MOMENTOUS FRAGMENTED MEL FREQUENCY CEPSTRAL COEFFICIENT AND DISTANCE-BASED FOR HUMAN GUIDED COMPUTERIZED AL-FATIHAH RECITATION ASSESSMENT

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DEDICATION

This thesis is dedicated to my beloved father, my late mother and my family who have given infinite encouragement and prayers to the results of this thesis. Special thanks and love to my beloved wife and children who always give me space and encouragement to enhance my knowledge in the process of completing this PhD study. Thanks be to Allah who always gives help in solving all problems that arise and gives guidance in all things in the world, as well as matters related to the hereafter. May God always bless and always take care of us all.

Despite being digitally guided in the evolution of life, the honesty in worship remains inspired by purity of heart as a trigger engine. Indeed, the genuine of such voice of heart serve the basis of articulation, extraction, and classification of the Almighty words for truly guidance to the right path and for any difficulty in the presence of His Gracious.

(Biarpun dipandu secara digital dalam evolusi kehidupan, kejujuran dalam ibadah tetap terinspirasi oleh kesucian hati sebagai injin pencetus. Malahan, suara hati yang tulus itu menjadi asas artikulasi, pengekstrakan dan pengkelasan kata-kata Yang Maha kuasa untuk benar-benar memberi petunjuk ke jalan yang benar dan untuk sebarang kesulitan dalam kehadiran Yang Maha Pemurah.)

Noraimi Shafie, 2021

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ABSTRACT

The use of technological speech recognition systems with a variety of approaches and techniques has grown exponentially in a variety of human-machine interaction applications. The advanced methodology for Al-Quran recitation evaluation is obligatory; referring to the regularity of the reader in adhering to the rules of *Tajweed* which generally consists of the laws of *Makhraj* (articulation process), *Sifaat* (letter features or pronunciation), and *Harakaat* (length of pronunciation). The main focus of this undertaken research is on the work of digitally transforming the voice signals of Al-Quran recitation, with identification of recitation errors according to the *Tajweed* law as well as the ability to evaluate the recitation based on syllable pronunciation. In other words, the research adopts/involves a complete methodical and tactical approach, functioning as a computational machine that highlights scientific solutions in pre-processing work, feature extractor design, and threshold matching process on the assessment of the recitation of the Al-Quran. The methodology is, first and foremost, proposed to provide solutions to the general problem of unnecessary signal noise as well as other variations of speech signals. The results of this filtered signal are then followed by the challenge of investigating and selecting the appropriate digit Al-Quran Recitation Speech Signal (QRSS) syllable representation, feature extractor, Quranic Recitation Acoustic Model (QRAM), the threshold matching, and classification process. Technically, the properties of Formant Frequency and Mel Frequency Cepstral Coefficients (MFCC) used in this thesis, are those involving energy distribution in the time-frequency domain, with MFCC and Dynamic Time Warping (DTW), which had initially shown to be promising miniature features. As a result, an idea was successfully established; a structured experimental procedure was designed for enhanced momentous fragmentary MFCC-formants frequency that was broken down or fragmented into three bands that eventually served as miniature features of the QRSS in representing combined vowels and consonants. Each of the QRSS pronunciations is evaluated based on parameter estimation of Maximum Likelihood Estimation (MLE) and Minimum Path Cost (MPC) parameters. Both parameters are estimated from Gaussian Mix Model (GMM) and DTW model and used as non-phonetic transcription to obtain and test the genuineness of the designed factual salient features. Each syllable was also classified to confirm the accuracy of the MLE and MPC in representing the syllable signature using three types of classifiers which are Linear Discriminant (LD), Support Vector Machine (SVM), and K-Nearest Neighbor (KNN). KNN has shown high classification performance compared to LD and SVM. In the final stage, the threshold classification-based approach, which is technically considered as traditional *Talaqi*-like Al-Quran recitation approach was performed on 78 syllables of *Al-Fatihah* (Chapter 1) recited by 80 learners. This is done through the training and testing analysis using human-guided computerized assessment. The performance highlighted by the Intelligent Quranic Recitation Assistance (IQRA) system computing engine model for the MLEs of the low, middle, and high band were 87.27%, 86.86% and 86.33% respectively, with MPC performance of 90.34%. The overall results of the research study indicates that, for future work, a hyperparametric model can be used to process or estimate the threshold based on expert assessment automatically. Undoubtedly hyperparameter selection is usable for predicting model performance.

