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Automated Analysis Tool for Annual Beam-Scanning QA

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Abstract

Annual linac beam scanning QA traditionally depends on manual data handling and spreadsheet analysis, with site-specific workflows introducing inconsistency across machines.

An automated framework built within Radmachine was evaluated for processing and analyzing annual photon and electron percent depth dose (PDD) and profile data across 10 linear accelerators. Python 3.9 scripting enabled consistent data resampling and quantitative comparison, reproducing established clinical metrics while adding distance-to-agreement (DTA) and 1D gamma analysis against treatment planning system (TPS) data and commissioning baselines.

Analysis and reporting time dropped from two hours to 5–10 minutes per machine, with parallel benchmarking against manual transcription showing similar pass/fail outcomes and clinically insignificant numerical differences.

The framework eliminates manual transcription, applies TG-142–based conditional formatting, and centralizes documentation in a shared database.

Methods and Materials

The workflow utilizes Radmachine (v1.49.0) test lists and Python 3.9 scripting to ingest raw measurement files and resample data onto a common spatial grid. The framework was validated using annual QA datasets from 10 Varian TrueBeam linacs acquired via SNC Dosimetry software (v3.5.0.19215), with each machine acquiring 60 or 80 scans annually (depending on if FFF energies are enabled), covering photon beams (6X, 15X, 6FFF, 10FFF) and electron beams (6, 9, 12, 16, 20 MeV).

Measured PDDs were evaluated against treatment planning system (TPS) and commissioning baselines at clinical depths (D5, D10, D20, D25 for photons; Rmax, R90, R80, R50 for electrons). Profiles were assessed for flatness and symmetry against a TG-142 tolerance of 1% from baseline. Geometric evaluations integrated mean distance-to-agreement (DTA) and 1D gamma analysis (2%/2 mm criteria) along the profiles to capture high-gradient discrepancies in the distal falloff and penumbra regions with a gamma pass rate ≥90% considered passing.

Execution time and analytical accuracy were benchmarked against the legacy manual spreadsheet workflow.

Results

Automation reduced data analysis and report generation time from about two hours to 5–10 minutes per machine. For the first 1-2 machines at each site, automated results were benchmarked in parallel with manual transcription; resampling introduced small numerical differences between the two methods, but observed differences were clinically insignificant.

Structured tables and graphs populate automatically upon file upload, and finalized reports save to a centralized database, ensuring long-term accessibility and standardized documentation.

For photon beams, the workflow generates Photon profile comparison plots (Figure 1) show measured curves overlaid with TPS and commissioning baselines, supplemented by error plots and embedded metrics. Photon profile results table (Figure 2) displaying flatness and symmetry metrics across multiple configurations, using automated conditional formatting to flag out-of-tolerance results.

For electron beams, the system generates a structured electron PDD table (Figure 3) with measured, baseline, DTA, and 1D gamma comparison values, and outputs electron PDD plots (Figure 4) mapping continuous measured and baseline curves alongside DTA plots, and embedded quantitative comparison metrics.

