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Keywords

accelerator, analyse, tool, dynamic, comprehensive, log, files, elekta, synergy

Disciplines

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A comprehensive tool to analyse dynamic log files from an Elekta-Synergy accelerator

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Abstract. This study presents the development of a software tool ‘Treat Check’ to analyse the dynamic log files from an Elekta – Synergy accelerator. The software generates formatted output in the form of a plot presenting errors in various treatment delivery parameters such as gantry angle, Multi Leaf Collimator (MLC) leaf position, jaw position and Monitor Units (MU) for each of the control-points (CP) of the treatment beam. The plots are automatically saved in Portable Document Format (pdf). The software also has the functionality to introduce these treatment delivery errors into the original plan in the Pinnacle (Philips) treatment planning system (TPS) in order to assess the clinical impact of treatment delivery errors on delivered dose.

1. Introduction

Modern radiotherapy techniques such as Intensity Modulated Radiation Therapy (IMRT) and Volumetric Modulated Arc Therapy (VMAT) offer superior dose conformity to target volumes (TV) with improved control over the dose delivered to critical structures[1]. This advantage is realised through a highly complex process in both planning and delivery. In dynamic IMRT delivery Multi Leaf Collimator (MLC) leaves continuously move during radiation delivery in order to generate the intended intensity modulation. The delivery of VMAT is more complex than IMRT as many of the treatment delivery parameters such as MLC leaves, jaws, gantry, and dose rate continuously vary during the treatment delivery [2]. To ensure the dosimetric accuracy of treatment delivered by these complex techniques pre-treatment dosimetric verification is highly recommend by international governing bodies[3].

Generally pretreatment dose verification is performed using dose measuring systems in well defined and homogeneous phantom geometries. While such dose measurements ensure the accuracy of treatment plans in dosimeter geometry it assures the accuracy of treatment delivery only for that particular treatment delivery. The treatment delivery accuracy of individual fractions of patient treatment can be verified using in vivo dose measurements. Van Herk and Mijnheer demonstrated the possibility of performing in vivo 3D dose verification based on transit images acquired using Electronic Portal Imaging Device (EPID)[4]. Litzenberg et al[5] proposed the use of dynamic log files



recorded by the control system of Varian linear accelerator (Varian medical systems, Palo Alto, USA) to verify individual fractions of patient IMRT treatment.

The control system of Elekta-Synergy accelerators (Elekta, Inc. Crawley, UK) records the error between prescribed and delivered treatment parameters for individual control-points (CPs) of treatment plans. However this information can only be reviewed on the service page of the control system. Also some of the parameters such as MLC leaf positions and jaw positions are presented in the system as raw potentiometer readings. This presents a challenge to the end user to assess the significance of errors which occurred during treatment delivery. In this work we present the development of an in-house computer program, Treat Check, which processes the log files from the Elekta –Synergy control system and presents the result in a user friendly manner. The program also contains a module to introduce these errors into the original treatment plan in Pinnacle (Philips, Inc. Fitchburg, USA) TPS to assess the impact of these errors on delivered dose.

2. Materials and Methods

Elekta-Synergy accelerator with Desktop pro, v 7.0, control system software was used in this study. The Synergy accelerator used in this study is capable of producing 6 and 18 MV photon beams and 6, 8, 10, 12, 15 and 18 MeV electron beams. The photon beams can be delivered with one of the following nominal dose rates: 550, 275, 138, 69, 35, 18 and 9 MU/min. The electron beams can be delivered with a nominal dose rate of 400 MU/min. The secondary beam collimating system consists of 40 pairs of MLC leaves and a pair of backup jaws in the X direction and a pair of jaws in the Y direction. Mosaik, v 2.30.0D1, (Impac Medical Systems, Inc. California, USA) record and verification (R&V) system was used for the transfer of treatment plan parameters from Pinnacle TPS to the accelerator.

2.1. Dynamic log files

The control system of Synergy accelerators records the maximum positional error between prescribed and delivered parameters such as gantry angle, collimator angle, jaw position, MLC leaf position, MU, table lateral, longitudinal, vertical and rotation values for each of the CP of the beam in an individual file for delivered treatment plans. The tolerance values for each of these parameters is also recorded in the same file. However, reviewing this data has many practical limitations as described in the introduction. Figure 1 shows a screen capture of the dynamic log file view page of the Synergy control system. The control system presents the error values for each of the CP in an individual page. Analysing the error values in this manner is time consuming as IMRT and VMAT plans contain large numbers of CPs. The data are stored in the log files in a binary format and it presents a challenge to the user to interpret the stored data.

