Optimization of treatment planning for non-coplanar beam in external radiotherapy

Thesis location: LaTIM (Brest).

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1. Context and objectives

External radiotherapy is one of main treatment against cancer with surgery and chemotherapy, and it concerns 60% to 70% of patients care in oncology. This treatment consists in delivering the maximum dose as possible to the tumour using an ionized particle beam, while the delivered dose within the organs at risk must be reduced as much as possible. The past few years have seen widespread adoption of rotational beam-delivery techniques such as volumetric modulated arc therapy (VMAT), which refers to radiotherapy treatments in which the treatment beam is continuously on while the gantry rotates around the patient. Today, VMAT treatments are using a coplanar beam trajectory realized by a fixed couch angle, typically 0^0. Recently it has been established that treatment plans using non-coplanar beam angles, also called 4π radiotherapy (Papp et al., 2015), can yield impressive improvements in radiation dose conformality and sparing critical organ. Non-coplanar beams are obtained by moving the couch (position and rotation) during the gantry trajectory. Implementation of this treatment strategy has been hampered by inaccurate solution space modeling, limited automated beam selection methods, lack of efficient beam sequencing program and integrated collision prevention between the accelerator head and the couch. The aim of this thesis is to develop and validate new methods dedicated to non-coplanar beam therapy.

2. Detailed subject

A first stage will consist to propose new optimization algorithms. Number of promising non-coplanar beam directions can be selected using an heuristic iterative beam selection; these beams serve as anchor points to optimize the gantry and couch trajectories. Collision prevention and dosimetry metrics have to be integrated within the optimization global cost function. A 3D simulator has to be developed to study, show and assess placement of each system element. Dosimetry calculation will be estimated using the Monte Carlo software GGEMS (Bert et al., 2013).

A second stage will consist to evaluate and validate the proposed non-coplanar beam planning using a real system (VARIAN TrueBeam™ STx) available at the Brest Hospital University. This will also include developing software that interface the proposed optimization code with the treatment system that use xml language. The proposed optimize planning will be evaluated in term of dose accuracy, treatment run time and distribution of gantry angles.

The last stage of the thesis is the evaluation of the proposed method in a clinical context, especially in prostate cancer. Portal imaging on phantom will be used to measure the dose to the planning target volume. The aim is to compare the non-coplanar beam treatment against the widely use VMAT treatment. The final purpose of this study

will be to figure out if the non-coplanar beam method may improve the delivered dose to the tumor and propose a better treatment for cancer compared to the widely used VMAT.

3. Proposed course and method of collaboration

The Labex CAMI and the Britany region fund this research project. This project gathers the LaTIM (INSERM UMR1101) and the LIRMM (CNRS). The LaTIM research group has long experience in external radiotherapy, Monte Carlo simulation, dose calculation and the use of GPU architecture dedicated to medical applications. DEXTER (LIRMM lab) research groups have a long and significant experience in the design and control of robotic devices for medical applications. In addition this work is placed within a consortium including the Brest Regional University Hospital (CHRU Brest), the University of Western Brittany (UBO), the LaTIM and the company VARIAN, which is the international leader in radiotherapy devices. This consortium was initially started when a new generation of medical accelerator was installed at the CHRU where its usage is shared between clinical and R&D.

The PhD student should have a strong background as well as some experience in the field of robotics, control engineering and programming.

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