A New Generation of Quality Assurance for Radiation Oncology

Project #8 Project Report, EN.600.646 Spring 2014
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May 9, 2014

1. Statement of Purpose

Radiation Oncology medical devices need to be examined monthly to ensure the safety and accuracy of the whole system, and the examination process is called quality assurance (QA). Traditionally, it will take six to eight hours for the medical physicist to do monthly QA, and even longer to do the yearly QA, for the reason that there are many measurement to be done and the physicists need to go inside and outside the operating room very frequently to adjust the position of the measurement device. Dr. John W. Wong intends to accelerate the QA process. He came up with a unifying device for mechanical and dosimetric quality assurance measurements in radiation therapy, which is designed for monthly QA of radiation therapy machines and can measure and record optical, mechanical and radiation data at the same time.

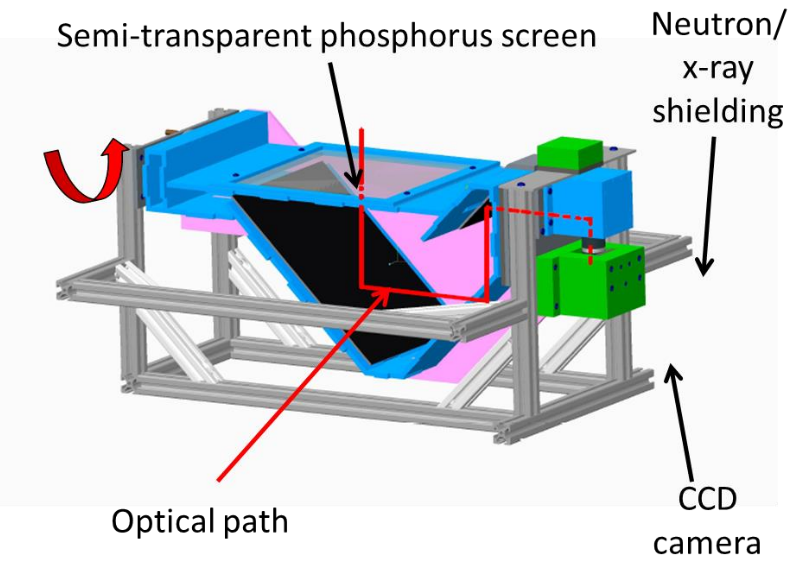

Fig.1 The mechanism of the Raven QA Box

The mechanism of the device is shown in Fig. 1, and it will be called as Raven QA Box in the following sections. There are three main parts of the Raven QA Box: mirror system, CCD camera, and the motor. The mirror system allows capturing images at the isocenter plane with a stationary camera, and it is fixed once the mechanical engineer has finished the designing job. The CCD camera records the image on real time for analyzing, and the motor controls the orientation of the box allowing it to face the radiation device's gantry anytime, and these two parts need to be controlled by software on the computer.

This project is about the software programming, and the software will be called as Raven QA in the following sections. Raven QA is responsible for four main functions: image acquisition, image processing, motor control and user workflow guidance. In function image acquisition, the software need to access the CCD camera to get different types of image, including changing the shutter time and gain of the camera, changing the size of the image and get background image on real time. In function image processing, the software must calculate the field size, flatness, symmetry and center of mess of the image to give sufficient data to medical physicists for future analyzing. In function motor control, Raven QA reads the data from an inclinometer which is fixed on the radiation device's gantry and controls the rotation stage of the Raven QA box to let it face the gantry at all time. The typical problem of other competitor's devices is a small delay time of the motion. Our goal is eliminating the delay time by employing proper control laws. In function user workflow guidance, Raven QA will give the users support when they are doing monthly QA by showing them the whole workflow and interacting with them when they are doing the job. Raven QA is designed to give users a branch new environment for them working comfortably.

2. Deliverables

Minimum Deliverables:

- i. Image Acquisition
  1. Camera Correction
     - a) Alignment Map — Done
     - b) Distortion Map — Done
     - c) Uniformity Map — Done
- ii. Image Processing — Done
- iii. Motor Controlling
  1. Step Motor Control — Done
  2. Inclinometer Control — Waiting for the device

Expected Deliverables:

- iv. 3D Rendering — Done
- v. Workflow Guidance — Done
- vi. Report Generation — Done

Maximum Deliverables:

- vii. Internet   Local database — Done
- viii. Software Documentation — Draft Done
- ix. Auto-alignment Map — Done

3. Software Overview

Raven QA software integrates all TG-142 standard quality assurance tasks including mechanical tests, optical tests and radiation field tests. For user convenience, I add a trending analysis mode to the software so that the user can get an idea of whether the accelerator is in good or bad condition, and to predict what will happen in the future.

