Proceedings of the First

University Journal of Research and Innovation

December, 2019

Organized by
University of Computer Studies (Pakokku)

Proceeding of

The First University Journal of Research and Innovation 2019

December , 2019

Organized by

University of Computer Studies (Pakokku)

Department of Higher Education ,

Ministry of Education , Myanmar

University Journal of Research and Innovation

Volume 1, Issue 1 2019

University Journal of Research and Innovation 2019

Volume 1 , Issue 1 , 2019

This journal and individual papers published at www.ucspkku.edu.mm.

Copies:110

All research papers in this journal have undergone rigorous peer-reviewed which is published annually. Full papers submitted for publication are refereed by the Associate Editorial Board through an anonymous referee process.

The authors of the paper bear the responsibility for their content.

Papers presented at the First University Journal of Research and Innovation(UJRI), University of Computer Studies (Pakokku), December 2019.

UJRI 2019 Editorial Board

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Proceedings of

The First University Journal of

Information and Computing Science 2019

December, 2019

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Recognition of Shan Syllables Sound Based on Convolutional Neural Network Model

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Abstract

Speech recognition is the process of converting speech signals to the text. A syllable centric speech recognition system in this aspect identifies the syllable boundaries in the input speech and converts it into the respective written scripts or text units. Automatic recognition of the syllable units is an important task for development of highly accurate speech recognition system.

This paper presents an automatic syllable sound recognition system to provide the speech recognition of Shan language. We explored the speech audio classification system by learning the nature and features of the spectrograms of each syllable and word sound. In this study, we treated speeches with a CNN (Convolutional Neural Network model) (Inceptionv3) to fit spectrogram images, performing transfer learning from pre-trained weights on Image Net. Validation accuracies of 60.70%, 73.20%, and 94.60% were achieved for the consonant and vowel level classifications, respectively. In order to determine the retrained model performance, both closed and open testing were conducted.

Keywords: *Speech recognition, CNN, Inceptionv3*

1. Introduction

Speech recognition technology allows computer to recognize and comprehend human languages. Speech recognition techniques are widely used in many application areas and were started in the 1950s.

According to Davis et al. [12], research related to vowel was conducted. Based on research by Olson and Belar [13], the first study for recognizing syllables was conducted. The study tried to recognize ten distinct syllables from a single talker, which was characterized by its spectral, amplitude, and frequency band. Later 1980s, several popular methods such as Support Vector Machines (SVM), Gaussian Mixture Model (GMM), Hidden Markov Model (HMM), Naive Bayes (NB), Linear Discriminant Analysis (LDA) and Multi-Layer Perceptron (MLP) or Artificial Neural Network (ANN) are commonly applied in recognizing and classifying speech signal [2,3,5,6]. Various types of classifier such as MLP, HMM, LDA, GMM, NB and speech analysis techniques such as MFCC and LPC are also used for classification of speech signals.

Furthermore, several studies have been conducted on spectrogram-based audio classification using neural network models [3,4,5], and this has become a research interest in the audio classification based on spectrogram images and using deep networks yields the highest accuracy rates. This paper presents the classification of Shan syllable signals by using a convolutional neural network (CNN) model (Inception-v3) to fit spectrogram images, performing transfer learning for speech classification.

The syllable sounds are initialize with plosives and followed by vowel. We tested the method for consonants and vowels on our recorded database of 19-consonant, and 80-vowel sound classes, Shan spectrograms of speech. Because Shan language is tonal, the sounds are very similar for precise classification based on audio features, while the visual representations differ. Therefore, it is important to consider the visual representations of audio in classifying the language. In order to reduce the development costs, we apply transfer learning using Google's pre-trained CNN model (Inception-v3) that can be fine-tuned.

The remainder of this paper is organized as follows: Section 2 describes the nature of the Shan language. In section 3, we describe the methodology used for classification of the language. Section 4, presents the experimental setup. Section 5 discusses the result findings and finally, section 6 concludes the paper.

2. Nature of Shan language

2.1 Syllable

Shan language is spoken by about 3.3 million people in the states of Myanmar in northeast of the country, also in parts of northern Thailand and in the Xishuanbanna (Sipsongpanna). The language is also known as Shan-Yai, Shan-Long. The speaker of

Shan language, classified as Sino-Shan. It is distantly related to Cantonese and other Chinese dialects, and closely related to Lao and Thai.

In Shan language, symbols are in circular shape, like those of the Myanmar language. Moreover, if is a tonal language, which means that a syllable or word changes along the tone. The script consists of 19 basic consonants, 80 vowels, 5 basic medial, and other symbols and special characters. For example, **"ၽ"** and "ၾ" have the same pronunciation, "pha."The script is written from left to right. Conventionally, although sentences in the script are delimited by sentence boundary markers, there are no white spaces between words, as in English. However, in model writing, spaces are used between words to provide readability. The script is generally syllabic in nature, consisting of sequences of syllables. In the language, the syllable is the smallest linguistic unit, and it can generally be assumed that one word consists of one or more syllables. Syllables are composed of consonants and (zero or more) vowel combinations starting with a consonant. In general, at least one major syllable must exist in a word. For example, in the word '"မႂ်ႇသုင်ၶႃႈ" (MI SON KA), there are three syllables. The first syllable is formed by the following combination: consonant မ (ma.) with dependent vowel ႂ် (kwil), vowel ႇ(yak), second is a consonant သ (tsa), vowel ု(tit),consonant င(nga), killer ် (phat), and The third consonant ၶ (kha.) vowel ႃ(are), vowel (yaktsam).

2.2 Notable Features

Type of writing system: syllabic alphabet- each letter has an inherent vowel. Other vowels sounds are indicated using diacritics attached to the consonants. Direction of writing: left to right in horizontal lines. It is a tonal language with five tones, plus a seventh which is used for emphasis.