ABSTRAK

Penggunaan sistem teknologi pengecaman suara menggunakan pelbagai pendekatan dan teknik telah berkembang dengan pesat terutama dalam aplikasi interaksi manusia-mesin. Metodologi terkini dalam penilaian bacaan Al-Quran melibatkan manusia-mesin pada dasarnya merujuk kepada pematuhan bacaan mengikut peraturan Tajwid yang umumnya terdiri dari hukum Makhraj (proses artikulasi), Sifat (ciri huruf atau sebutan) dan Harakat (memanjangkan sebutan). Fokus utama penyelidikan ini ialah proses mengubah isyarat suara bacaan Al-Quran ke bentuk digital, mengenal pasti kesalahan bacaan berdasarkan hukum Tajwid dan juga kemampuan untuk menilai bacaan Al-Quran berdasarkan sebutan suku kata. Dengan kata lain, kajian ini mengguna pakai pendekatan metodologi dan taktikal yang lengkap sebagai mesin berkomputeran dengan mengetengahkan penyelesaian secara saintifik dalam pra-pemprosesan, rekabentuk pengekstrak ciri dan juga proses penilaian ambang digunakan bagi menilai bacaan Al-Quran. Metodologi utama yang disarankan ialah mengatasi isyarat yang tidak dikehendaki, serta variasi suara yang pelbagai, diikuti dengan cabaran meneliti dan memilih perwakilan bagi isyarat suara pembacaan Al-Quran (QRSS), pengekstrak ciri beserta model akustik bacaan Al-Quran, proses penentuan secara ambang dan juga klasifikasi. Secara teknikal, sifat frekuensi formant dan *Mel Frequency Cepstral Coefficients* (MFCC) telah dipilih dan digunakan dalam tesis ini yang melibatkan pengagihan tenaga dalam isyarat domain frekuensi-masa, dengan penggunaan MFCC serta terbitannya dan juga *Dynamic Time Warping* (DTW) telah menunjukan ciri miniatur yang boleh menjadi ciri-ciri unik kepada isyarat suara. Justeru itu, idea serta prosedur ekperimen dirancang bagi meningkatkan *Momentous Fragmentary MFCC-formants* dipecahkan atau dibahagikan kepada tiga jalur yang berfungsi sebagai ciri miniatur QRSS dalam mewakili gabungan vowel dan juga konsonan dalam sukukata. Setiap sebutan QRSS dinilai berdasarkan nilai parameter-parameter *Maximum Likelihood Estimation* (MLE) dan juga parameter *Minimum Path Cost* (MPC). Kedua-dua parameter tersebut diolah dan dianggarkan daripada Model Campuran Gaussion (GMM) dan DTW dan seterusnya digunakan sebagai transkripsi bukan fonetik bagi mendapat dan menguji ciri menonjol dalam suku kata. Setiap suku kata juga telah diklasifikasi bagi mengesahkan ketepatan MLE dan MPC dalam mewakili identiti corak suku kata menggunakan tiga jenis pengkelasan iaitu *Linear Discriminant* (LD), *Support Vector Machine* (SVM) dan *K-Nearest Neighbor* (KNN). KNN telah menunjukkan prestasi klasifikasi yang tinggi berbanding LD dan SVM. Pada peringkat akhir, secara teknikalnya kaedah klasifikasi secara ambang boleh dinyatakan sebagai penilaian bacaan Al-Quran secara *Talaqi* yang dilakukan pada 78 suku kata surah *Al- Fatihah* (Bab 1) dan dibacakan oleh 80 orang pelajar. Ini dilakukan melalui analisis latihan dan ujian menggunakan penilaian berkomputer berpandukan manusia. Model Mesin Pengkomputeran Bantuan Mengaji Al-Quran Pintar (IQRA) bagi MLE jalur rendah, tengah dan tinggi menunjukan prestasi masing-masing adalah 87.27%, 86.86% dan 86.33%, sementara MPC pula adalah 90.34%. Daripada hasil kajian, model hiperparameter dapat digunakan pada masa akan datang bagi memproses dan mendapatkan nilai ambang berdasarkan penilaian pakar secara automatik. Sememangnya pemilihan hiperparameter dapat digunakan untuk meramalkan prestasi model dengan lebih baik.

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LIST OF ABBREVIATIONS

BIC	-	Bayesian Information Criterion
DCT	-	Discrete Cosine Transform
DFT	-	Discrete Fourier Transform
DSP	-	Digital Speech Processing
DTW	-	Dynamic Time Warping
FA	-	False Acceptance
FAR	-	False Acceptance Rate
FMLLR	-	Feature-Space Maximum Likelihood Linear Regression
FNR	-	False Negative Rate
FR	-	False Rejection
FRR	-	False Rejection Rate
GFCC	-	Gamma Frequency Cepstral Co-Efficient
GMM	-	Gaussian Mix Model
HMM	-	Hidden Markov Model
KNN	-	K-Nearest Neighbor
LD	-	Linear Discriminant
LPC	-	Linear Prediction Coding
MFCC	-	Mel-Frequency Cepstral Co-efficient
MLE	-	Maximum Likelihood Estimation
MLLR	-	Maximum Likelihood Linear Regression
MPC	-	Minimum Path Cost
NPA	-	Non-Parametric Analysis
PA	-	Parametric Analysis
PLP	-	Perceptual Linear Prediction
QRAM	-	Quranic Recitation Acoustic Model
QRSS	-	Al-Quran Recitation Speech Signal
RASTA	-	Relative Spectral-Perceptual Linear Prediction
SDC	-	Shift-Delta Co-Efficient.
STFT	-	Short-Time Fourier Transform
SVM	-	Support Vector Machine

