

**MIMIC HUMAN SPEECH IN BAHASA INDONESIA USING
SPEECH RECOGNITION AND SPEECH SYNTHESIS**

By

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A Thesis
Submitted to the Faculty of Computing
President University
in Partial Fulfilment of the Requirements
for the Degree of Bachelor of Science
in Information Technology

Cikarang, Bekasi, Indonesia

October 2018

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ABSTRACT

Everyday people use speech recognition and speech synthesis unconsciously. The technologies help them with their activities. With each technology can produce any kinds software related to speech. Combine both of technologies can produce many more. One of the combinations is mimic human speech. This research will discuss about Speech Recognition that use Convolutional Neural Network to as machine learning model and Speech Synthesis that use Concatenative Synthesis with syllables as speech unit. The purpose of this research is to develop application to collect, train, and mimic speech in Bahasa Indonesia. User can participate record their speech. The collected speech will be train to be used in the application to recognize the speech. After the collected speech is trained, User can mimic their speech by identify or recognize the speech and generate or synthesis the speech. The application to collect and mimic speech develops in website application.

Keywords: Mimic Speech, Speech Recognition, Speech Synthesis, Convolutional Neural Network, Concatenative Synthesis, Syllables, Bahasa Indonesia

ACKNOWLEDGMENTS

The author gratefully acknowledges the amazing supports, guidance and advices from:

1. Bebe, Annisa Feryannie Widya.
2. My beloved family, Ayah, Ibu, Mas Risky and Dek Lia.
3. B35TFR13NDZONE, Nisa, Marsel, Bora, Fira, Rai, Pindy, Oscar, and Michel.
4. Sangar Team, Mas Andreas, Mba Diana, Nisa, Alfian, and Aci
5. DV 14, Vovo, Gojal, Ariyel, Rino, Willy, Azmi, Damara, Atisah, Risda, Sonya, Dini, and Arizha.
6. My cool thesis lecturer, Mr. Wan Sen.
7. My second family, Van Lith XXII.
8. And you, yes you.

TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS	i
TABLE OF CONTENTS	ii
LIST OF TABLES	v
LIST OF FIGURES	vii
 CHAPTER	
I INTRODUCTION	1
1.1 Background	1
1.2 Problem Statement	2
1.3 Research Objective	2
1.4 Scope and Limitation	2
1.5 Thesis Methodology	3
1.6 Thesis Outline	4
II LITERATURE STUDY	6
2.1 Speech Synthesis	6
2.2 Syllable	7
2.3 Speech Recognition	7
2.4 Mel Frequency Cepstral Coefficients	8
2.4.1 Framing and Windowing	9
2.4.2 Discrete Fourier Transform and Power Spectrum	10
2.4.3 Mel Filterbank	10
2.4.4 Logarithm	12
2.4.5 Discrete Cosine Transform	12
2.5 Machine Learning	12
2.5.1 Supervised Learning	13
2.5.2 Unsupervised Learning	13
2.6 Neural Network	14
2.7 Convolutional Neural Network	15
2.7.1 Pre-processing	16
2.7.2 Convolution Layer	17
2.7.3 Max-pooling Layer	17
2.7.4 Fully-connected Layer	18
2.8 Related Work	18

CHAPTER	Page
2.8.1 Lyrebird	18
2.8.2 Google Translate	19
III SYSTEM ANALYSIS	21
3.1 System Overview	21
3.2 Functional Analysis	21
3.3 Software and System Requirements	22
3.4 System Architecture	23
3.4.1 Use-Case Diagram	23
3.4.2 Use-Case Narrative	24
3.4.3 Activity Diagram	28
3.4.3.1 Collect Application	28
3.4.3.2 Train Application	29
3.4.3.3 Mimic Application	30
IV SYSTEM DESIGN	32
4.1 User Interface Design	32
4.1.1 Collect Application	32
4.1.1.1 Home Page	32
4.1.1.2 Syllables Page	33
4.1.2 Mimic Application	34
4.1.2.1 Home Page	34
4.1.2.2 Identify Page	35
4.1.2.3 Generate Page	35
4.2 Class Diagram	36
4.2.1 Collect Application	37
4.2.1.1 home	37
4.2.1.2 syllables	37
4.2.2 Train Application	38
4.2.2.1 model	38
4.2.2.2 train	38
4.2.3 Mimic Application	39
4.2.3.1 home	39
4.2.3.2 identify	39
4.2.3.3 generate	40
4.2.4 Server	40
4.2.4.1 serverHanlder	41
4.2.4.2 createServer	42
4.2.5 Database	43
4.2.5.1 connection	43
4.2.5.2 model	43

CHAPTER	Page
IV SYSTEM DEVELOPMENT	44
5.1 User Interface Development	44
5.1.1 Collect Application	44
5.1.1.1 Home Page	44
5.1.1.2 Syllables Page	45
5.1.2 Mimic Application	46
5.1.2.1 Home Page	46
5.1.2.2 Identify Page	47
5.1.2.3 Generate Page	48
5.2 Application Details	51
5.2.1 Collect Application	51
5.2.1.1 home	51
5.2.1.2 syllables	52
5.2.2 Train Application	53
5.2.2.1 model	53
5.2.2.2 train	54
5.2.3 Mimic Application	56
5.2.3.1 home	56
5.2.3.2 identify	57
5.2.3.3 generate	58
5.2.4 Server	59
5.2.4.1 collect Router	60
5.2.4.2 identify Router	61
5.2.4.3 generate Router	62
5.2.4.4 serverHanlder	64
5.2.4.5 createServer	65
5.2.5 Database	66
5.2.5.1 connection	66
5.2.5.2 model	67
IV SYSTEM TESTING	68
6.1 Testing Environment	68
6.2 Testing Scenario	68
6.2.1 Collect Application	69
6.2.2 Train Application	70
6.2.3 Mimic Application	71
IV CONCLUSIONS AND FUTURE WORK	84
7.1 Conclusion	84
7.2 Future Work	84
REFERENCES	xi

LIST OF TABLES

TABLE	Page
3.1 Collect application functionality table	21
3.2 Train application functionality table	21
3.3 Mimic application functionality table	22
3.4 Use-case narrative – Access Collect application	24
3.5 Use-case narrative – Record Speech	25
3.6 Use-case narrative – Train model	25
3.7 Use-case narrative – Access Mimic application	26
3.8 Use-case narrative – Identify speech	27
3.9 Use-case narrative – Generate speech	27
4.1 Collect Home page description	33
4.2 Collect Syllables page description	33
4.3 Mimic Home page description	34
4.4 Mimic Identify page description	35
4.5 Mimic Generate page description	36
6.1 Collect application scenarios	69
6.2 Train application scenarios	70
6.3 Mimic application scenarios	72
6.4 Tester 1 results on noisy background	73
6.5 Tester 1 results on semi noisy background	74
6.6 Tester 1 results on not noisy background	75

TABLE	Page
6.7 Tester 2 results on noisy background	75
6.8 Tester 2 results on semi noisy background	76
6.9 Tester 2 results on not noisy background	77
6.10 Tester 3 results on noisy background	77
6.11 Tester 3 results on semi noisy background	78
6.12 Tester 3 results on not noisy background	79
6.13 Tester 4 results on noisy background	79
6.14 Tester 4 results on semi noisy background	80
6.15 Tester 4 results on not noisy background	81

LIST OF FIGURES

FIGURE	Page
1.1 RAD Diagram [3]	3
2.1 Sound sampling process [12]	8
2.2 40 Filterbank from 0 Hz to 4000 [14]	11
2.3 Neural network to find estimated price from specific input [19]	14
2.4 Computer read an image [19]	15
2.5 The basic neural network where it only recognizes the object on the center (top), but doesn't on another surface (bottom) [19]	15
2.6 Before (left) and after (right) pre-processing image [7]	16
2.7 Two example of CNN for its own problem that trying to be solved [19, 20]	16
2.8 Convolution process on single tile (top) and overview all tiles (bottom) [19]	17
2.9 Max-pooling layer with 2x2 pool size and 2 stride [19]	17
2.10 Fully-connected layer in CNN[19]	18
2.11 Screenshot of Lyrebird in website [21]	19
2.12 Screenshot of Google Translate in website [22]	19
3.1 Use-case diagram	24
3.2 Collect application activity diagram	29
3.3 Train application activity diagram	30
3.4 Mimic application activity diagram	31
4.1 Collect Home page	32

FIGURE	Page
4.2 Collect Syllables page	33
4.3 Mimic Home page	34
4.4 Mimic Identify page	35
4.5 Mimic Generate page	36
4.6 Collect application class diagram	37
4.7 Train application class diagram	38
4.8 Mimic application class diagram	40
4.9 Server class diagram	42
4.10 Database class diagram	43
5.1 Collect Home Page	44
5.2 Collect Syllables page with 'a' syllable	45
5.3 Collect Syllables page after record process is finish	46
5.4 Mimic Home page	46
5.5 Mimic Identify page	48
5.6 Mimic Identify page alert user indicating identify process in the server is finish	48
5.7 Mimic Identify page alert user indicating there is no value in Input element	48
5.8 Mimic Generate page	49
5.9 Mimic Generate page play the generate speech after generated process success	50
5.10 Mimic Generate page alert user indicating there is no value in textarea element	50

FIGURE	Page
5.11 Mimic Generate page alert user indicating there is error in the generate process	50
5.12 Collect home html code	51
5.13 Collect syllables btnRecord code	53
5.14 Train model modelML code	54
5.15 Some part of Train train extractWav code	56
5.16 Mimic home html code	57
5.17 Mimic identify xhrPostIdentifySPeech code	58
5.18 Mimic generate xhrGetSpeechId code	59
5.19 Server collect router uploadCollect code	60
5.20 Some part of Server identify router identifySpeech code	62
5.21 Some part of Server generate router generateSpeech code	63
5.22 Server serverHandler code	65
5.23 Server createServer code	66
5.24 Database connection code	66
5.25 Database model code	67
6.1 Screenshot of process upload record request scenario from Collect application	70
6.2 Screenshot of load and split collected data and extract the data scenarios from Train application	71
6.3 Screenshot of process identify speech on Identify request scenario from Mimic application	73

FIGURE	Page
6.4 Screenshot of Tester 1 with a and i syllables on not noisy background.	82

CHAPTER I

INTRODUCTION

1.1 Background

“Ok Google, play some music”. “Siri, what should I eat for lunch?”. Everyday people use their artificial assistance to boost their activities. People very like to use it because they just asked to their device and then in seconds, the wish is granted. It seems like, people are talking to the computer. The truth is, speech recognition takes big role with the help of machine learning. Google Assistance, Apple Siri, Microsoft Cortana, Amazon Alexa, and others have thousands of speech data to be analysed with the machine learning and they easily add data by collecting people speech from the assistance with permission.

If speech recognition is the process to get data by analysed speech, the opposite of speech recognition is speech synthesis, the process to produce artificial speech. Therefore, speech recognition is known as speech-to-text and speech synthesis is known as text-to-speech. “Hey Cortana, read my email” command make artificial assistance generate speech from the email text. With each technology can produce any kinds software related to speech. Combine both of technologies can produce many more. One of the combinations is mimic human speech.

1.2 Problem Statement

This research aims to develop application which can be used to collect speech data, train machine learning model with collected data and mimic speech in Bahasa Indonesia. The application to collect and mimic speech develops in website application. The application can recognize the speech and generate speech from text.

1.3 Research Objective

This research sees an opportunity to implement speech recognition and speech synthesis to create a mimic speech.

1.4 Scope and Limitation

This research focuses on developing an application which will be able to:

1. Perform collecting data.
2. Perform train model.
3. Perform speech recognition.
4. Perform speech synthesis.

The limitations of this application are as following:

1. There are 9 selected syllables to be used in the application, a, i, na, ma, mu, di, ri, and ku.
2. Recorded speech in 1 second, with sample rate 16000 and mono sound.
3. Speech recognition data is taken from recorded speech in Bahasa Indonesia.
4. Speech synthesis data is taken from saved speech, result from speech recognition.
5. Application is developed as website application.

1.5 Thesis Methodology

Rapid Application Development (RAD) methodology will be used in the development of this application. RAD method is a term originally used to describe a software development process introduced by James Martin in 1991 [1]. RAD method is a methodology to develop software that requires minimum planning for rapid prototyping. As James Martin says, RAD is a lifecycle used for development of software which provides faster development and also gives high quality software then, by using traditional software development lifecycle. In short, RAD is the process which accelerates the cycle of development of an application [2]. The RAD diagram is depicted in Figure 1.1.

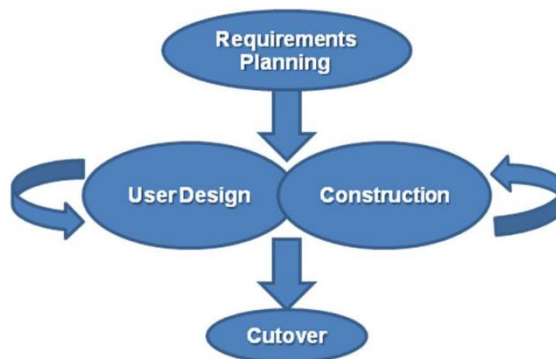


Figure 1.1 RAD Diagram [3].

The RAD model implemented in this thesis will consists of four major phases:

1. Requirement Planning Phase

This phase combines elements of the system planning and systems analysis phases of the Systems Development Life Cycle (SDLC) [3].

2. User Design Phase

During this phase, users interact with systems analysts and develop models and prototypes that represent all system processes, inputs, and outputs. This phase is a continuous interactive process that allows users to understand, modify, and eventually approve a working model of the system that meets their needs [3].

3. Construction Phase

This phase focuses on program and application development task similar to the SDLC. In RAD, however, users continue to participate and can still suggest changes or improvements as actual screens or reports are developed. Its tasks are programming and application development, coding, unit-integration and system testing [3].

4. Cut Over Phase

This final phase resembles the final tasks in the SDLC implementation phase, including data conversion, testing, changeover to the new system, and user training. Compared with traditional methods, the entire process is compressed. As a result, the new system is built, delivered, and placed in operation much sooner [3].

1.6 Thesis Outline

The thesis consists of seven chapters, which are as follow:

1. Chapter I: Introduction

This chapter introduce the research background, problem, and objective. It also explains the research scope and limitation, method to achieve the objective.

2. Chapter II: Literature Study

This chapter contain the literature study that related to the research background.

3. Chapter III: System Analysis

This chapter explains the analysis of the application – both in its function and behaviour, in order to fulfil the prescribed requirements.

4. Chapter IV: System Design

This chapter explains the system design of interfaces and class diagram based on the previous chapter that will be used in the next chapter.

5. Chapter V: System Development

This chapter explains the system development of interfaces and code details on the application.

6. Chapter VI: System Testing

This chapter ensures the application system runs well by evaluating all the features, and making sure the system fulfils its function requirements.

7. Chapter VII: Conclusion and Future Work

This chapter sums up this research and also suggestion for future research work.

CHAPTER II

LITERATURE STUDY

2.1 Speech Synthesis

Speech synthesis is the process with the goal of building a system that can start with text and produce speech automatically [4]. As in mimic speech, the speech is taken from recognized speech, concatenative synthesis can be the best approach.

Concatenative synthesis connecting pre-recorded natural utterances is probably the easiest way to produce intelligible and natural sounding synthetic speech. One of the most important aspects in concatenative synthesis is to find correct unit length. The selection is usually a trade-off between longer and shorter units. With longer units, high naturalness, less concatenation points and good control of coarticulation are achieved, but the number of required units and memory is increased. With shorter units, less memory is needed, but the sample collecting and labelling procedures become more difficult and complex.

In present systems units used are usually words, syllables, demisyllables, phonemes, diphones, and sometimes even triphones [5]. As there aren't found any exact amount of Bahasa Indonesia phonemes, syllables can be the best options for the speech unit.

2.2 Syllable

Syllable is a unit of pronunciation having one vowel sound, with or without surrounding consonants, forming the whole or a part of a word; for example, there are two syllables in water and three in inferno [6]. As in Bahasa Indonesia there are many rules to decoding a word to get the syllable. It constructed from 5 *vokal* (vowel), 21 *konsonan* (consonants), 4 *diftong* (diphthong), 4 *gabungan huruf konsonan* (cluster) [7].

2.3 Speech Recognition

Speech recognition is the process of converting a speech signal to a sequence of words, by means of an algorithm implemented as a computer program. [8]. There are so many techniques and approaches [8, 9] to do speech recognition, it depends on the problem that going to be solved in optimum way. In mimic speech, as a speech is constructed by word and word constructed by syllables, convolutional neural network is one of optimum way to word spotting [10].

The way that computer understand the speech or signal is by sound sampling. Sound sampling is taking a reading thousands of times a second and recording a number representing the height of the sound wave at that point in time [12]. Nyquist sampling theorem provides a prescription for the nominal sampling interval required to avoid aliasing. The sampling frequency should be at least twice the highest frequency contained in the signal [11].

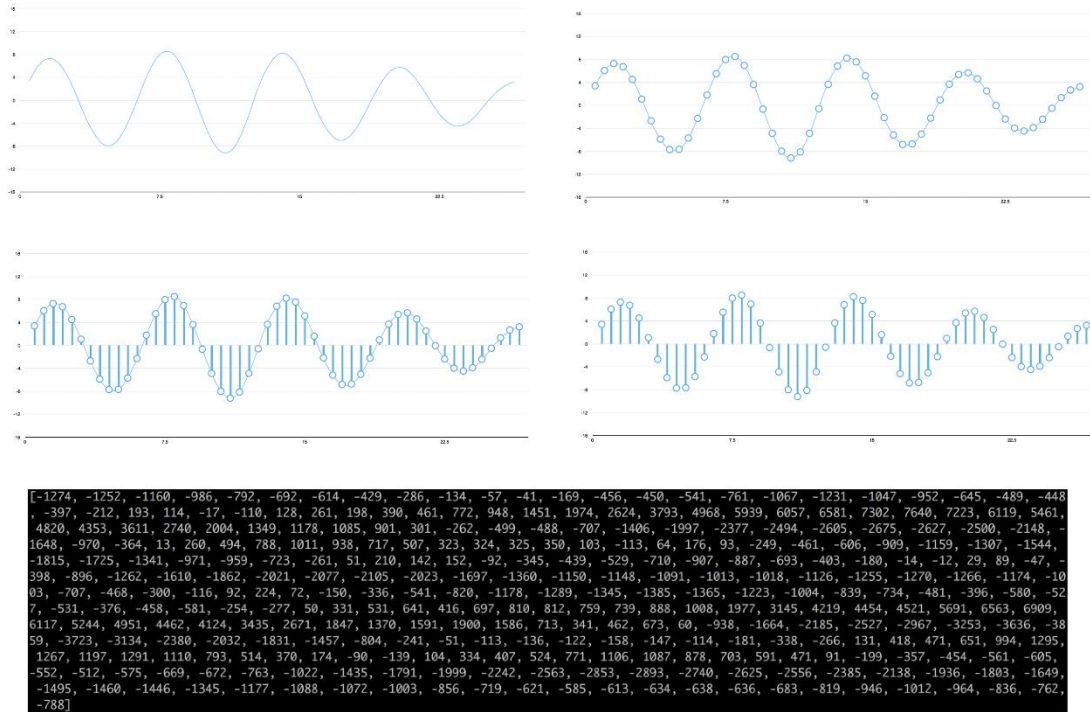


Figure 2.1 Sound sampling process [12].

