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

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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 and compared to machine learning methods.

Introduction

◆ *Respiratory signal prediction*

- In radiation therapy, the patient's breathing has a great influence on the treatment of various organs.
- Especially, proton therapy is very 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 is potentially more importance because a very high dose is irradiated in an extremely short period of time.
- Researches to predict patient respiration signals has been conducted using statistical and machine learning methods but calculation speed and the prediction accuracy are not satisfactory.
- Therefore, in this study, patients' breathing was predicted with machine learning methods, specifically Bi-directional Long Short-Term Memory (Bi-LSTM) and the performance was evaluated.

Methods

◆ *Data processing*

- 569 breathing data of 397 patients who underwent proton therapy at Samsung Proton Therapy Center were used for respiration prediction.
- Respiration 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.
- The averaged respiratory frequency was 30 Hz, each and respiration signal of train set was normalization to 0 ~1, and smoothed using a median filter. (Fig 1)

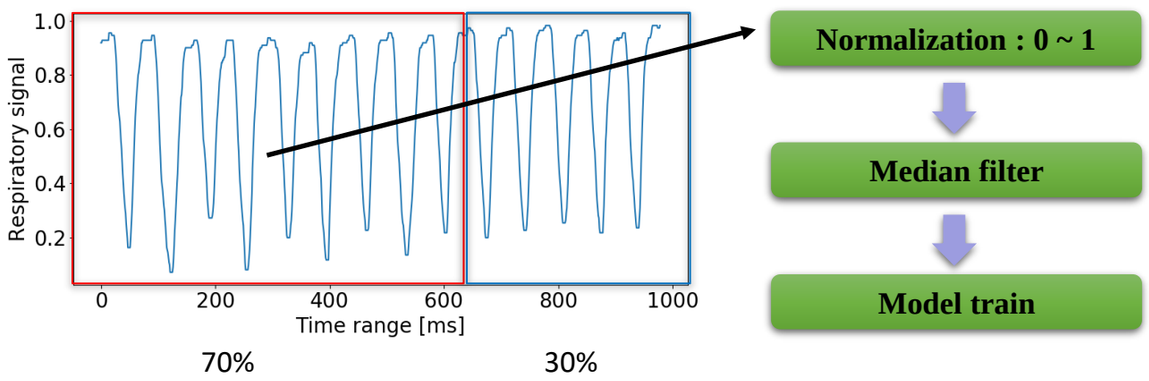

Figure 1. All data processing.

- A network was developed to be trained with 2 sec period of breathing data and to predict the patient's respiration amplitude after 0.5 sec. The predicted respiratory data is smoothed through a median filter.
- Bi-LSTM algorithm which predicts signals from forward and backward in time using two LSTM models was used considering the excellent capacity for predicting time series data. (Fig 2)

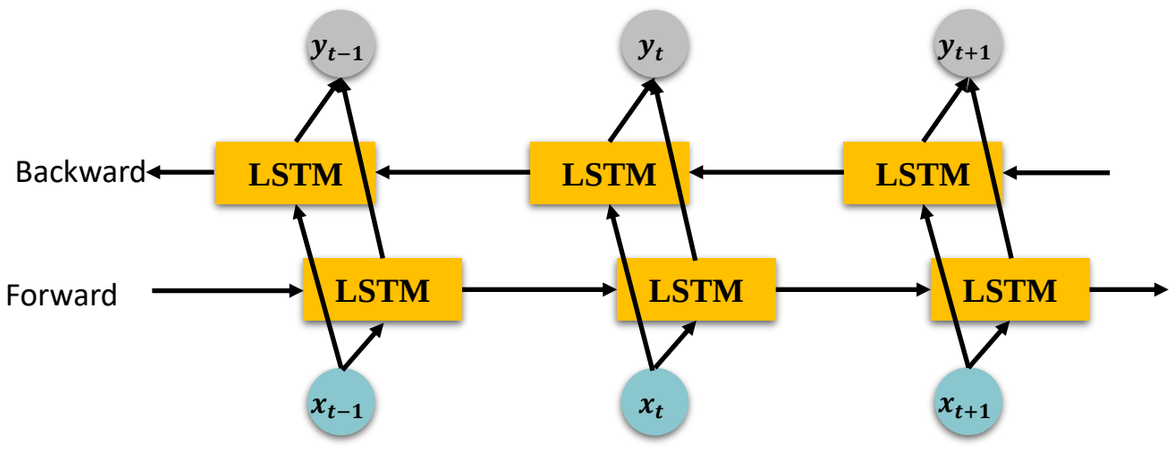

Figure 2. Bi-LSTM structure.