TA	-	True Acceptance
TPR	-	True Positive Rate
VTLN	-	Vocal Tract Length Normalization
WCC	-	Wavelet Cepstral Co-Efficient
WERs	-	Word Error Rate

LIST OF SYMBOLS

E_n	-	Short Time Energy
Z_n	-	Average Zero Crossing Rate
w	-	Mixture of Gaussian Weight
μ	-	Mean
σ	-	Covariance

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CHAPTER 1

INTRODUCTION

1.1 Overview on Al-Quran Recitation and Technological Approaches

Al-Quran(Relaño-Iborra *et al.*, 2019) is believed as words of God (*Allah*), was revealed to the Prophet Muhammad gradually over a period of 23 years through the approach of revelation to the Prophet Mohamad by using the Arabic language (Haider, 2016). On the other hand, *Al-Hadith* is a compilation of words and practice of the Prophet, where both Al-Quran and Al-Hadith are two major references for Islam followers. The generality of the statement lies on the fact that the practice and rule-based guidance of God are inherently bound for a human to pursue life. In this regard, the contents provided in Al-Quran have believed comprise of all aspects of life routine for references towards the end of the world.

Historically, the evolution of collecting, reciting and memorizing verses of the Al-Quran began with the Prophet, then memorized by the followers of the Prophet, and subsequently transferred to materials such as stone, animal skins and paper to allow the continuity of the Al-Quran. In addition, this Arabic-based holly Al-Quran was written diacritically to guide Muslims to read the Al-Quran correctly. Today, the Al-Quran is available not only in the form of a book using paper, but also in the form of digital formats for text, voice and even video, which have become increasingly popular. Diacritical marks, as well as colored marks are added value to facilitate and improve recitation and memorization performance. In addition, many reciting derivative techniques such as ABaTa, Bagdadi, *Qiraat*i, Iqra, Al-Barqy and *Tartil* exist to help learners around the world in reading the Al-Quran better and more effectively (Hasnatul Balqies Hashim *et al.*, 2016)(Nuratikah *et al.*, 2017)(S. Ahmad *et al.*, 2019)(Ratnaria *et al.*, 2019).

Basically, Muslim who want to recite the Al-Quran should learn the correct technique of reciting the Al-Quran. According to Islam regulation, this is important because without the correct knowledge of proper recitation technique and rules will result in the different pronunciation of Arabic words and leads to the different meaning for any particular verse in Al-Quran. Indeed, the Muslim believes that wrongly reciting the Al-Quran because of improper learning the *Tajweed* (Arabic: تجويد tajwīd, IPA: [tædʒˈwiːd], 'elocution') will bring sin and will be punished by Allah (God). *Tajweed* is a set of rules for the correct pronunciation of the letters with all their qualities and learned through the various traditional methods of recitation (*Qiraat*). This includes the rules of *Makhraj, Harakaat*, and *Sifaat* (Hassan *et al.*, 2012), (Muhammad et al., 2010) which refer to pronunciation, punctuation and accent when reading the Al-Quran. Most *Tajweed* errors are usually based on word loss, sentences and misreading. All of this is taken seriously because of as mentioned previously Islam believes that every word in the Al-Quran is the word of the one and only God. This importance has triggered the study presented in this thesis emphasizing the application of technology in correcting errors in reading verses in the Quranic Book where a scientific approach is applied in analysing the reading. Indeed, the recitation of Al-Quran is an incomparable art and the melodious recitation is based on the aspects of eloquence in reading, *Makhraj* letters (point of articulation), *Tajweed*, vocal and songs or melody (*taranum*) to produce the *Tartil* recitation (the most higher quality of recitation) (Tabbal et al., 2006).

Trends in speech processing and recognition research are still ongoing as can be seen in speaker recognition (Gaafar et al., 2014) (Turner and Joseph, 2015) (Chung et al., 2018), assessment of English pronunciation (Li et al., 2014), assessment of Hindi pronunciation (Patil and Rao, 2016) and English proficiency for Japanese students (Fu et al., 2020). Clearly, despite being used drastically in a variety of applications, speech recognition techniques remain consistent in research continuity because of the complexity in analysing such spoken languages. Furthermore, pattern recognition in machine interactive development still faces the issue of robustness where speech processing and analysis techniques are constantly challenged by noise signals and other elements that are not required in the recognition of the signal (Gaikwad et al., 2010).