2.2.1 Consonants

ၵ ၶ င ၸ သ ၺ တ ထ ၼ
ပ ၽ ၾ

[ka][kha][nga][tsa][sa][nya][ta][tha][na][pa][pha][fa]

မ ယ ရ လ ဝ ႁ ဢ

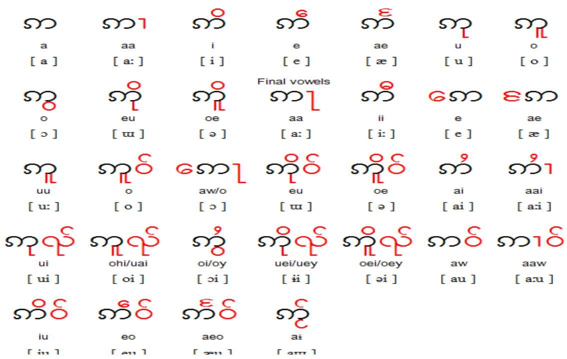
[ma][ya][ra][la][wa][ha][a]

2.2.2 Final consonants and other symbols

ၵ် င် ၺ် တ် ၼ် ပ် မ်

[Ka phat][nga phat][nya phat][ta phat][nap phat][pa phat][ma phat]

2.2.3 Vowels



2.2.4 Tones and punctuation

Shan name		Type	Example		
ပဝ်ႇ	pàu	rising	လီ	/li:/	good
ယၵ်း	yák	low level	ၼႃႇ	/na:/	very
ယၵ်းၸမ်ႈ	yák tsăm	low falling	ၼႃႈ	/na:/	face
ၸမ်ႈၼႃႈ	tsăm nā:	high falling	ၼႃး	/na:/	paddy field
ၸမ်ႈတႂ်ႈ	tsăm tău	mid falling	ၼႃႉ	/na/	aunt, uncle
ယၵ်းၶိုၼ်ႈ	yák khĕun	mid level	ၼႃႊ	/na:/	thick
၊ comma		။ fullstop			

2.2.5 Numerals

႐ ႑ ႒ ႓ ႔ ႕ ႖ ႗ ႘ ႙
0 1 2 3 4 5 6 7 8 9

To say "Thank you very much," in Shan langage, it is said as ယိၼ်းလီၼမ်ၼမ်ၶႃႈ (pronounced as Yin lii nam nam ka). The usual greeting in a village, ၵိၼ်ၶဝ်ႈယဝ်ႉႁႃႉ (pronounced as Kin khao yao ha?) that means , "Have you eaten?" The reply is probably yes, so the follow-up question asks what the person had lunch or dinner. A popular expression is ဢမ်ႇပိၼ်သင် (pronounced as Am pen tsang-) means "No problem" .

3. Methodology

3.1. Inception-v3

In Google, numerous neural network models have been made publicly available for use in Tensor Flow [7]. In order to reduce the development costs, we apply transfer learning using Google's per-trained CNN model(Inception-v3)that is ready to be fine-tuned. It was released as the 2015 iteration of Google's Inception architecture for image recognition. Inception-v3, which is a CNN, was trained on more than one million images from the Image Net database. The Inception-v3 model achieved 78.00% top-1 and 93.90% top-5 accuracy on the Image Net test dataset [8]. Moreover, the network is 48 layers deep and consists of two parts: (1) feature extraction with a CNN, and (2) classification with fully connected and soft max layers. In the first part, the model extracts general features from the input images; in the second part, it classifies these input images based on those features. Therefore, the first part involves preprocessing only, and it is only necessary to train the second part. The architecture of Inception-v3 is explained in [9] and illustrated in Figure 1.

3.2 Transfer Learning

Transfer learning is a machine learning technique whereby the knowledge gained during training in one problem is used for training in another, similar type of problem. In transfer learning, the base network and ask are trained on a base dataset, following which the learned features are repurposed on a target dataset and task. In deep learning, the first several layers are trained to identify problem features. During transfer learning, the final layer can be replaced with the desired dataset. For our experiment, in which the problem was to classify speech automatically, we needed to collect a large amount of labeled data for training the sound classification models for each consonant, vowel, and word. However, it is expensive and requires substantial time to Shan a trained model. In such cases, transfer learning can aid in training neural networks in considerably less time. In Figure 2, the architecture of the transfer learning for the speech classification is explained. According to Figure 2, the word was recognized using transfer learning for image classification.

4. Experimental Setup

In this section, the Shan of the experimental setup for the speech classification are described. The experiment consisted of four main parts: data pre-processing, audio featuring, training, and testing.

