Virtual Reality Training for Radiotherapy becomes a Reality

R PHILLIPS [a,1], J W WARD [a], L PAGE [a], C GRAU [b], A BOJEN [b], J HALL [c],
K NIELSEN [b], V NORDENTOFT [b], A W BEAVIS [d]

[a] *Department of Computer Science, University of Hull, Hull, UK*
[b] *Aarhus University Hospital, Aarhus, Denmark*
[c] *Birmingham City University, Birmingham, UK*
[d] *Princess Royal Hospital, Hull and East Yorkshire NHS Trust, Hull, UK*

Abstract. A report in 2007 to the UK Government identified a crisis in England for training staff and students for the radiotherapy treatment of cancer. The Hull authors have developed an immersive life size virtual environment of a radiotherapy treatment room, known as VERT, to address this problem. VERT provides the trainee with models, simulation, enhanced visualization and training aids for treatment of virtual patients in a virtual treatment room. In 2007 immersive VERT systems for radiotherapy training were established for training purposes at the University Aarhus Hospital (Denmark) and the Birmingham City University (UK). This paper reports on early evaluations of VERT by these two institutions.

Keywords. Virtual environment, visualization, radiotherapy, training.

1. Introduction

With increased life expectancy and improvements in radiotherapy treatment techniques (e.g. IMRT, IGRT and adaptive radiotherapy) the use of radiotherapy treatment in the UK is predicted to rise 91% by 2016 [1]. The same report also recognised the benefits of reducing the attrition rate of radiography students from 35% to 15%. To address this potential crisis in England for training staff and students for radiotherapy treatment of cancer the report recommended that a workforce action should be to pursue the following project:
 "***the introduction of Hybrid Virtual Environment (HVE) skills training facilities from 2007*** *- these simulate the radiotherapy equipment and treatment rooms. SHA workforce commissioners and higher education providers should roll this out across the 10 educational providers and 52 clinical sites from 2007 to support first year students and Assistant Practitioners.*"
    The University of Hull and the Princess Royal Hospital have together developed a Virtual Environment for Radiotherapy Training (VERT). This provides a life size

---

[1] Corresponding author: Roger Phillips, Department of Computer Science, University of Hull, Cottingham Road, Hull, East Riding of Yorkshire, UK, HU6 7RX; E-mail: r.phillips@hull.ac.uk

virtual radiotherapy treatment room with all its equipment and a patient on the treatment couch. VERT aims to provide the trainee with simulation and visualization of the full functionality of the treatment equipment, except for producing radiation. VERT has been developed over the past 5 years. Detail on the functions, visualization and usage of earlier versions of VERT have previously been reported in [2, 3].

In 2007 VERT systems for radiotherapy training were established for training purposes at the University Aarhus Hospital (Denmark) and Birmingham City University (UK). This paper first reviews briefly the functionality provided by VERT. It then explains how Aarhus and Birmingham have used VERT for training and it reports on their results and insights into VE training for radiotherapy.

2. Tools and Method

The structure of functionality in VERT is shown in Fig 1. The VE provided by VERT includes models of a treatment room, a linear accelerator treatment machine (hereafter known as a Linac), a treatment couch and various treatment aids. VERT puts a model of a patient on the treatment couch by loading anatomy and a treatment plan in DICOM RT format. As the majority of radiotherapy planning systems (e.g. CMS, ARIA, ADAC, etc.) are DICOM compliant, this means that students, tutors, national Colleges, etc. can build up their own databases of patient cases for training. Such databases would cater for different treatment sites, local practices and illustrate problems and complexities of treatment. This approach means that training is not limited to just 'canned' datasets. However, VERT does provide some bespoke patient datasets for training of treatments where computer-based treatment plans are not used. An example of this is skin apposition where a full body patient model has been created from the Visible Female dataset.
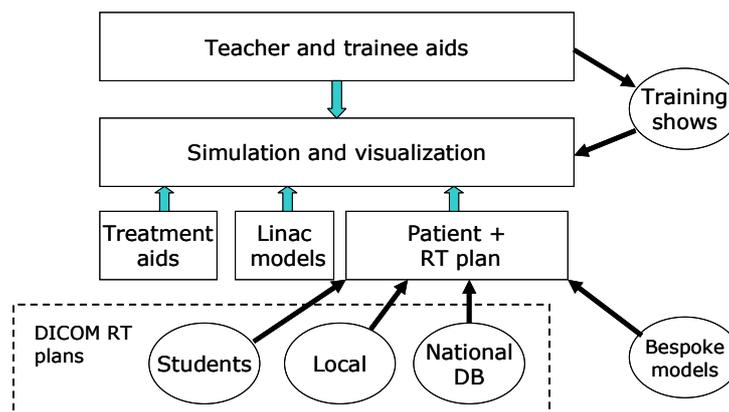