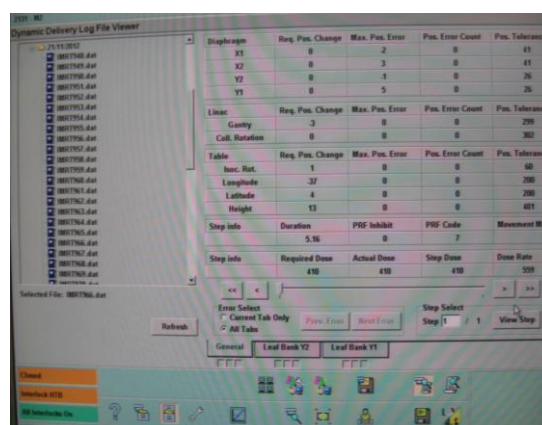


Figure1: Screen capture of the dynamic log file view page in the Elekta-Synergy control system.

2.2. Treat Check - In-house computer program

A computer program, Treat Check, was developed in-house using MATLAB, v 7.11.0.584 (R2010b), (MathWorks, MA, USA) to process the log files derived from the Synergy control system. The overall function of the program is shown in figure 2. Treat Check reads the log file and processes the data to identify the parameter type. The positional error values of jaws and MLC leaf positions are stored as raw potentiometer values. These values were converted in to real positional values using the following formula prescribed by the Synergy manufacturer.

$$\text{positional error in millimeter} = \text{Rawpositional error vaule} * \text{Scaling Value} \quad (1)$$

Where, the raw positional error value is determined from the log file and the scaling value is calculated following equation.

$$\text{Scaling Value} = \frac{204.8}{\text{Gain value of the parameter}} \quad (2)$$

The gain value for each of the jaws and MLC leaf bank is obtained from synergy control system.

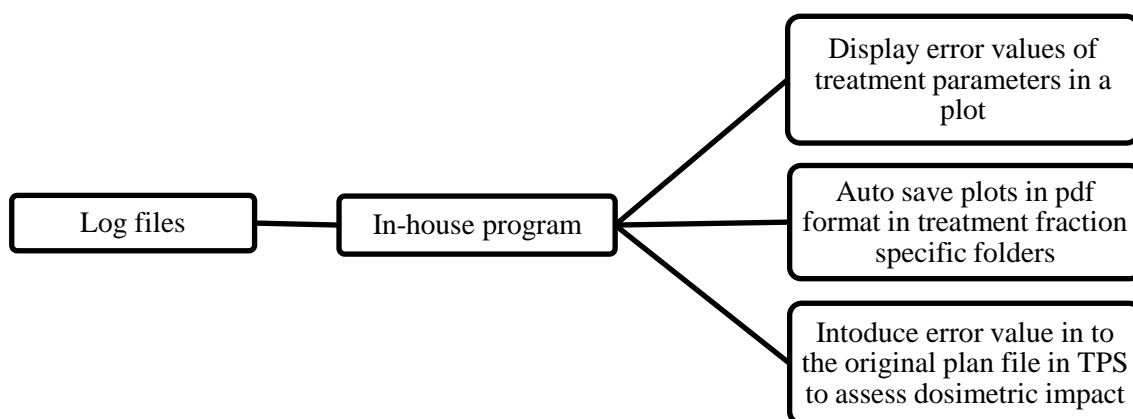


Figure2: Flowchart showing the overall functions of Treat Check.

For the easy interpretation and review of the error values all the CP error values of each of the parameters are plotted individually by Treat Check . The plots are also automatically saved by the Treat Check in a treatment specific folder in pdf for future review. Treat Check also includes a module to introduce these error values into the original plan in the TPS. This module reconstructs a plan file for the Pinnacle TPS using a treatment delivery file of a plan in radiotherapy prescription (RTP) format and errors read from Elekta dynamic log files.[6] This allows the assessment of the impact of these errors on the delivered dose by comparing the dose distribution and Dose Volume Histogram (DVH) parameters. The accuracy of data interpretation of the software was tested by comparing the error values calculated by software and those displayed on the synergy control system for an IMRT and VMAT delivery.

