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Implementation of an Improved Model for Medical Images Using PIC Microcontroller in Telemedicine

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ABSTRACT This paper aims to design and develop a low-cost, lightweight, portable system for critical patient monitoring system. The proposed system employs a Peripheral Interface Circuit (PIC) Microcontroller and MALAB 7.5.0(R2007) platform that performs analysis of the acquired brain image continuously. A brain tumor is identified and analyzed by detecting the infected region using a combination of Self Organizing Maps (SOM) followed by K- means algorithm. PIC Microcontroller based Region of Interest (ROI) detector in various medical images is implemented on a PIC 16F877A board and is interfaced with a Personal Computer (PC) to send status about the detection of brain tumor serially. If any abnormality is detected by the system, it sends an alarm, which sounds automatically and the warning message is also displayed on the LCD monitor device. Medical images are compressed at a lower bit rate and the abnormal data is transmitted to healthcare services or a personal doctor for diagnosis. Finally, the warning messages are sent to the doctor's mobile whenever the patients require medical advice for treatment.

INTRODUCTION

Telemedicine has been introduced by the Medical Research Centers in USA. In a telemedicine system, patient data is transmitted from one place to another place using wire and wireless networks (Alfred et al. 2013). A cost-effective and alternate method for face-to-face consultation is telemedicine or telehealth or e-health, includes diagnosis, consultation and supervision and treats remote patients. Many new solutions have been obtained in the field of telemedicine by the combination of new technologies in wireless and mobile telecommunication networks (Dong et al. 2008). Mobile cellular networks like GSM, GPRS and 3G mobile communication aid wireless telemedicine, thereby freeing the doctor and the patient from fixed locations with added advantage of a low cost. These systems facilitate mobility for doctors with a 24x7 monitoring capability regardless of physical locations of physicians, the infrastructure, and affordability of the patients for effective and efficient treatment. An ECG patient monitoring system had been introduced where the output data is transmitted to the receiver end through Global System Mobile (GSM) employing a microcontroller based system (Voskarides et al. 2003). Medical treatments and healthcare services are given to patients with the help of development in medical technology. The various communication systems such as the telephone and the Internet are used to provide treatments and services nowadays. A microcontroller based portable system (Mitra et al. 2006) capable of transmitting ECG signal to a remote PC for analysis has been implemented. A mobile Tele-Cardiac system (Thulasi Bai et al. 2008) with GPRS transceiver was proposed and simulated in a MATLAB environment and ECG signal analysis was performed using ARM microcontroller. Real time monitoring of ECG signal using PIC and web server were also implemented (Saurabh 2013).

Heart rate and temperature are detected using a heartbeat sensor and LM35 sensor. The sensed signals are further processed by the microcontroller. On exceeding the threshold, an SMS alert will be sent to the doctor through a GSM module (Shahin et al. 2015). The health of the patient is continuously monitored and the data so collected is analyzed using a personal computer through the GUI (Graphical User In-

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terface) developed using MATLAB. An alarm is triggered whenever a particular patient's health parameter lowers or exceeds a threshold value (Aung et al. 2015). In this paper, a PIC microcontroller based system is proposed, which helps diagnose diseases for poor patients in rural areas. This system also develops equipment that warns the abnormality via mobile phone network, which is low-cost, portable and simple to use. Whenever the patient is in an abnormal condition, the proposed system transmits the warning messages to a patient's physician and their attendee, to help the patients in remote areas. The proposed scheme also transmits the patient's locations to the concerned physician to save the life of the patient in a short time.

METHODOLOGY

The block diagram of the proposed system is shown in Figure 1 and it consists of three major stages. The first stage is the image processing system (Himanshu et al. 2012) in the patient monitoring system. It is used to calculate the area of the segmented image (Pal et al. 2014). The second stage is the PIC microcontroller, which receives information from the image processing system and analyzes the critical conditions of segmented and compressed images and then passes the image to the communication stage. The communication stage transmits information (normal or abnormal) to authorized healthcare services or a personal doctor via a mobile phone network.

