Treatment Interrupted Trajectory Log Analysis Via Fully Automated Interpolation of the Treatment Planning System's Plan Parameters

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INTRODUCTION

- To the Authors' knowledge, this is the first fully automated software to analyze treatment interrupted trajectory log files.
- Trajectory logs are files that captures the positions of LINAC components during treatment delivery every 20 ms. These include the MLCs, Gantry, Jaws, and Collimator positions, including monitor units (MU) and Unexpected Beam Holds.
- These time-resolved components when compared to the predicted positions of the treatment planning system (TPS) can validate that a patient's treatment was accurately and safely delivered as intended.
- However, when a treatment is interrupted, the trajectory logs get split into multiple partially-delivered files that historically could not be analyzed. These deliveries may be more at risk for delivery errors, especially when gone unchecked.
- Independent checks of the LINAC delivery are recommended in reports such as in the AAPM Task Group 218 [1].

MATERIALS AND METHODS

- All trajectory log files were analyzed using in-house code named "**TrajectoryLogMagik**" written in MATLAB 2023a. [2] All trajectory log files for a given delivery are automatically found, matched to its respective plan from the TPS, and TPS fields are reordered in the order that they were delivered on the LINAC.
- Multiple interrupted trajectory log files are "stitched" together, appending the end of the first interrupted file's position data with the beginning of the next file and continue until all files are equivalently a single trajectory log file.
- Control Points (CP) in the Eclipse TPS are then linearly interpolated [3] using data from the exported DICOM treatment plan. Interpolation is produced by using Equation (1),

$$xSS(t,xfCP) = xfCP(xCP_{n+1} - xCP_n) + xCP_n \quad \text{Eq. (1).}$$

- The TPS's CPs are interpolated every 20 ms (t) to match the Snapshot (SS) frequency of the LINAC delivery.
- Fractional Control Points for a given component x ($xfCP$) are decimal values ranging from 0 to 1 indicating the component's proximity in time from the current CP position (xCP_n) to the next CP (xCP_{n+1}). The resulting interpolated component value xSS is then compared directly with the delivered LINAC SS value using the binary trajectory log files generated by the LINAC.
- The differences between the delivered and expected TPS component values are analyzed. Our clinic's standard Monthly QA Tolerance and Action Levels are used to report failing plans, automatically printing results into an Excel spreadsheet.
- Failing plans can be analyzed on-demand by inputting the User ID, Plan Name, and Treatment Date into **TrajectoryLogMagik**.
- Patient LINAC delivery analysis is illustrated in Figures 1-4.

RESULTS

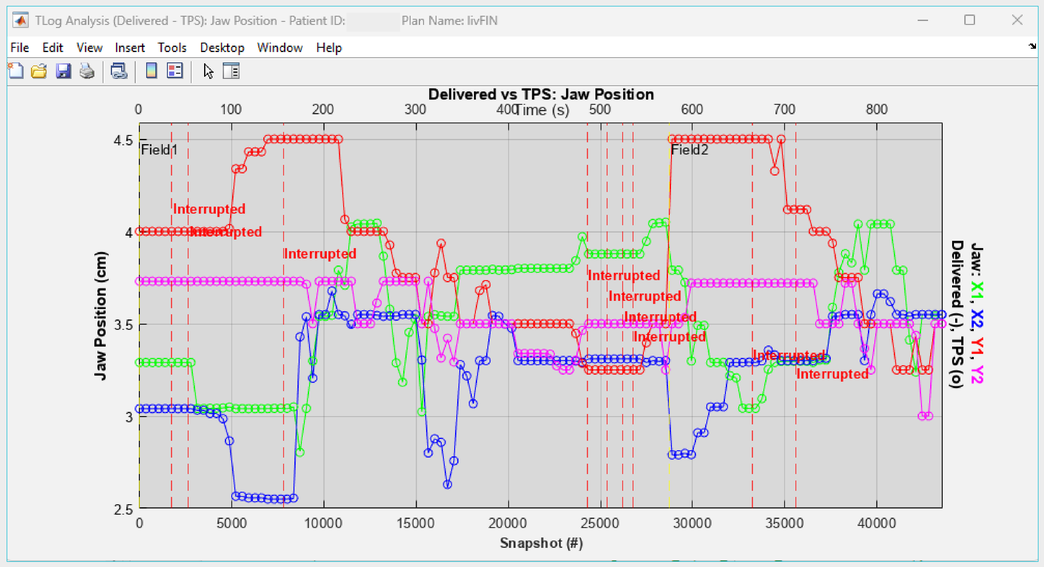

Figure 1. Delivered jaw positions from trajectory log (-) vs expected jaw positions from TPS (o). This liver patient had 9 interrupted partially delivered trajectory log files with interrupted locations labeled within the plot.

