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Asphyxia Screening Kit

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Abstract— **Infant asphyxia is a condition due to insufficient oxygen intake suffered by newborn babies. A 4 to 9 million occurrences of infant asphyxia are reported each year by WHO. Early diagnosis of asphyxia is important to avoid complications such as damage to the brain, organ and tissue that could lead to fatality. This is possible with the automation of screening of infant asphyxia. Here, a non-invasive Asphyxia Screening Kit is developed. It is a Graphical User Interface that automatically detects asphyxia in infants from early birth to 6 months from their cries and displays the outcome of analysis. It is built with Matlab GUI underlied with signal processing algorithms, capable of achieving a classification accuracy of 96.03%. Successful implementation of ASK will assist to screen infant asphyxia for reference to clinicians for early diagnosis. In addition, ASK also provides an interface to enter patient information and images to be integrated with existing Hospital Information Management System.**

I. INTRODUCTION

Asphyxia is a condition caused by insufficient oxygen intake, commonly found in infants[1]. It is important to diagnose asphyxia in infants at early birth. Delay in treatment and improper treatment can cause hypoxia. As a result of inadequate supply of oxygen to the brain, organ and tissues, this could result in further complications, the worst being infant morbidity

Asphyxia is associated with the central nervous system disorders, including spinal cord and brain injury[1]. The first sign of asphyxia is deficiency in oxygen that occurs on the first day after birth [2]. The World Health Organization reports that 4 to 9 million cases of newborn asphyxia occur each year. Of these, death accounts for 20% while a million who survived develops permanent neurological sequels such as mental retardation, cerebral palsy, speaking/hearing/visual and learning disabilities [3]. Asphyxia occurs in infants with neurological level disturbance, which is found to affect the sound of cry produced by infants [4]. The infant cry signals with asphyxia have distinct patterns which can be recognized with pattern classifiers, such as Artificial Neural Network (ANN).

The use of ANN to discriminate between the different types of infant cries has been reported in previous works. A Time Delay Neural Network (TDNN) has been used to discriminate between normal, deaf and asphyxiated infant cries. The study reported a classification accuracy of 86.06% using TDNN with 144 neurons on the input, 60 hidden units and 3 output layers [4]. Other works compared the performance of Feed Forward Neural Network (FFNN), Recurrent Neural Network (RNN) and TDNN to differentiate between cries from three different conditions: pain, fear and hunger. The study found that FFNN was the most accurate method with a classification accuracy of 69.23% [4]. However, the use of MultiLayer Perceptron (MLP) as structure for classifier has not been reported.

The mortality rate due to asphyxia could be reduced if the condition could be detected promptly. Hence, there is a need for an automated system to perform screening of asphyxia in infants from their cries, with an added benefit of being non-invasive. Asphyxia Screening Kit (ASK) is designed, as a tool to screen infants for early sign of asphyxia before referring to doctors for diagnosis.

The system developed acquires one-second infant cry signals as inputs, pre-processes, analyzes and extracts useful information embedded in them for classifying into asphyxia. Analysis with ASK gives flexibility for result to bias towards sensitivity, i.e. the percentage of infants who are correctly identified as having asphyxia, or specificity, i.e. the percentage of infants who are correctly identified as not having asphyxia. Patient information and screening outcomes can be saved as records for transfer to the hospital database server for patient information pooling and sharing as well as asphyxia registry in the future. Signal processing theories that underlies ASK are first introduced. Next the design architecture embedded with these theories is described. Then, screenshots from its operation are displayed and discussed.

II. THEORY

A. *Mel Frequency Cepstrum Analysis*

MFC analysis is an algorithm for extracting features from audio signals. Since it takes into account frequencies related to human perception sensitivity, it is thus ideal for voice recognition. It transforms cry signals into a representation of coefficients, representing dominant features in the acoustic information over a specified window of time.

For a signal with *N* frames, the MFC coefficient at *nth* frame is defined as:

$$c(n) = DCT\left(log\left(\left|FFT\left(s(n)\right)\right|\right)\right) \quad (1)$$

s(n) is the signal at *nth* frame, after pre-filtering and application of Hamming window, and $n = 0, 1, \ldots..(N-1)$.

The filter bank of MFC analysis is designed to span over the mel-scale frequencies, to emulate the human hearing system, which can detect tone lower than 1 kHz in linear scale but higher that 1 kHz in logarithmic scale. Hence, the

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lower range of the mel-spaced frequencies is linear while the higher range is logarithmic.

B. *Artificial Neural Network*

ANN has proven to be useful for solving pattern classification problems [5]. With its massively distributed processor made of many parallel simple processing units, the ANN learns from a set of pre-defined examples, for input to follow a desired output. ANN learns by adjusting the interconnection between units (i.e. weight), according to a cost function, by comparing between the actual and desired output, over an entire set of input vectors.

