A virtual environment for the training and development of radiotherapy techniques

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Abstract

Purpose: Radiotherapy techniques have rapidly evolved in recent years, partly due to the availability of new treatment machines. One consequence is that more demands are placed on limited resources in clinics. Many training centers have identified that reduced access to such clinical resources and an increased complexity in techniques have resulted in a serious problem for the training of new and existing staff groups. In this work we have developed a set of virtual reality tools which have been implemented to alleviate this problem in our training center.

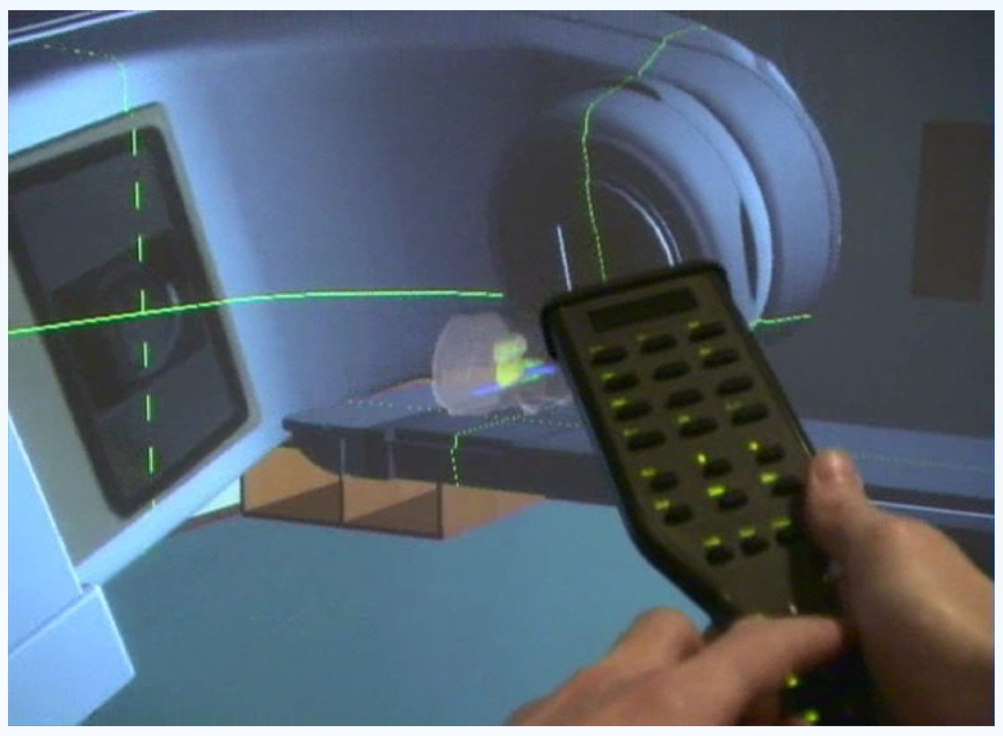
Method: Our training tools are developed and implemented within an Immersive Visualisation Environment (IVE) in order to add to the users sense of reality. This includes the use of 3D-stereoscopic visualisation, interactive control, sound and position tracking of the user. At the Hull IVE we are able to project our graphics display on a 5.3 m by 2.5 m 'Power Wall' with Stereoscopic visualisation enabled via LCD shutter glasses. We have created a faithful representation of a bunker containing a Varian 2100CD treatment machine. The Linac and couch are controlled with an actual Hand Pendant, which, with realistic sound production and the scale of the stereoscopic 3D projection, adds to the sense of immersion. The 'position tracking system' allows individual users to view the scene from any position again adding to the sense of reality. We have used the IVE to demonstrate very simple concepts such as the isocentre and exit dose to first year students. To enable this we developed an interface to read patient plans from the CMS XiO treatment planning system. The patient (contoured structures and the planning CT images) is shown 'fixed' to the couch, mirroring reality, computed dose is also displayed within the patient. Furthermore, we have implemented tools to visualise the effect of patient mis-alignment or mis-positioning on the treatment couch. In a pilot study we have developed a specific environment to enable students to gain experience setting up a 'direct' electron field. This commonly used technique often proves problematic for students and difficult to quickly master. It is therefore a good example to test whether the use of virtual reality software/ training environments may prove useful in the training of radiotherapy personnel.

