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AI-based dose calculation in medical physics

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Monte Carlo simulation has remained the “gold standard” for dose calculation in medical physics since the 1970s, providing highly accurate estimates of patient radiation exposure for applications ranging from diagnostic imaging to cancer treatment such as radiotherapy. Monte Carlo simulations model particle interactions and follow the law of large numbers. Their inherently stochastic nature represents their main limitation, as obtaining high-statistical-quality results requires substantial computation time. Over the past five decades, researchers have sought to improve efficiency through both algorithmic innovations, including variance-reduction techniques, and advances in computing hardware, from early supercomputer parallelization to massively parallel GPU-based implementations in the 2010s. Today, the emergence of Artificial Intelligence (AI) introduces new opportunities to drastically accelerate Monte Carlo simulations by learning to approximate, guide, or emulate radiation transport while preserving physical accuracy. This presentation focuses on these AI-driven strategies and examines how they enable fast, and in some cases real-time, radiation dose estimation across a range of medical physics applications.

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