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Wavelet Packet Transform based Feature Extraction Technique for the Analysis of Infant cry signals

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ABSTRACT

The analysis of infant cry signals is important for understanding the health and development of infants. In this paper, we propose a Wavelet Packet Transform (WPT) based feature extraction technique for analysing infant cry signals. The proposed technique involves decomposing the cry signals into different frequency bands using the WPT using wavelet packet tree nodal analysis, and then extracting features from each subband using statistical measures. The extracted features are then used to classify the cry signals into different categories based on their acoustic characteristics and wavelet packet tree nodal analysis. Experimental results on a dataset of infant cry signals show that the proposed technique achieves high accuracy in classifying cry signals into different categories, such as hunger, pain, and discomfort. The proposed technique can provide a useful tool for healthcare professionals to monitor and diagnose the health and well-being of infants.

Keywords Infant cry signals, subband, statistical measures, wavelet Packet Transform, wavelet packet tree, nodal analysis

1. INTRODUCTION

Wavelet packet tree analyses both low and high-frequency sub-bands of a signal, consequently providing more elaborate information to be exploited for extracting features[1]. WPT provides us with a piece of valuable information that can be used to form a feature vector for any digital signal, in this paper we will provide an analysis of WPT to use the approximations and details for various levels of WPT to get the needed information necessary to create digital signal features vector [2].Infant cry signals are resourceful due to many applications requiring these data types, these types of information are usually converted from analog signals to digital signals by applying sampling, quantization, and encoding then these signals are used in many vital applications [3].A method for the automatic classification of infant cries using wavelet packet transform and hidden Markov models was used to extract features from the cry signal, and the hidden Markov models were used for classification [4]. The results showed that the proposed method achieved high classification accuracy for different cry types. An automated system for infant cry classification using wavelet packet decomposition and support vector machine [5]. The wavelet packet decomposition was used to extract features from the cry signal, and the support vector machine was used for classification[6]. Investigation onthe use of wavelet packet analysis of infant cries for the detection of perinatal asphyxia extract features from the cry signal, and the results showed that the proposed method achieved high sensitivity and specificity for the detection of perinatal asphyxia.

A method for feature extraction of infant cry signals using wavelet packet transform for neonatal pain assessment was used to extract features from the cry signal, and the results showed that the proposed method achieved high accuracy for the detection of neonatal pain.Several studies have investigated the use of WPT in infant cry classification. For example, a study used WPT to extract features from infant cries and then used a back-propagation neural network (BPNN) to classify the cries into different categories [7]. The results showed that the proposed method achieved high classification accuracy for different types of cries.Another study proposed a WPT-based method for detecting infant hypoxia. The method used WPT to extract features from the cry signal and then used a linear discriminant analysis (LDA) classifier to detect hypoxia. The results showed that the proposed method achieved high sensitivity and specificity for the detection of hypoxia.These different feature techniques were compared using the missing rate and average deviation. A combination of the Hidden Markov Model (HMM) and Support Vector Machine (SVM) was used to learn the data [8]. The suggested approach had the best rate of classification results for cry signals. An innovative method of categorizing baby wail sounds using histograms of recovered phase spaces This approach is a novel process that differs markedly from established methods. The feature extraction method used was MFCC The findings revealed that DBN did better than HMM in identifying one class while HMM had the greatest success rate in identifying the othersa pattern-based technique for precise plosive recognition [9]. The hierarchical approach and multi-class choices have been used to find a solution to the false silent detection issue. The feature methods of the MFCC and Mel Best Tree (MBT) were used.