Figure 1. Conceptual structure of VERT.

The above model of the virtual treatment room VERT includes the following types of simulation.

- Full articulation of the Linac, couch and the multi-leaf collimator (MLC).
- Control of the virtual equipment using an actual control pendant for the Linac; this is used for hands-on 'flight simulator' mode of training.

- Displays of the in-room monitor that provide information on Linac status.
- The room lasers that are used to assist the set-up of a patient set-up.
- Skin surface display that is an aid for set-up of a patient.

On top of these simulations VERT provides various visualizations that the trainee would have in the actual treatment room. These considerably enhance understanding by trainees as they can see in the same visual space of the treatment room, the patient, the Linac, the treatment beam, anatomy, dose, etc. In this sense one can say that VE training is *better than reality*. Such visualizations include:

- Various views of the anatomy of the patient on the treatment couch, e.g. segmented anatomy of tumour and organs at risk, planning data sets (CT, MRI), view from treatment beam position (i.e. beam eye view).
- Visualization of treatment beams and their constituent segments.
- Numerous visualizations of radiation dose distributions, e.g. isodose surfaces, dose colourwash on surface of tumour and surrounding organs.

On top of the above simulations and visualizations VERT provides a number of training tools. These tools help the tutor to explain specific concepts in radiotherapy treatment or they extend how VERT can be used for training. VERT currently provides the following training tools.

- Automated collision detection between the equipment and the patient which warns students about imminent damage
- Visualization aids to explain the isocentre concept which first year students often have considerable difficulty in grasping.
- Automated placement of skin tattoo marks on the virtual patient; this means students can use VERT to practice set-up for their own treatment plans.
- A tool that provides a quantified set-up error for the position of a patient.

VERT is intended to be used in an immersive VE with life size projection on a large 3D work wall with head tracked viewing. Examples of the VERT hardware for Aarhus and Birmingham are given in the next section.

3. Studies and Results

VERT can be used in two modes, namely 'demonstrator' mode for classroom style teaching or 'hands-on / flight simulator' mode where a trainee acquires practical skills such as set-up of a patient on the couch in preparation for treatment.

This section discusses how the Aarhus University Hospital and Birmingham City University have deployed VERT and presents their experiences. These two institutes have developed pedagogic approaches for using VERT in a research collaboration with the VERT development team at Hull. This has resulted in numerous refinements to VERT.

3.1. VERT at Aarhus University Hospital

The Department of Radiation Oncology at Aarhus University Hospital, Denmark established in March 2007 a Radiotherapy Training Centre. Both nurses and doctors are trained at the Centre. The purpose of the Training Centre is to increase the quality of the theoretical education and clinical training with new educational elements using VERT. A further aim is to increase the throughput of

radiotherapist students at the clinic. As far as we know, this is the first time a full size 3D VE training facility has been installed in a radiotherapy clinic, and routinely used as a part of the clinical training programme for all specialities involved in the radiotherapy process.

