Infant Cry Detection and Pain Scale Assessment: A Pilot Study

N. Sriraam, Centre for Medical Electronics and Computing, M. S. Ramaiah Institute of Technology, Bangalore, Karnataka, India

S. Tejaswini, Centre for Medical Electronics and Computing, M. S. Ramaiah Institute of Technology, Bangalore, Karnataka, India

ABSTRACT

A biological alarm system that connects mother and new born is referred as infant cry. Infant cry is a first means of communication through which mother understands the level of distress/ needs. Infant cry can be considered a multimodal behavior which involves limb movements, facial expressions which changes over time to identify the needs of an infant. The cry of the baby cannot be predicted accurately and it is hard to identify for what it cries for. The infant's cry is mainly a vocal signal which is a way of communication that aims to get attention of the listener to a physical state like hunger, pain, discomfort, fear, illness, wet diaper etc., .Pain is one of the most common symptoms experienced world over. Pain is an unpleasant feeling that is conveyed to the brain by sensory neurons. The discomfort signals actual or potential injury to the body. This pilot study gives an insight on the current state of works in infant cry analysis and pain scale assessment and also concludes with thoughts about the future directions for better representation and interpretation of infant cry signals.

Keywords: *Artificial Neural Network (ANN), Illness, Infant Cry, Mel Frequency Cepstrum Coefficient (MFCC), Pain Scale Assessment*

1. INTRODUCTION

The cry serves as the primary means of communication for infants. It is their first linguistic manifestation. Infant cry comprises important information regarding their emotional, physical and health status. The analysis of biological signals has been essential mean for detecting pathologies and recognizing physiological and neurological states of the human body. One of the common biological signals is the infant cry, which according to specialists; it could contain valuable information about the state of the baby including hunger, pain, fear and physiological abnormalities. The frequency of infant cry is 250Hz – 600Hz and the voiced sounds are harmonics. First cry represents an 'overwhelming sense of inferiority at thus suddenly being

DOI: 10.4018/ijbce.2014010104

confronted by reality without ever having had to deal with its problems'. The feeling of inferiority at least serves a useful function in ventilating the lungs. Infant cry analysis is of great importance to identify the characteristics present in the cry wave, as they provide additional information that allows recognizing variations and similarities between normal and pathological cry (Ali Messaoud, et al.,2011, Azlee Zabidi, et al., 2010, J. Saraswathy, et al.,2012, Ramu Reddy Venpada, et al., 2012, Rohilah Sahak, et al., 2010).

Pain assessment in patients who are unable to verbally communicate is a challenging problem in patient critical care. Depending on the patient group (e.g., neonates, children, adults, etc.) pain scale assessment have been developed, and indicators of pain in each group is different. Infants are unable to directly report their level of pain, and hence, medical staff is responsible for pain assessment for neonates. Pain and distress behaviors in neonates, include facial expression, cry, and body movement, and a series of methods have been suggested to objectively assess pain in neonates based on aforementioned behaviors.

The International Association for the study of Pain has defined pain as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage". The interpretation of pain is subjective. Neonates cannot verbalize their pain; they depend on others to recognize assess and manage their pain. Therefore, health care professionals can diagnose pain only by recognizing the neonates associated behavioral and physiological responses. (Pritam Pal, et al., Rasha Srouji, et al., 2010).

2. RELATED BACKGROUND

Almost half decades ago, the attention has been made on acoustic analysis of infant cry and pain scale assessment to investigate the relationship between cry signal and physiological or physical status of new born infants.

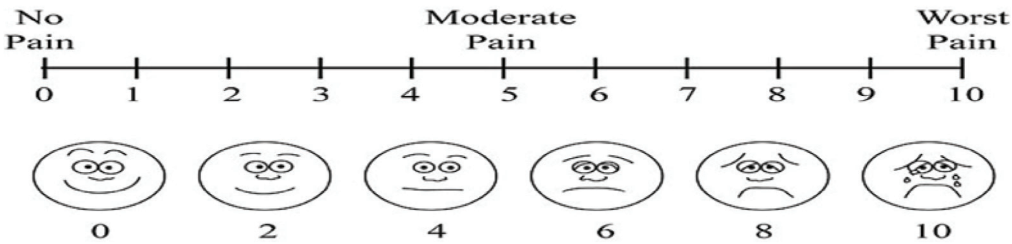
2.1. Infant Cry

The infant cry signal used for the study is taken from Chillanto, Mexican data base which is used for the study of characteristics of the cry with conditions such as normal, pain, hunger, deaf and Asphyxia. The full recording and the segmented of each recording are used as the preliminary study infant cry recordings. The data base gives us the details about all the mentioned cry and these cries can be used reference for the recorded cry in this project. It is similar to Automatic Speech Recognition system process which comprises two main stages. They are signal processing and pattern classification. The main aim of this system is to discriminate the different types of cries and identify the pathology cry. In signal processing step raw cry signal is preprocessed such as cleaning, filtering and normalization. Then smoothed signal is analyzed and by suitable feature extraction techniques the salient features are derived.