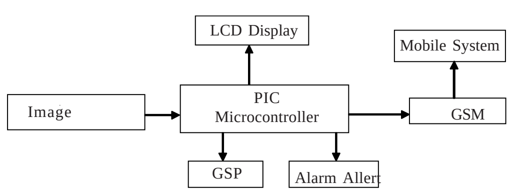

Fig. 1. General Block diagram of proposed method

Image Processing Unit

The block diagram of image processing unit is shown in Figure 2. The features such as mean and variance are extracted from the medical image. These feature vectors are applied to the SOM network. Medical image is segmented into Region of Interest (ROI) and Non Region of Interest (NROI) by SOM in a competitive unsupervised training methodology followed by K-Means algorithm. An accurate segmentation of brain tissues provides a way to identify many brain disorders. The proposed method generates more segmented details of the input images. Medical images are compressed at a lower bit rate and transmit only the abnormal data to the healthcare service or personal doctor for diagnosis and the warning messages are sent to receiver's mobile whenever the patients require medical advice for treatment.

Feature Extraction

Feature extraction is transforming the input data into the set of features and reduces the dimension of an image instead of the full size input. The features include mean and brightness. These features are given as input to the system.

Segmentation

Segmentation is the process of separating abnormal parts from the medical image. A Self-Organizing Map (SOM) is the powerful method for segmentation.

Self-Organizing Map (SOM)

The SOM system (Hujun et al. 2008; Demirhan et al. 2011) has a feed-forward structure with a single computational layer of neurons arranged in rows and columns. This is also known as a Kohonen Network. This network (Saleh et al. 2015) helps recognize the correct number of clusters and segments automatically. The proposed algorithm has advantages in accuracy and robustness against noise in comparison with the well-known unsupervised algorithms. The architecture of SOM is given in Figure 3. The SOM algorithm consists of various stages, which are summarized as follows:

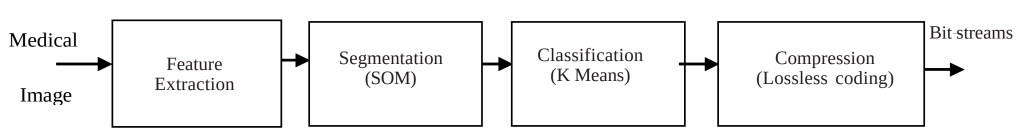

Fig. 2. Block diagram of image processing unit

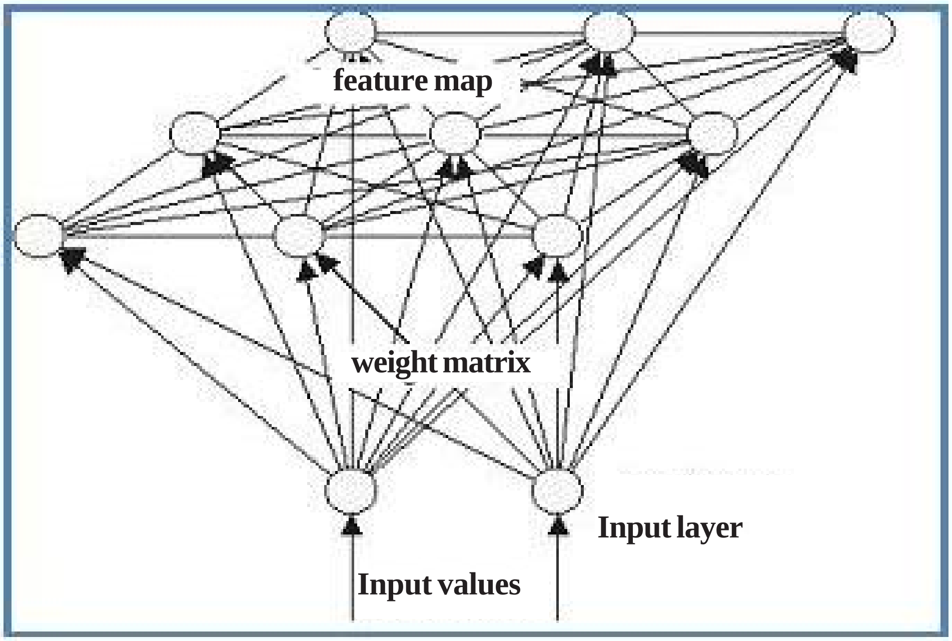

Fig. 3. Architecture of self-organizing map

Step 1: The initial weight vector **w***j* is chosen randomly.