The Training Centre has three rooms, namely:

1. **IT laboratory for computer based training and education**. This has 8 workstations with 16 seats for students, and a workstation for the teacher. Since the IT-laboratory has its own network, students can work and train with patient data without interfering with actual clinical data. Patient data is available from the clinic in DICOM RT format. Software available includes Varian's ARIA with Time-Planner, RT-chart and Treatment Planning.

2. **The virtual radiotherapy treatment room as provided by VERT**. The virtual room has a Varian 2100 C/D Linac, a treatment couch, an on board CT imager and various treatment aids. The treatment room is visualised on a 3D Work Wall with a screen size of 308 x 233 cm using rear projection from two passive projectors (1400 x 1050 pixels, 5000 lumens). 3D viewing is achieved via circular polarised glasses. Users can control the virtual Linac and couch using an actual Varian hand pendant. Treatment plans created in the IT-laboratory or anonymous dose plans can be uploaded directly into VERT.

3. **Classroom with library, computers, projectors etc**.

To test the technological and pedagogical possibilities of VERT a pilot project with eight nurses started in March 2007. All these nurses had a 3½ year bachelor degree and were taking an additional one year training course to become radiation therapists (RTT). This would allow them to treat patients using Linacs. The training course consists of 10 weeks of theory and 35 weeks of practical training.

Within this training course, VERT was used by nurses in the following ways.

1. To gain familiarity with the control of the Linac.
2. Positioning of patients with the set-up lasers giving due consideration to beam entrance and possible collisions.
3. Visualization of the dose volume and IMRT plans.
4. Exercises on the treatment isocentre and associated reference points.
5. The nurses were shown examples of organ at risk in treatment plans with a physicist and an oncologist explaining issues of dose planning.
6. The nurses reviewed papers with clinical patient data, adapted them and then discussed them using the 3D facilities of VERT.
7. Some oncology sessions were combined with treatment planning in the IT-laboratory followed by simulation and visualization of plans using VERT.
8. Treatment plans with CT data were presented using VERT and digitally reconstructed radiographs (DRRs) produced by VERT were used for discussion and education.

A formal evaluation was made in October 2007 after seven months in the Training Centre. The data has been collected and is currently being analysed. A few of the nurses' statements from the evaluation are reproduced here:

- "to train without destroying anything is a good possibility" and "the same for learning basic skills without thinking of patients"
- "it's useful to take a virtual look at the accelerator and how it is working; to find out what is happening inside the patient, what are we treating and what we attempting not to treat"

- "the possibility to take a look at organ at risk, fields and tumours with margins gives a very good understanding before starting at the clinic"
- "Seeing wrong positioning is useful and good knowledge"
- "I was able to think in 3D, I thought! - But now I am much better" comment by an experienced nurse who had worked with CT-scanners for several years.

The initial findings suggest that training in a 3D VE of a treatment room is both beneficial for trainees and effective from a teaching perspective. Students have used VERT in 'hands-on' mode to acquire experience and become familiar with the routine in making daily treatments. For this they need to be able to drive the VERT software; this is reasonably straightforward. These hands-on training sessions are generally relatively short in which only 2 or 3 people work together.

Workshops for residents in radiation oncology have also been very successful, and it is planned to integrate the use of the Centre into the national training courses for physicians at all levels. The 3D accelerator was also used as a basic introduction to radiation therapy for student nurses. The aim here was to give the students an appreciation of radiotherapy and to advertise the speciality for later recruitment.

3.2. VERT at Birmingham City University

The virtual radiotherapy treatment room as provided by VERT became available at Birmingham in August 2007. As with Aarhus the treatment room is based on a Varian Linac with a real control pendant. The treatment room is visualised on a 3D Work Wall with a screen size of 380 x 230 cm using front projection from two passive projectors.

So far VERT has been used mainly by first year students on a BSc in Radiography. Assessment of VE based training will be undertaken in November 2007 prior to their first clinical placement of four weeks. So far all the students have been extremely positive about using VERT and seem to enjoy the sessions.

