Development and validation of an EPID based software for LINAC QA built on a free Python package

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Background

QA of linear accelerators is an important part of the radiotherapy quality assessment. Recommended tests and tolerances for a LINAC QA program are described in AAPM Reports [1,2]. In 2023, current recommendations for LINAC QA were updated to emphasize the importance of testing MLC dynamic delivery for modern IMRT/VMAT radiotherapy techniques [3].

Material and methods

We developed a software for evaluating several AAPM reports [1,2,3] parameters from EPID images, based on the free python package Pylinac [4,5]. The software has a user friendly GUI and can be run from Windows computers, without the need of any installation. Acceptance criteria and machine specifications can be set in configuration files. Results are automatically stored in excel files, to be easily accessible outside the software.

The program performs different analysis:

- The first tab evaluates field size, flatness and symmetry (consistency check for test 2.D.1.14 [2]);
- The second tab analyses Winston-Lutz (WL) images to assess gantry, collimator and couch isocenter sizes and the coincidence between mechanical/radiation or CBCT/radiation isocenters (tests 2.D.2[2], in particular 2.D.2.1[2], 2.D.2.2[2], 2.D.2.3[2] and 2.D.2.5[2]. It can be used for 2.F.3.3[2] as well; or tests M11[3] and MLC4[3])
- The third tab calculates EPID sag;
- The fourth tab assesses MLCs performances: leaf position accuracy (tests 2.F.2.1[2], 2.F.2.2[2], 2.F.2.4[2] or test MLC2[3]) and repeatability (2.F.3.2[2]), abutting fields junctions (2.F.1.1[2]), leaf travel speed (2.F.2.3[2]);
- The fifth tab can perform Dynamic Delivery control (DDC) tests D5[3]. To evaluate DCC we used an IBA Matrixx detector.
- LINAC performances over time are shown in the sixth tab.
- The last tab converts Elekta Movie format to a DICOM series to be able to evaluate Leaf Travel Speed;

We evaluated the software on an Elekta LINAC with Agility head equipped with an iView EPID panel.

