

A Virtual Environment for Radiotherapy Training and Education - VERT

J. W. Ward^{1,3}, R. Phillips^{1,3}, A. Boejen⁴, C. Grau⁴, D. Jois³ and A.W. Beavis^{2,3}

¹ University of Hull, Hull, UK

² Hull and East Yorkshire (NHS) Hospitals Trust, Hull, UK

³ Vertual Ltd, Hull, UK

⁴ Aarhus University Hospital, Aarhus, Denmark

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 VERT systems for radiotherapy training were established for training purposes at the University Aarhus Hospital (Denmark), Birmingham City University (UK) and the University of Ulster (UK). There are now some 70 VERT systems around the world. This paper reports on the simulation and visualization capabilities and reports on the use of VERT from the Aarhus University hospital and on the national evaluation of VERT in the UK [AC10]. These reports clearly indicate the clinical benefit of using a virtual environment approach, such as VERT, for training and education in radiotherapy.

Categories and Subject Descriptors: I.3.1 Three-dimensional displays; I.3.4 Virtual device interfaces; I.3.7 Virtual reality; I.3.6 Interaction techniques; I.3.3 Picture/Image Generation. Keywords: Computer Graphics, Virtual Reality, Radiotherapy, Radiation Therapy, Simulation, Scientific Visualization, Education, 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 [NRA07]. The same report also recognised the benefits of reducing the attrition rate of radiography students from 35% to 15%. To address these issues the report recommended: “the introduction of Hybrid Virtual Environment (HVE) skills training facilities from 2007 - these simulate the radiotherapy equipment and treatment rooms”. Consequently VERT was acquired by over 50 sites in England.

From 2001 to 2007 The University of Hull and the Princess Royal Hospital at Hull together developed a Virtual Environment for Radiotherapy Training (VERT). In 2007 the company Vertual Ltd was founded to commercialise VERT. The VERT system provides a life size 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. Detail on the functions, visualization and usage of VERT have previously been reported in [BAW*07, PWB*06, PWP*08].

In 2007 the first installation of a VERT system for radiotherapy training was established at the Aarhus University Hospital (Denmark). 69 further systems have now been installed in 12 countries. This paper first reviews the functionality provided by VERT. The Studies and Results Section reports on how the Aarhus University Hospital have benefited from integration of VERT into their new Training Centre facility, and presents the key findings of a National UK Report [AC10] on the evaluation of VERT systems in England.

2. The VERT System

2.1 Projection Hardware

The virtual environment for radiotherapy training (VERT) software provides a virtual world of a radiotherapy treatment room. The projection hardware of VERT includes a single or triple DLP stereoscopic projector with brightness between 4,500 and 10,000 ANSI lumens, native projector resolutions varying from 1024 × 768 to 1920 × 1200 pixels and a workstation with an Open GL 2.1 compatible graphics card. Typically the size of the projection screen varies from 3.0 x 2.25 metres to 5.0 x 2.8 metres. The VERT system can have either rear or front projection; these are

referred to as Immersive and Seminar VERT systems respectively. VERT also provides head-tracked viewing of the virtual treatment room using Intersense technology (a hybrid ultrasonic and gyroscopic tracking system). With this a single user can walk around the virtual treatment room and to this user the room appears stationary.

2.2 Simulation of the Treatment Machine

Detailed manufacturers' CAD drawings of linear accelerator radiotherapy treatment machines (hereafter known as Linacs) were used to create accurate models of Linacs from three major manufacturers. VERT provides the following virtual Linacs: Varian C series, Varian iX, Elekta Synergy, Synergy Platform and Siemens Artiste. All Linacs include the simulation of a multi-leaf collimator (MLC) for accurate arbitrary shaping of the radiation beam.

An immersive virtual environment faithful to the real world eases the transition for trainees into treatment clinics and aims to reduce stress for these trainees as they are already familiar with operating the actual equipment and the layout of the room through their experience in the virtual environment where they can make mistakes safely, without risk to the patient.

The virtual Linac has the full articulation of a real Linac. Thus the gantry and the delivery head rotate. Similarly, the virtual couch has a full range of articulation, namely: vertical, longitudinal, lateral and rotational motion. The treatment room has three orthogonal lasers which intersect at the treatment isocentre. These are used to help position the patient on the couch during treatment.

Mouse, joystick and touch panel controls are provided for controlling the equipment in the treatment room, i.e. gantry, couch, positioning lasers and room lights. As manual manipulation of gantry and couch is a key core skill for trainees, we have interfaced actual control handsets to the virtual treatment room so that trainees can use them to operate equipment in the virtual room. Thus, the trainee can move the virtual linac and couch, and control the simulation of lasers, room lights, field lights and skin surface display all from the actual pendant. The hand control pendants from each of the three Linac manufacturers (Varian, Elekta and Siemens) have been interfaced into VERT.

