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Real three-dimensional cardiac imaging using leading-edge holographic display

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Abstract

Understanding three-dimensional cardiac anatomy is fundamental for the practice of clinical cardiology. However, if three-dimensional images are displayed on two-dimensional monitors, they fail to provide depth perception. Currently, novel technologies, including the three-dimensional printing, three-dimensional monitors/projectors, and virtual reality applications can provide real three-dimensionality with depth perception. However, their relatively high cost and limited user-friendliness prevent their wide application. We introduce novel and commercially available holographic display, which allows multiple observers to see the full-color holographic images simultaneously without any specific glasses and headgear. This leading-edge technology is immediately applicable in both educational and clinical settings.

Keywords

Anatomy; Cardiology; Hologram; Imaging; Medical education; Three-dimensional Imaging

Understanding cardiac anatomy is central for the practice of clinical cardiology. However, the constant increase in medical information has impeded medical students, and post graduate trainees from spending sufficient time devoted to learning anatomy (Ruzycki et al., 2019). To maintain and improve the quality of anatomical knowledge, dissection-based teaching has been complemented with newer teaching/learning methods, based on clinical imaging including computed tomography and magnetic resonance imaging (Ruzycki et al., 2019). “Three-dimensional” cardiovascular images are widely available during routine clinical practice. However, if “three-dimensional” images are displayed on two-dimensional monitors and/or other surfaces, they cannot provide precise depth perception (Mori et al., 2020). Currently, novel technologies, including the three-dimensional printing (Harb et al., 2019), three-dimensional monitors/projectors with anaglyphic glasses, and virtual reality applications with headgears (Silva et al., 2018; Iwanaga et al., 2021a) can provide real three-

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dimensional images/models with depth perception. However, their relatively high cost and limited user-friendliness prevent their wide application. Furthermore, the need to wear glasses and headgear may be somewhat inconvenient especially in clinical situations, and has the added inconvenience of the need for every individual such devices to share depth perception. To overcome these limitations, we have recently revisited and re-introduced an alternative simple and conventional approach, stereoscopic display, viewed using a cross-eyed method for better appreciation of real three-dimensional cardiovascular images with depth perception (Mori et al., 2020; Mori et al., 2021). Using this approach, observers can visualize images without the need for wearing special devices. However, even this simple approach is not without its own limitation as stereopsis requires a certain degree of training and an associated learning curve.

Recent advances in technology enables us to introduce commercially available holographic display (Looking Glass, Looking Glass Factory Inc., NY, USA) with input resolution of 2560 x 1600 pixels or more (Figure 1) depending on the model. Similar to two-dimensional monitors, it allows multiple observers to see the full-color static/dynamic holographic images simultaneously without any specific glasses and headgear. These systems are powered by proprietary light field and volumetric display technologies within a single three-dimensional box-shaped display system that updates at up to 60 fps. It generates 45 to 100 multidirectional views of a three-dimensional object so that multiple people standing around the display can see corresponding parts of the object. Thus, when moving around the display, eyes are exposed to different sets of three-dimensional information. The hologram zone, the cone view area where observers can see the object appropriately, would be 50 to 60° depending on each model. Setting up is easy with convenient interfaces connected to personal computers using USB and HDMI. However, compared to stereoscopic display (Mori et al., 2020; Mori et al., 2021), which basically needs only two paired images aligned side by side at a horizontal rotation angle of 10–15°, this holographic display requires 45 to 100 multidirectional images at a horizontal rotation angle of approximately 0.5 to 1° per each image interval to be observed within the 50 to 60° hologram zone. Thus, when using the autopsy specimen, this requires serial rotational photographs of the specimen placed on a manual rotation table, or motion capture of the specimen diplayed on an automatic rotation table followed by post-hoc serial capture of the consecutive frames. When using volume-rendered images reconstructed from computed tomography or magnetic resonance imaging, exporting such serial rotational images is required. Once such continuous JPEG images are obtained, real photographs (Figure 2, Supplementary movie 1) as well as any clinical imaging datasets such as volume-rendered images reconstructed from computed tomography (Figure 3, Supplementary movie 2) can be utilized to generate holographic images using designated software. These images are immediately applicable in both educational and clinical settings. The visual experience is near life-like and has the appearance of the actual heart in the translucent box (Supplementary movies 1, 2). Further expansion of its use of educational and clinical environments are warranted to determine its applicability for teaching anatomy and imaging. Although limitations in the hologram zone, compatibility with various medical imaging software, and ability to modify images on the display will require further improvement, this leading-edge technology may reduce the barriers to access to real three-dimensional field.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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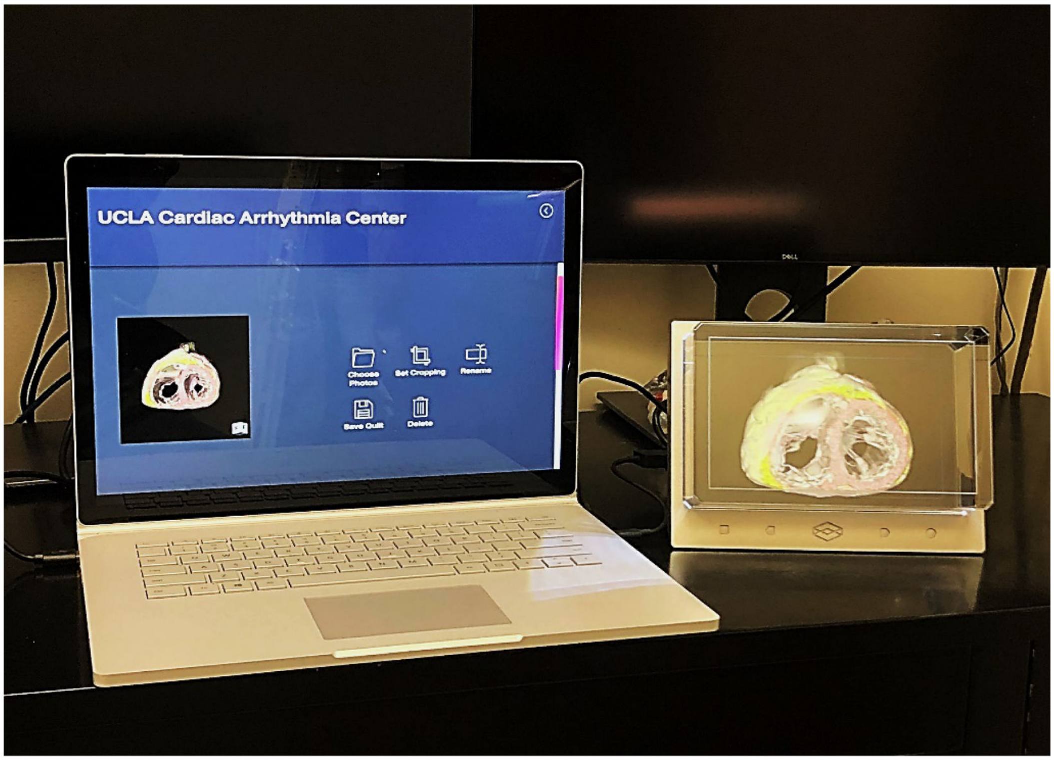