One of the most popular feature extraction techniques used to provide inputs to the ANN is Mel Frequency Cepstral Coefficients (MFFC). MFFC extraction is highly dependent on its extraction is highly dependent on its extraction parameters(Ali Messaoud, et al., 2011, J. Saraswathy, et al., 2012, Ramu Reddy Venpada, et al., 2012).The characteristics of the cry can be attributed to the characteristics of vocal tract system and excitation source and supra segmental characteristics. The spectral peaks, bandwidths and slopes are unique for each condition of cry. Hence if we extract this information one can discriminate the infant cry condition (Rohilah Sahak, et al., 2010). Pitch is one of the important and distinguished acoustic features to analyze the infant cry. Linear prediction analysis is a time domain analysis which has been used frequently in infant cry analysis. Linear prediction analysis attempts to predict a speech sample through linear combination of several previous samples.

The extracted features are further processed for acquiring the required signal cry signal. It

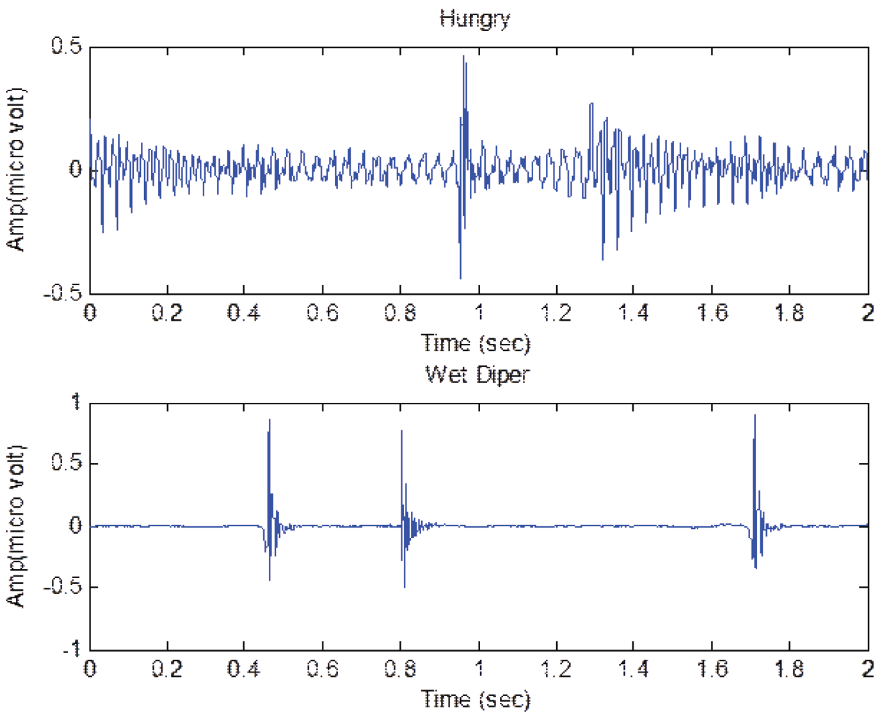
Figure 1. Pain scale assessment



is possible to apply filter banks of the Mel or Bark scale in order to perform pitch wrapping or subjective loudness warping to the cry segments prior to cry analysis. This in turn selects the extracted feature for classification. The classification technique such as an Artificial Neural Network (ANN) has ability to discriminate between several types of infant cries. Feed Forward Neural Network, Recurrent Neural Network and Time Delay Neural Network have been used to classify cries from normal, deaf and asphyxiated infants. The infant cry signals have distinct patterns which can be recognized with pattern classifiers such as artificial neural network and support vector machine. For example, time delay neural network classifies cries between normal, deaf and asphyxiated infants. Feed forward neural network, recurrent neural network to differentiate between cries from three different stimulus situations such as pain, fear and hunger. Support vector machine using kernels like linear, quadratic, polynomial and radial basis function kernel to differentiate different types of cry.

