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A Successive LP Approach with C-VaR Type Constraints for IMRT Optimization

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Abstract:

In this paper, we propose a successive linear programming (LP) approach for an intensity-modulated radiotherapy treatment (IMRT) optimization. The use of IMRT enables to control the beam intensities accurately and gives more flexibility for cancer treatment plans, but finding a feasible plan that satisfies all dose-volume constraints (DVCs) requires expensive computation cost. Romeijn et al. [Physics in Medicine and Biology, 48(21):3521, 2003] replaced the DVCs with C-VaR (conditional Value-at-Risk) type constraints, and successfully reduced this computation cost. However, the feasible region of the LP problem was small compared to the original DVCs, therefore, their approach often failed to find a feasible plan even when the DVCs were not so stringent.

In the proposed method, we integrate the C-VaR type constraints with a successive LP approach. Exploiting the solution of LP problems, we automatically detect outliers and remove them from the domain of the C-VaR type constraints. This reduces the sensitivity of the C-VaR type constraints to outliers, therefore, we can search feasible plans in a wider region than the C-VaR type constraints. We give a mathematical proof that if the optimal value of an LP problem in the proposed method is non-positive, the corresponding optimal solution satisfies all the DVCs. From a numerical experiment on test data sets, we observed that the proposed method found feasible solutions more appropriately than existing successive LP approaches. Moreover, the proposed method required fewer LP problems, and this was reflected in a short computation time.

Keywords: Intensity-modulated radiotherapy treatment, Fluence map optimization, Linear programming, Condtional Value-at-Risk

1 Introduction

In many countries, cancer is considered to be one of the principal causes of death. In Japan, it was reported in [9] that the fatalities number rose to 350 thousand people and 800 thousand people were newly diagnosed as cancer in the year 2010. Prevalent types of cancer treatment include chemotherapy, surgery, and radiation therapy. An investigation conducted by Ministry of Health, Labor and Welfare of Japan [11] reported that their percentages are 81%, 72%, and 32%, respectively (the numbers include combinations of treatment types). The National Cancer Institute reported that a half of the cancer patients receive radiation therapy during their treatment [13]. Among radiation therapy, intensity-modulated radiotherapy treatment (IMRT) has brought a remarkable flexibility in dose irradiated from the beams. The computation of IMRT

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