The Role of Optimization and Machine Learning in the Era of Personalized Cancer Treatment

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Abstract: The goal in precision medicine is to tailor the treatment course of individual patients not only based on disease-specific characteristics, but also on the specific biological makeup of each patient. In the field of cancer radiation therapy (RT), many forms of patient-specific data are acquired for each patient, usually in the span of several weeks, from the time of cancer diagnosis until the end of the treatment course. This includes multiple radiological images, tumor genomic assays, and immune system markers. The crux of the problem is how to integrate such heterogenous, noisy and often incomplete data streams into a coherent view of the patients' response to cancer treatment.

This requires theoretical and practical developments on three main fronts: (i) biological markers (biomarkers) discovery, (ii) interpretable and probabilistic machine learning, and (iii) adaptive treatment optimization. In the first one (biomarker discovery), image processing and advanced data analytics tools are employed to find novel or re-purpose existing biomarkers of RT response. In the second, state-of-the-art machine learning tools are used to derive transparent and probabilistic predictive models of RT response. Finally, the third step involves the use of various forms of optimization theory to address modeling and data uncertainty, as well as to adapt the treatment plans according to biomarker information and model's predictions.

In this talk, we will focus on the applications of machine learning and optimization in order to tackle these issues and pave the way towards personalized radiation therapy. First, we will see how *probabilistic* Machine Learning (*p*ML) can be applied to predict the RT response of advanced-stage patients to lung cancer chemo-RT. Next, we will discuss how the inherent uncertainty and temporality in medical data and decision making can be addressed using the relatively new concept of Adjustable Robust Optimization (ARO). Finally, we will focus on Conic Optimization (CO) and see how several structural characteristics of the popular mathematical functions in RT optimization can be exploited to derive more efficient solutions compared to standard convex optimization approaches.

Bio: Ali Ajdari is an Instructor at the Department of Radiation Oncology at Harvard Medical School (HMS) and Massachusetts General Hospital (MGH), and the co-director of the Optimization Lab at the Radiation BioPhysics group at HMS/MGH. He received his Ph.D. from the Industrial & Systems Engineering Department of University of Washington, where he worked on the applications of dynamic and robust optimization in RT treatment planning. During his time at MGH/HMS, he has focused his efforts on combining optimization and machine learning techniques to personalize the treatment course of advanced stage cancer patients and improve their therapeutic outcome.