2.4 Mel Frequency Cepstral Coefficients

Mel Frequency Cepstral Coefficients (MFCC) is one of the most commonly used feature extraction method in speech recognition introduced by Davis and Mermelstein in the 1980's [13]. The technique is called FFT based which means that feature vectors are extracted from the frequency spectra of the windowed speech frames [9].

The common steps to do MFCC are framing and windowing, Discrete Fourier Transform (DFT) and power spectrum, mel filterbank, logarithm, and finally Discrete Cosine Transform (DCT) before feeding to convolutional neural network. [9, 13, 14, 15]. Yet there can be variations can be made in process [15].

2.4.1 Framing and Windowing

A step can be done before framing and windowing is to apply a pre-emphasis filter on the signal to amplify the high frequencies. A pre-emphasis filter is useful in several ways such as, balance the frequency spectrum since high frequencies usually have smaller magnitudes compared to lower frequencies, avoid numerical problems during the Fourier transform operation, and may also improve the Signal-to-Noise Ratio [14]. The pre-emphasis filter can be applied to a signal x using the first order filter in the following equation where typical values for the filter coefficient (α) are 0.95 or 0.97 [14]:

$$y(t) = x(t) - \alpha x(t - 1)$$

Framing is done because of an audio signal is constantly changing, so to simplify things, assuming that on short time scales the audio signal doesn't change. Typically, signal is framing into 20-40ms frames (25ms is standard). If the frame is much shorter, it doesn't have enough samples to get a reliable spectral estimate, if it is longer the signal changes too much throughout the frame [13]. Frame stripe typically is 10ms, which allows some overlap to the frames. If the speech file does not divide into an even number of frames, pad it with zeros so that it does [13]. This step is similar to pre-processing image in the convolutional neural network in the previous section.

After slicing the signal into frames, apply a window function such as the Hamming window to each frame can be done. Several reasons apply a window function to the frames, notably to counteract the assumption made by the FFT that the data is

infinite and to reduce spectral leakage. Hamming window has the following form where, $0 \leq n \leq N - 1$, N is the window length [14]:

$$w[n] = 0.54 - 0.46 \cos\left(\frac{2\pi n}{N-1}\right)$$

2.4.2 Discrete Fourier Transform and Power Spectrum

Compute each window with Discrete Fourier Transform (DFT) or Fast Fourier Transform (FFT) can be followed with compute power spectrum (periodogram). Motivated by the human cochlea which vibrates at different spots depending on the frequency of the incoming sounds. The periodogram estimate performs a similar job, identifying which frequencies are present in the frame [13]. Periodogram use the following equation where, x_i is the i^{th} frame of signal x and N is FFT size as a power of two greater than or equal to the number of samples in a single window length [14]:

$$P = \frac{|FFT(x_i)|^2}{N}$$

2.4.3 Mel Filterbank

The periodogram spectral estimate still contains a lot of information not required for speech recognition. In particular the cochlea cannot discern the difference between two closely spaced frequencies. This effect becomes more pronounced as the frequencies increase. For this reason, take clumps of periodogram bins and sum them up to get an idea of how much energy exists in various frequency regions. This is performed by mel filterbank [13].

Computing mel filterbank is applying triangular filters, typically 20 – 40 (26 or 40 is standard) filters, on a mel-scale to the power spectrum to extract frequency bands. Mel-scale aims to mimic the non-linear human ear perception of sound, by being more discriminative at lower frequencies and less discriminative at higher frequencies. The formula to convert between Hertz (f) and Mel (m) using the following equations [14]:

$$m = 2595 \log_{10} \left(1 + \frac{f}{700} \right) \quad f = 700 \left(10^{\frac{m}{2595}} - 1 \right)$$

Each filter in the filterbank is triangular having a response of 1 at the center frequency and decrease linearly towards 0 till it reaches the center frequencies of the two adjacent filters where the response is 0 [14]. Good values are to start filter from 300Hz for the lower and up to 8000Hz for the upper frequency [13]. The filterbank can be modelled by the following equation [14]:

$$H_m(k) = \begin{cases} 0, & k < f(m-1) \\ \frac{k - f(m-1)}{f(m) - f(m-1)}, & f(m-1) \leq k < f(m) \\ 1, & k = f(m) \\ \frac{f(m+1) - k}{f(m+1) - f(m)}, & f(m) < k \leq f(m+1) \\ 0, & k > f(m+1) \end{cases}$$

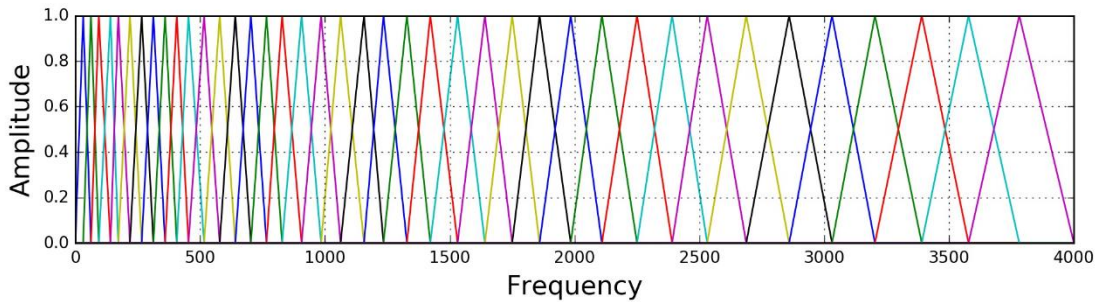


Figure 2.2 40 Filterbank from 0 Hz to 4000 [14].

2.4.4 *Logarithm*

Once compute the mel filterbank, the next is simply take the logarithm of them. This is also motivated by human hearing, as humans don't hear loudness on a linear scale. Generally, to double the perceived volume of a sound it needs to put 8 times as much energy into it. This means that large variations in energy may not sound all that different if the sound is loud to begin with. This compression operation makes the features match more closely what humans actually hear [14].

2.4.5 *Discrete Cosine Transform*

The final step is to compute the Discrete Cosine Transform (DCT). There are 2 main reasons this is performed. It because the filterbanks are all overlapping and the filterbank energies are quite correlated with each other. The DCT decorrelates the energies which means diagonal covariance matrices can be used to model the features. But only 12 of the DCT coefficients are kept. This is because the higher DCT coefficients represent fast changes in the filterbank energies and it turns out that these fast changes actually degrade speech recognition performance, so dropping them will get a small improvement [13].

2.5 **Machine Learning**

Machine learning is a form of AI that enables a system to learn from data rather than through explicit programming [16]. Others state that machine learning usually refers to the changes in systems that perform tasks associated with artificial intelligence (AI) [17].

In general, there are 2 types of machine learning, Supervised Learning and Unsupervised Learning [16, 17, 18].

2.5.1 Supervised Learning

In supervised learning, the algorithms are trained using pre-processed examples, and at this point, the performance of the algorithms is evaluated with test data. Occasionally, patterns that are identified in a subset of the data can't be detected in the larger population of data. If the model is fit to only represent the patterns that exist in the training subset, it creates a problem called overfitting [16].

Overfitting means that the machine learning model is precisely tuned for the training data but may not be applicable for large sets of unknown data. To protect against overfitting, testing needs to be done against unforeseen or unknown labelled data. Using unforeseen data for the test set can help evaluate the accuracy of the model in predicting outcomes and results [16].

2.5.2 Unsupervised Learning

In unsupervised learning, the algorithms segment data into groups of examples (clusters) or groups of features. The unlabelled data creates the parameter values and classification of the data. In essence, this process adds labels to the data so that it becomes supervised [16].

Unsupervised learning can determine the outcome when there is a massive amount of data. Unsupervised can be used as the first step before passing the data to a

supervised learning process if one doesn't know the context of the data being analysed, and labelling isn't possible at the stage [16].

2.6 Neural Network

A neural network is an approach to machine learning in which small computational units are connected in a way that is inspired by connections in the brain [18]. Non-linear elements have as their inputs a weighted sum of the outputs of other elements, much like networks of biological neurons do [17].

Every neural network model is basically a three-layered system, which are Input layer, Hidden Layer and Output Layer [16, 18]. Input layer, is designed to receive information from the outside model. While the other side of the network, an output layer, communicates a decision about the data that has been received. Between these, other layers communicate information about elements of the input to each other, which contribute to the output [18].

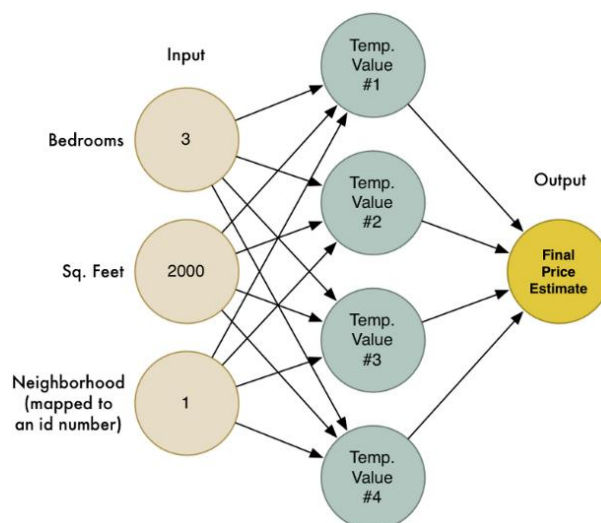


Figure 2.3 Neural network to find estimated price from specific input [19].

2.7 Convolutional Neural Network

Convolutional neural network (CNN or ConvNet) is one of known variants neural network model to recognized image [20]. As an image is just an image is really just a grid of numbers that represent how dark each pixel to a computer [19].

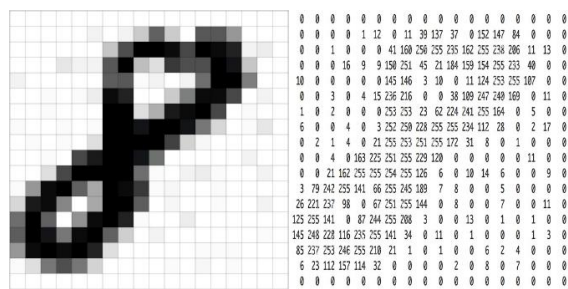


Figure 2.4 Computer read an image [19].

The model is designed to recognize an object no matter what surface the object is on. The model doesn't have to re-learn the idea of child for every possible surface it could appear on [19].

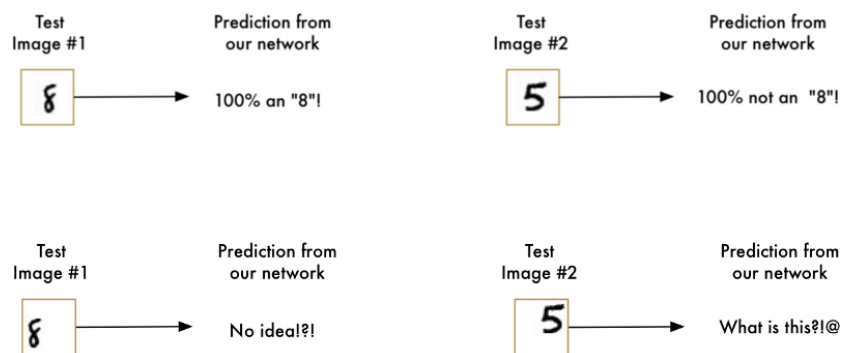


Figure 2.5 The basic neural network where it only recognizes the object on the center (top), but doesn't on another surface (bottom) [19].

The steps to applied convolutional neural network is the combination of convolution, max-pooling, and fully-connected layers. And yet, it might need a lot of

experimentation and testing. Training a lot of model before find the optimal structure and parameters to solve the problem [19].

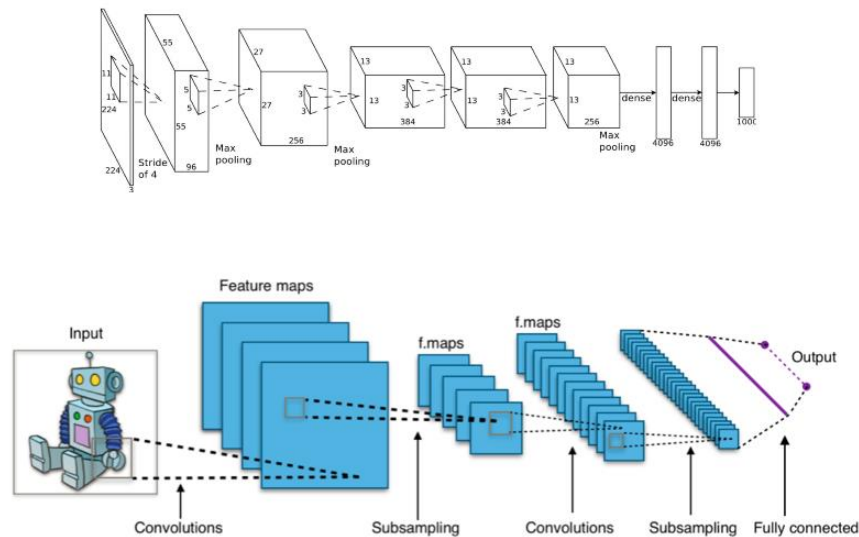


Figure 2.6 Before (left) and after (right) pre-processing image [19, 20].

2.7.1 Pre-processing

Pre-processing is the preparation process by breaking the image into overlapping image tiles so that it can be feed into the model. Sliding window over the entire image will break the image into overlapping image tiles resulting equally sized tiny image tiles [19].



Figure 2.7 Before (left) and after (right) pre-processing image [19].

2.7.2 Convolution Layer

Convolution layer is the layer to feed the pre-processing image or another output into small neural network. The small neural network treating every image or output equally. It will mark if something interesting appears as the model learning [19].

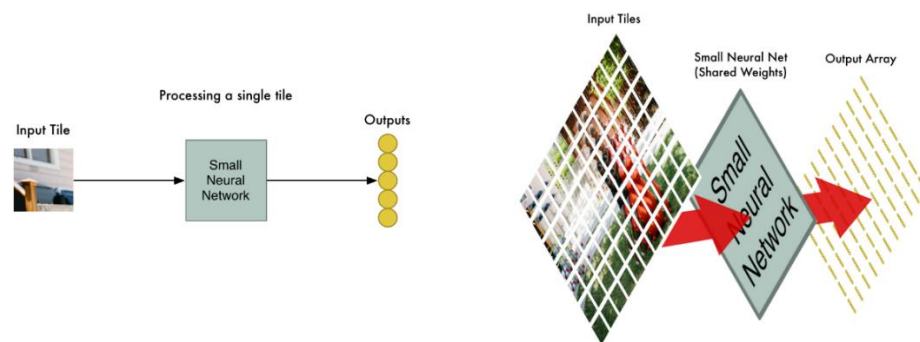


Figure 2.8 Convolution process on single tile (top) and overview all tiles (bottom) [19].

2.7.3 Max-pooling Layer

Max-pooling or down sampling is the layer to reducing the output by finding maximum value in the output. The process is similar like pre-processing in the previous section. The output broke down into equal pool size and stride or slide into entire output. Then, each pool is found the maximum value [19].

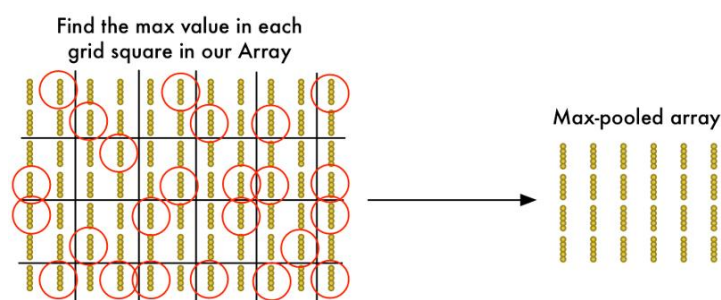


Figure 2.9 Max-pooling layer with 2x2 pool size and 2 strides [19].

2.7.4 Fully-connected Layer

Fully-connected is the layer to high-level reasoning in the dense neural network to recognize the image [20].

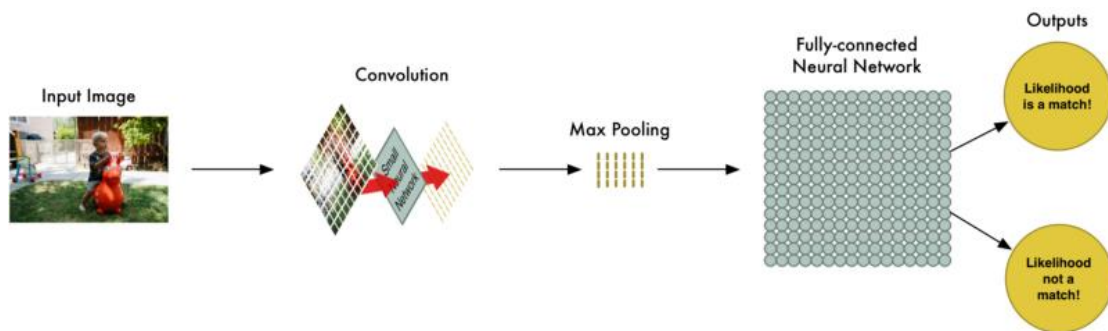


Figure 2.10 Fully-connected layer in CNN [19].

2.8 Related Work

The following are most related work to the research. Have relation to mimic speech, both speech recognition and speech synthesis.

2.8.1 Lyrebird

Lyrebird is website application, <https://lyrebird.ai>, that has 3 products: Custom Voice, Vocal Avatar, and Vocal Avatar API. Custom voice is a product to create speech based on real people's speech, it can control the intonation, expression, and the emotion of the speech. Vocal avatar is a product to create own digital speech by read some English sentences, and then generate any sentences with own digital speech. Vocal avatar API is a product to provide API to use user's own vocal avatar [21].

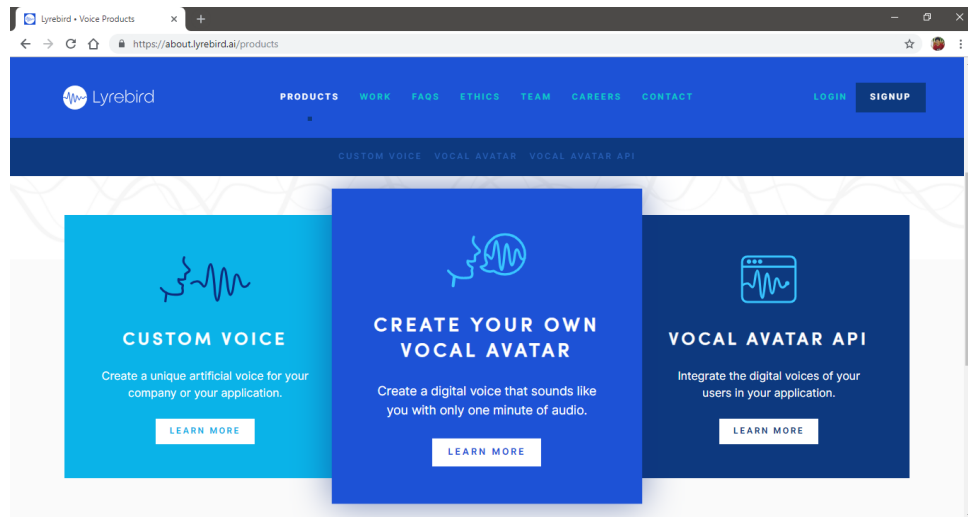


Figure 2.5 Screenshot of Lyrebird in the website [21].