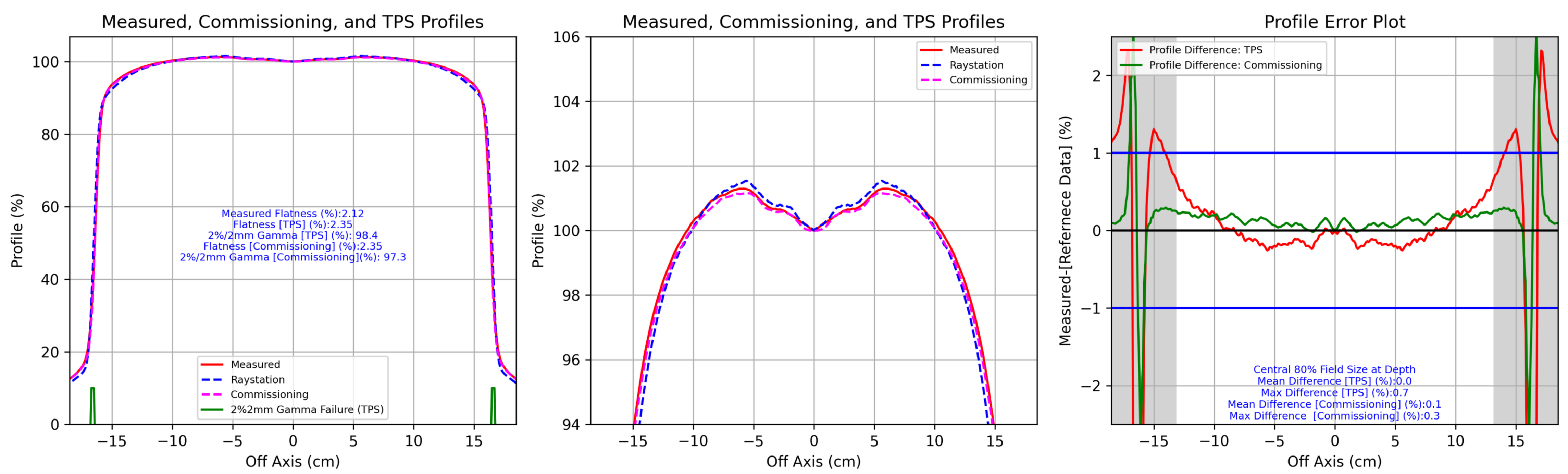

Figure 1. Automated comparison of a 30x30 6MV profile with TPS and commissioning baseline data, including generated error plots.

Energy	6x							
Field Size	Depth	Orientation	Flatness					Symmetry
			Measured	TPS	Meas. vs TPS %diff	Commisioning	Meas. vs Commis. %diff	Measured
10 x 10	dmax	Crossplane	1.28	0.57	-0.71	0.67	-0.62	-1.41
		Inplane	0.66	0.64	-0.01	0.73	0.07	0.16
	10 cm	Crossplane	2.65	2.25	-0.41	2.23	-0.42	-1.15
		Inplane	2.40	2.10	-0.30	2.33	-0.07	0.18
30 x 30	dmax	Crossplane	2.00	1.85	-0.15	1.65	-0.35	-1.34
		Inplane	1.72	1.73	0.00	1.67	-0.06	0.43
	10 cm	Crossplane	2.22	2.22	0.00	1.86	-0.36	-0.89
		Inplane	1.98	2.35	0.37	1.85	-0.13	0.39

Figure 2. Automatically populated 6X profile results table with flatness and symmetry metrics, and TG-142–based conditional formatting.

Field Size	10x10						TPS		Commissioning	
Energy	Depth	Measured (cm)	TPS (cm)	Meas - TPS (cm)	Commissioning (cm)	Meas. - Commis (cm)	Mean DTA (cm) [Dmax-R10]	1DGamma [2%/2mm]	Mean DTA (cm) [Dmax-R10]	1DGamma [2%/2mm]
6MeV	Dmax	1.28	1.30	-0.02	1.30	-0.02	-1.0	95.1	0.0	100.0
	R90	1.80	1.72	0.08	1.77	0.03				
	R80	1.99	1.92	0.07	1.97	0.02				
	R50	2.41	2.33	0.08	2.39	0.02				

Figure 3. Automated electron PDD QA results table including measured, baseline, DTA, and 1D gamma comparison metrics.