Figure 2. Shows one proposed pilot study schematic diagram

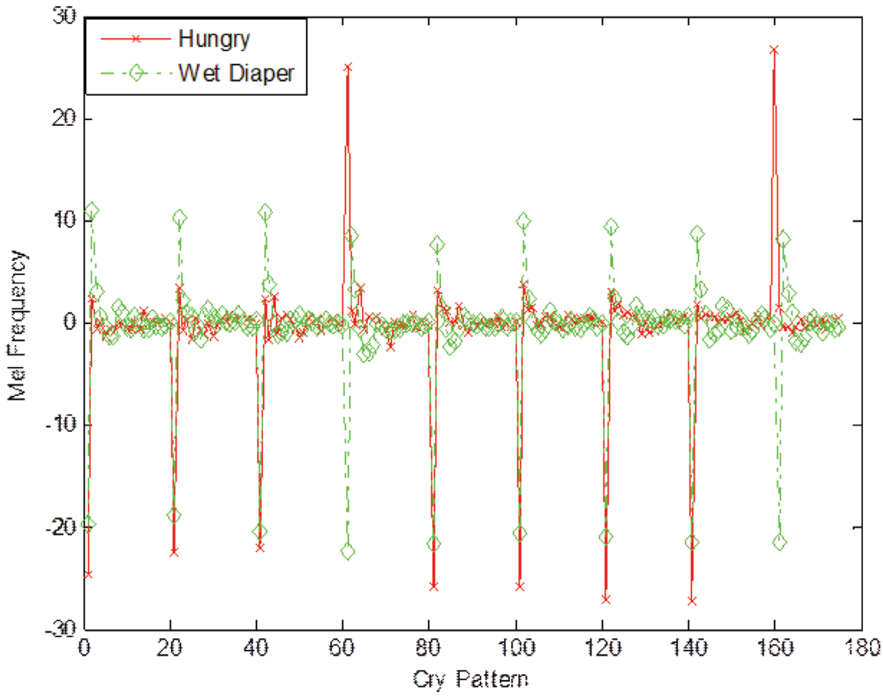
Figure 3. Sample recordings of infant cry



2.2. Pain Scale Assessment

Pain scale assessment is mainly an image processing problem. The National Initiative on Pain Control (NIPC) has provided diagnostic tools to assist in assessing the severity and quality of pain experienced by patients. The image processing module takes the image data, i.e. the image of the infant's crying face and processes it to infer the level of pain. The processing involves detecting changes that occur in certain features like the mouth, the eyes, eyebrows and the wrinkles. The different combination of all these will dissipate the level of cry. The NIPC is classified ten levels of pain such as no pain to worst pain. The first three levels of pain is classified has a minor pain. Minor pain is a kind of pain which does not interfere with most of the activities and this is also adaptable pain. These three levels are named as just pain, mild pain and uncomfortable pain. The next three levels, i.e. four, five and six pain levels are classified as moderate level pain. Moderate pain is pain which interferes with activities and requires changes by the subject and it is inadaptable pain. They are annoying pain, moderate pain and just bearable pain. It is a deep piercing pain such as a sprained ankle. It is a kind of pain which is noticed all the time. The next four levels are classified as sever. They are strong pain, severe pain, horrible pain and worst pain. It is kind of pain where subject is unable to engage in normal activities. Patient is disabled and he is unable to function independently. The pain is so intense that the subject cannot tolerate it and demand a pain killer or surgery, no matter what the side effects or risk. For reader's understandability, pain scale assessment as reported in literature is shown in Figure.1 (Mc Caferry et al., 1999).

Figure 4. MFCC for hunger and wet diaper condition (only samples are shown)



2.3. Need for Portable System for Cries Detection

In neonatal healthcare monitoring, understanding the nature of infant cries is quite a challenging task for the pediatric medical community. Cries are considered as observer rated pain assessment tool that helps in assessing vital signs, facial expressions and sleeplessness of the infant. Although several attempts have been made to analyze the cry patterns offline, there is a need to develop an independent portable system for interpreting the real-time infant cries. The reason is due to the fact that in neonatal ward, continuous monitoring of infants is tedious and time consuming. A system which makes use of recording infant cries with a provision to record video of facial expression is essential for making efficient clinical interpretation.

