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Model Order Selection Criterion for Monitoring Haemoglobin Status in Dengue Patients using ARX Model

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Abstract - **This paper describes the development of linear autoregressive with exogenous input (ARX) models to monitor the progression of dengue infection based on hemoglobin status. Three differents ARX model order selection criteria namely Final Prediction Error (FPE), Akaike's Information Criteria (AIC) and Lipschitz number have been evaluated and analyzed. The results showed that Lipschitz number has better accuracy compared to FPE and AIC. Finally based on Lipschitz number, appropriate model orders have been selected to monitor the progression of dengue patients based on hemoglobin status. Further work is to apply this appropriate model orders to nonlinear Autoregressive (NARX) model.**

I. INTRODUCTION

Dengue hemorrhagic fever (DHF) is an infection associated with an increase in microvascular permeability, a decrease in plasma volume, an in severe forms hypotension and shock [1, 2]. A significant percentage of DF patients develop a more severe form of disease, known as dengue hemorrhagic fever (DHF). DHF is an infection associated with an increase in micro vascular permeability, a decrease in plasma volume, and in severe forms hypotension and shock [3]. In order to monitoring the risk in DHF patients, two conventional techniques are using. First technique is monitoring the onset and progression of plasma leakage by measuring the total increase in hematocrit (Hct) (over 20%) or hemoglobin (Hb) concentration (Hb above the upper normal range limit) [3]. Second conventional method for monitoring the risk in DHF patients is to monitor their platelet count [3]. These techniques are considered as invasive, tedious, and time-consuming. Furthermore, frequent blood taking will cause further injury to the subcutaneous tissue and potentially risky to the DHF patients [4]. Ibrahim et al [5] has introduced a new approach in modeling the Hb non-invasively using bioelectrical impedance analysis (BIA) technique. This model seems promising, however, its prediction accuracy is low and can be improved using an advanced signal processing.

Parameter estimation or system identification of continuous-time systems is an important subject and has numerous applications ranging in control, signal processing, astrophysics and economics [1]-[7]. This is because most physical systems or phenomena are continuous time in nature. In spite of this, due to the advent of digital computers, research of control and identification of these continuous-time system and process has concentrate on their discretized models with the samples from the underlying continuous-time system inputs and outputs. One particular interesting and practical scenario is the identification-time systems using discrete data.

The purpose of this paper is to analyze the performance of three different types of order selection criteria for linear autoregressive with exogenous (ARX) models. This linear ARX models is used to monitor the progression of dengue patients based on hemoglobin status.

II. AUTOREGRESSIVE WITH EXOGENOUS INPUT (ARX) MODELS

The model equation can express as:

$$G(z,p)=\frac{B(z)}{A(z)}, \qquad H(z,p)=\frac{1}{A(z)} \tag{1}$$

where

$A(z)=1+a_1z^{-1}+...+a_{n_a}z^{-n_a}$

$B(z)=b_1z^{-1}+...+b_{n_b}z^{-n_b}$

G(z,p) and *H(z,p)* are filters of finite order and functions of a parameter vector *p*,

$p=[a_1...a_{n_a} \quad b_1...b_{n_b}]^T$

In this form, the white noise term, $\varepsilon(t)$ enters the difference equation as a direct error. Figure 1 shows the ARX model structure.

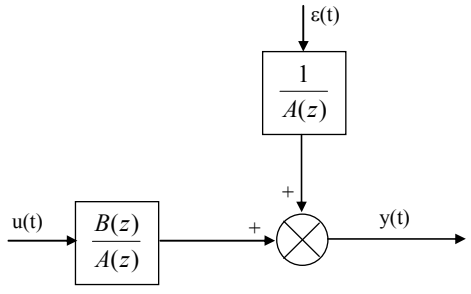

Fig.1: The ARX model structure

Final prediction error (FPE) and Akaike's Information Criteria (AIC) are based on mathematical statistics by Akaike [8]. The FPE minimizes the following function:

$$FPE = s^2 p \ \frac{N + p + 1}{N - p - 1} \tag{2}$$

where p is the model order, N is the number of data points, s^2p is the total squared error divided by N and is given by:

$$s^2 p = \frac{1}{N} \sum_{p}^{N-1} e^2(n) \tag{3}$$

The fractional portion of FPE increases with p and as such represent the inaccuracies in estimating the AR parameters. While the AIC minimizes the following function:

$$AIC = N \ln s^2 p + 2p \tag{4}$$

The term $2p$ represents the penalty for higher orders.

