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

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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 physiciansmanaged 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 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.

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).

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.

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