Using Virtual Reality to Teach Radiographic Positioning

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Using virtual reality to teach radiographic positioning overcomes many of the limitations of traditional teaching methods and offers several unique advantages. This article describes a virtual reality prototype that could be used to teach radiographic positioning of the elbow joint. By using virtual reality, students are able to see the movement of bones as the arm is manipulated. The article also describes the development and challenges of using virtual reality in medical education.

This article is a directed reading. See the continuing education quiz at the conclusion.

Virtual reality is more than a transient media catchphrase; it is a technology that has the power to revolutionize many facets of modern life.

Once primarily associated with computer games and other forms of entertainment, VR applications now are springing up in a variety of settings from aviation to medical education to psychotherapy.[1-4]

Its potential is perhaps greatest in medicine. Specific medical applications of VR include surgical simulation,[5,6] fetal ultrasound in conjunction with VR[7-9] and clinical planning for plastic surgery or prostheses.[10] As Satava[11] stated, "Whenever something is too dangerous, expensive or distant in time, place or imagination to physically experience, there have been attempts to simulate the experience.... The new technology of virtual reality brings a measure of the conveyed experience with interactivity."

Rapid advances are being made in three-dimensional medical imaging of the human body for noninvasive diagnostic and therapeutic purposes. The increasing dependence on computer-based techniques indicates the power and convenience of these methods. Virtual reality has simplified the procedures and techniques by providing better visualization ability for medical personnel, including those in radiologic science. Considering that computer-assisted instructional packages already are firmly established, VR-based medical educational tools are inevitable and justifiable.[5,10,12,13]

This article discusses the development of an innovative approach to teaching radiographic positioning. This prototype approach uses virtual reality to help students understand three-dimensional aspects of anatomy in motion. In doing so, this approach overcomes many of the limitations of traditional radiographic teaching methods.

To demonstrate the feasibility of this novel approach to positioning instruction, our prototype focuses on motion of the arm at the elbow joint.

This article describes the VR radiographic positioning tool. With this interactive tool, electronic devices worn by the student and a model who acts as a patient are connected through a computer. The computer coordinates information to impose an image of the bones, in appropriate orientation, onto the flesh of the "patient's" arm while the arm is manipulated by the student. The student, thus, can witness the effect that moving the arm has on the bones.

This article also presents the stages of development to overcome the predicted technical challenges and discusses the advantages of using virtual reality as a teaching tool for radiographic positioning, which far outnumber the disadvantages.

Development beyond the prototype will allow virtual reality technology to be applied to all other aspects of radiographic positioning instruction. Applying virtual reality to radiographic positioning eventually could revolutionize radiographic education.

Traditional Radiographic Positioning Teaching Methods

Traditional methods of teaching radiographic positioning include:

- Two-dimensional textbook photographs, instructions and labeled radiographs.
- Memorization of standard central ray centering points and degree of beam angle.
- Demonstrations by the instructor that are passively observed by students.
- Simulations on classmates.
- Laboratory exposures of positioning phantoms or skeletons.
- Videotapes, slides and audiotapes that describe positioning methods.
- Supervised positioning of actual patients in clinical settings.

Each of these traditional methods of teaching radiographic positioning requires the radiography student to correlate the educational presentation with what he or she knows about the three-dimensional structure of the human body. The three-dimensional dynamic changes that occur when a patient moves his or her body are difficult for some radiography students to visualize and understand.

Each of these teaching methods has limitations. They may not realistically simulate the alignment and movement of anatomical joints; they may not teach compensations for patients with limited range of motion; and they may not reinforce the connection between the anatomical part being imaged and the rest of the patient.

Successful radiographic positioning is based on the technologist's ability to visualize the patient's anatomy and adjust his or her position to demonstrate specific perspectives of the anatomy. This aspect of radiography is natural for the experienced radiographer, but sometimes is difficult for the radiography student to grasp. A more useful teaching technique, therefore, would be to impart a thorough understanding of the three-dimensionality of human anatomy through a 3-D visualization modality.[14]

