Master's Thesis Engineering Technology

2022-2023

Implementing of VMAT-related LINAC QA

Okan Huyuk

Nuclear Engineering Technology Master of Software Systems

Introduction

Volumetric modulated arc therapy (VMAT) involves continuously adjusting the beam aperture, gantry speed, and dose rate while using one or more gantry arcs to treat the patient. These features allow for optimization of dose conformality, accuracy, and delivery efficiency [1-3]. However, due to its many functionalities, VMAT treatment also requires sufficient Quality Assurance (QA). Formerly, for each patient's treatment at the 'Limburgs Oncologic Centre' (LOC), specific patient-related QA was performed, but due to the time-consuming aspect, it is currently only performed for complex plans and treatments with a dose greater than or equal to 5 Gy per fraction.

As a result, patient pre-treatment QA has been reduced to one quarter. Therefore, the LOC would like to establish **additional machine QA for VMAT and Intensity Modulated Radiotherapy (IMRT)** on a six-weekly basis to better ensure the reliability of treatment quality. This thesis focuses on different methods of testing and analysing the implementation of machine QA using the software tools **PyLinac** and **Varian Portal Dosimetry**.

Method

The features of VMAT are investigated using a series of tests performed on two types of Varian Linacs, the TrueBeam and the Clinac. The **picket fence (PF) test** is used to examine the Multileaf collimator (MLC) position accuracy and alignment. This is done by aligning the leaves on both sides to create a constant 1 mm gap, called the pickets. The pickets are the vertical lines shown in figure 1.
The dose rate and gantry speed (DRGS) test makes use of seven different combinations of dose rate, gantry speed and gantry range to deliver the same dose to seven strips (cfr. fig.2). The **MLC speed test** during rapid arc is controlled. This test uses four combinations of leaf speed and dose rate to give equal dose (cfr. fig.3).
Finally, a **dose test** is performed in which a sweeping gap, shown in figure 4, moves over the field while the gantry is still. As the dose given in this test is ideally uniform, any variation in dose is related to the gap being wider or narrower than the expected 0.50 cm.

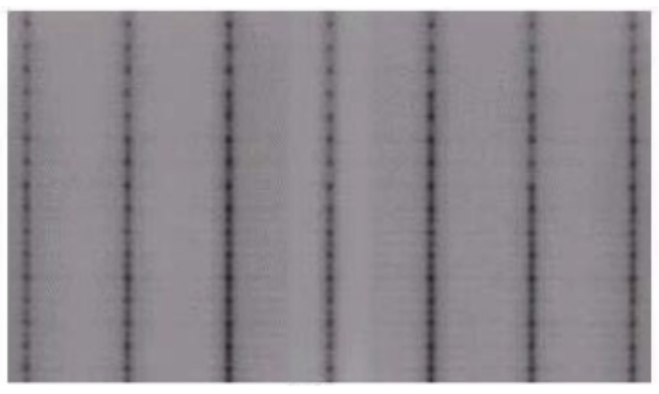

Figure 1: Picket Fence plan [4]

