Institution: University of Hull

Unit of Assessment: B11: Computer Science and Informatics

Title of case study: Vertual and VERT (Virtual Environment for Radiotherapy Training)

1. Summary of the impact (indicative maximum 100 words)

VERT is a multiple award-winning virtual environment training simulator for radiotherapy education, developed during a six year research collaboration with Hull and East Yorkshire Hospitals (HEYH) NHS Trust. A National Radiotherapy Advisory Group (NRAG) Report (2007) and the Department of Health (DoH) NHS Cancer Reform Strategy (2007) identified the potential for VERT to address a skills shortage and improve the radiotherapy workforce. The UK government provided £5M capital funding to implement VERT at 40 hospitals and 10 universities in England from February 2008.

The company Vertual Ltd was created to commercialise VERT. It now has an annual turnover of £2M and has created 10 new high-skilled jobs since 2008. With 92 VERT systems installed across 16 countries, it has delivered a quantum change in radiotherapy education in the UK. An active international VERT user group has been established and its impact is growing world-wide.

2. Underpinning research (indicative maximum 500 words)

The research underpinning VERT was conducted from 2001 to 2008 by the University's Computer Science Department in collaboration with the Medical Physics Department at the HEYH NHS Trust. The researchers involved were Andy Beavis (Honorary Professor, 2008 to 2011), Roger Phillips (Research Professor, 1990 to 2011) and James Ward (Research Lecturer, 2001 to present).

The objective was to investigate innovative and beneficial applications of immersive environment technologies in Radiotherapy treatment of cancer. Radiotherapy (RT) aims to maximise therapeutic radiation dose to the tumour whilst minimising collateral damage to neighbouring organs. Improved delivery techniques are being developed such as IMRT (Intensity Modulated RT), IGRT (Image Guided RT), and adaptive therapy. These achieve improved outcomes but demand higher precision. Excellent 3D visualization and spatial awareness of the treatment in terms of dose, beams, anatomy, equipment and potential variations from the planned treatment is fundamental to planning and reviewing RT treatments.

Using advanced computer graphics technology, the University of Hull developed a sophisticated and highly realistic training simulator for Radiotherapy [5,6]. This provides a life-sized virtual simulation of the treatment room with all its equipment, controls and a simulated patient.

VERT uses stereoscopic 3D projection to create a high sense of presence for trainees. Novel head-tracking technology enables a user to literally walk around the virtual treatment room [4], with life-sized visualization of the equipment. It provides highly detailed and realistic simulations of Linac treatment machines from major manufacturers (Varian, Elekta and Siemens). Authentic hand controls have been interfaced to control the Linac, enabling trainees to develop psychomotor skills in VERT. Training can be carried out without risk to the patient or access to the real equipment [3].

VERT provides training tools to teach safety critical skills, including detailed simulation of the calibration and quality assurance processes for the treatment machine [1,2].

Actual patient anatomy and treatment plans can be imported into the simulation, which enables the use of real patient cases for training. VERT provides a full body patient model for skin apposition treatment training [4] and includes examples of prostate, breast, and head and neck treatment plans and paediatric cases.

VERT provides visualizations that go beyond what the trainee would see in the actual treatment room. In this sense, virtual environment training improves on reality. For example, the patient can be rendered transparent to reveal the location of the tumour and neighbouring organs. Similarly, the normally invisible radiation beam can be made visible, to better understand its spatial relationship to other structures. VERT also provides numerous visualizations of radiation dose

distributions, to illustrate the benefits of different treatment techniques.

Together, these visualization tools make VERT an effective platform for teaching the technical skills and fundamental principles of radiotherapy treatment.

3. References to the research (indicative maximum of six references)

1. The Development of a Virtual Reality Dosimetry Training Platform for Physics Training, A Beavis, J Ward, Medical Physics 06/2012; 39(6):3969. DOI:10.1118/1.4736199
2. Calibrating an Ionisation Chamber: Gaining Experience Using a Dosimetry 'Flight Simulator', A Beavis, J Saunderson, J Ward, Medical Physics 06/2012; 39(6):3970. DOI 10.1118/1.4736201
3. Virtual Reality Training for Radiotherapy becomes a Reality. R Phillips, JW Ward, L Page, C Grau, A Bojen, J Hall, K Nielsen, V Nordentoft, AW Beavis. Studies in health technology and informatics 02/2008; 132:366-71.
4. The Development and Evaluation of a Virtual Radiotherapy Treatment Machine using an Immersive Visualization Environment. Bridge P, Appleyard RM, Ward JW, Phillips R, Beavis AW, Computers & Education, 49 (2), pp 481-494, 2007. DOI:10.1016/j.compedu.2005.10.006.
5. A Hybrid Virtual Environment for Training of Radiotherapy Treatment of Cancer, Phillips R, Ward JW, Bridge P, Appleyard RM, Beavis AW, Proceedings of SPIE and IS&T Electronic Imaging: Stereoscopic Displays and Applications, San Jose, USA, Jan 2006, SPIE Vol 6505, pp 6055008 1-12.
6. Immersive Visualization Training of Radiotherapy Treatment, Phillips R, Ward JW, Beavis AW, Proceedings of Medicine Meets Virtual Reality 13, Studies in Health Technology and Informatics, 111, pp 390-396, January 2005, IOS Press.

