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Bayesian optimization to design a novel x-ray shaping device

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Purpose:

In radiation therapy, x-ray dose must be precisely sculpted to the tumor, while simultaneously avoiding surrounding organs at risk. This requires modulation of x-ray intensity in space and/or time. Typically, this is achieved using a multi leaf collimator (MLC) — a complex mechatronic device comprising over one hundred individually powered tungsten 'leaves' that move in or out of the radiation field as required. Here, an all-electronic x-ray collimation concept with no moving parts is presented, termed "SPHINX": Scanning Pencil-beam High-speed Intensity-modulated X-ray source. SPHINX utilizes a spatially distributed bremsstrahlung target and collimator array in conjunction with magnetic scanning of a high energy electron beam to generate a plurality of small x-ray "beamlets."

Methods:

A parametric simulation environment was developed in Topas Monte Carlo enabling simulation of a SPHINX structure from linac phase space to dose in water tank including transport through scanning magnets. The SPHINX geometry was parameterized with 8 variables, which were optimized using Bayesian optimization. The goal of the optimization was to maximize dose rate for a user input beamlet width without violating physical geometric constraints. Designs for beamlet widths of 5, 7, and 10 mm were generated, with 200 iterations run for each model. For the seven-mm design, a simulation of dose in water for a 50x50 mm square field was carried out, incorporating transport through custom scanning magnets.

Results:

The Dose per charge was 3574, 6351, and 10015 Gy/C for the five, seven, and ten mm models respectively.

Conclusions:

SPHINX designs for user-input beamlet widths were generated using Bayesian Optimisation of topas monte carlo simulations.

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