# Integration of the M6 Cyberknife in the *Moderato* Monte Carlo platform and prediction of beam parameters using machine learning

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**Introduction**

We first describe the modelling of the MLC-based M6 Cyberknife system (Accuray Inc., Sunnyvale, CA), in EGSnrc. The system is then integrated in the *Moderato* platform [1] and patient plans are re-calculated. Finally, a new machine learning method is proposed to predict the values of the electron beam parameters from water phantom measurements, allowing significant time gain in the modelling of the linac.

**Materials & Methods**

The first step consisted in modelling the Incise2 MLC included in the M6 version of the Cyberknife accelerator in EGSnrc. Electron beam parameters (energy and spot size) were optimized from measured dose profiles in water using BEAMnrc/DOSXYZnrc. The model was then integrated in *Moderat*o [1], an automated system offering easy and independent 3D verification of dose distributions calculated by the Treatment Planning System (TPS), and semi-automatic plan evaluation based on dose constraints for organs-at-risk (OAR), as introduced in [2]. Dose distributions from both algorithms included in the TPS (Finite-Size Pencil Beam *FSPB* and Accuray Monte Carlo *AMC*) and from *Moderato* were compared for patient plans. The last part of this work consisted in designing a machine learning (ML) algorithm to find the optimal parameters of the electron beam. A series of simulated dose profiles were obtained while varying beam spot size (from 1 to 4 mm) and energy (from 4 to 8 MeV). A regression algorithm was trained to predict the energy and spot size by extracting features from these simulated profiles, and was tested using cross-validation.

**Results**

Comparisons in the homogeneous water phantom resulted in an optimal agreement between simulated and measured profiles for a monoenergetic electron beam of 6.75 MeV with a gaussian spatial distribution of 2.4 mm full-width at half maximum (examples are shown in figure 1). Re-calculation of patient plans showed a good agreement (< 2 %) between the three algorithms, although significant differences (> 5 %) were detected for some cases, where many so-called ”peripheral” fields were used (these beams cover only part of the PTV and can have very narrow and irregular shapes). These differences are currently being investigated through measurements. Finally, a 10-fold cross-validation of the ML algorithm showed that electron beam energy and spot size could be predicted with a mean absolute error (MAE) of 0.1 MeV and 0.3 mm respectively.

**Discussion & Conclusions**

The *Moderato* platform now includes the MLC-based Cyberknife in its supported accelerators, allowing for routine verification of patient plans. In addition, a ML algorithm was tested to validate the concept of predicting electron beam parameters from profile data. Further work is ongoing to reduce the uncertainty on energy, and apply this principle to other devices.