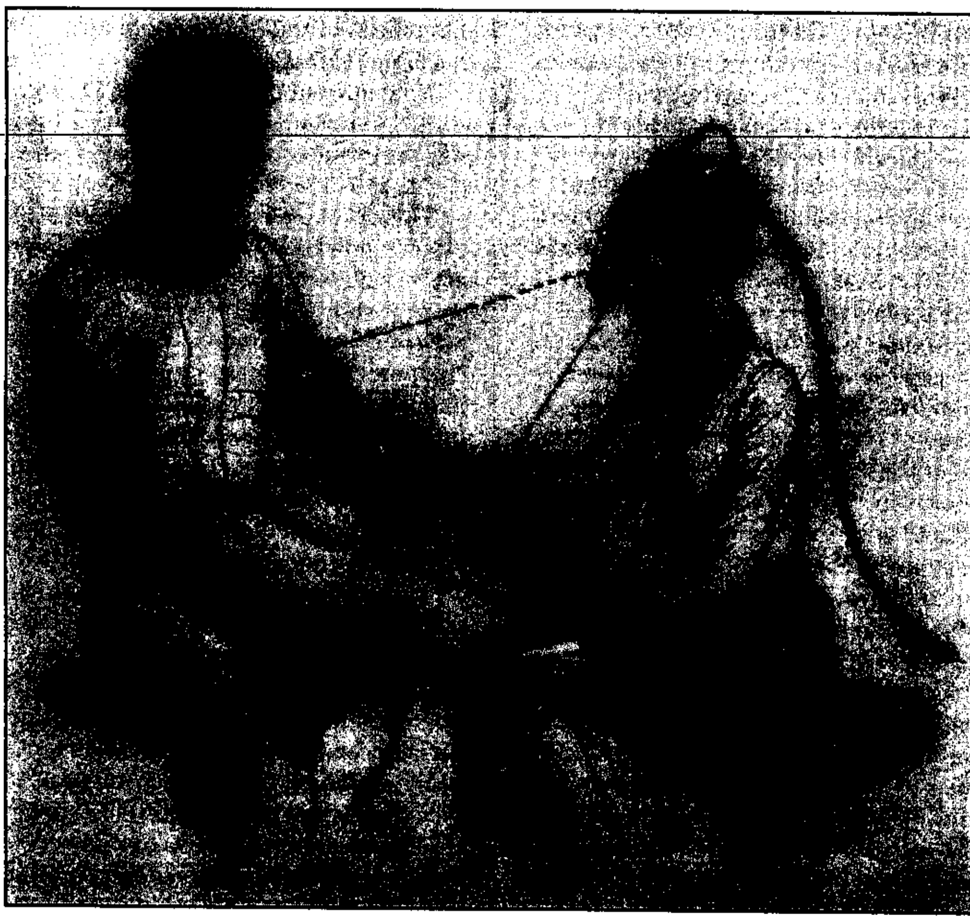


Fig. 1. *This illustration depicts how the VR radiographic positioning tool could be used. Drawing courtesy of Andrei State.*

The VR Radiographic Positioning Tool

Radiographic positioning using virtual reality provides a unique combination of visual and tactile learning experiences for the student. This innovative approach to bony anatomy positioning combines computer technology and hands-on patient contact. The VR radiographic positioning tool is based on augmented reality, a modified version of virtual reality that "augments" the real world view by superimposing computer-generated graphics.

The learning setting for our prototype involves a student and a model who acts as a patient. (See Fig. 1.) The student wears a head-mounted display (HMD) virtual reality gear. (See Fig. 2.) The see-through HMD allows the student to view his or her real world while also allowing computer-generated images to be superimposed on the real world. Semitransparent mirrors enable this superimposition. A head motion tracker keeps the computer informed about the position and orientation of the user's head.

The "patient" wears a set of magnetic trackers on the body part to be positioned, as shown in Fig. 3. Ideally, microtrackers would be surgically implanted in the "patient's" bones to allow accurate tracking of bone movement. Instead, Velcro bands are used to attach the magnetic trackers to the "patient's" skin surface.

To demonstrate elbow positioning, one tracker is placed on the distal humerus, one is placed on the proximal forearm and another is placed on the distal forearm. These trackers monitor movements by the "patient" and report information to the computer. The trackers must be mounted firmly to prevent sliding along the "patient's" body part. Consistent positioning is essential for calibration and registration.

Specific challenges in augmented VR include registration of real and graphical objects, the ability to occlude a real object by a graphical object and vice versa, calibration of the HMD and accuracy and resolution of the trackers. For example, technical problems could arise if some bone-joint spaces are smaller than the errors reported by the trackers.

To use the VR radiographic positioning tool, the student positions the "patient's" body part. The computer produces the appropriate real-time images of the bones as they would appear with the arm in any position. (See Fig. 4 and Fig. 5.) The computer-generated images of bones then are superimposed on the "patient's" real flesh. The student simultaneously sees the real arm and the bones in motion.

Because image lag-time is detrimental to the VR experience, one challenge is to make the computer-generated graphics fast enough to make the process seem realistic. Lag-time is the delay between what you should see — based on your experience in the real world — and what you see when in the virtual world. The delay is dependent in part on the complexity of the computer-generated images, but also on other factors such as the quality of the trackers used for measuring motion of the head and other anatomical parts, image generation and display capabilities. Using deliberate, controlled movements can diminish lag-time problems.