Overall, these studies demonstrate the effectiveness of wavelet packet tree analysis in infant cry classification systems. Wavelet packet analysis can provide a multi-resolution representation of the signal with high frequency and time resolution, allowing for the extraction of relevant features from the signal. These features can then be used as inputs to machine learning algorithms for the classification of the cry signal, which can be used for the early detection and diagnosis of medical conditions in infants

2. DISCRETE WAVELET TRANSFORM

Discrete Wavelet Transform (DWT) is a signal processing technique that decomposes a signal into its constituent frequency components, allowing for a multi-resolution analysis of the signal. The DWT is particularly useful for analyzing non-stationary signals, such as audio or biomedical signals, where the frequency content of the signal varies over time.The DWT is a type of wavelet transform, which uses wavelets as a basis function for decomposition. Wavelets are mathematical functions that can be scaled and translated to fit any signal [10]. The DWT applies a set of wavelet functions to the signal at different scales and positions, resulting in a multi-resolution decomposition of the signal.The DWT operates by dividing the signal into frequency subbands, with each subband representing a different frequency range. The decomposition is performed by iteratively applying a low-pass filter and a high-pass filter to the signal, resulting in two sets of coefficients for each level of the decomposition. The low-pass filter coefficients represent the low-frequency subband, while the high-pass filter coefficients represent the high-frequency subband.

$$\varphi_{j,k}(t) = (1)/(\sqrt{2}^{j})\varphi(2^{-j}t - k) \quad k\epsilon z \qquad (1)$$

$$\psi_{j,k}(t) = (1)/(\sqrt{2}^{j})\varphi(2^{-j}t - k) \quad k\epsilon z \qquad (2)$$

The DWT can be visualized as a binary tree structure, where each level of the decomposition represents a different frequency band. The lowest level of the tree represents the original signal, while the highest level represents the highest frequency subband.One of the key advantages of the DWT is its ability to provide a multi-resolution analysis of the signal, which allows for the extraction of important features at different scales. This can be particularly useful for signal processing applications, such as feature extraction or signal compression.The DWT has a wide range of applications, including signal and image processing, data compression, and pattern recognition. In signal processing applications, the DWT can be used for feature extraction, denoising, and signal classification.

3. WAVELET PACKET DECOMPOSITION

Wavelet packet transform (WPT) is a type of wavelet transform that decomposes a signal into a set of wavelet packets, which are wavelets that have been further subdivided into smaller frequency subbands. This allows for a more detailed representation of the signal than traditional wavelet transform, and can be particularly useful in signal processing applications, such as infant cry classification [11].Infant cry classification is an important application in pediatric medicine, as it can provide valuable information about the health and well-being of infants. WPT has beenhown to be effective in extracting features from infant cry signals, which can be used to classify different types of parent led analysis of the signal, by decomposing the signal into a larger number of frequency subbands.

$$\psi_{j+1}^{2p}(t) = \sum_k h[k]\psi_j^{2p}(t - 2^{-j}k) \qquad (3)$$

$$\psi_{j+1}^{2p+1}(t) = \sum_k g[k]\psi_j^{2p}(t - 2^{-j}k) \qquad (4)$$

This can be particularly useful in infant cry classification, where the different types of cries may have subtle differences in frequency content [12].In an infant cry classification system using WPT, the cry signal is first decomposed into wavelet packets, and then features are extracted from each subband using statistical measures such as mean, variance, and energy. These features are then used as inputs to a machine learning algorithm, such as a support vector machine (SVM) or artificial neural network (ANN), to classify the cry signal.Overall, WPT has been shown to be an effective method for feature extraction in infant cry classification systems, allowing for a more detailed analysis of the signal than traditional wavelet transform [13]. The use of WPT in infant cry classification can provide valuable information for early detection and diagnosis of medical conditions in infants, improving the overall quality of pediatric care.

4. WAVELET PACKET TREE

A wavelet packet tree is a powerful tool for analyzing and processing signals, and it has been applied to various applications, including speech recognition, image processing, and biomedical signal analysis [14]. In the context of infant cry classification systems, the wavelet packet tree can be used to extract relevant features from the acoustic signal of infant cries. Infant cry classification systems are used to analyze the acoustic characteristics of infant cries and classify them into different categories based on the cry type, duration, and pitch. These systems are important for the early diagnosis of various medical conditions, such as hypoxia, hearing impairment, and neurological disorders [15].