It is more complex to integrate real couch based movement controls in a virtual world, for these VERT has a touch panel interface (e.g. an iPad) that provides a highly realistic visual representation of the couch control panel.

VERT provides most of the software menus and controls on a touch panel display on the instructor's console. This reduces considerably the need to display 2D information on the 3D projection screen and thus improves the immersive experience of users.

In VERT the in room monitor for the treatment room that displays the position of the Linac and the couch is also simulated on a separate display monitor. This monitor is typically mounted to one side of the projection screen.

This integration of real equipment with virtual equipment creates a hybrid virtual environment (HVE). This is more appropriate for training the psychomotor skills for positioning the couch and gantry as it provides trainees familiarity with the actual human-equipment interactions of the treatment room and it goes part way to developing in the trainee the required hand-eye coordination skills.

2.3 Visualization of Equipment and Patient

The virtual environment (VE) provided by VERT includes models of a treatment room, 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. MONACO, ECLIPSE, PINNACLE, PROWESS, etc.) are DICOM compliant, this enables students, tutors, etc. to build up 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 provided with the system. However, VERT does provide some bespoke patient datasets for training of treatments where computer-based treatment plans are not used. For example, this includes a skin apposition treatment where a full body patient model has been created from the Visible Female dataset (National Library of Medicine).

VERT provides various visualizations that go beyond what the trainee would see in the actual treatment room. These enhance understanding as trainees can see in the same visual space of the treatment room, the patient, the Linac, the treatment beam, anatomy, dose, etc. In this sense VE training is *better than reality*. Such visualizations include:

- Various anatomical views of the patient on the treatment couch, e.g. segmented anatomy of tumour and organs at risk, planning data sets (CT).
- Visualization of the view from treatment beam position (i.e. beam eye view). Within this view the anatomy can be seen as segmented structures or as a digitally reconstructed radiograph (DRR). This DRR is reconstructed in real time from the planning CT by VERT thus showing immediately the anatomy as the couch, gantry, collimator and patient are moved. The view also shows the position of the leaves of the MLC.
- Visualization of treatment beams and their constituent segments. Animation of IMRT leaf sequences and animation of rotational arc treatments such as Rapidarc and VMAT.
- Numerous visualizations of radiation dose distributions, e.g. isodose surfaces, dose colourwash on tumour surface and surrounding organs, treatment beam dose.

2.4 Training Tools

VERT provides a number of training tools. These tools help the tutor to explain specific concepts in radiotherapy treatment and extend the usefulness of VERT for training. VERT currently provides the following training tools.

- Automated collision detection between the equipment and the patient which warns students about imminent risk of injury to the patient, or damage to equipment.
- Visualization aids to explain the isocentre concept which students have considerable difficulty in grasping.
- Automated placement of skin tattoo marks on the virtual patient; this means trainees 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. Set-up errors can also be generated

randomly and hidden from the trainee providing them with numerous examples for practising patient set-up.

- An IGRT (Image Guided Radiation Therapy) set-up tool. This allows trainees to practice patient set-up using intra-treatment imaging with anatomical matching to pre-treatment planning CT.

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. The benefits and early application of VERT are described by Bridge et al [BAW*07].

Aarhus University Hospital were the first external users of the VERT technology. Aarhus has developed pedagogic approaches for using VERT in close research collaboration with the Hull authors. This has resulted in numerous refinements to VERT. Initial findings from a study assessing the effectiveness of VERT was published in 2010 [AC10].

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 was to increase the throughput of radiotherapist students at the clinic. It is believed that this was the first time a full sized 3D VE training facility was installed in a radiotherapy clinic, and used routinely as 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. In this laboratory students can work and train with patient data without interfering with actual clinical data. Software available includes Varian's ARIA with Time-Planner, RT-chart and Treatment Planning.
2. **The virtual radiotherapy treatment (VERT) room.** This has 3D projection screen size of 3.08 x 2.33 metres using passive rear projection from two projectors (1400 x 1050 pixels, 5000 lumens). Their VERT system has head-tracked viewing, a touch panel display for controlling VERT and an in-room monitor next to the 3D screen. Treatment plans created in the IT-laboratory or anonymous dose plans can be uploaded directly from the above lab into VERT.

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

To test the technological and pedagogical possibilities of VERT a pilot project with eight nurses started in March 2007. All the nurses had a 3½ year bachelor degree and were taking an additional one year training course to become radiation therapists (RTTs). This would allow them to treat patients using Linacs. A formal evaluation was made after the pilot project.

Some of the nurses' statements from the evaluation are given below:

- "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.

The VERT project has succeeded in doubling the clinical training capacity to 20 students per year [Boj10].

The training course consists of 12 weeks of theory, 13 weeks of clinical virtual reality training using VERT and 20 weeks of practical training. Within this training course, VERT is used by nurses in the following ways.