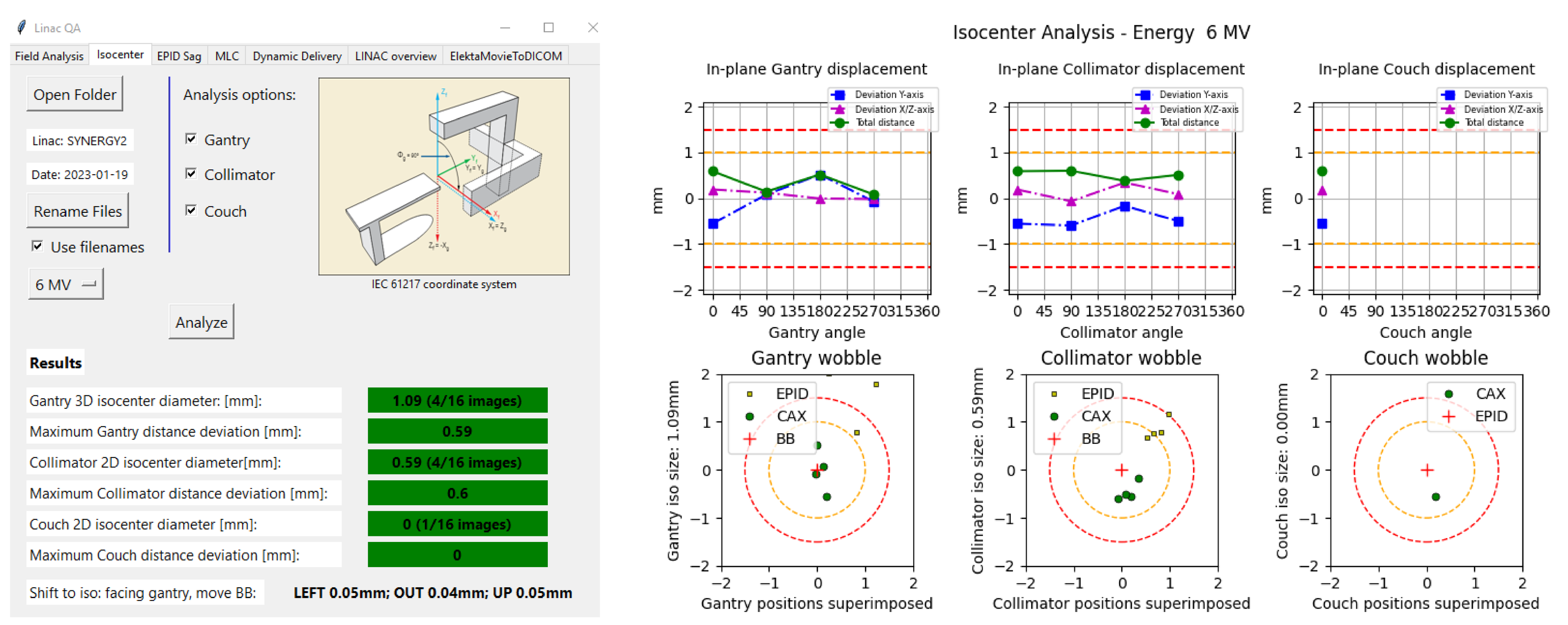

Figure 1. Isocenter analysis tab with results

Results

Algorithms analysis accuracy was evaluated by repeating measurements in the same conditions and assessed smaller than 0.15 mm for all parameters.

For WL analysis (**Figure 1**), AAPM recommends a tolerance of 1 mm radius[1,2]. We set a tolerance of 1.5 mm diameter for gantry and couch isocenter, 1 mm diameter for collimator isocenter. Furthermore, the software was used to correct radiation isocenter position for all energies: the WL phantom was centered at CBCT isocenter. Deviations for all energies were evaluated and corrected by proper beam steering if needed.

For the MLCs analysis (**Figure 2**), we modified the Pylinac algorithm to calculate absolute leaves positions and single leaf error analysis, as recommended by AAPM [1,2,3]. Absolute leaves positions are calculated from the radiation field center, identified by the use of **4 additional square fields images at different collimator positions**. Relative leaves positions to the median position is also performed. We evaluated the algorithm by introducing known errors in single leaves and MLC banks. The modified algorithm was able to detect leaves and bank errors beyond 0.3 mm and correctly identify failing leaves numbers. In our protocol we set attention level = 0.3 mm and action level = 0.5 mm, as new recommendations[3] suggest.

Abutting fields (**Figure 3**) analyses field junctions and evaluates the percentage dose difference at junctions compared to the homogenous surrounding dose. It gives information on leaf tips match. A background image can be used to normalize the picket and fence pattern. We saw that a 9% difference corresponds to ~ 0.5 mm displacement at the junction. AAPM recommends a tolerance of 1 mm[1,2]. We decided to set stricter values with attention level at 8% and action level at 9%.

Leaf travel speed (**Figure 4**) was tested by using EPID Elekta movie acquisitions and individual leaf speed was calculated from 2 frames. 2 consecutives and non-consecutives frames were tested. Delivered beams were designed so that the carriage won't move. Results were always within the 0.5 cm/s tolerance [1,2].

LINAC QA recommendations were updated in 2023 to emphasize the importance of testing DDC components[3]. To test DDC parameters (**Figure 5**), we designed different dynamic fields by varying each parameter individually. In particular, we compared profiles of the same dynamic field by varying leaf speed only, dose-rate only, gantry speed only and a combination of gantry speed and dose-rate. Beams were obtained by increasing MUs (MU linearity is tested separately), profiles are normalized to the central axes value.

Percentage difference was always <0.5% for all parameters in the 80% in-field area.

