Abstract ID: 16020 Title: Hierarchical real-time respiratory motion prediction: a divide-and-conquer scheme for application-oriented optimality

Purpose: Motion management applications differ in their measurement rates and prediction length requirement: it is unlikely to find a universally optimal predictor. This study develops a divide-and-conquer scheme, by partitioning the operation region and assigning proper predictor to each sub-region. Such hierarchical fusion architecture achieves application-dependent optimal prediction performance.

Method and Materials: We parameterize the overall operation region of real-time prediction in terms of (measurement rate, prediction length) to parameterize the configuration and requirement of various motion management systems. The region of study is set to be [5Hz, 30Hz]*[200ms,600ms], spanning the full scope from non-tomographic to tomographic measurement, and for both gating and tracking controls. Four predictor candidates are examined: (a) adaptive linear (b) interactive multiple linear (MLM) (c) KDE (d) local circular motion (LCM); and it is determined that LCM is optimal for low measurement rates and short prediction lengths, while KDE is superior for medium-to-high measurement rate and medium-to-long prediction length. An operation-region specific hybrid model is developed and compared with the individual predictors. Prediction performance is quantified by nRMSE between predicted value and retrospective observations. Normalization with data deviation ensures meaningful population-based statistics.

Results: The proposed method outperforms all individual benchmark methods uniformly. The nRMSE was controlled to be under 0.15 for 200ms prediction and 0.4 for 600ms prediction, translating to sub-mm prediction accuracy for typical respiratory motions.

Conclusion: We have developed a hybrid predictor that adapts to specific motion management applications. This hybrid predictor combines the simplicity of the LCM model under low data rate condition, and the flexibility of the nonparametric KDE approach for long prediction lengths. The general methodology of divide-and-conquer extend to incorporate other predictors naturally, should they offer better performance in a sub-region. The resulting hierarchical predictor uniformly outperforms individual methods, and provides an ideal motion management module for motion-adaptive radiotherapy.