In addition, third year students participated in an unstructured but supervised workshop so that they could explore the capabilities of VERT and then provide feedback. This provides a qualitative open approach with students who had experienced two years of the current approach to training. They were asked to comment on how VERT could be used for training and the potential benefits of training in this VE. Six students took part in this 'snapshot' qualitative evaluation. They were very enthusiastic. Within their comments the following themes emerged:

- **Fear**. All students spoke about fear related to 'looking stupid' when trying to learn or refine clinical skills, fear of the unknown, fear of unsettling patients and fear of upsetting or irritating Radiographers. They thought that the VERT would provide an environment which minimised such fears.
- **Peer support**. They liked the idea of shared clinical learning, peer support / review and student team working, much of which is not possible in a clinic.
- **Approaches to learning**. Use of VERT to refine / reinforce skills, consolidate planning knowledge and to understand difficult concepts (e.g. tilted volumes and floor twists) were cited. Generally they liked the idea of learning being more interactive. They also thought that the learning would be better due to reduced fear and learning in an exploratory manner using the 'what if' approach and learning from mistakes with no consequences.

Generally they thought that this VE approach would build confidence and provide students with a 'head start' in the clinical environment. VERT was also seen as helpful to tutors when trying to explain what was required in a clinical situation.

The students raised very few reservations of which none were surprising. Students did not see VERT as a replacement for clinical placement time. They were also keen to stress that interaction with patients is very important and that this could not, currently, be done virtually.

4. Conclusions

At the time of writing VERT has been used for training at Aarhus University Hospital for 7 months. Their conclusion is that an IT-laboratory, a VE of a radiotherapy treatment room provided by VERT and a classroom in close proximity provides an optimal environment for a radiotherapy training facility. It enables a training session to be interleaved effectively across these resources. Such training resources provide time and opportunity for discussions and reflections that would not be possible in the clinic. Furthermore, the virtual treatment room considerably improves the spatial understanding of complex radiotherapy plans. Training in a VE is thus a valuable supplement to clinical training of radiotherapists that must be coordinated with intermittent practical training in real clinics.

The need to train more radiotherapy staff at Aarhus will expand in the coming year. The current bottleneck for efficient education is practical training in the busy clinical environment. Hopefully the Training Centre will address this problem.

Birmingham City University have used VERT for training for 3 months. Their initial evaluation concludes that VERT provides an environment for training that is more conducive to learning due to a friendly training atmosphere, the opportunity for improved peer support and a more flexible and effective approach to learning.

Both of these training sites conclude that VERT will never be a complete substitute for the clinic, but it is a valuable and effective supplement to the ordinary theoretical and clinical training. They expect VE based radiotherapy training in due course to impact curricula and eventually become a criterion for certification.

As reported in the Introduction the UK government proposed in 2007 the adoption of VE training for skill acquisition in radiotherapy throughout England. This is being progressed by a £5M grant from the Department of Health to provide VE training facilities at all Universities and radiotherapy clinics. This will involve in 2008 the installation in England of some 56 VE training systems for radiotherapy. Thus *virtual reality training in radiotherapy is about to become a reality*.

References

[1] *Radiotherapy: developing a world class service for England*, Report to Ministers from National Radiotherapy Advisory Group (NRAG), May 2007.

[2] Phillips R, Ward JW, Bridge P, Appleyard RM, Beavis AW, *A Hybrid Virtual Environment for Training of Radiotherapy Treatment of Cancer*, Proc. Electronic Imaging Science & Technology: Stereoscopic Displays & Applications, San Jose, USA, Jan 2006, SPIE, Vol 6505, pp 6055008 1-12.

[3] Bridge P, Appleyard RM, Ward JW, Phillips R, Beavis AW, *Development and Evaluation of a Virtual Radiotherapy Treatment Machine using an Immersive Visualization Environment*, Computers and Education, 49 (2), pp 481-494, 2007.