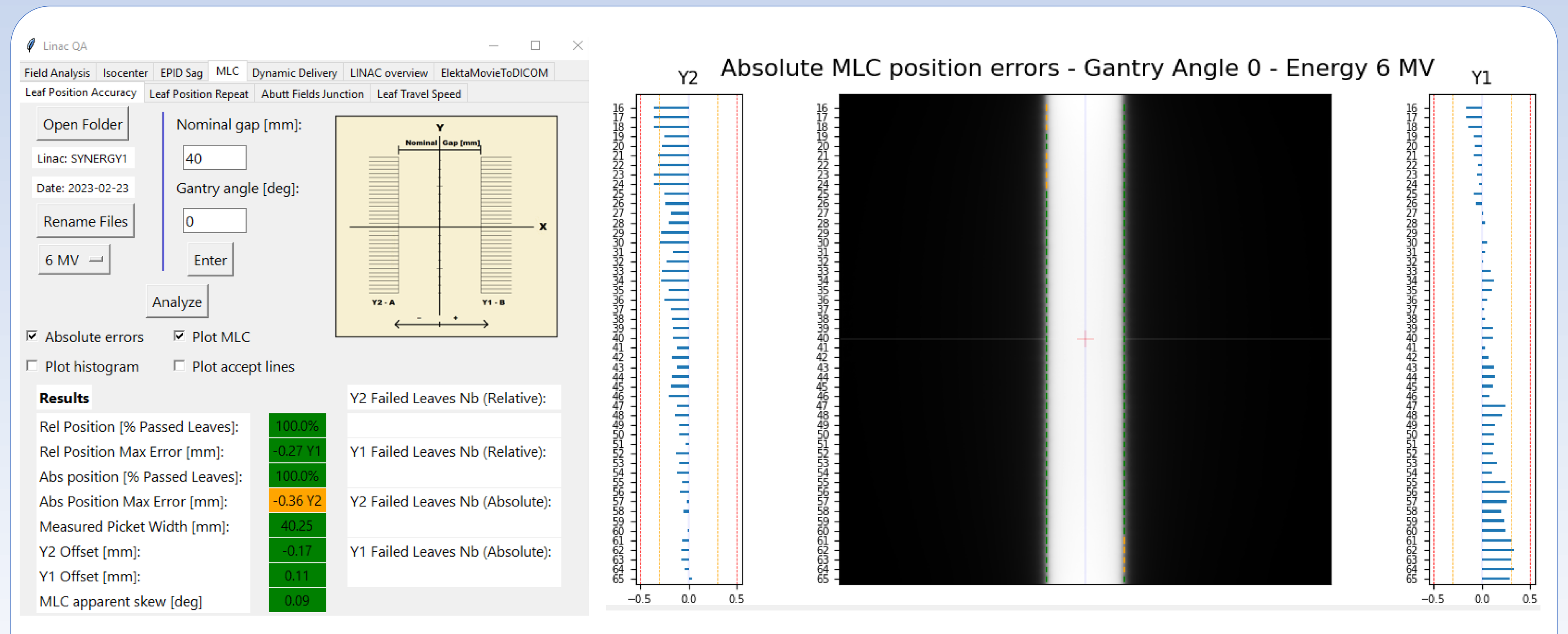

Figure 2. MLC position accuracy tab results. Two analysis can be done: relative position to the median value and absolute position relative to the collimator radiation isocenter