Results: In the general studies we have found that the Linac IVE is universally accepted by those given access to it. All comment on the benefits from being able to learn from mistakes without inconveniencing clinical colleagues or patients, or worse, creating dangerous situations. In the direct-field pilot study we found all the participating students reported the training environment to be realistic. 93% reported that their understanding of this clinical technique was improved by using the virtual reality software and 69% found the control system easy to master.

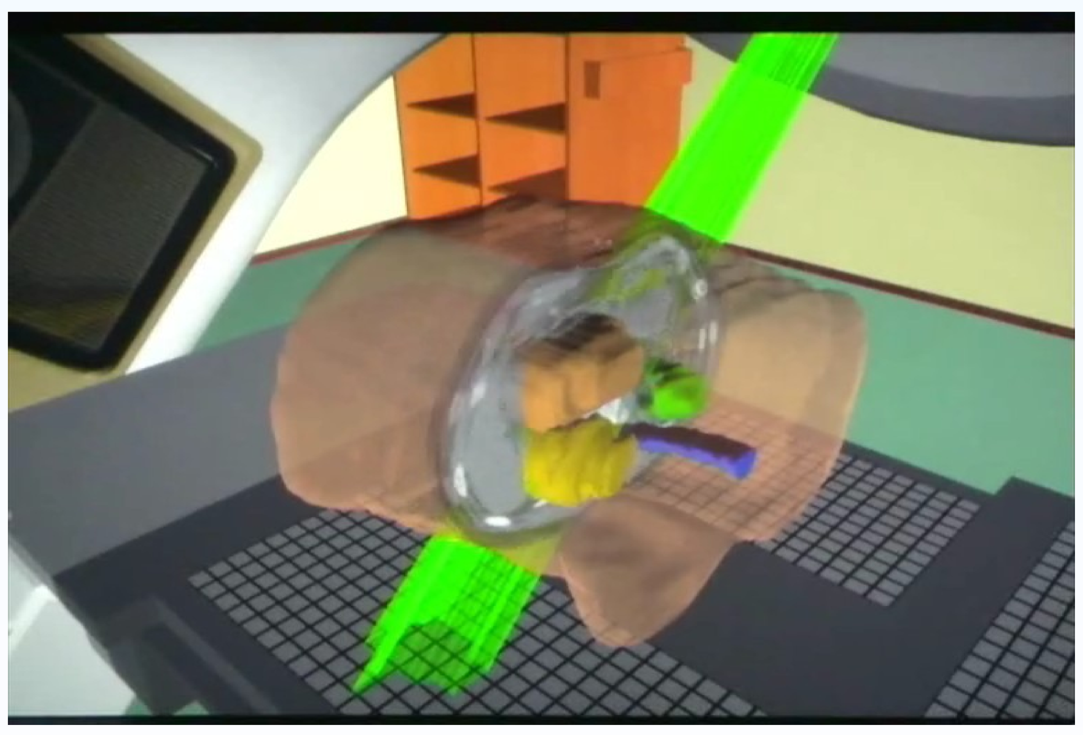
Conclusions: We believe our training environment to be a useful experience for students. It is not intended to replace their clinical experience, rather support and enhance it; visualisation of CT data, contoured structures and dose information is not available in the treatment bunker! Given prior exposure and practice on a Virtual Reality Linac (and patient) the students can concentrate on developing their 'patient-skills' when later gaining experience in the real environment.

The Virtual Reality training platform

The training platform was designed to simulate a Varian 2100CD and its treatment bunker. 3D CAD models of the room contents were built, from data collected via laser scans, using commercial software. In house software was written to provide real time display and interaction with these models. The components of the Linac were given all the motions and articulations of its real world counterpart. An interface was written to allow treatment plans to be loaded, and thereby displayed in the VR world, from our CMS treatment planning system.

