be copied with the same RGB lasers to produce serial copies. Another advantage of the CHIMERA technique is that it produces images that pop out in front of a glass plate, which attracts attention from viewers.

This study was performed using a batch of very low resolution (427 × 545 pixels) images. If the original silver photographs—if they still exist—are digitized in high definition, it will be possible to restore and diffuse the portraits recorded by Louis Lumière a century ago, owing to CHIMERA and holostereosynthesis.

Conventional holography gives better results than photostereosynthesis in terms of parallax and 3D effects, and the interest to redevelop this technique is first historical because it brings to light an ingenious and forgotten invention. However, plenoptic cameras will soon equip the new generation of smartphones, allowing everyone to easily create 3D portraits using the method of Louis Lumière. Moreover, the development of new artificial intelligence programs should make it possible to obtain the same result from any single photo. Holostereosynthesis and CHIMERA can then be used to print these brand new 3D images, which will be the subject of our further research.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app122412524/s1, Video S1: 768 perspective images.

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