Table 1. Neural network configuration

No of hidden neurons	**10**
Performance goal	0.01
Learning rate	0.5
No of epochs to reach network convergence	44
Gradient	0.164
Computation time	0.4seconds

The proposed system is divided into three parts. They are data set acquisition, infant cry analysis system and pain scale management system.

3. DATA SET ACQUISITION

The cry samples that have to be used for this study are recorded using Sony voice recorder. The samples of cry are collected from babies added less than 8 months. The gender should also be considered when recording the cry signals as the fundamental frequency of male infant is greater than female infant. The cry is recorded in context with babies cry during pain, hunger and wet diaper. The face expression of the baby is recorded using the Microsoft webcam. The images of children are collected in the range of three to eight years children.

4. INFANT CRY ANALYSIS MODULE

The typical block diagram of infant cry analysis consists of a recorder, preprocessing, feature extraction, classification and display. The raw signal must be preprocessed in order to eliminate noise in the recorded cry signal. Normalization, cleaning and filtering should be done in order to eliminate noise in the recorded signal and it should be suitable to extract required parameters such as MFCC's, pitch and LPC. One of the most common feature extractions is Mel frequency cepstral coefficients which are used to encode the speech signals that contain irrelevant information with large amount of storage space into compressed and useful information. The infant cry signals have distinct patterns which are recognized with pattern classifiers such as Artificial neural networks and support vector machine. The display is the important part of

Figure 5. ROC of the proposed classifier

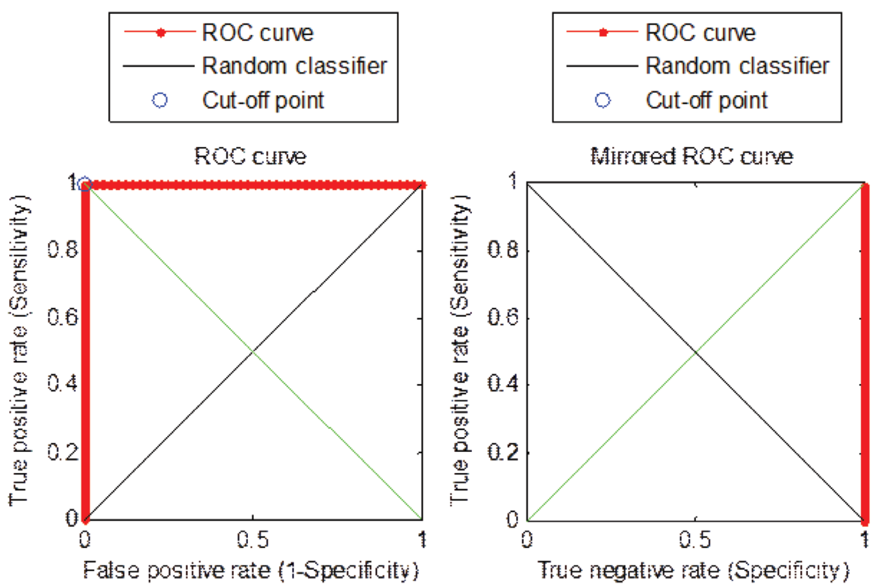
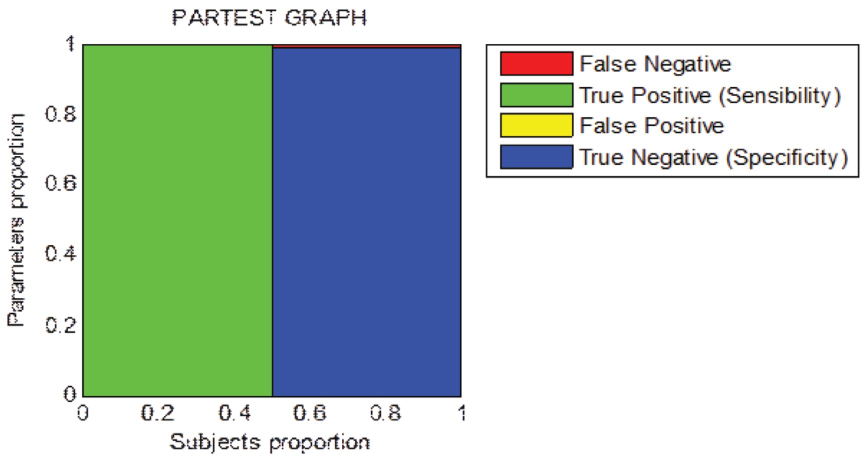


Figure 6. Partest graph



the infant cry system. The processed, classified cry signal is distinguished and named accordingly is displayed on the laptop LCD screen. The display gives the information about the cry which is normal or abnormal. The condition of the cry is displayed.

