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Development and validation of a breathing motion prediction model for tumour motion management

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Purpose

Tumour motion management (TMM) typically consists of measuring, quantifying and mitigating the tumour motion. Each of these steps is affected by latencies (eg. image acquisition, data transfer, etc) in the order of a few 100 ms. For tumour motion tracking these latencies are not negligible. Thus, motion prediction is required.
In our work, we developed and validated a long short-term memory (LSTM) neural network for breathing motion prediction of an optical surface scanner signal.

Materials and Methods

The training data for the LSTM network was based on breathing data of 25 healthy volunteers performing 5 min of regular breathing followed by 1 min of chest breathing and 1 min of abdominal breathing. The validation dataset was based on four patients undergoing treatment with concurrent surface scanner imaging.
For training of the LSTM model the breathing signal of the healthy volunteers was divided into training data and test data to perform hyper-parameter tuning. The best model was validated by performing a prediction on the patient dataset with a prediction horizon of 500 ms. The quality of the prediction was quantified by calculating the root mean square error (RSME) of the predicted data compared to the actual breathing signal for both the amplitude and the breathing phase.

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Results

The mean breathing amplitude of the healthy volunteer dataset was 6.6 mm. For Patient 1, 2, 3 and 4 it was 1.2 mm, 4.5 mm, 1.0 mm and 20 mm, respectively. The RSME for a prediction horizon of 500 ms for Patient 1, 2, 3 and 4 was for the breathing amplitude 0.15 mm (12 %), 0.08 mm (2 %), 0.05 mm (5 %) and 0.3 mm (2 %) and for the breathing phase 24°, 7°, 15° and 7°, respectively. The mean runtime required for performing a prediction was 11.2 (+/-1.18) ms.

Conclusion

Our LSTM neural network trained with breathing data of a low number of healthy volunteers was able to predict the breathing amplitude and breathing phase with a prediction horizon of 500 ms. This prediction horizon is sufficient to compensate for imaging and image processing latencies as well as mechanical MLC movement required for tumour tracking.
In this study the breathing data obtained by a surface scanner was used, which is only a surrogate of the actual tumour motion. Adding patient specific correlation between surface scanner data and the internal tumour motion using 4D-CT data as well as intrafractional kV-imaging will be investigated in future work.