Figure 1: Holographic Display Setup

Holographic display (8.9") on a desk next to a laptop personal computer (15.0"). The atrioventricular valves are visualized in the display.

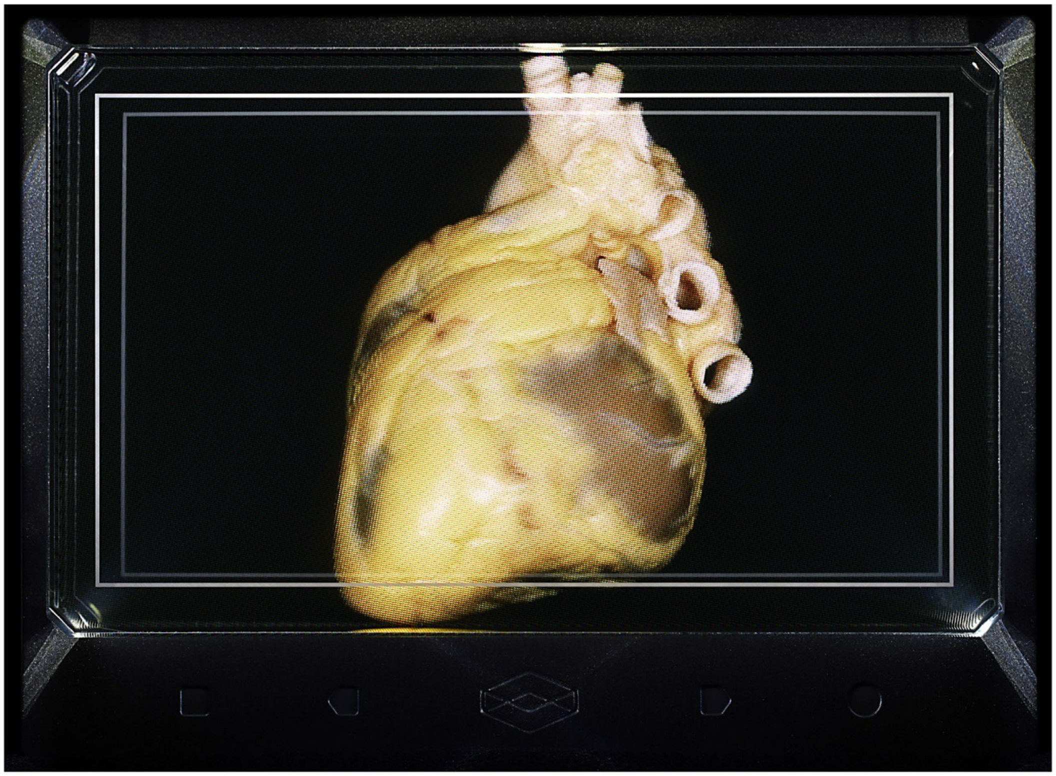

Figure 2: Display of an Autopsy Specimen

Photograph of autopsied heart visualized in the holographic display. See supplementary movie 1.

Figure 3: Display of a Three-dimensional Computed Tomographic Image

Photograph of reconstructed image of the heart visualized in the holographic display. Image reconstruction was performed using cardiac computed tomographic dataset with a commercially available workstation (Ziostation2, version 2.9.7.1, AMIN Co., Ltd., Tokyo, Japan, Ziosoft Inc., Tokyo, Japan). See supplementary movie 2.