Grants

1. 6/2007 - 5/2009, £50,000, Virtual Environment Radiotherapy Training, University of Ulster, R Phillips, A Beavis, J Ward.
2. 3/2007 - 2/2009, £166,225, Immersive Visualization of Radiotherapy Planning, CMS, A Beavis, R Phillips, J Ward.
3. 3/2007 - 2/2009, £50,000, Virtual Environment Radiotherapy Training, University of Central England, R Phillips, A Beavis, J Ward.
4. 1/2007 - 12/2008, £50,000, Virtual Environment Radiotherapy Training, Aarhus University Hospital, Denmark, R Phillips, A Beavis, J Ward.
5. 1/2006 – 8/2007, £5,500, VR Studies, Sheffield Hallam University, J Ward, R Phillips, A Beavis.
6. 11/2005 – 12/2006, £124,116, Immersive Visualization of Radiotherapy Planning, CMS, A Beavis, R Phillips, J Ward.
7. 4/2005 –10/2005, £10,480, Immersive Visualization of Radiotherapy Planning, CMS, A Beavis, R Phillips, J Ward.

Awards and Prizes

1. First Prize winner of 2011 Eurographics Medical Prize – Dirk Bartz Prize for Visual Computing in Medicine. €400 prize money.
2. Medilink Innovation award for Virtual Environment for Radiotherapy Training (VERT), 2008
3. Finalist for Health and Social Care Awards, 2008.
4. Service Improvement Day, Local NHS Combined Trusts Award, 2008.
5. BCS IT Industry Awards, Winner of 2007 Project Excellence Awards for BT Flagship Award for Innovation and Social Contribution Project.
6. BCS IT Industry Awards, Runner-up for 2007 Project Excellence Awards for Social Contribution.
7. First prize winner of the Medipex 2006 Yorkshire and Humber NHS Innovation Competition 2006 under the Innovation category. £2,000 prize money.
8. National finalist for Healthcare Service Journal Award 2006, Skills Development category.
9. A Beavis awarded IPEM's 2009 Manufacturers Award, for contribution to VERT.
10. A Beavis awarded Dept. Of Health's Chief Science Officers Innovation and Technology

Award in recognition of his contribution to VERT.

4. Details of the impact (indicative maximum 750 words)

In 2007, an NRAG report recognised the need to reduce the attrition rate of radiography students and identified a potential crisis in England for training staff and students for RT treatment of cancer.

The report identified the potential impact and benefits of VERT in this context, and recommended the introduction of Hybrid Virtual Environment (HVE) skills training facilities, to be rolled out across 10 educational providers and over 40 clinical sites to support first year students and Assistant Practitioners. This was reinforced by the DoH's Cancer Reform Strategy 2007 which recommended the introduction of VERT as part of a national programme, supported by £5M of capital funding from the UK government.

VERT was rolled out to 40 clinics and 10 universities in the UK from February 2008, effectively covering all RT trainees in England. The main beneficiaries were students, teaching staff and health trusts. An independent evaluation of the impact of the exploitation of VERT recruitment and retention, and on students' knowledge and understanding was undertaken. It also made recommendations for future curriculum design and teaching. The Final Project Report was published in June 2010 (see Section 5 [C1]). Overall feedback was positive; pre-placement experience with VERT was thought to enhance basic practical skills and enhance confidence, including improved confidence operating hand pendant controls. Skills developed in VERT were found to transfer well to the clinical environment. 90% of students responding to a questionnaire agreed or strongly agreed that VERT contributed to their enjoyment of learning and teaching scenarios. There was a perception that use of VERT had a positive impact on: development of understanding of radiotherapy concepts (82% agreed or agreed strongly); enhancement of practical skills (72% agreed or strongly agreed); and motivation (70% agreed or strongly agreed?).