1.2 Research Motivation

The awareness of Muslim followers on the issue of reciting the Al-Quran along with the absolute responsibility to the creator has indirectly prompted the research that has been conducted and reported in this thesis. Conventionally, *Talaqi* and Musyafahah are the most suitable techniques used in the process of reciting the Al-Quran, where learners read the Al-Quran in front of an expert and the correction of *Tajweed* recitation of the Al-Quran can be done perfectly (Hassan and Zailaini, 2013). Through this approach, the expert knows where the start points of learner and level suitability. A student's fluency in mastering good reading usually depends on the seriousness, competence and frequency of learners reading, especially guided and monitored by experts. Generally, in the first stage, the expert will evaluate the learners reading by listening to the correct pronunciation of syllables based on *Tajweed* rules in the context of *Makhraj*, *Sifaat* and *Harakaat* (MSH) (Wahidah et al., 2012). Then learners read repeatedly in front of the expert to confirm the correct recitation especially on the pronunciation or articulation of *Makhraj* letters with the proper use of *Tajweed*. The role of the expert in this conventional approach is very important to ensure correct reading and rectify the errors. All of this requires commitment in terms of time and practical effort. Without an expert, the reading assessment process is quite impossible to implement. However, the lifestyles of teachers and learners in the modern world also limit the frequency of meetings to read with the *Talaqi* approach. Furthermore, many learners in today's generation feel uncomfortable when reading the Al-Quran in front of experts. Besides that, learners of non-native Arabic language will face the problem with vocabulary and pronunciation mistakes. In addition, the evaluation performed by one expert may be different from other experts, i.e. depending on different reading accents. At the same time, as ordinary human beings, teachers are no exception to the possibility of making inconsistent assessments. *Tajweed* checking system by using the speech recognition techniques were the most expected to provide the solution where the learner may perform the revision independently (Ahsiah *et al.*, 2013). Commercially, techniques or applications of such automated assessment are almost non-existent in the market, as studies in this area are currently gaining rapid attention from researchers all over the world, especially Islamic scholars. If there is

any, only one can listen to the reading and facilitate in reading, but not to the extent of automatically assessing the errors of recitation.

Therefore, the purpose of this research is to develop an Al-Quran recitation assessement system based on computing technology. Rationally, the system that is being developed may be able to interact with the reader of the Al-Quran more accurately and consistently where the processing and analysis of readings are based on engineering and machine capabilities. The system can also of course be designed with a user-friendly situation, as is the trend of modern technological inventions. The purpose of the research is also to find significant assessment methodology for Muslims to enable the reading of the Al-Quran correctly regardless of time and place, as long as it meets certain rules. The encouragement of the production of this automated reading assessment system can also allow a person to do reading exercises before meeting a specialist according to a specific schedule. In fact, the lack of such applications also draws special attention in this research to study and build a platform that can help in correcting the recitation of the Al-Quran automatically. This can be a pre-diagnosis or self-assessment of the reading before the reading is heard and evaluated by an expert. In addition, learners can send speech reading signals to experts through automated machine systems and experts can evaluate readings online at any convenient time. Indeed, this system is very important to be created so that it can continue to be improved from time to time with enhanced features or specifications.

1.3 Background of Research Problem

Theoretically, Quranic rules and reading property (*Tajweed*) can be transformed and trained in a computerized system and will progressively play a role as a virtual expert to automatically help and correct learners' mistakes in reading the Al-Quran. The main agenda in this thesis is to intensify efforts to demonstrate a model of computational engine for intelligent automatic Al-Quran recitation assessment system.

Real-time processing such as Digital Speech Processing (DSP) should be able to represent, extract and classify the uniqueness of *Tajweed*-based on speech signals.

The DSP technique capability is used and applied to identify and classify *Tajweed* reading errors. However, the complexity in speech, the challenge of choosing the appropriate DSP technique in representing and expressing the *Tajweed* errors are among the major issues that need to be considered in any research in this regard. Speech complexity such as acoustic variability, speech variability, speaker variability, language variability, phonetic variability and Lombard effects are among those that influence analysis and performance. Difficulties further to be shown in the context of comparing the nature of the similarity between the reader's and expert's speech signal where such threshold value range must be experimented and manipulated.

The results of the research as reported in the literature found that studies revolve around covered research areas such as the production of speech assessment evaluation techniques. This involves the pre-processing, feature extraction and classification of recitation voice signals which are collected based on the nature of *Tajweed* rules. Pre-processing is often done to avoid unnecessary signal waveforms such as noise or unwanted information before being the input to the identification process. However, this includes the probability of silently deleting important data and the failure of endpoint detection. Therefore, pre-emphasis or noise and channel normalization is not something that can be taken lightly (Abuzeina et al., 2011) (Mourtaga et al., 2007) (Abro et al., 2012). In addition, the reading signal needs to go through the normalization process and also the speaker's adaptation needs to be done to ensure the complexity, variation and unwanted signals can be addressed before it can be used at the next level. Thus, at the next stage of feature extraction, those features will be extracted from reading speech signals that have been considered reliable digital representations. Basically, the feature extraction used in the development of this prototype refers to the process of compressing the signal without losing important information. There are many speech processing techniques such as Mel- Frequency Cepstral Coefficients (MFCC), Linear Prediction Coefficients (LPC) and Perceptual Linear Prediction (PLP) that have been used in many applications around the world. However, the most promising result for feature extraction is the use of MFCC (Dey et al., 2012), (Ahsiah et al., 2013), (Mahmood, 2020), and is widely used in automatic speech algorithms. The MFCC technique processes large vector extraction features that have the same frequency format values grouped. A set of formant frequencies can represent the frequency of phonetic sounds produced from

speech production. In the final stage, the task of classification or matching process will be experimentally performed using dynamic programming to model the data as sequential and static patterns. The pattern for each verse of the Al-Quran will be correlated and with the pre-determined threshold of acceptance between experts and learners' recitations, the judgement of correctness may be made reasonably. Figure 1.1 demonstrates various purposes of Al-Quran recitation and potential applications such as demonstrated in any Intelligent Quranic Recitation Assistance (IQRA).