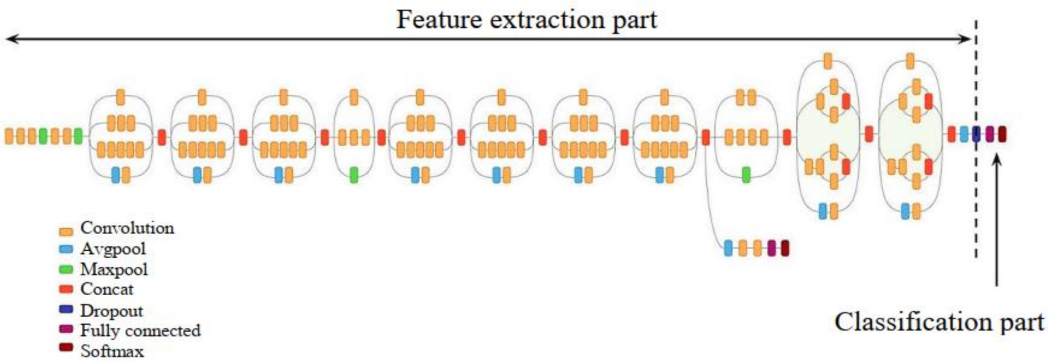


Figure 1. Inception-v3 architecture

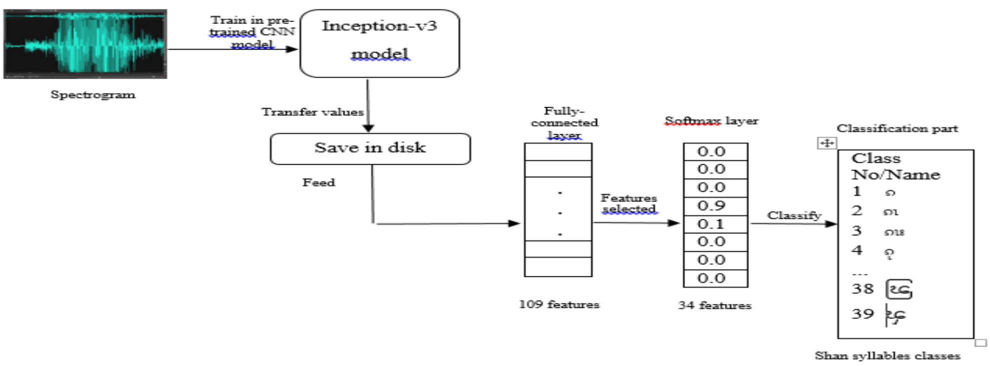
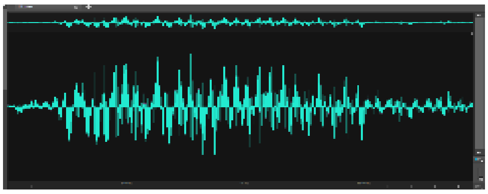
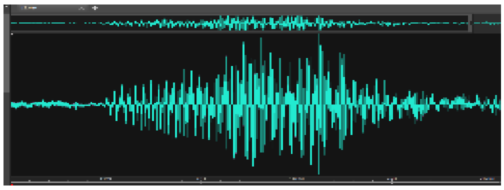


Figure 2. Architecture of transfer learning for Shan syllable classification



(a)Spectrogram of ‘ၽ’Pha



(b) Spectrogram of ‘ၾ’Fa

Fig.3. Spectrograms of Shan syllables

4.1. Data Pre-processing

We prepared audio files of the 19 consonants and 80 vowels in Shan language from 5 native speakers. All speech samples are recorded using a wave pad song editor built-in microphone and are stored in spectrogram format files. There were 20 audio files for each word class. The duration of each audio file was approximately one second. All recorded audio files were down-sampled from a sampling rate of 44 kHz to 16 kHz with a mono channel.

4.2. Audio Featuring

Data representation is a crucial step in any learning process. In our experiment, the audio files were represented in the form of visual images (spectrograms) that can be used to identify spoken words phonetically. In general, a spectrogram is a visual representation of sound frequencies that is used in music, sonar, radar, and speech processing. Two examples of the word spectrograms are presented in Figure 3.In the figure, the spectrograms of ၽ pha and ၾ fa appear alike as they have a similar tone, and may be difficult to distinguish.

4.3. Training and Testing

In the training stage, using the retrained model, we tested the syllable-classification of syllables for both closed testing and open-testing (with the other record audio files of the same speaker). In the closed testing, spectrograms from the dataset, recorded by multiple speakers used in the training, were randomly selected. In the open testing, other spectrograms of different audio files were selected at random.

Table.1 Data Preparation

Number of Syllables	Training spectrogram	Test spectrogram
All syllables	500	30
Speakers	5	5

We performed 19 classifications for each consonant class and 6 for each vowel class. As mention above, 10 spectrograms from the dataset are used in training where randomly chosen for closed testing. Another 10 spectrograms were picked out from second audio dataset. Table 2 shows the number of spectrograms used in testing and training.

5. Results and Discussion

We achieved validation test classification accuracies of 60.70%, 73.20%, and 94.60% class most correctly classified by our model was class 8, “ၺ” (nya), at 20 times, and the second was class 13, “ပ” (pa.), at 18 times. Furthermore, we divided the consonants into five pairs, where syllables shared a similar tone within each pair. The five pairs of consonants are displayed in Table 1. A comparison of the classification accuracies for these five pairs in the closed and open testing is presented in Figure 4. According to Figure 4, it can be assumed that our model could classify pair 5 most correctly and pair 3 least correctly in both the closed and open testing.

5.1 Consonant Classification

For the consonant classification, the validation test accuracy was 60.70%. In the closed test, the classification accuracy was approximately 38.18%. In contrast, according to the results, the accuracy was 34.55% in the open test. In the closed testing, the classification using transfer learning for image classification.

Moreover, for these five consonant pairs, the classification results were presented as a confusion matrix in order to determine the performance, as illustrated in Figure 5. According to the confusion matrix for the results of each pair, the pair that the model could recognize most correctly was pair 3 (ပ ၽ ၾ), with 10 times, one time, and 12 times in the open test and 18 times, 3 times, and 12 times in the closed test for each class, respectively. In contrast, the pair that our model classified incorrectly numerous times was pair 2(တ, ထ). In the closed test, our model classified class 9 correctly only. Pair no. five times, and class 11 correctly once. However, our model could not classify other classes within the third pair correctly, with the only exception being class 9. The second-best pair in both the open and closed test was pair 3 (င ၺ ၼ). However, in the open test, it was classified incorrectly as other classes when classifying class 4.

6. Conclusion

In this paper, the classification of Shan speech using transfer learning for image classification has been presented, achieving validation accuracies of 60.70% and 73.20%, for the consonant and vowel, and classifications, respectively. In the closed testing, we achieved classification accuracies of 8.18% and 61.67%, with 34.55% and 60%, in the open testing for the consonant and vowel, sound classes, respectively. Based on the experiment a speech includes consonants, vowels, and words. The results demonstrated that transfer learning can achieve classification when the number of classes is not high. In the future explain to conduct further Shan experiments sound classification using transfer learning with other freely available models, and comparing the results. Moreover, in order to use this approach in practical applications, it is intended to conduct a further study concerned with the retraining part of the transfer learning on duct a further study concerned with the retraining part of the transfer learning.

Table 2. Five pairs of Shan Consonants

Pair no.	Class no.	consonants IPA format
1	1, 2	ၵ ၶ Ka, k^ha,
2	4,5	ၸ သ tsa, sa
3	7,8	တ ထ ta,tha
4	3,6,9	င ၺ ၼ nga , nya ,na
5	10,11,12	ပ ၽ ၾ pa, pha, fa

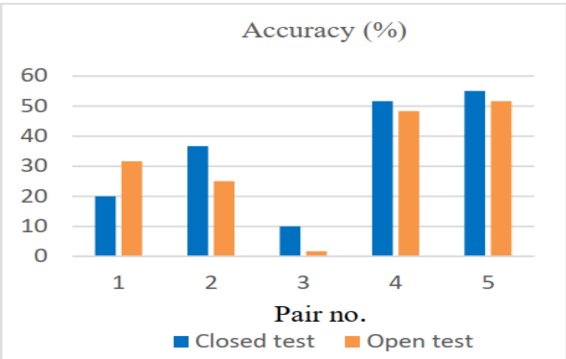


Fig.4. Comparison of consonant classification accuracies for five pairs in close and open tests

Acknowledgement

The authors gratefully acknowledge the teachers and students from the University of Computer Studies, Kyaing Tong, who participated in recording the sounds for the Shan consonants and vowels, and who aided in recording the words.

