Quran Recitation Recognition & Interactive learning of Quran recitation

By: Rahma Hassan

Presentation Flow:

- 1-Introduction
- 2-Problem Definition
- 3-Motivation
- 4-Challenges
- 6-Feature extraction techniques
- 7-MFCC
- 8-Literature Review
- 9-Conclusion
- 10-References

Introduction

- Holy Quran is divine book for Muslims, and it is very important for them.
- Quran has some rule [Tajweed] which should be followed to recite Quran properly.
- People need to learn how to recite Quran correctly.

Automatic speech recognition

ASR is a process which computer takes voice and transform it to words for specific purpose.

Tajweed

Set of rules, like where to stop and for how long, when to merge two letters in pronunciation ,etc.

Essential in reading Quran

Different reading might give different meanings.

Motivation

- Help Muslim Arabs in Reading Quran accurately
- Many Muslims are not Arabic native speakers and need to learn Quran.
- Traditional methods [face to face learning] is not enough .

  -Needs expert Quran Teachers.

  -Problems in the environment[surrounding noise/lack of attention]

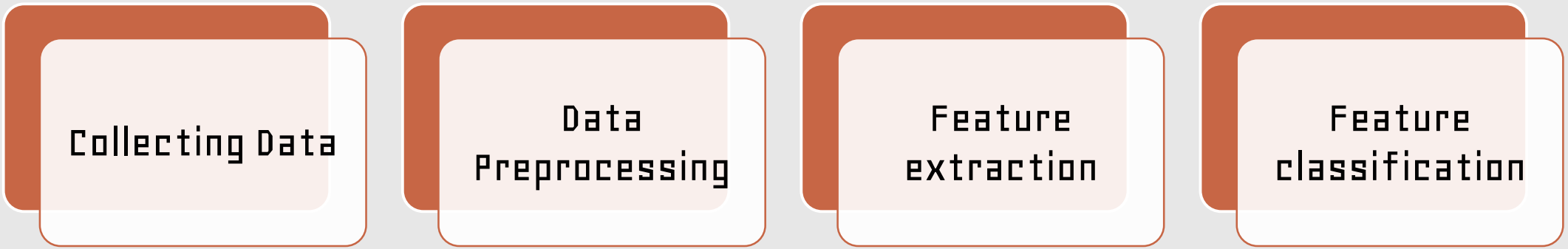
  -Learning Sessions with Quran Teacher has limited time.
- Facilitate Quran recitation using software applications on our Smartphones .

Challenges

1-Arabic language Challenges.

2-Quran Rules ‘Tajweed” Challenges.

Whole Speech Recognition Process



Feature Extraction techniques

- Perceptual Linear Prediction [PLP].
- Linear Predictive Coding [LPC].
- Mel-Frequency Cepstrum Coefficients [MFCC].
- Linear Prediction Cepstral Coefficients[LPCC].
- Discrete Wavelet Transform [DWT].
- Linear Discriminant Analysis [LDA].