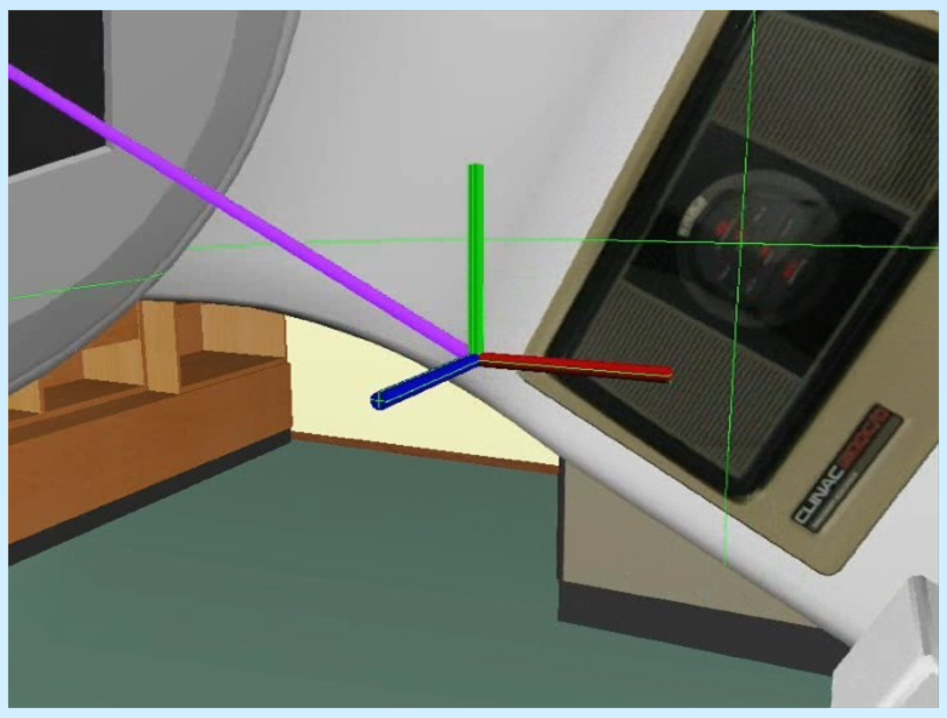


Our training platform is deemed to be much more than simply a Virtual Reality simulation of the Linac. It is clear that the platform can provide information and user experiences that are simply not possible in reality. The patient can be made transparent to show the position of organs or targets that were contoured in the treatment planning system; Any imaging data present in the plan can also be visualised. Possibly most importantly, the virtual patient cannot suffer any harm – no matter how catastrophic a situation the user creates!



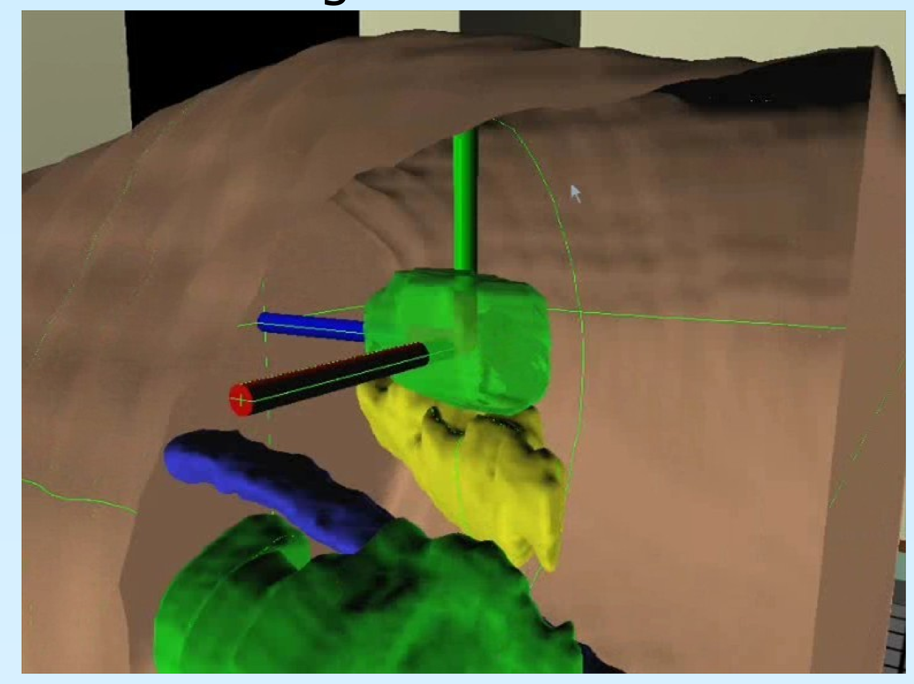
The key to Virtual Reality systems is to ensure the user believes his interaction with it is as real as possible. We have achieved this by projecting the scene using Stereoscopic techniques in life size proportions. At the Hull Immersive Visualisation Environment (HIVE) facility at the University of Hull we use a 5.3 m by 2.4 m, back projected screen and an 'active' Stereoscopic projection system. We integrated a Linac hand pendant as the control device for the software; Providing a further hook to reality. We continue to develop these aspects of the user interface. For example, we have implemented 'head tracking'. The user can move around the room, whilst the scene appears to remain static, thereby allowing him to wander from the 'left' side of the patient to the 'right'.