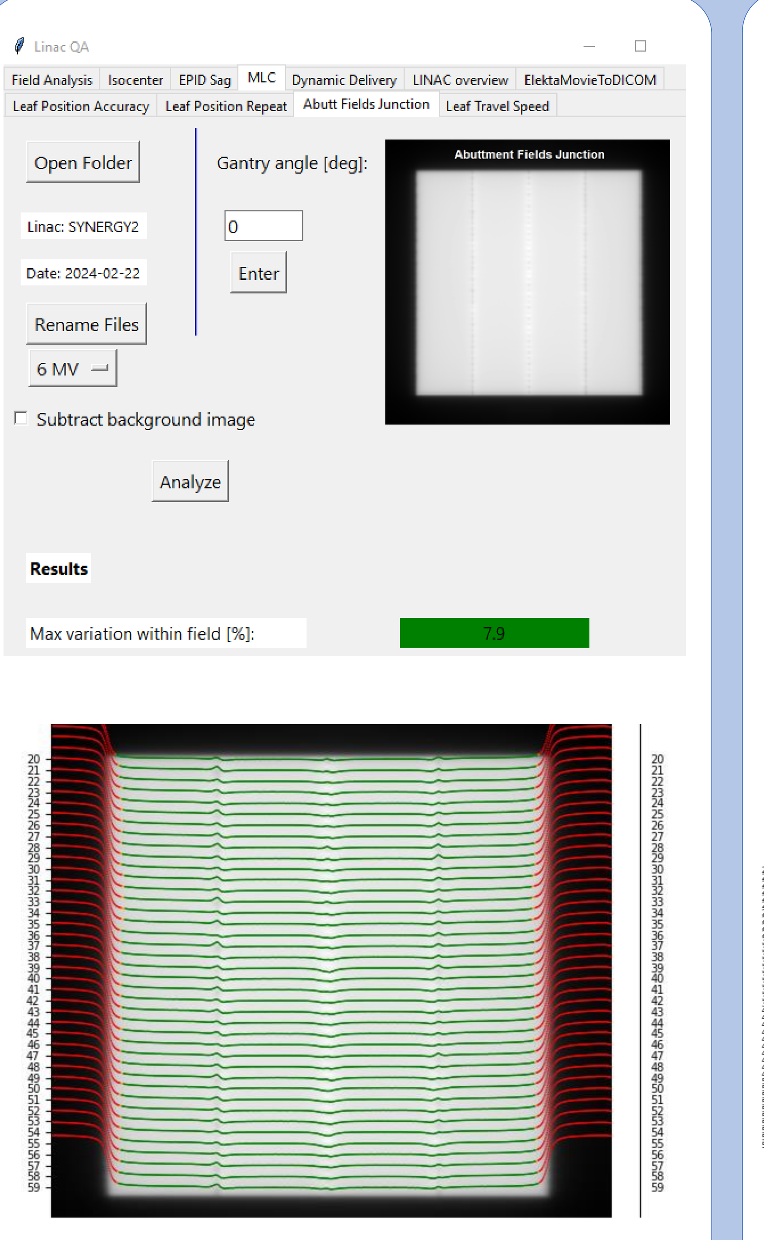

Figure 3. Abutting Fields Junctions analysis

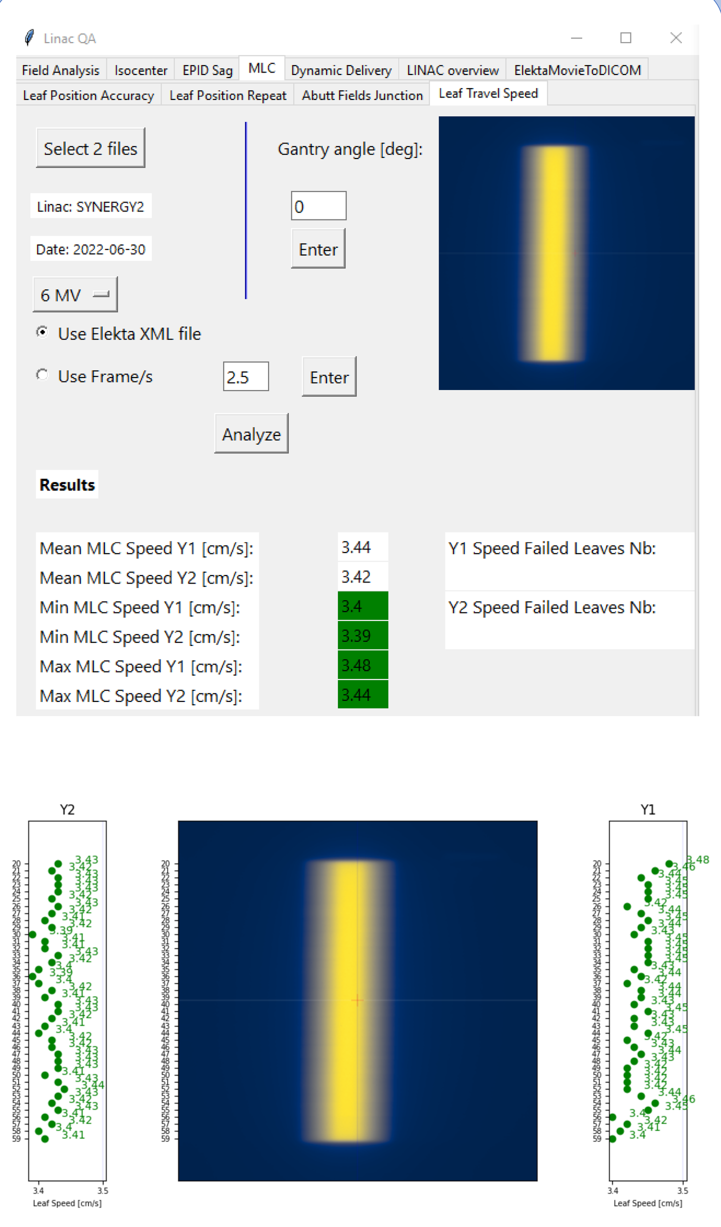

Figure 4. Leaf Travel Speed analysis

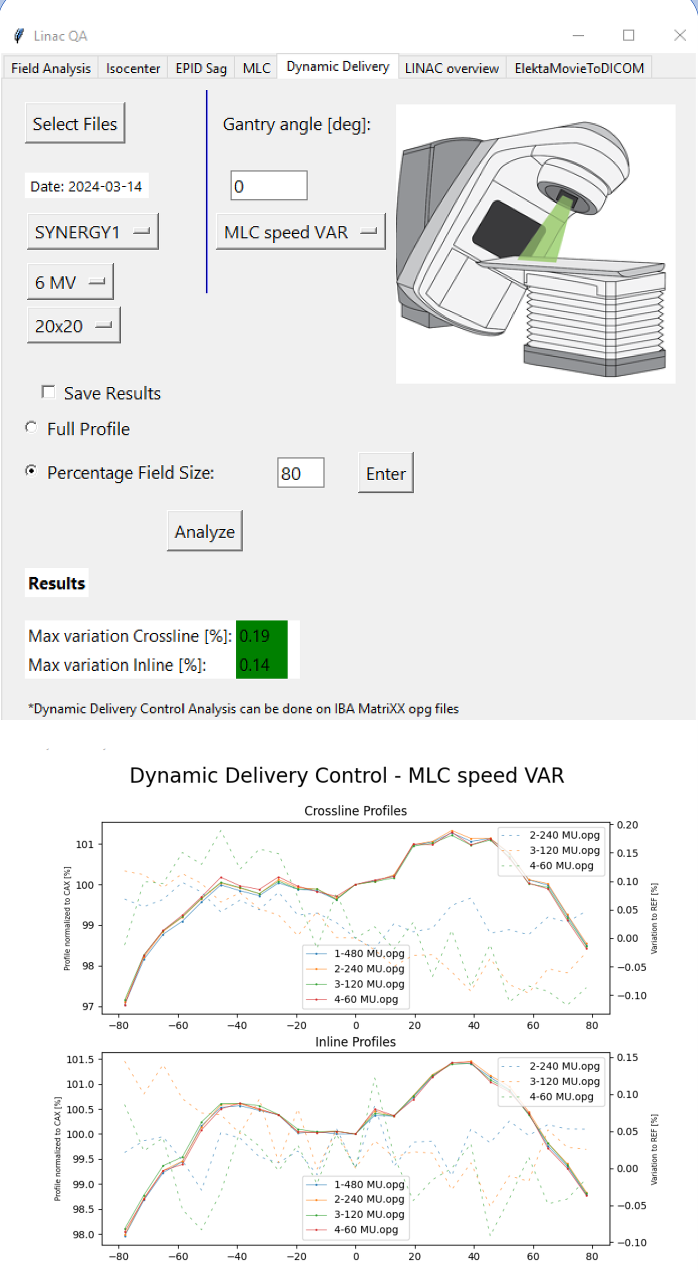

Figure 5. DDC analysis

Conclusions

The software has shown to be an effective tool for LINAC QC and performance monitoring. Nevertheless, we emphasize the importance of a thorough code understanding and extensive validation when using free libraries.

References

(1)AAPM Task Group 142 Report (Klein et al., 2009, Med Phys)

(2)AAPM Task Group 198 Report (Hanley et al., 2021, Med Phys)

(3)AAPM Medical Physics Practice Guideline 8.b: Linear accelerator performance tests (Krauss, 2023, J. Appl. Clin. Med. Phys.)

(4)github.com/jrkerns/pylinac

(5)Pylinac: Image analysis for routine quality assurance in radiotherapy (Kerns, 2023, JOSS)

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https://github.com/glomio/LinacQA-Software