MMFC structure

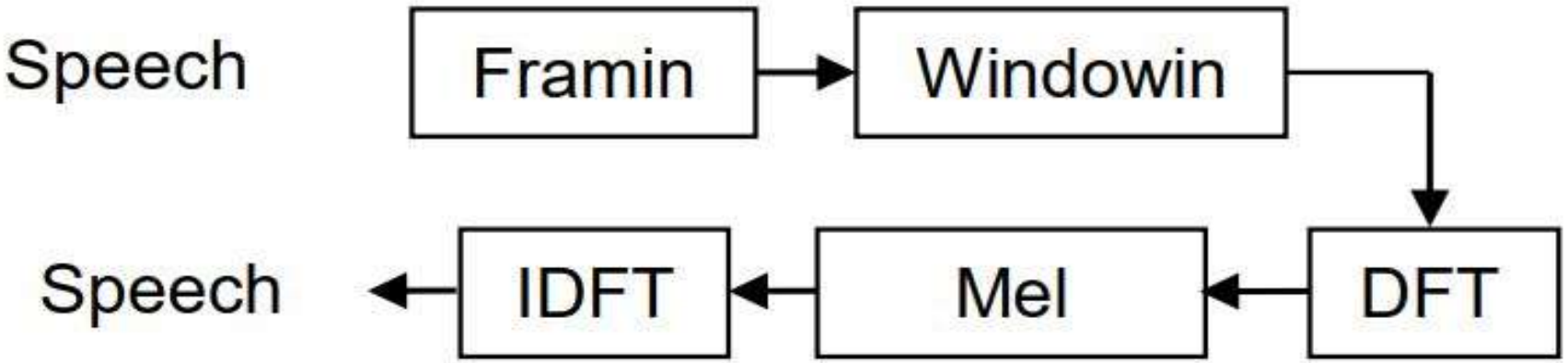


Figure 3 Block diagram of the MFCC processes

Features classification techniques

1] Acoustic Phonetic Approach

2] Pattern Recognition Approach

3] Artificial Intelligence Approach

Literature Review

-Development of Quranic recitation Systems have increasing importance

-Many Papers exist in topic 'Quran Recitation Recognition'

-In addition, Some software applications exist like 'Tarteel application'.

Paper:1

SMARTAJWEED AUTOMATIC RECOGNITION OF ARABIC QURANIC RECITATION RULES

- By: Ali Alagrami [Department of Computer Science, University of Venice] and Maged Eljazzar [Faculty of Engineering, Cairo University, Egypt].
- Published **2020.**
- The main purpose is to **recognize different rules of Tajweed in audios.**
- Improve existing tools for Tajweed learning.
- The whole process is applied in 'Imam' app in its beta version too.
- The purpose was building system that can **generally** recognize the rule in any verse of Quran.
- They proposed a tool for recognition of 4 rules of **Tajweed (Edgham Meem, Ekhfaa Meem, tafkheem Lam, Tarqeeq Lam)**
- Data collected from Volunteers and paid Specialists.
- Data contains right and wrong ways for the pronunciation.

The whole system:

