Cleveland Clinic

Classification of Atrial Fibrillation Prone Patients Using Electrocardiographic Parameters in Neuro-fuzzy Modeling

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Abstract

Atrial Fibrillation (AF) is a significant clinical problem and the complications of cardiovascular postoperative AF often lead to longer hospital stays and higher heath care costs. The literature showed that AF may be preceded by changes in electrocardiogram (ECG) characteristics such as premature atrial activity, heart rate variability (HRV), and P-wave morphology. We hypothesize that the limitations of statistics-based attempts to predict AF occurrence may be overcome using a hybrid neuro-fuzzy prediction model that is better capable of uncovering complex, non-linear interactions between ECG parameters. We created a neuro-fuzzy network that was able to classify the patients into the control and AF groups with the performances: 99.42% sensitivity, 99.89% specificity, and 99.74% accuracy for 30 minutes just before AF onset.

Introduction

- Post surgical AF: stroke, ventricular arrhythmias, and permanent pacemakers
- Method to identify patients with highest AF risk; continuous monitoring, non-invasive, and use clinically available information
- AF - the most common cardiac arrhythmia: 2.5 million people/year/US; > 350/min electrical impulses from ectopic sources over the atria
- Prediction of AF from ECG parameters
- Neuro-fuzzy model to solve prediction problem

Data & Methods

ECG Data Used

- 98 CVICU patients with inclusion criteria: no chronic AF and no pacing

Table 1: Subject Demographics

		AF	Control
gender	male	28	32
	female	15	23
age (years)	average	70	59
	range	46-88	23-88

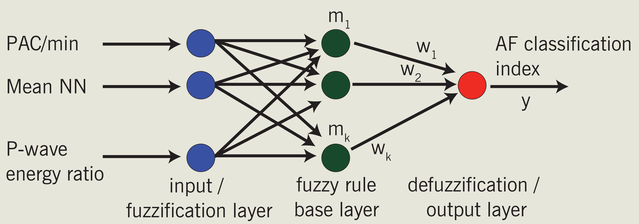
Table 2: Subject Demographics

Domain	Parameter	Measurement unit
Atrial ectopic activity	Premature Atrial Contractions/min	#/min
Heart Rate Variability		
Linear	NN	ms
	SDNN	ms^2
	RMSSD	ms^2
Frequency	Total Power	ms^2
	High Frequency Power	ms^2
	Low Frequency Power	ms^2
	Low/High Frequency Components ratio	scalar
	Low Frequency Power normalized	scalar
Non-linear	Approximate Entropy	scalar
P wave parameters	Duration	ms
	Inflection Point	ms
	Shape	scalar
	Energy Ratio	scalar
	Magnitude	mV

Neuro-fuzzy network

- 43 AF vs. 55 control patients
- Pairs of ECG inputs and known outputs use to build the network: for AF patients ECG parameters for 30 minutes prior to AF onset as inputs and the output is 1 (AF), for control group 30 minutes before the end of the registration and the output is 0 (no AF)
- 2654 data pairs to develop the network
- Number of rules, Gaussians membership parameters, and inter-nodal weights obtained via optimization and training

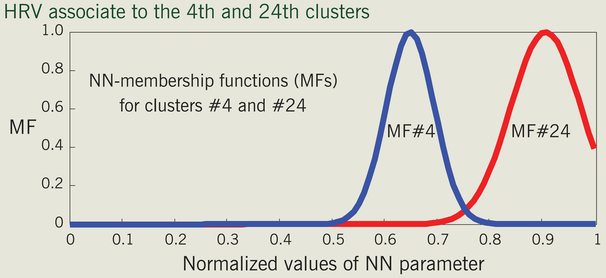
FIGURE 1: The architecture of the proposed neuro-fuzzy model



1. Fuzzification Layer

Determines membership values of crisp parameter values

FIGURE 2: Gaussian membership functions for NN parameter of HRV associate to the 4th and 24th clusters



2. Fuzzy Rule based Layer

- 25 IF-THEN fuzzy rules determined by a fuzzy c-means clustering algorithm
- Optimization trade: compactness within and separation between clusters

Example: **Rule #14**

IF PAC/min is MFPAC#14 **and** NN is MFNN#14 **and** SDNN is MFSDNN#14 **and** RMSSD is MFRMSSD#14 **and** TP is MFTP#14 **and** HF is MFHF#14 **and** LF is MFLF#14 **and** LF/HF is MFLF/HF#14 **and** LFn is MFLFn#14 **and** ApEn is MFApEn#14 **and** Pwave duration is MFPdur#14 **and** Pwave infl_point is MFPinfl#14 **and** Pwave shape is MFPshape#14 **and** Pwave en_ratio is MFPen_r#14 **and** Pwave magnitude is MFPmagn#14 **then** AFindex is MFAF#14

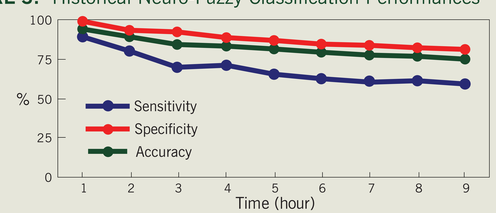
3. Defuzzification Layer

The output, AF classification index, is the weighted average of the outputs of each rule with multiplication used as the AND operator.

Results

- Optimization algorithm: BP 3000 epochs
- Testing data - 3,974 at 1 hour to 40,949 at 9 hours prior to AF onset
- Training data set: 99.42% sensitivity, 99.89% specificity, and 99.74% accuracy; sufficient information for the neuro-fuzzy model to classify 30 minutes prior to clinical diagnosis.
- 9 hours prior AF onset, classify with 93.99% accuracy (88.98% sensitivity, 97.48% specificity)

FIGURE 3: Historical Neuro-Fuzzy Classification Performances



Summary & Next Steps

- A novel neuro-fuzzy network using 15 ECG parameters differentiates AF prone and control patients
- 2654 data pairs, network of 25 rules. The neuro-fuzzy classification model has all metrics > 60% to 9 hours prior to onset of AF
- Refinement of the network, testing on an existing database, and an observational clinical trial

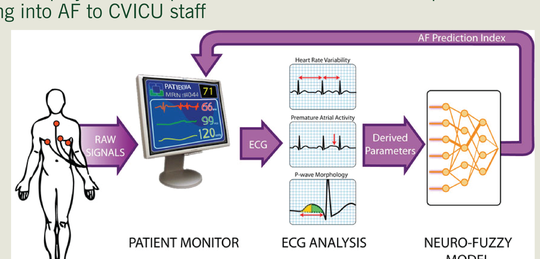



FIGURE 4: An overview of the proposed clinical monitoring system. Parameters derived in real-time from patient ECG signals will be interpreted by the neuro-fuzzy model which calculates a single parameter, the AF index. The index is then displayed on the patient monitor to indicate the patient's current risk of going into AF to CVICU staff