3. Results and Discussion

3.1. Performance of Treat Check

Treat Check successfully reads the dynamic log files from the Synergy control system and performs the tasks as described in the figure2.The comparison of error values of the various parameters

calculated by Treat Check and the same displayed on the control system showed no discrepancies, demonstrating accurate performance of the program.

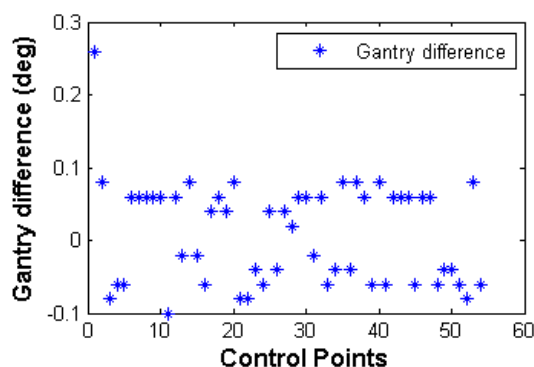


Figure 3: Gantry positional error plot generated by Treat Check for a prostate VMAT plan.

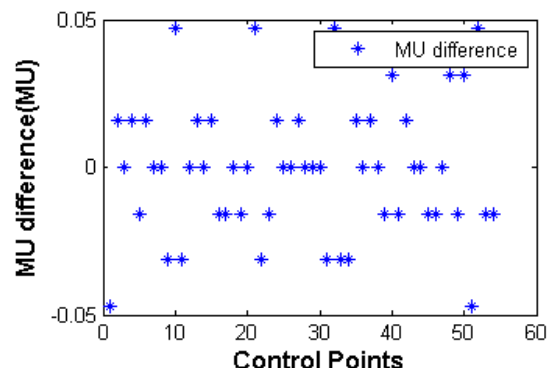


Figure 4: Monitor Units error plot generated by Treat Check for a prostate VMAT plan.

Figures 3 and 4 show the Treat Check output for the error in gantry position and MU delivery for each of the CPs of a prostate VMAT plan with 60 CPs. The gantry error for most of the CPs except the first were within $\pm 0.1^\circ$. The relatively larger error in the first CP delivery could be due to inertia of the gantry at the start of the VMAT delivery. The MU delivery error for each of the CPs was within ± 0.05 for the studied VMAT plan.