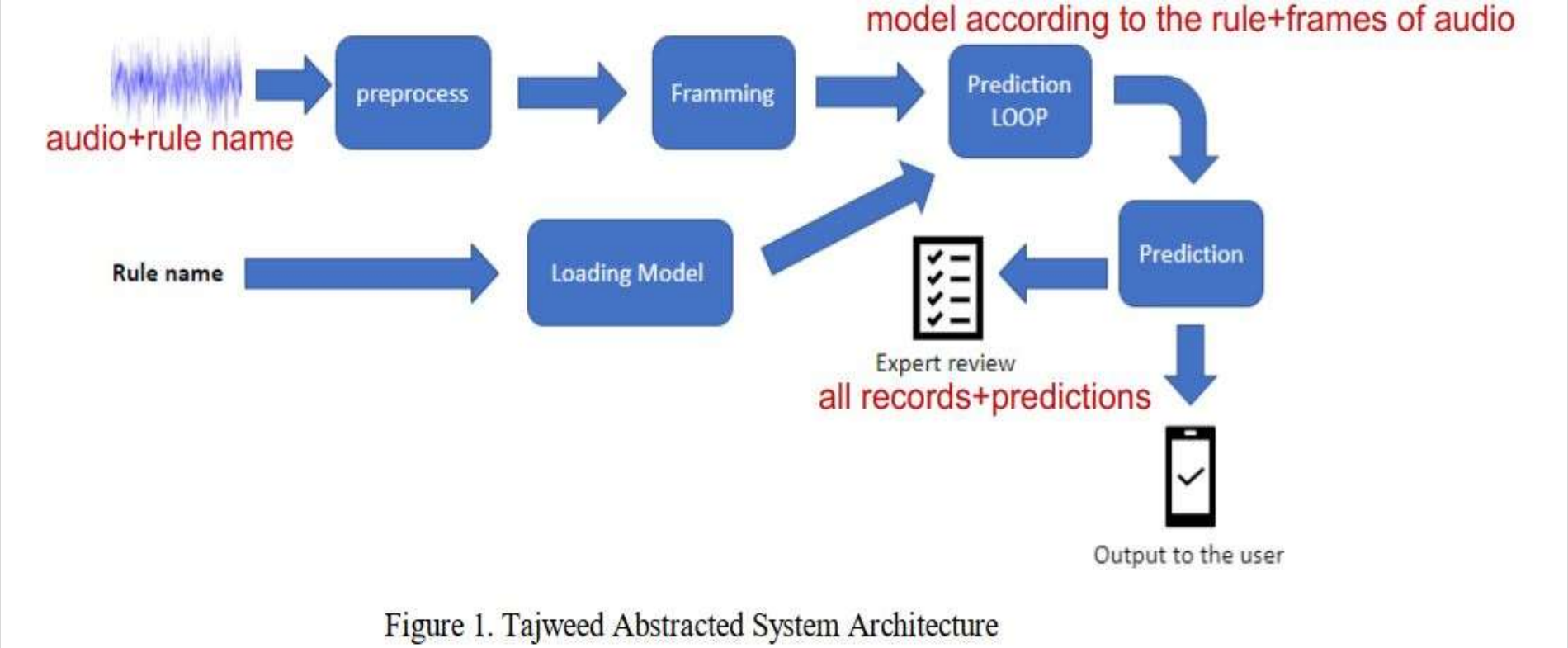


Figure 1. Tajweed Abstracted System Architecture

Paper 1-Dataset & Processing

- Input : audios along with name of rule.
- Dataset : 80 record for each Rule name and type with a total of 657 recordings of 4 different rules.
- To increase data: They used data[recordings] from users of the app in its beta version ,reviewed by experts.
- This improves the model.
- All files is cut to contain the 'rule' only.
- The length of all files becomes 4 seconds as the average length of audio files

  -silence added.

  -file truncated randomly.

Paper1:
Feature extraction & Classification

- Feature extraction(Filter banks applied):

  1-Signal are cut to frames(each frame is 25ms)

  2-Hamming window applied to decrease noise.

  3-FFT to get spectrum.

- Classification Model:

  -Support Vector Machine [supervised machine learning algorithm]

  -hyperparameters: C [Regularization parameter] = 1 , gamma = 0.1

Paper 1:Results

- Each model[there are 4 models] in the system tested against 30% of the Data with a validation accuracy of 99%
- Then ,the whole system tested against full verses to extract rules.
- System not recognize rule only but also get accurate timing in which the rule is started and ended.
- The problem is treated as a normal binary classification problem.
- Goal□ include more recitation rules in the app [IMAM app].

Table 1. Confusion Table for the 4 SVM models

Rule Name	True Positive	False Positive	True Negative	False Negative
Edgham Meem	30	0	30	0
Tafkheem Lam	30	0	30	0
Tarqeeq Lam	29	0	30	1
Ekhfaa Meem	30	0	30	0

TESTING

Table 2. Samples of the verses used in the testing phase

Rule Name (Right)	Chapter	Verse
Ekhfaa Meem	41	52
Ekhfaa Meem	7	45
Ekhfaa Meem	40	75
Ekhfaa Meem	38	46
Tafkheem Lam	2	9
Tafkheem Lam	2	10
Tafkheem Lam	8	16
Tafkheem Lam	2	149
Tafkheem Lam	14	51
Tarqeeq Lam	2	67
Tarqeeq Lam	14	5
Tarqeeq Lam	18	26
Tarqeeq Lam	16	41
Edgam Meem	38	62
Edgam Meem	38	4
Edgam Meem	6	164
Edgam Meem	4	1
Edgam Meem	37	151
Edgam Meem	39	60

Paper 2:

E-Hafiz: Intelligent System to Help Muslims in Recitation and Memorization of Quran

- Hafiz :person who knows Quran very well and can correct with Tajweed rules and can correct mistakes for others.
- The E-Hafiz app detect wrong recitation and notify user but doesn't recognize recitation rules 'Tajweed'
- **Authors:**

Dept. of CS & E, University of Engineering & Technology, Lahore.
Department of Computing and Technology, IQRA University, Islamabad, Pakistan.
Dept. of CS, CINVESTAV-IPN, D.F. Mexico.

- Extract Features of recordings using MFCC.
- Compare users' recitations and experts' recitations.
- Any mismatch between expert recitation and recordings is pointed out for user to correct it.
- System can detect mistakes on word level.
- If mistake found ,system gives option to user to listen the verse again from stored recitations and read and record it again like what happens in real life.