Here, a MLP classifier is selected. It is one of the many ANN structures that arranges its units in multiple layers and propagate the inputs in feed-forward manner. The MLP is trained using supervised method. The weights of the interconnections are adjusted until the MLP finds the smallest error between the actual and desired outputs, with a least square cost function. The performance of the MLP is highly dependent on its training algorithm, a scale conjugate gradient optimization method [6-8].

III. Design of ASK

Before the design for ASK, investigation has been conducted to search for the optimal choice of filter, window size, FFT points, number of filter banks and coefficients for the MFC analysis part while the optimal setting of parameters such as the number of input/output/hidden nodes, feature optimization and dimension reduction for the MLP part to obtain the optimal classifier performance, from our previous works [6-8]. These settings for the feature recognition and classification technique are then introduced into the design of ASK.

```
Load patient cry signal

Plot cry signal in panel

if patient information entered
        display patient information in panel
else
end

extract feature from cry signal using MFCC

select optimal MFCC extracted feature

simulate feature using optimal Artificial Intelligent network

pass simulate data through the ROC threshold to verify the cases

display patient result in panel

plot ROC threshold in Panel

if result is save
        take patient information and result and write in excel
        save current figure
else
end
```

Figure 1 Pseudo code for Main script of ASK

In designing the program, a script is written to enable use with Matlab Graphical User Interface. For ASK to run, one main script and four function scripts are applied. The Main script describes the main layout of ASK (see Figure 2). The other four Function scripts are used to receive inputs from user, execute query and send output/result to the main layout respectively.

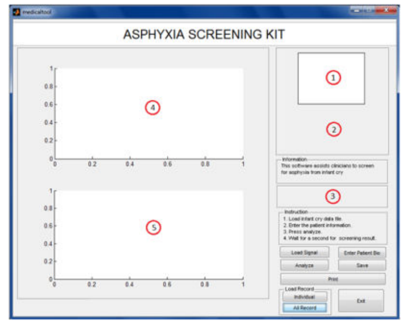

Figure 2 Layout of ASK

Figure 2 layouts the four major components of ASK: Input for user cry signal (IIIA); Input for user information (IIIB); Classification process (IIIC) and Data storage (IIID). In the main layout, the biodata and image of the subject are displayed in (1) and (2), the classification result is displayed in (3), the waveform of cry signal is shown in (4) and the Receiver Operating Characteristic plot is shown in (5). Design of this layout is made with reference to the design architecture of ASK as shown in Figure 3.

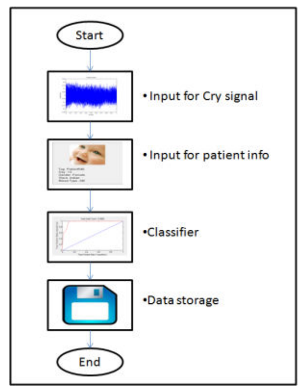

Figure 3 Design Architecture for ASK

A. *Input for cry signal function script*

This function script is designed to acquire one second length of cry signal with sampling frequency of 8000 in .wav format. When the 'Load Signal' push button is executed from the main script, this function script is called to inquire data from a cry database, which contains cry signals recorded from patients. The data that has been selected will be stored in the memory and the cry pattern will be shown in the panel (4).

B. *Input for user information function script*

This function script is designed to collect ID of the patient, age, blood type, gender, race and image of the patient. When the 'Enter Patient Bio' push button is executed from the main script, this function script is called. It invites input to be written into the pop-up text box (see Figure 4). The information that has been written is loaded into the panel (2) of Figure 2. This function script is also designed to accept and load subject image into panel (1) of Figure 2.

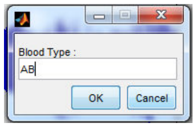

Figure 4 Text box

C. *Classifier function script*

This component contains the intelligence of ASK. This function script is designed to report if the subject is normal or asphyxiated. As stated at the beginning of this section, the optimal settings determined from our previous works are applied to this classifier function script. When the 'Analyze' press button is executed, this function script is called to initiate the MFC analysis and MLP classification process. The outcome of classification is then passed through the receiver operating characteristic graph (ROC) threshold to give it a quantitative evaluation. The outcome is shown in panel (3) of Figure 2. At the same time, the ROC curve is generated and plotted on panel (5) of Figure 2 to illustrate the outcome.

D. *Storage function script*

After the subject has been classified, the outcome of classification and the patient information can be stored. This function script is designed so that when the 'Save' button is executed, the function script saves the patient information and the type of cry in Microsoft Excel format and Matlab figure.

IV. RESULT AND DISCUSSION

To start, the user loads the subject cry signal by clicking on the 'Load Signal' button, a new pop up window appears to allow the user to choose the desired file as shown in Figure 5. After the desired cry signal has been selected and opened, waveform of the signal is plotted on the panel as in Figure 6.