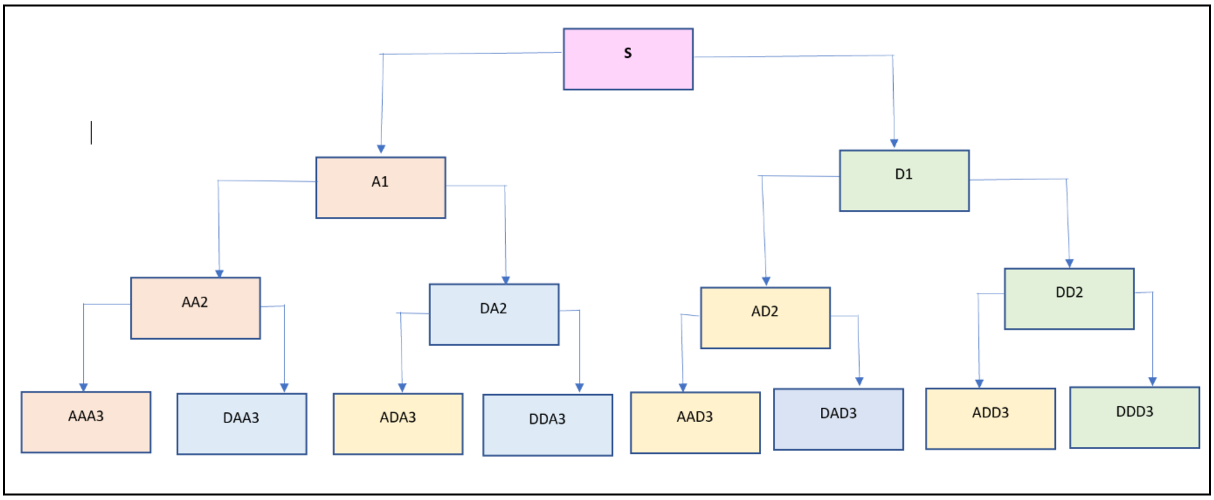

Figure 1 Wavelet Packet Decomposition Tree Structure

As shown in Figure 1, the wavelet packet tree is a multi-resolution decomposition of a signal that provides a more detailed analysis than traditional wavelet transforms. It allows for the extraction of not only the low-frequency components but also the high-frequency components of the signal, providing a more comprehensive representation of the signal.

