A Benchmarking Application for Image-Based Machine QA

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INTRODUCTION

- **RadBenchmarkImage** is a software application developed by **Dr. L. Jonathan Dowell** to generate two-dimensional radiation field images and dose profiles with known characteristics for benchmarking radiation therapy quality assurance (QA) software.
- Radiation fields are simulated using numerical models based on **AAPM TG-45** and two NIH publications, allowing users to define beam parameters such as energy, filtration, jaw settings, and wedge filters.
- The application generates realistic radiation field characteristics, including **geometric penumbra, beam flatness, symmetry, wedge effects,** and **ROI values**, with real-time visualization of dose profiles and images.
- Images can be exported with a text file containing known reference values.
- Physicists can compare QA software measurements against these predefined reference values to verify accurate calculation and reporting of spatial and dosimetric field characteristics.

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PURPOSE

•Present a novel application for testing and benchmarking radiation therapy QA software.
•Enable physicists to verify that QA software accurately measures dose profile characteristics, including flatness and symmetry, using datasets with known reference values.
•Demonstrate the application's utility through an in-house validation of our QA software.

METHODS

Benchmark image generation

- RadBenchmarkImage generates simulated radiation field images and dose profiles from user-defined beam parameters, including field size, geometric penumbra, flattening-filter characteristics, wedge angle, and beam symmetry (Figure 2).
- Beam characteristics are calculated using published numerical models (Equations 1–3), producing realistic radiation fields with known reference values for flatness, symmetry, and other dosimetric parameters.
- Generated images can be exported with accompanying metadata for use as standardized QA test datasets.

$$F(x) = F_0(x) - B * e^{(0.5 * \frac{x^2}{\sigma^2})} \quad (1)$$

$$Penumbra_{D(s)} = \frac{T}{2}(1 - \frac{s}{\sqrt{n + s^2}}) \quad (2)$$

$$G_W(x) = G_0(x) * [1.0 + (m * x)] \quad (3)$$

QA software evaluation

- Benchmark datasets were imported into our in-house radiation therapy QA software to evaluate measurement accuracy.
- Two representative tests were performed:
  - **Flattening-filter evaluation:** Measured flatness was compared with reference values across a range of flattening-filter amplitudes (Table 1, Figure 3).
  - **Wedge-filter evaluation:** Flatness and symmetry measurements from simulated wedged fields were compared with known reference values (Figures 4–5).
- These examples demonstrate a subset of the software validation studies that can be performed using RadBenchmarkImage.

Figure 1: Sample benchmark image generated

RESULTS

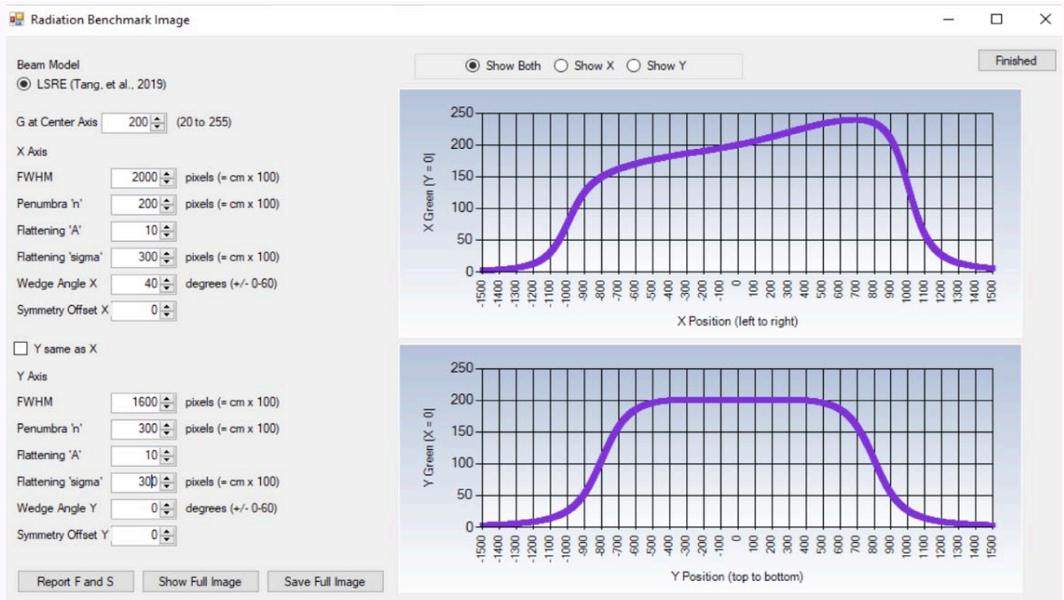

Figure 2: Application User Interface

Table 1: Measured Flatness Comparison for Different Flattening Filters and Gaussian Smoothing