Application: Learning the basics

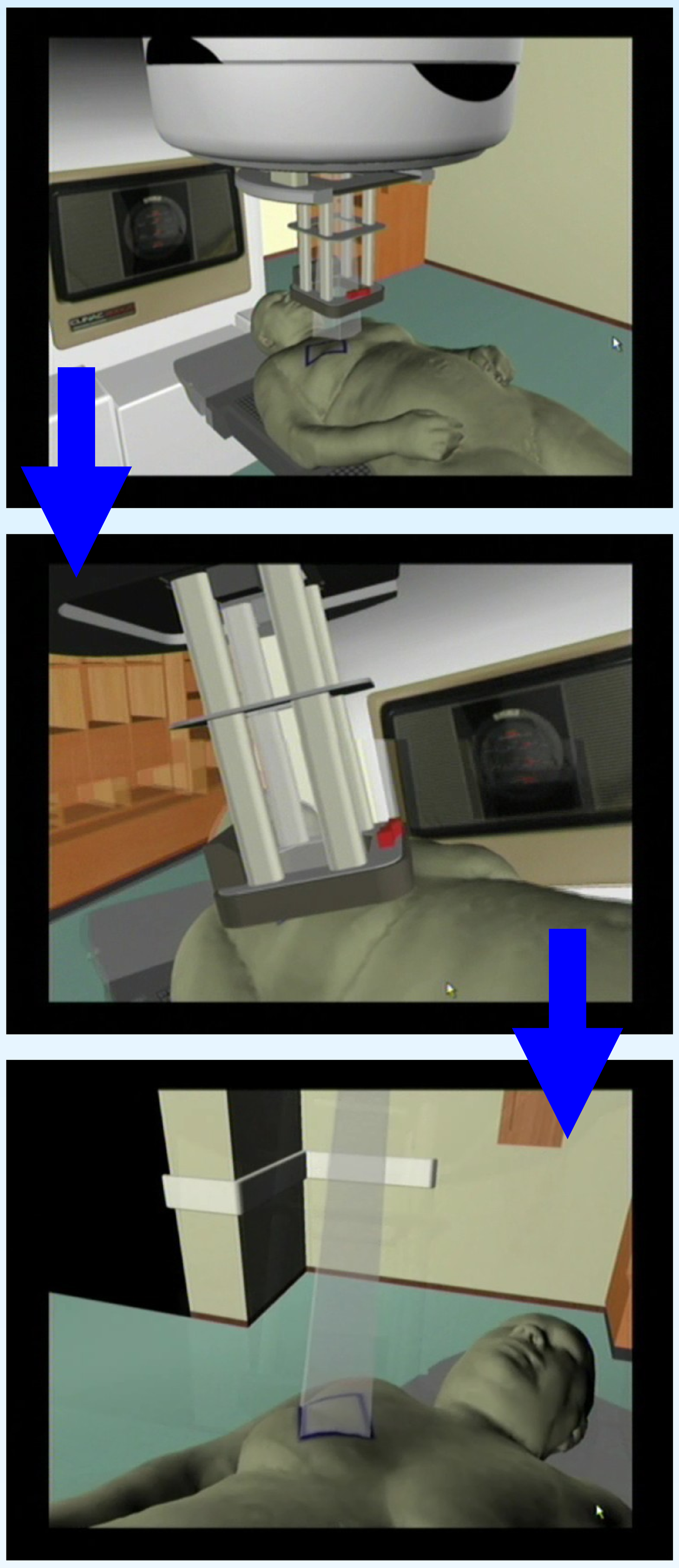


Discussions with student radiographers and their trainers highlighted a need for simple graphical explanation of the mechanical isocentre and how it related to the treatment plan. We implemented a virtual front pointer (seen in purple to the left) and visible 'Linac coordinate axes' with their origin on the isocentre. As the Gantry, collimator or bed are rotated, the concept is clearly demonstrated. A collision detection algorithm is implemented which enables students to get a feel for the allowed movements of the Linac, this includes the patient when present in the scene. When collisions 'occur' the motion is allowed to continue, however the Linac covers glow red.

