VISUALIZATION OF COMPLEX MEDICAL DATA USING NEXT-GENERATION HOLOGRAPHIC TECHNIQUES

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The next generation of holo-video and high quality, direct-write holographic techniques have the potential to aid doctors, medical workers, students and diagnosticians in understanding complex medical conditions, and it may even save lives. Medical holograms could translate data, from existing sources such as DICOM format, to hard copy dimensional visualizations, in order to better represent anatomical information for purposes of analysis, diagnostics and healthcare records. The medical hologram system we propose will print the data from DICOM (Digital Imaging and Communications in Medicine) using the next generation of direct-write systems.

Holographic technology in medicine will have several significant applications: **(1) 3D Visualization:** Understanding complex phenomena that are too small, fast or detailed to comprehend with conventional techniques; **(2) Medical Education:** Teaching some aspects of anatomy without the use of cadavers; **(3) Specialized Medical Processes and Techniques:** Surgical assessment and planning as well as a surgical tool in the operating theatre. A commercial example includes Voxel Corp; **(4) Diagnostic Tool:** In non-urgent diagnosis of illness where hard copy data is required as a specialized document; **(5) Forensic Medicine:** Hard copy legal document for court records that adequately illustrates 3D data and makes it consumable by non-experts; **(6) Self-Diagnosis or Participatory Medicine**: This new area of medicine provides that patients, without access to sophisticated medical imaging technology, have person-readable data.

Problems with using conventional holographic imaging (direct-write) for medical imaging include resolution and hogel size; viewing angle and recording geometry; and, brightness and efficiency (fidelity). Medical data requires close-up examination. Conventional digital holography does not support a close-up interface due to its current hogel size. A hogel, also known as a holographic pixel, is an independent holographic recording. Direct-write holograms are comprised of thousands (and sometimes 100s of thousands) of hogels. The next generation of holographic printing will see hogel size reduced from as large as 1.6 millimetres to as small as 200 microns. The angle of view will be increased from as little as 60 degrees horizontal to 180 degrees, with the addition of vertical parallax of 180 degrees. The recording geometry of some direct write recording techniques uses a linear path, restricting the look-around view. Next generation holography will use a circular path. Finally, by using the finest full-colour silver-halide film available in the world (4 nm grain size), the next generation direct-write hologram will have greatly improved image fidelity.

Advantages of hardcopy medical holograms include a better sense of location and spatial relationship when dealing with critical medical data. Hard copy holograms, reconstruct data in dimensional space, creating a simulation closer to the way humans perceive objects in real life. On-screen visualizations, by contrast, provide two-dimensional information, which must be manually manipulated in order to view the perspectives of the virtual subject. Some systems employ head tracking to infer parallax, and in this case, only one user may view the data at a time. While life-size full-body scans require high-end computers with advanced GPUs to display, a hologram can store a large amount of image data in a single frame.

Disadvantages of hardcopy medical holograms include limitations in creating interactivity. Holograms also require specialized lighting. Although, there have been many successful design solutions that have created self-contained lighting systems. The Voxbox, designed by Voxel Corp., in the '80s demonstrates such a lighting design solution specifically within the field of medical holography.

A rich history precedes the proposition of using medical imagery as content for current direct-write and next generation direct-write holographic imaging. In 1971, Dennis Gabor and his colleagues proposed, in addition to other holographic display uses, that "…[O]ne application may be a new x-ray-like form of 'ultrasonic' "sonoradiography," for use in medical diagnostics"[1]. In 1968, Stephan Benton's invention of white light viewable rainbow holograms allowed for easier accessibility of viewing holograms. Between 1973-4, Lloyd Cross's invention of multiplex holograms allowed for a holographic recording created by a multitude of 2D still images. A year later, Gilbert Baum and George Stroke demonstrated that holograms of mammograms could be made by a multitude of sonogaphic images. They stated, "[t]his volume of data may be effectively reduced by forming a three-dimensional ultrasonogram from the individual serial ultrasonograms by optical holographic techniques"[2]. They articulated that the advantages to an optical holographic display included that it would have multiple angles of view and transparency. Until the 1980s, medical display holography was limited in that the hologram was static and monochromatic. A team of researchers out of the MIT Media Lab, including Jeffrey Kulick, Stephen Benton, M. Halle and M. Klug, wrote in favour of the use of computer generated holograms for the display of medical data from CAT, PET and MRI systems. Listed benefits for medical holograms included that they are portable, full colour, hard copy images with motion parallax[3].