2.8.2 Google Translate

Google Translate is one of Google products that is an application to translate languages. Google Translate can be access freely through <https://translate.google.com/>. It has many features and one of them is Talk feature. Talk has function to input text from speech and generate speech from text in any languages [22].

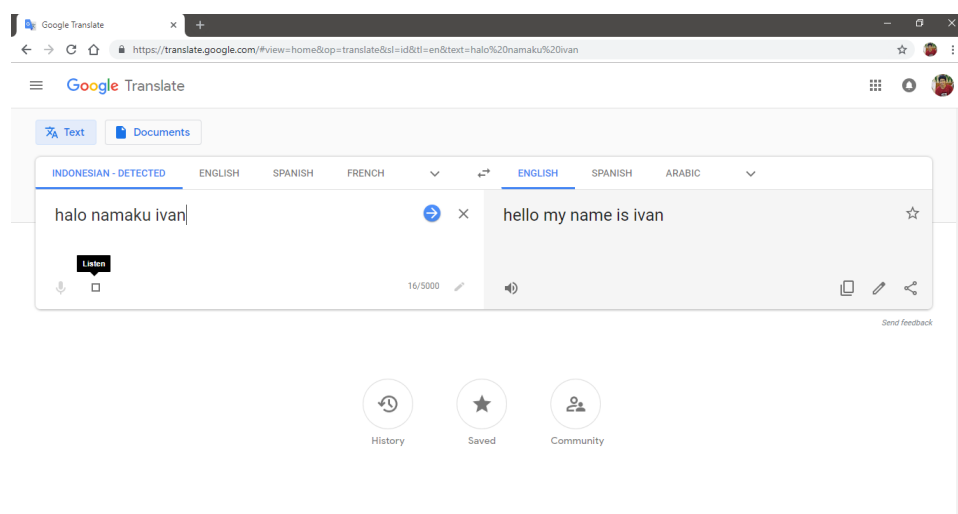


Figure 2.12 Screenshot of Google Translate in website [22].

From related work, it can be concluded that Lyrebird can mimic speech with its vocal avatar, but the speech is in English. In the other hand, Google Translate could mimic speech into any languages, but the speech vocal is from the Google Translate itself.

CHAPTER III

SYSTEM ANALYSIS

3.1 System Overview

This research is intended to implement speech recognition and speech synthesis into this research. This research consists of 3 application, Collect, Train, and Mimic application. Collect application is used to collect speech data. Train application train model with collected data for speech recognition with convolutional neural network as machine learning model. Mimic application is used to mimic the speech. It identifies what user said with trained model. Saves the speech data if the model recognizes. Then, it generates speech with concatenating saved speech data. Collect application and Mimic application develops in website application.

3.2 Functional Analysis

There are several functions for each application listed in the Table 3.1 up to 3.3.

Table 3.1 Collect application functionality table.

No	Function Description
1	Allow user to access Collect application.
2	Allow user to record user's speech.

Table 3.2 Train application functionality table.

No	Function Description
1	Allow user to train model with collected data.

Table 3.3 Mimic application functionality table.

No	Function Description
1	Allow user to access Mimic application
2	Allow user to identify user's speech.
3	Allow user to generate speech.

3.3 Software and System Requirements

This research and application development should be supported by the following list requirement in order to write the research, build and run the application well.

1. Laptop / Personal Computer

Laptop or Personal Computer is used as the tool where operating system is run. In this research, ASUS A455LN is used with Windows 10 as the OS.

2. Browser

Browser is used as development tool when developing website application. In this research, Chrome v70.0.3538.110 is used.

3. Microsoft Office Word

Microsoft Office Word is used to write the research documentation. In this research, Microsoft Office Word 2016 is used.

4. Node.js, JavaScript Run-Time Environment.

Node.js is an open source server environment – Node.js is free – Node.js runs on various platform (Windows, Linux, Unix, Mac OS X, etc) – Node.js uses JavaScript on the server [23]. In this research, Node.js v10.14.1 is used.

5. NoSQL document-oriented database

Document databases pair each key with a complex data structure known as a document. Documents can contain many different key-value pairs, or key-array pairs, or even nested documents [24]. In this research, MongoDB Community Server 4.0.2 as database server and MongoDB Compass 1.15.4 as MongoDB UI.

6. Integrated Development Environment (IDE)

IDE is used as application development environment. In this research, Visual Studio Code 1.30.0 is used.

7. Git

Git is used as version control. The repository is placed on local and cloud as preventive action. In this research, Git 2.18.0.windows.1 and GitLab as cloud repository is used.

3.4 System Architecture

The system architecture explains about the use-case diagram and narrative for this application in both point of view, the actors and the system.

3.4.1 Use-Case Diagram

Use-Case Diagram defines the functionality of a system and explains it in user point of view. The actors in this research is the application user. The diagram is shown in Figure 3.1.

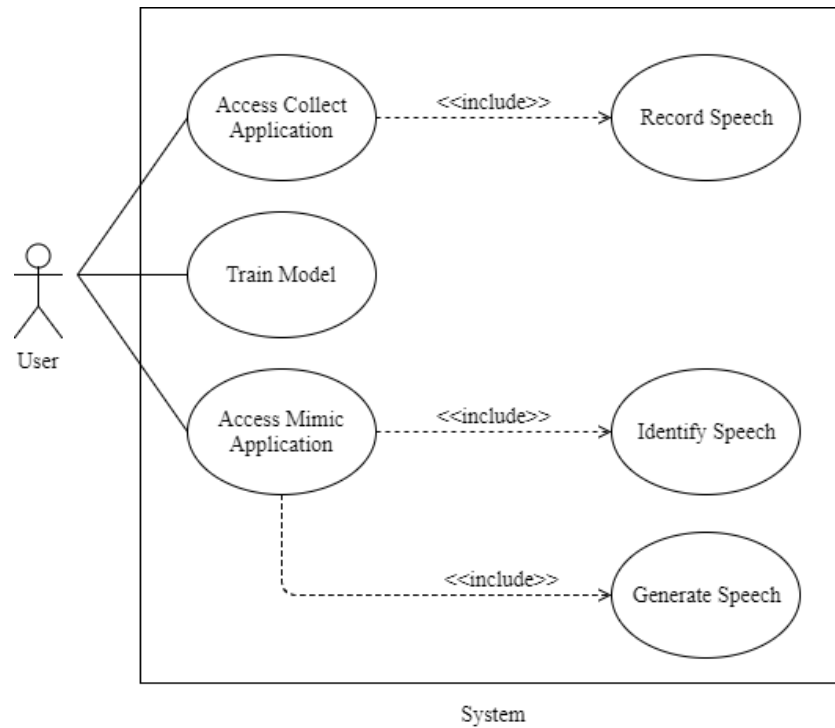


Figure 3.1 Use-case diagram.

3.4.2 Use-Case Narrative

Use-Case Narrative explains the interaction between the actors and the system. It describes the detail of use-cases such as name, description, pre-condition, post-condition, business rules, and the course of events that happened in the system. The Use-Case Narrative is shown in Table 3.4 up to Table 3.9.

Table 3.4 Use-case narrative – Access Collect application.

User Case Name	Access Collect application
Use Case ID	UC01
Priority	High
Primary Business Actor	User
Primary System Actor	System
Another Participating Actor	None
Description	This use-case describes the event when user opens Collect application through browser.

Precondition	None	
Trigger	User opens Collect application.	
Typical Course of Event	Actor Action	System Response
	Click Start button.	Syllables page is shown.
Alternate Course	None	
Post Condition	Home page is shown.	
Business Rule	None	
Implementation Constraint and Specifications	None	

Table 3.5 Use-case narrative – Record speech.

User Case Name	Record speech	
Use Case ID	UC02	
Priority	High	
Primary Business Actor	User	
Primary System Actor	System	
Another Participating Actor	None	
Description	This use-case describes the event when user opens Syllables page.	
Precondition	User clicks Start button from Home page.	
Trigger	User opens Syllables page.	
Typical Course of Event	Actor Action	System Response
	Click Record button and say asked syllable.	Record the speech and upload to save it.
Alternate Course	Actor Action	System Response
	Click Next button.	Next Syllables or Home page is shown.
Post Condition	Recorded speech is played on audio element.	
Business Rule	None	
Implementation Constraint and Specifications	None	

Table 3.6 Use-case narrative – Train model.

User Case Name	Train model
Use Case ID	UC03
Priority	High
Primary Business Actor	User
Primary System Actor	System
Another Participating Actor	None

Description	This use-case describes the event when user start Train application.	
Precondition	None	
Trigger	User starts Train application.	
Typical Course of Event	Actor Action	System Response
		Load and extract collected data.
		Split into train, validation, and test data.
		Convert data to model's input and output.
		Train the model with train data and validate with validation data.
		Test the model with test data and insert the model to MongoDB.
Alternate Course	None	
Post Condition	Model is trained and inserted in MongoDB.	
Business Rule	None.	
Implementation Constraint and Specifications	None	

Table 3.7 Use-case narrative – Access Mimic application.

User Case Name	Access Mimic application	
Use Case ID	UC04	
Priority	High	
Primary Business Actor	User	
Primary System Actor	System	
Another Participating Actor	None	
Description	This use-case describes the event when user opens Mimic application through browser.	
Precondition	None	
Trigger	User opens Mimic application.	
Typical Course of Event	Actor Action	System Response
	Click Identify Speech or Generate Speech button.	Identify or Generate page is shown.
Alternate Course	None	

Post Condition	Home page is shown.
Business Rule	None
Implementation Constraint and Specifications	None

Table 3.8 Use-case narrative – Identify speech.

User Case Name	Identify speech	
Use Case ID	UC05	
Priority	High	
Primary Business Actor	User	
Primary System Actor	System	
Another Participating Actor	None	
Description	This use-case describes the event when user opens Identify page.	
Precondition	User clicks Identify Speech button from Home page.	
Trigger	User opens Identify page.	
Typical Course of Event	Actor Action	System Response
	Click Record button and say something.	Record the speech and upload to save it.
		Recorded speech is played on audio element.
	Insert speech ID in input element and click Identify Speech button.	Recorded speech is identified with trained model.
		Speech data is updated to MongoDB if recognized.
Alternate Course	Actor Action	System Response
	Click Finish button.	Home page is shown.
Post Condition	Information whether recognized or not is alerted in the browser.	
Business Rule	None	
Implementation Constraint and Specifications	None	

Table 3.9 Use-case narrative – Generate speech.

User Case Name	Identify speech
Use Case ID	UC06

Priority	High	
Primary Business Actor	User	
Primary System Actor	System	
Another Participating Actor	None	
Description	This use-case describes the event when user opens Generate page.	
Precondition	User clicks Generate Speech button from Home page.	
Trigger	User opens Generate page.	
Typical Course of Event	Actor Action	System Response
		Load speech data from MongoDB.
	Choose speech ID from datalist element.	Speech ID selected.
	Insert text in input element and click Generate Speech button.	Speech is generated based selected speech ID and inserted text.
Alternate Course	Actor Action	System Response
	Click Finish button.	Home page is shown.
Post Condition	Generated speech is played on audio element.	
Business Rule	None	
Implementation Constraint and Specifications	None	

3.4.3 Activity Diagram

Activity Diagram presents a series of actions and flow of control in a system.

The activity diagram is separated into each application.

3.4.3.1 Collect Application

This activity describes the Collect application which is start when user opens the application. Home page will be shown as the home page. As user clicks Start button, the Syllables page will be shown. User can record asked syllables by click Record button. Recorded speech is played in audio element. User can also change the next

asked syllables by click Next button and the next Syllables page will be shown. If there are no more asked syllables, Home page will be shown instead the next Syllables page.

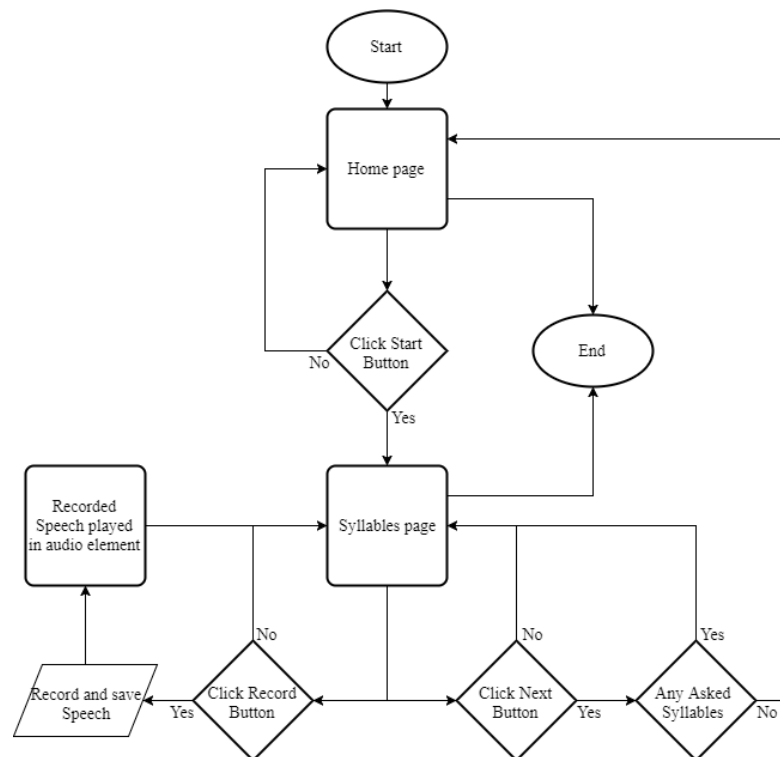


Figure 3.2 Collect application activity diagram.

3.4.3.2 Train Application

This activity describes the Train application which is start when user starts the application. Collected data will be loaded and extracted. Then, data split into train, validation, and test data. Each split data converted to model's input and output. The model is trained with train data and validated with validation data. Finally, the model is tested with test data and inserted to MongoDB. The model is trained and ready to use by Mimic application.

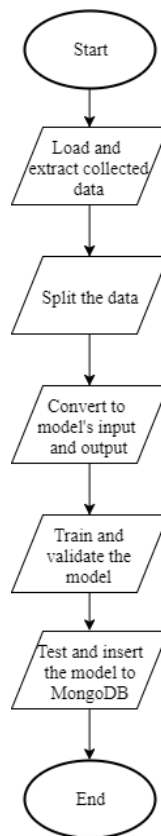


Figure 3.3 Train application activity diagram.

3.4.3.3 Mimic Application

This activity describes the Mimic application which is start when user opens the application. Home page will be shown as the home page. As user clicks Identify Speech button, the Identify page will be shown. User can record speech by click Record button. Then, user inserts speech ID on input element to name the speech data and click Identify Speech button to identify the recorded speech. Recognized speech will update the speech data to MongoDB. Any information regarding to identify process is alerted when finish to the browser. User can also click Finish button and Home page will be shown again. As user clicks Generate Speech button, the Generate page will be shown.

Speech ID is loaded as shown as the page is loaded. User can choose speech ID. Inserts text on textarea element. And clicks Generate Speech button to generate speech based on the speech ID and the text. Generated speech is played in audio element. There's also Finish button in Generate page that also shown Home page when clicked.

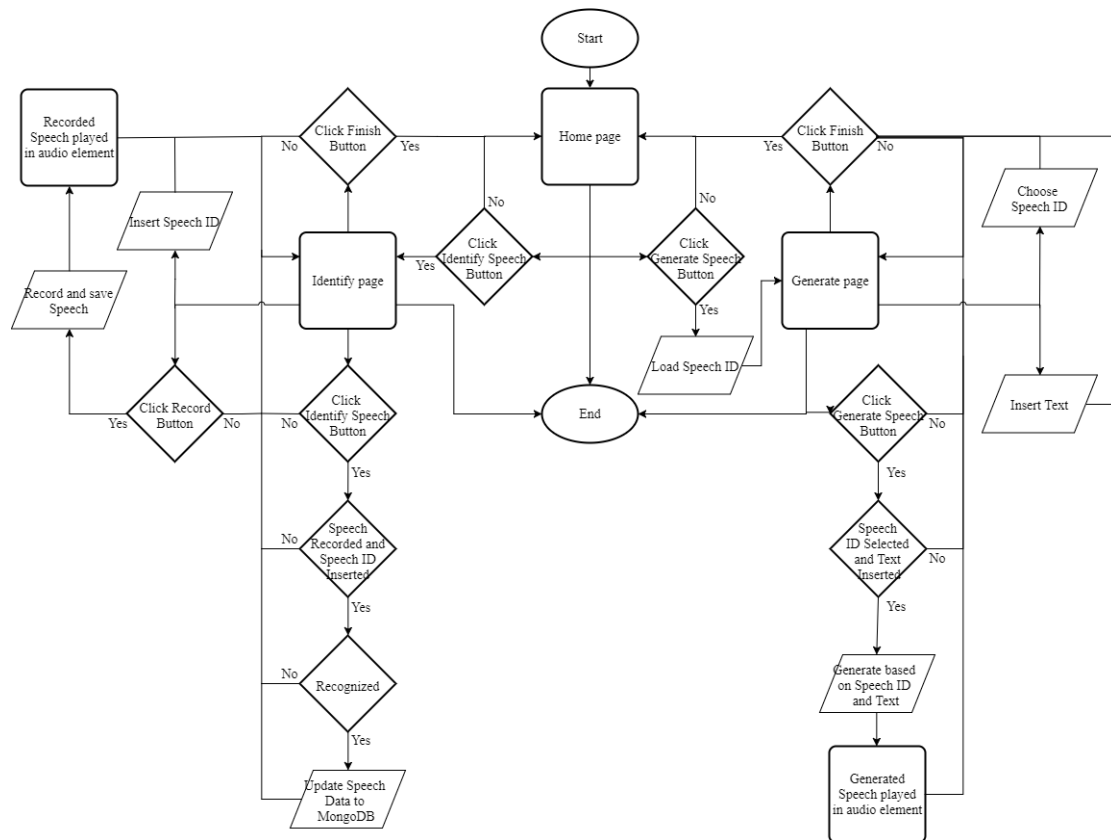


Figure 3.3 Mimic application activity diagram.

CHAPTER IV

SYSTEM DESIGN

4.1 User Interface Design

The UI is applied on Collect and Mimic application. There are two core pages in Collect application and three core pages in Mimic Application.

