

## **Respiratory motion prediction by fuzzy logic approaches: ANFIS vs. Interval Type-2 Non Singleton Fuzzy System**

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**Keywords:** respiratory motion prediction, ANFIS, Type-2 Fuzzy Systems

### **Purpose**

Respiratory motion prediction is a chaotic time series prediction problem. In this study, respiratory motion predictability from 12 traces from breast cancer patients is examined by using Adaptive Neuro-Fuzzy Inference System (ANFIS) and Interval Type-2 Non Singleton Fuzzy System (IT2NSFLS).

### **Methods**

Free breathing data curves were obtained from Real Time Position Management system (RPM system) from 12 breast cancer patients. The sampling rate was 25 Hz. Two different methods (ANFIS and IT2NSFLS) were tested over a prediction interval of 20 seconds.

### **Results**

Average root mean square error (RMSE) values were calculated to be 0.1268 and 0.0538 for prediction by ANFIS and IT2NSFLS, respectively. It is also seen that IT2NSFLS is more robust and precise than ANFIS for predicting respiratory motion in breast cancer patients.

### **Purpose**

In radiation therapy, it is known that the target motion often affects the conformability of the therapeutic dose distribution delivered to thoracic and abdominal tumors. Tumor motions can not only be associated with patient's stochastic movements and systematic drifts, but also involve internal movements caused by such as respiration and cardiac cycles [1]. The target motion often affects the conformability of the therapeutic dose distribution delivered to thoracic and abdominal tumors, and thus tumor motion monitoring systems have been developed. Even we can observe tumor motion accurately; however, radiotherapy systems may inherently have mechanical and computational delays to be compensated for synchronizing dose delivery with the motion. For solving the delay problem, we have compared two different fuzzy logic reasoning approaches: Adaptive Neuro Fuzzy Inference System (ANFIS) and Interval Type-2 Non Singleton Fuzzy Logic System (IT2NSFLS).

### **Methods**

We describe briefly the two approaches tested for respiratory motion prediction.

a) ANFIS: Combines the ability of Neural Network (NN) to learn, with the Fuzzy Logic (FL) to reason in order to form a hybrid intelligent system called ANFIS (Adaptive Neuro Fuzzy Inference System). The goal of ANFIS is to find a model or mapping that will correctly associate the inputs (initial values) with the target (predicted values). Fuzzy inference system (FIS) is a knowledge representation where each fuzzy rule describes a local behaviour of the system. If we view a FIS as a feed-forward network structure where the primary inputs and intermediate results are being sent around to compute the final output, then we can apply the same back-propagation principle for learning as in neural networks. The network structure that implements FIS and employs hybrid-learning rules to train is called ANFIS [2].

b) IT2NSFLS: Among various kinds of Type-2 fuzzy systems that can be designed we have made use of Interval T2 Non Singleton Fuzzy Logic Systems (IT2NSFLS) firstly described in [4]. The main elements of such a system are: a Type-1 fuzzification of input variables, Interval Type-2 Fuzzy Sets to represent the input domain, based on the concepts of upper and lower MFs. the extended sup-star composition introduced in [4] for the fuzzy inference engine, back propagation optimization method using a steepest descent algorithm with

learning parameters that decrease as iterations increase with an exponential law, a type-reducer block, and a defuzzification step.

Data was obtained by monitoring respiratory motion for breast cancer patients referred for adjuvant radiotherapy at the Department of Radiation Oncology, Rigshospitalet, Copenhagen. All patients received respiratory gated radiotherapy. The monitoring system was the RPM-system™ provided by Varian Medical System Inc. The RPM™ system consists of a passive, infrared light-reflecting marker that is placed on the patient's chest wall in close relation to the breast. The anterior-posterior (AP) motion of the marker is tracked by an infrared sensitive video camera and the input projected to a computer screen as a breathing curve[3].

### Results

A comparative analysis with simulations from ANFIS and IT2NSFLS are depicted in Table 1 and Figure 1. It is seen that IT2NSFLS depicts more precision and robustness on this dataset

### Conclusion

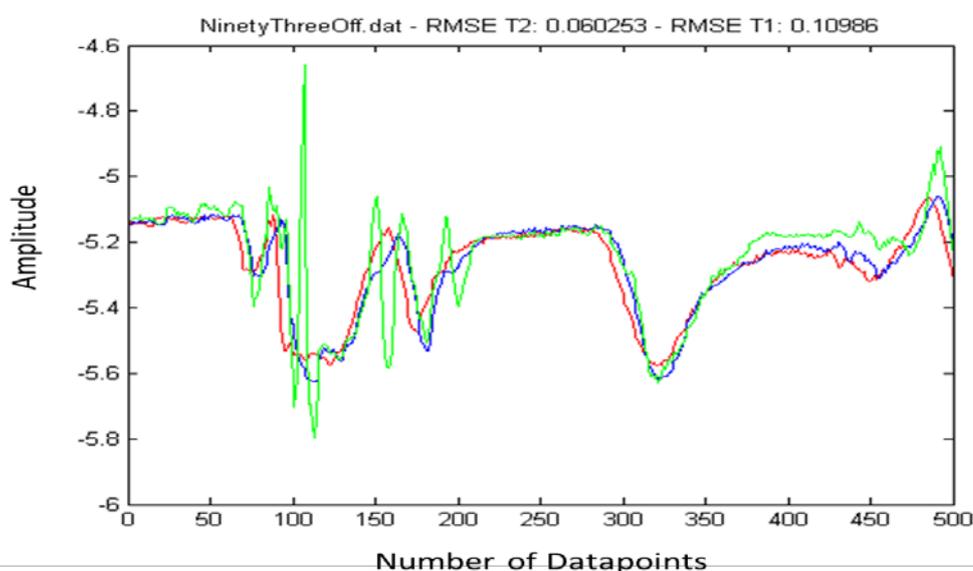
The conclusion is that IT2NSFLS is more robust and precise for predicting respiratory motion in breast cancer patients.

### References

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	ANFIS	IT2NSFLS
Average RMSE Training	0.017445	0.028470
Average RMSE Testing	0.126822	0.053882

**Table 1:** Average RMSE obtained after testing on 12 patients



**Fig. 1** A typical simulation depicting the robustness of IT2NSFLS over ANFIS. The red line depicts the sampled respiratory curve, the green line depicts testing after training with ANFIS and the blue line represents simulation by IT2NSFLS.