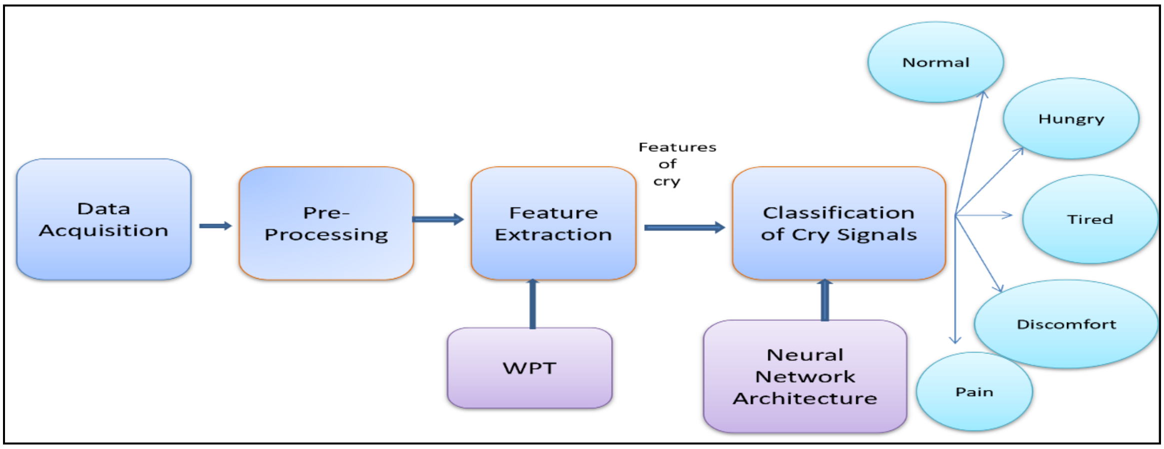

Figure 2 Proposed Block Diagram

In the context of infant cry classification systems, as illustrated in Figure 2, the wavelet packet tree can be used to extract relevant features from the acoustic signal of infant cries, such as the frequency and duration of different cry components. The wavelet packet tree can also be used to identify the presence of abnormal patterns in the cry signal, such as long pauses or irregularities in the crying pattern, which may indicate the presence of an underlying medical condition. The wavelet packet tree can be used in conjunction with various machine learning algorithms, such as support vector machines, neural networks, and decision trees, to classify infant cries into different categories based on their acoustic characteristics. The combination of wavelet packet tree analysis and machine learning algorithms can provide a powerful tool for the early detection and diagnosis of medical conditions in infants.A wavelet packet tree is a powerful tool for the analysis and processing of signals, and it can be used in infant cry classification systems to extract relevant features from the acoustic signal of infant cries. The wavelet packet tree can provide a more comprehensive representation of the signal, allowing for the identification of abnormal patterns that may indicate the presence of an underlying medical condition.

5. FEATURE EXTRACTION

Feature extraction from nodes in a wavelet packet tree is an important step in signal processing applications, including infant cry classification systems. A wavelet packet tree is a powerful tool for analysing and decomposing signals, providing a multi-resolution representation of the signal with high frequency and time resolution. Each node in the wavelet packet tree represents a specific frequency and time interval in the signal, and feature extraction from these nodes can help to identify important characteristics of the signal. There are various methods for feature extraction from nodes in the wavelet packet tree, and some common approaches include statistical measures, frequency-domain features, and time-domain features.In the context of infant cry classification systems, feature extraction from nodes in the wavelet packet tree can help to identify important characteristics of the cry signal, such as the frequency and duration of different cry components. These features can then be used as inputs to machine learning algorithms, such as support vector machines, neural networks, and decision trees, for classification of the cry signal.

Here, the extracted features from the wavelet packet tree nodal analysis forms a feature vector for each class and fed as an input for the neural network for the efficient classification of infant cry signals with good accuracy and reliability .The following metrics such as accuracy, precision, recall and F- score was calculated for the provided feature vector.

6. MODEL PERFORMANCE METRICS

6.1 Precision

It provides the probability of true positive results amidst all positive results.

$$Precision = \frac{TP}{TP+FP} x100 \quad (5)$$

6.2 Recall

It gives the probability of true positive results among all expected positive results

$$Recall = \frac{TP}{TP+FN} x\ 100 \qquad (7)$$

6.3 F1- Score

A parameter which is based on the combination of both precision and recall is known as the F score.

$$F1\ Score = \frac{2*Precision*recall}{recision + recall} x100 \qquad (8)$$

6.4 Accuracy

It is the parametric measure used to evaluate and provides the measure how much the class is classified accurately.

$$Accuracy = \frac{TP+TN}{TP+FN+TN+FP} \quad x\ 100 \qquad (9)$$

7. RESULTS AND DISCUSSION

The following results were obtained while computing the wavelet packet tree structure for the following infant cry signals and the following parametric were evaluated for the efficient classification of infant cry signals.

7.1 Normal Infant Cry signal WPT analysis

The following figure 3 represents the nodal analysis of infant cry signal. In the shown normal cry signal at each node of the wavelet packet tree the informative content present in the signal also varies

