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Adaptive Neuro-Fuzzy Inference System for diagnosis risk in dengue patients

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ABSTRACT

Dengue disease is considered as one of the life threatening disease that has no vaccine to reduce its case fatality. In clinical practice the case fatality of dengue disease can be reduced to 1% if the dengue patients are hospitalized and prompt intravenous fluid therapy is administrated. Yet, it has been a great challenge to the physicians to decide whether to hospitalize the dengue patients or not due to the overlapping of the medical diagnosis criteria of the disease. Beside that physicians cannot decide to admit all patients because this will have major impact on health care cost saving due to the huge incident of dengue disease in the country. Even if the physicians managed to identify the critical cases to be hospitalized, most of the tools that have been used for monitoring those patients are invasive. Therefore, this study was conducted to develop a non-invasive accurate diagnostic system that can assist the physicians to diagnose the risk in dengue patients and therefore attain the correct decision. Bioelectrical Impedance Analysis measurements, Symptoms and Signs presented with dengue patients were incorporated with Adaptive Neuro-Fuzzy Inference System (ANFIS) to construct two diagnostic models. The first model was developed by systematically optimizing the initial ANFIS model parameters while the second model was developed by employing the subtractive clustering algorithm to optimize the initial ANFIS model parameters. The results showed that the ANFIS model based on subtractive clustering technique has superior performance compared with the other model. Overall diagnostic accuracy of the proposed system is 86.13% with 87.5% sensitivity and 86.7% specificity.

1. Introduction

Dengue is an acute, febrile infection widespread in many tropical and subtropical regions of the world. In Malaysia dengue is considered as endemic since 1971 (Ministry of Health Malaysia, 1974). The burden of the disease has increased dramatically. From the first major epidemic of dengue severe manifestations in 1973, the incidence of dengue has increased by 48-fold in 2008 whereby 49,335 dengue cases were reported (Ministry of Health Malaysia, 2008).

Some of the dengue patients might recover spontaneously while others face critical plasma loss which leads to death. If dengue vaccine is available, the burden of the disease would be reduced. Yet, no any effective vaccines or antiviral drugs exist for dengue infection (World Health Organization, 1997). In clinical practice without the vaccine, the fatality of the disease still can be reduced to less than 1% by closely monitoring the dengue patients to detect the onset of plasma leakage and provides prompt intravenous fluid replacement (Ng, Lum, Ismail, Tan, & Tan, 2007; World Health Organisation, 2009). However, two main difficulties can face the implementation of this method. Firstly the decision to admit the dengue patients to monitor their plasma leakage has been a great challenge for the physicians due to the overlapping of the medical classification criteria of dengue disease (Bandyopadhyay, Lum, & Kroeger, 2006; Phuong et al., 2004). On the other hand, physicians cannot decide to admit all patients because this will have major impact on health care cost saving due to the huge incident of dengue disease in the country. Secondly even if the physicians managed to identify the critical cases to be hospitalized, monitoring the onset and progression of plasma leakage requires either measure the total increase in hematocrit (Hct) and hemoglobin (Hb) (World Health Organization, 1997) or monitor patients' platelet count and liver function status (Kuo et al., 1992). However, these techniques are invasive and can be potentially risky to the Dengue Hemorrhagic Fever (DHF) patients since it require frequent blood drawn from the patients which causes further injury to their subcutaneous tissue (Ibrahim, Taib, Abas, Guan, & Sulaiman, 2005).

Few studies have proposed non-invasive systems to diagnose the risk in the patients infected by the dengue virus. Studies conducted by Ibrahim et al. (2005) utilized the Bioelectrical Impedance Analysis (BIA) technique to monitor and classify the daily

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risk in DHF patients. The results demonstrated that the Reactance (one of the Bioelectrical Impedance parameters) is a potential tool to classify the risk in DHF patients. Based on this findings Ibrahim, Faisal, Salim, and Taib (2010) employed the reactance and dengue patients' data includes day of fever, gender to classify the risk on dengue patients by using Artificial Neural Networks (ANN). The results showed that the system achieved 96.27% prediction accuracy. However, this result subjected to 25% error. Moreover, there is no any validation technique was implemented in this study to eliminate the bias associates with the random sampling of the training and testing data. Faisal, Taib, and Ibrahim (2010a) employed the combination of the self-organizing map and multilayer feed-forward neural networks to predict the risk in dengue patients. Only 70% prediction accuracy was achieved by using the proposed model. Another study conducted by Faisal, Taib, and Ibrahim (2010b) to develop a dengue patients' diagnostic system based two multilayer perceptron neural networks trained via Levenberg–Marquardt and Scaled Conjugate Gradient algorithms. Diagnosis accuracy of 75% has been achieved for classifying the risk in dengue patients using Scaled Conjugate Gradient algorithm while 70.7% diagnosis accuracy were achieved by using Levenberg–Marquardt algorithm. Even though, the findings from those studies might assist the physicians for diagnose the risk in dengue patients, however, the accuracy of the systems is not too satisfactory to be utilized in practice for life threatening diseases such as dengue disease.

In order to overcome this difficulties, there is a crucial need for an accurate non-invasive diagnostic system that is capable to diagnose the dengue patients according to their risk level in order to assist the physician to decide whether to hospitalize the dengue patients or not. Such system not only reduces the burden and the fatality of dengue disease but also reduce the number of unnecessary hospital admissions of dengue patients which leads to substantial the saving costs on the health care sector and overall economy.