Figure 1.1 Examples of availability of Al-Quran recitation purposes and potential applications for proposed Intelligent Quranic Recitation Assistance.

1.4 Research Problem

A completed design of the computational engine of Al-Quran recitation assessment must conform to a set of rules, known as *Tajweed* rule, where both pronunciation and meaning of a recited syllable must have complied. During the transformation, the digitized Quranic recitation audio of nonlinear speech signal must highly maintain the original contents of *Tajweed*-based representation although in the presence of signal variation complexity, such as noise, speaker behavior and other related intrinsic and extrinsic variations. The designed representation must also be able

to contain neither to lose the information nor to mix with the noise where both cases may lead to the bogus input and analysis. Technically, it is clear that the automated *Tajweed* assessment process, (from digital transformation to assessment tasks) inevitably involve with the reliability issues of kind of salient features to be represented and with the highly technical sensitivity of what extracting and classifying approaches or technique to be best used. A further critical consideration is a design of mutual complementary filters for both extractor and classifier to be able to work together on the selected salient features with less or no conflict between them in the task of similarity and dissimilarity extraction and classification. Feature extraction is an important and key component in automated speech processing. In fact, it becomes extremely important and sensitive in the extraction of salient features, the feature in which are defined as successful features to represent or carry a discriminatory feature of adequate syllable information (Mahmood, 2020). This is one of the main reasons the salient features are suitable for use as an indicator component in designing a forecast model, commonly known as predictive model. In the context of a predictive model of syllable feature representation, which is technically capable of offering salient features extraction and representation, such model can be used in the evaluation of *Tajweed* rules, either using non-phonetic transcription or phonetic transcription approach. Phonetic transcription selection, on the other hand, is widely used in other languages, but obviously, not in Arabic or Quranic phonemes creation (AbdulQader Al-Bakeri, 2017). This is due to difficulties in producing pronunciation files, mainly due to irregular pronunciation problems (AbdulQader Al-Bakeri, 2017). Thus, non-phonetic transcription prediction models are chosen and focused to be applied in evaluating *Tajweed* rules, which can be developed using feature-based, statistical-based or distance-based models. This crucial-based decision is momentous in the comparison task of predictive model because of the learner's signal (probe) versus the expert's signal (reference) fall 'within the common classes', rather than 'between the classes', which lead to small differences or higher in similarity and definitely highly challenge the syllable classification task.

A large amount of research in the literature has focused on classification groups such as hijaiyah characters, selected Quranic word types and the nature of compound characters. However, the evaluation of speech related to the continuous recitation of the Al-Quran is not much considered. This is in stark contrast to the situation that

occurs in other language research, especially in speech assessment whose primary focus is in a self -directed learning environment. The selection of such features is mostly related to the use of formant frequencies and MFCC with various classification algorithm approaches to reveal the vowel and consonant properties embedded in a syllable. In general, vowel letters, consonants, or letter combinations in the speech production of syllable pronunciation are involved with natural and formant frequency. Thus, the formant frequencies represented by the Mel Frequency Cepstral Co-Efficient (MFCC) are particularly beneficially used to reveal vowel and consonant features (Darch et al., 2005) (Khelifa et al., 2017). Salient features of Mel Frequency Cepstral Co-Efficient (MFCC) and Short Transform STFT features that represented the characteristics of syllables in time-frequency domain with time occurrence properties as segmented energy are widely used in speech processing because of the strength to reasonably challenge the signal variation with minor computational complexity and better accuracy. However, the transformed and parameterized Quranic continuous recitation signal with unique embedded *Tajweed*-based syllable features (pronunciation and *Tajweed* type) using statistical-based predictive model (Ling *et al.*, 2015)(Houidhek *et al.*, 2018) is very crucial to be burdening the ability of identifying the place of articulation (*Makhraj*) and co-articulation (*Makhraj Sifaat*). The core of research problem is to experimentally reveal the pattern of appropriated *Tajweed* rules, both places of articulation and *Harakaat* (the duration).

Practically, since the recitation of the Al-Quran is done with the continuous combination pronunciation of phonemes or syllables to form the word and verse, it is not an easy task to distinguish between one word and another. The problem is further aggravated if the technical approach used is based on syllables or phonemes. This challenge is also followed by the uniqueness of the pronunciation that must follow the rules of *Tajweed*. Classification algorithms with statistical model approaches and probabilities are among the models that can be used in speech assessment. The chosen statistical model and salient features (Mahmood, 2020), that is capable not only needs to be able to provide recognition but should also be able to provide a good score or quality of Quranic recitation. Therefore, the reliability of the computer engine has to include the involvement of expert assessment in the training and testing computerized matching process.

