Stereoscopic Visualization: A Novel Approach to Anatomy Teaching and Procedural Planning

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Published on 21st October 2024

ABSTRACT

Traditional anatomy teaching in medical curricula, particularly in India, relies heavily on cadaveric dissection and two-dimensional diagrams. While these methods provide foundational knowledge, they fail to convey the intricate three-dimensional complexities necessary for understanding anatomical structures in the context of surgical and interventional procedures. Stereoscopic visualisation, which leverages binocular vision to simulate depth perception when adapted for medical education, offers a promising alternative by enhancing spatial understanding of anatomical structures.

The stereoscopic visualisation system, developed collaboratively by the Sree Chitra Tirunal Institute for Medical Sciences and Technology (SCTIMST) and Government Engineering College Barton Hill (GECBH), successfully provided 3D visualisations of patient anatomy, enhancing spatial understanding. Key features included real-time processing of CT and MRI data, the ability to visualise large groups simultaneously, and cost-effectiveness. The system allowed for direct visualisation of DICOM files without preprocessing and included customisable features such as windowing techniques and arbitrary plane sectioning. Users reported significant improvements in understanding complex anatomical relationships and planning surgical interventions. Additionally, the system was superior to cadaveric learning for certain visceral anatomies due to its ability to maintain anatomical orientation and spatial relationships. All this makes it a valuable tool in medical education and practice. Despite challenges such as the need for specific software, hardware, and a dark room setup, the system's benefits outweigh these limitations. Future improvements could enhance its capabilities and applicability in medical education and surgical precision. The system thus represents a significant advancement in leveraging stereoscopic technology to bridge the gap between traditional anatomy education and modern clinical requirements.

Keywords: Stereoscopic Visualisation, Anatomy Teaching, Surgical Planning, 3D Virtual Reality, Medical Education, Spatial Understanding

*See End Note for complete author details

INTRODUCTION

Traditionally anatomy has been taught during preclinical years of medical curriculum in India using cadaveric dissection and 2D diagrams. However, understanding anatomy's relevance in surgery and interventional procedures requires a deeper, three-dimensional comprehension. Each procedure (surgical or interventional) needs a unique plan due to the variability in patient anatomy. In a semi poetic statement it is often stated

Cite this article as: Palanisamy DR, Alex A, Shenoy SJ, Vavachan AA, Vimala S, Sukesan S, et al. Stereoscopic Visualization: A Novel Approach to Anatomy Teaching and Procedural Planning. Kerala Medical Journal. 2024 Oct 21;17(3):186–90.
| DOI: https://doi.org/10.52314/kmj.2024.v17i3.671

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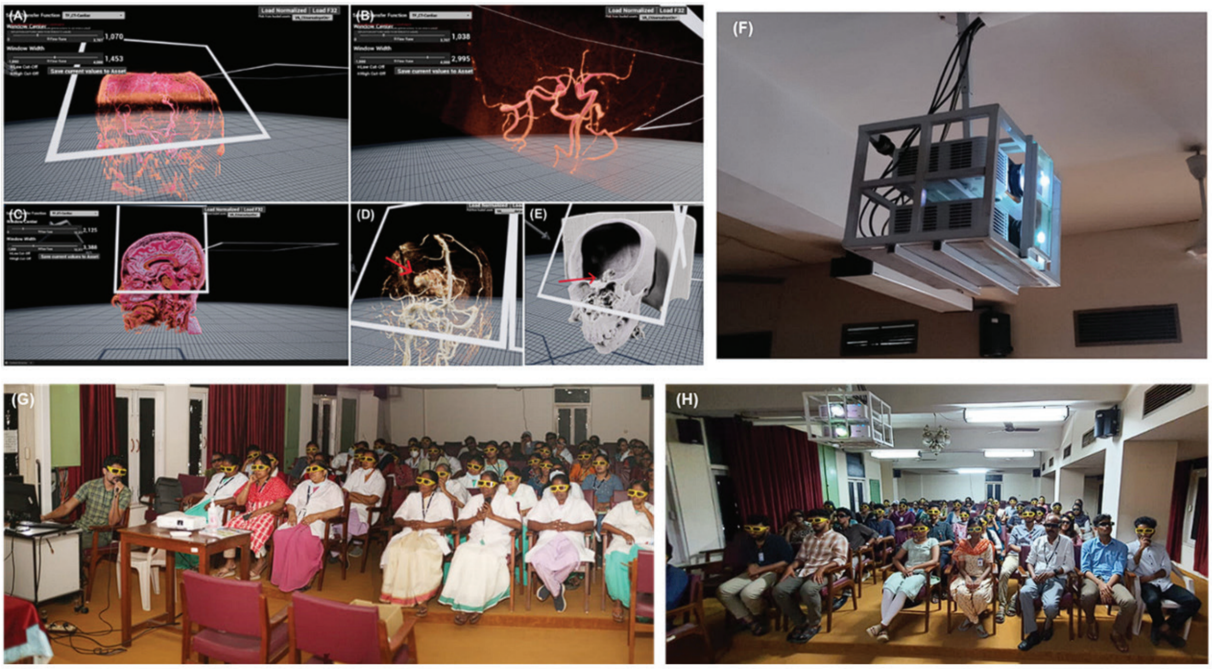