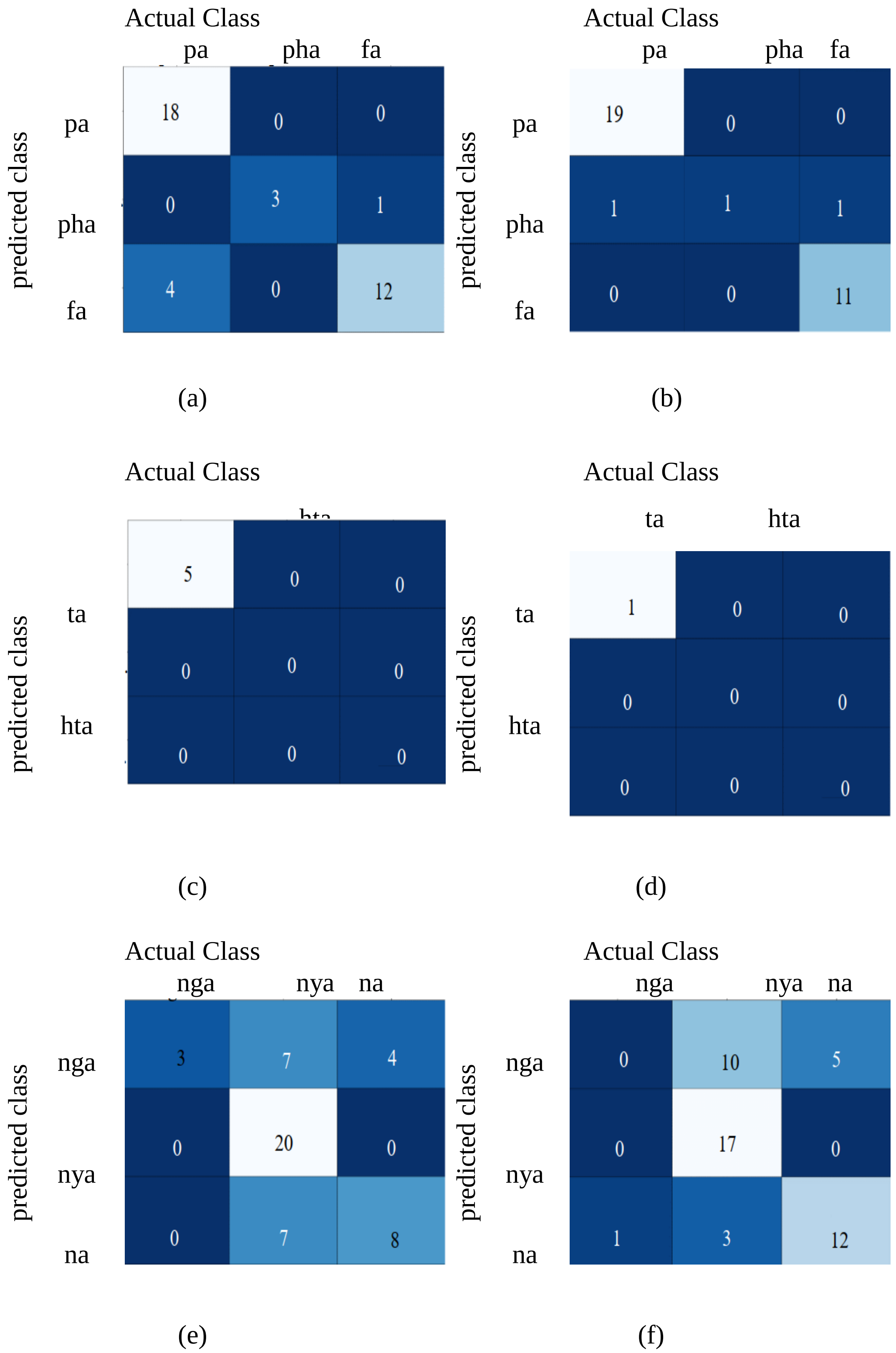


Figure 5.(a)Confusion matrix for pa and hpa, a. pair in closed test; (b) Confusion matrix for pa., hpa., and fa. Pair in open test; (c) Confusion matrix for nga, nya, and na. Pair in closed test; (d) Confusion matrix for nga., nya, na. Pair in open test; (e) Confusion matrix for ta and hta, Pair in closed test; and (f) Confusion matrix for ta and hta, Pair in open test.

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Prediction of Diabetes Diseases by Building a Machine Learning Model

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Abstract

Today, the processing strength and storage ability has increased dramatically and huge amounts of data are widely available. There is an urgent need for transforming data into useful information and knowledge. With the rapid development of machine learning, many aspects of medical health has applied a variety of machine learning approach. Given a number of elements all with certain features, we want to build a machine-learning model to identify people affected by type 2 diabetes. This research work focuses on pregnant women suffering from diabetes. The aim of this paper is to compare the six different learning algorithms in order to predict diabetes in patients more accurately using the Pima-Indians-Diabetes Dataset obtained from UCI Machine Learning repository site, the Centre for Machine Learning and Intelligent Systems at the University of California, Irvine.

Keywords: Machine Learning, Support Vector Machine, Artificial Neural Network, Decision Tree, Logistic Regression, Naïve Bayes

1. Introduction

Diabetes is one of the deadliest and chronic diseases in the world; this disease inflicted 246 million people. Diabetes is a kind of illness. It affects the ability of the body in producing the hormone insulin. It in turn makes the metabolism of carbohydrate abnormal and raise the levels of glucose in the blood. Diabetes can divide into type 1 diabetes (T1D) and type 2 diabetes (T2D). T1D patients are commonly less than 30 years old and T2D occurs most in middle-aged and elderly people. In Diabetes, a person generally suffers from high blood sugar. Intensify thirst, Intensify hunger and Frequent urination are some of the symptoms caused due to high blood sugar. Many complications occur if diabetes remains untreated.