4.1.1 Collect Application

Two core pages in Collect application are Home page and Syllables page.

4.1.1.1 Home Page

Home page is the home page of the Collect application. When user opens the Collect application or directed from Mimic application or redirect back from Syllables page, it will show the Home page that consist of title, information regarding to Collect application, and 2 buttons such as Start and Mimic Home.

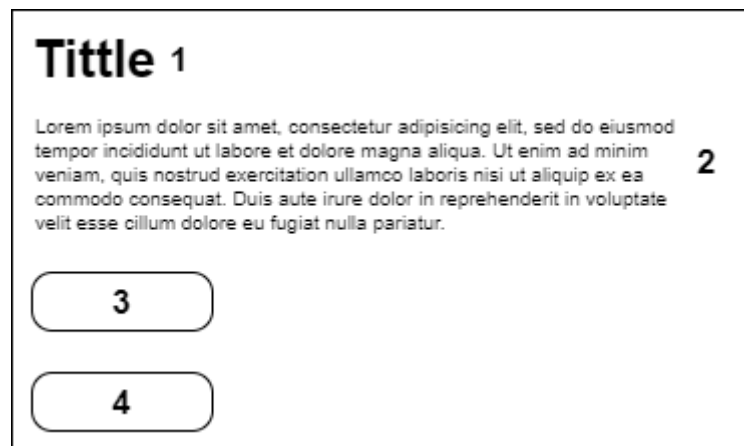


Figure 4.1 Collect Home page.

Table 4.1 Collect Home page description.

No	Description
1	Title
2	Information
3	Start Button
4	Mimic Home Button

4.1.1.2 Syllables Page

Syllables page is the main page of the Collect application. When user click Start in the Home page, it will show the Syllables page that consist of title regarding to which syllables should be recorded, audio element, and 2 buttons such as Record and Next.

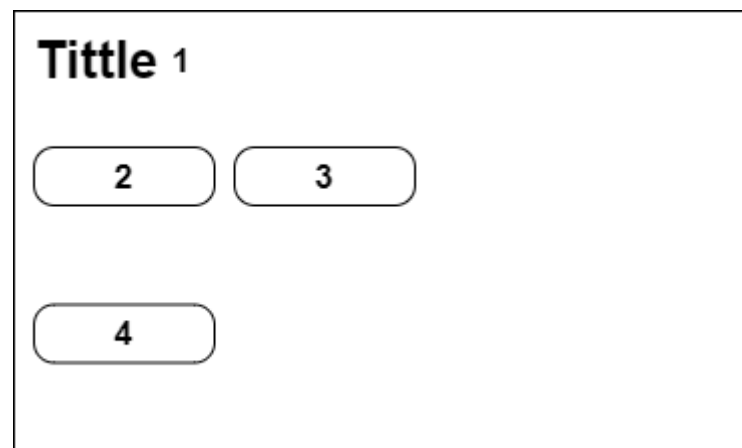


Figure 4.2 Collect Syllables page.

Table 4.2 Collect Syllables page description.

No	Description
1	Title
2	Audio Element
3	Record Button
4	Next Button

4.1.2 Mimic Application

Three core pages in Mimic application are Home page, Identify page, and Generate page.

4.1.2.1 Home Page

Home page is the home page of the Mimic application. When user opens the Mimic application or directed from Collect application or redirect back from Identify or Generate page, it will show the Home page that consist of title, information regarding to Mimic application, and 3 buttons such as Identify Speech, Generate Speech and Collect Home. The description of the design layout is shown in Table 4.3.

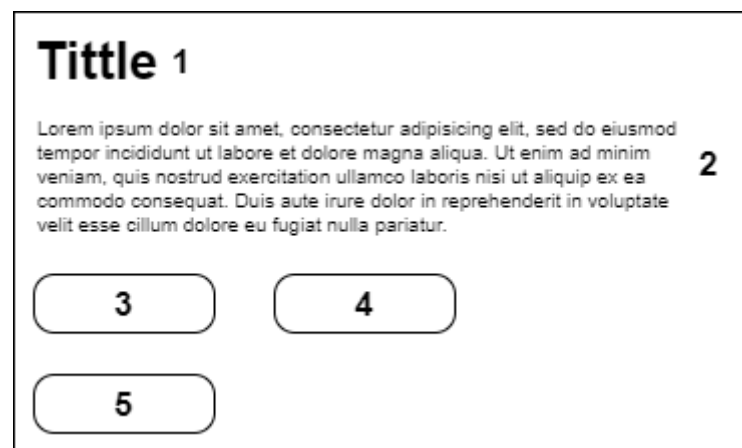


Figure 4.3 Mimic Home page.

Table 4.3 Mimic Home page description.

No	Description
1	Title
2	Information
3	Identify Speech Button
4	Generate Speech Button
5	Collect Home Button

4.1.2.2 Identify Page

Identify page is the one of the main pages of the Mimic application. When user click Identify Speech in the Home page, it will show the Identify page that consist of title, information registered syllables, 2 elements such as input and audio, and 3 buttons such as Record, Identify Speech, and Finish.

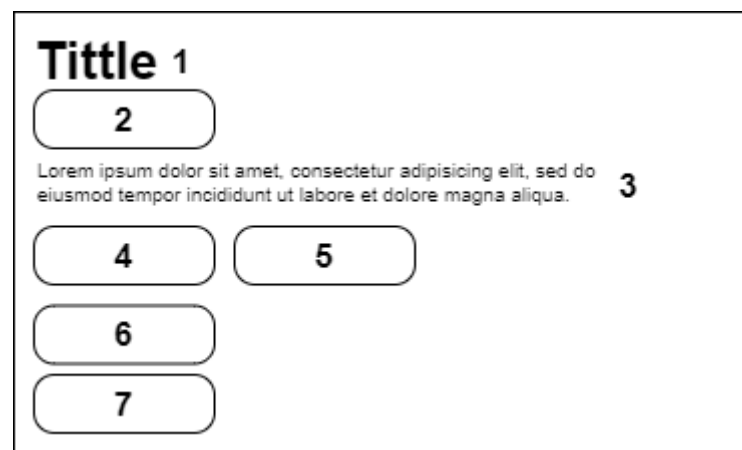


Figure 4.4 Mimic Identify page.

Table 4.4 Mimic Identify page description.

No	Description
1	Title
2	Input Element
3	Information
4	Audio Element
5	Record Button
6	Identify Button
7	Finish Button

4.1.2.3 Generate Page

Generate page is the other main pages of the Mimic application. When user click Generate Speech in the Home page, it will show the Generate page that consist of title,

3 elements such as datalist, textarea, and audio, and 2 buttons such as Generate Speech, and Finish.

Figure 4.5 Mimic Generate page.

Table 4.5 Mimic Generate page description.

No	Description
1	Title
2	Datalist Element
3	Textarea Element
4	Audio Element
5	Generate Button
6	Finish Button

4.2 Class Diagram

The class diagram is the structure of the system used toward this research. The class diagram in this research consist of Collect, Train, and Mimic application, server that handle Collect and Mimic application, and database that handle connection to MongoDB.

4.2.1 Collect Application

The core classes in the Collect application are `home` and `syllables`. They are the front-end of Collect application.

4.2.1.1 *home*

`home` is HTML that render the Home page. It consists html tags based on the UI design on the previous section and JavaScript to handle the buttons.

4.2.1.2 *syllables*

`syllables` is HTML that render the Syllables page. It consists html tags based on the UI design on the previous section, JavaScript to handle the buttons, and JavaScript to handle the record that will be uploaded.

The upload handler contains `file`, `randomString`, and `XMLHttpRequest` methods. `file` is used to create wav blob from the record. `randomString` is used to randomize string for naming the record file and reducing duplicate that will overwrite one file to another. `XMLHttpRequest` is used to send upload request to the server and receive response from the server.

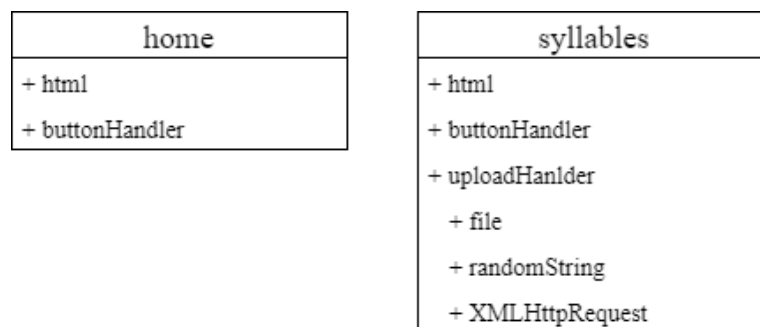


Figure 4.6 Collect application class diagram.

4.2.2 Train Application

The core classes in the Train application are `model` and `train`. They are the code to train the machine learning model with collected data.

4.2.2.1 *model*

`model` is JavaScript that define `model` to be Convolutional Neural Network model that will be used by `train`. It contains `add` method. `add` is used to add layer to the model.

4.2.2.2 *train*

`train` is JavaScript that setup and train the model based on `model`. It contains `loadData`, `nextBatch`, `saveModelDB`, `fit`, and `test` methods. `loadData` is used to load collected data from Collect application, split to train, validation, and test data, and extract all of them. `nextBatch` is used to get portion of `loadData` result and convert it to model input output. `saveModelDB` is used to insert the model to MongoDB. `fit` is used to train the model with train data and validate with validate data. `test` is used to test the model with test data.

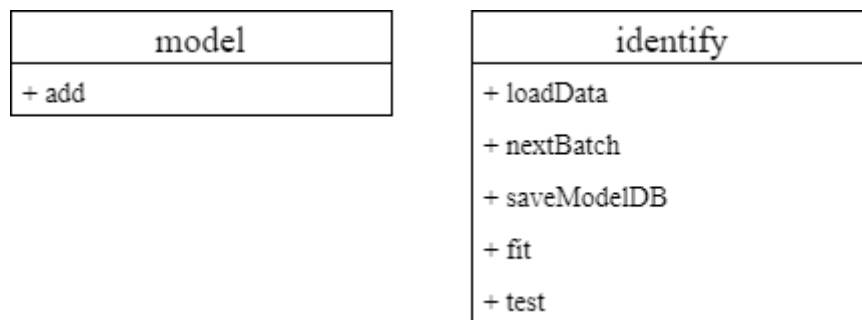


Figure 4.7 Train application class diagram.

4.2.3 *Mimic Application*

The core classes in the Mimic application are `home`, `identify`, and `generate`. They are the front-end of Mimic application.

4.2.3.1 *home*

`home` is HTML that render the Home page. It consists html tags based on the UI design on the previous section and JavaScript to handle the buttons.

4.2.3.2 *identify*

`identify` is HTML that render the Identify page. It consists html tags based on the UI design on the previous section, JavaScript to handle the elements and buttons, JavaScript to handle the record that will be uploaded, and JavaScript to handle the record that will be identified.

The upload handler contains `file`, `randomString`, and `XMLHttpRequest` methods. `file` is used to create wav blob from the record. `randomString` is used to randomize string for naming the record file and reducing duplicate that will overwrite one file to another. `XMLHttpRequest` is used to send upload request to the server and receive response from the server.

The identify handler contains `XMLHttpRequest` methods. `XMLHttpRequest` is used to send identify request to the server and receive response from the server.

4.2.3.3 generate

generate is HTML that render the Generate page. It consists html tags based on the UI design on the previous section, JavaScript to handle the elements and buttons, JavaScript to handle the speech data that will be loaded from database, and JavaScript to handle the speech ID and text that will be generated to audio.

The load handler contains `XMLHttpRequest` methods. `XMLHttpRequest` is used to send load request to the server and receive response from the server.

The generate handler contains `XMLHttpRequest` methods. `XMLHttpRequest` is used to send generate request to the server and receive response from the server.

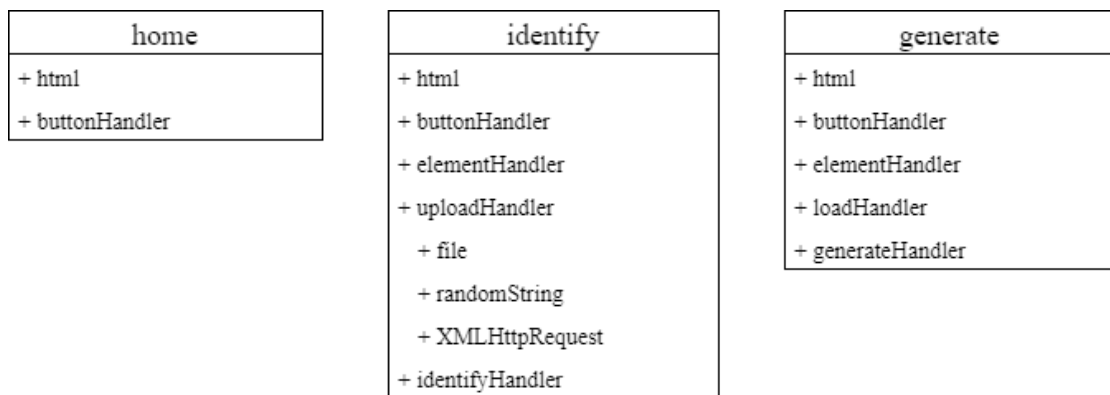


Figure 4.8 Mimic application class diagram.

4.2.4 Server

The core classes in the server are `serverHandler` and `createServer`. They are the back-end of Collect and Mimic application.

4.2.4.1 *serverHandler*

`serverHandler` is JavaScript that define server listener that will be used by `createServer`. It consists of JavaScript to handle upload from Collect application, JavaScript to handle upload and identify from Mimic Identify page, JavaScript to handle load and generate from Mimic Generate page, and JavaScript to handle URL that will display and load in the browser.

The collect handler contains `router` and `upload` methods. `router` is used to check whether the request is point to collect handler or not. If yes, then `upload` will be executed. `upload` is used to upload file based on the request. Then, convert its upload path location to URL. It returns the URL as response.

The identify handler contains `router`, `upload`, and `identify` methods. `router` is used to check whether the request is point to identify handler or not. If yes, then `upload` or `identify` will be executed. `upload` is used to upload recorded file based on the request, then convert its upload path location to URL. It returns the URL and upload path as response. `identify` is used to identify the recorded file based on the request. It loads the latest trained machine learning model from database. Then, the extract result is test with the model. If the test result show high accuracy the file path is inserted to MongoDB based on the speech ID in the request and the identify result. It returns the information whether the model can identify or not as response.

The generate handler contains `router`, `load`, and `generate` methods. `router` is used to check whether the request is point to generate handler or not. If yes,

then `load` or `generate` will be executed. `load` is used to load all the speech ID from speech data in the MongoDB. It returns the result as response. `generate` is used to generate speech based on text from the request. It loads the speech data from speech ID based on the request. Then, the text is check with the loaded speech data. If unmatched is found, it returns error as response. If all matched, the speech data corresponding to text is combined to 1 audio file. Finally, the file path is converted to URL and returns the result as response

4.2.4.2 createServer

`createServer` is JavaScript that create the server. It contains `listen` method. `listen` is used to listen any request that comes to the server. The request will be proceeded to `serverHandler`.

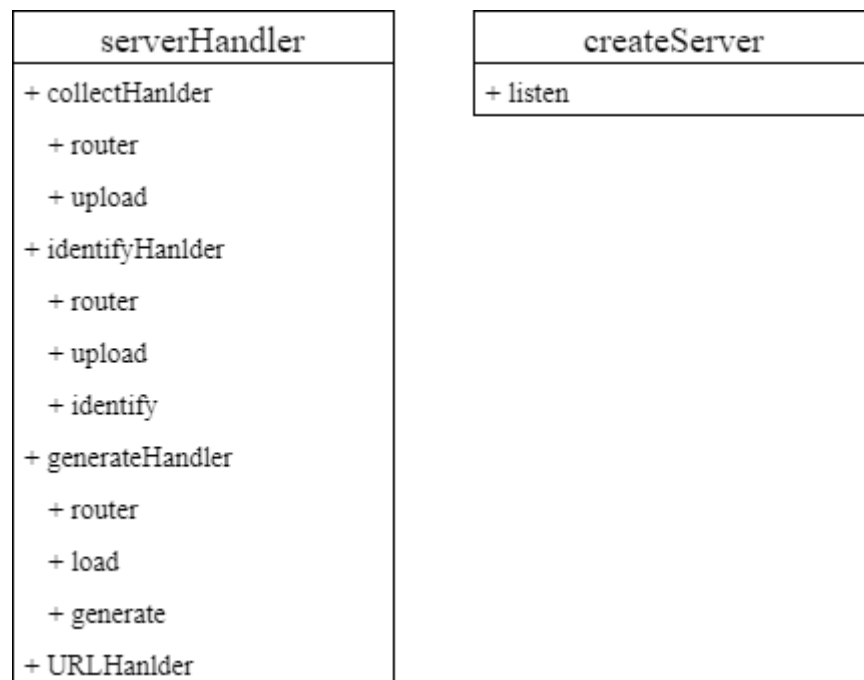


Figure 4.9 Server class diagram.

4.2.5 Database

The core classes in the database are `connection` and `model`. They are the code that create connection to MongoDB and collection model scheme of the database on MongoDB.

4.2.5.1 connection

`connection` is JavaScript that handle the connection with MongoDB. It contains `connect` and `disconnect` methods. `connect` is used to establish the connection to MongoDB. `disconnect` is used to close the established connection.

4.2.5.2 model

`model` is JavaScript that create the collection model scheme of the database on MongoDB. It contains `speechDatas` and `models` schemes. `speechDatas` is used to define model for speech data collection scheme that is used on Mimic application. Each collection record speech ID and syllables. `models` is used to define model for machine learning model collection scheme that is used on Train and Mimic application. Each collection record model's path and the date the model is saved.

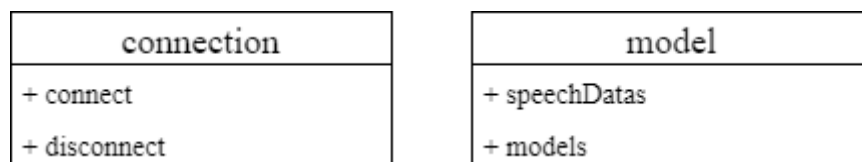


Figure 4.10 Database class diagram.

CHAPTER V

SYSTEM DEVELOPMENT

5.1 User Interface Development

The UI is applied on Collect and Mimic application. There are two core pages in Collect application and three core pages in Mimic Application.

5.1.1 Collect Application

Two core pages in Collect application are Home page and Syllables page.

5.1.1.1 Home Page

Home page is the home page of the Collect application. It shows information about how the collecting process works and information regarding to the collecting process. There are also 2 buttons, Start and Mimic Home button.

Start button will direct user to Syllables page to start collecting. Mimic Home button will direct user to Mimic application Home page.

