

# Rapid and accurate dose computation and optimization for IMPT

Sullivan, Alan; Brand, Matthew

TR2016-071 May 22, 2016

## Abstract

The speed of IMPT dose optimization is the key factor limiting the rate of treatment plan generation. Long optimization times have the effect of forcing dosimetrists to compromise due to time limitations and potentially select lower quality plans. The speed of dose optimization is determined both by the optimization algorithm itself and by the underlying dose computation algorithm.

*Particle Theory Co-Operative Group*

© 2016 MERL. This work may not be copied or reproduced in whole or in part for any commercial purpose. Permission to copy in whole or in part without payment of fee is granted for nonprofit educational and research purposes provided that all such whole or partial copies include the following: a notice that such copying is by permission of Mitsubishi Electric Research Laboratories, Inc.; an acknowledgment of the authors and individual contributions to the work; and all applicable portions of the copyright notice. Copying, reproduction, or republishing for any other purpose shall require a license with payment of fee to Mitsubishi Electric Research Laboratories, Inc. All rights reserved.

Mitsubishi Electric Research Laboratories, Inc.  
201 Broadway, Cambridge, Massachusetts 02139



**Background:** The speed of IMPT dose optimization is the key factor limiting the rate of treatment plan generation. Long optimization times have the effect of forcing dosimetrists to compromise due to time limitations and potentially select lower quality plans. The speed of dose optimization is determined both by the optimization algorithm itself and by the underlying dose computation algorithm.

**Method:** To overcome limitations in the speed of dose optimization we have developed a novel dose computation algorithm, the Outer Product Algorithm (OPA), which produces highly accurate dose distributions with extraordinary speed. We have coupled OPA to a novel gradient-free quadratic optimization algorithm, Parallel Quadratic Programming (PQP), which uses multiplicative updates and incorporates hard constraints.

**Results:** The OPA, implemented for GPU, is capable of computing 3D dose distributions for clinical treatment plans, e.g.  $(512 \text{ mm})^3$  patient CT with  $1 \text{ mm}^3$  voxels and  $\sim 10^5$  treatment spots, in  $\sim 10$  ms with a maximum dose error of  $<10\%$  and a  $3\text{mm}/3\%$  Gamma match of  $>98\%$  for liver and lung tumors in comparison to the dose from the TOPAS Geant4 application. PQP leverages this high dose computation speed to enable full multi-port optimization to converge in a few seconds.

**Conclusion:** The high speed IMPT dose optimization provided by the combination of OPA for dose computation and PQP for optimization enables the nearly real-time response of a TPS to user input. This enables a dosimetrist to try many different treatment scenarios and potentially produces better plans with greater tumor control and OAR sparing.