Direct-write digital holographic printing of color reflection holograms for visualization of artworks and historic sites.

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The Hellenic Institute of Holography

Established in Athens in 1987. Non-profit scientific and educational organization with its income derived by members’ contributions and services to third parties.

Mission:
Introducing and promoting Holography in Greece and abroad in all possible areas: cultural heritage, science, art, media and authentication.
A first program in cultural heritage for the HiH (1995)

https://cordis.europa.eu/project/rcn/33449_en.html
The HiH HoloCultura program

In 2009, on the grounds of accelerated technological progress in various disciplines such as solid-state lasers, panchromatic emulsions, LED illumination, computer processing power, digital hologram printing etc., the Hellenic Institute of Holography set out its own ambitious HoloCultura program for the use of colour display holography in applications related to cultural heritage.
The HiH HoloCultura program

Analogue holography

• \( Z^3_{RGB} \) (trans)portable Denisyuk type colour holography system
• HoLoFoSTM RGB illuminant
• OptoClonesTM

Results so far: OptoClonesTM from four Museums in two countries.
Acquisition and preparation of datasets for DWDH printing.

• Acquisition of parallax related images of natural scenes
  • Z-linear rail with rotating head. Simple or re-centering mode. Computer controlled.
  • Z-axial rotating platform. Embedded controller.

• Software and workstations
  • Generation of virtual 3D CG scenes
  • Image processing and preparation of parallax related datasets for digital printing of holograms
Direct-write digital holographic printing (DWDH) is a technique by which color reflection holograms or white-light transmission holograms of an object or a scene can be produced out of a series of suitable parallax related images.

• The technique is well suited to the production of scaled up or down holographic images of objects or scenes allowing at the same time slight movements, animation, layering and multiple channels to be encoded.

• The series of perspective images can be digitally captured in video or photographs or be produced by rendering frames of a 3d scene with the aid of 3d computer graphics programs.

The Hellenic Institute of Holography (HiH) has been testing the process since 2009 producing suitable series of perspective images by using most of the available image capturing techniques and subsequently printing rendered data by Geola Digital (Lithuania) for the visualization of artworks and historic sites.
Principles of DWDH printing

Schematic Courtesy of Geola Digital uab
Principles of DWDH printing

Classical digital holographic printer’s objective: 1- SLM; 2 - objective’s waist; 3 - objective’s FOV; 4 - photomaterial; 5 - reference beam; 6 - Fourier plain.

Optical holopixel’s formation: 1- SLM; 2 - objective’s waist; 3 – viewing angles of particular SLM pixels; 4 – holopixel’s recording place; 5 – holopixel; 6 – view from holopixel’s window under different viewing angles.

Schematics Courtesy of Geola Digital uab
Principles of DWDH printing

Holopixels exposure onto photomaterial (horizontal parallax hologram). 1 - Rows of exposed holopixels; 2 - photomaterial; 3 photomaterial movement; 4 - reference beam.

Schematic Courtesy of Geola Digital uab
Parallax related images from 3d program
Parallax related images from a real scene

- **Single camera mode**: Big FOV or Shift camera
- **Recentering camera mode**: Normal FOV, Needs printer specific corrections
- **Circular mode**: Normal FOV, Needs printer specific corrections
'Dispilio Vase' by HiH (2009)

Hologram of a Paleolithic ceramic vase found in the village of Dispilio (Kastoria, Greece), scanned and digitally 3D-modelled by the National Technical Univ. of Athens (Photogrammetry Section). The 3d model in obj format was imported in 3ds Max and a virtual camera was set up to move in linear mode rendering parallax pictures of the object in simple camera mode as described by Geola Digital uab instructions. Digital parallax images preparation for by HiH. Printed by Geola Digital, 20x25cm portrait, holopixel size 0.8 mm.
A hologram of a ceramic vase (original video filmed on rotational turntable) in a multi-layered composition by HiH demonstrating various depth planes. The original video footage was transformed into a jpg pictures sequence and used as surface material for a plane in a 3ds Max scene. A computer model of a distorted torus with a glossy green surface material was also introduced in the scene. A virtual camera was set up to render the parallax images while the software was advancing the jpg sequence surface material of the plane exposing geometrically corrected sequential perspective images of the vase to the camera. Digital parallax images preparation by HiH. Printed by Geola Digital, 20x25cm portrait, holopixel size 0.8 mm.
'Karyatis' by HiH (2011)

