AbstractID: 7091 Title: Objective characterization, estimation and prediction for modeling breathing-related movement

Purpose: To propose a hierarchical model for estimation, tracking, and prediction of respiratory tumor motion. To incorporate modeling on different scales: semi-reproducibility globally and slow frequency/displacement variation locally.

Method and Materials: The problem is formulated with a hierarchy of scales: On the finer scale, a data-based approach is used to estimate the local variation of both displacement and frequency, utilizing classic control and chaos theory. A warping procedure is used to "counteract" local variation, resulting in a much more regular post-warping signal. On the global level, the post-warping (phase-synchronized) signal is modeled as a noisy observation of an intrinsic periodic system, and the best periodic pattern is estimated within a nonparametric optimization setting. For tracking and prediction purposes, the locally estimated warping map (together with proper interpolation or extrapolation, whichever applies) is used to un-warp the globally obtained periodic pattern. A recursive method is devised to further improve the efficiency for real-time processing.

Results: The obtained estimation/prediction signal demonstrates similar local variation as the raw observation, while semi-periodicity is incorporated to decrease its noise sensitivity and enhance prediction accuracy. Verification using RPM data shows that the proposed method reduces 1-period look-ahead prediction error (RMSE) by more than 50% compared to perfect periodic modeling. Conventional local linear models generally fail in such long-term prediction tasks.

Conclusions: This work provides an infrastructure for incorporating information on different knowledge levels, and offers the flexibility to adaptively balance the roles of physical prior knowledge and data fidelity. The model-based method on the global level incorporates the well-recognized semi-periodicity pattern of respiratory motion, overcoming the myopia of local state models. Data-driven local phase map estimation used in warping and un-warping fully utilizes the observation and enjoys the freedom of nonparametric setup.

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