Paper 2 : [Architecture]

- Features vectors are big so they reduced by getting most representative vectors by VQ.
- Vector Quantization is the data compression technique.
- Each set of vectors are clustered.
- So, in every cluster there is a mean value called the code vector of that cluster.
- All code vectors in all clusters is called a codebook.
- **Features Reduction.**

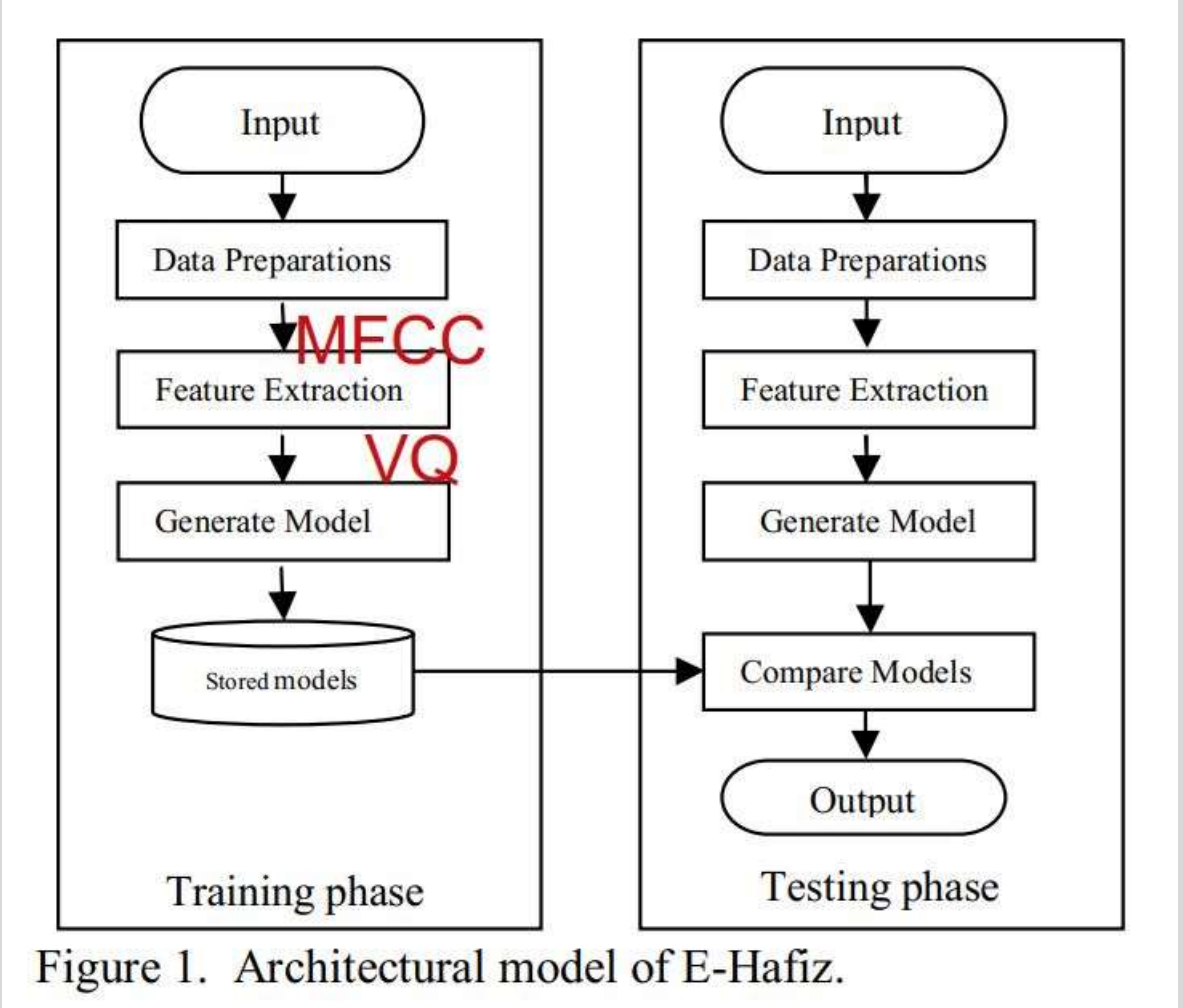


Figure 1. Architectural model of E-Hafiz.

Paper 2: [whole process]

1. Gets record of a selected verse recited by users.
2. Make processing on it by extracting the words in the record.
3. Extract features of each word using MFCC
4. Generate codebook of these recorded words and form array represents whole verse.
5. Make the same thing in database by extracting codebooks array of same verse recited by experts.
6. Compare Expert's codebook array and user's codebook array of each word, compute averages, calculate distance between them.
7. Resultant distance value compared with Threshold value. Determine matching or mismatching.