1.5 Research Questions

1. What are convincing analytical approaches for acquiring the digital signal representation of recitation voice without (or less) unnecessary variation or noise and the limitation of current recitation signal representation for Al-Quran recitation.
2. What are the limitation of existing features and the technical consequences involved in obtaining the salient features, extractor and prediction model that reliably perform in carrying the *Tajweed* requirement for Al-Quran recitation?
3. How to solve the issue of reliability in training, testing and verifying the analysis results of a designed computational engine for Al-Quran recitation?

1.6 Research Objectives

In underlying the rationality of the computational engine of the automated *Tajweed* assessment machine and realizing the purpose for which the research was made, three objectives corresponding to the research inquiry (or questions) were revealed and listed as follows.

1. To obtain the reliable recitation signal representation by study and investigate the prominent characteristics of digital representation form for Al-Quran recitation speech signal.
2. To acquire the salient features, suitable extractor design and prediction model design that be able to represent the characteristics and properties of required *Tajweed* rules for Al-Quran recitation.
3. To validate the designed Al-Quran recitation assessment computational engine.

1.7 Research Scope

The development of the computing engine is strategically planned by dividing the research work into three main stages. The first, second and third stages can be grouped as below.

i. Data preparation and pre-processing for a group of reciters (Malay ethnic),

ii. experimental works of identifying the salient features, the best extractor design and prediction model design to be used,

and finally,

iii. the design of suitable features classifier, together with the training, testing and evaluation of results.

The collected a set of data is limited to non-Arab (Malays) of various gender and ages for reciting Chapter One of Al-Quran (*Surah Al-Fatihah*), in the recording studio of Universiti Teknologi Malaysia, located in the Kuala Lumpur campus branch. The equipment in the studio has complied with the quality requirements as outlined by the FINAS standard. As many as not less than 98 selected reciters speech signals Al-Quran sentences speech signals were successfully recorded in wav audio format that exists in Chapter One of Al-Quran (*Surah Al-Fatihah*), which consists of 7 sentences (*ayat*) or 78 syllables. This chapter basically comprised *Tajweed* properties of more than 30 and include various classes that are based on combination vowels and consonants in syllables with respect to *Harakaat* (prolongation), *Makhraj* (articulation) and *Sifaat* (co-articulation). For *Harakaat*, it is related to the long and short pronunciation of phoneme, syllable or word and *Makhraj*/*Sifaat* are related to phoneme, syllable or word and their diacritic marks with the articulation from the vocal tract and glottal pulse. The recitation is performed with the approach of the famous Malaysian recitation *Qiraat* (reciting), known as *Toriq al-Syatibi.* In Malaysia in particular, the method of learning and teaching *Tajweed* is more dominant to Toriq al-Syatibi. Muslims in Malaysia recite Qiraat حفص عن عاصم using Toriq al-Syatibi.

At the first stage (in response to Research Question 1 and Objective 1), speech representation and pre-processing are performed, mainly for this Quranic signal processing. It is only limited to the works of silent removal, amplitude normalization and vocal tract length normalization (VTLN). This specific scope have identified for speakers' adaptation, syllables segmentation, signal compensation, and pre-emphasis. Besides that, the noise profile is used by audacity software to remove any noise signals that exist in voice signals in pre-processing stage before proceed to the first stage. The type of signals recorded are continuous speech recitation and segmented as syllable of Al-Quran Recitation Speech Signal (QRSS) which recitation is guided by diacritic Al-

Quran Image. The speech signal is divided into two categories which are experts and learners.

At the second stage (in response to Research Question 2 and Objective 2), the extraction techniques of speech signals are limited with the application of Mel Frequency Cepstral Coefficients (MFCC) where the analysis is based only on the human auditory system (Ahmad *et al.*, 2004) and Shift Delta Coefficients (SDC), (Ambikairajah, 2006). In this approach, the research in this thesis has limited the fundamental frequency and alternating current removal of 50/60 Hz noise of voice signal and to be removed by the tribank filter with the specified range between 300Hz to 3700Hz. The selection is reasonably coincides with (Asadullah and Nisar, 2016) that used band pass filter to remove fundamental frequency of 85 to 255 Hz and defined that the voice usable range frequency lies between 300 Hz to 3400 Hz. Analysis of statistical and distance Model-based Quranic speech signal are selected to represent the error of *Tajweed*. The features from the speech production of human speech signal extracted based on Cepstral spectrum which represents the energy distribution and formant frequency of Quranic speech signals in Time-Frequency domain.

At the third stage (in response to Research Question 3 and Objective 3), the works of threshold matching process and classification for experts and reciters' recitation are scoped based on only *Tajweed* properties representation in the Chapter One (1) of Al-Quran and verified by the assigned expert to observe the validity of parameters estimation. In addition, the experimental work of sequential classification is limited to the selected classifiers of Linear Discriminant (LD), Support Vector Machine (SVM) and K-Nearest Neighbor (KNN) for syllable signatures classification. The rationality of using these specified classifiers is explained in the proceeding chapters. Figure 1.2 illustrates the research stages in the scope of thesis research works.

In conventional reading assessment, *Tajweed* rules are applied to syllable-based pronunciation in each sentence where syllable utterances are assessed from compound and consonant vowels. Each syllable pronunciation that carries the *Tajweed* order in a sentence is read in continuous reading as a sequence syllable.