Sales of VERT worldwide have grown from 2008 to the present, and the beneficiaries have been:

- Health trusts, students and patients: VERT offers a safe and effective training environment with the potential to reduce training costs, increase training capacity, provide more effective training and ultimately improve patient safety, as detailed in sections 3-5.
- Vertual Ltd and its shareholders: 92 VERT systems have been installed worldwide in 16 countries, with economic impacts including an accumulated gross profit over 3 years of £965k and typically £2M annual turnover.
- Employees of the company, with employment/economic impacts in terms of 10 new jobs created since 1st January 2008, with an average salary of £30k. This includes 4 full-time software developers.
- A network of 12 distributors worldwide, with economic impacts in terms of profits from distributing VERT.
- Significant economic benefits to other UK industry, including equipment suppliers and local manufacturing. Vertual partner with a UK based VR system supplier to provide over £400k annual hardware sales, including installation and support services. Vertual also use UK based companies for electronic printed circuit board manufacture and assembly, electronic components, manufacture of enclosures, printing, graphic design and exhibition services.
- Benefits to the educational, medical and research community: Vertual is a Diamond Partner of the UK College of Radiographers, providing financial support for research and educational projects. Vertual regularly sponsor student graduation awards and prizes in the UK, US and Canada, and fund student / staff attendance at conferences.

VERT is an established and recognised tool for training radiotherapy professionals at over 90 institutions worldwide. VERT has been continuously used for RT training at Aarhus University Hospital from 2008 to present, resulting in a doubling of the training capacity [Ref. C3]. A training centre has been established where VERT is a key facility, reducing the demand for training in the real clinic. Following the same model, three other VERT simulation centres have been established at Birmingham City University, Michener Institute and City University.

A VERT user community was established from the outset which continues to actively conduct and publish research and studies evaluating VERT, expanding its scope and application, and sharing best practice. The beneficiaries are users of VERT, evidenced by the International User Meetings in Bristol (March 2010), London (September 2011) – where 70 delegates from UK, Europe, USA and Canada attended – and Hertfordshire (April 2013). An annual user meeting is held in the USA, to cater for the increasing number of US users (15 VERT installations in the USA and Canada, and growing).

Impact is evidenced by the adoption of VERT under nationally funded training programmes. Following on from its uptake in the DoH (UK), in 2011 the Australian Department of Health funded the installation of 5 state-of-the-art VERT systems throughout Australia to improve radiographer training. This was followed in 2013 by the first installation in New Zealand at the University of Otago, which was opened by the Minister of Health. VERT has also been adopted for training by Varian Medical System, the global market leader for radiotherapy linear accelerators.

The scope of the use of VERT includes graduate and postgraduate RT training, continuing professional development, anatomy training, skills assessment, patient awareness, nurse training, staff training and research. VERT has an important role to play in improving patient safety and in 2010 was adopted by the prestigious MD Anderson Cancer Centre (Texas, USA) where it has been used to reconstruct RT treatment errors and identify remedial actions with trainees (several institutions in the UK use the system in the same role).

In summary, VERT is increasingly used worldwide for RT education and training. Radiotherapy professionals are identifying innovative applications far beyond its initial scope. VERT is continually under development to improve its effectiveness for training, to keep abreast of improvements in techniques and technology and cater for its expanding diversity of use.

5. Sources to corroborate the impact (indicative maximum of 10 references)

1. Virtual Environment for Radiotherapy Training (VERT) Final Project Report, Appleyard R., Coleman C, Society of Radiographers, 2010 (available online at http://doc-lib.sor.org/vert-final-project-report) – corroborating the impact on RT training (including students' knowledge and understanding) and recruitment and retention.

2. Financial and sales information on Vertual (available on a confidential basis on request) – corroborating sales of and revenue from VERT installations.

3. 3D Accelerator in Radiation Therapy Training – From Apprenticeship to Virtual Reality Training, Boejen A., European Oncology Nursing Society Newsletter, 24-25, Summer 2010 (available online at http://www.cancernurse.eu/documents/newsletter/2010summer/EONSNewsletter2010summerPage24.pdf) – corroborating the doubling of RT training capacity at the hospital.

4. Head of Radiotherapy Research, Aarhus University Hospital, Denmark – corroborating the increase in training capacity at the hospital, consequent cost savings and shorter waiting times for RT patients.

5. Programme, presentations and survey results from International VERT User Community Meetings (available on request) – corroborating the benefits to the VERT community of evaluating and developing VERT.