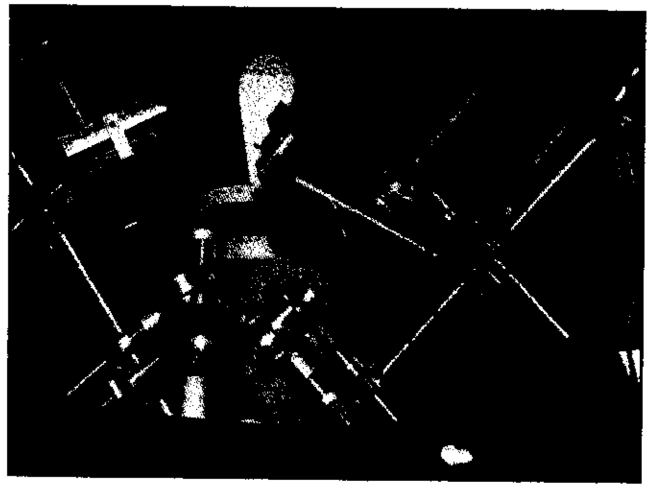


Fig. 2. *An example of see-through, head-mounted virtual reality gear.*

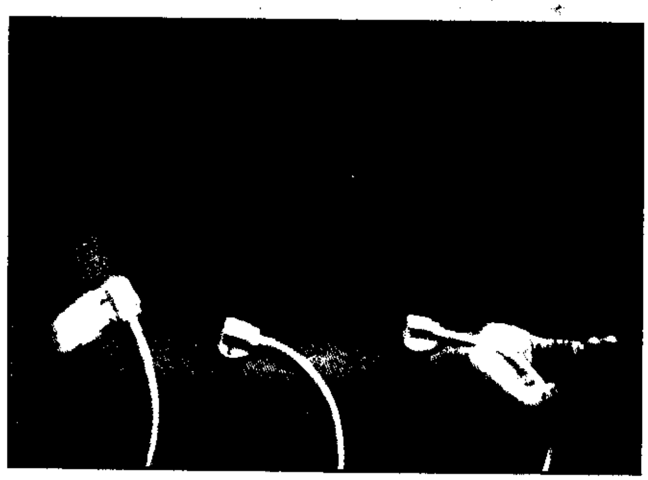
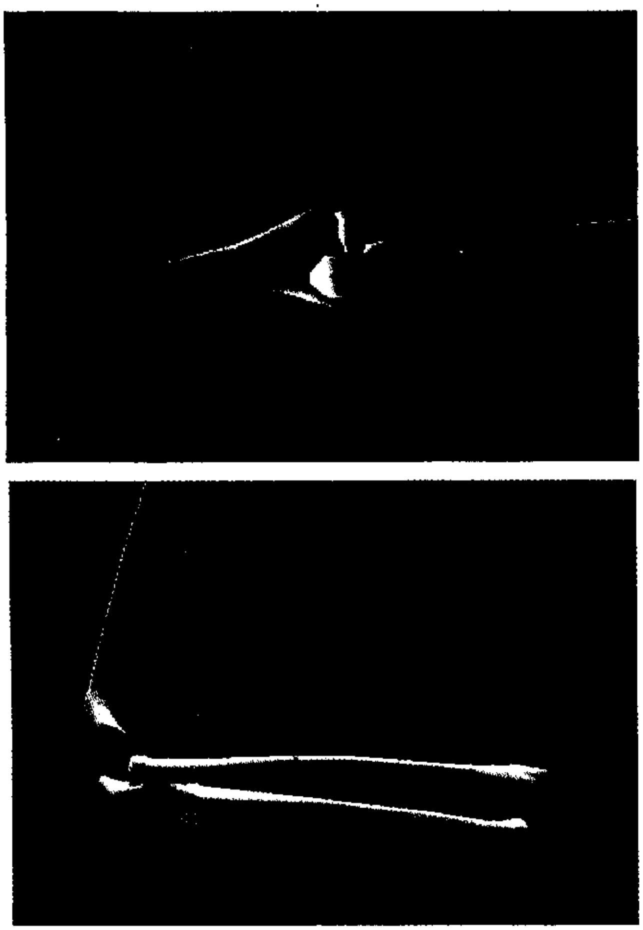


Fig. 3. *A model, acting as a patient, wears magnetic trackers that allow the computer to follow his movements.*

The "patient" cannot see the graphics bones but can respond to the manipulation as a real patient would by adjusting his or her body to a more comfortable position, limiting his or her range of motion or expressing concerns about the procedure. This reinforces to the student the importance of dealing with the patient as a whole rather than just positioning a body part.



Figs. 4 and 5.

The prototype is designed to describe an elbow joint because of its accessibility, clinical significance and simplicity of joint dynamics. The prototype will demonstrate flexion, extension and the effects of pronation and supination on the elbow joint. The humerus is in a fixed position for these manipulations. Because the system is designed to demonstrate bone relationships, rapid "patient" movements should be avoided.