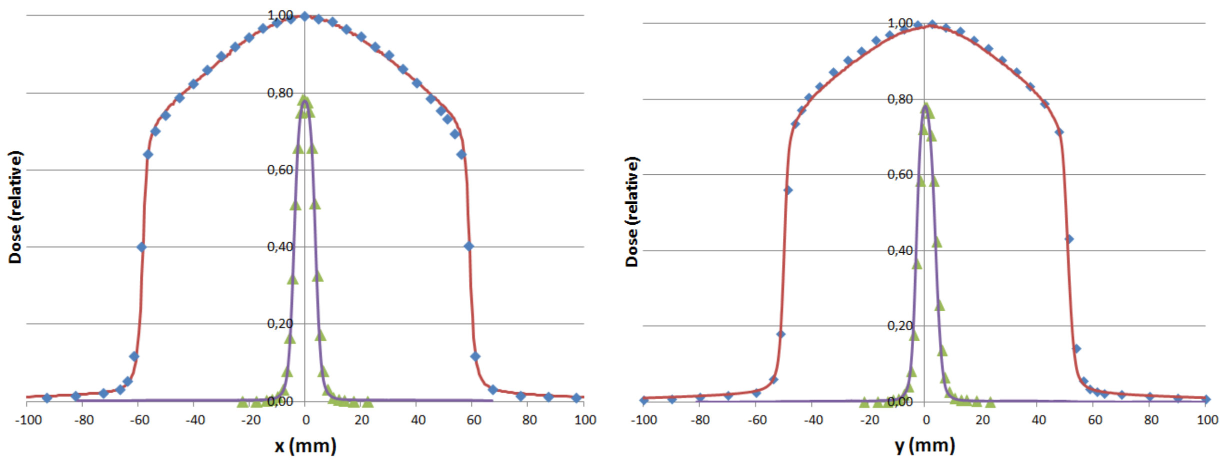


**Figure 1:** *Measured (solid curves) and simulated (symbols) dose profiles for the 115x100mm and 7.6x7.7mm field size. The x axis corresponds to the leaf travel direction.*

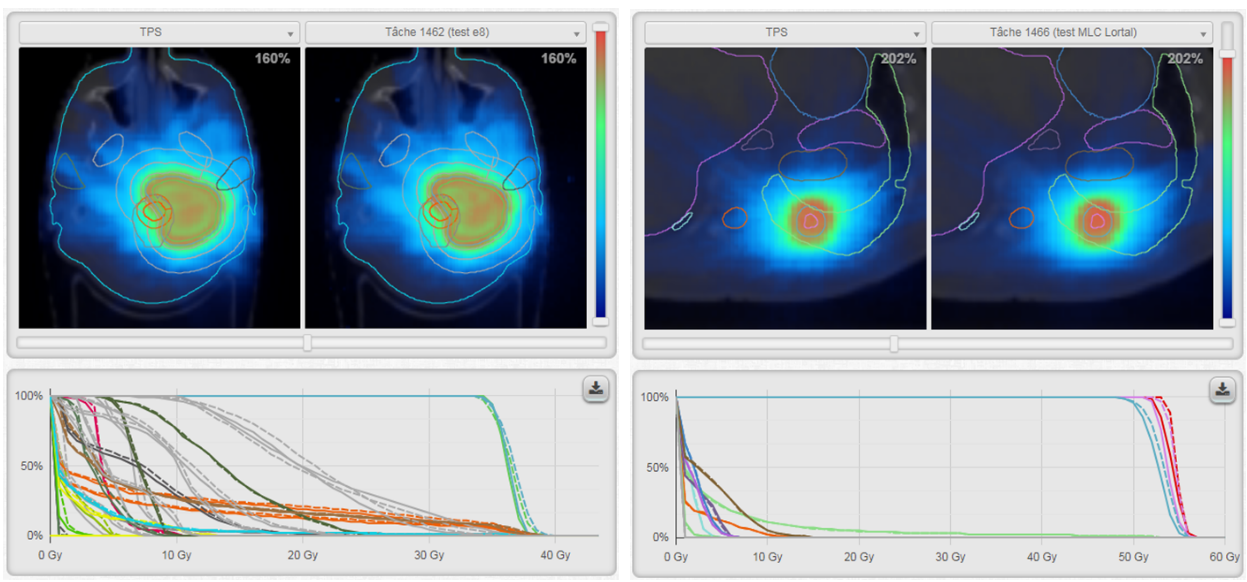


**Figure 2:** *Re-calculations of a brain and a lung Cyberknife treatments. Median dose to the PTV were within 2 % between the TPS algorithm and Moderato (TPS corresponds to the FSPB algorithm for the brain case, and to AMC for the lung case).*

**References**


[1] N. Reynaert et al, "Clinical implementation of a Monte Carlo based treatment plan QA platform for validation of Cyberknife and Tomotherapy treatments," Phys Med 2016 Oct; 32(10): 1225-1237

[2] A. Wagner et al, "Use of an in-house Monte Carlo platform to assess the clinical impact of algorithm-related dose differences on DVH constraints", Phys Med 2017 Oct; 42: 319-326



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