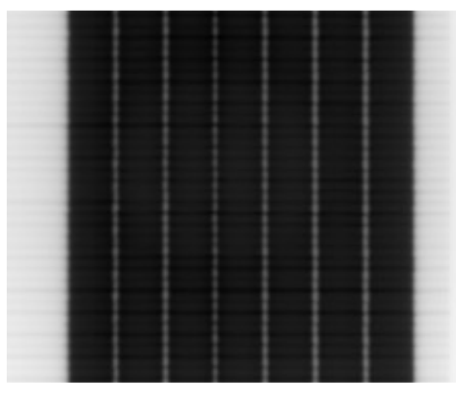

Figure 2: DRGS plan

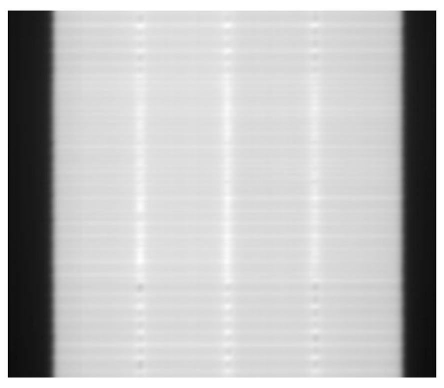

Figure 3: MLC speed plan

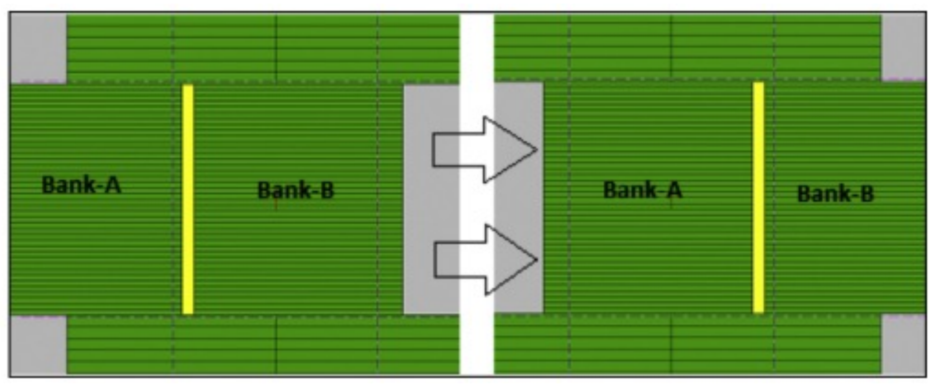

Figure 4: Sweeping gap [5]

Result PyLinac

A **PF test with an intentional error**, shown in figure 5, was first used to set the tolerance levels for this test. The selected level was **0.20 mm** and all measurements made with the TrueBeam and Clinac were within this tolerance.
The tolerance for the **DRGS test** was set at **2.0%** and the **MLC speed test** was also tested at **2.0%**.
The measurements taken with the TrueBeam were all within the tolerances while the measurements with the Clinac failed for these tolerances.
PyLinac does not support any way of analysing the dose test.

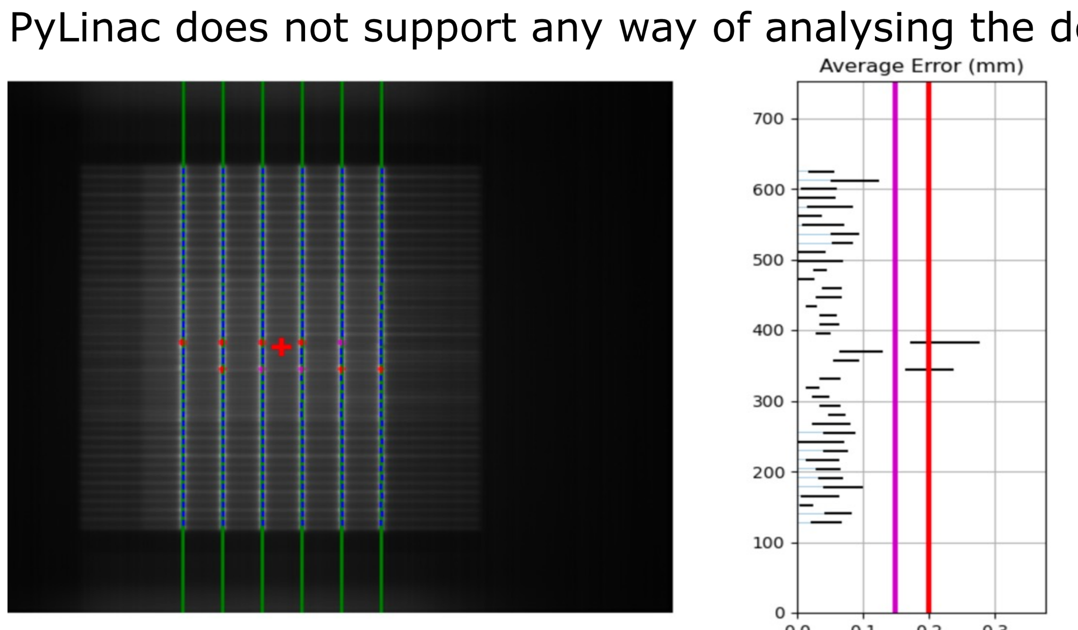

Figure 5: Picket fence plan with intentional error and the average error of the MLC positions