Step 2: A sample training input vector **x** from the input space is drawn.

Step 3: The winning neuron *I*(**x**) is calculated by finding the minimum value of *dj(x)*, which is given in equation 1. It means that the weight vector of the winning neuron is closest to the input vector.

$$dj(x) = \Sigma_{i=1}^{D} (xi-w_{ji})^2 \quad (1)$$

The total squared distance value represents goodness of the approximation, and it is given by equation 2.

$$D = \Sigma_x \ ||(x-w_{I(x)}||^2 \quad (2)$$

Step 4: The weight is updated, which is given as equation 3.

$$\text{H) } w_{ji}= \eta(t)T_{j,i(x)} (t) (x_i-w_{ji}) \quad (3)$$

Where, $T_{j,I(x)}$ represent a Gaussian neighborhood and η(t) is the learning rate.

Step 5: Go back to Step 2 until the feature map stops changing.

A set of the best features is selected by the Self-Organizing Map for approximating the underlying distribution. The input space is vector-quantized or clustered and produces a map, which preserves topology by SOM. It has been used for segmentation, and the map is trained on examples of known categories. The nodes are then classified or labeled so that the map can be used to classify unseen samples. The computational form of the entire algorithm is simple and efficient.

Classification

Classification (Pal et al. 2014) is a decision-theoretic approach to identify cancer and non-cancer regions in images based on the geometric feature sets. The classes may be specified into sets of prototype classes *like a priority known* by an analyst as in *supervised classification* and automatically clustered as in *unsupervised classification*, here the number of desired categories specifies by the analyst.

K- Means

K-Means algorithm is one of the simplest region-based segmentation methods. The algorithm step is as follows.

Step 1: The number of clusters such as C1, C_2…Cn and the positions of initial seed points such as p_1, p_2…p_3 are assumed.

Step 2: The difference of pixel value of the initial seed point p_i and its neighboring points are computed, then define the neighboring point into Ci, when the difference value is smaller than the threshold value, where i = 1, 2…n.

Step 3: The new boundary of Ci and new seed points pi(s) are calculated. In addition, the average pixel values of the new boundary are calculated, respectively.

Step 4: Repeat Steps 2 and 3 until all pixel values are grouped into suitable clusters.

Compression

Lossless Coding

The frequency of occurrence of the data item is the basic phenomenon of Huffman coding. The method is to use a minimum number of encoding bits to encode the frequently occurring data. A codebook is constructed for every image or a group of images to store the codes for each image. For the purpose of decoding, the codebook along with the encoded data must be transmitted. The Huffman algorithm is now briefly summarized:

a) Order the given symbols in the decreasing probability.
b) Combine the bottom two (that is, the least probability symbols into a single symbol that replaces in the next source reduction).
c) Repeat the above two steps until the source reduction is left with 2 symbols per probability.
d) Assign ‘0’ to the 1st symbol and ‘1’ to the next symbol and coding each reduced source, starting with the smallest source and working back to the original source.

Processing Unit

PIC Microcontroller

The PIC microcontroller is used to process the data and find abnormality in the medical image. This processing stage (Thakare et al. 2008; ThulasiBai et al. 2009; Sirikham et al. 2011) consists of five subgroups, such as the Microcontroller chip, GSM, GPS and LCD display and alarm unit. LCD display is used to display the abnormality of the medical image on the patient’s side. GPS module is used to tell the location of the patient. The processor units receive information about the medical image via a RS232 cable. It determines whether the condition is normal and abnormal, and if any abnormal is detected, then immediately it sends a warning message to the receiver by GSM. Prototype of the PIC Microcontroller based patient monitoring system is shown in Figure 4.