This trial digital hologram is aiming to demonstrate the use of already existing and freely available digital content in a low-resolution 3D model available for public common application depicting a well-known Greek object of cultural interest. The original model in obj format was imported into a e-on Vue software 3d scene. A background plane with neutral lighting was introduced to enhance the 3D impression of the statue in the final hologram without any further additions to this iconic statue of world cultural heritage. Digital parallax images preparation by HiH. Printed by Geola Digital, 35x50cm portrait, holopixel size 0.8 mm.
'Diomedes Horse' by HiH (2011)

A trial digital hologram aiming to demonstrate the use of original filming footage of a relatively larger object of cultural interest by using the portable traveling-camera setup (Z_Linear) of HiH and mixing of footage with CG. A cast statue of a horse of 1m in height and of approx. 50x50cm in footprint was filmed with the camera moving in recentering mode under suitable white LED lighting. The horse was filmed in digital video with a green screen background which was removed by color keying. The video sequence was exported as a png sequence with transparency and used as surface material for a plane in an e-on Vue 3d software scene. Animated logos were added to the rendered views by compositing in AfterFX. Digital parallax images by HiH. Printed by Geola Digital, 60x48cm landscape, holopixel size 0.8 mm
A digital 3D model in obj format of the iconic Memorial of monumental size (sculpture by G. Zongolopoulos) available from on-site laser scanning of the construction by the Photogrammetry Section of the National Metsoveion Polytechnic (Prof. G. Georgopoulos) was digitally placed on a virtual mountain rock in e-on Vue software 3d scene. An atmosphere with clouds and a blue sky was also added to enhance the image. This majestic monument of Zallongo, Western Greece was created between 1954-1960 and consists of 4500 pieces of white stone based on a beton skeleton, of size 15m in height and 18m in length, visible from a distance of 25km. Printed by Geola Digital, 35x50cm portrait, holopixel size 0.8 mm. Digital parallax images preparation by HiH.
A digital holographic print depicting an **aerial 3D-view** of the fully restored (2013) Naval Cathedral in the city of St. Petersburg. The Naval cathedral of Saint Nicholas in Kronstadt is the main church of the Russian Navy and dedicated to all fallen seamen. The building was **video filmed by a drone** flying in a circular path Commissioned by ITMO University. Concept and execution: ITMO University. This hologram was created in multiple versions (variant logos: ITMO, HiH, MirNauki) and sizes (**larger format 64x48cm-2 copies, smaller format 42x32cm**). The original larger size hologram (framed) was the official donation of ITMO Univ. to Patriarch Kyrill of Russia on his birthday (2016). **Original footage** filmed in June 2014: A.G. Karmanov, N.G. Anisimova. Digital parallax images preparation by HiH. Printed by **Geola Digital**, holopixel size 0.8 mm.
An impressive digital holographic print of an aerial view of Saint Alexander Nevsky Lavra, founded by Peter I of Russia in 1710 at the eastern end of the Nevsky Prospekt in Saint Petersburg, the supposed site of the Neva Battle in 1240. Commissioned by MirNauki (an affiliate of ITMO Univ. and the City of SPb). Aerial drone footage by GeoScan on basis of HiH instructions. Part of the original footage totaling 700 frames was selected and digitally stabilized. This part was interpolated to 2135 frames then exported as a jpg image sequence. This sequence was assigned as the surface material of plane in a 3dsMax scene. Printed by Geola Digital in 2 copies (64x48cm) for use by local customer and one copy (42x32cm landscape) for HiH demo collection. Holopixel size 0.8 mm. Digital parallax images preparation by HiH.
"St. Alexander Nevsky Lavra in St. Petersburg" by HiH (2016)

3d model created by Geoscan by 2d to 3d conversion of aerial footage. Loss of detail especially in foliage.