Fig.2 shows a general GUI for users. There are 6 main areas of the screen. The left top part is the user workflow guidance. User can click on any task to start QA or to review the former QA results. The left bottom part is the motor control window, in this area, we can manually rotates the QA box to any angle we desire. The right top part is the live image area, we can see live image from the CCD camera after image correction, which will give us the real image position and size. The middle top part is the image processing area; it will give users the results from the image processing algorithm. The middle bottom part is the workflow guidance part; user can follow the instructions given here to perform a QA task. The right bottom part is the chart and figure part; it will show the numeric results from the QA tasks.

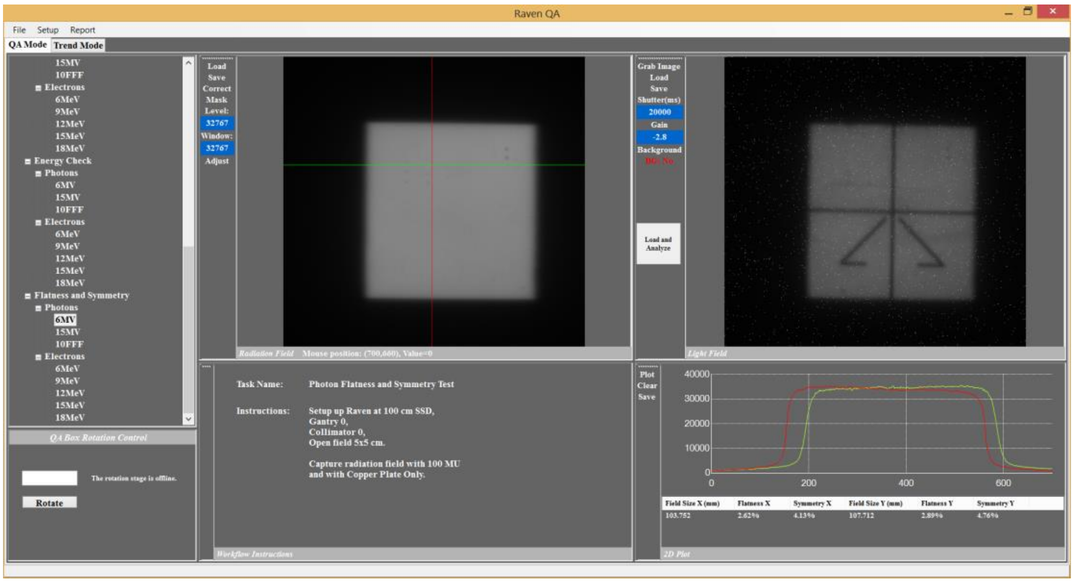

Fig.2 Software Screenshot: Flatness and Symmetry Test

Fig.3 shows the trending analysis window in the software. In this window, we can check QA results from the database. The red lines in the chart indicate the tolerance range according to TG-142 standard. Any points outside the read lines indicate that the accelerator is not working in good condition.

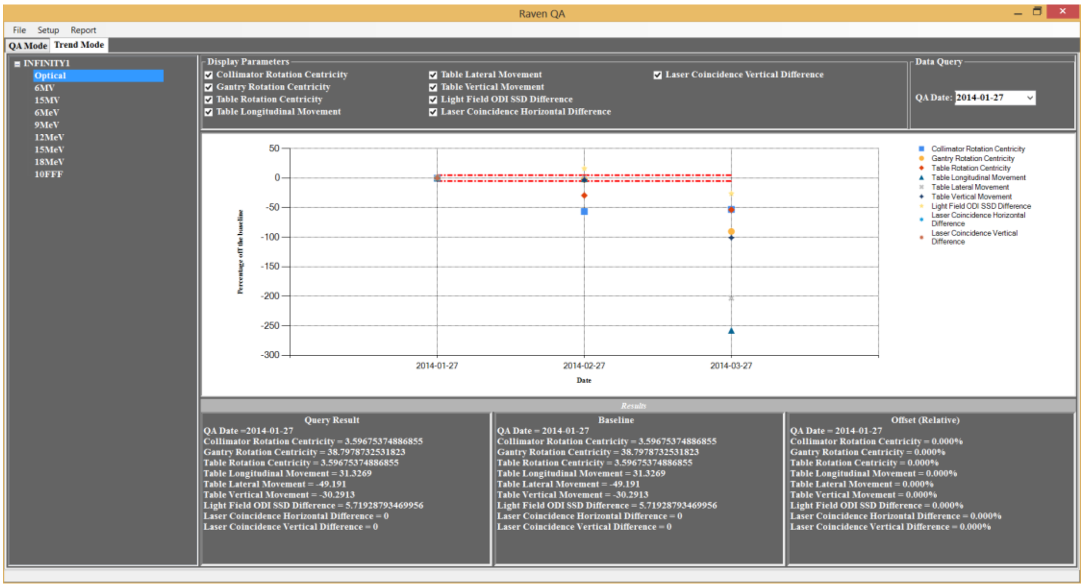

Fig.3 Software Screenshot: Trend Analysis

4. Raven QA workflow

Following the TG-142 workflow, I redesign the Raven QA workflow as following. The idea of the redesigning is to separate the QA box from the user to reduce the times when the user has to go inside the radiation room. All tasks should be performed on the computer which remotes the QA box.

