Neural network diagnostic system for dengue patients risk classification

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Introduction

Dengue virus, a mosquito-borne human viral pathogen, has recently become the most common arboviral infection in many tropical and subtropical regions of the world [1–3]. The worldwide threatens of Dengue virus has increased dramatically. Annually, the World Health Organization (WHO) estimated of 100 million cases of dengue fever (DF) occurs and between 250,000 to 500,000 cases of dengue hemorrhagic fever (DHF) [3]. In Malaysia, dengue disease is a major public health problem. It has dramatically increased since the first major outbreak occurred in 1973 [4]. In 1995, 6543 cases were occurred. This number was significantly increased in 2008 by 75.4% with 122 deaths [5].

Currently no any effective vaccines or antiviral drugs exist for dengue infection [3]. Although some of the dengue patients might recover spontaneously, others faced critical plasma loss and they require proper intravenous fluid therapy so that they can be prevented from death.

Two ways have been followed to reduce the severity of the disease: closely monitoring the dengue patients or accurately diagnosis the dengue patient to determine the risk level.

By monitor dengue patients the onset of plasma leakage can be detected so that prompt intravenous fluid replacement can be administered [6]. However, this will have major impact on health care cost saving due to the huge incident of dengue fever in the country. On the other hand, accurately diagnosis the dengue patients to determine the risk level has been a great challenge for the physicians due to the overlapping of the medical classification criteria for classifying the dengue patients.

Few studies have been conducted to overcome these issues from the engineering prospective [7–11] F. Ibrahim et al., 2005a, 2005b [7, 8] utilized the Bioelectrical Impedance Analysis (BIA) technique for monitoring and classifying the daily risk in DHF patients. The results demonstrated the capability of the reactance for classifying the risk in DHF patients. F. Ibrahim et al., 2005c [9] employed the clinical symptoms and signs for predicting the day of defervescence of fever in dengue patients incorporated with artificial neural network (ANN). The study achieved 90% prediction accuracy for predicting the day of defervescence of fever. Tarig et al. [10] reexamined the risk criteria in dengue patients using self organized map. Three risk criteria were defined to classify the risk in dengue patients. The risk criteria were able to classify the dengue patients as high risk and low risk patients. Another study conducted by T. Faisal et al. [11] proposed a noninvasive intelligent technique for predicting the risk in dengue patients. A combination of the self-organizing map (SOM) and multilayer feed-forward neural networks (MFNN) were employed for this task. However, only 70% prediction accuracy was achieved by using the proposed model.

Designing a noninvasive medical diagnostic system to classify the risk in dengue patients utilizing a Multilayer perceptron (MLP) neural network trained via Levenberg-Marquardt algorithm (LMA) or Scaled Conjugate Gradient algorithm (SCGA) has never implemented in dengue disease field even though it has been successfully used in several medical applications for classifying and predicting several diseases [12–15]. Most of the medical applications that utilized those algorithms have been relied on the fact that those algorithms are fully automated including no any learning factors need to be modified apart from the number of the neurons and the iterations. However, some other significant parameters are included in those algorithms can be optimized to achieve the highest performance.

Therefore, this study aimed to construct a diagnostic system for classifying the risk in dengue patients. Clinical symptoms, signs and BIA measurements presented with the dengue patients were used as the predictors for constructing the diagnostic system. The significant predictors were obtained based on the statistical analyses technique. The system employed the SCGA and LMA for constructing the MLP network models. All the internal parameters included in those algorithms were precise tuned in order to achieve the highest performance from the diagnostic models. Finally, the models were evaluated and some conclusions were drawn concerning the models performances.

Dengue fever and dengue haemorrhagic fever

Dengue infection has been classified by the World Health Organization as dengue fever (DF) and dengue haemorrhagic fever (DHF)/dengue shock syndrome (DSS). DF 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. Due to the increase in the vascular permeability, significant number of DF patients might progress to dengue haemorrhagic fever (DHF). DHF patients present with some of the haemorrhagic evidence. The first sign of DHF is Fever or history of acute fever lasting 2–7 days [3]. Second sign is the Hemorrhagic tendencies evidenced by at least one of the following: a positive tourniquet test (TT), petechiae, purpura, ecchymoses; bleeding from mucosa, gastrointestinal tract, injection sites or other location; haematemesis or melena. Third sign is Thrombocytopenia (100,000 cells per mm^3or less). Finaly, Haemoconcentration (20% or more rise in the haematocrit (Hct) value relative to baseline average for the same age, sex and population) or sings of plasma leakage such as pleural effusion, ascites and hypoproteinaemia. Furthermore, the WHO classified DHF patients into four categories: DHF I, DHF II, DHF III, DHF IV. DHF I is DF patient who has fever and hemorrhagic manifestation (indicated by only positive tourniquet). DHF II is the DF patient who has spontaneous bleeding plus the manifestations of DHF I. DHF III is the DF patient who has the signs of circulatory failure (rapid/weak pulse, narrow pulse pressure, hypotension, cold/clammy skin). Finally, DHF IV is a DF patient who profound shock with undetectable blood pressure or pulse. Both DHF III and DHF IVare considered as DSS. Even thoughWHO classification criteria have been used for long time, recent studies have shown that several difficulties have been faced by the clinicians to apply these criteria [10]. Therefore, in this study the dengue patients were classified by the risk criteria proposed by Tarig et al. [10]. The study proposed three risk criteria:

1- Platelet counts (PLT) less or equal than 40,000 cells per mm^3.
2- Hematocrit concentration (HCT) great than or equal 25%.
3- Aspartate aminotransferase (AST) rose by 5-fold the normal upper limit for AST or alanine aminotransfansferase (ALT) rose by 5-fold the normal upper limit for ALT.

Based on those criteria, the dengue patients were classified as high risk patients or low risk patients. High risk patients are the dengue patients who experienced at least two risk criteria whereas low risk patients are the dengue who experienced less than two risk criteria

Multilayer perceptron MLP

Generally, multilayer perceptron (MLP) contains three main layers: input layer, hidden layer, and output layer. Each layer composes of number of neurons. The number of neurons in each layer is chosen according to the system requirement. The number of the neurons in the input and the output layers corresponds to the number of the system inputs and the outputs respectively. The number of neurons in the hidden layer should be set experimentally (try and error) based on the desired system performance. The neurons in all layers are fully connected through varying weights as it's shown in Fig. 1.

Initially, two sets of data are given to the network: the inputs and the desired outputs. The principle of neural 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 with the desired outputs, the error is calculated. The learning process takes a place by adjusting the values of the weights until an adequately small value of the error is achieved or a given number of iterations are completed.

The calculation of the neural network output is carried out according to the following procedures:

Full text is available at :

http://link.springer.com/article/10.1007/s10916-010-9532-x