Healthcare data is complex and high in dimensionality and contains irrelevant information; therefore, the prediction accuracy is low. Classification problems are prediction of class labels where number of classes is fixed and pre-defined. There is nothing like a particular classification method is accurate to classify the data in all situations. The accuracy of classification method is depends on the data we want to classify. In health related studies, the main research is going on the risk prediction. Predicting the risk in study of any disease is the main goal of health related studies. Recently, health related studies researchers are using machine-learning techniques to predict diabetes. By doing this the researches want to show the conditions those causes that particular disease. For this research the classification methods are very helpful and giving the best results. In this study, we used K Nearest Neighbor, Artificial Neural Network, Support Vector Machine, Decision Tree, Logistic Regression and Naïve Bayes to predict the diabetes.

2. Classification

Classification is very helpful method in predicting the risk in diabetes disease prediction.

Classification categorizes the items into target classes. Aim is to make predicting the target class accurately from the data [1]. Classifier can learn from the examples. Modern classification learning techniques gives more intelligent prediction results [2, 3].Classification techniques used in this research work described as below.

2.1. K-Nearest Neighbor (KNN)

M. Cover and P. E. Hart proposed K-nearest neighbor algorithm. KNN is a non-parametric lazy learning algorithm. It means that it does not make any assumptions on the underlying data distribution. In this algorithm, we know the type of class and the object's group to which it belong to is unknown. It considers more than one nearest neighbor to identify the class to which the data point it belongs to [4]. We can assign the training points with some weights based on their distance from data points. To improve memory limitations, we can use the NN training set to structure using different techniques. To defeat the memory limitations data set size is trim down.

2.2. Artificial Neural Network (ANN)

Artificial Neural networks are those systems modeled based on the human brain working. As the human brain consists of synapses that interconnect with millions of neurons, a neural network is a set of connected input/output units in which each connection has a weight associated with it. Multi-Layer Perceptron (MLP) network models are the popular network architectures. It is used in most of the research applications in medicine, engineering, mathematical modeling, etc.

In MLP, we pass the weighted sum of the inputs and bias term to activation level through a transfer function to produce the output, and arrange the units in a layered feed-forward topology called Feed Forward Neural Network (FFNN) [5]. It is highly fault tolerant and suitable for all kinds of real-world problems. The challenge of training neural networks involves carefully selecting the learning rate.

2.3. Support Vector Machine (SVM)

Support vector machine is an algorithm that attempts to find a linear separator (hyper-plane) between the data points of two classes in multidimensional space. These models closely relate to neural networks. They use a sigmoid kernel function, which is equivalent to a two-layer, perceptron neural network. The aim of SVM is to find the best classification function to distinguish between members of the two classes in the training data [6]. It is a good classifier because of its high generalization performance without the need to add a priori knowledge, even when the dimension of the input space is very high.

2.4. Naïve Bayes Classifier (NB)

Naive Bayes is a classification technique with a notion, which defines all features, are independent and unrelated to each other. It defines that status of a specific feature in a class does not affect the status of another feature [7]. Since NB based on conditional probability, it is a powerful algorithm employed for classification purpose. It works well for the data with unbalancing problems and missing values.

2.5. Decision Tree (DT)

We can use the Decision Tree for decision analysis. The main objective of using Decision Tree is the prediction of target class using decision rule taken from prior data [8]. In Decision Trees, where target values can take continuous values are known as the regression trees. Considering the tree, we represented the input values as a path from the root to the leaves, where each leaf represents the target variable [9].

2.6. Logistic Regression (LR)

Logistic regression is a generalized form of linear regression. It is a linear model for classification not for regression. When predicting the binary or multi-class dependent variables, we can use logistic regression primarily. As the response variable is discrete, linear regression cannot modeled directly. While logistic regression is a very powerful modeling tool, it assumes that the response variable is linear with respect to the predictor variables. A lack of explanation about what has learned can be a problem.

Table 1. Summary of classification learning models

Name	Advantages	Disadvantages
KNN	1. Easy to implement multiclass problem. 2. Training is very fast and robust to noisy training data. 3. Effective if the training data is large.	1. Need to determine value of parameter K. 2. Computation cost is quite high. 3. Being a supervised learning lazy Algorithm i.e., runs slowly. 4. It is sensitive to the local structure of the data.
ANN	1. Have the ability to work with inadequate knowledge and fault tolerance. 2. Have numerical strength that can perform more than one job at the same time.	1. The realization of the equipment is dependent. 2. Difficult to know how many neurons and layers we need to process and duration is also unknown. 3. When producing a solution, it does not give a clue as to why and how.
SVM	1. It scales well to high dimensional data. 2. The risk of overfitting is less. 3. It works well with unstructured and semi structured data.	1. Choosing a good kernel function is not easy. 2. Long training time for large datasets. 3. It is hard to visualize their impact.
NB	1. Need less training time. 2. Very simple, easy to implement and fast. 3. Not sensitive to irrelevant features.	1. Chance the loss of accuracy. 2. Algorithms cannot modify dependencies. 3. Makes a very strong assumption on the shape of data distribution.
DT	1. It produces the accurate result. 2. It takes the less memory, less model build time and short searching time. 3. Support multi-output tasks.	1. Relatively expensive as complexity and time taken is more. 2. Inadequate for predicting continuous values. 3. Computation is slower and can encounter overfitting.
LR	1. Works with almost any kind of dataset. 2. Gives good information about the features. 3. Very efficient to train.	1. It is often inappropriate used to model non-linear relationship. 2. It is limited to predicting numeric output. 3. Can only predict a categorical outcome.

3. Diabetes Prediction

Proposed research work introduces a framework to develop a machine-learning model based on data mining classification techniques. To solve the problem we will have to analyze the data, do any required transformation and normalization, apply a machine-learning algorithm, train a model, check the performance of the trained model and iterate with other algorithms until we find the most performant for our type of dataset.