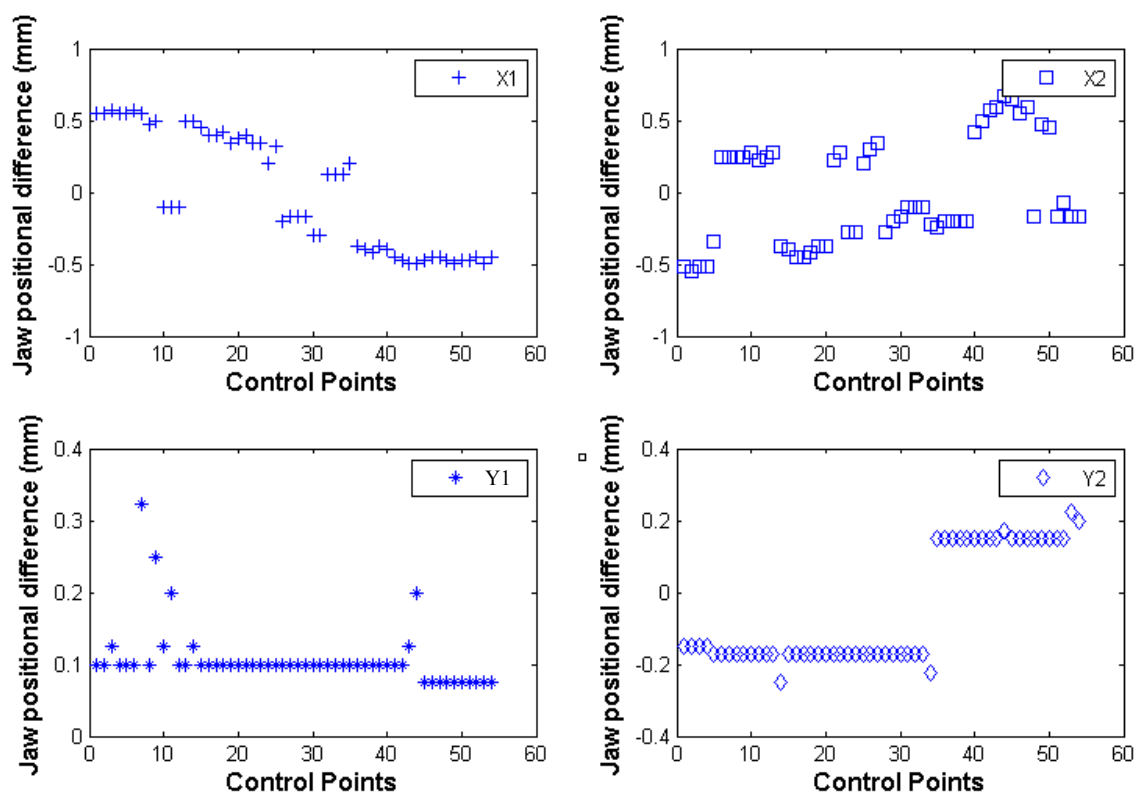


Figure 5: Jaw positional error plot generated by Treat Check for a) X1, b) X2, c) Y1 and d) Y2 jaws.

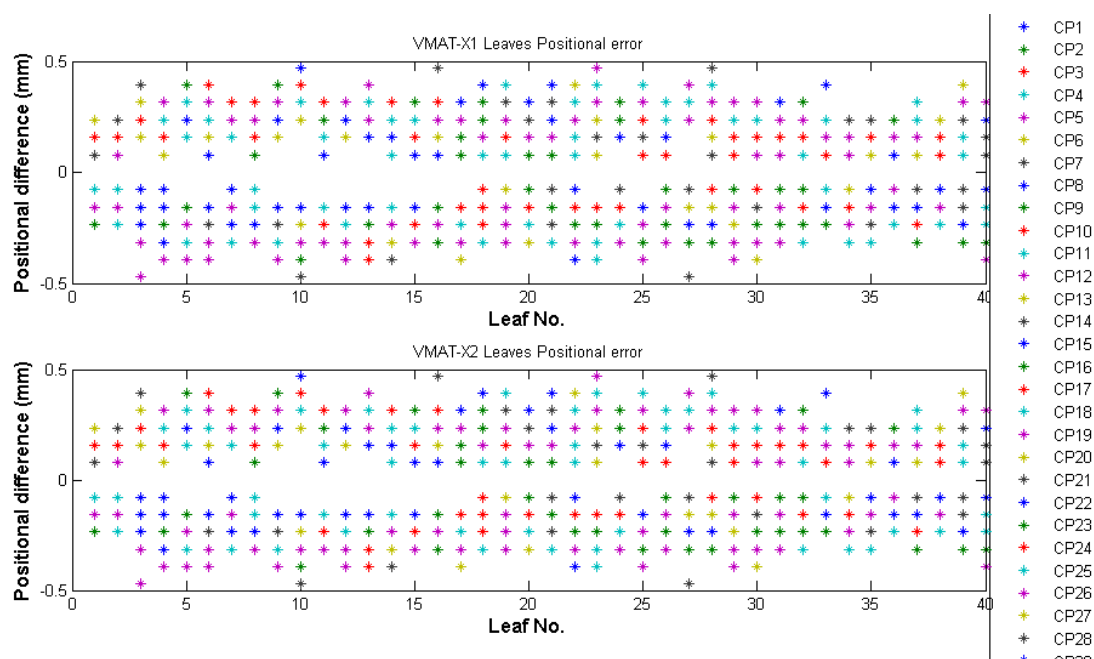


Figure 6: Leaf positional error plot generated by Treat Check for X1 and X2 banks of MLC leaves for all CPs of the studied VMAT plan.

Figures 5 a, b, c and d show the positional error for X1, X2, Y1 and Y2 jaws for all the CPs of the studied VMAT plan. The positional errors for most of the CPs were within ± 0.5 mm for X1 and X2 jaws. However for some CPs the error for X2 jaw was up to 0.8 mm. The error values observed for the Y jaws did not vary between CPs greatly because in VMAT delivery Y jaws, which define the length of the field do not move whereas X jaws track the outer most leaf position of their respective bank in order to reduce leaf leakage. Figure 6 shows the positional error for all the leaves of X1 and X2 MLC banks for all the CPs of the studied VMAT plan. The positional error values for the leaves were within ± 0.5 mm for the studied VMAT delivery.

