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AUGMENTED REALITY IN MEDICINE: TECHNIQUE, SCOPE AND STATUS

Radiology

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ABSTRACT

Augmented reality (AR) is the technology by which real world experience is augmented or modified by computer generated sensations. It is a rapidly evolving, revolutionary technology which has the potential to extensively transform many aspects of medical field. The use of AR in medical field is not new but its applications were minimal due to its technical limitations. Recent development of holographic stereoscopic high-resolution displays, better image registration techniques and faster processing units have circumvented many of the limitations. Hardware and software improvements made AR applications possible in smart phones. The most critical application of AR is in surgery and related procedures. The crucial concept is fusion of real time image of a patient to the radiological data, which will considerably reduce the risk, length and expertise needed while increasing the patient safety. Understanding the current techniques and scope of AR will help in early adaption of this technique.

KEYWORDS

AR, Augmented reality, 3D visualisation.

Introduction

AR is a technology which integrates computed generated virtual (computer generated) inputs to the real world experience in real time.(1,2) The role of AR is to enhance the user's perception of and interaction with real environment and make a task easier to perform.(2) Currently vision, hearing and touch can be satisfactorily augmented. The cardinal role of AR is in visual augmentation. Readers who are new to the technology are advised to see the videos on Microsoft HoloLens official web site and try a smart phone AR app for a basic understanding.

Technology

The key concepts in augmenting vision is adding computer generated graphics to the real vision. This can be direct (optic see-through and projective) or indirect (video see-through).

In optic see-through technique, optical combiners are placed in front of the eye. These combiners are partially transmissive so the user will be able to see the real environment without affecting the real world resolution and with slightly reduced brightness. The partially reflective nature of these combiners helps to reflect images produced in a camera. Thus, the computer generated images (virtual objects) are blended to the real environment. Preservation of real word optical resolution and 3D visualisation are the most attractive features of this technology. 3D visualisation is desirable for most of the medical applications. At present holographic display technology is leading. More advanced technologies like light field displays and virtual retinal display (VRD) are under development.

Projective displays use one or more projectors to projects the augmented graphics onto a surface. In video see-through method the real world environment is first captured by cameras. The computer generated augmented graphics are blended with these images and displayed to a screen. 3D models or objects for AR are produced from specialised software or by scanning a real life model by specialised scanners. Computed tomography (CT), magnetic resonance imaging (MRI) or 3D ultrasound obtains 3D volumetric data and can be included in the latter group. Here each pixel in the image will be associated with three coordinates. In some occasions, 3D models of surgical instruments will be also required. This can be done easily with the same modelling options.

In stereoscopic 3D visualisation, each eye is presented with 2D images of the 3D objects in two slightly different angles. This angle depends on the depth at which the object should be perceived. Multiple objects at multiple depth can be visualised by varying the viewing angle between the images. Creating a perspective from an angle is easy for an object in a 3D coordinate matrix. The same techniques used for viewing volumetric radiological images in a particular angle using volume rendering or rotating 3D models in computer are used for this. In mono ocular visualisation, the 3D objects are displayed by 3D rendering. 3D rendering is a technique by which a 3D model is converted to a 2D image having mono ocular 3D characteristics. In mono ocular visualisation, perception of depth is simulated by various techniques including motion parallax, apparent size, texture gradient, occlusion, shades, and shadows. For optimum experience and operation, the objects in the real and virtual worlds must be properly registered (aligned) with respect to each other. Precise registration is one of the most important requirements in medical AR which is determined by the accurate positioning and orientation of the real and virtual coordinate systems. Real environment must be registered with the three coordinates and viewing angles. Any positional or angular changes should also be detected and registered properly. The positioning of the viewer or the AR device in a coordinate system is obtained usingvarious measuring tools and sensors. These includes accelerometer, gyro meter, magnetometer, global positioning system (GPS) (all of these are present even in some of the low end smart phones; GPS is not accurate to be useful in medical AR), markers (fiducials) at known coordinates, feature tracking (matching objects known to the system), electromagnetic fields triangulation methods, ultrasound, LASERs etc. In addition to this the depth of the real world objects from the viewer are determined by specialised depth sensing cameras which are increasingly used in many fields nowadays. The surgical instruments may also require positioning and orientation. This can be done by the described methods.

In AR, when a virtual graphic is displayed beyond an opaque real world object, the illusion of reality is lost because this occlusion is one of the strongest depth cues. The user experienced optical confusion. Similarly, when a generated graphic object is displayed in front of a bright real world object, the virtual object will appear translucent. This occlusion is also a critical problem in medical AR. In direct HMDs one way to solve this is by making the view frame or viewing optics (through which the user sees the real world) selectively opaque based on the depth received by the specialised cameras, the relative depth between the real object and the virtual one, the brightness and the requirement of opacity. This can be done by using liquid crystal technology. In projective displays, the former type of occlusion is impossible. In indirect AR, this is easy to solve by simply simulating transparency by blending the real images available in digital form with the virtual images. In indirect AR, this can be done even without depth sensing mechanism.

