A noninvasive intelligent approach for predicting the risk in dengue patients

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Introduction

Dengue virus is arthropod-borne flavivirus that is widespread in many tropical and subtropical regions of the world (Gubler, 1998, 2002; Hales, de Wet, Maindonald, & Woodward, 2002; Monath, 1994; World Health Organization, 1997). According to the WHO classification, dengue infection is classified as dengue fever (DF) and dengue haemorrhagic fever (DHF)/dengue shock syndrome (DSS). DF is a self-limited illness that begins with a sudden temperature increase accompanied by headache, myalgia, macular rash, loss of appetite, nausea, vomiting, abdominal pain, metallic taste of food, change in psychological state and moderate thrombocytopenia (Gubler & Kuno, 1997). Due to the increase in the vascular permeability, some of DF patients might progress to DHF patients, who presents with some form of the haemorrhagic manifestations. According to the WHO, the criteria of DHF are fever, haemorrhagic tendencies, thrombocytopenia and haemoconcentration. Moreover, the WHO subdivides DHF into four categories: DHFI, DHFII, DHFIII and DHFIV. The positive tourniquet test is the only haemorrhagic manifestation of grade I, while grade II presents with spontaneous bleeding. Grade III has signs of circulatory failure, while grade IV presents with circulatory failure signs. Both grade III and IV are considered as DSS.

Recently, some studies showed that several difficulties have been faced by the clinicians to apply the WHO classification criteria (Bandyopadhyay, Lucy, & Kroeger, 2006; Xuan et al., 2004). A study conducted by Bandyopadhyay et al. (2006) reviewed the literature published between 1975 and 2005 for the classification of dengue disease suggested that the WHO criteria needs to the re-visiting. The difficulties reported by the clinicians to apply the four criteria of the DHF cases were the reason behind this suggestion. Another study (Xuan et al., 2004) declared that no validation of the WHO system has been attempted yet due to the absence of an independent diagnostic marker. Moreover, the overlapping in the major clinical features that differentiate DF from DHF makes the classification of dengue patients difficult. The study suggested that urgent research is needed in order to understand the pathophysiologic mechanisms underlying the various clinical manifestations seen in dengue infections.

Due to above-mentioned difficulties that have been faced by the implementation of the WHO system, many descriptive statistical studies were proposed and implemented different risk criteria or risk factor for the classification of dengue patients (Chai, Goh, Chan, el_Amin, & Lam, 2002; Ibrahim, 2005; Ibrahim, Taib, Wan Abas, Chan, & Sulaiman, 2005a; Kalayanarooj et al., 1997; Narayanan, Aravind, Ambikapathy, Prema, & Jeyapaul, 2003; Shivbalan, Anandnathan, Balasubramanian, Datta, & Amalraj, 2004; Tantracheewathorn & Tantracheewathorn, 2007).

In conjunction with the medical knowledge, the biomedical engineering perception was enrolled to assist the clinicians for predicting and investigating the risk in dengue patients (Abdul Rahim, Ibrahim, & Taib, 2006; Faisal, Ibrahim, & Taib, 2008a, 2008b; Ibrahim, 2005; Ibrahim, Taib, Wan Abas, Chan, & Sulaiman, 2005b). The involvement of biomedical engineering was enrolled through bioelectrical impedance analysis (BIA) and artificial neural network (ANN).

BIA is a technique that evaluates the human body composition by passing tiny current through the human body. It has been used in dengue disease to classify the risk in DHF patients (Ibrahim, 2005; Ibrahim et al., 2005a). The results showed that reactance is a potentially useful tool for classifying the risk factor of DHF patients.

ANN is a well established technique used widely in biomedical applications for modeling, analysis and diagnostic classification (Engin et al., 2007; Gil, Johnsson, Manuel, Soriano, & Ruiz, 2008; Icer, Kara, & Guven, 2006; Qiu, Tao, Tan, & Wu, 2007). Two types of artificial intelligence techniques were implemented in dengue disease field: supervised learning, namely, multilayer feed-forward neural networks (MFNN) (where the inputs and the outputs will be provided to the network for the training purpose) and unsupervised learning technique, namely, self-organizing map (SOM) (where only the inputs will be given). Ibrahim et al. (2005b) proposed a noninvasive prediction system for predicting the day of defervescence of fever in dengue patients using supervising learning. The study used the clinical symptoms and signs for predicting the day of defervescence of fever via MFNN. Ninety percent prediction accuracy was achieved in this study. Another study conducted by Abdul Rahim et al. (2006) was able to predict and model the haemoglobin concentration status in dengue patients using the linear autoregressive model (AR); with an accuracy of 76.70%.

SOM technique is an aid for visualizing, analyzing and understanding the complexity of high-dimensional data. It maps the data into a simple low-dimensional display to simplify the observation of the complexity of the data. In dengue disease, the SOM was used to identify the significant prognosis factors that discriminate between the dengue patients and the healthy subjects (Faisal et al., 2008b). Moreover, the study conducted by Faisal et al. (2008a) employed SOM to obtain the significant risk criteria that can differentiate the dengue patients

Precise and efficient prediction of the level of risk in dengue is critical for clinical care, surveillance and lifesaving. Accordingly, the scope of the difficulties in dengue disease that most of the studies addressed includes the definition of the risk criteria in dengue disease and the prediction of the risk in dengue patients. Even though significant results were showed from some studies, a complete, systematic approach for predicting the risk in dengue disease has never been published yet.

This study presents the development of a noninvasive intelligent approach for predicting the risk in dengue patients. A combination of the SOM and MFNN was employed for this task. First, the SOM was employed for determining the correlated risk predictors from the clinical manifestations (symptoms/signs) and the bioelectrical impedance analysis (BIA) parameters, whereas the MFNN was used for constructing the prediction model using the correlated risk parameters.

Methods

Multilayer perceptron (MLP)

Generally, multilayer perceptron (MLP) consists of three main layers: input, hidden and output layers. Each layer is composed of a number of neurons chosen according to the system requirement. Generally, the number of the neurons in the input layer and the output layer is constantly predefined in such a way that they represent the numbers of inputs and the outputs of the system, respectively. The number of neurons in the hidden layer is variable, and it is be set experimentally. The neurons in all layers are fully connected through varying weights as shown in Fig. 1.

Initially, a set of data comprising input–output pairs, known as training data, are given to the network. The principle of the network is that when the inputs are presented to the first layer, the outputs are calculated for each consecutive layer. By comparing the last layer outputs and the desired outputs, the error is calculated. The training iterations or the learning process takes place by adjusting the values of the weights until an adequately small value of the error is obtained.

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