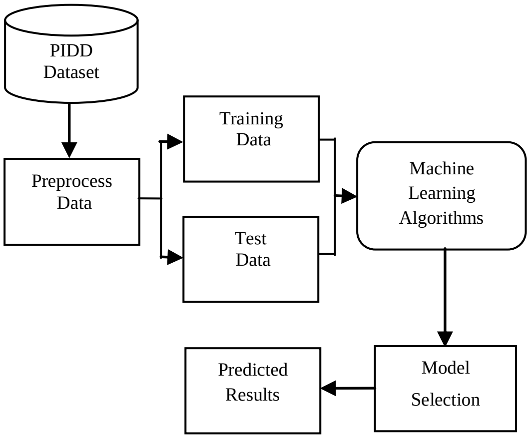

Figure 1. Diabetes prediction model

3.1 Dataset Description

The Pima are a group of Native Americans living in Arizona. A genetic predisposition allowed this group to survive normally to a diet poor of carbohydrates for years. In the recent years, because of a sudden shift from traditional agricultural crops to processed foods, together with a decline in physical activity, made them develop the highest prevalence of type 2 diabetes and for this reason they have been subject of many studies.

We performed computer simulation on a Pima Indians Diabetes dataset available UCI Machine Learning Repository. The features describe different factor for diabetes reoccurrence. The main aim of this study is the prediction of the patient affected by diabetes using the python language by using the medical database PIDD. The Pima is one of the most studied populations for diabetic analysis around the world [10].

Table-2 shows a brief description of the dataset. PIDD (Pima Indian Diabetes Dataset) contains of 768 instances of female patients. The dataset also consists of discrete-valued eight attributes. The last column of the dataset indicates if the person has been diagnosed with diabetes (1) or not (0). We describe attributes descriptions in Table 3. We are available the original dataset at UCI Machine Learning Repository and can download from [11].

Table 2. Dataset description

Database	No. of Attributes	No. of Instances
PIDD	8	768

Table 3. Attribute description

Attribute	Abbreviation
1. Number of times pregnant	pr
2. Plasma glucose concentration	pl
3. Diastolic blood pressure (mm Hg)	pr
4. Skin fold thickness (mm)	sk
5. 2-Hour serum insulin (mu U/ml)	in
6. BMI (weight/(height)^2)	ma
7. Diabetes pedigree function	pe
8. Age in years	ag
Class ’0’ or ’1’	cl

3.2 Data Preprocessing

We apply the data cleaning techniques first. Identify the missing values and replaced by the group median. Further, apply the min-max scaling technique to have the features value range between zero and one.

3.2.1 Data Cleaning

Some instances have missing data for some of the features. Machine learning algorithms cannot work very well with missing data. To find a solution to "clean" the data, the easiest option is to eliminate all those records, but in this way, we would eliminate many important data. Another option is to calculate the median value for a specific column and substitute that value everywhere in the same column that have missing data.

3.2.2 Data Transformation

In the dataset, the Age ranges from 20 to 80 years old, while the number of times a patient has been pregnant ranges from 0 (zero) to 17.

Most of the machine learning algorithms do not work very well if the features have a different set of values. The solution is to apply the feature scaling technique. Feature Selection Technique (FST) eliminates the less important features and reduces the time complexity of the machine learning technique.

The type of scaling depends on the data fed to which model, so there is no universally best approach. In this paper, min-max normalization techniques is used. Min-max normalization preserves the relationships among the original data values. It always boosts the classification accuracy and minimizes the computational cost.

3.3 Splitting the Dataset

Splitting the dataset is a very important step for supervised machine learning models. We split the dataset into two parts: training and testing dataset. In this paper, we use the K-fold cross-validation method. It partitions the original data set into equal-sized sub-segments. The number of segments depends upon the value of *k* taken; in our case, we have taken *k* to be 10. We use the first part to train the model ignoring the column with the pre assigned label. Then we use the trained model to make predictions on new data, which is the test dataset, not part of the training set, and compare the predicted value with the preassigned label.

3.4. Comparison of different Algorithms

We compare the accuracy (ACC) of multiple algorithms with the same dataset and pick the one with the best score.

$$ACC = \frac{TN+TP}{TN+TP+FP+FN} \quad (1)$$

Where true positive (TP) denotes the number of identified positive samples in the positive set. True negative (TN) represents the number of classification negative samples in the negative set. False positive (FN) is the number of identified positive samples in the negative set. False negative (FN) means the number of identified negative samples in the positive set. The accuracy is as the ratio of the number of samples correctly classified by the classifier to the total number of samples.

No.	Learning_Model	Accuracy
1	K Nearest Neighbor	72.96
2	Artificial Neural Network	76.37
3	Support Vector Machine	74.91
4	Naive Bayes	74.10
5	Decision Tree	70.02
6	Logistic Regression	75.40

Figure 2. Performance comparison on the basic of accuracy

Using the python programming language, we present the resulted output of the learning algorithms that predict the diabetes disease in Figure 2.

Table 4. Performance comparison on the basic of classified instances

Total Instances	Learning Model	Correct predict	Incorrect predict
768	KNN	548	220
	ANN	587	181
	SVM	575	193
	NB	569	199
	DT	550	218
	LR	579	189

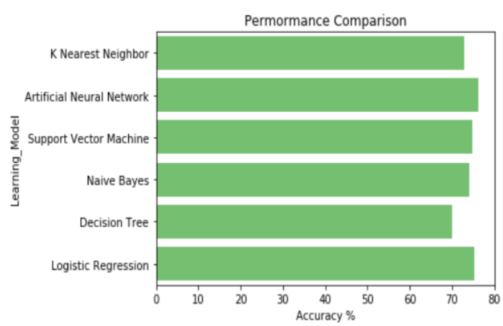

Figure 3. Performance evaluation of different learning algorithms

In Table 4, we described the comparisons of performance on classified instances. It illustrates how many instances they correctly classified according to the results of Figure2. We plot the chart of the performances of all classifiers based on accuracy measures in Figure-3.

From the above results, we observed that the Artificial Neural Network is performing better amongst all the other algorithms. Therefore, the ANN machine learning classifier can predict the chances of diabetes with more accuracy as compared to other classifiers.

