Correcting for Intra-fraction Breathing motion based on Offline and Online Analysis of respiratory patterns

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Purpose

To develop an offline and online predictive model by analyzing the patient's breathing pattern in order to correct for the intra-fraction motion effect during radiation therapy treatment.

Materials and Methods

A model based analysis of the breathing signal was performed to help predicting motion associated with respiration. Two adaptive filters, the Kalman filter and linear predictive filter were implemented to predict the online breathing signal. The patient breath signal was acquired using a Varian Real-time Position Management (RPM) with a sample frequency 30 Hz. To remove the noise from the signal, the first-order smoothing filter was used. For the offline analysis, the piecewise cosine function model was used as basic model using a partitioned nonlinear least squares algorithm to perform the model based analysis. For online prediction, the time lag was set to 200 ms. Both the Kalman filter and Linear Predictive filter were applied to evaluate the model's ability to predict the breathing signal.

Results

Figure 1 shows the patient's breathing curve as well as the offline and online analysis results. The model based offline analysis can predict several parameters, including the expiration duration, the inspiration duration and amplitude of the breathing cycle. The model follows closely the breathing signal, except for the peak inspiration and expiration. The R-square value of the prediction result with the Kalman filter is up to 0.95, while with the Linear prediction is 0.98.

Conclusions

Based on patient data collected using the Varian RPM, we performed a model based offline analysis and an adaptive real-time online analysis using the Kalman filter and the linear predictive filter. In our study we found the piecewise cosine model to work better than the sinusoidal model used in previously published data [1-5]. Since the piecewise cosine model is derived based on the lung motion mechanism, parameters like inhale time, exhale time and breathing cycle amplitude can be obtained through this model-based offline analysis. The linear prediction can provide more precise estimation, but is sensitive to the noise and the signal sampling frequency. The models predicted analysis of the breathing pattern allow for more precise margin definition of the target during planning and have been used in our clinic for target tracking during dynamic delivery.

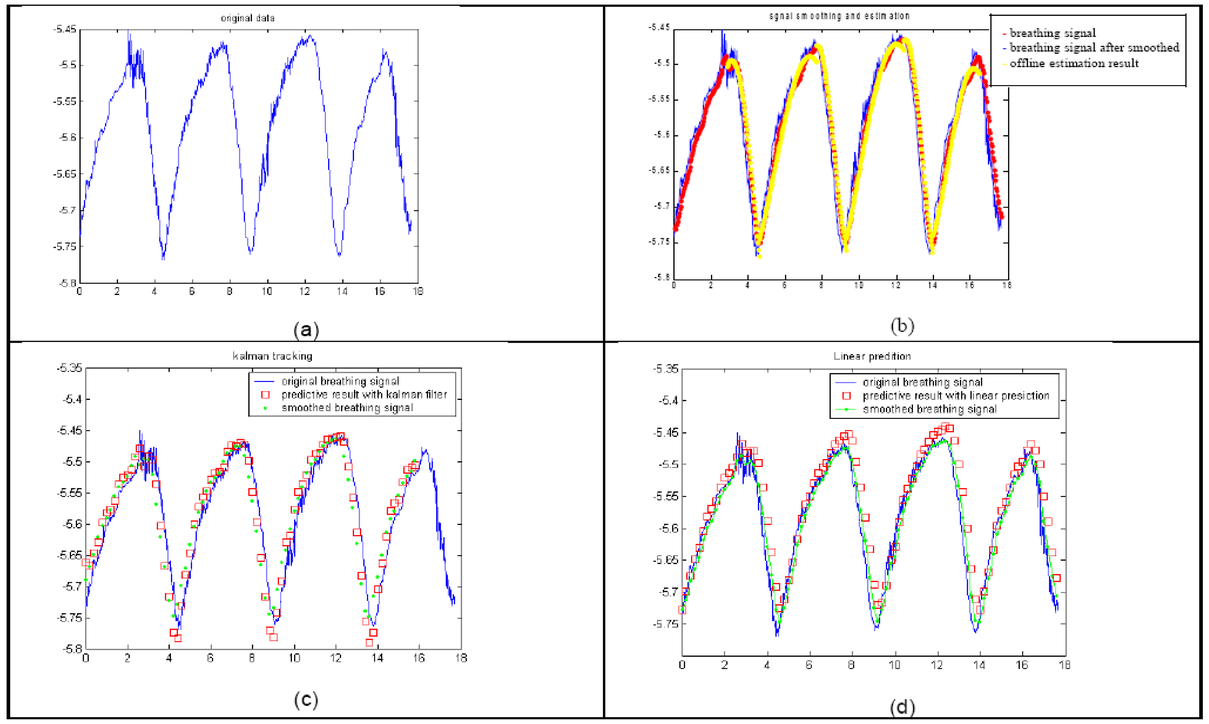

Figure 1. (a) Signal of a patient's respiratory pattern; (b) Model fitting the measured respiratory data; (c) The result of Kalman filter tracking; (d) The result of Linear Prediction.

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