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Evolutionary DVH-evaluation for beam orientations in intensity-modulated radiation

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The problem of beam orientations in intensity-modulated radiation therapy (IMRT) is an important, but large-scale NP-hard optimization problem. A considerable part of this difficulty is due to the essential prerequisite of defining, appropriately, counter-intuitive criteria for a mathematical plan evaluation that coincides with the clinical judgment of the considered plan. Moreover, the quality of beam directions depends heavily on its corresponding beam intensity profiles. Usually a stochastic selector is utilized for optimizing beam orientations, and an inverse treatment planning algorithm is employed to optimize beam intensity profiles for every selection of beam orientations. Thus, intensity profiles are calculated many thousands of times, each time for a different selection of beam directions, resulting in excessive time complexity. Therefore selecting an appropriate set of beam directions in IMRT is still a time-consuming manual trial-and-error search procedure that depends on intuition and empirical knowledge. To overcome these difficulties, this work utilizes the concept of dose volume histogram (DVH), which is one of the main recognized quantitative measurement tools used for plan judgment, to present a DVH evaluation scheme that parallelizes plan evaluation with clinical plan judgment. The DVH evaluation scheme is then combined with an evolutionary algorithm manufactured particularly to solve the problem of beam orientation in IMRT. The results of applying the presented methods to real clinical cases demonstrated that while the evolutionary algorithm converges to appropriate solutions in practical clinical time slot, significant improvement were reported in all clinical cases in comparison to the standard equally spaced beam plans, even when sometimes using a fewer number of beams. A fewer number of beams is always desirable without compromising the quality of the treatment plan. This results in a shorter treatment delivery time which reduces potential errors in terms of patient movements and decreases discomfort, as well as the risk of reoccurring cancers in the future.

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