AbstractID: 4658 Title: An Imaging Based Statistical Shape Model and Its Application in Radiotherapy Margin Design

Purpose: A novel imaging based model is proposed to describe the stochastic nature of the shape and location of a volume of interest (VOI). Based on the VOIs in sequential patient images, the model can predict the probability that a specific point will belong to the VOI. An application of the model is in customized radiotherapy margin design.

Methods: N sequential patient images taken on-board or online contain *all* VOI information immediately before or during the treatment sessions. Typically these images are already registered in the radiation device coordinates, a signed distance transform (SDT) will be applied to the VOI boundary in each image to generate a distance map $d(\vec{r})$. The sign of $d(\vec{r})$ indicates whether the point $\vec{r}$ is inside (negative) or outside (positive) the VOI. The VOI shape/location random variation around its mean will propagate through SDT into $d(\vec{r})$. It is reasonable to assume that $d(\vec{r})$ is Gaussian and its measured values are independent from each other. Consequently, $t = \frac{\mu(\vec{r}) - \bar{d}(\vec{r})}{s(\vec{r})}$ obeys Student's t-distribution, with $N-1$ degrees of freedom. Here $\bar{d}(\vec{r})$, $\mu(\vec{r})$, and $s(\vec{r})$ are the sample mean, the expected mean, and sample variance of $d(\vec{r})$. By definition of level-set theory, before any more measurement, a point belongs to the expected VOI if and only if $\mu(\vec{r}) \le 0$. The probability that a point $\vec{x}$ belongs to the VOI can be estimated by $\mathrm{Pr}_{VOI}(\vec{r}) = \mathrm{Pr}(\mu(\vec{r}) \le 0) = \mathrm{Pr}(t \le -d(\vec{r})/s(\vec{r}))$. When the VOI is clinical tumor volume (CTV) we can use $\mathrm{Pr}_{VOI}(\vec{r})$ to design our radiation field margin after a cut-off coverage probability p is specified. All points in space with $\mathrm{Pr}_{VOI}(\vec{r}) \ge p$ are included as part of the expected CTV. Thus we effectively generated a planning tumor volume (PTV).

Conclusion: The model has been tested on real clinical cases. The results show that it is robust and easy to use. The customized probability/imaging based non-uniform margin obtained through this model should be extremely useful in image guided radiation treatment.