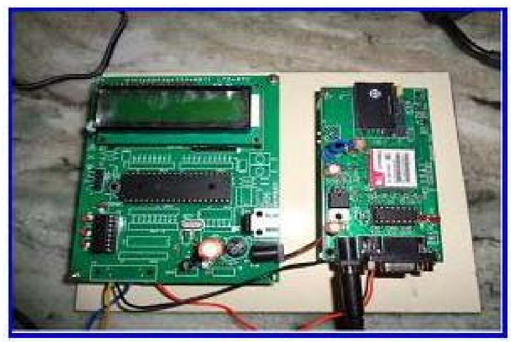

Fig. 4. PIC Microcontroller based patient monitoring system

This family reduces system cost and supports the lowest cost configuration solution, parallel flash memory and the function integration of many chips into a single programmable chip.

LCD Module

The LCD module is connected with the PIC Microcontroller through a port to display the alert message and status of the operation. It is kept in the patient room.

Alarm Unit

The alarm beeps when any abnormality is detected, and this is also connected with PIC Microcontroller through a port.

Communication Unit

Global System Mobile

Global system for mobile communication is a globally accepted standard for digital cellular communication. The GSM-ECON SIM300-V7.03 module is used to communicate using a mobile phone network. This GSM module is used to send critical data as short messages to the healthcare service or doctor’s mobile if the patient is in critical condition.

Global Positioning System

Global Positioning system is used to locate a position and its equivalent global time on the whole earth's surface. The GPS satellite passes the altitude, latitude and height of any location on the earth surface to the earth station. The earth station then uses these three parameter values and calculates the actual location of the place on the earth surface. Based on these concepts, it can identify the patient's location and share it for immediate treatment.

RESULTS

Figure 5 show input color image, gray scale image, edge detected image, abnormal part of an image using SOM+K-Means, and compressed image. The output warning message is seen on the LCD display. For example, if the max area is more than 1000 then the device shows the warning message as 'Brain Tumor is detected', which is depicted in Figures 6a and 6b, or else if the max area is less than 1000 then it displays the message as 'Brain Tumor is not detected', which is depicted in Figures 7a and 7b. Figure 8 shows the message received on the mobile phone. So that immediate diagnosis can be done by the medical practitioner. The quality of the image such as peak to signal to noise ratio (PSNR), time period and compression ratio are measured at the output of the decoder. The PSNR in terms of decibels (dBs) is given by equation 4.

Fig. 5. Input colour image, gray scale image, edge detected image, abnormal part of an image using SOM+K-Means, Compressed image

$$\text{PSNR}= 10\ \log 10\left(\frac{255^2}{\text{MSE}}\right) \qquad (4)$$

The capability of the compression system is characterized by compression ratio, which is calculated as equation 5.

$$\text{Compression Ratio}= \frac{\text{size of the compressed image}}{\text{sixe of the original image}} \qquad (5)$$

Fig. 6a. maxarea value more than 1000

Fig. 6b. Warning Message in LCD

Table 1 shows the calculated quality measure values for various methods. The developed algorithm is compared with existing algorithms in terms of PSNR, CR and time period. This is done in order to show the effectiveness of the developed algorithm. Thus, from the data collected it is inferred that the developed algorithm has the best CR and PSNR values comparatively. Furthermore, the quality of the image has been maintained without any loss. Time period is de-

Fig. 7a. maxarea value less than 1000

Fig. 7b. Warning Message in LCD

fined as the total time required to compress and decompress the medical image. This time period so measured using the developed algorithm is shown in Figure 9. It is seen that the time taken for compression and decompression is only 7 seconds for a given medical image using the developed algorithm, as compared to the existing algorithm, which took 17 seconds. Hence, it is concluded that the developed algorithm requires lesser time as compared to the existing algorithm, in order to execute the entire process, comparatively.

Table 1: Comparison of quality measures of medical image

Methodology	*Quality Measures*	
	CR	*PSNR(dB)*
JPEG+JPEG 2000	1.55	36.6
Integer Wavelet Transform+ JPEG 2000	1.76	36
Wavelet Transform +SVD+ Arithmetic coding	1.3	20
Prediction+ Rice coding	1.74	14
WT+ Singular Value Decomposition +LZW coding	0.6	33
SVD+ Contourlet Transform+ Huffman Coding	0.5	12
Filtering + Back Propagation Neural Network	0.25	22.5
WT+EZW Coding	1	11
Proposed method	1.9	41

DISCUSSION

First the Region of Interest is extracted from the given medical image and then its area is measured or calculated. If the calculated area is greater than 1000, then the abnormality is detected by the developed system, in turn an SMS is delivered to the caretaker of the patient.