Motion tracking, a wide field of view, adjustment to convergence or accommodation and outdoor capabilities are not crucial in medical AR. So these factors, which are constraintsof today's AR technology will not seriously affect medical AR. Photorealistic capabilities including lighting conditions, surface reflexions and shading capabilities, which are yet not well developed are optimal but not indispensable for medical AR.

Scope.

The scope of AR in medicine can be divided into four basic categories – (1) displaying inconspicuous details like visualisation of underlying anatomy by using radiological data, (2) displaying ancillary data, which includes displaying graphically generated data or displaying textual data like patient's vitals or instructions, (3) enhancing the perceivable details, like enhancing the difference between blood vessels and soft tissue in case of surgery, (4) hiding details, similar to making the superficial structures transparent while doing a radiologically guided needle biopsy. Most of the AR applications use a combination of the four techniques. How these methods are implemented is described in 'technology' section.

AR in *surgery and related procedures* is widely awaited. Here, the previously acquired or real-time radiological 3D volumetric data obtained can be visualised as if it is inside patient's body as the overlying tissues are made semi-transparent. Planned data can also be visualised outside the tissues. The surgeon will be able to see the previously acquired or real time anatomical details, details of surgical instruments within tissues or planned data deep inside or outside patient's body. This will increase the accuracy, ease and safety of the procedure. In scenarios like in tumours and in re-explorative surgeries, where the normal anatomy is altered, AR will help in making the surgery more complete, along with all the other advantages.

In *reconstructive and cosmetic surgeries*, a previously planned 3D virtual model can be overlaid on the desired part and the reconstruction can be based on this planned model. This may improve the cosmetic as well as the functional outcome.

In *robotic surgeries and laparoscopic surgeries*, video see-through AR technologies are easy to implement as they relay on images captured by camera.(3) This technology provides the surgeon more control on the procedure as well as the anatomical details of the obscured structures. The range and motions of the instruments can be anticipated and pre-planned.

Virtual objects in AR can also be based on non-radiological data. Critical structures like arteries or nerves can be identified outlined either visually or radiologically before or during the procedure and displayed as augmented graphics so that it can be avoided during procedures. The video recorded by AR device also can be used for creating virtual objects. For example, multiple bleeding spots in a surgical field, which will obscure the vision rapidly can be identified by rewinding the recorded video and creating virtual markers over the required vessels. Displaying textual data and other information are also useful features. The clinician will be able to access these data without losing much of focus from main task.

One of the other advantage while using AR technology is the ability of multiple experts to see what the surgeon observes from remote stations and obtaining guidance from them. Whatever is captured by the cameras also can be documented and reviewed. If previously acquired data is precisely registered, a guided biopsy can be performed with minimum added radiation exposure. Head mounted devices (HMD) with optic see-through technology and stereoscopic capability is best suited for this purpose.

Video see-through AR technology using smart phones or tablets are much cheaper and widely available compared to HMDs hence got immense potentials. Many apps and games which uses this technology are available in android and apple app stores. There will be some initial adaptation problems while using this technology, comparable to that seen with laparoscopic procedures and the display is essentially 2D. Although AR with mobile devices are not suitable for many surgical scenarios, it is promising for relatively simple procedures like image guided biopsy. In its most basic form, this technology can guide the needle based on externally created AR objects like a virtual guide line. It is also possible to virtually project the biopsy target and occluded needle inside patient's body for a better procedure. The localisation method can be based on a simple marker. This marker can be placed on the body and the coordinates relative to the target can be obtained through a CT or MRI localisation methods. In these scenarios, this technology shows immense potential considering the easy implementation and wide availability of capable devices.

Status

Microsoft HoloLens is the most successful direct HMD AR device till date. Indirect AR technologies are being implemented very quickly in mobile devices including smart phones and tablets, Google's ARCore is an example. Most of the technologies for application of AR in medical field are ready now and seems applicable. All the technological giants including Microsoft, Google and Facebook are actively involved in developing new technologies in the field of AR. The current limitations in AR will be solved by itself along with technological developments.

Conclusion

AR is a rapidly evolving technology. AR will be incorporated into many of the existing fields including medical field and revolutionise them. Familiarity with the techniques and applications will lead to an early adoption of this technique into medical field.

Conflict of interests

Nil

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Not applicable

Ethics committee approval

Not applicable

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