First of all, as shown in Fig.4 a Winston-Lutz test is performed with a BB machine. The test will find the isocenter of the accelerator, then the QA box will be set to the isocenter. The BB machine is also controlled in the Raven QA software. Now the user is inside the radiation room to setup the mechanism of the QA box.

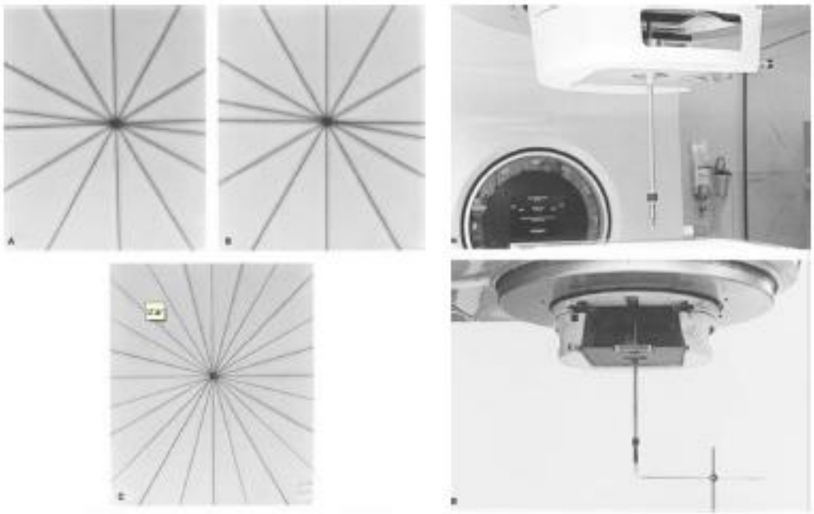

Fig.4 Winston-Lutz test with a BB machine

Then I integrate the mechanical test and the optical test together. As shown in Fig.5, several tests such as collimator rotation test will be performed. The user should go outside the radiation room before the mechanical and optical tests. All tasks can be remote from the laptop.

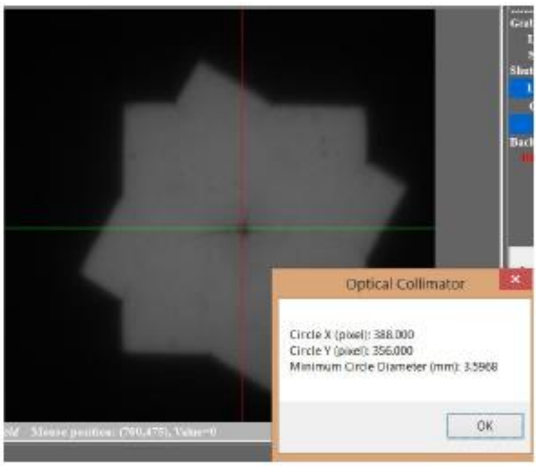

Fig.5 Mechanical/Optical Tests

Finally, the radiation tasks can be implemented. Flatness and symmetry test is performed as the geometric test, and a dose comparison test is performed as the dosimetric test. The user will go inside the radiation room once when doing the dosimetric test to change the solid water on the QA box.

