Patient anatomical variation during the radiotherapy course can be modeled using a stochastic process. In this process, spatial position of each subvolume in patient organs of interest is defined as a random vector described using a probability distribution function (pdf). Two main parameters, the mean and the standard deviation, of the pdf have been historically used to characterize patient anatomical variation during the radiation treatment. It has been demonstrated that treatment dose distribution in an organ of interest can be evaluated approximately using these two parameters alone, without the full knowledge of organ motion distribution. The approximation is, however, dependent on the scale of the standard deviation as well as the number of treatment delivery fractions. It is straightforward to estimate these two parameters if patient anatomical variation process is stationary. In this case, the two parameters are constants or time-invariance during the treatment course. However, the estimation will be relatively difficult if patient anatomical variation process is non-stationary.

Patient anatomical variation in radiotherapy can be systematically managed using image feedback adaptive treatment technique. The fundamental difference between adaptive treatment technique and other image-guided techniques is the use of patient-specific treatment information. Adaptive technique intends to use all patient-specific dose information - including what has been delivered in the previous treatments, what can be delivered at the present treatment, and what would be delivered in future treatments - in the design of treatment plan. Therefore, treatment plan designed in adaptive radiotherapy is called 4D adaptive plan, which is in principle a treatment control law to manage treatment process. Mathematically, treatment control law is a spatial mapping from the parameter space of patient variation to the parameter space of treatment delivery control, which can be determined including the patient variation in the planning optimization or inverse planning. The objectives in adaptive planning optimization are constructed based on a selection of control strategies that could be either the online or the offline with one control action, multiple actions or continue actions. Selection of control strategy and number of control actions is, of course, dependent on the nature of patient variation process as well as the estimation uncertainties, and has to be determined considering also the clinical practice.

The lecture will provide an overview of the models and characteristics of patient anatomical variation process during the radiotherapy, the 4D dose summation methodology and the strategies of adaptive treatment process.

Educational Objectives:

1. Understand the characteristics and dynamic model for patient anatomical variation during the course of radiotherapy
2. Understand the model and methodology of 4D dose summation
3. Understand the options of control strategy for image guided adaptive radiation treatment