Purpose: We introduce a novel multi-objective treatment planning system called PARETO (Pareto-Aware Radiotherapy Evolutionary Treatment Optimization), which simultaneously optimizes beam angles and fluence patterns by treating the PTV conformity and dose to OARs as separate objectives that are optimized by a powerful multi-objective parallel genetic algorithm (GA).

Methods: PARETO treats radiotherapy treatment planning as a single monolithic optimization problem, in which beam angle configurations and fluence patterns are explored to simultaneously optimize the PTV dose conformity and a dose objective for each OAR. We use a Pareto-ranking scheme to discover necessary compromises between objectives. A final non-dominated database of solutions is compiled from all plans evaluated during the run such that no solution in the database is superior to any other solution in all objectives. A graphical tool allows rapid navigation of the pre-optimized database to select a final treatment option for the patient.

Results: PARETO is at the stage of a working prototype. Solutions are of high quality, as judged by DVH curves and dose distribution, and consistent results are obtained between runs. Only minor differences in trade-off surfaces result from four different fluence parameterizations of varying complexity, but they differ by a factor of ~4 in speed. A novel feature allows optimization of the number of beams and a realistic test case shows that no further improvements in conformity are found for more than ~9 beams. A newly implemented GPU-based ray tracer, including convolution with a patient dose kernel, results in a speed-up factor of ~3 compared to CPU-based computation.

Conclusions: This work demonstrates PARETO's feasibility as a treatment-planning tool, which replaces manual iterative optimization of treatment plans with a rapid graphical exploration of pre-optimized solutions. Clinically acceptable run times of less than an hour appear within reach by combining several of our GPU-based systems in parallel.

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J. Fiege discloses authorship of the Ferret GA (used by PARETO) and ownership of nQube Technical Computing Corporation, which distributes this optimization software.