Result Portal Dosimetry

A **gamma evaluation** was performed comparing a predicted plan with the measured one which is visualised in figure 6. For the **PF test**, only the MLC positions of the pickets are relevant, and these were tested using the **distance-to-agreement (DTA)** criteria of **0.50 mm** and a **dose difference** of **1.0%**. The warning level was set at 97.0% and the action level at 95.0%; the TrueBeam measurements were successful, whereas the Clinac measurements failed.
No unambiguous criteria could be found for the **DRGS test** and the **MLC speed test** using a gamma evaluation. Therefore the DRGS and MLC speed plans were corrected by using an **open beam** plan of the same size, so that the analysis was performed in **a similar way to PyLinac** and with similar results.
The values were obtained with Portal dosimetry and the analysis was done with Excel.
The **dose test** was investigated by first measuring the plan with a **pinpoint detector** and then comparing it to a **calculated value** within Portal Dosimetry. A **significant difference** was found.
Then, the effect of **gravity** was checked for the cardinal angles. They were in good agreement And **below 0.50%**.

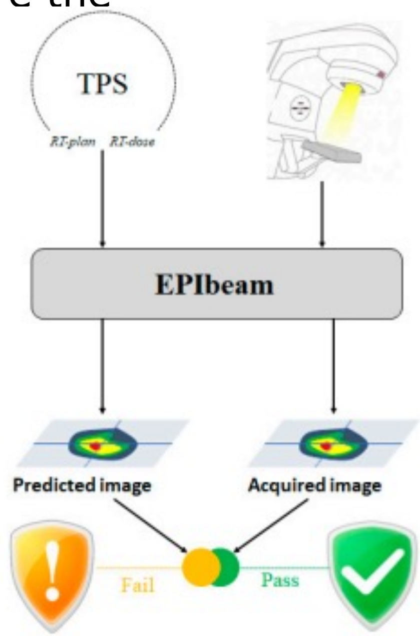

Figure 6: Gamma evaluation [6]

Conclusion

The **PyLinac software** is used to analyse **the PF test, the DRGS test and the MLC speed test**. Both TrueBeam and Clinac measurements of the PF test can be analysed with PyLinac. The **TrueBeam** measurements for the **DRGS** and **MLC speed test** could be analysed with both **PyLinac** and **PD** using the **open beams for correction**, giving similar results.
Due to **excessive noise** caused by the **sensitivity of the EPID** to scatter radiation, the DRGS and MLC speed tests could not be analysed using a gamma evaluation on PD.
A suitable reference for comparison with the **dose test** measurements could not be found. The cause of the deviations is not yet known and further investigation is required. This test is only used to investigate the effect of gravity.

Supervisors / Co-supervisors / Advisors: External supervisors: Kenny Geens, Rani Truyens
Internal supervisor: Prof dr.Brigitte Reniers

[1] C. C. Ling, P. Zhang, Y. Archambault, J. Bocanek, G. Tang, and T. Losasso, "Commissioning and quality assurance of RapidArc radiotherapy delivery system," Int. J. Radiat. Oncol. Biol. Phys., vol. 72, no. 2, pp. 575–581, 2008.
[2] I. Iftimia, E. T. Cirino, L. Xiong, and H. W. Mower, "Quality assurance methodology for Varian RapidArc treatment plans," J. Appl. Clin. Med. Phys., vol. 11, no. 4, pp. 130–143, 2010.
[3] E. Infusino, "Clinical utility of RapidArcTM radiotherapy technology," Cancer Manag. Res., vol. 7, pp. 345–356, 2015.
[4] C. D. Venencia and P. Besa, "Commissioning and quality assurance for intensity-modulated radiotherapy with dynamic multileaf collimator: Experience of the Pontificia Universidad Católica de Chile," J. Appl. Clin. Med. Phys., vol. 5, no. 3, pp. 37–54, 2004.
[5] M. S. Bhagwat, Z. Han, S. K. Ng, and P. Zygmanski, "An oscillating sweeping gap test for VMAT quality assurance," Phys. Med. Biol., vol. 55, no. 17, pp. 5029–5044, 2010.
[6] S.-H. Baek et al., "Clinical efficacy of an electronic portal imaging device versus a physical phantom tool for patient-specific quality assurance," Life (Basel), vol. 12, no. 11, p. 1923, 2022.

LIMBURGS ONCOLOGISCH CENTRUM

De opleiding industrieel ingenieur is een gezamenlijke opleiding van UHasselt en KU Leuven

UHASSELT KU LEUVEN