Another criterion is Lipschitz and in the noise free case it is sometimes possible to determine the lag space (number of past inputs and outputs) automatically. The model order is given as:

$$q^{-n} = \left(\prod_{k=1}^{p} \sqrt{nq}^{(n)} (k) \right)^{\frac{1}{p}} \tag{5}$$

III. RECEIVER OPERATING CHARATERISTIC (ROC) CURVE

ROC curves display the relationship between sensitivity (true positive rate) and 1-specificity (false positive rate) across all possible threshold values that define the positivity of a disease. They show the full picture trade-off between true positive rate and false positive rate at different levels of positivity. The ANN must be trained before the ROC curve can be generated. The resulting network is referred to as a "basic trained network". This initial instance of the ANN provides one operating point. The result is a set of instances of the network chosen to represent a point on the ROC curve. The goodness of this set of network instances are then evaluated using separate test data. Sensitivity and specificity are the basic measures of the accuracy of the diagnostic test. They describe the abilities of the test to enable one to correctly diagnose disease when the disease is actually present and to correctly rule out disease when it is truly absent. The accuracy of a test is measured by comparing the results of the test to the true disease status of the patient. Sensitivity and specificity depend on the threshold (also known as 'operating point' or 'cut point') used to define positive and negative test results. As the threshold shifts, the sensitivity increases while the specificity decreases, or vice versa.

The closer the ROC curve is to 1.0, the better the diagnostic test [9]. The percentage for diagnostic accuracy (DA) refers to the percentage of samples that have been correctly diagnosed. In any test with a fixed threshold, it is desirable for a decision model to produce TPR and FPR pair nearby this point. Therefore, measurement of *Euclidean Distance* (*ED*) of any coordinate pairs in the plot to this ideal point would distinctively differentiate performance between models for a fixed threshold. Calculation of this *ED* from any coordinate pair can be defined as:

$$ED = \sqrt{(TPR - 1)^2 + FPR} \tag{6}$$

Rough guides for classifying the accuracy of diagnostic test are as defined in Table 1.

TABLE 3.1:
ACCURACY OF DIAGNOSTIC TEST USING ROC

AUC	Accuracy
0.90 - 1.00	excellent
0.80 - 0.90	good
0.70 - 0.80	fair
0.60 - 0.70	poor
0.50 - 0.60	fail

IV. METHODS

The dengue data was obtained from Ibrahim, F [6]. According to [6], since the patients were admitted at different stages of their illness, the daily progress of the patients were dated with reference to the day fever subsided. 'Hence, 'fever day 0' is defined as the day of fever subsided when the body temperature fell below 37.5°C. Days prior to fever day 0 were designated as fever day –1 (1 day before fever subsided), *etc.* Days after the fever subsided is designated as fever day +1 (1 day after fever subsided), fever day +2, and onwards [7]. Previous study conducted by Ibrahim *et. al*. [5] found that four significant predictors to model Hb concentration status in dengue patients (gender, weight, reactance (Xc) and vomiting) using multivariate analysis. The model [8, 9] has been improved by Abdul Rahim, H *et. al*. [9] in the application of linear autoregressive model (AR) model using five predictors.

These input variables were used to determine the order of ARX model. Orders of the ARX model chosen in this analysis are FPE, AIC and Lipschitz.

The accuracy value of hemoglobin based on model fitted was observed to evaluate the ability of the 3 different models order selection criteria chosen.

V. RESULTS

The system is a multi-input single-output (MISO) system. The model order for the 3 different types of models order selection criteria in autoregressive (ARX) models have been fixed.

First, the model order was chosen with three different types of order selection criteria in ARX model. Figures 2, 3 and 4 illustrate Lipschitz number , FPE criterion and AIC criterion plots for five input variables of dengue patients and show the value of the model order (p=4), (p=15) and (p=25), respectively.