We adapted a patient's treatment plan to provide visible skin 'set-up' marks; This allows the user to set the patient into the treatment position using the Linac room lasers. However, since reality is easily augmented the user can then 'zoom in', passing through the patient's skin, and see how they have set the internal anatomy up with respect to the machine isocentre. In the figure on the right we see the lasers projected onto the inside of the patients skin surface and the 'isocentre axes' thus showing how the target volume is 'centred' on the isocentre. In pilot study groups, first year Radiography students universally comment on how useful and intuitive this demonstration is.



Application: Difficult clinical set-up



A version of the VR platform was created to include an electron applicator and a 'standard', full body, patient; Its intended use: to facilitate practising setting up an electron field Skin Apposition treatment.

The generic patient has 15 different clinical mark-ups over its torso, which are individually selected to model 'different' patients. Similarly to the real scenario, using the Linac hand pendant the user moves the bed/patient into the correct position such that the incident electron beam strikes the patients skin with normal incidence. This is a technique that demands a lot of practice to master and typically causes students problems, we felt therefore that it was an excellent application for our VR platform. A pilot study was performed using 42 first year Radiographer students. To assess the impact of the VR tool they were given pre- and post- exercise questionnaires. To familiarise the group an example patient was set-up by the tutor, followed by exercises in smaller groups. Finally, the students were individually given a 'test patient' to set-up and their performance was assessed. For feedback, geometrical data was provided by the software to show how well the patient was set-up. The students were analysed to find that there was an improvement in their (self-assessed) understanding of the technique and their confidence in going forward to use it clinically. Those that did not find the controls easy to master were from centres that did not have Varian Linacs – thus indicating the necessity for our providing a wider selection of VR Linacs.

Users Comments following sessions using the VR training application:

- '…visualisation of the isocentre was really useful….'
- '…no risk of causing damage to patient….'
- '…no risk of causing damage to equipment….'
- '….able to practice without being under pressure…'

Impact on learning	Pre-Test	Post-Test	p-value
Understand the technique principles	*56.8%*	*77.5%*	*<0.001*
Understand how to apply technique	*46.5%*	*68.5%*	*<0.001*
Have confidence to assist clinically	*52.5%*	*73.3%*	*<0.001*
Combined scores	*51.8%*	*73.0%*	*<0.001*

Ease of use and realism	Strongly agree	Agree	Undecided	Disagree	Strongly disagree
The controls were easy to master	*5*	*24*	*6*	*7*	*0*
I enjoyed using the application	*16*	*23*	*2*	*1*	*0*
I found it to be a realistic representation	*12*	*25*	*5*	*0*	*0*

Current Developments

We continue to develop the Virtual reality training platform. We have implemented an anatomy training tool where the user can interact with a segmented 3D model of a human brain. This system utilises head tracking which gives the visualisation an almost holographic quality. Interaction via a hand held, virtual pointer, enables the user to point at selected parts of the brain or select them from a list of virtual buttons. Once activated audio and visual information is given. The users progress through the model and information is tracked such that users preferences can be analysed. This work is the basis of a PhD project for one of our students.

Conclusions

We have implemented a number of Virtual Reality based training tools for the use in Radiotherapy. The VR Linac training tool has been tested in pilot studies and is well received by students and training staff. The ability to practice for 'infinite' time periods as compared to the time available in busy clinics is cited by students to be a definite advantage. Furthermore, the potential for training experienced professionals in new techniques using new Linac technology is obvious; We are currently developing VR training tools to help with the adoption of Image Guided equipment. We are actively looking to build further collaborations to help develop the use of these exciting tools, we are interested in forming a consortium of interested training programs and schools.

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