



Original software publication

QALMA: A computational toolkit for the analysis of quality protocols for medical linear accelerators in radiation therapy

Md Mushfiqur Rahman ^a, Yu Lei ^b, Georgios Kalantzis ^{a,*}^a Medical Physics Program, Department of Physics, Florida Atlantic University, Boca Raton, FL, 33431, USA^b Department of Radiation Oncology, University of Nebraska Medical Center, Omaha, NE, 68198, USA

ARTICLE INFO

Article history:

Received 17 November 2017

Received in revised form 12 February 2018

Accepted 8 March 2018

Keywords:

Star shot

Picket fence

Winston–Lutz

Light radiation coincidence

Log file analysis

Quality assurance

ABSTRACT

Quality Assurance (QA) for medical linear accelerator (linac) is one of the primary concerns in external beam radiation Therapy. Continued advancements in clinical accelerators and computer control technology make the QA procedures more complex and time consuming which often, adequate software accompanied with specific phantoms is required. To ameliorate that matter, we introduce QALMA (Quality Assurance for Linac with MATLAB), a MALAB toolkit which aims to simplify the quantitative analysis of QA for linac which includes Star-Shot analysis, Picket Fence test, Winston–Lutz test, Multileaf Collimator (MLC) log file analysis and verification of light & radiation field coincidence test.

© 2018 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

Code metadata

Current Code version

Permanent link to code/repository used of this code version

Legal Code License

Code Versioning system used

Software Code Language used

Compilation requirements, Operating environments & dependencies

If available Link to developer documentation/manual

Support email for questions

V1

<https://github.com/ElsevierSoftwareX/SOFTX-D-17-00089>

GPLv3

git

MATLAB

Image Processing Toolbox, Signal Processing Toolbox, Symbolic Math Toolbox

<https://github.com/mrmushfiq/qalma/wiki>2mushfiq@gmail.com

1. Motivation and significance

Quality Assurance (QA) procedures play a vital role in all aspects of external radiation therapy with a linear accelerator (Linac). In particular, the technical characteristics of QA procedures are usually well established through several protocols, codes of practice and recommendations from the American Association of Physicists in Medicine (AAPM) [1]. The AAPM Task Group (TG) 142 [1] was published in 2009, to recommend QA techniques for newer technologies such as intensity modulated radiation therapy

(IMRT), stereotactic radiosurgery (SRS) and stereotactic body radiotherapy (SBRT). TG 142 did not only replace the TG 40 [2], but also filled the gap between TG 40 and TG 100 [3].

Linac QA tests quite often involve several radiation field patterns, and corresponding beam measurement techniques which are specifically designed for diverse verifications, such as MLC checks [4], star shot analysis [5–7], Winston–Lutz test [8–10] and light and radiation field coincidence [11]. MLC positioning checks can be performed with the Picket Fence test [12,13] and Dynalog file analysis for Varian Linacs [4,14], the mechanical rotational alignment of the gantry, collimators, MLC and treatment couch position is checked by the Star Shot analysis, and the Winston–Lutz (W–L) test is performed to verify that the radiation isocenter coincides with the mechanical isocenter in a Linac system. The recommendations for QA of a megavoltage radiation therapy equipment also require the coincidence of the light and radiation.

* Corresponding author.

E-mail address: gkalan@gmail.com (G. Kalantzis).

To perform the QA tests, there are several commercial software available from different vendors such as DoseLab™ or PIPSPRO™ and several authors have published QA procedures using the software and phantom provided by the Linac manufacturers [15,16]. However, the cost-effectiveness and customizability have always been an issue since commercial software do not always provide enough flexibility to the medical physicist to adjust and/or modify any QA procedure according to the needs of each facility.

In this work, we present QALMA (Quality Assurance for Linac with Matlab), a user-friendly Matlab based computational toolkit to perform Quality Assurance tests on Medical Linear Accelerators. QALMA can perform quantitative analysis of various QA tests such as: Picket Fence, DynaLog analysis, Star Shot analysis, Winston–Lutz test, Light and Radiation field coincidence and also generates reports.

2. Software framework

QALMA is designed as a MATLAB graphical user interface (GUI). Methods for the three most important modules are in Fig. 1. In this section, we briefly discuss the methods used for each module.

