Modeling Respiratory Motion Using Auto Regressive Integrated Moving Average

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Purpose: Respiratory motion is a significant source of error for radiotherapy on the thorax and upper abdomen. In this study we apply auto regressive integrated moving average (ARIMA) models to make real-time predictions on the tumor surrogate positions during treatment.

Methods: The given surrogate position time series are first checked for stationarity, in case of not stationary, a differencing operator is performed until the data are finally made stationary. the ARIMA modeling procedure has three steps: (a) identifying the model order p an q; (b) estimating the model coefficients; and (c) forecasting the surrogate positions in real time. Identifying the model order is done using correlation analysis. The ARIMA model coefficients are estimated using the Gaussian maximum likelihood estimation method. The model is then validated by the Akaike information criterion (AIC). The best suited ARIMA model has the minimum value of AIC. After all the model parameters have been determined, the next surrogate positions are predicated using the available past positions and the model parameters in real time.

Results: We test the method with a data set consisting of 7 simulated breathing time series and 15 real breathing time series. The average root mean square error over all cases was less than 1 mm and no case has an error worse than 2 mm. The computation time for one prediction was less than 20ms on a PC with a 4.5 GHz CPU.

Conclusion: This study indicates the potential of ARIMA method to quantify respiratory motion characteristics, such as patterns of frequency changes and amplitude changes, and can be applied to both internal and external motion, such as internal tumor positions and external surrogates.