Voxel Corporation, which formed in 1988, used a technique developed by Stephen Hart in collaboration with Allan Wolfe to make volumetric holograms from CT and MR data. They developed their own unique film, called voxgrams, that could be viewed on their own display system called a voxbox. They state that characteristics of the voxgrams included transparency, perspective context, fusion, interactivity, faithfulness and being life size[4]. A strategy used by Voxel Corp. was to make their voxgram film the standard size that radiologists are accustomed to. For example, their holographic films were 14x17 inches, the same dimensions of a chest x-ray. Like an x-ray, they were size-as-is to human anatomy and achromatic, that is colourless.

In 1999 a group of researchers including Stephen Benton, headed by Patrick Hunziker, wrote about the then “recent” development of online holographic printing and its medical applications, specifically in improved reporting, visualizing and archiving of echocardiographic imaging. They projected that in the future, post processing would be automated and integrated into a printer that could print directly from an echocardiogram machine within minutes after image acquisition. They stated that, “[a] major limitation for broad application of the described technique at the present time is the availability of a holographic printing device”[5]. Hunziker’s team and Voxel Corp. highlight the past demand and necessity of a rapid turnaround time for medical holograms in the healthcare industry. Today, this is now possible.

Using the next generation technologies of direct-write holographic imaging, we propose to create a medical holography pipeline between hospitals and healthcare centers to a service bureau that can handle DICOM file formats. Just as we saw that Voxel Corp. did not try to re-invent medical imaging, but work with existing file formats and presentation norms, our plan is to make a print-ready data sets that are compatible with existing medical imaging and DICOM file formats. The DICOM file format is currently used to store 3D volumetric data, that can potentially be used to inform other 3D imaging mediums such as digital holography. One medical consultant, tells us, if a hologram can convey even 10% more information, it has the potential to save lives. Our research does not suggest that medical holograms will replace existing visual diagnostic systems, rather, it will be incorporated into the medical imaging process, with the intention to support findings, provide immersive imaging engagements and complement other existing imaging modalities.

With the support of NSERC, Canada's National Science and Engineering Research Council, we have developed our own pipeline for the creation of digital holograms of electrical activity in the brain. Working with Dr. Mark Doidge and his team at Cerebral Diagnostics in Toronto, we have taken EEG data from multiple sensors to form a 3D image of the brain and successfully translated the data to form a distortion free full-colour hologram[6]. The workflow, resolving in direct-write digital holographic visualizations, is derived from code written by our team combined with open-source software that work together flawlessly. Dr. Doidge's workstation will soon send camera-ready artwork to a holographic printer, via FTP, providing content to demonstrate how direct-write medical holograms could become a new form of output for medical imaging. This "pipeline" points the way to other similar pipelines for three dimensional medical and educational data sets. MRI, PET scan, CAT scan and confocal microscopy are examples of data which is recorded dimensionally, yet is most often seen in 2D, on computer screens. In the early 1900's in Canada, many of the medical textbooks used were illustrated by graduates of the Medical Illustration Program at the Ontario College of Art (now OCAD-University). We plan to be a part of that evolution, both in holography and medical imaging. The next generation of direct-write full-parallax printers, will markedly increase resolution and efficiency. Digital holography can affect how medical workers perceive complex data. Dennis Gabor coined the term holography in 1947 from Greek root words to mean a 'whole message.' Medical Holography seeks to provide a visual representation system that makes dimensional and whole the often confusing, flat and fragmented anatomical visualizations that are currently displayed with traditional two-dimensional means.

1. D. Gabor, W. Kock, and G.W. Stroke "Holography: The fundamentals, properties and applications of holograms are reviewed," *Science,* Vol. 173, No. 3991, pp. 11-23 (July 2, 1971).
2. G. Baum and G.W. Stroke, "Optical Holographic Three-Dimensional Ultrasonography," *Science,* Vol. 189, No. 4207, pp. 994-995 (Sep 19, 1975).
3. J.H. Kluick, S.A. Benton, M. Halle, M. Klug, "Volumetric Display of Soft Tissue Via Holography," *SPIE Medical Imaging II*, Vol.914, (1988).
4. S. Fredrick, "Digital volumetric holograms for medical imaging: An interview with Allan Wolfe and Stephen Hart, Voxel", From OE Reports Number 159, (1997). From web source: http://spie.org/x22917.xml Accessed, June 23, 2015.
5. P.R. Hunziker, S. Smith, M. Scherrer-Crosbie, N. Liel-Cohen, R.A. Levine, R. Nesbitt, S.A. Benton, M.H. Picard, "Dynamic Holographic Imaging of the Beating Human Heart," *Circulation,* 99:e3, (1999).
6. PHASE Lab Cerebral-holography: http://www.ocadu.ca/research/health-research/cerebral-holography.htm. Accessed; October 30th, 2015.