The DWDH printed hologram from the original aerial footage.
The Temple of Bel as it stands today (2018)

Photo: Maher Al Mounes / AFP/Getty Images
"The Temple of Bel" by HiH (2018)

A digital holographic print depicting a 3d view of the Temple of Bel in Palmyra, Syria, as it was before it was destroyed in August 2015. Hundreds of photos taken by tourists visiting the Temple of Bel site in the past years were submitted to Arc/k Project (http://arck-project.org/) to produce this crowd sourced 3d model. The sequence of parallax views was screen captured from the online model created by the Arc/k Project as presented in the Sketchfab web site (https://sketchfab.com/models/7a82cb38ebf042b28735339379d911e5). The captured sequence was interpolated to 2135 frames. An experimental holographic print to explore the possible uses of holography in the visualization and preservation of historical sites by crowd sourced input. Printed by Geola Digital, size 30x40 cm landscape, holopixel size 0.8 mm. Digital parallax images preparation for DWDH by HiH.

During the course of works at the Fabergé Museum, an exclusive license was granted to HiH to video-film in-situ the most famous and recognizable of the Imperial Faberge Eggs, the 'Coronation Egg’, for the first time in high-resolution and under controlled parameters. This filming took place in the evening of April 30, 2015 by Elena Bobritskaya of ITMO University with the assistance of Museum Curator Alexey Pomigaloff on the instructions and supervision of Andreas Sarakinos using equipment brought in the Fabergé Museum by HiH. Excerpt from this 360o footage was digitally processed and rendered by A.Sarakinos using the facilities of HiH in Athens, Greece and was used by GEOLA DIGITAL uab in Vilnius, Lithuania as in-kind sponsorship of the event for the origination of a master hologram on photo-resist. The resulting master was then used by HOLOGRATE in St. Petersburg (also sponsor of ISDH2015) to emboss a limited number of 200 pressure-sensitive labels in transparent high-refractive material for manual application. Size approx 8x5 cm portrait, 0.8 mm holopixel size.
A series of 8 ship replicas ranging in size from 50 cm to 2.50 meters approximately were digitally captured with a linearly travelling camera moving in a quasi recentering mode with a green screen background. These are replicas of the Russian navy battleships that took part in the Battle of Tsushima in 1905. The shooting was done in collaboration with ITMO University in June 2016. Three of these datasets were used in 2016 for lenticular printing backlit 3d posters that are in display inside the Aurora battleship in St. Petersburg, Russia. The files were processed in 2018 in 3ds max and AfterFX to produce the corrected datasets for DWDH printing. Printed by Geola Digital, size 20x25 cm landscape each, holopixel size 0.8 mm. Digital parallax images acquisition supervision and preparation for lenticular and DWDH printing by HiH.
Conclusions

The DWDH printing process is capable of producing holographic prints from a variety of parallax datasets acquired with digital video, digital photos or computer generated.

Drone acquired images can be used for the holographic visualization of large buildings and historical sites.

Crowd sourced images can be used to construct 3d models of artworks or sites and then be DWDH printed.

The ease of combining footage of physical objects with computer generated 3d models is an appreciated option.

It is of great significance that the video or photographically captured perspective views of a real object or scene, as processed by Geola Digital uab, may result in holograms which recreate 3d images with details resolution far better than those of a 3D model produced from the 2D-to-3D conversion of the same set of perspective views, especially foliage.

We hope that the presented DWDH printed holograms of various artworks and historic sites, the various methods used for capturing perspective views and the underlying printing processes can be used as a reference tool for eventual use of digitally printed holograms in cultural heritage preservation.
Thank you,
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