Figure 1. **Surgical planning system at SCTIMST: (A-E) Images of the renderings of different anatomical regions using the developed tool, (F) Photograph of 3D dual projector setup, and (G-H) clinicians and students viewing images using 3D glasses.**

that 'Anatomy is the war map for the operations of a physician".[1] Current imaging techniques often lack depth perception, which is crucial for spatial anatomical concepts, limiting effective procedural planning and cross communication among various disciplines of medicine (Physician, Radiologist and surgeon).

STEREOPSIS AND STEREOSCOPY

Stereopsis is the ability to perceive depth due to binocular vision, where each eye captures a slightly different image because of the location of the eye balls (interpupillary distance - 6 cm), so that the images falling on each of the retinae are slightly different (retinal/binocular disparity) and the brain merges these images in to a single three dimensional image with an illusion of depth.[2]

Stereoscopy replicates this by using two images with slight differences to create a 3D effect, enhancing the understanding of spatial relationships in anatomy. The term Stereoscopy is derived from Greek, where 'stereo' means solid and 'scopy' means to see. This technique which was widely used in the entertainment industry for making 3D movies, is now being used in medical education and procedural planning to provide detailed anatomical visualisation.

THE STEREOSCOPIC VISUALISATION SYSTEM

The system developed by SCTIMST and GECBH, a cost-effective, indigenous, student-built, 3D virtual reality system to aid anatomy teaching and surgical planning. The software part of the system is developed using a high-performance 3D game development tool. The entire software **(Figure 1A-1E)** is controlled using a customised handheld device. The system uses a dual projector setup (developed as part of an earlier project in collaboration with IIIT Hyderabad and SCTIMST[3,4] with two polarising lenses in front of each projector **(Figure 1B)**, each projecting an image of a slightly different perspective. The viewer wears a simple pair of polarised glasses **(Figure 1C)** to ultimately "cheat the brain" into perceiving a 3-dimensional image.

Unique features of include:

1. Stereoscopic Vision and 3D visualisation of patient data from CT or MRI
2. A larger group of audience can visualise at the same time
3. Direct visualization of DICOM files without pre-processing
4. Cost effective

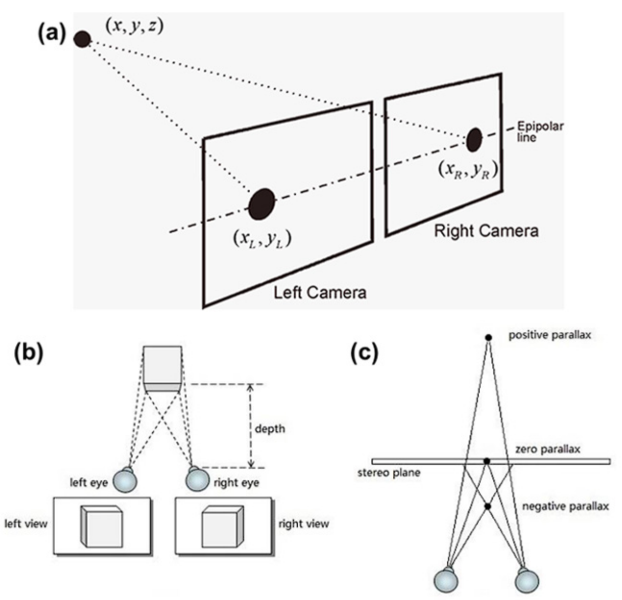

Figure 2. **Two cameras, acquiring images of the same scene, have two different 2D representations of a common 3D point. With proper processing, the position and depth of the 3D point can be extracted from the images.[5] B) Principles of stereoscopic 3D. (a) Binocular views. (b) Three types of horizontal parallax.[6]**

CAPABILITIES OF THE SYSTEM

The system processes CT data (plain or contrast) in the DICOM format (Digital Imaging and Communications in Medicine - A file format used in radiology for images) in no time generating 3D images visible through stereoscopy (which we call models) (See **Figure 2**) These models thus produced, can be tilted or rotated in any direction to change the view. They can also be sectioned through any arbitrary plane. This approach is distinct from the currently available graphic models in the market for anatomy teaching. Windowing techniques allow the visualisation of specific structures by adjusting the intensity values. Structures can be distinctly coloured based on intensity values for better differentiation.