Image Number	Flattening Amplitude	Gaussian Sigma	Known Flatness	Measured Flatness
1	10	100	4.326	4.3
2	10	150	4.154	4.1
3	10	200	3.895	3.9
4	10	250	3.616	3.6
5	10	300	3.412	3.4
6	20	100	4.959	4.8
7	20	150	4.698	4.7
8	20	200	4.344	4.3
9	20	250	3.903	3.8
10	20	300	3.403	3.4

The **mean delta** in the flatness values is **-0.0410**.

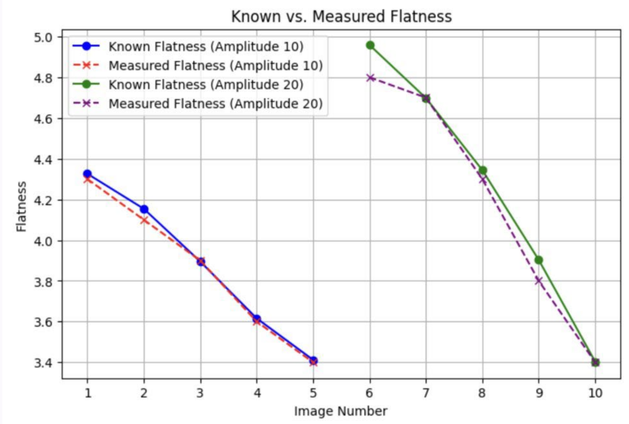

Figure 3: Measured and Known Flatness Plot

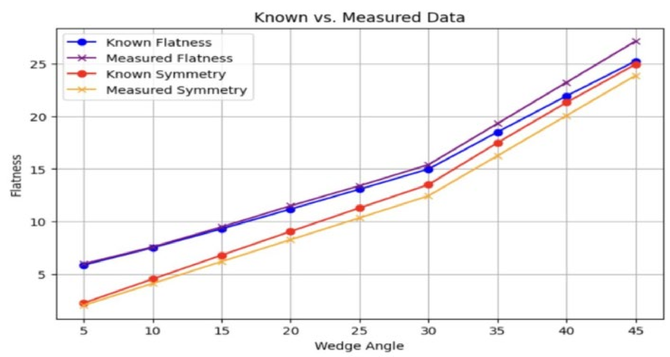

Figure 5: Flatness/Symmetry Comparison with Varied Wedge Angles

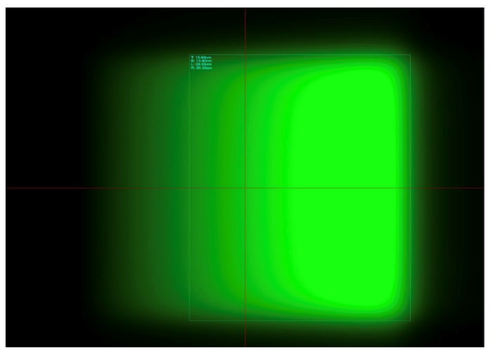

Figure 4: Simulated Radiation Field with a 60 °Wedge.

CONCLUSIONS

Our Application, RadBenchmarkImage, provides fully customizable radiation field images and dose profiles with known reference characteristics for evaluating radiation therapy QA coded analysis. Our proof-of-concept testing demonstrated how these benchmarks can be used to assess the accuracy of device-generated flatness and symmetry measurements under different field conditions. This software may offer physicists a flexible and accessible tool for software validation, quality assurance, and development.

REFERENCES

[1] M. Ahmed et al., "Studying wedge factors and beam profiles for physical and enhanced dynamic wedges," Journal of Medical Physics, vol. 35, no. 1 (2010).
[2] S. Tang et al., "An empirical model for describing small field penumbra in radiation therapy," BioMed Research International, Article ID 7584743 (2019).