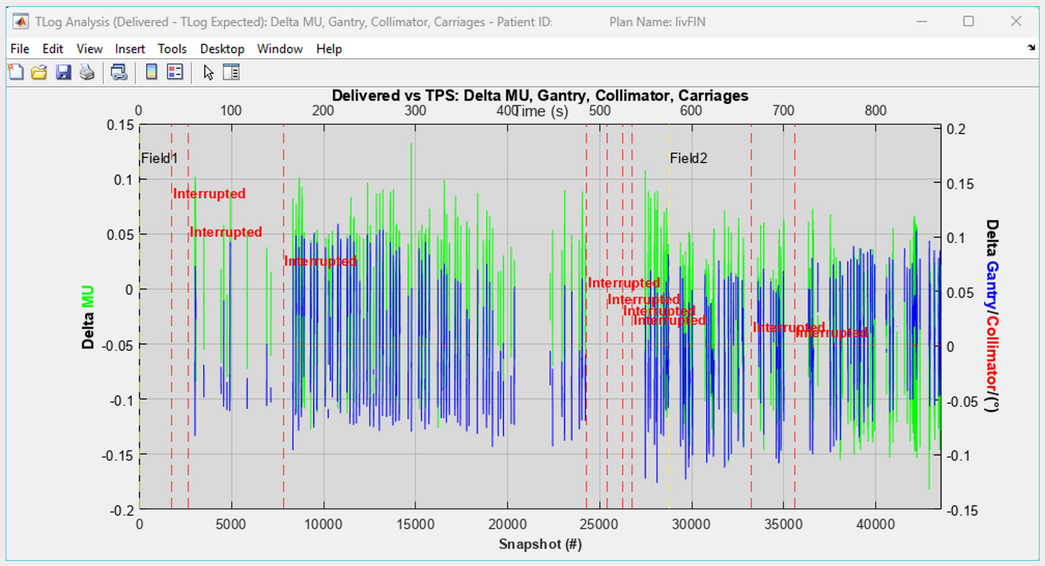

Figure 2: The differences (delta) between delivered trajectory log and expected TPS values for MU, gantry, and collimator positions at every snapshot while the beam is on. Locations of treatment interrupts are also plotted.

Figure 3: Illustration of excessive unexpected beam holds during the first field leading up to a treatment interrupt. Displayed are actual (delivered), expected (TPS), MU (MUs don't increment), and unexpected (actual minus MU) beam holds. Unexpected beam holds may be an indicator of mechanical delivery problems.

ANALYSIS

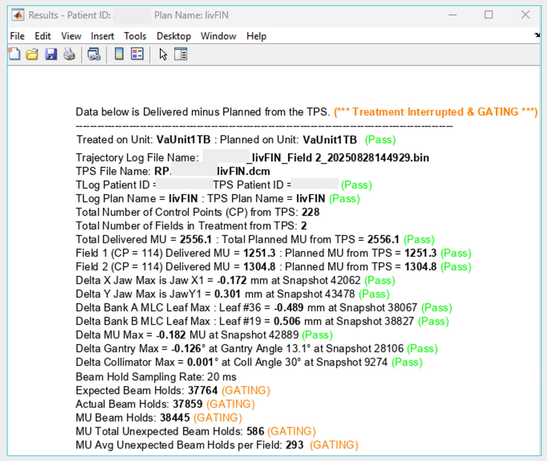

Figure 4: Numerical analysis of delivered trajectory log files compared to expected TPS values for a gated liver patient.

DISCUSSION

- Out of 13,869 VMAT fractions delivered at our centre thus far in 2026, approximately 1.5% of delivered LINAC treatments exhibited some type of treatment interruption during beam delivery.
- Majority of failures have been located at the interruption interfaces, with maximum MU, gantry/collimator, and jaw/MLC deviations of 0.3MUs, 1.4 degrees, and 5.1 cm, respectively.
- Has caught multiple patient treatments where fraction MUs where not completely delivered.
- **TrajectoryLogMagik** works for Varian TrueBeam and Ethos/Halcyon LINACS.

CONCLUSIONS

- **TrajectoryLogMagik**, a fully automated code, checks every patient's delivered VMAT fraction at our clinic every day against the expected values of the TPS, including treatment interrupted deliveries.

REFERENCES

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2. The MathWorks Inc. MATLAB. Natick, MA, USA. 2023.
3. Kai-Cheng Chuang *et. al.*, On The Use Of Trajectory Log Files for Machine & Patient Specific QA. *Biomed. Phys. Eng. Express. Express 7. 2021.*

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