POTENTIAL USES AND IMPLICATIONS

Teaching Anatomy:

Though traditional teaching methods in anatomy are time-tested, studies have shown that students often fail to translate their anatomical understanding in clinical practice.[7] This may be more relevant in the current era where use of clinical imaging has advanced exponentially. Stereoscopic visualisation tool could be an effective teaching aid for medical students due to its capability to provide an effective spatial understanding of anatomy and the correlation with radiological and surgical anatomy.[8] The 3D model in this technology is derived from actual patient data, which creates an "early clinical exposure" (ECE) to the preclinical phase students, which is what NMC currently recommends. Traditional anatomy teaching can be complemented with 3D visualisation thus training medical students in the early years itself. This will avoid unnecessary 'unlearning' and 'relearning' of anatomy that can occur in the future years of medical training; but rather students can "build upon" what they learn in preclinical years.

Alternative to Cadaver Scarcity:

Since cadaver/ specimen availability is poor in various medical colleges (especially in private medical institutes) 3D virtual models seen here can be used. This is also a more ethical alternative and cadavers can be channelled to more practical training like surgical approach, procedures and skill training.

Superior to Cadaveric Learning:

Certain visceral anatomy (eg. cardiac chambers), its orientation and relations can be better learned through this method than in a cadaver. The reason for this is that once the heart is removed from its in-situ position the "attitude" of the heart can never be recreated. Also once dissected, repositioning the tissues is also not possible in cadaveric anatomy learning. These advantages of 3D visualisation makes it a superior choice for learning the spatial anatomy of certain structures.

Paramedical and Allied Health Science Training:

Paramedical courses like nursing, medical lab technologists, cardiac perfusionists, occupational therapists etc. who do not require dissection in their curriculum, can make use of this tool for making the students understand the proper orientation as per their learning requirement.

E-learning Modules:

Though stereoscopy is not practical in e-learning modules, photographs and videos of the 3D model can be taken in a non-stereoscopic mode and learning modules can be created in the setting of a digital classroom. As Indian medical education is reviving its e-learning capabilities, this tool can have a significant impact.

Procedural Planning (surgical and interventional) and Management:

Adult/ Paediatric cardiac intervention and surgery: Three dimensional visualisation enhances the cardiologist/cardiac surgeon to understand complex anatomical substrates such as congenital heart disease and structural heart disease. This is essential because most of the procedures are done using 2D fluoroscopic images by the cardiologist and 2D CT images will not give complete information regarding the morphology in complex congenital heart disease for corrective surgeries.

Vascular surgery and intervention: The technology allows the surgeons to visualise the abnormality in the vasculature such as congenital abnormalities, the origin and extent of stenosis, dissection, aneurysm etc in aortic and other great vessels and allows for planning of the types and size of stents, flow diverters etc. without additional imaging such as DSA.

Neurosurgery requires precise trajectory to the lesions to avoid injury to eloquent areas of the brain. This technology can allow for planning of the surgery in areas involving eloquent areas and also to avoid injury to vessels and preservation of cranial nerve function in complex neurovascular and skull based surgeries.

Postgraduate Training: The system has immense application in the teaching and training of postgraduate students from various discipline. Application of this system to their curriculum will help them to have better appreciation of the anatomy thereby improving their procedural skills also.

CHALLENGES

- Requires specific software and hardware.
- Needs skills to operate (which can be acquired by some training)
- May cause eye strain and discomfort for spectacle users.
- Requires a dark room setup.
- Initial setup cost can be high.
- Additional improvements needed for rendering certain tissues like brain.

FUTURE DIRECTIONS

This tool has immense potential in anatomy education and surgical planning, offering realistic and immersive environments. Further development can improve its efficacy and contribute significantly to medical education and practice.

CONCLUSION

Stereoscopic visualization, leveraging binocular vision to create 3D images, enhances anatomy teaching and surgical training. The SCTIMST system, with its dual projector setup and polarizing lenses, offers numerous advantages despite some challenges, with potential for further improvements to advance medical education and procedural precision.

END NOTE

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Conflict of Interest: None declared

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