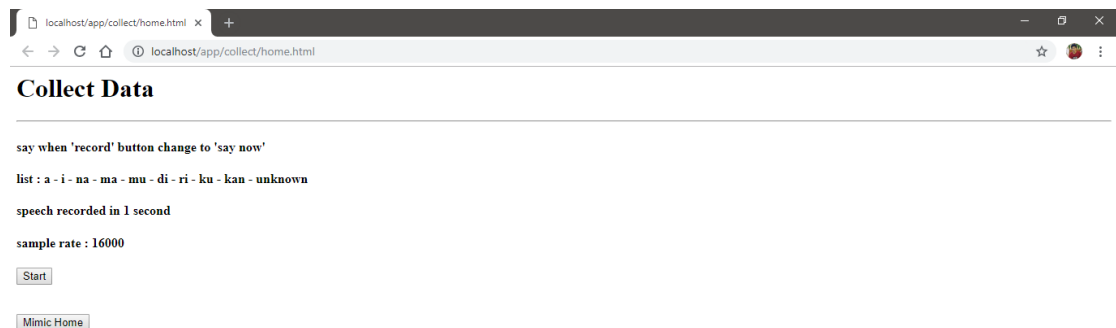


Figure 5.1 Collect Home page.

5.1.1.2 Syllables Page

Syllables page is the main page of the Collect application. It shows information about which syllable should be recorded and replayed the record. There are also 2 buttons, Record and Next button and an audio element. Any response from the server is also printed in the console.

Record button will start the record process. When the record process is starting, Record button will be renamed to 'Say Now' which tell user that the record process is starting and indicate user to say the relevant syllable. When the record process is finish, the recorded blob is uploaded to the server and Record button will be renamed to 'Record Again' which tell user that the record process is finish and user can do the next record. Next button will direct user to the next Syllables page. In this application there are 9 Syllables and 1 unknown Syllable. On the last syllables, Next button will direct user back to Home page.

Audio element will be shown when the record process is finish with an audio from the record. User can hear the replay of the record from the audio element.



Figure 5.2 Collect Syllables page with 'a' syllable.



Figure 5.3 Collect Syllables page after record process is finish.

5.1.2 Mimic Application

Three core pages in Mimic application are Home page, Identify page, and Generate page.

5.1.2.1 Home Page

Home page is the home page of the Mimic application. It shows information about how the mimic process works and information regarding to the identify and generate process. There are also 3 buttons, Identify, Generate, and Collect Home button.

Identify button will direct user to Identify page to start identifying speech. Generate button will direct user to Generate page to start generating speech. Collect Home button will direct user to Collect application Home page.

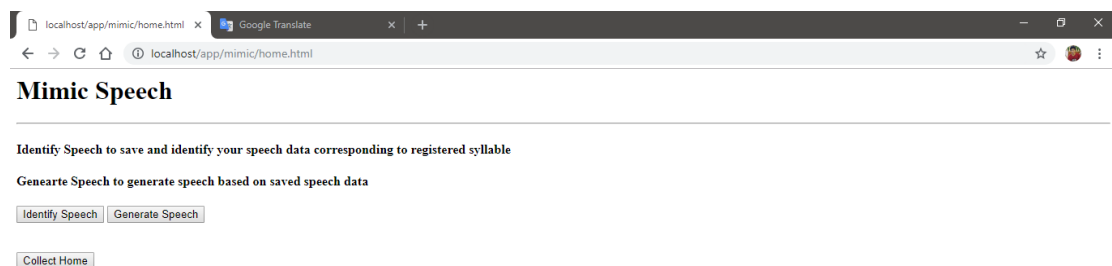


Figure 5.4 Mimic Home page.

5.1.2.2 *Identify Page*

Identify page is the one of the main pages of the Mimic application. It shows information about which syllable is recognizable and form of input and audio that will be used to identify the speech and update it to database. There are also 3 buttons, Record, Identify Speech and Finish button, and an input and an audio element. Any response from the server is also printed in the console.

Record button will start the record process. When the record process is starting, Record button will be renamed to 'Say Now' which tell user that the record process is starting and indicate user to say the syllable. When the record process is finish, the recorded blob is uploaded to the server Record button will be renamed to 'Record Again' which tell user that the record process is finish and user can do the next record. Identify Speech button will take the value of input element and file source of audio element, then, send them to the server to be identify. The indication of identify process in the server is success or error is there is alert on the browser that show any information regarding to identify process in the server. If there is no value of input element or file source of audio element, Identify Speech button will alert user that there is not any value. Finish button will direct user back to the Home page.

Audio element will be shown when the record process is finish with an audio from the record. User can hear the replay of the record from the audio element. Input element is used as input of user speech ID value.

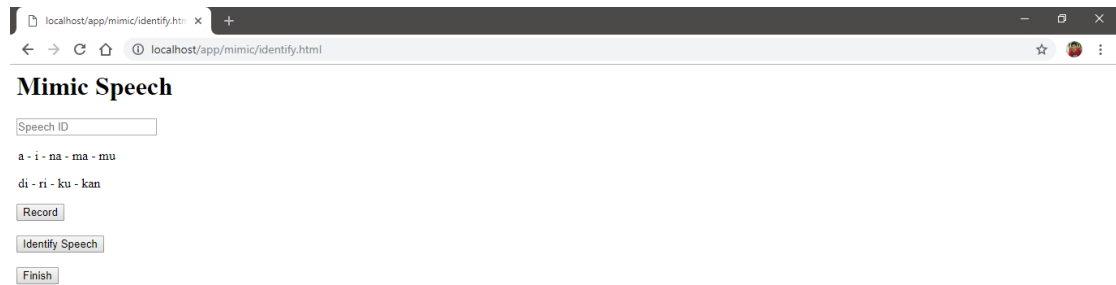


Figure 5.5 Mimic Identify page.

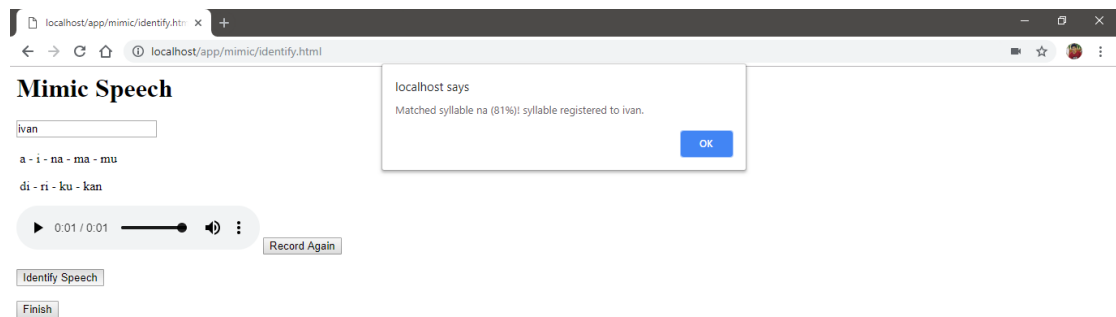


Figure 5.6 Mimic Identify page alert user indicating identify process in the server is finish.

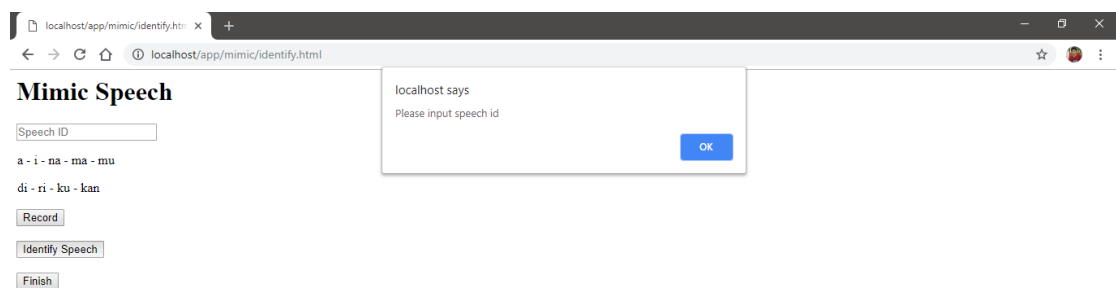


Figure 5.7 Mimic Identify page alert user indicating there is no value in input element.

5.1.2.3 Generate Page

Generate page is the one of the main pages of the Mimic application. It shows form of data list and text area that will be used to generate the speech. When the page is loading, it also loads speech data from the database and then store it on data list. If

there is no speech data found, it will alert user and direct user back to Home page. There are also 2 buttons, Generate Speech and Finish button, and a datalist element, a textarea element and an audio element. Any response from the server is also printed in the console.

Generate Speech button will take the value of datalist element and textarea element, then, send them to the server to be generate. The indication of generate process in the server is error is there is alert on the browser that show any error information regarding to generate process in the server. The indication of generate process in the server is success is the audio element is shown with an audio from the generated speech. If there's no value of datalist element or textarea element, Identify Speech button will alert user that there is not any value. Finish button will direct user back to the Home page.

Audio element will be shown when the generate process is success with an audio from the generated speech. User can hear the generated speech from the audio element. Datalist element is shows all speech data from database and it is used as input of user speech ID value. Textarea element is used as input of words that user want to generate.

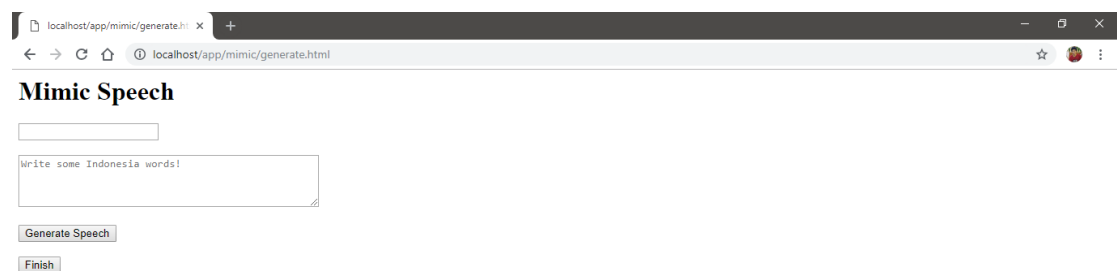


Figure 5.8 Mimic Generate page.

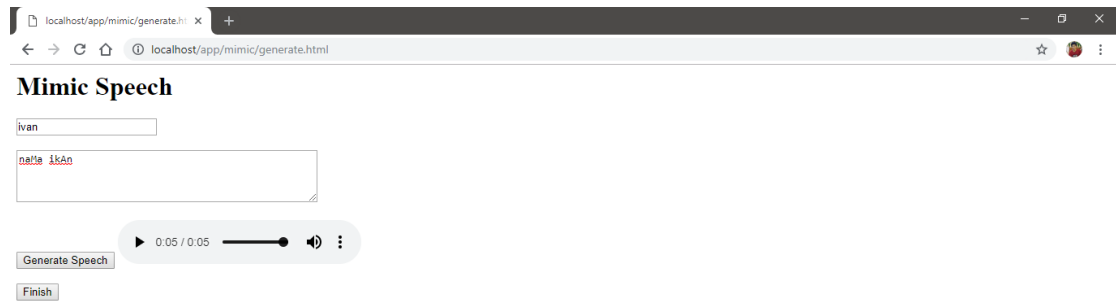


Figure 5.9 Mimic Generate page play the generated speech after generate process success.

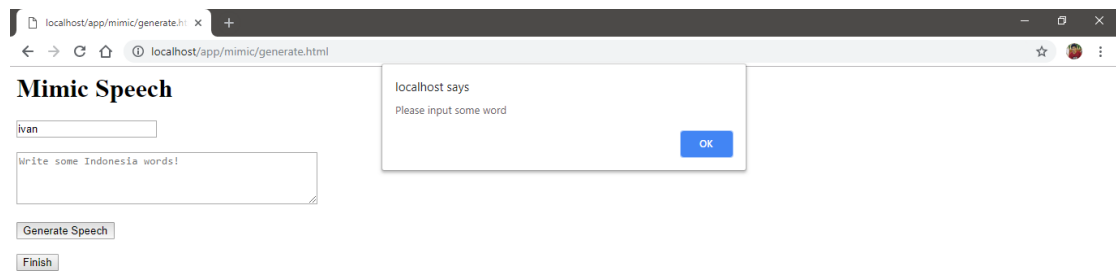


Figure 5.10 Mimic Generate page alert user indicating there is no value in textarea element.

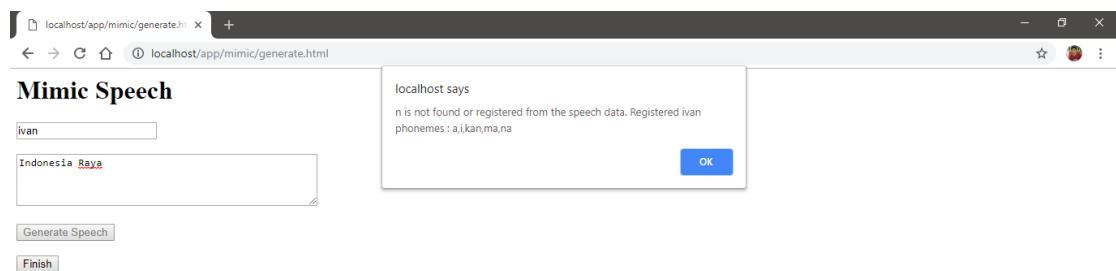


Figure 5.11 Mimic Generate page alert user indicating there is error in the generate process.

5.2 Application Details

The application details explain some codes on Collect, Train, and Mimic application, server and database code based on previous chapter.

5.2.1 Collect Application

Collect application code is used to create the front-end of Collect application. It consists of home and syllables.

5.2.1.1 home

home is used to render the Home page as shown in figure 5.1 and also handle the button in Home page. It is written on HTML and JavaScript.

home contains `html`, `btnStart`, and `btnMimic`. `html` is used to render Home page. `btnStart` is used to direct user to Syllables page. `btnMimic` is used to direct user to Mimic Home page.



```

1 <html>
2
3 <body>
4   <h1> Collect Data </h1>
5   <hr />
6   <h4> say when 'record' button change to 'say now' </h4>
7   <h4> list : a - i - na - mu - d1 - r1 - ku - kan - unknown </h4>
8   <h4> speech recorded in 1 second </h4>
9   <h4> sample rate : 16000 </h4>
10  <button id='btnStart'>Start</button>
11  <br />
12  <br />
13  <br />
14  <button id='btnMimic'>Mimic Home</button></Link>
15
16  <script src='./script/home.js'></script>
17 </body>
18
19 </html>

```

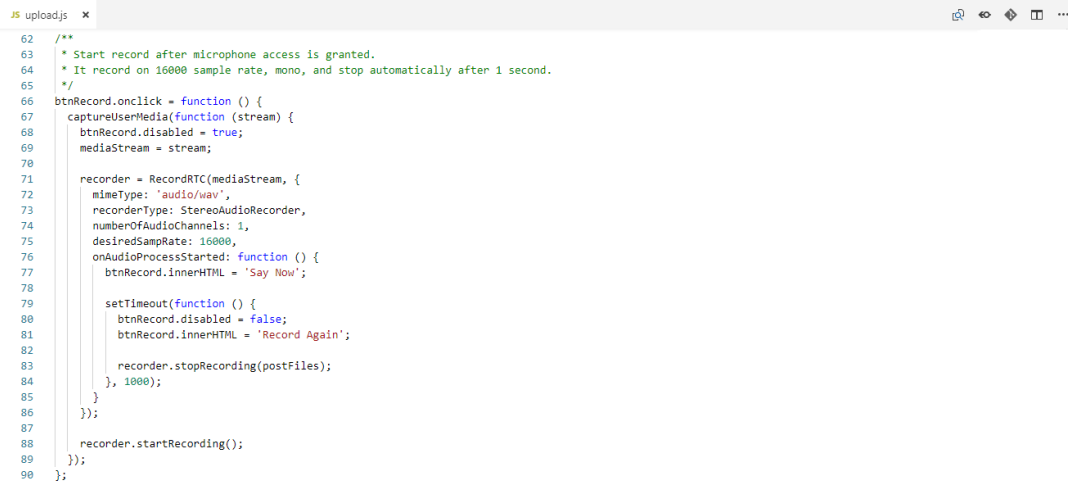
Figure 5.12 Collect home html code.

5.2.1.2 *syllables*

`syllables` is used to render the Syllables page as shown in figure 5.2 up to 5.3, handle the button in Syllables page, and also handle upload record. It is written on HTML and JavaScript. The upload handler, that contains `file`, `randomString`, and `XMLHttpRequest`, is forked from RecordRTC package. RecordRTC is a JavaScript-based media-recording library for modern web-browsers. It is optimized for different devices and browsers to bring all client-side recording solutions in single place [25].

`syllables` contains `html`, `btnNext`, `btnRecord`, `captureUserMedia`, `postFiles`, `generateRandomString`, and `xhrPostUploadCollect`. `html` is used to render Syllables page based on corresponding syllable. `btnNext` is used to direct user to the next Syllables page or redirect back to Home page if there is not any next syllable.

`btnRecord` is used to start record. It runs `captureUserMedia` first, that is used to ask user's microphone permission. If the permission granted, it then starts recording for 1 seconds. After that it runs `postFiles`, that is used to store the wav blob from the record and generate random string for naming the file files from `generateRandomString`. Finally, `xhrPostUploadCollect`, that is used to send upload request based on corresponding syllable with the wav blob to the server and receive response from the server as the upload result, is run.



```

62  /**
63   * Start record after microphone access is granted.
64   * It record on 16000 sample rate, mono, and stop automatically after 1 second.
65   */
66  btnRecord.onclick = function () {
67    captureUserMedia(function (stream) {
68      btnRecord.disabled = true;
69      mediaStream = stream;
70
71      recorder = RecordRTC(mediaStream, {
72        mimeType: 'audio/wav',
73        recorderType: StereoAudioRecorder,
74        numberOfAudioChannels: 1,
75        desiredSampRate: 16000,
76        onAudioProcessStarted: function () {
77          btnRecord.innerHTML = 'Say Now';
78
79          setTimeout(function () {
80            btnRecord.disabled = false;
81            btnRecord.innerHTML = 'Record Again';
82
83            recorder.stopRecording(postFiles);
84          }, 1000);
85        }
86      });
87
88      recorder.startRecording();
89    });
90  };

```

Figure 5.13 Collect syllables btnRecord code.

5.2.2 Train Application

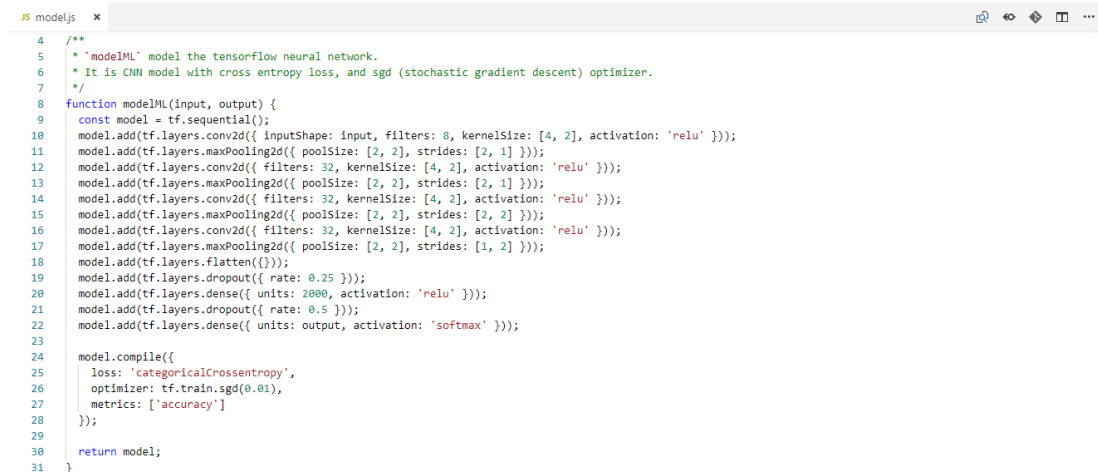
Train application code is used to train the machine learning model with collected data. It consists of `model` and `train`. It is develop using TensorFlow.js. TensorFlow is a JavaScript library for training and deploying ML models in the browser and on Node.js [26].

