CHAPTER 8 Conclusions and Future Works Recommendation

8.1 Summary

The new approach for the automatic recognition of ECG signals has been developed using online learning EKF based neuro fuzzy classification system. This system has been tested successfully for 4 types of ECG signals such as STDP, TNV, SVT and NSR. The overall average classification rate of this system is 91.8%. The main contributions and strengths of this novel approach are:

1) The method of unconstrained optimisation for a function of one variable has been applied in the detection of peak R for an ECG cycle. This simple method, as discussed in Chapter 3, generates the time invariant input patterns for the MLPN and also allows for the use of the state transition model in VPC feature detection.

2) The system has also introduced a simple state transition model for the detection of VPC presence in ECG signals, as discussed in Chapter 4.

3) The ECG classification system employs online learning in an EKF based neural network, which allows physicians to further train the system with more ECG signals that may have some special characteristics that are not recognised by the system.

4) Another strength of our approach lies in its use of neuro fuzzy techniques. The advantages of using neuro fuzzy techniques are such that when one or more MLPN from the neural networks ensemble fail to recognise a particular ECG signal, the fuzzy inference system will cluster these signals to the unknown category of the corresponding MLPN, thus excluding weak

results (neural network outputs around 0.5) and consequently avoiding any ambiguity.

5) The final strength of our approach refers to the fact that the system is scaleable, *i.e.:* the neural network ensemble can be extended to more than 3 neural networks if necessary. The inclusion of more neural networks will be useful when physicians require other abnormal signals to be classified by the system. Although the table-lookup scheme of the fuzzy inference system will require retuning, the tremendous computational time and power previously used for the training of the three neural networks will be saved.

The main limitation of our approach, which is actually a realistic constraint, concerns the size of the ECG signal database used. Although much effort was employed by a consultant cardiologist and electrophysiologist, Dr. Razali Omar [61], to manually scan through the whole MIT-BIH arrhythmia databank [13] for the various abnormalities such as STDP, TINV, SVT and NSR [13], the resulting database of extracted signals was understandably small, since these signals are difficult to be found due to the noisiness of the raw ECG signals. Therefore, only 6 samples of ECG signals were selected from each of the three pathological groups and the normal group summing up to 24 samples of ECG signal. We had only trained the classification system with 12 patients' ECG for the four types of signals such as STDP, TINV, SVT and NSR, each one consisting of 3 samples.

Cross-validation techniques were not adopted in our original training since they were not expected to produce better results [105] than a simple train and test procedure, given the particular non-linearities of the problem.

8.2 Future Works Recommendation

In the pre-processing of ECG signals, we applied the traditional windowing and features extraction algorithm to generate the time invariant input patterns for the MLPN. The windowing and features extraction algorithm could be error-prone if the ECG signals are highly contaminated with noise. Hence, a Time Delay Neural Network (TDNN) structure is proposed to recognize the time varying input patterns without resorting to any features extraction algorithm.

Classical neural models tend to exhibit low memory capacity. This problem can be overcome by replacing each classical neuron by an artificial neuron with Quantum Mechanical Properties. Quantum computation uses microscopic quantum level effects to perform computational tasks and has produced results that in some cases are exponentially faster than their classical counterparts. Choosing the best weights for a neural network is a time consuming problem that makes the harnessing of this "quantum parallelism" appealing [105]. A model for a quantum neuron is recommended and is described in Section 8.4. Quantum neurons probably reflect the tendency to replace multi-class classical neural systems by (i) a single-class and (ii) by single-pattern systems, which are trained by using one example only. For pattern association it is sufficient to use a single quantum neuron. This exponential reduction in resources is the result of the use of quantum superposition. The simplest view of the model of quantum neuron can be obtained if we forget about the division of the weight set into the input and additional weights. Then the quantum neuron can be thought as a generalization of the model of a classical neuron with binary weights. The quantum analogue of this classical neuron has quantum weights represented by qubits, which are generally in a superpositional state as shown in Figure 7.2. It is sufficient to generalize only the model of classical neuron with binary weights, because only single-pattern systems can be considered. Therefore, it is important to stress that the elimination of the need to build a network using the quantum approach solves the difficult technological problem of wiring neurons in a network, which complicates the physical implementation of classical neural system.

With incorporation of the power of quantum computation, many ECG waveforms of various substructures of abnormalities may be partitioned into more homogeneous groups in the clustering stage. But eventually this phenomena will burden or breakdown the fuzzy inference system at the classification stages. It may so happen that the number of rules that have been generated are very high and may even exceed the number of patterns that have been used to generate the rules. It is possible that a subset of rules classifies the entire set of patterns, or that a subset of rules classifies a specific subset of patterns which are again classified by a different subset of rules. In such a scenario, we go for minimization over the original set of rules that have been generated. But to do this, we need to know which rules classify which patterns. Then we select the smallest set of rules that classifies all the training patterns. This means finding the minimum cover of a finite set which is computationally very expensive. So, we will use an approximate but effective technique to get a reasonably small set of rules. Such a procedure is to retain rules that classify more points only. This is very reasonable as for example, if a rule classifies just one point, then that rule is not expected to have much generalization capability.

In the context of engineering and computer science literature, artificial neural network research has stressed pattern recognition and input-output maps. The development of machines that can match biological information processing requires much more than just pattern recognition. Neural network research is now beginning to deal with questions of organization, awareness and consciousness. This constitutes an important frontier where the concerns of neurophysiologists, computer scientists, psychologists have come together.

But these studies have been largely unsuccessful in explaining the synthetic part of cognition. On the other hand, quantum or holistic models related to a neural system have not been equally well studied. But the recent rise of interest in quantum neural computation is due to some of the favourable characteristics of such a model as described in the following [107, 108]:

1) It explains intuition, or the spontaneous computation of the kind performed in a creative moment, as has been reported by Poincare, Hadamard and Penrose [106].

2) A wave function that is a sum of several component functions explains why the free-running mind is a succession of unconnected images or episodes. The classical neural model does not explain this behaviour.

3) One can admit the possibility of tunnelling through potential barriers. Such a computer can then compute global minima, which cannot be done by classical neural computer, unless by the artifice of simulated annealing. (The simulated annealing algorithms may not converge.)

4) Non-local effects of quantum dynamics may be at the basis of the communication between conscious individuals.

5) Being a linear sum of a large (or infinite) number of terms, the individual can shift the focus to any desired context by the application of an appropriate measurement hardware that has been designed through previous exposure (reinforcement) or through inheritance. Such a shifting focus is necessary in speech or image understanding.

Since the use of quantum computing will enable new advances previously thought impossible in the field of artificial intelligence, therefore attempting to apply quantum computing to medical diagnosis support system might provide the right fodder for researchers within the biomedical community.