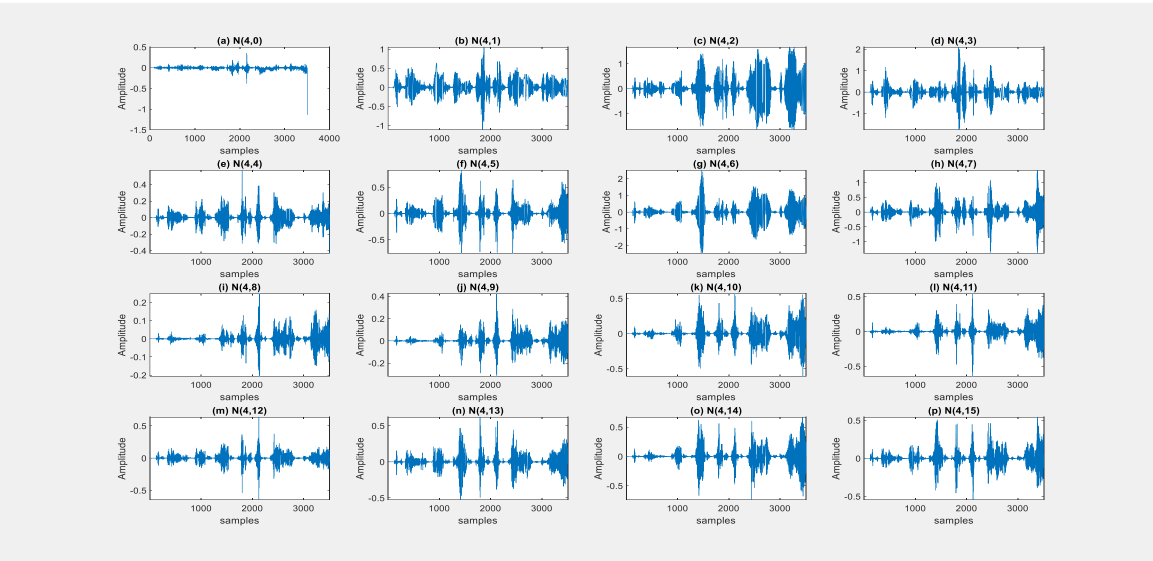

Figure 3 WPT nodal analysis of normal cry signal

It is observed that the amplitude of the cry signal varies in each node for example at node N(4, 0) the magnitude varies between 0 to -1whereas in node N(4,1) the magnitude of the amplitude reaches peak of 1 . Similarly the 16 nodes obtained from the wavelet packet tree differs to each other.

7.2 Hunger infant Cry signal WPT analysis

The below Figure 4 shows the terminal nodes of the hunger cry signal obtained from the wavelet packet tree analysis

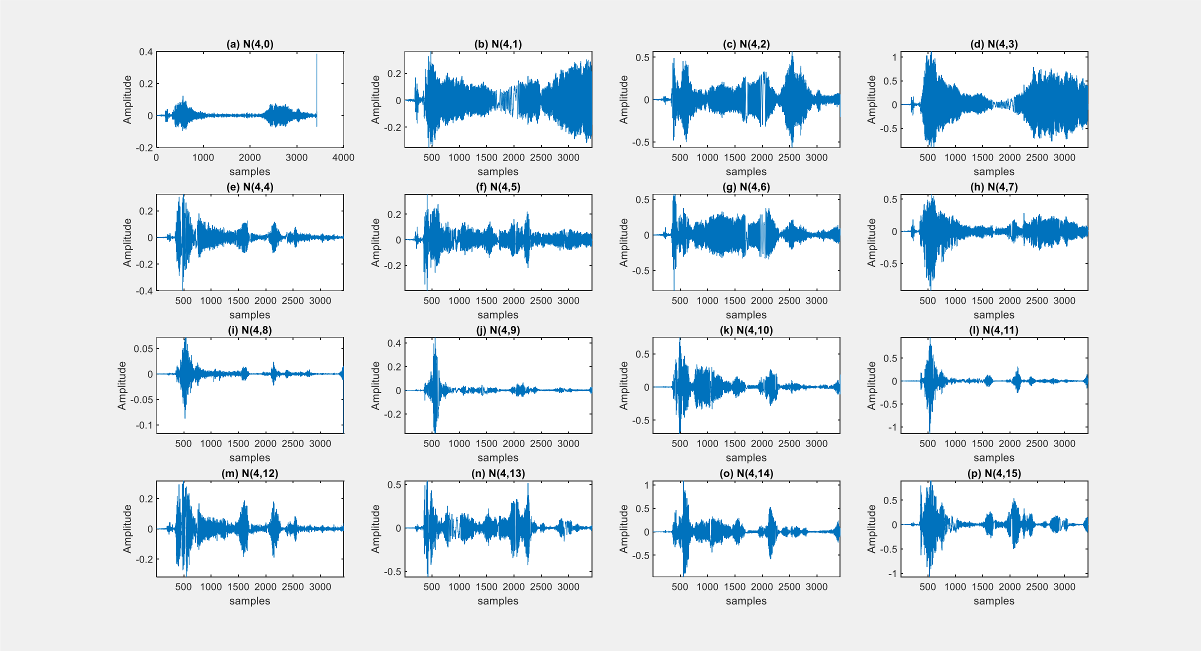

Figure 4 WPT nodal analysis of hunger cry signal

It is depicted that the nodes ranges from N(0,1) to N(4, 15) varies in the amplitude magnitude of hunger cry signal and enables to form a feature vector for the classification

7.3 Belly Pain infant Cry signal WPT analysis

The Figure 5 obtained shows the terminal nodes of the belly pain infant cry signal obtained from the wavelet packet tree analysis.