Paper 2: [Results & Future work]

- Results Three groups of reciters men, women and children are chosen in experiment.
- Candidates recites verses in front of Quran experts along with E-Hafiz app.
- Results of E-Hafiz compared by Hafiz person to determine accuracy of E-Hafiz.

Table 1. Accuracy evaluation of E-Haiz

Type of Reciters	Number of Reciters	Accuracy Rate
Men	10	92%
Children	10	90%
Women	10	86%

- Future work To make Recognition on the level of letters so a miss pronunciation of a letter of can be identified.

Paper 3:Using Deep Learning for Automatically Determining Correct Application of Basic Quranic Recitation Rules

- Authors: Mahmoud Al-Ayyoub, Nour Alhuda Damer, and Ismail Hmeidi
  Jordan University of Science and Technology, Jordan
- Published:2018
- Special paper because…It addresses the problem of identifying the correct usage of Ahkam Al-Tajweed in the **entire Quran.**
  focus on **eight** Ahkam Al-Tajweed.
- The goal is to extract as **few features as possible without affecting the accuracy of the system**.
- Feature Extraction: traditional & non-traditional techniques. for the non-traditional type, Convolutional Deep Belief Network (CDBN).
- **CDBN:**[get spectrogram, PCA, training of layers by filters, output models from training processes used to extract out the features from dataset, calculate mean and SD].

Paper 3: Classification Techniques

1-Nonlinear ML Algorithms [use one-layer processing] :

KNN

SVM

ANN

2-Ensemble ML Algorithms

Random Forest

Multiclass Classifier

Bagging

Paper 3: [Results]

- CDBN can get **more accurate results in feature extraction** since good classifications depend on the best features obtained.
- This combination , [MFCC features, WPD features, mean of HMM-SPL features and features using CDBN] gives **better results in feature extraction.**
- Results prove that model can identify the recitation rule in a verse on which it is not trained with 96.4% accuracy.
- Best results can be obtained by using MFCC, WPD, HMM-SPL and CDBN for feature extraction **and SVM for** classification. [**506 out of 525 instances classified correctly**].

Table 4. Experiments Results while Testing Our Model using New Verses.

Classifier	Precision	Recall	F-Measure	ROC Area	Test Time	# instances	Accuracy
Bagging	0.958	0.956	0.956	0.996	2.840	502	0.956
RF	0.857	0.840	0.829	0.989	0.300	441	0.840
ANN	0.906	0.886	0.877	0.988	3.310	465	0.886
SVM	0.966	0.964	0.963	0.993	1.130	506	0.964

Paper:4

Towards Using CMU Sphinx Tools for the Holy Quran Recitation Verification

- Uses: Carnegie Melon University [CMU] Sphinx which is a statistical speaker-independent set of tools using the Hidden Markov Models [HMM].
- **CMU used** □ train and evaluate a language model on Quran recitations
- Published:June,2016
- **An acoustic model** is **used in automatic speech recognition** to represent the relationship between an audio signal and the phonemes or other linguistic units that make up speech
- Used before by many researchers for Arabic speech recognition.
- They focus using of a simplified set of Arabic phonemes instead of the Romanized set of phonemes.
- Acoustic model needs □ transcription file, phonetic dictionary, set of phonemes, audio files.

Paper:4 Data

- Recordings of verses of chapters [1,112,113,114].
- Choosing chapters [1,112,113,114] because they contain few set of Tajweed rules.
- Recordings converted to 16 kHz,16 bit.
- Some manual processing needed like cutting the beginning and ending of files.
- Used small set of audio files during the training phase.

Paper:4 [Results and discussion]

- Good accuracy in Recognition.
- Word Error Rate □ lower than 2% in many configurations and settings.
- Min Word Error Rate [1.5%].
- **Future Work:**

  Include more chapters, include more recitation recordings to increase data set.

Paper 5:

MFCC-VQ APPROACH FOR QALQALAH TAJWEED RULE CHECKING

- System for *Qalqalah* checking
- Published:2014
- The purpose is to help students read Quran properly.
- Feature Extraction and Classification Technique: hybrid MFCC-VQ architecture.
- MFCC needs high computational time.
- Overall real-time factor using hybrid MFFC-VQ was **faster than** traditional method using MFFC.