1. To gain familiarity with the controls 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, IMRT and rotational IMRT plans.
4. Exercises on the treatment isocentre and associated reference points.
5. Explanation using VERT of organs at risk in treatment plans by physicist and an oncologist.
6. Nurses review papers with clinical patient data, adapt them and then discuss them using VERT.
7. Oncology sessions are combined with treatment planning in the IT-laboratory followed by simulation and visualization of plans using VERT.
8. Treatment plans with CT data are presented using VERT and digitally reconstructed radiographs (DRRs) produced by VERT for discussion.
9. To test the students' knowledge level in a 3D VE after 15 weeks, templates with exercises and evaluation after Blooms Taxonomy are used.

The findings strongly 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 of making daily treatments.

Workshops for residents in radiation oncology have also been very successful, and it is planned to integrate the use of VERT into the national training courses for physicians at all levels. VERT is also used as a basic introduction to radiation therapy for student nurses. At present a pilot project is using VERT for education for radiotherapy patients and their families is running. Work continues at Aarhus into the integration of VERT into radiotherapy practice [BC10].

3.2 National UK VERT Project

A UK national project commenced in 2007 to deploy VERT at all radiotherapy skills training facilities in England. This project was completed in late 2009. VERT is now installed in over 40 clinics and 12 universities throughout the UK. The VERT project [AC10] aimed to provide an integrated approach to the introduction of VERT into educational institutions and clinical radiotherapy and to evaluate the following:

- Assess the potential impact of VERT on student recruitment and retention;
- Investigate how students learn in virtual environments;
- Assess impact of VERT on student confidence and student enjoyment of their courses;
- Assess the extent to which VERT enhances students' knowledge and understanding of relevant radiotherapy concepts;
- Determine the extent to which students' psychomotor and practical skills can be developed using VERT;
- Share the learning outcomes associated with VERT use;
- Make recommendations regarding VERT's impact on future curriculum design and teaching, learning and assessment strategies.

Feedback from the project was positive overall; pre-placement experience with VERT was thought to provide enhanced basic practical skills and enhanced confidence including improved confidence operating the Linac hand pendant controls. Skills developed during pre-placement VERT experience were thought in general to transfer well to the clinical environment. 90% of students responding to a questionnaire agreed or strongly agreed that VERT had contributed to their enjoyment of the learning and teaching scenarios. There was a perception that use of VERT had a positive impact on: development of their understanding of radiotherapy concepts (82% agreed or agreed strongly); enhancement of practical skills (72% agreed or strongly agreed); and motivation (70%).

Comments from students on VERT included:

- 1: "VERT has helped me to understand the importance of accurate contouring and what the dose distribution looks like in 3-dimensions. It has made me realise that I have to think in 3D when I'm planning."
- 2: "The anatomy sessions were brilliant and really helped to gain an in depth understanding of how organs overlapped and sat next to each other."

The Report made several recommendations to educational institutions and clinics on VERT and these included:

- The use of VERT for the development of basic psychomotor/practical skills and to enhance confidence prior to initial clinical placements,
- Inherent spatial ability of students is assessed to assist identification of individuals who are likely to benefit most from VERT experience.

4. Conclusions and Discussions

VERT is becoming an established and recognised tool for training radiotherapy professionals at Universities, hospitals, radiotherapy clinics and training centres for Linac manufacturers. There are VERT systems at 70 sites spanning 12 countries and three continents. VERT has been used continuously for training at Aarhus University Hospital for over 3 years. They have developed a new radiotherapy training centre where VERT is a key facility. Their experience clearly shows the clinical benefit of VERT. Furthermore it has allowed them to double their training capacity [Boj10] as VERT has reduced the demand for training in the real treatment room. Similar simulation focussed centres using VERT have been established elsewhere (e.g. Birmingham City University and Michener Institute, Toronto). The National VERT project in the UK

provides further evidence of the benefits of VERT to improve radiotherapy training. VERT users are now regularly reporting on their use and effectiveness of VERT, for example Mount Vernon report on VERT for anatomy Training [SW10]. The first International VERT User Meeting was held at Bristol in March 2010.

Training in a VE is a valuable supplement to, and compliments, clinical training of radiotherapists. VERT will never be a complete substitute for training and presence in the clinic by students, however VERT is a valuable and very effective tool when appropriately combined with theoretical and clinical training. Patients benefit as training on them is reduced and using VERT frees up time in the treatment room so more patients can be treated. The authors expect VE based radiotherapy training to increasingly impact curricula and to become a criterion for certification.

In summary, a virtual environment approach in radiotherapy training and education is increasingly being adopted around the world. The use of this technology is expanding and radiotherapy professionals are identifying innovative applications for this technology beyond its initial scope. VERT is continuing to be developed to improve its effectiveness for training, to keep abreast of improvements to radiotherapy techniques and technology and to cater for its expanding diversity of use.

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