However, the automated extraction basically falls into another area of study. Syllables used in this computing engine are limited by manually extracting from continuous reading in order to provide input to the computational engine, where the scope of work begins with the digital representation for the purpose of salient features identification and extraction. Besides the syllables are taken as the basis of the recitation evaluation, the medium speeds of recitations are also manually measured and figured out by the assigned experts in this research. These works are applied in both verification and validation of analysis.

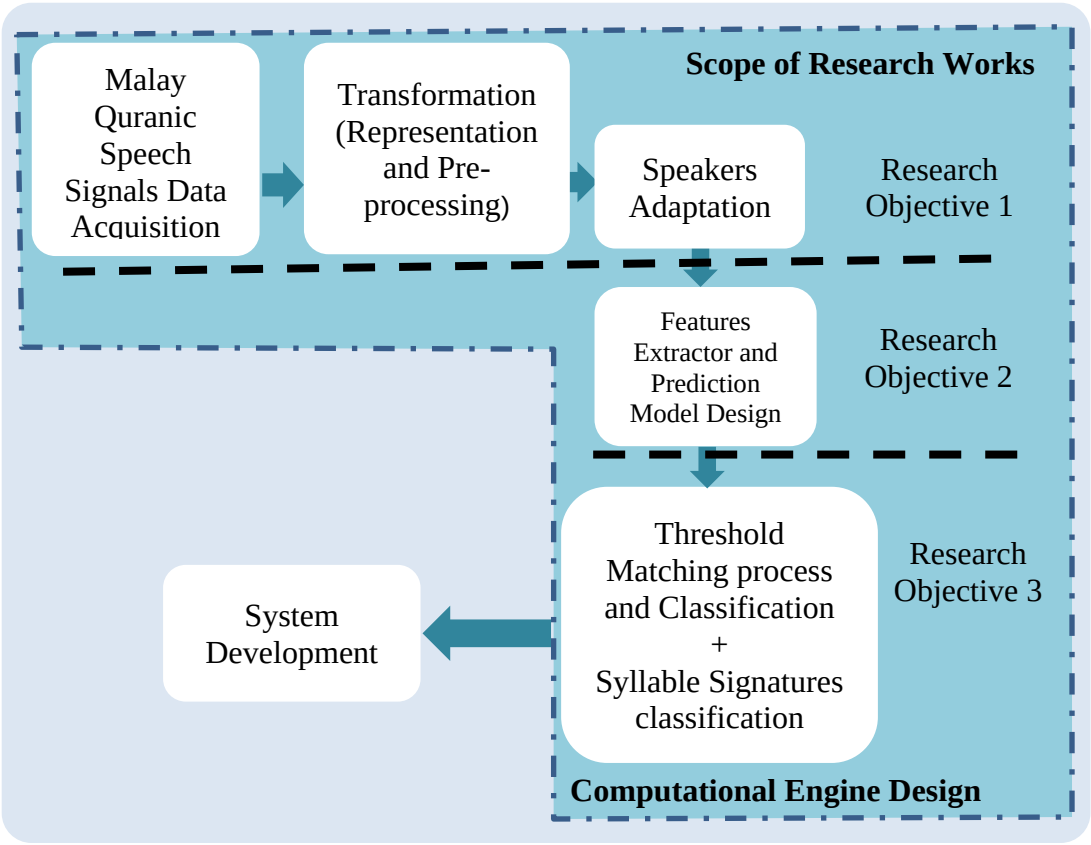

Figure 1.2 The block diagram for the scope (and limitation) of research works.

1.8 Significance of Research Works

By transforming the conventional assessment of Al-Quran recitation to computer method, as modelled through the proposed prototype of Intelligent Quranic Recitation Assistance (IQRA) system is the ultimate aim of this research. The detail of the proposed computational engine is explained in Chapter Three (Research

Methodology). As will be explained in proceeding chapters, the proposed computational engine is focused on the evaluation of non-phonetic transcription. Currently, the development of Arabic phonetic transcription or phonetic acoustic models is however, not adequately or completely applicable for Arabic as compared to English transcription (AbdulQader Al-Bakeri, 2017), (Tabbaa and Soudan, 2015). Therefore, the proposed computational engine significantly does not require phonetic transcription references to evaluate pronunciation or recitation (Fu *et al.*, 2020). The selection of feature extractors to reveal features important for the feature representation of non-phonetic models has been best implemented. The extractor that is based on Mel Frequency Cepstral Co-efficient (MFCC) and Shift-Delta Co-efficient (SDC) (derivatives from ΔMFCC and ΔΔ MFCC)(Maqsood *et al.*, 2019)(Fu *et al.*, 2020) are used to extract the features. Furthermore, from the unique significant features of energy distribution, formant frequency and prosody represented as model parameters estimation (Sahu and Babu, 2020) can be used in matching the classification process towards realizing the design and prototype of the computational engine. Indeed, the most significant work of the assessment mapping model in this research is presented to find the *Tajweed* errors by producing the range of threshold values. There are several conference paper publications that has been presented from the result of thesis, clearly signified that the development of Al-Quran recitation evaluation system can support Islamic *Da'wah* through the use of modern media technology. In another conference paper, the ability of the proposed normalization technique has achieved convincing success in dealing with intrinsic and extrinsic variations (Rabiner and Schafer, 2007) in the evaluation of Al-Quran recitation, namely by focusing on the normalization of vocal tract length (VTLN) (Furui, 2001) and normalization amplitude. In addition, stages in the processing of Al-Quran recitation signals such as pre-processing, feature extraction, speech modeling approach and feature classification using DSP methodology have been proposed in evaluating the Al-Quran recitation. The study has untangled the understanding of vowel, consonant and combination of both in the digital representation by obtaining a series of formant frequencies (Kent and Vorperian, 2018)(Nuratikah *et al.*, 2017). These formant frequencies represent the concentration of acoustic energy around a particular frequency in the speech signal.