2.1. Star shot

Once the start-shot [5–7] image is loaded, it is converted to grayscale and an adaptive filter is employed for image noise reduction. Wiener filter was chosen as default due to its ability to minimize the mean square error between the estimated random process and the desired process [17]. Then the star-shot flowchart (Fig. 1) is followed to determine the co-ordinates of the brunches and to find the intersection between the beams. Considering an image having only two beams or four brunches, assume the determined co-ordinates for the spokes are (x_1, y_1) , (x_2, y_2) , (x_3, y_3) and (x_4, y_4) . Then the corresponding slopes (a_1, a_2) and intercepts (b_1, b_2) for the two beam center lines can be found using the following equations:

$$a_1 = \frac{y_3 - y_1}{x_3 - x_1}; \quad b_1 = y_1 - a_1 x_1 \quad (1)$$

$$a_2 = \frac{y_4 - y_2}{x_4 - x_2}; \quad b_2 = y_2 - a_2 x_2 \quad (2)$$

The intersections can be simply found by solving for x and y ,

$$a_1 x + b_1 = a_2 x + b_2 \quad (3)$$

$$y = a_1 x + b_1 \quad (4)$$

where (x, y) is our intersection point of the two star lines.

The final step is to use all the intersections to fit a circle by minimizing certain objective function. Let us consider the equation of a circle (Eq. (5)), where a, b, c are undetermined coefficients. Then (Eq. (6)) defines the summarization of the squares of distances between the circumference and all intersections (x_i, y_i) [6].

$$x^2 + y^2 + ax + by + c = 0 \quad (5)$$

$$Q(a, b, c) = \sum_n (x^2 + y^2 + ax + by + c)^2 \quad (6)$$

We consider Eq. (6) as the function of optimization and let it is three partial differentials equal to zero

$$\frac{\partial Q}{\partial a} = \frac{\partial Q}{\partial b} = \frac{\partial Q}{\partial c} = 0 \quad (7)$$

The solution of (Eq. (7)) is obtained by simply solving three linear equations simultaneously for a, b and c .

Finally, the center and the radius of the minimum circle are calculated by Eqs. (8) and (9),

$$(x_0, y_0) = \left(-\frac{a}{2}, -\frac{b}{2} \right) \quad (8)$$

$$r = \max \left\{ \sqrt{(x_i - x_0)^2 + (y_i - y_0)^2} \right\} \quad (9)$$

2.2. Picket fence

Once the Picket fence DICOM image [13] is loaded the user is prompted to select the pickets required to be analyzed. The coordinates are then stored as initial reference points, which can be used to find the location of the Bank A and Bank B of the collimator (Fig. 2(a)).

Firstly, a Wiener adaptive noise removal filter [17] is applied to obtain smooth profiles (Fig. 2 (b) and (c)) as shown in the flowchart (Fig. 1). Positions of the banks 1–5 (Fig. 2(a)) are then used to extract the intensity profiles perpendicular to the movement of the leaves (Fig. 2(c)). The centers of each leaf pairs can be found at the minima of the profile. The individual leaf positions can be obtained by averaging the two consecutive minima [13].

The intensity profiles across the pickets are extracted at the position obtained in the previous step for each collimator leaf. The image used for this report has five minima (Fig. 2(b)) due to the five pickets (Fig. 2(a)) in each profile. Subsequently each profile was inverted and the baseline was subtracted, followed by a cubic spline interpolation. Ten intervals were considered between each pixel to interpolate the intensity profile (Fig. 2(b)). Full Width Half Maximum (FWHM) was determined by extracting the positions of two points at the 50% of the local pick of the profile. These two points determine the edges of the leaf pairs (Fig. 2(a)).

2.3. Winston–Lutz

The W–L phantom consists of a small metallic ball of size 6 mm attached to the end of a rod and aligned to the isocenter, which is placed at the target and is fixed to the treatment table. Once the DICOM image is loaded The QALMA Winston–Lutz module utilizes morphological filtering techniques since the main challenge is to separate the radiation field and the metal ball as two different objects, so that their centers can be determined separately. To achieve that, once the W–L image (Fig. 3) is loaded, it is converted to a grayscale one and subsequently is filtered through an adaptive noise removal filter. In the next step, it is passed through two morphological filters: the top-hat and the bottom-hat [8,18].

The top-hat filter was implemented using MATLAB's 'imtophat' function to obtain the center of the ball (Fig. 3: Filter I). The bottom-hat filter was implemented using MATLAB's 'imbottomhat' function to obtain the center of the radiation field (Fig. 3: Filter II). Subsequently, the two separate images from the two different filters are converted to binary images and the center of the ball (circular white object) and the radiation field (rectangular white object) is obtained by deploying the MATLAB's 'regionprops' function.

2.4. Log file analysis

The Varian Trilogy and Varian Clinac iX models both generate two separate files for A and B MLC banks and assigns unique file names to the generated Dynalog files as a record of the Dynamic Multi-Leaf Collimator (DMLC) delivery details recorded at every 50 ms for a dynamic treatment [19,20]. By analyzing these log files, the positional error of each individual leaf can be determined. QALMA provides a simple GUI to verify the result of the Picket Fence test with a log file analysis for Varian Trilogy or Varian Clinac iX.

Download English Version:

<https://daneshyari.com/en/article/6964858>

Download Persian Version:

<https://daneshyari.com/article/6964858>

[Daneshyari.com](https://daneshyari.com)