5.2.2.1 model

`model` is used to define `model` to be Convolutional Neural Network model that will be used by `train`. It is written on JavaScript. The model is inspired from TensorFlow `speech_commands` [27] and forked from TensorFlow.js `speech_commands` [28].

`model` contains `modelML`. `modelML` is used to contain defining process. As TensorFlow.js imported, use `sequential` to define model as a stack like. After that,

add layer by simply use `add` and followed by the name of the layer. Finally, use `compile` to configures and prepares the model for training and evaluation.



```

4  /**
5   * 'modelML' model the tensorflow neural network.
6   * It is CNN model with cross entropy loss, and sgd (stochastic gradient descent) optimizer.
7   */
8  function modelML(input, output) {
9    const model = tf.sequential();
10   model.add(tf.layers.conv2d({ inputShape: input, filters: 8, kernelSize: [4, 2], activation: 'relu' }));
11   model.add(tf.layers.maxPooling2d({ poolSize: [2, 2], strides: [2, 1] }));
12   model.add(tf.layers.conv2d({ filters: 32, kernelSize: [4, 2], activation: 'relu' }));
13   model.add(tf.layers.maxPooling2d({ poolSize: [2, 2], strides: [2, 1] }));
14   model.add(tf.layers.conv2d({ filters: 32, kernelSize: [4, 2], activation: 'relu' }));
15   model.add(tf.layers.maxPooling2d({ poolSize: [2, 2], strides: [2, 2] }));
16   model.add(tf.layers.conv2d({ filters: 32, kernelSize: [4, 2], activation: 'relu' }));
17   model.add(tf.layers.maxPooling2d({ poolSize: [2, 2], strides: [1, 2] }));
18   model.add(tf.layers.flatten({}));
19   model.add(tf.layers.dropout({ rate: 0.25 }));
20   model.add(tf.layers.dense({ units: 2880, activation: 'relu' }));
21   model.add(tf.layers.dropout({ rate: 0.5 }));
22   model.add(tf.layers.dense({ units: output, activation: 'softmax' }));
23
24   model.compile({
25     loss: 'categoricalCrossentropy',
26     optimizer: tf.train.sgd(0.01),
27     metrics: ['accuracy']
28   });
29
30   return model;
31 }

```

Figure 5.14 Train model `modelML` code.

5.2.2.2 *train*

`train` is used to setup and train the model based on `model`. It is written on JavaScript. The code is inspired from TensorFlow `speech_commands` [27] and TensorFlow.js `speech_commands` [28].

`train` contains `extractWav`, `createMelFilterbank`, `loadData`, `nextBatch`, `train`, and `saveModelDB`. `loadData` is used to load collected data from Collect application, split to train, validation, and test data, and run `extractWav` to extract all of them. `extractWav` is used MFCC to do extraction process. `createMelFilterbank` is used to create the filterbank model that is used by `extractWav`. The extraction is inspired from many sources, `python_speech_features` [29], `node-mfcc` [30], and `meayda` [31], as there are many variations in the process. In

the process node-wav package [32] is used to decode the collected file in the beginning of extraction process. Also, dct package [33] is used to calculate DCT in the last step of extraction process.

When the data is loaded, it is shuffled by shuffle-array package [34] to reduce overfitting. Every iteration when extracting the loaded files is printed. If inconsistent data is met, the process stops and exit. Then, it loads `model` first, before run `nextBatch`, that is used to get portion of `loadData` result and convert it to model input output. It converts test data to be prepared for testing. After that `train` is run. At first, it converts train and validation data using `nextBatch` corresponding to train iteration. Then, it runs `fit`, that is provided by TensorFlow.js to train using train data and evaluate using validation data. `fit` is iterate based on the epoch that is defined.

Every train iteration evaluation result are printed. Test is run every n time in train iteration and last iteration. It uses `predict` to `predict` the test data and `confusionMatrix` to print all the test result. Both is provided by TensorFlow.js. Every test iteration the model saved with random name to avoid overwrite using `crypto-random-string` package [35]. It also run `saveModelDB`, that is used to insert the model to MongoDB.

```

55 // fft and power spectrum.
56 let prefftSample = [];
57 let fftSample = [];
58 let powSample = [];
59 if (fftSize > frameSize) {
60   for (i = 0; i < winSample.length; i++) {
61     let frame = new Float32Array(fftSize);
62     for (j = 0; j < fftSize; j++) {
63       if (j < frameSize) frame[j] = winSample[i][j];
64       else frame[j] = 0;
65     }
66     prefftSample.push(frame);
67   }
68 } else {
69   prefftSample = winSample;
70 }
71 fftSample = prefftSample.map(frame => fft.util.fftMag(fft.fft(frame)));
72 powSample = fftSample.map(frame =>
73   // With the power produce double the trailing zeros.
74   // new Float32Array(frame.map(sample => Math.pow(Math.abs(sample), 2) / fftSize))
75   new Float32Array(frame.map(sample => sample))
76 );
77
78 // calculate mel filterbank and dot product with the sample.
79 let filSample = [];
80 let fbank = require('./createMelFilterbank')(lowFreq, highFreq, melFilter, fftSize, sampleRate);
81 let fbankTranspose = [];
82 for (i = 0; i < fbank[0].length; i++) {
83   let filter = new Float32Array(fbank.length);
84   for (j = 0; j < fbank.length; j++) {
85     filter[j] = fbank[j][i];
86   }
87   fbankTranspose.push(filter);
88 }
89 for (i = 0; i < powSample.length; i++) {
90   let frame = new Float32Array(fbankTranspose[0].length);
91   for (j = 0; j < fbankTranspose[0].length; j++) {
92     for (k = 0; k < powSample[i].length; k++) {
93       frame[j] += powSample[i][k] * fbankTranspose[k][j];
94     }
95   }
96   filSample.push(frame);
97 }
98
99 // logarithm the sample.
100 let logSample = [];
101 logSample = filSample.map(frame => frame.map(x => Math.log(1 + x)));
102
103 // dct the sample and take 0 until 13.
104 let dctSample = [];
105 dctSample = logSample.map(frame => new Float32Array(dct(frame).slice(0, 13)));

```

Figure 5.15 Some part of Train train extractWav code.

5.2.3 Mimic Application

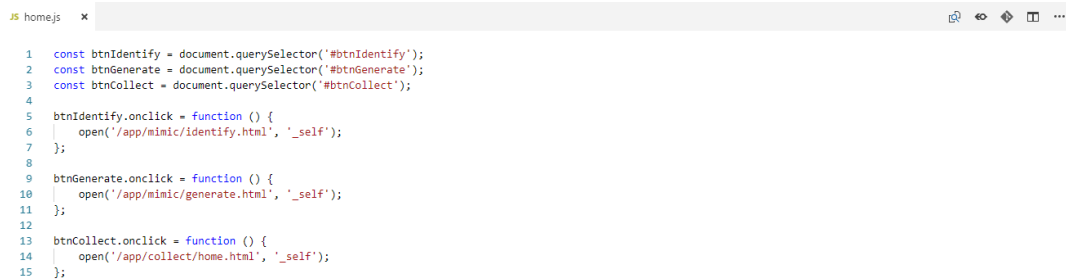
Mimic application code is used to create the front-end of Mimic application. It consists of home, identify, and generate.

5.2.3.1 home

home is used to render the Home page as shown in figure 5.4 and also handle the button in Home page. It is written on HTML and JavaScript.

home contains html, btnIdentify, btnGenerate, and btnCollect. html is used to render Home page. btnIdentify is used to direct user to Identify page.

`btnGenerate` is used to direct user to Generate page. `btnCollect` is used to direct user to Collect Home page.



```

1  const btnIdentify = document.querySelector('#btnIdentify');
2  const btnGenerate = document.querySelector('#btnGenerate');
3  const btnCollect = document.querySelector('#btnCollect');
4
5  btnIdentify.onclick = function () {
6    | open('/app/mimic/identify.html', '_self');
7  };
8
9  btnGenerate.onclick = function () {
10 | open('/app/mimic/generate.html', '_self');
11 };
12
13 btnCollect.onclick = function () {
14 | open('/app/collect/home.html', '_self');
15 };

```

Figure 5.16 Mimic home html code.

5.2.3.2 *identify*

`identify` is used to render the Identify page as shown in figure 5.5 up to 5.7, handle the button and element in Identify page, and also handle upload and identify record. It is written on HTML and JavaScript.

`identify` contains `html`, `inSpeechId`, `btnFinish`, `btnRecord`, `btnIdentify`, `captureUserMedia`, `postFiles`, `generateRandomString`, `xhrPostUploadCollect`, and `xhrPostIdentifySpeech`. `html` is used to render Identify page. `inSpeechId` is used to place for user to input speech ID. `btnFinish` is used to redirect back to Home page.

`btnRecord` is used to start record same like Collect syllables `btnRecord`. `btnIdentify` is used to identify recorded speech. It alerts error to user if there is not any value in `inSpeechId` and recorded speech. It identifies by run

`xhrPostIdentifySpeech`, that is used to send identify request with `inSpeechId` and recorded speech to the server and receive response from the server.

```

41 /**
42  * xhrPostIdentifySpeech send 'name' and 'filePath' to server, identify it and save to MongoDB.
43  *
44  * Send POST 'identifySpeech' request with input text as 'name' and 'filePath' on it.
45  * Accept 'status' from response and alert it.
46  */
47  function xhrPostIdentifySpeech(data) {
48      const request = new XMLHttpRequest();
49      request.onreadystatechange = function () {
50          if (request.readyState == 4 && request.status == 200) {
51              const status = JSON.parse(request.responseText).status;
52
53              console.info('status', status);
54              alert(status);
55
56              btnRecord.disabled = false;
57              btnIdentify.disabled = false;
58          }
59      };
60      request.open('POST', '/identifySpeech');
61
62      const formData = new FormData();
63      formData.append('name', data.name);
64      formData.append('filePath', data.filePath);
65      request.send(formData);
66  }

```

Figure 5.17 Mimic identify `xhrPostIdentifySpeech` code.

5.2.3.3 generate

`generate` is used to render the Generate page as shown in figure 5.8 up to 5.11, handle the button and element in Generate page, and also handle load and generate speech. It is written on HTML and JavaScript.

`generate` contains `html`, `inSpeechId`, `listSpeechId`, `txtAreaText`, `btnFinish`, `btnGenerate`, `xhrGetSpeechId`, and `xhrPostGenerateSpeech`. `html` is used to render Generate page. After render the page, it runs `xhrGetSpeechId`, that is used to send load request to the server and receive response from the server. The loads result which is speech data is stored to `listSpeechId`. If there is no speech data found, it alerts error to user and redirect user back to Home page.

`inSpeechId` is used to place for user to input speech ID that also show speech data list. `txtAreaText` is used to place for user to input text. `btnFinish` is used to redirect back to Home page. `btnGenerate` is used to generate speech. It alerts error to user if there is not any value in `inSpeechId` and `txtAreaText` or inputted speech ID in `inSpeechId` is not exist in `listSpeechId`. It generates by run `xhrPostIdentifySpeech`, that is used to send generate request with `inSpeechId` and `txtAreaText` to the server and receive response from the server.

```

11  /**
12   * `xhrGetSpeechId` load all speech data from the server.
13   *
14   * Send GET `loadSpeech` request.
15   * Accept `speechId` from response to be used as `listSpeechId` datalist.
16   * It also give alert message whenever the response contain `error` message.
17   */
18  function xhrGetSpeechId() {
19    const request = new XMLHttpRequest();
20    request.onreadystatechange = function () {
21      if (request.readyState == 4 && request.status == 200) {
22        speechId = JSON.parse(request.responseText).speechId;
23        const error = JSON.parse(request.responseText).error;
24
25        console.info('speechId', speechId);
26
27        if (typeof error !== 'undefined') {
28          alert(error);
29          open('/app/mimic/home.html', '_self');
30        } else {
31          for (i = 0; i < speechId.length; i++) {
32            const option = document.createElement('option');
33            option.value = speechId[i];
34
35            listSpeechId.appendChild(option);
36          }
37
38          btnGenerate.disabled = false;
39          btnFinish.disabled = false;
40        }
41      }
42    };
43    request.open('GET', '/loadSpeech');
44    request.send();
45  }

```

Figure 5.18 Mimic generate `xhrPostIdentifySpeech` code.

5.2.4 Server Code

Server code is used to create the back-end of Collect and Mimic application. It consists of `collect`, `identify`, and `generate` routers, `serverHandler` and `createServer`. The server is inspired and forked from RecordRTC package [25]. The

routers use formidable package [36] that is used to parse request data and upload file from request.

5.2.4.1 collect Router

`collect` router is used to handle upload request from Collect Syllables page that will be used by `serverHandler`. It is written on JavaScript.

`collect` router contains `uploadCollect` and `router`. `router` is used to check whether the request is from Collect Syllables page or not. If yes, it runs `uploadCollect` corresponding to matched syllable request. If no, it returns nothing. `uploadCollect` is used to upload file from the request to the directory that have the same syllable name in collect directory. It converts its upload path location to URL. It returns the URL as response.

```

4  /**
5   * 'uploadCollect' upload file in the 'request' based on defined directory and
6   * then convert its path location to url.
7   *
8   * Return the url as 'fileURL'.
9   */
10 function uploadCollect(address, port, label, request) {
11   const dirData = '\\data';
12   const dirCollect = '\\collect';
13   const dirLabel = '\\ ' + label + '\\';
14
15   const form = new formidable.IncomingForm();
16   form.uploadDir = process.cwd() + dirData + dirCollect + dirLabel;
17   form.keepExtensions = true;
18   form.maxFieldsSize = 10 * 1024 * 1024;
19   form.maxFields = 1000;
20   form.multiples = false;
21
22   return new Promise(function (resolve) {
23     form.parse(request, function (err, fields, files) {
24       const file = util.inspect(files);
25
26       const fileName = file.split('path:')[1].split('\\')[0].split(dirData)[1].split(dirCollect)[1].split(dirLabel)[1].toString().replace(/\\/g, '').replace(
27         /\\/g, '');
28       const fileURL = 'http://' + address + ':' + port + '/data/collect/' + label + '/' + fileName;
29
30       console.log('fileURL: ', fileURL);
31       resolve(JSON.stringify({ fileURL: fileURL }));
32     });
33   });

```

Figure 5.19 Server collect router `uploadCollect` code.

5.2.4.2 *identify Router*

`identify` router is used to handle upload request from Mimic Identify page that will be used by `serverHandler`. It is written on JavaScript.

`identify` router contains `extractAndConvert`, `createMelFilterbank`, `uploadSpeech`, `identifySpeech`, and `router`. `router` is used to check whether the request is from Mimic Identify page or not. If yes, it runs `uploadSpeech` or `identifySpeech` depends to matched request. If no, it returns nothing. `uploadSpeech` is used to upload file from the request same like `collect` router `uploadCollect`. The different are, `uploadSpeech` upload to the speech directory and returns the URL and upload path as response.

`identifySpeech` is used to identify the recorded file from request. First, it loads latest inserted trained model from MongoDB `models` collection. Then, it runs `extractAndConvert` alongside with `createMelFilterbank`, that is used to extract the file and convert to model input same like `extractWav` and `nextBatch` combined, then feed it to model. Error connection or found model will return the information as response. Unsatisfied identification or results below 0.75 (75%) from identification also will return information as response. If none of those is occurred, which means model identify the recorded file with high accuracy, will update the MongoDB `speechDatas` collection based on its speech ID from the request and identified syllable. Then it returns the information as response.

```

148 // identify the speech and process data from it.
149 const prediction = tfModel.predict(data).dataSync();
150 let predictionLabel = 0;
151 for (i = 0; i < prediction.length; i++) {
152   if (prediction[predictionLabel] <= prediction[i]) predictionLabel = i;
153 }
154 const label = labels[predictionLabel]
155 const labelData = prediction[predictionLabel]
156
157 // return if result unsatisfied, below 75%.
158 if (labelData < 0.75 || label === 'unknown') {
159   status = 'No syllables matched.';
160   console.log('Status:', status);
161
162   resolve(JSON.stringify({ status: status }));
163 } else {
164   // find if 'name' is already registered in MongoDB or not.
165   try {
166     model.speechDatas.db = await connection.connect();
167     resultDB = await model.speechDatas.findOne({ name: name }).select('syllables _id').exec();
168
169     // create the document if not found, update if found before update to MongoDB.
170     let updateData = {};
171     if (resultDB === null) {
172       updateData.name = name;
173       updateData.syllables = {};
174       updateData.syllables[label] = filePath
175     }
176     else {
177       updateData = resultDB;
178       updateData.syllables[label] = filePath
179     }
180     await model.speechDatas.updateOne({ name: name }, updateData, { upsert: true });
181
182     await connection.disconnect();
183   } catch (err) { // return if connection error is occurred.
184     status = err.errmsg;
185     console.log('Status:', status);
186
187     resolve(JSON.stringify({ status: status }));
188   }
189
190   status = 'Matched syllable ' + label + ' (' + (labelData.toFixed(2) / 1 * 100) + '%)! syllable registered to ' + name + '.';
191   console.log('Status:', status);
192
193   // return success identify speech information.
194   resolve(JSON.stringify({ status: status }));
195 }
196 });
197 });
198 }

```

Figure 5.20 Some part of Server identify router identifySpeech code.

5.2.4.3 generate Router

generate router is used to handle upload request from Mimic Generate page that will be used by **serverHandler**. It is written on JavaScript.

generate router contains **loadSpeech**, **generateSpeech**, and **router**. **router** is used to check whether the request is from Mimic Generate page or not. If yes, it runs **loadSpeech** or **generateSpeech** depends to matched request. If no, it returns nothing. **loadSpeech** is used to load all registered speech ID from MongoDB **speechDatas** collection. If error connection or no speech ID is found it return error message as response. If not, it returns the load result as response.