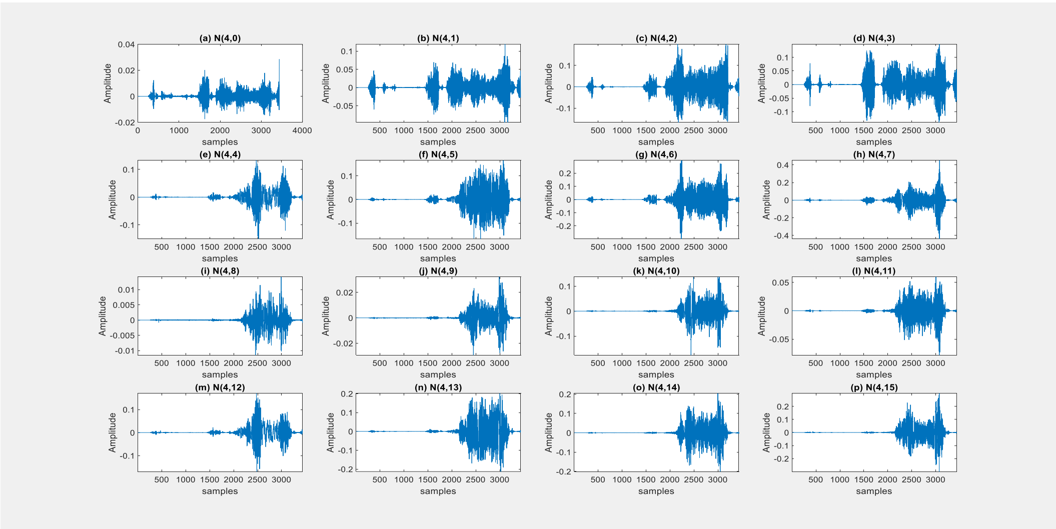

Figure 5 WPT nodal analysis of Belly pain cry signal

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It is clearly demonstrated that, the nodes from N(0,1) to N(4, 15) varies in the amplitude magnitude of belly pain cry signal and thus form a feature vector for the classification

7.3 Discomfortinfant Cry signal WPT analysis

The below Figure 6 shows the terminal nodes of the discomfort cry signal obtained from the wavelet packet tree analysis

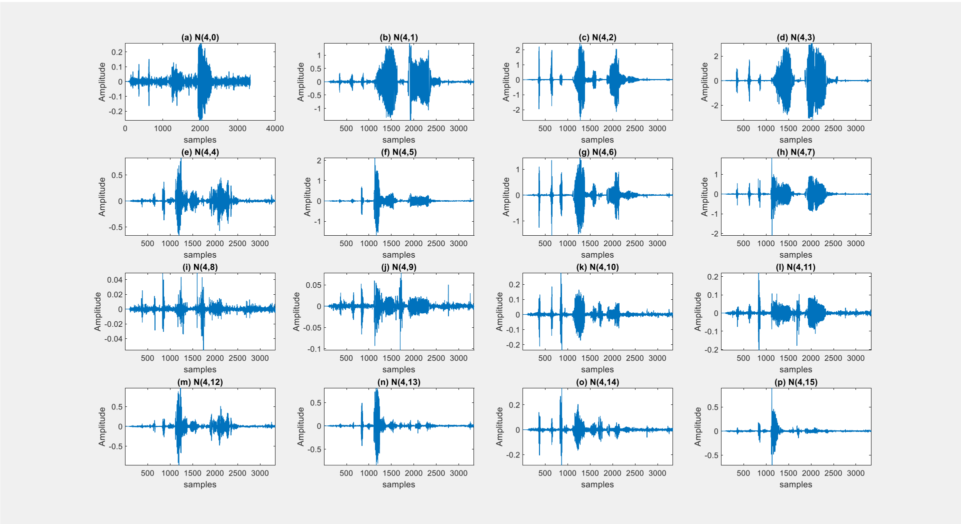

Figure 6 WPT nodal analysis of discomfort cry signal

It is inferred that the nodes ranges from N(0,1) to N(4, 15) varies in the amplitude magnitude of discomfort cry signal and enables to form a feature vector for the classification