Furthermore, this system is implemented using the PIC microcontroller and recent medical image processing techniques. The CR and PSNR values are obtained to be around 2 and 41 dB using the developed system.

Fig: 8 Messages received in mobile phone

Previous researchers in this field have measured the heart rate, temperature, ECG, and pressure, and have sent these wirelessly either to the caretaker of the patient and/or to the doctor for further diagnosis. Also, most of the researchers have concentrated on detecting the abnormality only, without considering the medical image quality. However, in this developed system, the abnormality has been detected and compressed at a lower bit rate and has been saved in the database, as well. Furthermore, the developed system sends messages to the caretaker or doctor within the short time. This is the major contribution of this paper, which has not been contributed by any of the researchers so far for the same application.

CONCLUSION

The infected region is identified through SOM and K-Means algorithm, which needs to be perfect for accurate ROI identification resulting in a better treatment. The image quality met-

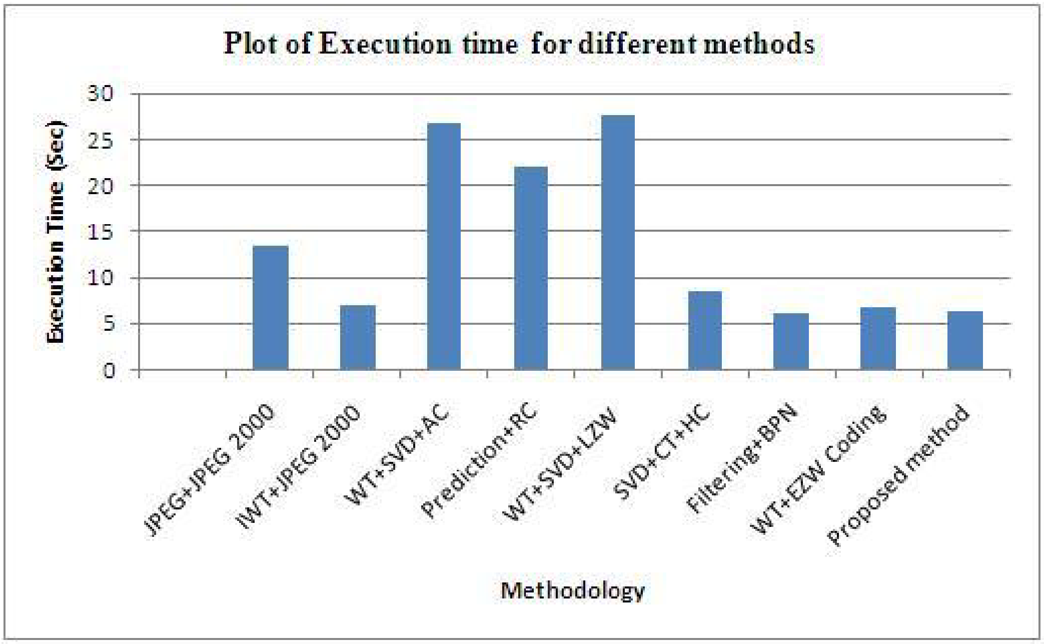

Fig. 9. Plot of Time period for different methods

rics show that the proposed GUI based brain tumor diagnostic system is good. The patient's physician or relative will receive a warning message with a Short Message Service (SMS) via the GSM module, if any abnormal data is detected by the system. This device also detects the patient location by use of GPS. Moreover, the system can detect the abnormality with better accuracy. The compression results of the proposed method show that it provides a better compression ratio with good quality compared to existing methods.

RECOMMENDATIONS

For future work, it is recommended to transmit the compressed image wirelessly at a lower bit rate, after abnormality detection. It can be implemented in rural areas, however, needs a high-speed GPS network and GSM, as well.

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