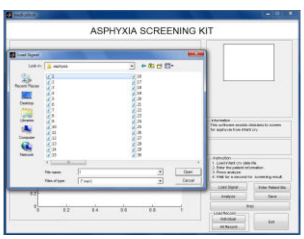

Figure 5 Select data screen

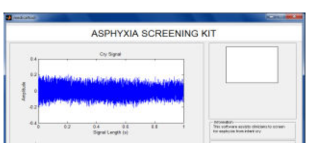

Figure 6 Plot signal

Next, when the user enters the patient biodata by clicking on the 'Enter Patient Bio' button, a new pop up window appears to allow the user to enter the patient information. The patient information being inquired are currently, but not limited to 'Tag', 'Day', 'Gender', 'Race', 'Blood Type', as shown in Figure 7.

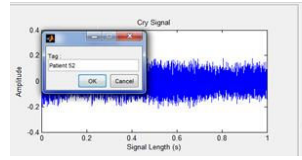

Figure 7 User input data

After all the information has been entered, a new pop up window appears to ask the user to upload the picture. After the picture has been uploaded, the pop up displays details of the patient information that has been entered previously in full as in Figure 8.

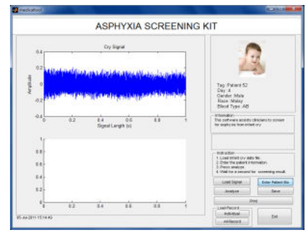

Figure 8 Patient information with image

Finally, when the 'Analyze' button is clicked, ASK classifies the signal with the outcome and a quantitative measure of the outcome displayed as ROC graph as in Figure 9.

Figure 9 Analysis result of ASK

ASK allows the user to save the result above by clicking on the 'Save' button, the result is then stored in a folder as shown in Figure 10. Two different ways are devised to recall the stored data: either single record (by clicking 'Single Record' button) or all records (by clicking 'All Records' button).

If the 'All Records' button is selected, the patient information and outcome of screening of all the previously stored records will be displayed in Excel table format, as in Figure 10.

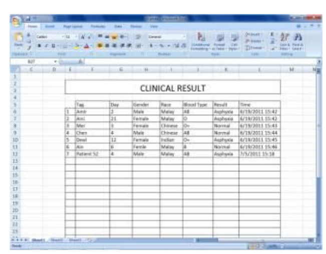

Figure 10 Display of all records in Microsoft Excel format

If the 'Single Record' button is selected, a new pop up window appears to show a list of patient records that have been stored for selection, as in Figure 11. When the user clicks on the desired record, a screen in Figure 10 pops up, revealing patient information, screening outcome and analysis graph related to the patient.

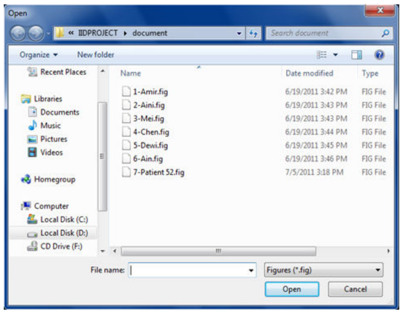

Figure 11 Display of single record.

As an area of medical informatics, the aim of a Hospital Information Management Systems (HIMS) is to provide a continuum of health care, from support of patient care, outcome to administration [8]. An indispensable part of it is to present data where needed and acquiring data from networked electronic devices. ASK is designed to be one such device to be integrated with the HIMS, doubled its role as a clinical decision support system. This will enable screening of babies for asphyxia from anywhere and anytime as illustrated in Figure 12. The data collection and signal processing algorithms will reside on the clients, at home or hospital. Once transmitted and saved into the hospital database server, these records will be available for easy access to information and knowledge needs of health care practitioners to refine outcome from ASK. The design criteria will abide by the 6 key aims for improvement in health care: safe, efficient, effective, timely, patient-centered and equitable, quoted from the Institute of Medicine [9].

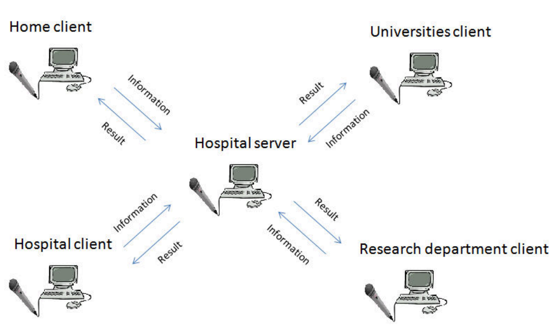

Figure 12 Server and client integration system

V. Conclusion and Future work

An Asphyxia Screening Kit offering non-invasive automated screening of asphyxia in infants is developed. It is built with Matlab GUI with underlying signal processing algorithms for screening asphyxiated infants from their cries, with a classification accuracy of 96.03%, as proven from our previous works. Successful implementation of ASK will assist to screen infant asphyxia for reference to clinicians for early diagnosis. In addition, ASK also provides an interface for easy access to data storage and retrieval between client and server, once integrated with existing Hospital Information Management System.

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