7.4 Tired infant Cry signal WPT analysis

The following Figure 7 shows the infant cry signal signal outcome in their respective nodes namely from N(4,0) to N(4,15).

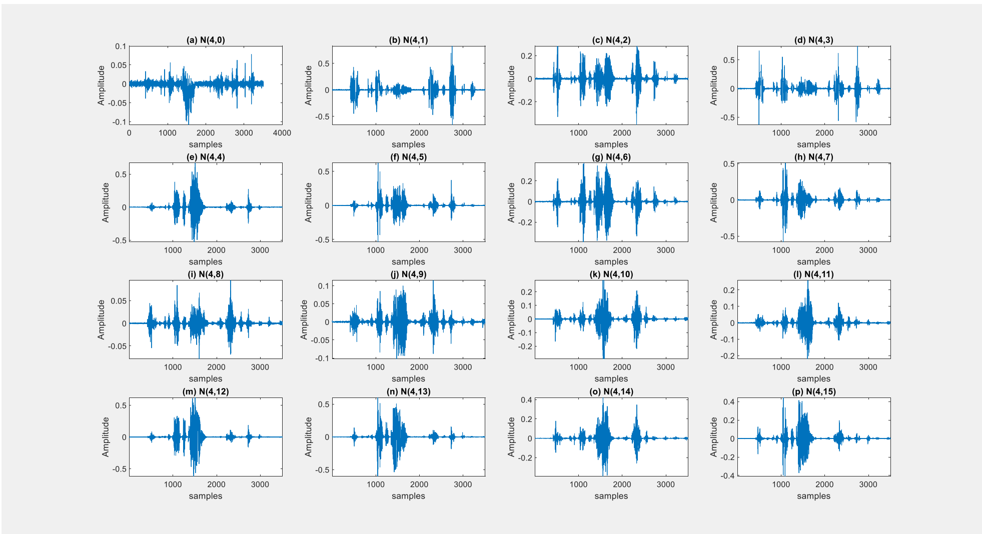

Figure 7 WPT nodal analysis of tired cry signal

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From the Figure it is depicted that the amplitude of the signal at each node varies and thus forma a feature vector for the efficient cry signal classification.

8. INFANT CRY SIGNAL CLASSIFICATION SYSTEM

Infant cry signals have been used to distinguish between various cry signal classes, including hunger, tired, discomfort, and belly pain. Researchers have been using cutting-edge techniques to differentiate between abnormal and typical crying over the last ten years. The most widely studied illness is asphyxia scream. The most recent research on separating asphyxia lament from regular cry. Accuracy, the most recent SVM model, the deep learning FFNN model, and Probabilistic Neural Network (PNN) all achieve high accuracy.