4. Conclusions

This paper was using the dataset from the UCI repository. First, replace the group median values in all missing values. Further, apply the data transformation technique with a proper feature scaling method. We use six learning algorithms along with *k*-fold cross-validation. This enabled to perform data analysis to obtain the optimal result. We found by the result with the highest accuracy of 76.37% was achieved by using the Artificial Neural Network with *10*-fold cross-validation. From the results, we observed that the Neural Network was performing better compared to all the other classification algorithms. Future work will include trying a study with different data transformations or trying algorithms that we have not tested yet for further analysis of the dataset.

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Development of Remote Health Monitoring System

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Abstract

Wearable sensors are very applicable nowadays due to low cost, light weight and easy to use. In this work, remote health monitoring system is developed with body sensor node. This node consists of three types of wearable biosensors such as body temperature sensor, pulse oximeter sensor and heart rate click sensor. Health data from three sensors is collected with time scheduling of relay module. The system is remotely monitored on ThingSpeak cloud and wirelessly accessed by using GSM module controlled with Ardunio Uno. Focusing on health applications, long term engagement is necessary to detect person's health changes behavior. Based on tests and measurements, lifetime analysis is done for long term usage of body sensor node implemented in this system.

Keywords: Wearable Sensor, Body Sensor Node, Health Monitoring, Lifetime Analysis, Scheduling

1. Introduction

Current trend of IoT and wearable sensors are attractive to develop for health care system remotely. Regarding to health monitoring, vital parameter measurement includes most concept on physical activity, heart rate, body temperature, blood pressure, SpO2, respiration, GSR, EEG and BGL [1]. Integration of mobile devices and wearable sensor are attractive solution for patient centric health monitoring. In [2], patent can monitor his or her health device profile on mobile phone using Bluetooth protocol. Enhancing communication quality and faster data transmission of data can give better patient service using online system. Development of this system can be found in [3]. Especially ECG monitoring was tested by remote health monitoring in [4] implemented with mobile device and cloud service. The system in [5] monitor heart rate and temperature especially for infant's heath.

In most of health care oriented wireless sensor network, energy efficient solutions are necessary for sensor nodes to be operated long period of time. To increase life time of battery-based sensor node, sources of energy consumption was studied and investigated [6]. Considering energy, life time are modelled to be analyze the effectiveness of life time model [7]. To evaluate energy consumption and node lifetime, estimation of number of sensor nodes needed to design a network for given life time. A comprehensive energy model in [8] considered the estimation of sensor energy consumption. Duty cycling scheme and data collection schemes are the techniques for prolonging the lifetime of wireless sensor networks. Qualitative review of recent advances in data collection techniques are presented in [9] for low power, low cost nodes to monitor in remote environment.

The rest of the paper is organized as follows; design aspect of body sensor node in section 2, hardware design in section 3, system description in section 4. Tests and measured results are discussed in section 5 and the presented work is concluded in section 6.

2. Design Aspect of Body Sensor Node

To maximize lifetime, hardware units for body sensor node for remote health monitoring system are selected based on prediction of energy consumption. Several parameters are considered as shown in the following sections [10].

2.1. Lifetime

For battery-based sensor node, the equation for life time L of sensor node is expressed as,

$$L = \frac{C_{battery}V}{E} \quad (1)$$

where $C_{battery}$ is the capacity of battery, supply voltage V and energy consumption in E. Life time is also dependent on the duty cycle and transmission energy. It can be described as,

$$L = \frac{C_{battery} \times 3600}{E_{tx}D} \quad (2)$$

where D is duty cycle.

2.2. Energy Model

Total energy consumption E of sensor node is given by,

$$E = E_{tx} + E_{rx} + E_{listen} + E_d + E_{sleep} \quad (3)$$

The energy is consumed for receiving, transmitting, sleeping mode of radio module, listening messages and sampling data of microcontroller module. Each sensor node can be constructed by using radio transceiver and microcontroller.

2.3. Energy Saving Technique

Concerned with data collection techniques, contributions in [10] only takes account energy consumption of each sensor. Energy consumption for transmission is greater than for receiving when collecting sensed data. In this data gathering scheme, size of any sensor data is identical to a fixed length. For periodically sensed data, energy efficient way is using low duty cycle for maximizing life time.

3. Hardware Design

Arduino Uno is main controller for data collection from three sensors such as MAX30100 pulse oximeter and heart-rate sensor, MLX90614 IR temperature sensor and SpO_2 sensor. All sensor data are sensed alternately by using 4 channel relay switches. And GSM module SIM900 is used as radio module to communicate with ThingSpead cloud. All sensed data can be monitored on tablets or mobile phone when internet connection is available.

3.1. IR Temperature sensor

Body temperature is one of human vital physiological parameter. In this system, small size low cost IR temperature sensor MLX90615 (shown in Figure 1) is used for non-contact measurements in constructing body sensor node. Due to low noise amplifier and 17 bits resolution ADC, high accuracy and resolution can be achieved. The sensor temperature range is -40 to +125C. Supply voltage is 3 V for this senor to operate properly.

Figure 1. Body Temperature Sensor

3.2. Heart Rate Sensor

For elderly people, proper monitoring for heart rate is necessary. In this body sensor node, MAX30100 (shown in Figure 2) is used to detect pulse oximetry and heart rate signals. Supply voltage 3.3 V is used to operate this sensor in this system tests. It is ultra-low power consumption and 16 bits resolution ADC. This sensor measures absorbance of passing blood.

Figure 2. Heart Rate Sensor

3.3. Pulse Oximeter Sensor

For people with breathing and heart problem, amount of oxygen levels in blood is necessary to monitor. Pulse oximeter sensor (shown in Figure 3) measures arterial blood oxygen saturation SpO_2. It consumes very low amount of power and can give accurate reading. This heart rate click is plug and play sensor type and operating voltage is 3 V.