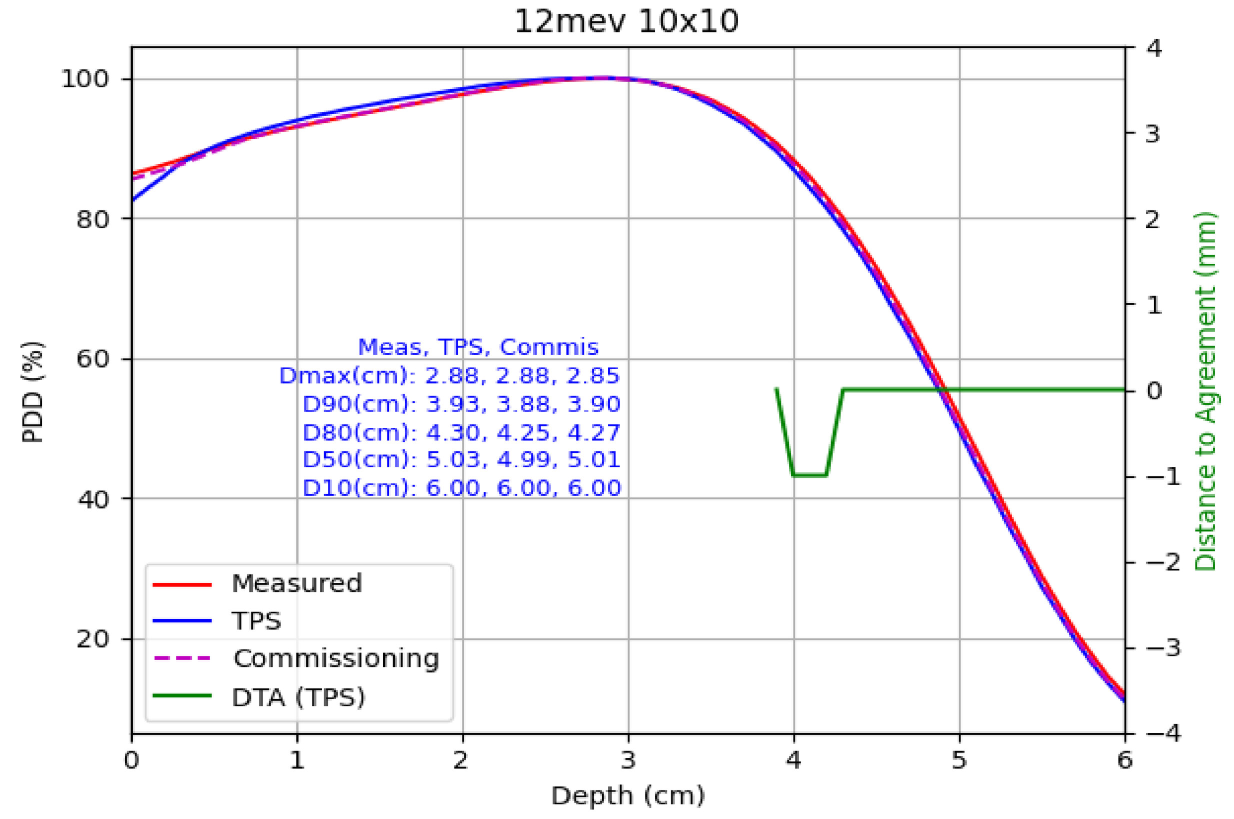

Figure 4. Automated 10x10 12MeV electron PDD comparison with TPS and commissioning baselines, including DTA plot, and embedded comparison metrics

Discussion

Transitioning from manual spreadsheets to a centralized, calculation-driven framework enforces identical evaluation criteria across all linear accelerators, minimizing user-dependent variability. Centralized recordkeeping also streamlines regulatory compliance during state audits.

Automated profile difference error plots, mean DTA, and 1D gamma calculations give physicists metrics unavailable through manual review. Automated yellow alerts for out-of-tolerance parameters change the review process itself: rather than searching dense records for errors, physicists can immediately troubleshoot anomalies, such as the crossplane symmetry discrepancy identified in Figure 2. This shifts physicist time from data entry toward clinical review.

Conclusions

Automating annual beam scanning QA within Radmachine reduces physics workload while improving consistency, reproducibility, and documentation quality. The framework strengthens quantitative evaluation capabilities and supports centralized QA recordkeeping across multi-machine linac programs.

Planned extensions include accepting additional file formats, such as IC Profiler data, to accommodate tankless annual beam scanning setups.

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