

DEVELOPING NUMERICAL METHODS AND SIMULATIONS FOR TRAININGS IN RADIOTHERAPY

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ABSTRACT

A very important step in radiotherapy during the treatment process is the procedure of image processing (Matlab) and the radiation doses calculations. Many commercial software and techniques are developed for these procedures. The methodology of using numerical methods in medical imaging and radiotherapy for training and simulations is very important for students and researches in laboratories before clinical practice. Using Matlab, we can analyze data, develop algorithms, and create models and applications. The language, tools, is built in math functions enable us to explore multiple approaches and reach a solution faster than with spreadsheets or traditional programming languages, such as C/C++ or Java. Matlab is a high-level language and interactive environment for numerical computation, visualization, and programming. From 2010 our team is working to adapt a module in Matlab environment for Medical Physics and Medical Imaging Technicians based on several modules in Matlab. First, we describe the computational environment for radiotherapy research, developed to facilitate reproducible research in radiation oncology treatment planning in Matlab environment, as a basic framework to make inter-institutional treatment planning research more feasible. At the end we describe the first Albanian module for training and simulation in radiotherapy called PPIR¹. One of the most important applications of this module is medical images processing, visualization and structure contouring for radiotherapy treatment. The simulation procedure of linear accelerator and the configuration of beams for tumor treatments is another application of this module. The dose calculation on this module is based on Eudmodel for dose volume histograms (DVH), which in radiotherapy treatment plan evaluation relies on an implicit estimation of the tumor normal tissue complication probability and control probability.

INTRODUCTION

Radiotherapy uses high frequency radiation to damage the DNA of cancer cells, which usually replicate at a faster rate than normal cells in the body. Typical modalities are external beam radiotherapy with photons, external beam radiotherapy with electrons and brachytherapy with nuclear source. We must have a good understanding of the equipment available for pre-treatment imaging purposes and the use of DICOM and PACS systems [1]. We must be able to describe the design of the basic conventional radiotherapy simulator equipment and must have good understanding of computed radiography, SIM - CT and CT simulation.

MATERIAL AND METHODS

The main role of a Medical Physicist as a qualified person, is to works directly with the doctor in treatment planning and delivery. They are responsible for developing and directing quality control programs for equipment and procedures that ensure the equipment

¹ The image processing program in radiotherapy (in albanian: Program për Procesim Imazhesh në Radioterapi).

works properly. They also take precise measurements of radiation beam characteristics and do other safety tests on a regular basis.

A very important step in radiotherapy during the treatment process is the procedure of image processing of structures and the radiation doses calculations [6] where many commercial software and techniques are developed for these procedures. In this paper we describe a computational environment for radiotherapy research, developed to facilitate reproducible research in radiation oncology treatment planning. We view this system, along with the underlying Matlab environment, as a basic framework to make inter-institutional treatment planning research more feasible. Matlab is a high-level language and interactive environment for numerical computation, visualization, and programming. Using Matlab, we can analyze data, develop algorithms, and create models and applications. The language, tools, and built-in math functions enable us to explore multiple approaches and reach a solution faster than with spreadsheets or traditional programming languages, such as C/C++ or Java.

RESULTS AND DISCUSSION

As mentioned above, the main role of the Medical Physicist in radiotherapy is to prepare the treatment planning systems and make dose calculation to ensure that the tumor will be treated with relevant dose. This procedure is performed by sophisticated software programs, known as treatment planning systems (TPS) which are commercially available to tailor-make treatment plans for individual patients. These systems mainly allow clinicians to predict the dose delivered to each voxel in the patient for a given orientation of the radiation beams and other parameters used before treating the patients [4]. Treatment simulations are used to plan the geometric, radiological, and dosimetric aspects of the therapy using radiation transport simulations and optimization (Podgorsak, 2005). For medical physicists this procedure is not only very difficult but many times very complex because needs practical simulations and clinical tests which sometimes are not available.

In this work we describe some applications of PPIR software, finalized by our team in 2014 in Matlab environment. This program integrates two Matlab package, Computational Environment for Radiotherapy Research (CERR) and Dose response explorer system, (DREES). The PPIR also have several new functions focused in image visualization and processing and is organized and adapted to perform the most important procedures that are applied in radiotherapy in the treatment of tumors such as: medical images import, delineation of structures, treatment dose, DVH management etc. CERR and DREES are built using a high-level graphical analysis and programming package, Matlab (Spezi et al., 2002, Joseph, 2003) [9]. PPIR also includes analytical and normal tissue complication probability and tumor control probability [8]. Multi-metric regression modeling of dose-volume variables, bio markers, and patient-specific clinical factors, actuarial analysis and hazard regression, dimensionality reduction and principle component analysis, nomogram representation are other possibilities with PPIR.

To demonstrate the functions of the PPIR, we choose a head and neck image, DICOM format. The main functionality is contouring the structures of TPS such are the Gross Tumor Volume (GTV), Clinical Target Volume (CTV), and Planning Target Volume (PTV = CTV + 1 cm) based on graphical representation of the volumes of interest. Contouring usually is a “homemade” process but for regular structures, this can be performed automatically [2].