Development of the radiographic positioning tool occurs in three stages:

- The first stage accomplishes animation of the computer-generated graphics bones with a Silicon Graphics Workstation. A commercial bone model data set will be adapted based on biomechanical references related to axes and ranges of motion. Comparisons with dry skeletal arms and fluoroscopic images provide information on realistic joint movement. The model will need to be scaled for arm size variations based on external "patient" measurements.

  The prototype graphics bones do not account for gender differences, individual anatomical variations or pathologies. Future models may be based on digitally scanned computed tomography or magnetic resonance images rather than rendered graphics bones. Future versions also may simulate anatomical and physiologic variations and limitations such as congenital defects, degenerative changes or acute pathologies.

  The first stage displays are monoscopic with no stereo involvement. The goals for this stage are realistic bone movement and familiarity with graphics manipulation.
- The second stage involves enhanced reality. In this stage, trackers are applied to the model patient's arm. A single miniature camera records the student's perspective when positioning a body part. Manipulation of the "patient's" arm is recorded and displayed on a monitor. Images of the graphics bones are superimposed on the video images of the "patient's" arm. The displays are not stereoscopic and do not compensate for real-time head movement.

  The goals during this stage are to resolve problems with calibration, registration and tracking mechanisms.
- The third stage involves the bench-type optical see-through HMD. This stage is called augmented reality because the student will see the real world superimposed with the graphics bone renderings. During this stage, the real-time images are stereoscopic but are not compensated for head movement because the bench-type HMD limits head movement.

  The goals during this stage of development continue to be resolution of problems with calibration, registration and tracking mechanisms, with the addition of the see-through real world images.

Advantages of the VR Radiographic Positioning Tool

Similar to other medical virtual reality applications,[6] the VR radiographic positioning tool offers a number of advantages:

- Students will be better prepared to work with real patients in actual clinical situations. By using virtual reality positioning, students may become more adept with clinical problem-solving because they understand the reasons behind the positioning practices rather than just memorizing positioning descriptions. This may mean improved patient care and fewer repeat radiographs attributed to positioning error.
- Virtual reality positioning permits students to learn through several senses simultaneously. They can touch a real human, feel the resistance from soft tissues, see the results of their manipulation, and talk to and hear from the "patient" about comfort and other sensations associated with the procedure. Learning through multiple senses helps reinforce the learning experience.
- Radiographic positioning can be taught in a more holistic way. Patient communication, patient care, joint range of motion and other components of radiography can be reinforced through virutal reality positioning.
- Students get immediate feedback about the accuracy of the positions they create. This creates an interactive learning system. Rather than memorizing facts, the students see what works and what doesn't work.
- The "patients" in a virtual reality learning situation have no risk from radiation exposure or repeated attempts to position a part correctly. The experience is more realistic than radiographing phantoms, which do not have realistic joint range of motion. Also, it is safer than learning radiography by positioning real patients whose injuries may be exacerbated by manipulation.
- Students who need additional practice or individualized learning experiences can work independently from other students.

Disadvantages of the VR Radiographic Positioning Tool

The virtual reality radiographic positioning tool currently faces many deterrents; one of the biggest obstacles to its widespread implementation is cost. Powerful computer support — including equipment, software and experienced personnel — is prohibitively expensive for many educational institutions. As with most computer-based applications, this obstacle probably will become less significant with the passage of time.

Other deterrents to widespread implementation include:

- Complex shapes in motion within the virtual environment are difficult to transmit rapidly. In fact, the computational support necessary for absolutely realistic VR sensory input and object reactivity has not been developed yet.
- Some VR operators suffer nausea in the virtual environment. Using an optical see-through HMD may alleviate this problem.
- Some VR operators lack the tactile sense and coordination skills to manipulate items in the virtual environment.

Conclusion

Using virtual reality to teach radiographic positioning is an innovative approach to helping students understand dynamic three-dimensional anatomy. The prototype VR project described in this article provides a unique combination of visual and tactile learning experiences from perspectives unavailable with traditional teaching methods.

This article also describes the realization of the first prototype in three stages. Those stages aim at solving milestone challenges. The prototype will demonstrate the feasibility of using virtual reality applied to elbow joint positioning. With this prototype, a student can manipulate a model patient's arm and see appropriate images of the bones as they change position in response to the manipulation.

The potential advantages of medical applications of VR outweigh the current disadvantages, especially considering how effectively VR can overcome some of the limitations of conventional radiographic positioning education. The VR positioning learning experience is far more realistic than working with radiographic phantoms or skeletons and safer than learning radiography on actual patients.

Such a teaching tool could not only eventually revolutionize the way that educators teach radiographic positioning, but could be applied to any situation in which objects need to be visualized as they move through space in real time.

Development of this virtual reality radiographic positioning teaching tool presents many challenges, but the benefits and potentials for future applications promise to be astonishing.

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