Hopefully, the designed computing engine system for *Tajweed* rules assessment can help Muslims to read the Al-Quran more regularly through the process of modernity. All the efforts poured in can hopefully be a motivation for other researchers to contribute and improve the computing machine system with the sophistication of the appropriate platform for further application. This can change the world of Muslim life, especially in diversifying the approach of reading and correcting the Al-Quran recitation in the future.

1.9 Thesis Organization

The thesis is structured with the five (5) chapters in which each of them relates to the stages of knowledge acquisition levels, processes, understanding and manipulation towards the new knowledge contribution.

Chapter One (1) has generally explored the issues of robustness in challenging the broad perspective of to what extent that the research might be pursued in this area. The issues will then indirectly reveal the motivation and purpose or aim of the research. The formulated problem is clearly stated in the statement of the research problem to reveal the research gap, with the explanation of background of research problem. In completion of the current chapter, the objectives, questions and limitations of the research are outlined, listed and briefly explained respectively. The chapter is ended up with the highlights of the significance of research outcomes and roadmap of the thesis.

Chapter Two (2) initially provides the foundation knowledge and in-depth overview of the laws of *Tajweed*. The explanation is followed with the topic of scientific models of recitation assessment that based on signal processing. By reviewing the literature, the theory of speech production that peels points of articulation (Makjraj), the properties of letters (*Makhraj Sifaat*) up to the formation of phonemes, syllables, words and sentences are explained adequately. The basic methods of representation, pre-processing, speaker adjustment, feature extraction and classification are explained with an emphasis on the fundamental importance of knowledge to the development of the computational engine of Al-Quran recitation

assessment. The chapter also includes the breakdown sequence of methods and knowledge in realizing the prototype of the computational engine, namely as nur-IQRA.

Chapter Three (3) presents the methodology and scientific approach for developing the computational engine using model-based parameters estimation. The review of methods for speech parameterisation on spectrum of recitation speech signal is made clear. The speech features, namely as MFCC and SDC are explored to reveal the formant frequency and energy distribution of recitation speech spectrum. These are described with particularly expressed on the modification of filtering and extraction of the miniatures features in representing the Al-Quran *Tajweed*-rule-based recitation speech signal. A further explanation is made for the *Tajweed*-based features that were modelled into acoustic/languages. The study of the model and possible comparison with the existing model of other languages are explained. The chapter also reviews the existing matching or classification process based on a suitable approach in determining the *Tajweed* errors.

Chapter Four (4) is devoted to the explanation of the experimental results and outcome analysis in making the computational engine. The function of threshold value of accepted and rejected recitation range for experts and reciters is explained. Combination of recitation speech parameterisation from miniatures features that represent *Tajweed* errors in a time-sequenced frame is presented and namely as Quranic recitation Acoustic Model (QRAM). The matter of adjusted thresholds that depend on the manual evaluation from the expert and similarity pattern-based of parameters estimation is scientifically uncovered. In addition, the use of sequential classification approach is disclosed in determining the clustering performance for each *Tajweed* type correspond to the *Al-Fatihah* syllables. A discussion of the findings from each stage is stated. At the same time, details work on miniatures features extraction, dynamic programming approach on speaker adaptation, speech parameters estimation from model-based and threshold processing are revealed to report the accomplishment of the successful threshold processes for the mapping process. Finally, the chapter is ended with the discovery of parameter estimation in Al-Quran recitation assessment

based on *Harakaat*, *Makhraj* articulation and *Makhraj* co-articulation using threshold matching process and syllables signature classification.

The thesis summary, conclusions and recommendations are integrated in Chapter Five (5), where the research works that have been done and final knowledge contribution are described. A reasonable magnitude of discussion on potential future work and proposals of performance enhancement with various techniques are reported mainly to improve the development of the computational engine.

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LIST OF PUBLICATIONS

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2. **Shafie, N**., Adam, M. Z. and Abas, H. (2017) 'THE MODEL OF AL-QURAN RECITATION EVALUATION TO SUPPORT IN DA'WAH TECHNOLOGY MEDIA FOR SELF-LEARNING OF RECITATION USING MOBILE APPS', in *3rd International Seminar of Dakwah*, pp. 37–39.