`generateSpeech` is used to generate speech based on text from the request. First, it loads registered syllables from MongoDB `speechDatas` collection based on speech ID from the request. Error connection will return error message as response. Then, the text is extracted by check to loaded syllable one by one. If unmatched is found, it returns error as response. If all matched, the extract result is decoded and combined to 1 audio file. the speech data corresponding to extract result is combined to 1 audio with node-wav package, encode and decode [32]. The audio file is saved into generate directory. It converts its file path location to URL. It returns the URL as response.

```

75 // extract the 'words'.
76 const extractWord = [];
77 for (i = 0; i < words.length; i++) {
78   if (words[i] === ' ') { // check if it is space.
79     extractWord.push(' ');
80   } else if (1 + 3 <= words.length && syllables.includes(words.substring(i, i + 3))) { // check if it the next 3 char is in 'syllables'.
81     extractWord.push(words.substring(i, i + 3));
82     i = i + 2;
83   } else if (1 + 2 <= words.length && syllables.includes(words.substring(i, i + 2))) { // check if it the next 2 char is in 'syllables'.
84     extractWord.push(words.substring(i, i + 2));
85     i = i + 1;
86   } else if (syllables.includes(words.substring(i, i + 1))) { // check if it the next char is in 'syllables'.
87     extractWord.push(words.substring(i, i + 1));
88   } else { // return if unregistered syllable is found.
89     error = words[i] + ' is not found on registered from the speech data. ' +
90       'Registered ' + name + ' syllables : ' + syllables;
91     console.log('Error:', error);
92   }
93   resolve(JSON.stringify({ fileURL: fileURL, error: error }));
94 }
95 }
96
97 // combine each 'extractWord' into 1 'channelData'.
98 const sampleRate = 16000;
99 const channelData = [new Float32Array(0)];
100 // iterate each 'extractWord'.
101 for (i = 0; i < extractWord.length; i++) {
102   const prevSample = channelData[0];
103   const offset = channelData[0].length;
104
105   let nextSample;
106   if (extractWord[i] === ' ') { // if space it fill the 'nextSample' with 0 'sampleRate' times.
107     nextSample = new Float32Array(sampleRate).map(() => 0);
108   } else { // else it fill from the decode result based on 'resultDB' and corresponding 'extractWord'.
109     buffer = fs.readFileSync(resultDB.syllables[extractWord[i]]);
110     nextSample = wav.decode(buffer).channelData[0].slice(0, sampleRate);
111   }
112
113   // arrange the sample and redefined the 'channelData'.
114   const sample = new Float32Array(sampleRate + offset);
115   sample.set(prevSample);
116   sample.set(nextSample, offset);
117   channelData[0] = sample;
118 }

```

Figure 5.21 Some part of Server genearte router `generateSpeech` code.

5.2.4.4 *serverHandler*

`serverHandler` is used to define server listener, `collect`, `identify`, `generate` router and file handler, that will be used by `createServer`. It is written on JavaScript.

`serverHandler` contains `fileHandler`. It first will import `collect`, `identify`, and `generate` router to check whether the request is for them or not. If yes, it runs to corresponding router depends to matched request. As it returns response it also returns 200 that means the request is successful [37]. If no, it run `fileHandler`. `fileHandler` is used to check whether the corresponding URL has file in the directory. If the file doesn't exist it returns 404, that means the requested resource could not be found [37], to the browser. If the file does exist but cannot be read or displayed, it returns 500, that means unexpected condition was encountered and no more specific message is suitable [37], to the browser. And if the file does exist and can be read or displayed, it will return the binary so that the browser can load and display alongside with 200.

```

10  /**
11  * `serverHandler` handle all request to the server each response corresponding to each request.
12  * There are 3 type main router `collect`, `identify`, `generate` to handle any request corresponding to them.
13  * When the request match it return 200 alongside with the response corresponding to the router.
14  * When the request doesn't match any of those, it check if the file url as `filename` is existed in working
15  * directory or not. When the `filename` not found it return 404 Not Found. When found it read the `file` and return it with 200
16  * so that it can be displayed by the browser. It return 500 if error occurred when reading the `file`.
17  */
18  async function serverHandler(request, response) {
19    const url = url.parse(request.url).pathname;
20    const filename = path.join(process.cwd(), url);
21
22    const collect = await require('./router/collect')(address, port, filename, request);
23    if (typeof collect !== 'undefined') {
24      response.writeHead(200);
25      response.write(collect);
26      response.end();
27      return;
28    }
29
30    const identify = await require('./router/identify')(address, port, filename, request);
31    if (typeof identify !== 'undefined') {
32      response.writeHead(200);
33      response.write(identify);
34      response.end();
35      return;
36    }
37
38    const generate = await require('./router/generate')(address, port, filename, request);
39    if (typeof generate !== 'undefined') {
40      response.writeHead(200);
41      response.write(generate);
42      response.end();
43      return;
44    }
45
46    fs.exists(filename, function (exists) {
47      if (!exists) {
48        response.writeHead(404);
49        response.write('404 Not Found: ' + filename + '\n');
50        response.end();
51        return;
52      }
53
54      fs.readFile(filename, 'binary', function (err, file) {
55        if (err) {
56          response.writeHead(500);
57          response.write(err + '\n');
58          response.end();
59          return;
60        }
61
62        response.writeHead(200);
63        response.write(file, 'binary');
64        response.end();
65      });
66    });
67  }

```

Figure 5.22 Server serverHandler code.

5.2.4.5 createServer

`createServer` is used to create http server in the computer that use `serverHandler` as request listener. It is written on JavaScript.

`createServer` contains `createServer` and `listen`. `createServer` is used to create the server and followed by `listen` that is used to listening for connection that comes to the server. It listens on defined host and port. When the server established, it prints information in console.

```

71 // create the server and listen with `serverHandler`.
72 app = server.createServer(serverHandler);
73 app = app.listen(port, address, function () {
74   // print information regarding to the app.
75   console.log('Could take time to load tensorflow before the page could be open. ');
76   console.log('Collect: ', 'http://' + address + ':' + port + '/app/collect/home.html');
77   console.log('Mimic: ', 'http://' + address + ':' + port + '/app/mimic/home.html');
78   console.log('Readme: ', 'http://' + address + ':' + port + '/readme.md');
79 });

```

Figure 5.23 Server createServer code.

5.2.5 Database Code

Database code is used to connection to MongoDB and collection model scheme of the database on MongoDB. It consists of connection and model.

5.2.5.1 connection

`connection` is used to handle the connection with MongoDB. It is written on JavaScript.

`connection` contains `connect` and `disconnect` methods. `connect` is used to establish the connection to MongoDB `mimic_speech` database on localhost. `disconnect` is used to close the established connection with MongoDB.

```

1  const mongoose = require('mongoose');
2
3  let connection;
4
5  /**
6   * `connect` establish connection to mongodb mimic_speech database on localhost.
7   *
8   * Established connection is saved in `connection`.
9   */
10 async function connect() {
11   connection = await mongoose.connect('mongodb://localhost/mimic_speech', { useNewUrlParser: true });
12   return connection;
13 };
14
15 /**
16 * `disconnect` close established `connection` to mongodb.
17 */
18 async function disconnect() {
19   await connection.disconnect();
20 }
21
22 // export `connect` and `disconnect` functions.
23 module.exports = {
24   connect,
25   disconnect
26 };

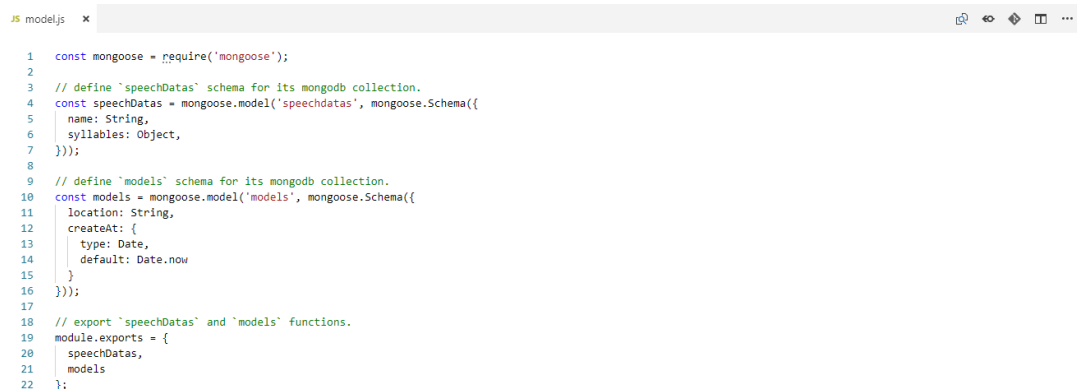
```

Figure 5.24 Database connection code.

5.2.5.2 model

`model` is used to create the collection model scheme of the database on MongoDB. It is written on JavaScript.

`model` contains `speechDatas` and `models` methods. `speechDatas` is used to define scheme with `name` as string and `syllables` as object. `speechDatas` scheme model is used for store the speech data. `name` is speech ID and `syllables` is the registered syllables by the corresponding speech ID. `models` is used to define scheme with `location` as string and `createAt` as date with current date being default value when create or update collection when `createAt` is not defined. `models` scheme model is used for store the machine learning model. `location` is the model location path in directory and `createAt` is the date when the model is created or saved to MongoDB.



```

1  const mongoose = require('mongoose');
2
3  // define 'speechDatas' schema for its mongodb collection.
4  const speechDatas = mongoose.model('speechdatas', mongoose.Schema({
5    name: String,
6    syllables: Object,
7  }));
8
9  // define 'models' schema for its mongodb collection.
10 const models = mongoose.model('models', mongoose.Schema({
11   location: String,
12   createAt: {
13     type: Date,
14     default: Date.now
15   }
16 }));
17
18 // export 'speechDatas' and 'models' functions.
19 module.exports = {
20   speechDatas,
21   models
22 };

```

Figure 5.25 Database model code.

CHAPTER VI

SYSTEM TESTING

6.1 Testing Environment

The testing environment specify the environment during testing. The environment specification are as follows:

1. Windows 10.
2. Chrome browser.

There is additional environment only on the identify process. Male user that the records is trained by the application is called Tester 1. Female user that the records is trained by the application is called Tester 2. Male user that the record hasn't trained by the application called Tester 3. Female user that the record hasn't trained by the application called Tester 4. Every tester is test in each the following environment:

1. Noisy background (Loud music or people chit-chat).
2. Semi noisy background (Rain noise or sound from the other rooms).
3. Not noisy background.

6.2 Testing Scenario

The testing scenario conducted by evaluating all the features with a set of cases or scenario in the application based on its functionality requirement and defined testing environment.

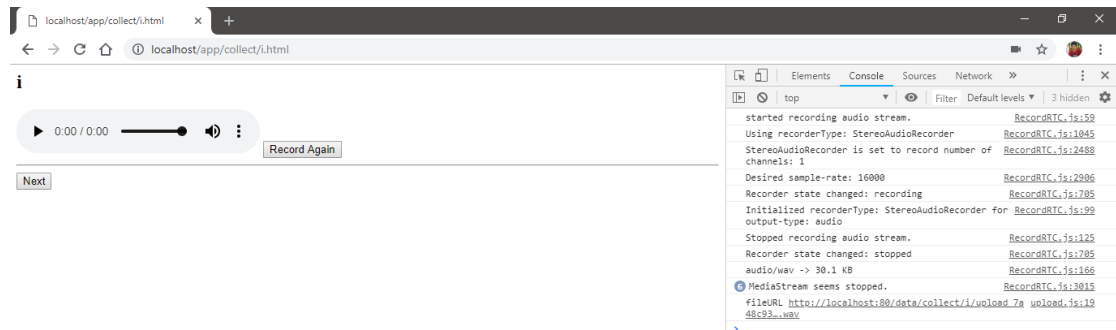
The testing scenarios of the application is categorized based on Collect application, Train application, and Mimic application.

6.2.1 Collect Application

The Collect application has 3 subcategorized scenarios, Collect server, Home page and Syllables page. The Collect server has scenarios to allow user to access Home page, Syllables page in the browser and process the upload record request. The Home page has scenarios to allow user to direct to Syllables page to start the Collect application and direct to Mimic application Home page to change to Mimic application. Syllables page has scenarios to allow user to upload the record to the server and direct to the next Syllables page or direct back to Home page.

Table 6.1 Collect application scenarios.

No	Scenario	Expected Result	Result
1	Access Home page	Home page is shown	As expected
2	Access Syllables page	Syllables page is shown	As expected
3	Process upload record request	Printed process results information on the console	As expected
4	Direct to Syllables page	Directed to Syllables page	As expected
5	Direct to Mimic application Home page	Directed to Mimic application Home page	As expected
6	Upload the record	Audio element is shown with the user record	As expected
7	Direct to the next Syllables page or direct back to Home page	Directed to the next Syllables page or Directed back to Home Page	As expected



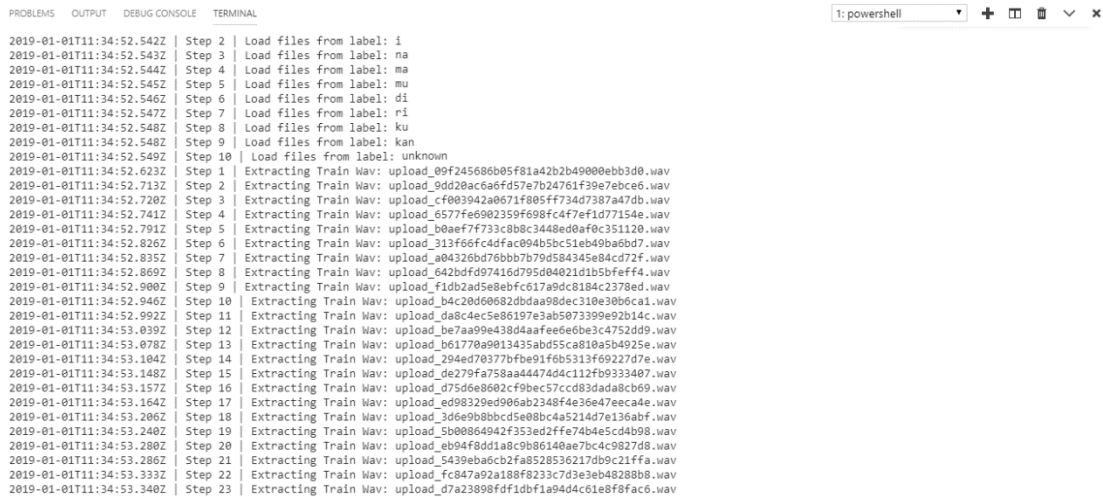
Figures 6.1 Screenshot of process upload record request scenario from Collect application.

6.2.2 Train Application

The Train application has scenario to allows user to train model with collected data. When train is run, it loads and splits collected data, extracts the data, gets the corresponding batch data, trains the TensorFlow model to fit the batch train data, tests the TensorFlow model from test data, and saves the TensorFlow model to database.

Table 6.2 Train application scenarios.

No	Scenario	Expected Result	Result
1	Load and split collected data	Printed information on the console	As expected
2	Extract the data	Printed information on the console	As expected
3	Get corresponding batch data	Printed information on the console	As expected
4	Train the TensorFlow model to fit batch train data	Printed information on the console	As expected
5	Test the TensorFlow model from test data	Printed information on the console	As expected
6	Save the TensorFlow model to database	Recorded document in mimic_speech database models collection	As expected



Figures 6.2 Screenshot of load and split collected data and extract the data scenarios from Train application.

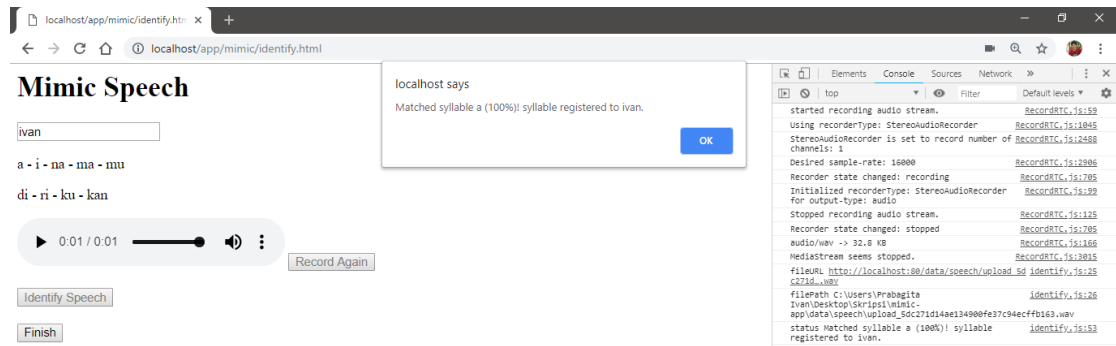
6.2.3 Mimic Application

The Mimic application has 4 subcategorized scenarios, Mimic server, Home page, Identify page, and Generate page. The Mimic server has scenarios to allow user to access Home page, Identify page, and Generate page in the browser and process the upload record and identify speech on Identify request and load speech data and generate speech on Generate request. The Home page has scenarios to allow user to direct to Identify page to start the identify speech application, direct to Generate page to start the generate speech application, and direct to Collect application Home page to change to Collect application. The Identify page has scenarios to allow user to upload the record to the server, send form request for identify speech to the server, and direct back to Home page. The Generate page has scenarios to allow user to load speech data from

the server, send form request for generate speech to the server, and direct back to Home page.

Table 6.3 Mimic application scenarios.

No	Scenario	Expected Result	Result
1	Access Home page	Home page is shown	As expected
2	Access Identify page	Identify page is shown	As expected
3	Access Generate page	Generate page is shown	As expected
3	Process upload record on Identify request	Printed process results information on the console	As expected
4	Process identify speech on Identify request	Printed process results information on the console	As expected
5	Process load speech data on Generate request	Printed process results information on the console	As expected
6	Process generate speech on Generate request	Printed process results information on the console	As expected
7	Direct to Identify page	Directed to Identify page	As expected
8	Direct to Generate page	Directed to Generate page	As expected
9	Direct to Collect application Home page	Directed to Collect application Home page	As expected
10	Upload the record	Audio element is shown with the user record	As expected
11	Send form for identify speech	Alert information despite success or error in the process	As expected
12	Direct back to Home page from Identify page	Directed back to Home Page	As expected
13	Load speech data	Datalist element store the speech data or alert if no speech data is found	As expected
14	Send form for generate speech	Audio element is shown with the generated speech or alert if error is occurred	As expected
15	Direct back to Home page from Generate page	Directed back to Home Page	As expected



Figures 6.3 Screenshot of process identify speech on Identify request scenario from Mimic application.

The dataset during the speech recognition testing on identify process is 10000 male and female speech data, each 500 on each syllable, on not noisy background and each 500 unknown sound. Corrected result shows from the more than 75% of model accuracy. The table also fill with accuracy with the syllable result along with it. Random or unknown condition is tested with silent condition, o, and mi syllables. The following tests table results below and figures that shows some screenshot of identify process results:

Table 6.4 Tester 1 results on noisy background.

