Automated Quality Assurance System for Clinical CT Systems

Leader: Heather Shumaker
BSAC: Sam Brenny
Communicator: Connor Ford
BPAG & BWIG: Rachel Reiter

Client: Prof. Tim Szczykutowicz, Dept. of Radiology
Advisor: Prof. John Webster, Dept. of Biomedical Engineering

BME 402, Dept. of Biomedical Engineering
University of Wisconsin – Madison, WI 53706

Abstract

Purpose: To create an open source software program capable of assisting a user in capturing the needed components of a computed tomography (CT) quality assurance (QA) report. The report is generated in a manner that expedites physicist to technician communication in cases where problems with the scanner are discovered.

Methods: The software program was created using MATLAB's graphical user interface platform. The graphical user interface (GUI) has fifteen panels, each facilitating a QA testing protocol by either collecting simple pass/fail or yes/no information, capturing physicist comments and measured values, and analyzing imported images. The GUI produces a LaTeX-formatted text file after the results are calculated which is compiled into a pdf final report. The program is designed to be open source and will accept new users adding new panels to enable customization for different tests.

Results: A graphical user interface was developed to assist in capturing CT report data, analyzing CT QA test results and generating a formatted report that details the testing protocols and results of the QA tests. The program is capable of analyzing images for artifacts, noise, CT number, CT uniformity, gantry tilt, beamwidth, slice width, and low contrast detectability (LCD), and accepting user input after testing the safety protocols, dose, protocol review, and the monitor. The resulting data from the analyses is organized and exported into a LaTeX-formatted text file which is used to create the report. Images of how laser alignment and couch travel are included in the report to aide conveying issues to technicians.

Conclusion: The CT QA report-building software combines all the necessary tools for QA testing into a single program, automating calculations, and generating formatted reports with the results and testing procedures. This program aims to improve communication between the medical physicist and service engineers by generating consistently-formatted reports and explaining the testing procedures to improve the reproducibility of each test.

Motivation

- No standardized protocols for computed tomography (CT) quality assurance (QA) → inconsistency and miscommunication
- Miscommunication can delay CT system adjustments
- CT quality assurance testing and reporting takes hours
- Measurements taken & computed by hand = room for error

Background

CT Quality Assurance

- Tests to assess machine functionality
  - Performed regularly on daily/weekly/monthly/yearly basis [1]
  - Multiple tests to assess certain machine functionalities [2]
- Image phantoms are used to evaluate CT machines [3]

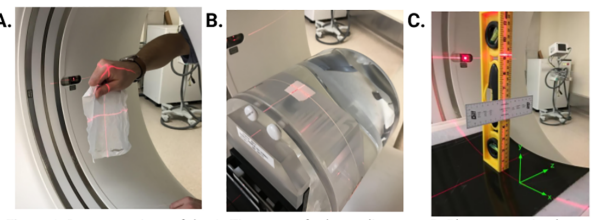

Figure 1. Demonstrations of the A. Tissue test for laser alignment, B. Phantom testing laser orthogonality, and C. A level and ruler measuring laser drift.

Design Criteria

MATLAB® Graphical User Interface (GUI)

Capabilities include:

- Automatic calculations
- Automatic CT image analysis
- Store and manipulate user input
- Export PDF of testing report

Methods & Materials

Materials

- MATLAB® software licensed by MathWorks®
- LaTeX document preparation system

Methods

- A GUI was developed in MATLAB
- Report & PDF capabilities added to finished program

Final Prototype

- MATLAB GUI featuring 15 panels - one for each QA test
- Panels include: Basic Information, Safety, Artifacts, Noise, CT Number, CT Uniformity, Low Contrast Detectability (LCD), Beam Width, Gantry Tilt, Monitor, Protocol Review, Dose, Slice Width, Lasers, and Couch testing protocols

Software Features

Software features & capabilities:

- Automatic CT image analysis
- QA report generated with push of button
- Performs calculations from user input
- Combines tools from several external programs into one
- Ability to export a LaTeX compatible text file to create properly formatted PDF

Final Design

Program Highlights

- Key functionalities and design solutions of a few QA test algorithms are described below and are used to improve quality of CT systems

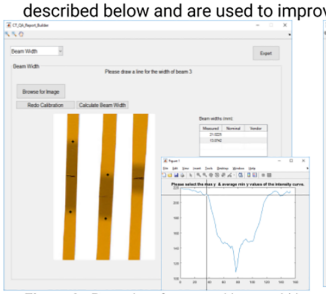

Figure 2. Procedure for manual beam width calculation using full width half maximum of intensity plot.

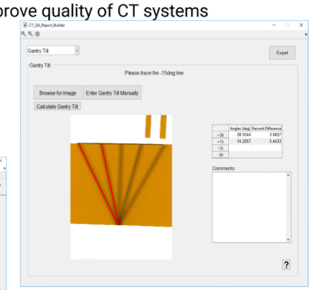

Figure 3. Gantry tilt calculation from radiochromic film at +/- 15° and +/- 30°.

Features & capabilities:

- Full width half maximum algorithm for beam width calculation
- Step-by-step pixel to distance calibration
- Automatic data acquisition and documentation
- Image-angle calculation
- Compiles image analysis software (*i.e. ImageJ*) into a single GUI

Final Design

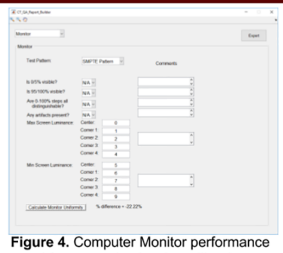

Figure 4. Computer Monitor performance panel for screen luminosity calibration.

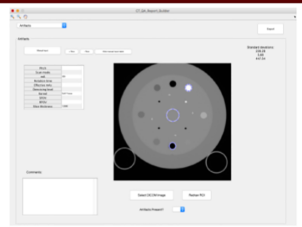

Figure 5. Panel for documenting and defining artifact ROIs.

Features & capabilities:

- Tests to assess equipment performance
- Region of interest (ROI) selection & analysis
- DICOM information extraction
- ROI distance-to-isocenter algorithm

Final Report

- The "Export" button generates LaTeX formatted report

Testing & Results

Testing

- Tested by:
  - Students in medical imaging class
  - Medical physicist & residents of the Wisconsin Institutes for Medical Research
- Survey-based feedback evaluated design, intuitiveness, and possible bugs
- Feedback used to improve user interaction & improve ease of use

Results & Significance

- Program streamlines communication between medical physicists and service engineers
- Reduces time and labor of CT QA testing

Future Work

- Continued extensive testing of user interaction with program
- Modifications & improvements based on tester feedback
- Incorporate additional QA tests & functionality upon client request
- Package & distribute as an open-source program or standalone application

Acknowledgements

We would like to thank:
Prof. Tim Szczykutowicz Prof. John Webster UW BME Dept.

References

[1] S. Mutic *et al.*, "Quality assurance for computed-tomography simulators and the computed tomography-simulation process," Medical Physics 30 (10). Oct. 2003.

[2] T.P. Szczykutowicz. "CT Scanner Annual Testing: East Clinic UWHC DHO," UW-Madison Dept. of Radiology. Madison, WI. July, 2016.

[3] D. J. Goodenough, "Catphan 500 and 600 Manual" Salem, NY. 2006.