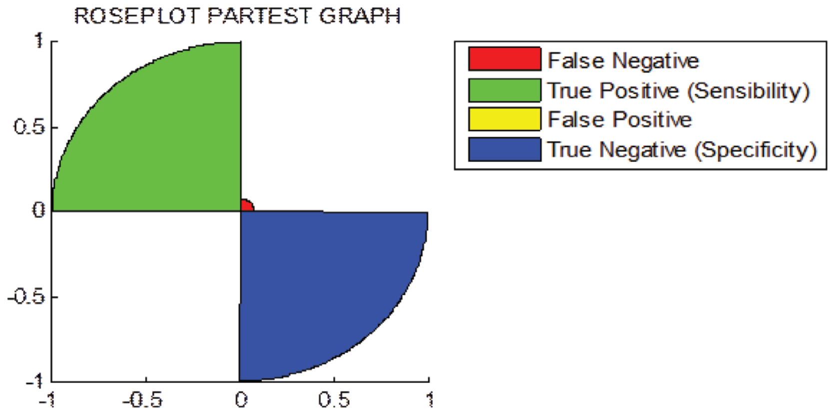
The cry signal is recorded using SONY ICD voice recorder which is suitable for infant cry recording with 44.1KHz and 16 bits. Firstly, the cry of the infant is recorded in the presence of noise by the mother. Later the recordings of the cry are refined with noise while recording. The duration of cry is 10-40 seconds for conditions such as hunger, pain and wet diaper. Figure 3 shows the sample recordings of infant cry during the two conditions.

Typical MFCC are extracted from the raw signals and are further used for pattern classification. Figure 4 shows the typical discrimination plot of MFCC for the two conditions. It can be observed from Figure 4, one can see good discrimination between the hunger and wet diaper condition of infant cry. To make a complete automated detection and classification, a recurrent Elman neural network classifier was introduced. The simulation study is performed with limited test patterns. To train the network, 1256 MFCC patterns derived from hunger and wet diaper were considered. Resilent back propogation learning algorithm was used with tan and log sigmoid activation functions were applied for input-hidden neurons and hidden-output neurons respectively. The performance of the training network is evaluated in terms of mse function. Table 1 shows the configuration of Elman neural network and convergence details

After the training, 744 patterns were used for testing which yields a classification accuracy of 99.1%. The network need to be trained with larger database for obtaining optimal convergence, configuration and classification results. The performance of the classifier was further studied using receiver operating characteristics (ROC). Figures 5 to 7 show the results.

It can be observed from the ROC results as depicted in Figures 5 to 7 that the proposed pattern classifier holds good for infant cries

Figure 7. Roseplot partest graph



detection. The method need to be tested with larger database.

5. PAIN SCALE ASSESSMENT AND FUTURE DIRECTIONS

The pain scale assessment system is based on image processing analysis. The video of the infant facial expression during cry is recorded. The clear facial expression is captured as an image. This image is considered the raw image for processing. The 10 levels of pain are classified according to the facial expression and template of the 10 levels is matched with the template of the captured image. The image is then classified accordingly to the particular level. This paper briefly describes the significant works on infant cry analysis. The methods used for extraction and classification process is discussed in order to an attempt an automatic infant cry recognition system and pain scale assessment system.

ACKNOWLEDGMENT

This research was supported by Vision Group of Science and Technology(VGST), Bangalore, Karnataka, India (SMYSR,GRD No.294/2013-14).

REFERENCES

Canadian Pediatric Society Statement, (2010). Prevention and management of pain and stress in the neonate. *Pediatric Child Health, 5*.

McCaffery, M., et al. (1999). Pain scale assessment. *Clinical Manual* (pp. 16).

Messaoud, A., & Tadj, C. (2011) Analysis of acoustic features of infant cry for classification purpose. In CCECE 2011, Canada. doi:doi:10.1109/CCECE.2011.6030415 doi:10.1109/CCECE.2011.6030415

Pal, P., Iyer, A. N., & Yantorno, R. E. (n.d.). *Emotion detection from infant facial expressions and cries*. Temple University.