3.2. Assessment of delivered dose

Figure 7 shows the DVH of target volumes (PTV-Planning Target Volume, Prostate and SV-Seminal vesicle) and critical structures (Bladder, Rectum, Right Head of Femur and Left Head of Femur) of the original and delivery error introduced plans for the studied prostate VMAT plan. Planned and delivered doses of various structures do not demonstrate any notable differences for the considered fraction of the treatment due to relatively small errors in the delivery parameters (Figures 3, 4, 5 and 6). This aspect of the program, the ability to introduce delivery errors into the planning system, provides the potential to assess delivered plans in clinically meaningful manner by evaluating delivered dose distributions and DVHs of structures.

In the present study the dose calculations of a delivered plan was performed on the planning CT data set of a studied patient. The dose calculation of the delivered treatment on the 3D image data set acquired on the day of treatment would contain the delivered dose information including treatment delivery errors and patient anatomical changes. This information will be of interest in the context of dose accumulation for adaptive radiation treatment. Future work will investigate dose calculations on daily 3D verification images.

3.3. Important considerations

It is important to acknowledge that the error values recorded in the log files of the control system are only true with respect to the accuracy of the calibration of a given parameter. If there are any systematic errors in the calibration these will not be reflected in the error values recorded in the log files. Hence the absolute accuracy of the treatment delivery parameters should be verified as recommended by AAPM TG142[7] guidelines. Further verifying patient treatment using log files does not replace the in-vivo dose measurements, because log files do not provide systematic errors in the treatment delivery parameters. However the analysis of the error values recorded in the log files can be used as supplementary data ensure the accurate delivery of patient treatment.

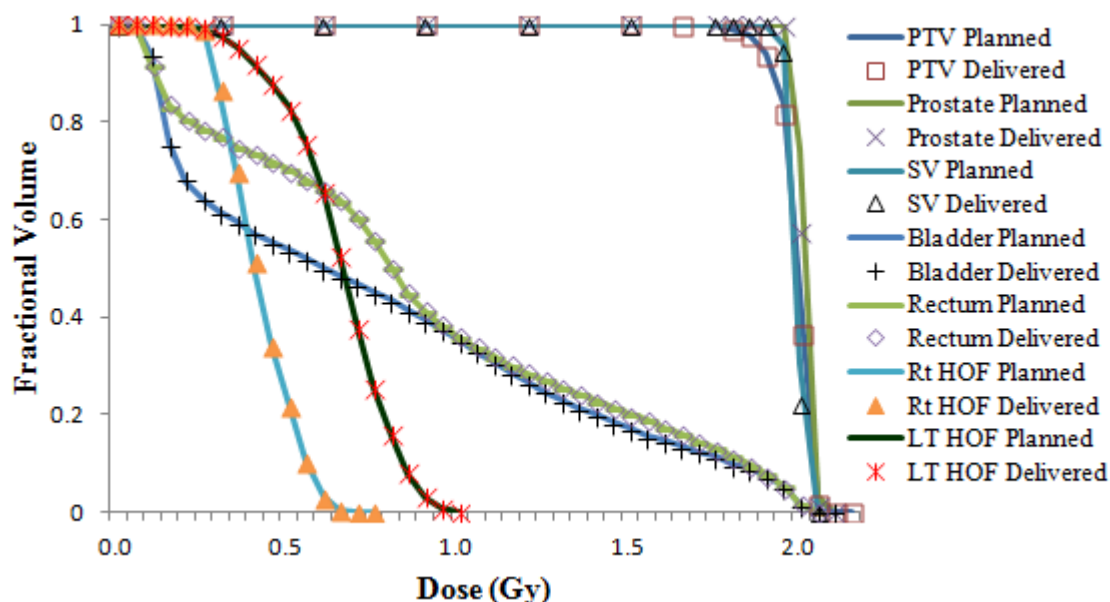


Figure 7: Planned and delivered dose for a treatment fraction of studied prostate VMAT treatment.

4. Conclusion

An in-house computer program was developed and demonstrated to successfully read the dynamic log files from an Elekta-Synergy accelerator. The program successfully generates comprehensive formatted output of the error values that can be easily reviewed by the user. The error values can also be transferred to the TPS allowing assessment of delivered dose in a clinically meaningful manner.

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