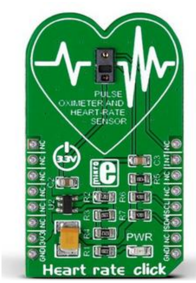

Figure 3. Pulse Oximeter Sensor

3.4. GSM Module

For wireless connectivity of body sensor node, GSM SIM 900 (shown in Figure 4) is used for connecting Arduino to Internet within GPRS wireless network. A SIM card is needed to plug in from an operator. Transmit power may be available 1 Watt or 2 Watt. Table 1 describes the current consumption of three different modes.

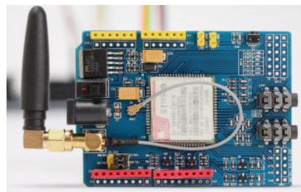

Figure 4. GSM Module

Table 1. Current Consumption

Mode	Supply Voltage	Current Consumption
Transmit	3.3 V	80 mA
Stand by	3.3 V	18 mA
Sleep	3.3 V	1 mA

3.5. Four Channel Relay

The relay interface board (shown in Figure 5) used in this system is optically isolated and can be controlled by Aurdino Uno. Amon four channels, three channels are used for sensor data collection. Time schedule is defined for data collection of changing one channel to others. sensor data such as heart rate, body temperature or SpO_2 are transmitted one channel at a time. The transmitted data can be monitored on ThingSpeak cloud.

Figure 5. Four Channel Relay

4. System Descriptions

For remote health monitoring, IoT base body sensor node (shown in Figure 6) is implemented in this work. ThingSpeak cloud services is used for monitoring purpose on the Laptop or mobile phone devices. Microcontroller first detect heart rate sensor via channel 1 of relay module for one minute. The sensor data expressed in BPM (blood pressure per minute) is transmitted to the Internet vis GSM module. Second detection for one minute is from sensor data of pulse oximeter sensor expressed in percentage of SpO2 level. Third detection for one minute goes to IR temperature sensor and sensor data is expressed in Fahrenheit. This detection procedure is repeated for the whole monitoring and can see measured data on ThingSpeak cloud. Battery capacity for constructed body sensor node is 2200 mAh.

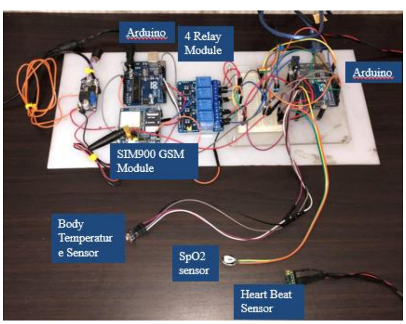

Figure 6. Constructed Body Sensor Node

5. Tests and Results

Constructed body sensor node is tested and results are monitored on ThinSpeak cloud. The accuracy of body temperature sensor is ± 0.36·F and heart rate measuring accuracy is ± 2 bpm. And then the measurement precision of SpO_2 is ± 2%. For normal healthy person, body temperature is 97·F to 99·F and for unhealthy person, it will be over 100.4·F. Oxygen situation level of normal healthy person is 95% to 100% and the value under 90% is indicated as low level of unhealthy situation occurs. Heart rate of normal healthy person is 60 bpm to 100 bpm and for unhealthy person, it will be around 120 bpm.

In Figure 7, temperature data is measured and collected from normal healthy person. The collected temperature is within 95°F to 97°F. The level of SpO_2 is strictly 97% show in Figure 8. This is measurement results for healthy person. As described in Figure 9, after straight value of 100 bpm, measured value increase from 100 bpm to 150 bpm. This changing result shows measured value includes healthy to unhealthy person.

Using equation 1, life time analysis for constructed body sensor node can be estimated as follow. The duty cycle for alternating sequence of three sensor nodes is taken as 0.3. Energy consumption for body sensor node is calculated by using equation,

$$E = \left(I_{on}D + (1 - D)I_{of}\right)T_{total}V_{bat} \qquad (4)$$

Table 2. Lifetime Calculation

T_{total} (s)	Energy Consumption E (μJ)	Life time L in hours
5	0.915	220
10	1.83	110
15	2.644	73
20	3.66	55

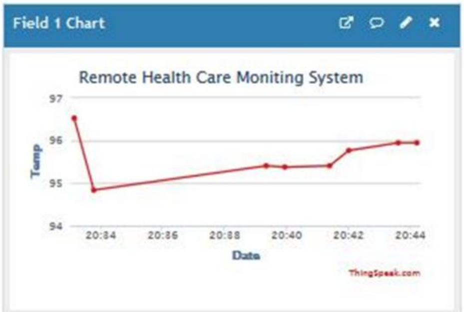

Figure 7. Monitoring Body Temperature

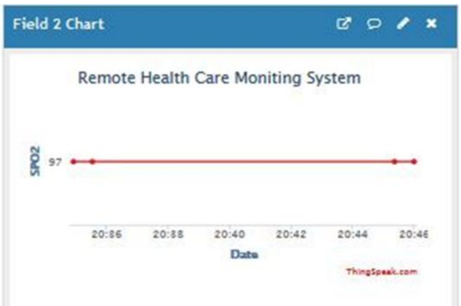

Figure 8. Monitoring SpO2 Level

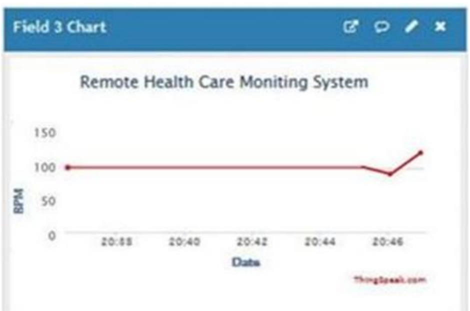

Figure 9. Monitoring Heart Rate

Rated voltage of battery is 5 V. The life time of constructed sensor node for several time taken are listed in Table 2. Total time taken is summed up wakeup, idle, listen and transmit. In conclusions, high speed radio module can give longer life time of body sensor node.

6. Conclusions

In this paper, development of remote health monitoring system was presented. Wearable sensors were especially considered for hardware design with low power consumption. Measured results can be monitored on cloud service and these are three critical human physiological parameters such heart rate, body temperature and SpO_2. Life time calculation was made for long term of body sensor node implemented by wearable sensor. Based on life time calculation, life time of constructed sensor node is mainly depend on selected radio module in hardware design.

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