Paper 5:

-Training data stored(data base),tested data compared by reference data.

-Feature Extraction □ MFCC

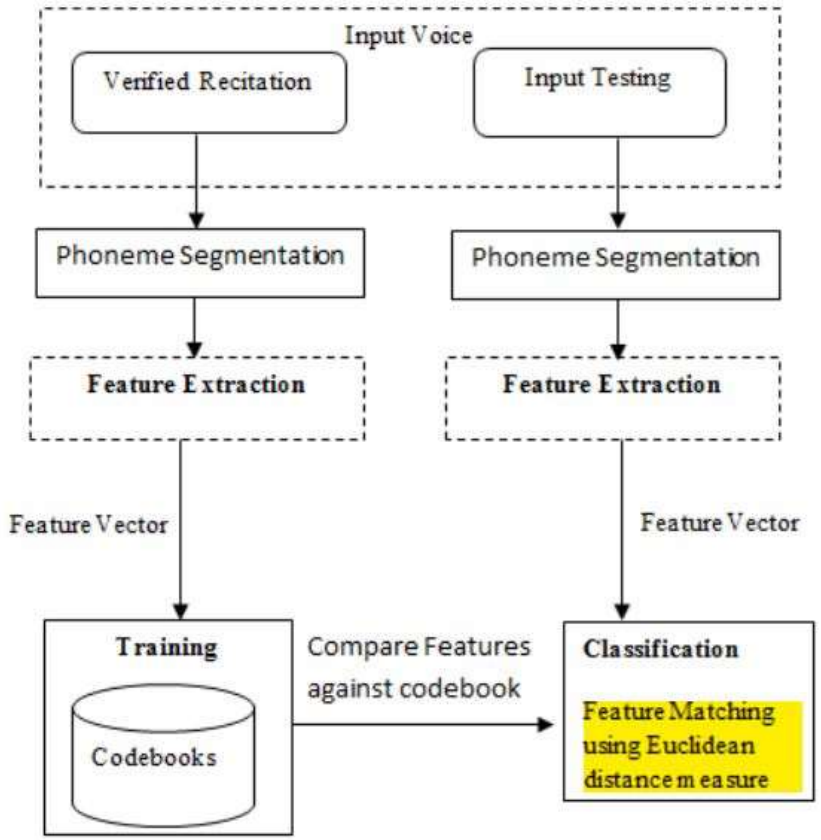


Fig. 1. Tajweed rule checking tool.

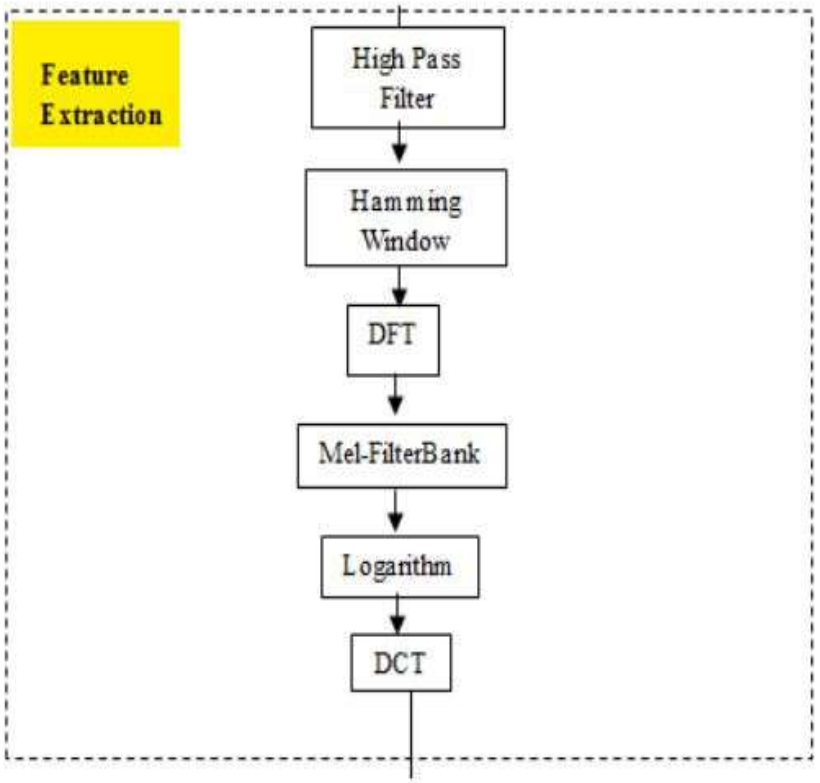


Fig. 2. Feature extraction.