Ruiz, M. A., & Altamirano, L. C. et al. (2010). Automatic identification of qualitative characteristics in infant cry. In *Spoken Language Technology Workshop, Berkely*, CA (pp. 442-447). doi:10.1109/SLT.2010.5700893

Sahak, R., Mansor, W., et al. (2010, October 4-6). Choice for a support vector machine kernel function for recognizing asphyxia from infant cries. In *Proceedings of the 2009 IEEE Symposium on Industrial Electronics and Application (ISIEA 2009)*, Malaysia (pp. 675-678).

Sahak, R., Mansor, W., et al. (2010). Performance of combined support vector machine and principal component analysis in recognizing infant cry with asphyxia. In *Proceedings of the 32nd Annual International Conference of the IEEE EMBS* (pp. 6292-6295). doi:doi:10.1109/IEMBS.2010.5628084 doi:10.1109/IEMBS.2010.5628084

Saraswathy, J., & Hariharan, M. Yaacob, S., & Khairuniazam, W. (2012). Automatic classification of infant cry: A review. In *Proceedings of the International Conference on Biomedical Engineering*, Penang (pp. 543-548).

Srouji, R., Ratnapalan, S., & Schneeweiss, S. (2010). Pain in children: Assessment and nonpharmacological management. *International Journal of Pediatrics, 2010*, 11.

Venpada, R. R., Kumar, S. A. B., & Sreenivasa Rao, K. (2012). Characterization of infant cries using spectral and prosodic features. In *National Conference Communications*, Kharagpur (pp. 1-5).

Zabidi, A., Khaun, L. Y., et al. (2010). Optimization of MFCC parameters using particle swarm optimization for diagnosis of infant hypothyroidism using multilayer perceptron. In *Proceedings of the 32nd Annual International Conference of the IEEE EMBS* (pp. 1417-1420).

Zabidi, A., Khaun, L. Y., et al. (2010). Classification of infant cries with asphyxia using multilayer perceptron neural network. In *Proceedings of the 2010 Second international Conference on Computer Engineering and Applications*, Bali Island (pp. 204-208). doi:doi:10.1109/ICCEA.2010.47 doi:10.1109/ICCEA.2010.47

Zabidi, A., Mansor, W., et al. (2010). Particle swarm optimisation of mel-frequency cepstral coefficients computation for the classification of asphyxiated infant cry. In *Proceedings of the 2010 3rd International Conference on Biomedical Engineering and Informatics*, Yantai (pp. 991-995). doi:doi:10.1109/BMEI.2010.5639674 doi:10.1109/BMEI.2010.5639674

Zabidi, A., Mansor, W., et al. (2010). Investigation of mel frequency cepstrum coefficients parameters for classification of infant cries with hypothyroidism using MLP classifier. In *Proceedings of the International Joint Conference on Neural Networks* (pp. 1-4). doi:doi:10.1109/IJCNN.2010.5595734 doi:10.1109/IJCNN.2010.5595734

N Sriraam received the B.E. degree in Electronics and Communication engineering(ECE) from the National Engineering College, Tamil Nadu, India, in 1996,the M.Tech degree(with distinction)in Biomedical Engineering from Manipal Institute of Technology(MIT),Manipal,India,in 2000,and the Ph.D. degree in Information Technology from the Multimedia University, Cyberjaya,Malaysia, in the area of biomedical signal processing, in 2007.He is currently working as Professor and h\Head, Department of Medical Electronics, M.S.Ramaiah Institute of Technology,Bangalore,Inida.He is the author or coauthor of 40 articles published in journals and has been involved in several sponsored research projects .His current research interests include biomedical signal processing, data mining, neural networks. He is the editor –in-chief of two journals:International Journal of Biomedical and Clinical Engineering (IJBCE),USA and International Journal Biomedical Signal Processing(IJBSP) and also reviewing panel member for Journals such as IEEE Transactions on Signal Processing Communications, IEEE Electronics letters, Elsevier publications such as Digital Signal Processing, Computers in Biology and Medicine, Expert Systems, Medical Informatics, Neurocomputing, Journal of Medical Systems .Dr. Sriraam is Senior Member of IEEE and IEEE Engineering in Medicine and Biology Society(EMBS),Signal Processing Society, life member of telemedicine Society of India and member of medical computer society of India. Currently he is serving as Chairman of IEEE EMBS Chapter,Bangalore Section India.

S Tejaswini is a full time PhD Scholar at Department of Medical Electronics, M.S.Ramaiah Institute of Technology,Bangalore,Inida and doing her PhD under the guidance of Dr N.Sriraam.. Her main areas of Interest are biomedical Signal Processin.