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Application of Virtual Environment for Radiotherapy Training System for Educational Purposes at Institute of Physics of Jan Kochanowski University in Kielce

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The paper presents the Virtual Environment for Radiotherapy Training system in the context of its application in the education of students at the Institute of Physics of the Jan Kochanowski University in Kielce, in the field of applying physics in medicine. The Virtual Environment for Radiotherapy Training system operates within the Virtual Radiation Therapy Laboratory, and its unique possibilities are the following: 3D simulations of commonly used equipment using external beam radiation, visualization of treatment plans in any location, simulations of the therapy equipment quality check and results, and also using different images to study human anatomy. The paper also discusses treatment planning systems available in the simulator laboratory. A general overview of the simulator possibilities concentrates on present and future users of the Virtual Radiation Therapy Laboratory, namely students of medical and technical physics, students of medicine, medical physicists and electroradiology technicians, doctors and other radiation therapy professionals.

topics: education, radiation therapy simulation, treatment planning, VERT

1. Introduction

A long tradition of the Institute of Physics at the Jan Kochanowski University (UJK) in Kielce (Poland) is to educate students in the field of applying physics in medicine and to teach a new generation of electroradiology technicians and medical physicists. A key element of the education process is to provide students with opportunities to develop practical skills by allowing them to work with professionals and modern devices and equipment. For example, such personal experience is crucial in establishing and implementing treatment plans that include external beam radiation.

A significant problem in the education of specialists in the planning and implementation of radiotherapy is often a lack of real access to equipment used in this field. Aiming to overcome this difficulty, the first in Poland fully equipped educational and training Virtual Radiation Therapy Laboratory, with the Virtual Environment for Radiotherapy Training (VERT) system [1], was created in the Institute of Physics of UJK. The mission of the laboratory is both to teach theoretical background of radiotherapy as a cancer treatment method and to help specialists in acquiring clinical experience. The laboratory can provide training for students but also for scientists and professionals already working in radiation therapy.

An additional, unique aspect of the VERT system application is the fact that it enables patients to understand the treatment process more easily.

The presented paper gives a general overview of the possibilities of the Virtual Radiation Therapy Laboratory also in the context of a treatment planning procedure.

2. VERT system

The VERT (Vertual Ltd., Hull, UK) [1] system is an interactive simulator working in a virtual reality (VR) 3D environment [2–4]. The VERT system (IMMERSIVE VERT CINEMA version) [1], operated in the Virtual Radiation Therapy Laboratory, is equipped with a 3 Chip DLD projector working in a rear projection configuration, a screen with the size of 4.2×2.5 m^2 for 3D visualization and several dozens of 3D active shutter glasses. The projector resolution is 1920×1200 (full HD) and the visualization format is 16:10 (widescreen). Additionally, the VERT system includes an image management system with a touch panel to control the projection,

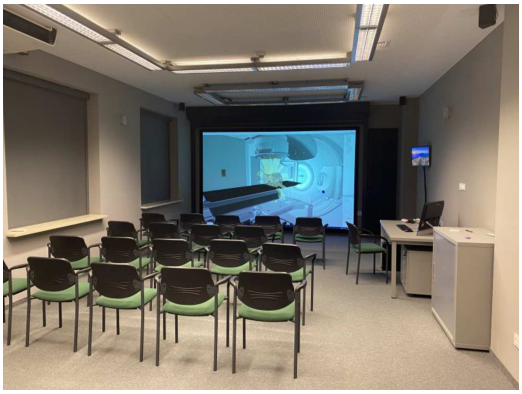

Fig. 1. Photo of the VERT system room, localized in the Institute of Physics of UJK.

a software for emulation of Elekta Synergy and Varian TrueBeam accelerators along with the original control consoles, and software for 2D and 3D virtual radiation therapy simulations. A photograph of the VERT room, localized in the Institute of Physics of UJK, is shown in Fig. 1.

Thanks to the latest innovations in VR technology, the VERT systems offers/allows:

- 3D simulations of commonly applied equipment using external beam radiation: X-ray, electron and proton, provided by Varian, Elekta and other producers, which are in everyday use in radiation therapy departments,
- importing of files with personal treatment plans including the usage of external beams via a treatment planning software in DICOM standard and evaluating them in a simulation mode,
- visualization of treatment plans in any location, realized for any commonly available real life equipment,
- simulations of equipment malfunctions, but also errors such as an incorrect patient position (set up) during treatment on accelerator as well as visualizations of the consequences of discussed mistakes, and influence of incorrect dose distribution on the treatment effect,
- simulations of the therapy equipment quality check and results as well as its possible impact on the treatment that is being worked on,
- using various modalities, such as MRI (magnetic resonance imaging), CT (computer tomography) and PET (positron emission tomography), for patient imaging,
- using of different images to study human anatomy, taking into account the regions of interest used in radiotherapy,
- analysis and comparison the dose distribution not only on the transverse images but also on the dose-volume histogram (DVH).

Examples of the VERT system applications are presented in Fig. 2.

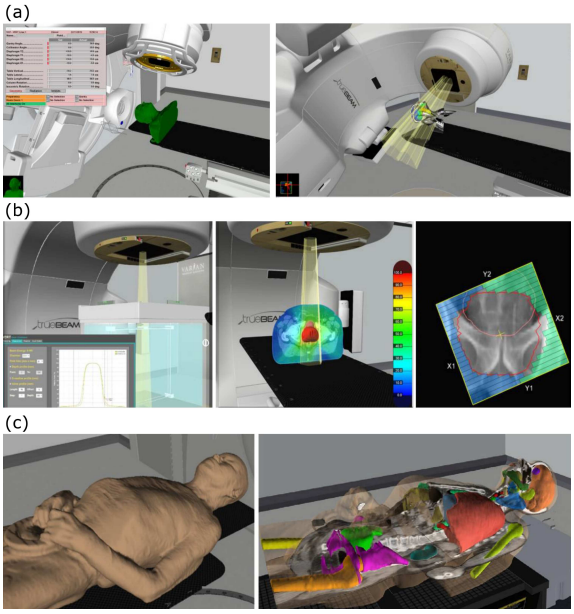

Fig. 2. Examples of the VERT system's possible applications: (a) patient positioning and radiotherapy simulation, (b) analysis of beam radiation distribution [1], (c) study of human anatomy [1].