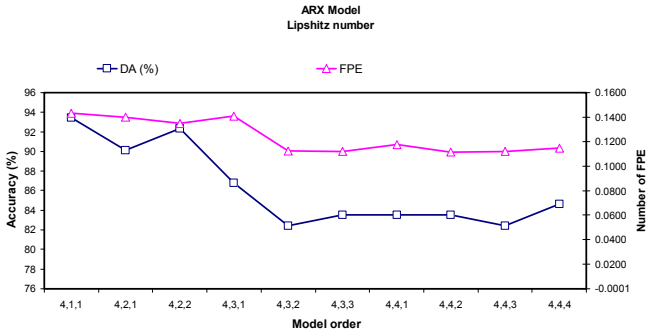

Fig.2: Plot of diagnostic accuracy and FPE against the number of model order using Lipschitz number criteria via ARX model

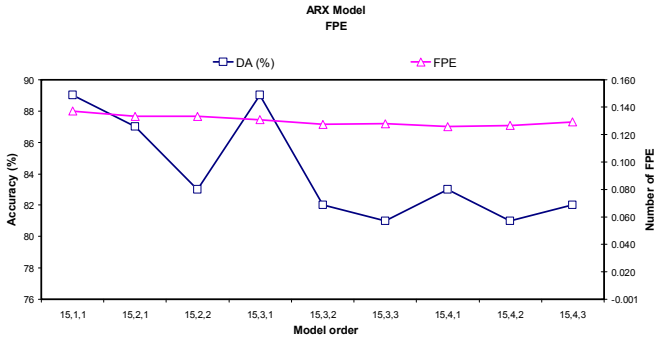

Fig.3: Plot of diagnostic accuracy and FPE against the number of model order using FPE model order criteria via ARX model

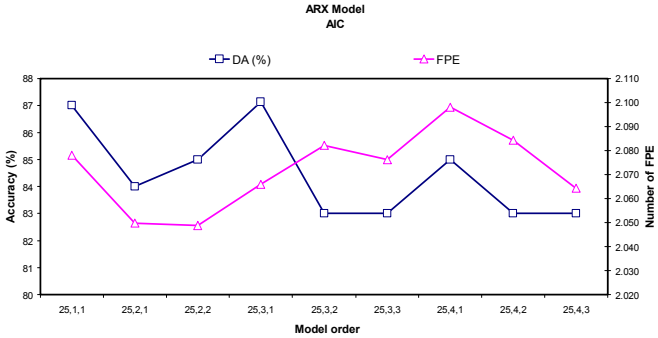

Fig.4: Plot of diagnostic accuracy and FPE against the number of model order using AIC model order criteria via ARX model

After the model order had been selected, the next stage is to find the percentage of AUC in different types of model order.

The ROC curve for the ARX model is shown in Figure 5. The closest ED is depicted from the ideal point (0,1) as 0.154 when the optimized model has a threshold of 0.5. The FPE model order criterion, the closest ED is depicted from the ideal point (0,1) as 0.237 when the optimized model has a threshold of 0.4 as shown in Figure 6. The AIC model order criterion, the closest ED is depicted from the ideal point (0,1) as 0.250 when the optimized model has a threshold of 0.5 as shown in Figure 7.

