A comparative study of deep-learning based respiratory signal prediction models for radiation therapy: Bi-directional Long-short term memory

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Purpose: In radiation therapy, the patient's breathing has a great influence on the treatment of various organs. Especially, proton therapy is more sensitive to the patient's breathing because it gives a high dose to the end of the proton track (Bragg-peak). In case of proton FLASH therapy, which has recently attracted high attention, accurately predicting patient's respiration has more importance because a very high dose is irradiated into the body in an extremely short period of time. In order to predict the patient's breathing, statistical methods and machine learning methods have been studied. However, computation takes long and the prediction accuracy is not that high. To predict the patient's breathing in real time with high accuracy, the Bi-directional Long Short-Term Memory (Bi-LSTM) deep learning method was tested.

Materials and Methods: The data used for respiratory prediction were 569 breathing data of 397 patients who underwent proton therapy at Samsung Proton Therapy Center. Breathing data were acquired with Anzai Medical equipment during proton therapy and CT simulation. The averaged respiratory frequency was 30 Hz, and each respiration signal was normalized to 0 ~ 1, and was smoothed using a median filter. Breathing data of one patient were divided into train set and test set (70% vs 30%). All patients' train sets and test sets were connected for network training and testing, respectively. A network was developed to be trained 2 sec period of breathing data and to predict the patient's respiration amplitude after 0.5 sec. Bi-LSTM algorithm which is a method of predicting from forward and backward in time using two LSTM models was used considering the excellent capacity of the model for predicting time series data. In addition, Multi Layers Perceptron (MLP) and Decision Tree models were used as comparison groups. Python was used for constructing the training network and the pytorch library was used for Bi-LSTM, and the Scikit-learn library for MLP and Decision Tree.

Results: The accuracy was analyzed using Root Mean Square Error (RMSE) and Correlation Coefficient (CC). The RMSE of Bi-LSTM, MLP, and Decision Tree were 0.0850, 0.0931, 0.0872, and the CC was 0.937, 0.929, and 0.932, respectively. The average of calculation times for respiration prediction of Bi-LSTM, MLP, and Decision Tree were 0.20 msec (min 0.12 msec, max 0.34 msec), 2.79 msec (min 1.39 msec, max 2.86 msec), and 0.51 msec (min 0.25 msec, max 1.14 msec).

Conclusions: The accuracy of Bi-LSTM was superior to MLP and Decision Tree algorithms in predicting patient's breathing. The computation time is short enough so that the patient's respiratory can be predicted with minimal delay time. With more training data, we will be able to predict the patient's respiration with higher accuracy.

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