Since the very beginning of the Virtual Radiation Therapy Laboratory's operation, students have used the VERT in different courses of their studies such as Radiotherapy, Basics of Human Anatomy, Physical Laboratory III and Biomedical Imaging. The VERT laboratory applications were also presented to a community of scientists, professionals and students during the conference "Virtual Reality — a New Tool in the Training of Medical Physicists, Electroradiologists and Radiotherapists".

3. Treatment planning systems

The VERT system is supported by two advanced multi-station software of Treatment Planning Systems: RayStation [5] (4 stations) and ProSoma [6] (10 stations). It provides an opportunity to teach specialists about treatment planning for different kinds of radiation techniques available for most commercial accelerators, including tomotherapy and proton therapy. Photos of computer laboratories dedicated to work with treatment planning systems are presented in Fig. 3.

Treatment planning systems use the most modern computational algorithms based on the Monte Carlo method. A deformative image registration allows for using diagnostic images to precisely determine the target of irradiation. Prepared plans are sent to one of the treatment tools installed in the VERT system and can be realized.

Treatment planning systems have tools for fusion images from CT, MRI and PET. On the basis of these images, it is possible to develop and follow the entire process of preparing the patient for irradiation. Treatment planning systems allow their

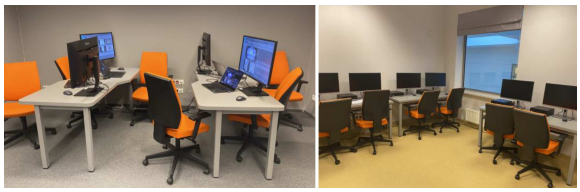

Fig. 3. Photos of computer laboratories dedicated to work with treatment planning systems.

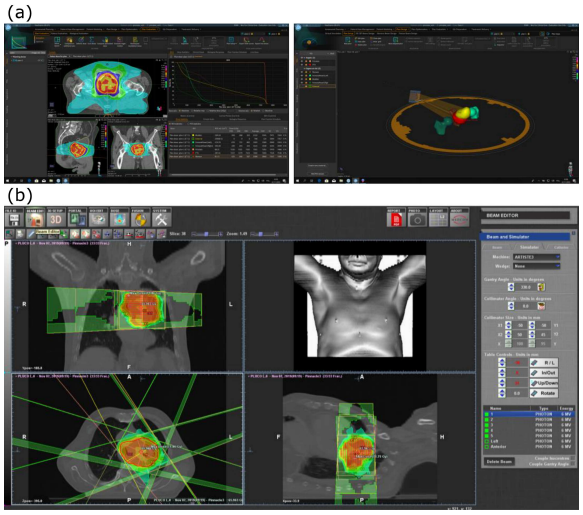

Fig. 4. Exemples of application of treatment planning systems: (a) optimization of dose distribution (left) and treatment planning (right) in RayStation software, (b) analysis of dose distribution in ProSoma treatment planning system.

user to enter and analyze the dosimetric data of any accelerator. In this way, the effects of incorrect accelerator modeling on subsequent calculations of dose distributions can be simulated which is impossible in a real treatment planning procedure.

The RayStation system has implemented modules for dose distribution optimization, using both physical and biological functions, which also makes it possible to compare these treatment plans and indicate critical points during optimization. The ProSoma system monitors the stability of the treatment plan implementation resulting from changes in the dose distribution caused, for example, by patient movements or changes in the position of the isocenter. This system also provides simulations of hardware errors or incorrect positioning of the patient during radiotherapy, together with the visualization of the consequences of such an action. The ProSoma can load reports from radiotherapeutic devices and recalculates the dose deposited in the patient's body.

Using the treatment planning systems, students can prepare data for accelerator modeling and analyze various stages of admitting systems to clinical operation, taking into account errors and dangers associated with them. By cooperating with the Holy Cross Cancer Center in Kielce and also other oncological centers and hospitals, the anonymized data in the Digital Imaging and Communications in Medicine (DICOM) standard can be used to create various irradiation scenarios for any tumor location. Using the treatment planning systems installed in the laboratory, students can prepare their own treatment plan proposals and compare them with each other or with a reference plan.

During the implementation of the therapy on the VERT system, it is possible to feed into it data on various inaccuracies and errors that may appear while working on the accelerator and as a result of the effects of incorrect implementation of the irradiation process. This allows to create different scenarios for training without the risk of causing any danger to the real patient. Examples of application of treatment planning systems are graphically presented in Fig. 4.

4. Conclusions

In this paper, the Virtual Radiation Therapy Laboratory, an innovative laboratory created in the Institute of Physics of the Jan Kochanowski University in Kielce, is presented. A general overview of the VERT possibilities is provided and also two advanced multi-station software of treatment planning systems (RayStation and ProSoma) are discussed. This laboratory plays a crucial role in student education in the medical physics and technical physics fields, especially for practical skills development.

The simulation-based radiation therapy education will help to prepare the future generation of highly skilled electroradiology technicians and medical physicists, being also the best way for a possible development of cooperation between all professional groups involved in the entire process of preparation and implementation of patient irradiation.

Acknowledgments

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[5] RaySearch, RayStation.

[6] OSL, ProSoma 3D & 4D Simulation.