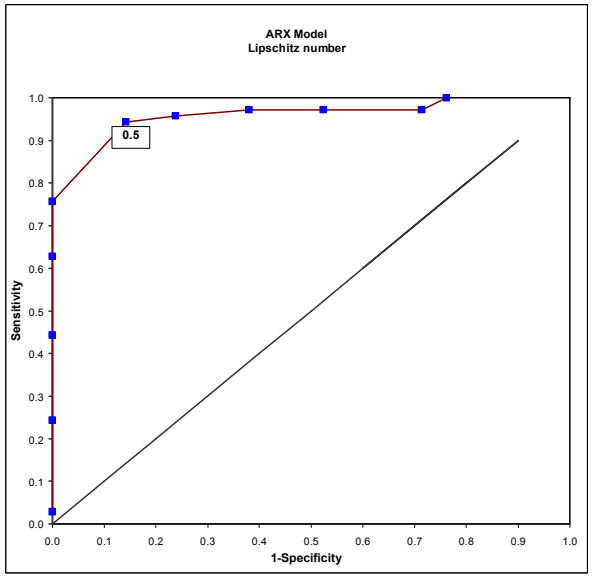

Fig.5: ROC curve for ARX model using Lipschitz number criterion

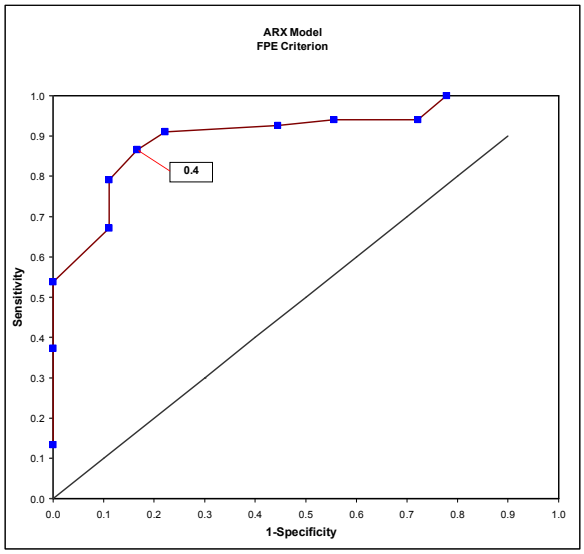

Fig.6: ROC curve for ARX model using FPE model order criterion.

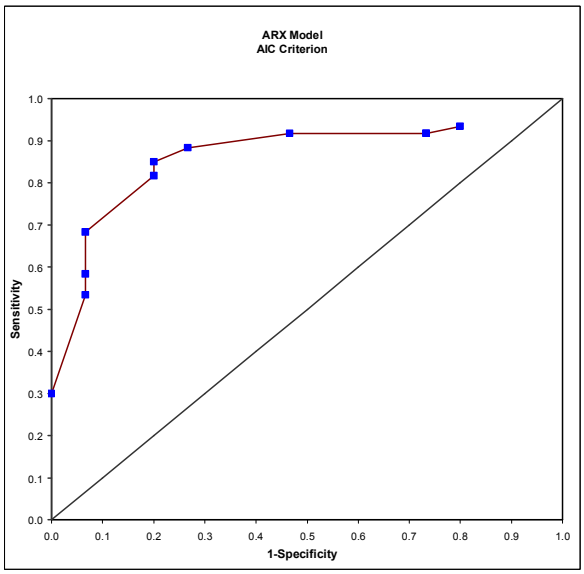

Fig.7: ROC curve for ARX model using AIC model order criterion

Table 2 shows the AUC of ARX model with the different model order criteria. Based on the AUC percentage value, it was found that the Lipschtiz number criterion produces the highest accuracy (71.80%) for the ARX model.

TABLE 5.1
THE DIAGNOSTIC PERFORMANCE OF ARX MODELS WITH THE DIFFERENT MODEL ORDER CRITERIA

Criterion	Model order	AUC (%)
Lipschitz	4,2,2	71.8
FPE	15,3,1	68.0
AIC	25,3,1	67.1

In order to evaluate the best model for dengue infection diagnosis all these AUC and summarized in Table 3, based on sensitivity, specificity, DA and ED, respectively.

TABLE 5.2
THE ACCURACY OF THE DIAGNOSTIC TEST USING ARX MODES WITH DIFFERENT MODEL ORDER CRITERIA.

	Lipschitz	FPE	AIC
Sensitivity	85.71	86.57	85.00
Specificity	80.95	83.33	80.00
Diagnostic Accuracy	84.62	85.88	84.00
Euclidean Distance from point (0,1)	0.154	0.214	0.250

VI. CONCLUSIONS

The analysis of the three models order criteria of linear ARX indicate that Lipschitz number gives highest accuracyof 71.80% as compared to FPE and AIC criteria. It can be concluded that the linear ARX model is not suitable in monitoring the progression of dengue infection based on the hemoglobin status.

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