Therefore, this study was conducted to develop a non-invasive accurate diagnostic system that can assist the physicians to determine the dengue patients' level of risk and therefore attain correct decision. Adaptive Neuro-Fuzzy Inference System (ANFIS) incorporated with Bioelectrical Impedance Analysis measurements and Symptoms/Signs presented with dengue patients were employed to construct the diagnostic model.

2. Adaptive Neuro-Fuzzy Inference System (ANFIS)

The development of the computerized decisions making system in medical domain is rather difficult due to their uncertainty which arises as a natural occurrence. In such situation fuzzy set theory appears as an appropriate tool for decisions making system since its deals with uncertainty by applying our knowledge and experience directly without explicit any mathematical models. Fuzzy logic describes human thinking and reasoning in a mathematical framework by using rule base (IF–THEN) which require a good deal of human experts to define them carefully. Successful implementations of Fuzzy logic in various applications have been reported, however, there are some basic aspects of fuzzy system which are in need of better understanding. Firstly, the need of a standard method for transforming human knowledge or experience into the rule base and database of a fuzzy inference system. Secondly, the need for effective methods for tuning the membership functions (Jang, 1993). Based on those needs, Jang proposed ANFIS to serve as a basis for constructing a set of fuzzy if then rules with appropriate membership functions to generate the stipulated input–output pairs in 1993 (Jang, 1993).

ANFIS was implemented successfully in several biomedical applications including predicting the behavior of cancer (Catto, Abbod, Linkens, & Hamdy, 2006), prostate cancer (Benecchi, 2006), detection of epileptic seizure in the Electroencephalography (EEG) signal (Subasi, 2007), intensive care applications (Kwok, Linkens, Mahfouf, & Mills, 2003), detection of internal carotid artery stenosis and occlusion (Ubeyli & Guler, 2005), classification of Electrocardiography (ECG) signals (AL-Bokhity, Nazmy, & EL-Messiry, 2010), Electromyography (EMG) applications (Khezri & Jahed, 2007), predicting the occurrence of gait events (Lauer, Smith, & Betz, 2005), diagnosis of renal failure disease (Akgundogdu, Kurt, Kilic, Ucan, & Akalin, 2009).

2.1. ANFIS structure

Adaptive Neuro-Fuzzy Inference System (ANFIS) (Jang, 1993; Jang, Sun, & Mizutani, 1996) is fuzzy system that uses ANN's theory to determine its properties (fuzzy sets and fuzzy rules). It utilizes the mathematical properties of ANN to tune the rule-based fuzzy system such as the fuzzy membership function parameters are extracted from the features of the data set that describes the system behavior.

If we consider the fuzzy inference system with two inputs x and y and one output z, then the first order Sugeno fuzzy model with two rule set can be represent as follow:

$$\begin{aligned} &\text{If } x \text{ is } A_1 \text{ and } y \text{ is } B_1, \text{then } f_1 = p_1x + q_1y + r_1 \\ &\text{If } x \text{ is } A_2 \text{ and } y \text{ is } B_2, \text{then } f_2 = p_2x + q_2y + r_2 \end{aligned} \quad (1)$$

The ANFIS architecture representation for this system is as shown in Fig. 1. (Jang, 1993; Jang et al., 1996).

The nodes in the same layer have similar functions. The output of the ith node in layer 1 is denoted as $O_{l,i}$. The output from each layer can be representing as follow:

2.1.1. Layer 1

The nodes in this layer are adaptive nodes. The output of each node can be representing as:

$$O_{1,i} = \mu_{A_i}(x) \quad \text{for } i = 1, 2, \text{ or } O_{1,i} = \mu_{B_{i-2}}(y) \quad \text{for } i = 3, 4, \quad (2)$$

The $O_{1,i}(x)$ is membership grade of the fuzzy set $A = (A_1, A_2, B_1 \text{ or } B_2)$ and its specifies the degree to which the given input x or y satisfies the quantifier A. The membership function can be any one of the given membership functions below:

Bell shaped function

$$\mu_A(x) = \frac{1}{1 + \left|\frac{x-c_i}{a_i}\right|^{2b_i}} \quad (3)$$

Gaussian shaped function

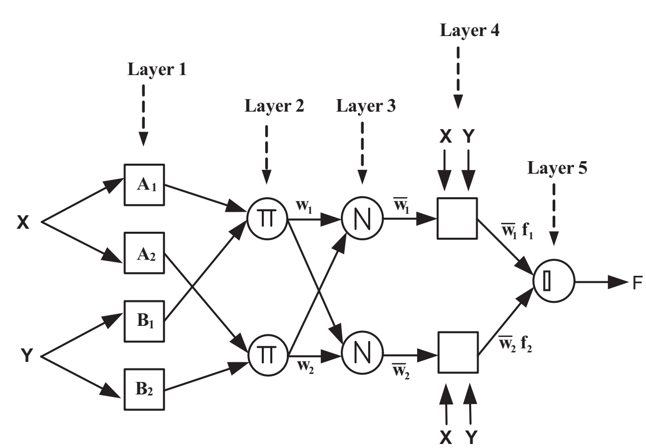

Fig. 1. ANFIS architecture.