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Predicting machine uncertainties from logfile data of a radiotherapy system using machine learning

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Purpose: In the context of cancer treatment, radiation therapy uses ionizing radiation to control or destroy malignant cells. The therapy is usually delivered by a linear accelerator. Over the years there have been major advancements in delivery techniques for radiotherapy. Recently, the Division of Medical Radiation Physics at Inselspital Bern has developed the research modality dynamic trajectory radiotherapy (DTRT), which extends state-of-the-art volumetric modulated arc therapy (VMAT) by dynamic table and collimator rotation during radiotherapy delivery. In this work, Lasso (L), Ridge (R), Random Forest (RF), Multi-layer Perceptron (MLP) and Recurrent Neural Network (RNN) regression are investigated to predict mechanical uncertainties of gantry, table and collimator rotation and monitor units of a TrueBeam® (Varian Medical Systems, Palo Alto, CA, USA) radiotherapy delivery system during DTRT from machine log file data.

Methods: During delivery of DTRT treatment plans on a linear accelerator, expected and actual values of all major machine components are recorded every 20 ms and saved in the machine log files. A total of 17 DTRT logfiles were recorded at Inselspital Bern, containing 777480 time points. The input dataset contains the expected values of gantry, table, collimator and monitor units. Additionally, the input dataset was extended by calculation of the speed of the beforementioned machine components from their expected values at each time point. L, R, RF, MLP and RNN regressions were trained on 80% of the data set and tested on the remaining 20% to predict the difference between expected and actual value of each component at each time point. Pre-processing included a MinMax scaling. The different regression methods were evaluated on the test-set according to the difference of the absolute recorded (G equals ground truth) and absolute predicted difference.

Results: The results are shown in Table 1 (best value per row in bold). Differences in table and collimator rotation could be accurately predicted, whereas the difference prediction of gantry rotation and monitor unit was inaccurate by up to 122%. Values of mean, max and 95% percentile absolute difference as G and as relative difference to recorded (G-X)/G are displayed, respectively.

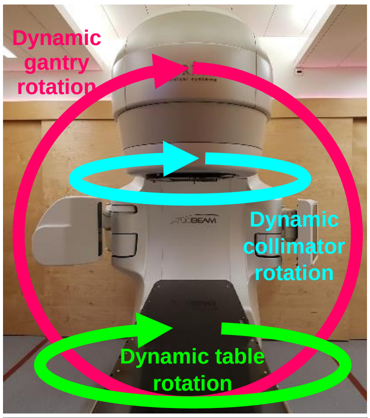

Figure 1: Linear accelerator for radiotherapy treatments at Inselspital Bern.

		$\lvert G\rvert$	$\frac{\lvert G-L\rvert}{\lvert G\rvert}*100$	$\frac{\lvert G-R\rvert}{\lvert G\rvert}*100$	$\frac{\lvert G-RF\rvert}{\lvert G\rvert}*100$	$\frac{\lvert G-MLP\rvert}{\lvert G\rvert}*100$	$\frac{\lvert G-RNN\rvert}{\lvert G\rvert}*100$
Gantry Rotation Difference	Mean, Max, 95% p.	0.091° 0.334° 0.222°	**92%** **84%** **85%**	93% 82% 86%	98% 134% 103%	100% 98% 91%	**92%** 88% **85%**
Table Rotation Difference	Mean, Max, 95% p.	0.081° 0.146° 0.129°	**8%** **25%** 17%	10% 26% **16%**	11% 52% 20%	11% 33% 18%	11% 26% 17%
Collimator Rotation Difference	Mean, Max, 95% p.	0.043° 0.172° 0.122°	**2%** **3%** **2%**	**2%** **3%** **2%**	**2%** 62% 38%	7% 18% 8%	18% 45% 31%
Monitor Unit Difference	Mean, Max, 95% p.	0.005 MU 0.022 MU 0.013 MU	**120%** **113%** 115%	**120%** 114% 123%	**120%** 118% **107%**	140% 122% 123%	**120%** 114% 115%

Table 1: Main results of the regression methods.

Conclusion: Accurate prediction of the difference between expected and actual value in the detectable range in collimator and table rotation was achieved with all regression methods, L and R performing best. The methods used, could not predict the difference in gantry and monitor units accurately. Further study is still needed to fully understand the uncertainties in all machine axes of a linear accelerator delivering DTRT treatment plans.