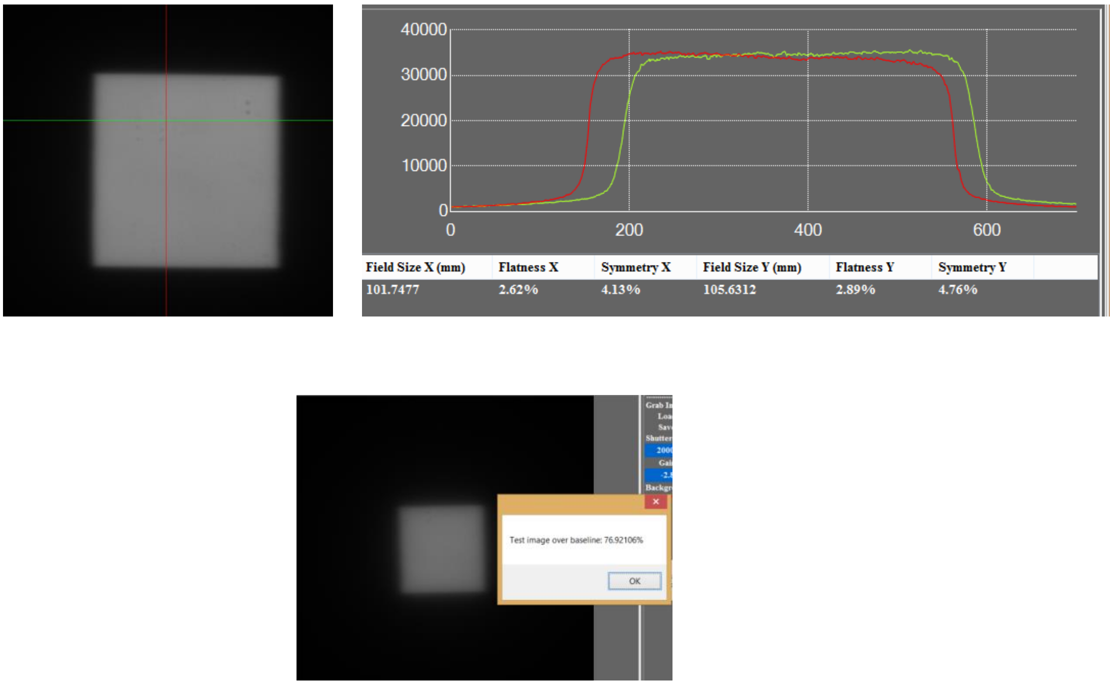

Fig.6 Radiation Tests

Fig.7 shows an overview of Raven QA workflow. The Raven QA workflow covers TG-142 daily, monthly, and part of the annual table. Physicists will go inside the radiation room once only. Mechanical and optical tests can be done within 15 minutes. Radiation tests can be done within one hour. The whole time of the QA will be less than one hour and a half, which is much less than the traditional QA time, which is as long as 8 hours.

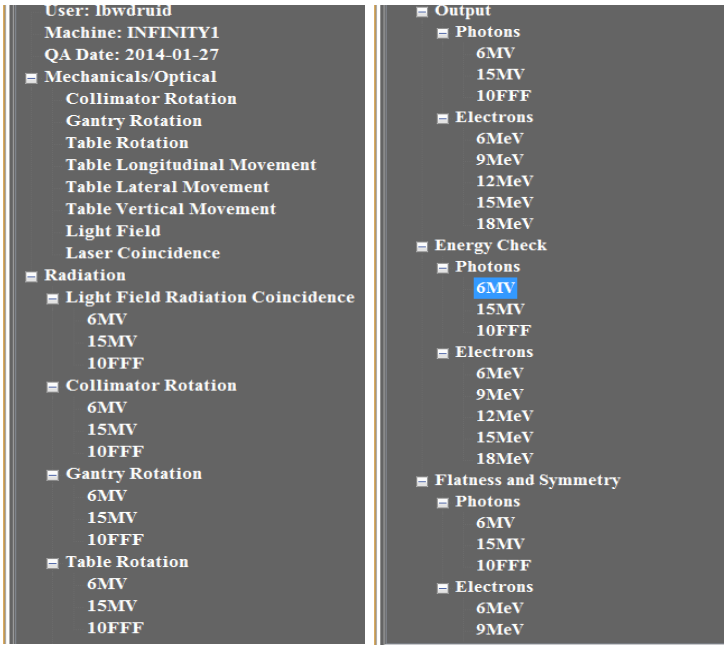

Fig.7 Overview of Raven QA workflow

5. Summary

I complete most of the tasks of this project. I will go on working on this project in this summer including integrating the inclinometer with the box, adjusting the software to the new hardware, preparing for the AAPM 2014 live show, and release a final version of the software for commercial use.

6. Reading list:

1. AAPM (American Association of Physicists in Medicine) (2009) Task Group 142 report: Quality assurance of medical accelerators. *Med. Phys.* 36.9:4197-4212.
2. AAPM (American Association of Physicists in Medicine) (1994) Comprehensive QA for radiation oncology: Report of AAPM radiation therapy committee task group 40. *Med. Phys.* 21:582-618.
3. AAPM (American Association of Physicists in Medicine) (1986) Neutron measurements around high energy x-ray radiotherapy machines. Report 19. AAPM, New York.
4. AAPM (American Association of Physicists in Medicine) (1984) Physical aspects of quality assurance in radiation therapy, Report 13. AAPM, New York.
5. Biggs P., Capalucci J., Russell M. (1991) Comparison of the penumbra between focused and non-divergent blocks-implications for multi-leaf collimators. Med. Phys. 18:753-758.