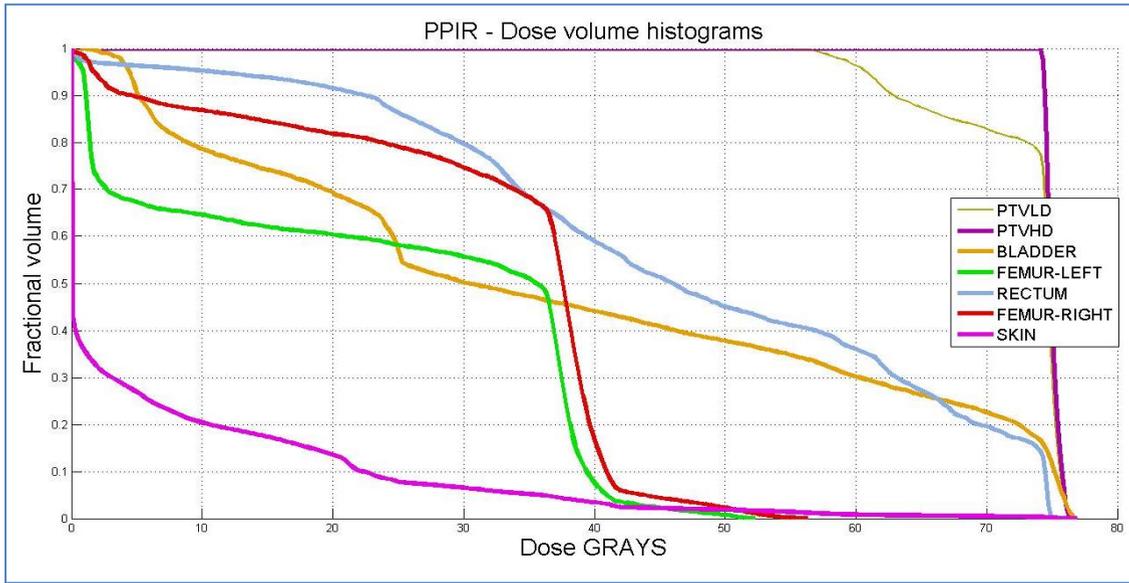


Figure 2: Graph of DVH for each structure (cumulative plot)

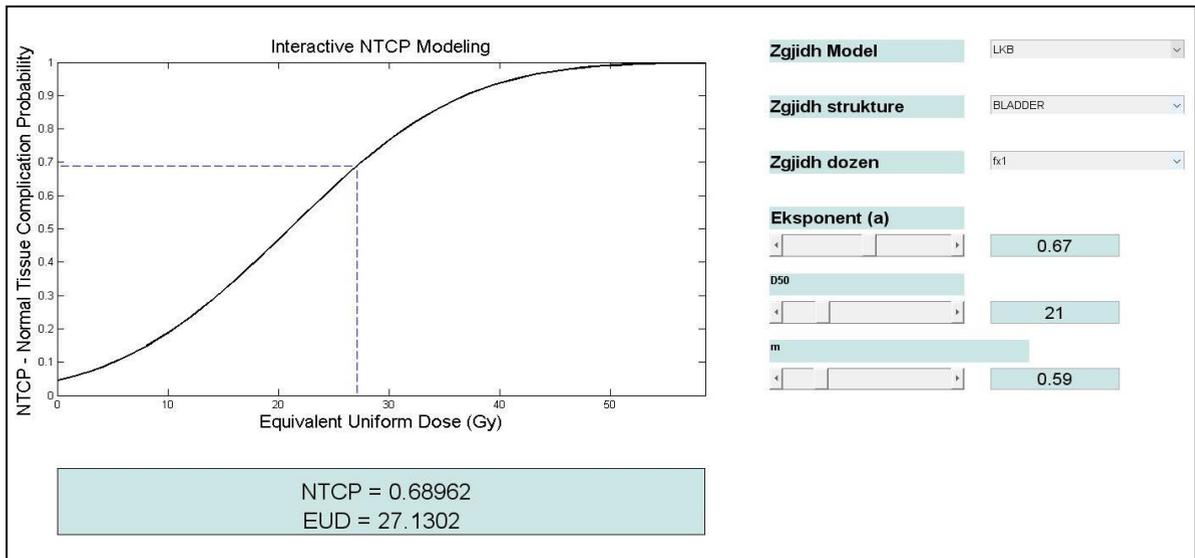


Figure 3: NTCP calculation, based on EUD [6]

Before a treatment procedure, we have to ensure that our machine will deliver the right dose to tumor. With “virtual simulator” (Hartmann G. H., 2009), [5], we can simulate LINAC and QA equipment's for measurements following these steps: Preparation of accelerator, Preparation of water phantom, Chamber preparation, T and P Measurements, Calculation under IAEA TRS-398 (Absorbed Dose Determination in External Beam Radiotherapy), Tumor treating. The “*E-training dose calibration software*” simulate the virtual equipment's for LINAC preparation and measurements such are: high

energy photon beam, ionization chamber, water phantom, electrometer, thermometer, barometer, as is shown in figure 4.[5]