No	Spoken Syllable	Noisy Background			Correct Result
		1	2	3	
1	a	52 (a)	100 (a)	100 (unknown)	1/3
2	i	62 (na)	85 (ri)	96 (ma)	0/3
3	na	100 (unknown)	86 (kan)	100 (unknown)	0/3
4	ma	100 (a)	84 (unknown)	100 (a)	0/3
5	mu	99 (kan)	71 (ku)	88 (unknown)	0/3

6	di	59 (<i>mu</i>)	100 (<i>ri</i>)	97 (<i>ri</i>)	0/3
7	ri	50 (<i>na</i>)	100 (<i>ri</i>)	92 (<i>a</i>)	1/3
8	ku	100 (<i>ku</i>)	85 (<i>a</i>)	100 (<i>kan</i>)	1/3
9	kan	72 (<i>unknown</i>)	61 (<i>kan</i>)	79 (<i>kan</i>)	3/3
10	Unknown 1 (<i>silent</i>)	99 (<i>unknown</i>)	100 (<i>a</i>)	99 (<i>unknown</i>)	2/3
11	Unknown 2 (<i>o</i>)	100 (<i>na</i>)	100 (<i>a</i>)	100 (<i>ku</i>)	0/3
12	Unknown 3 (<i>mi</i>)	100 (<i>a</i>)	51 (<i>kan</i>)	96 (<i>ma</i>)	1/3

Table 6.5 Tester 1 results on semi noisy background.

No	Spoken Syllable	Semi Noisy Background			Correct Result
		1	2	3	
1	a	100 (<i>a</i>)	100 (<i>a</i>)	100 (<i>a</i>)	3/3
2	i	100 (<i>i</i>)	36 (<i>ri</i>)	100 (<i>i</i>)	2/3
3	na	97 (<i>mu</i>)	48 (<i>ma</i>)	99 (<i>na</i>)	1/3
4	ma	49 (<i>i</i>)	98 (<i>ri</i>)	79 (<i>mu</i>)	0/3
5	mu	55 (<i>ri</i>)	99 (<i>ku</i>)	50 (<i>ri</i>)	0/3
6	di	57 (<i>i</i>)	100 (<i>di</i>)	100 (<i>i</i>)	1/3
7	ri	100 (<i>ri</i>)	75 (<i>ri</i>)	100 (<i>ri</i>)	3/3
8	ku	92 (<i>ku</i>)	68 (<i>ku</i>)	91 (<i>ku</i>)	2/3
9	kan	100 (<i>kan</i>)	94 (<i>na</i>)	100 (<i>kan</i>)	2/3
10	Unknown 1 (<i>silent</i>)	100 (<i>a</i>)	99 (<i>unknown</i>)	100 (<i>ma</i>)	2/3
11	Unknown 2 (<i>o</i>)	100 (<i>ku</i>)	89 (<i>ku</i>)	72 (<i>ku</i>)	1/3
12	Unknown 3 (<i>mi</i>)	100 (<i>ri</i>)	94 (<i>ri</i>)	100 (<i>ri</i>)	0/3

Table 6.6 Tester 1 results on not noisy background.

No	Spoken Syllable	Not Noisy Background			Correct Result
		1	2	3	
1	a	100 (a)	100 (a)	100 (a)	3/3
2	i	94 (i)	48 (kan)	94 (i)	2/3
3	na	80 (na)	99 (na)	100 (na)	3/3
4	ma	96 (di)	90 (i)	57 (di)	0/3
5	mu	100 (i)	86 (ku)	95 (i)	0/3
6	di	99 (ri)	100 (i)	80 (ri)	0/3
7	ri	100 (ri)	96 (ri)	91 (ri)	3/3
8	ku	85 (ku)	96 (ku)	100 (ku)	3/3
9	kan	92 (kan)	100 (kan)	100 (kan)	3/3
10	Unknown 1 (silent)	98 (unknown)	98 (unknown)	98 (unknown)	3/3
11	Unknown 2 (o)	100 (ku)	98 (ku)	65 (ku)	1/3
12	Unknown 3 (mi)	54 (mu)	100 (ri)	67 (mu)	2/3

Table 6.7 Tester 2 results on noisy background.

No	Spoken Syllable	Noisy Background			Correct Result
		1	2	3	
1	a	99 (unknown)	99 (a)	99 (a)	2/3
2	i	82 (unknown)	98 (ma)	99 (ri)	0/3
3	na	52 (ri)	99 (ma)	61 (ma)	0/3
4	ma	50 (unknown)	37 (unknown)	95 (ri)	0/3

5	mu	99 (unknown)	52 (di)	99 (unknown)	0/3
6	di	99 (i)	99 (unknown)	99 (unknown)	0/3
7	ri	86 (i)	20 (kan)	57 (di)	0/3
8	ku	99 (ku)	68 (kan)	90 (unknown)	1/3
9	kan	84 (kan)	99 (kan)	78 (a)	2/3
10	Unknown 1 (silent)	100 (unknown)	100 (unknown)	100 (unknown)	3/3
11	Unknown 2 (o)	99 (ma)	99 (ku)	99 (ku)	0/3
12	Unknown 3 (mi)	36 (di)	96 (mu)	99 (di)	1/3

Table 6.8 Tester 2 results on semi noisy background.

No	Spoken Syllable	Semi Noisy Background			Correct Result
		1	2	3	
1	a	100 (a)	100 (unknown)	99 (a)	2/3
2	i	92 (ri)	97 (unknown)	96 (ri)	0/3
3	na	83 (ma)	62 (unknown)	75 (kan)	0/3
4	ma	87 (unknown)	64 (ma)	90 (na)	2/3
5	mu	76 (ma)	78 (ku)	66 (di)	0/3
6	di	58 (mu)	48 (mu)	30 (kan)	0/3
7	ri	99 (kan)	89 (kan)	99 (ri)	1/3
8	ku	99 (unknown)	99 (ku)	88 (unknown)	1/3
9	kan	99 (kan)	65 (kan)	85 (kan)	2/3
10	Unknown 1 (silent)	100 (unknown)	79 (a)	99 (ri)	1/3
11	Unknown 2 (o)	99 (a)	82 (ku)	99 (na)	0/3

12	Unknown 3 (<i>mi</i>)	89 (<i>kan</i>)	35 (<i>ku</i>)	96 (<i>ri</i>)	1/3
----	----------------------------	----------------------	---------------------	---------------------	-----

Table 6.9 Tester 2 results on not noisy background.

No	Spoken Syllable	Not Noisy Background			Correct Result
		1	2	3	
1	a	88 (<i>a</i>)	99 (<i>a</i>)	99 (<i>a</i>)	3/3
2	i	99 (<i>i</i>)	99 (<i>i</i>)	52 (<i>i</i>)	2/3
3	na	97 (<i>a</i>)	54 (<i>kan</i>)	99 (<i>a</i>)	0/3
4	ma	99 (<i>na</i>)	99 (<i>na</i>)	98 (<i>na</i>)	0/3
5	mu	81 (<i>i</i>)	95 (<i>i</i>)	44 (<i>i</i>)	0/3
6	di	99 (<i>i</i>)	36 (<i>i</i>)	96 (<i>i</i>)	0/3
7	ri	47 (<i>ri</i>)	32 (<i>unknown</i>)	48 (<i>i</i>)	0/3
8	ku	98 (<i>ku</i>)	67 (<i>kan</i>)	99 (<i>ku</i>)	2/3
9	kan	84 (<i>na</i>)	85 (<i>na</i>)	87 (<i>na</i>)	0/3
10	Unknown 1 (<i>silent</i>)	99 (<i>unknown</i>)	99 (<i>unknown</i>)	100 (<i>unknown</i>)	3/3
11	Unknown 2 (<i>o</i>)	100 (<i>ku</i>)	99 (<i>ku</i>)	95 (<i>ku</i>)	0/3
12	Unknown 3 (<i>mi</i>)	67 (<i>ri</i>)	78 (<i>di</i>)	77 (<i>i</i>)	1/3

Table 6.10 Tester 3 results on noisy background.

No	Spoken Syllable	Noisy Background			Correct Result
		1	2	3	
1	a	100 (<i>a</i>)	99 (<i>a</i>)	100 (<i>a</i>)	3/3
2	i	71 (<i>ma</i>)	99 (<i>ri</i>)	99 (<i>ri</i>)	0/3
3	na	70 (<i>ku</i>)	99 (<i>a</i>)	57 (<i>unknown</i>)	0/3

4	ma	99 (a)	100 (a)	100 (a)	0/3
5	mu	74 (mu)	96 (kan)	74 (mu)	0/3
6	di	99 (ri)	96 (ri)	89 (ri)	0/3
7	ri	100 (unknown)	90 (na)	86 (a)	0/3
8	ku	98 (kan)	64 (mu)	99 (a)	0/3
9	kan	99 (na)	100 (kan)	98 (kan)	2/3
10	Unknown 1 (silent)	99 (a)	99 (a)	100 (a)	0/3
11	Unknown 2 (o)	92 (na)	84 (na)	61 (mu)	1/3
12	Unknown 3 (mi)	64 (kan)	53 (na)	99 (ri)	2/3

Table 6.11 Tester 3 results on semi noisy background.

No	Spoken Syllable	Semi Noisy Background			Correct Result
		1	2	3	
1	a	100 (a)	99 (a)	99 (a)	3/3
2	i	99 (ri)	90 (di)	92 (di)	0/3
3	na	100 (kan)	99 (kna)	92 (ma)	0/3
4	ma	99 (a)	100 (kan)	100 (kan)	0/3
5	mu	99 (mu)	99 (mu)	65 (ku)	2/3
6	di	99 (ri)	100 (ri)	99 (ri)	0/3
7	ri	95 (kan)	76 (i)	78 (di)	0/3
8	ku	99 (a)	96 (a)	100 (a)	0/3
9	kan	99 (a)	96 (a)	99 (a)	0/3
10	Unknown 1 (silent)	99 (ri)	73 (di)	60 (unknown)	2/3

11	Unknown 2 (o)	100 (a)	99 (ku)	100 (a)	0/3
12	Unknown 3 (mi)	99 (na)	99 (ri)	99 (i)	0/3

Table 6.12 Tester 3 results on not noisy background.

No	Spoken Syllable	Not Noisy Background			Correct Result
		1	2	3	
1	a	100 (a)	100 (a)	100 (a)	3/3
2	i	92 (ri)	95 (ri)	41 (ku)	0/3
3	na	99 (na)	74 (ku)	80 (a)	1/3
4	ma	59 (a)	84 (ku)	48 (kan)	0/3
5	mu	99 (mu)	99 (ri)	99 (ri)	1/3
6	di	100 (ri)	99 (i)	99 (i)	0/3
7	ri	99 (ri)	96 (ri)	94 (i)	2/3
8	ku	73 (di)	100 (mu)	99 (mu)	0/3
9	kan	100 (kan)	99 (kan)	96 (kan)	3/3
10	Unknown 1 (silent)	98 (unknown)	98 (unknown)	98 (unknown)	3/3
11	Unknown 2 (o)	99 (ku)	68 (mu)	100 (ku)	1/3
12	Unknown 3 (mi)	99 (ri)	93 (i)	100 (ri)	0/3

Table 6.13 Tester 4 results on noisy background.

No	Spoken Syllable	Noisy Background			Correct Result
		1	2	3	
1	a	100 (unknown)	99 (unknown)	94 (ma)	0/3
2	i	97 (unknown)	99 (ri)	99 (ri)	0/3

3	na	100 (na)	99 (ri)	99 (ma)	1/3
4	ma	93 (na)	99 (ma)	100 (na)	1/3
5	mu	55 (ri)	99 (unknown)	43 (unknown)	0/3
6	di	99 (ri)	54 (i)	99 (ma)	0/3
7	ri	97 (ri)	74 (ri)	100 (ri)	2/3
8	ku	68 (ma)	92 (ku)	52 (52)	1/3
9	kan	48 (ku)	22 (ku)	99 (a)	0/3
10	Unknown 1 (silent)	100 (unknown)	100 (unknown)	100 (unknown)	3/3
11	Unknown 2 (o)	100 (a)	100 (a)	100 (a)	0/3
12	Unknown 3 (mi)	55 (mu)	99 (ri)	94 (i)	1/3

Table 6.14 Tester 4 results on semi noisy background.

No	Spoken Syllable	Semi Noisy Background			Correct Result
		1	2	3	
1	a	73 (a)	91 (unknown)	99 (unknown)	0/3
2	i	81 (ri)	99 (i)	100 (ri)	1/3
3	na	100 (ma)	99 (unknown)	99 (unknown)	0/3
4	ma	99 (ma)	99 (na)	78 (ma)	2/3
5	mu	81 (unknown)	99 (unknown)	99 (unknown)	0/3
6	di	100 (ri)	99 (i)	99 (i)	0/3
7	ri	85 (ri)	99 (ri)	98 (ri)	3/3
8	ku	96 (ku)	89 (ku)	99 (a)	2/3
9	kan	100 (a)	99 (a)	64 (ma)	0/3

10	Unknown 1 (<i>silent</i>)	99 (<i>unknown</i>)	99 (<i>ri</i>)	100 (<i>unknown</i>)	2/3
11	Unknown 2 (<i>o</i>)	99 (<i>a</i>)	100 (<i>a</i>)	99 (<i>a</i>)	0/3
12	Unknown 3 (<i>mi</i>)	43 (<i>a</i>)	59 (<i>ri</i>)	99 (<i>unknown</i>)	3/3

Table 6.15 Tester 4 results on not noisy background.

No	Spoken Syllable	Not Noisy Background			Correct Result
		1	2	3	
1	a	99 (<i>unknown</i>)	75 (<i>a</i>)	100 (<i>a</i>)	2/3
2	i	88 (<i>i</i>)	99 (<i>i</i>)	99 (<i>ri</i>)	2/3
3	na	99 (<i>na</i>)	99 (<i>ma</i>)	99 (<i>ma</i>)	1/3
4	ma	55 (<i>ma</i>)	72 (<i>kan</i>)	99 (<i>na</i>)	0/3
5	mu	99 (<i>unknown</i>)	94 (<i>unknown</i>)	28 (<i>i</i>)	0/3
6	di	89 (<i>i</i>)	99 (<i>ri</i>)	99 (<i>ri</i>)	0/3
7	ri	99 (<i>ri</i>)	100 (<i>ri</i>)	99 (<i>ri</i>)	3/3
8	ku	39 (<i>kan</i>)	99 (<i>ku</i>)	58 (<i>mu</i>)	1/3
9	kan	100 (<i>a</i>)	99 (<i>a</i>)	100 (<i>a</i>)	3/3
10	Unknown 1 (<i>silent</i>)	40 (<i>unknown</i>)	24 (<i>unknown</i>)	60 (<i>unknown</i>)	3/3
11	Unknown 2 (<i>o</i>)	100 (<i>a</i>)	99 (<i>a</i>)	100 (<i>a</i>)	0/3
12	Unknown 3 (<i>mi</i>)	60 (<i>ri</i>)	100 (<i>i</i>)	99 (<i>ri</i>)	1/3

```

PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL
1: node

Windows PowerShell
Copyright (C) Microsoft Corporation. All rights reserved.

PS C:\Users\Prabagita Ivan\Desktop\Skrripsi\mimic-app> npm run start

> mimic-speech@1.0.0 start C:\Users\Prabagita Ivan\Desktop\Skrripsi\mimic-app
> node server.js

Could take time to load tensorflow before the page could be open.
Collect: http://localhost:80/app/collect/home.html
Mimic: http://localhost:80/app/mimic/home.html
Readme: http://localhost:80/readme.md
2019-01-16 02:36:18.723557: I tensorflow/core/platform/cpu_feature_guard.cc:141] Your CPU support
ts instructions that this TensorFlow binary was not compiled to use: AVX2
fileURL: http://localhost:80/data/speech/upload_6b207beb48426c017dec86393ffe4d12.wav
filePath: C:\Users\Prabagita Ivan\Desktop\Skrripsi\mimic-app\data\speech\upload_6b207beb48426c01
7dec86393ffe4d12.wav
Status: Matched syllable a (100%)! syllable registered to ivan.
fileURL: http://localhost:80/data/speech/upload_7e01d1a49bbd693e2d58409f8e08f411.wav
filePath: C:\Users\Prabagita Ivan\Desktop\Skrripsi\mimic-app\data\speech\upload_7e01d1a49bbd693e
2d58409f8e08f411.wav
Status: Matched syllable a (100%)! syllable registered to ivan.
fileURL: http://localhost:80/data/speech/upload_8da26de53011ee49b56309fae5d7ae06.wav
filePath: C:\Users\Prabagita Ivan\Desktop\Skrripsi\mimic-app\data\speech\upload_8da26de53011ee49
b56309fae5d7ae06.wav
Status: Matched syllable a (100%)! syllable registered to ivan.
fileURL: http://localhost:80/data/speech/upload_4be8b9107c4be0ab7df734afb2d3a8b0.wav
filePath: C:\Users\Prabagita Ivan\Desktop\Skrripsi\mimic-app\data\speech\upload_4be8b9107c4be0ab

```

Figures 6.4 Screenshot of Tester 1 with a and i syllables on not noisy background.

Although noisy and semi background on every tester not show a good result, it still can predict about 2 or 3 correct spoken syllables with high accuracy. Not noisy background isn't guaranteed all spoken syllables are correct even on tester 1 and 2. But, the result is better than noisy and semi background. This is because all the training data is recorded on not noisy background. Also, noise removal or reduction is not applied when extraction process is done before training begin.

Tester 1 and 2 at most moment have good result than tester 3 and 4. But, at some moment tester 3 and 4 have better result than tester 1 and 2. The most good result on tester 1 and 2 is due to the training data is all contain tester 1 and 2. When tester 3 and tester 4 have better result it can be cause by the background condition or the microphone ability to record the speech.

Syllable ma, mu, di, unknown o, and unknown mi have bad result on most time compare to others. The unknown o and mi are caused by the unknown training data is random and mostly background noise instead of focusing o and mi. The machine

learning model can't predict syllable ma, mu, and di well. Most times they have low accuracy but correct prediction or they predict the relative syllable, in example ri or i is the result on di. This can be improved by adding more the training data as the training data is still relatively small. An optimum machine learning model can also improve the result on them and also other syllables as well.

CHAPTER VII

CONCLUSIONS AND FUTURE WORK

7.1 Conclusion

The following list sums up that the application is achieved based on this research objective:

1. This application enables to recognize speech in Bahasa Indonesia speech from record audio.
2. This application enables to generate speech in Bahasa Indonesia speech from text.
3. This application enables to mimic speech through the website.
4. This application enables to collect speech data through the website.
5. This application enables to train model with collected speech data through the console.

7.2 Future Work

The following suggestion for further development and improvements of the research or application:

1. User Interface

Improvement on UI will always help the user experience. With some colourful theme, clear button or inputs, the application will comfortable to be used.

2. Speech Recognition

Improvement on machine learning model can be made. When there is no right or wrong in modelling the machine learning model, there is always optimal model to get the best prediction and accuracy. A research to find the optimal model to be compare with are big improvement in the application or even in speech recognition itself for mimic speech.

3. Speech Synthesis

Improvement on Speech Synthesis is when generating the speech. By removing some of silence or unused part of the speech and also reducing background will make generated speech more fluently and good to hear. A research in determining Bahasa Indonesia phonemes can be a big improvement since the application use syllables as concatenative synthesis.

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