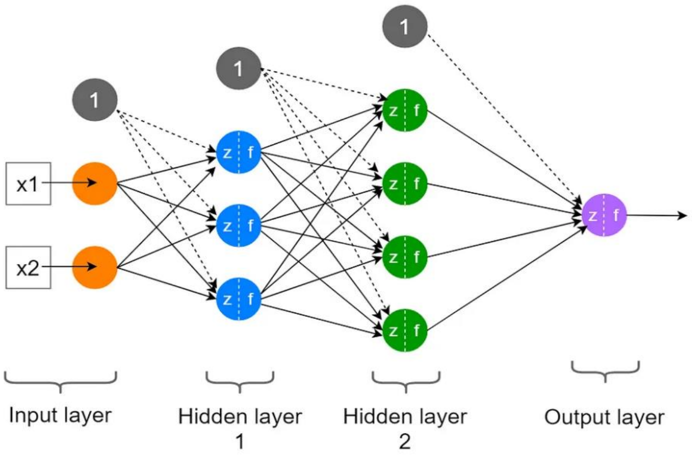

Figure 8 Artificial Neural network architecture

Nonlinear components at various levels are layered hierarchically to form an ANN as shown in Figure 8. The monkey visual system's sequential information processing was the design's main inspiration. Such hierarchical arrangements allow deep models to learn significant characteristics at various levels of abstraction. Deep neural networks (DNNs), a class of effective hierarchical ANNs, are suggested. Random Forest (RF), K- Nearest neural network (KNN), Linear Regression LR and Support Vector Machine (SVM) are deep belief neural networks with dynamic adversaries movement models These models capture both straightforward and intricate characteristics that are comparable to those found in the hierarchical areas of primate visual systems. As a result, the models work exceptionally well when handling signal classification, particularly complex cry detection tasks. The following metrics were evaluated and SVM shows the efficient classification of the cry signals as shown in Table 1.

Table 1 Result analysis of Neural network classifiers

Classifier	Accuracy	F1- Score	Recall	Precision
RF	85%	84%	82%	84%
KNN	87%	84%	86%	82%
LR	94%	89%	90%	91%
SVM	98%	96%	94%	97%

It is inferred from the Table 1 that the SVM classifier gives good accuracy of 98% accompanied with a furnished F1- score value of 96%, and a precision of 97%.

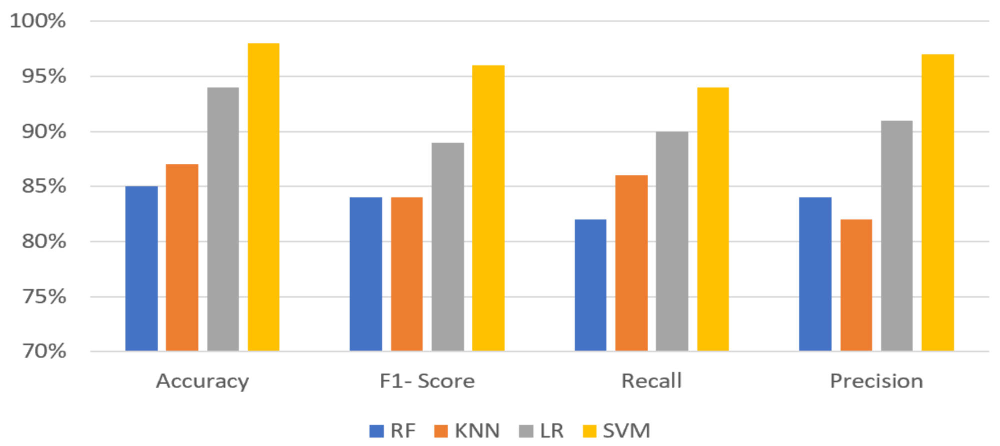

Figure 9 Performance Analysis of neural network architecture in the classificationof infant cry signals

Figure 9 demonstrates the comparison of performance metrics for the neural network architecture in the classification of infant cry signals. It is inferred that SVM outperforms other classifiers in the classification of infant cry signals.

9. CONCLUSION

The proposed Wavelet Packet Tree Transform (WPT) based feature extraction technique for the analysis of infant cry signals offers a promising approach for the diagnosis and monitoring of the health and well-being of infants. By decomposing cry signals into different frequency bands using the WPT and extracting features from each subband, the proposed technique enables accurate classification of cry signals into different categories based on their acoustic characteristics. The experimental results on a dataset of infant cry signals demonstrate the effectiveness of the proposed technique in achieving high accuracy in cry signal classification. The proposed technique can be a useful tool for healthcare professionals in identifying the underlying causes of infant crying, such as normal, hunger, pain,tired and discomfort. Overall, the proposed technique provides a valuable contribution to the field of infant cry signal analysis and has the potential to improve the diagnosis and treatment of infants with various health conditions. Further research can explore the application of the proposed technique in real-world clinical settings and investigate its potential for early detection of health issues in infants.

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