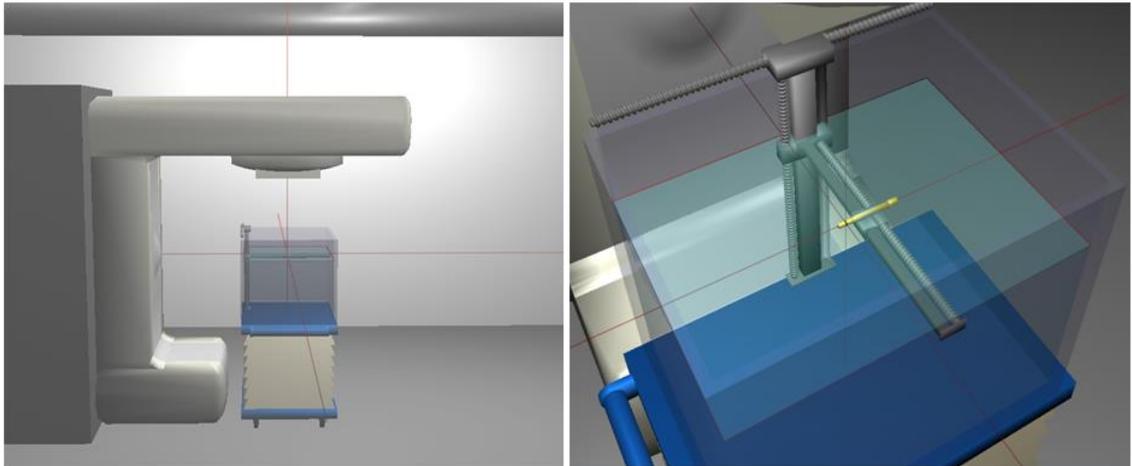


Figure 4: E-training dose calibration software

With a random example use PPIR module, to simulate the number and the configuration of beams an linac (Figure 5).

<i>Beam Number:</i>	8
<i>Beam Description:</i>	RPO(B8)
<i>Beam Modality:</i>	X-RAY
<i>Beam Energy:</i>	MeV: 15
<i>Beam Type:</i>	STATIC
<i>Nominal Isocenter Distance:</i>	100
<i>Collimator Type:</i>	Asymmetric
<i>Isocenter coordinate:</i>	-0.2, 0.6, 143.0
<i>Asymmetric Collimator Setting X:</i>	6.00, 6.00
<i>Asymmetric Collimator Setting Y:</i>	4.50, 6.00
<i>Collimator Angle:</i>	0
<i>Couch Angle:</i>	0
<i>Gantry Angle:</i>	135
<i>Wedge Angle:</i>	na
<i>Wedge Rotation Angle:</i>	na

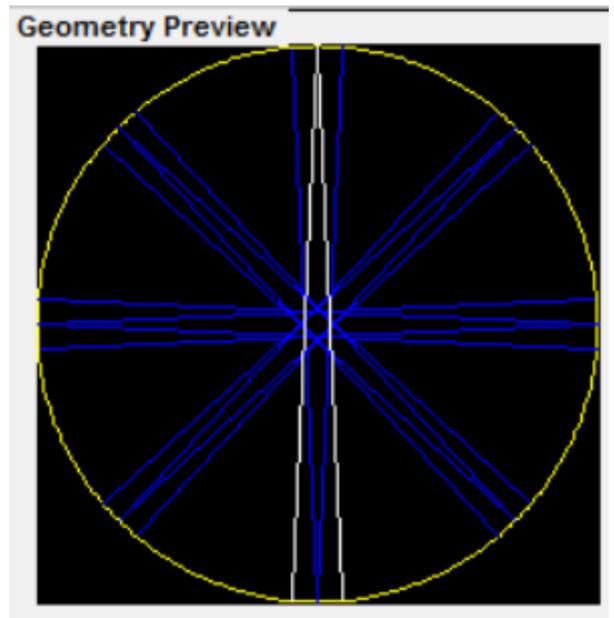


Figure 5: Basic data for TPS and beam configuration

After we finished all steps, now we can deliver the dose to the patient.

Conclusions

We showed shortly a method of using of PPIR as the first package of functions in Matlab with graphical user interface (GUI) in Albanian language which integrates CERR and DREES applications and is organized and adapted to perform the most important procedures that are applied in radiotherapy in as a module for computation and simulation in radiotherapy. This software module will be very necessary for students to develop medical physics teaching practice. gives opportunities for students to: apply in practice all procedure was followed in radiotherapy, to import treatment plans from a wide variety of treatment planning systems using different archive format, to manipulate treatment plans within a powerful data analysis and programming environment, for example for dose-volume-outcomes analyses, to visualize plans review tools (axial, sagittal, and coronal viewers). Some of the functions are modified and adapted to obtaining and calculate data based on TRS 398 of IAEA (International Atomic Energy Agency) [3].

We have to emphases that the PPIR is not tested and used for clinical purposes or test. We recommend to use it only for training, simulations and research.

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