- As for the comparison of the developed model, Multi Layers Perceptron (MLP) and Decision Tree models were used for breathing signal prediction for same data sets. The accuracy was analyzed using Root Mean Square Error (RMSE) and Correlation Coefficient (CC).
- The patient's respiratory data was acquired using ANZAI medical equipment.

Results

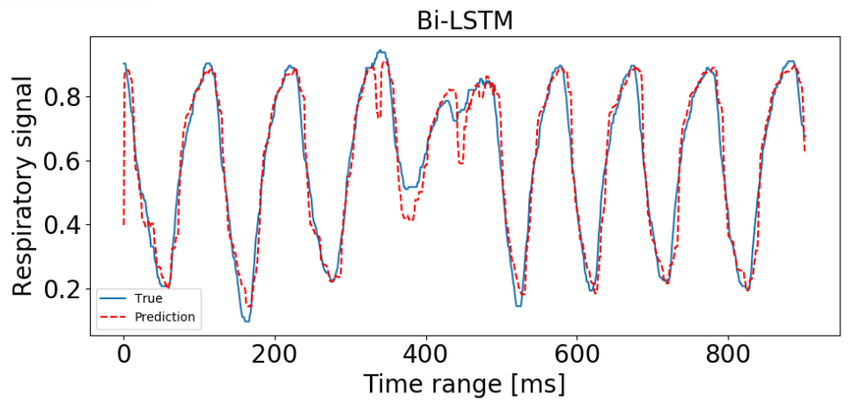

Figure 3. Comparison of true and predicted values using Bi-LSTM.

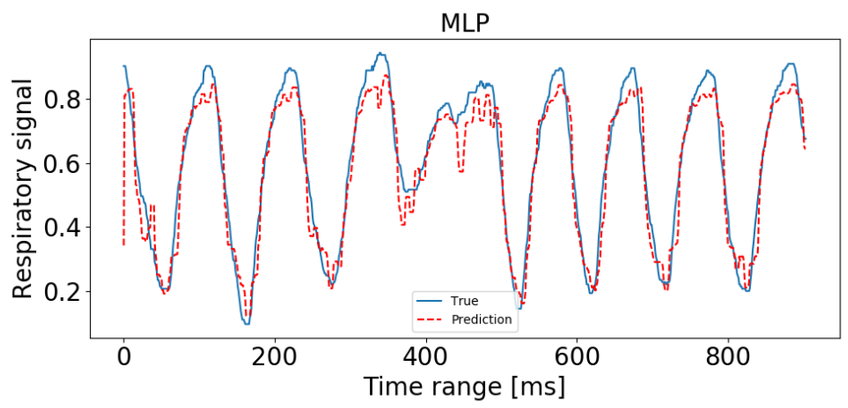

Figure 4. Comparison of true and predicted values using MLP.

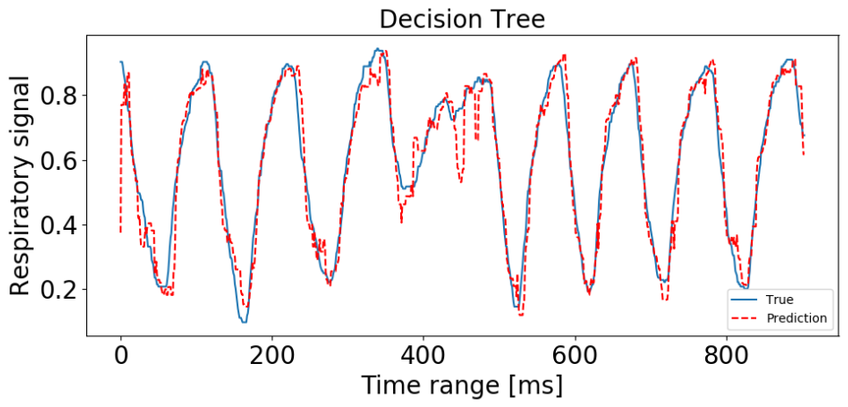

Figure 5. Comparison of true and predicted values using Decision Tree.

Table 1. Comparison of RMSE, CC, and Calculation time of each method.

	Bi-LSTM	MLP	Decision Tree
RMSE	0.0850	0.0931	0.0872
CC	0.937	0.929	0.932
Calculation time [msec]	0.20	2.79	0.51

Conclusion

- The accuracy of Bi-LSTM was superior to that of MLP and Decision Tree algorithms in predicting patient's breathing signal.
- 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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