Paper s: [Data]

- 45 speakers ,20 males, 20 females and 5 children.
- sourate *Al-Ikhlas.*

Table 2.Excerpt from the dictionary of sourate *Al-Ikhlas*

Ayates	Phoneme	The ayates in the Al-Qur'an	*Qalqalah Tajweed*
*Al-Ikhlas*1	*Qul huwa Allāhu aḥad*	قُلْ هُوَ اللَّهُ أَحَدٌ	*Kubrah*(د)
*Al-Ikhlas*2	*Allahu -ṣ-ṣamad*	اللَّهُ الصَّمَدُ	*Kubrah*(د)
*Al-Ikhlas*3	*Lam yalid wa lam yūlad*	لَمْ يَلِدْ وَلَمْ يُولَدْ	*Sughrah&Kubrah*(د)
*Al-Ikhlas*4	*Wa lam yaku(n)l lahu kufuwan aḥad*	وَلَمْ يَكُنْ لَهُ كُفُوًا أَحَدٌ	*Kubrah*(د)

Acoustic model plotting:

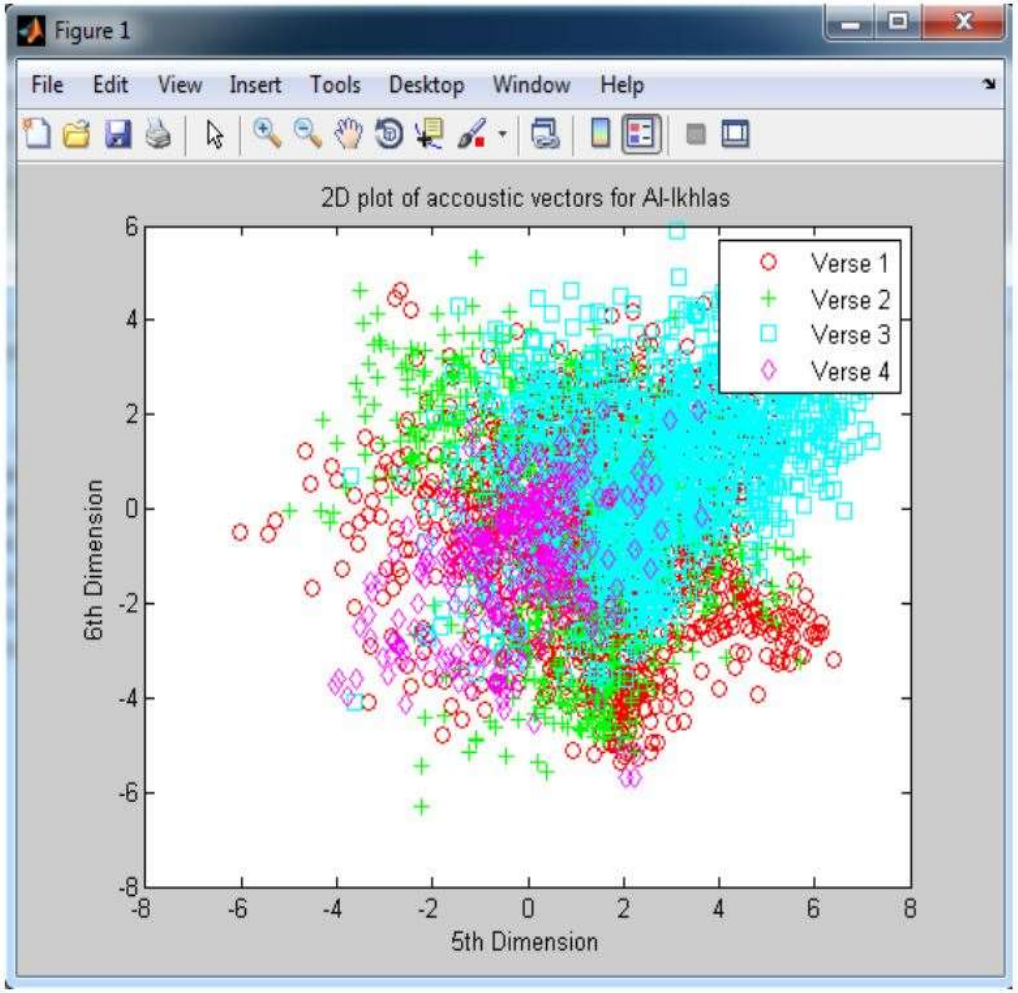


Fig. 5. The 2D acoustic vectors for *Al-Ikhlas*.

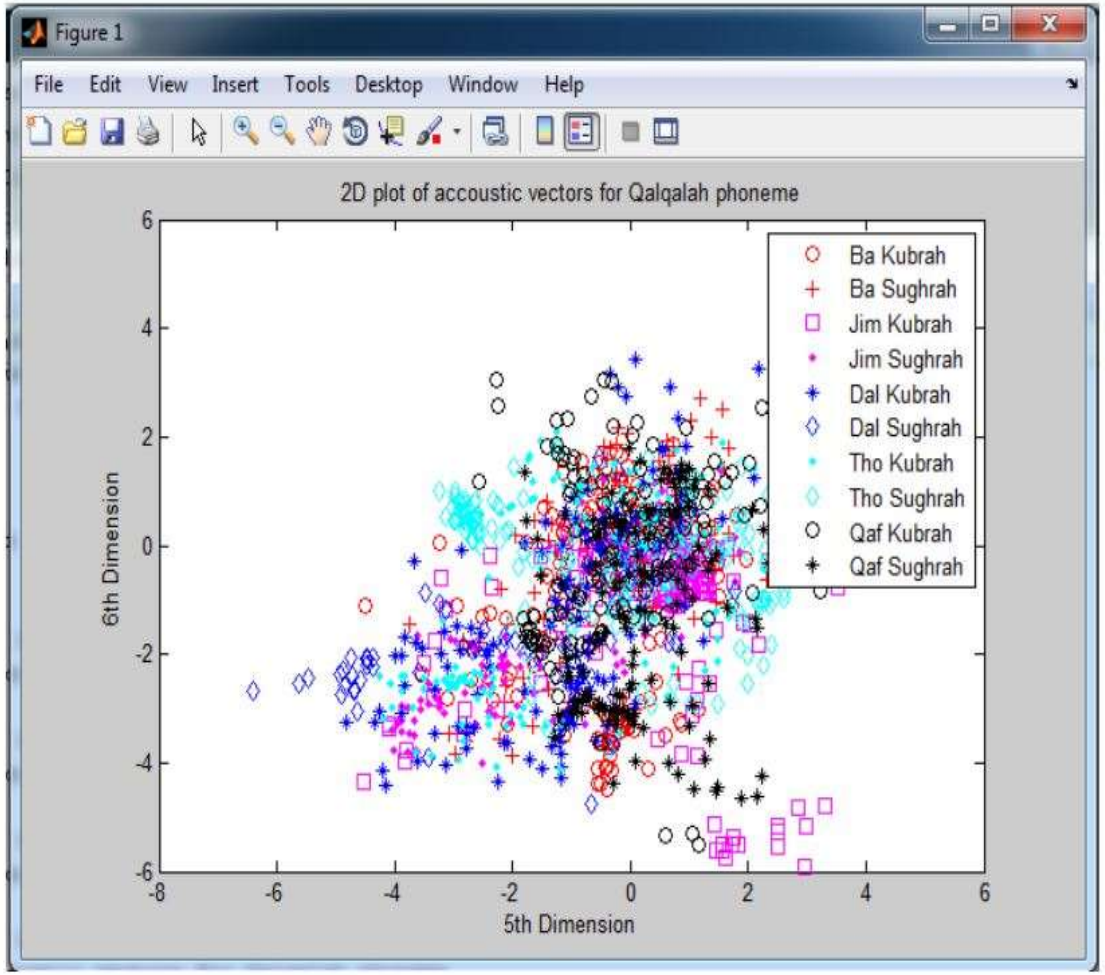


Fig. 6. The 2D acoustic vectors for *Qalqalah* phoneme.

2D VQ codebook :

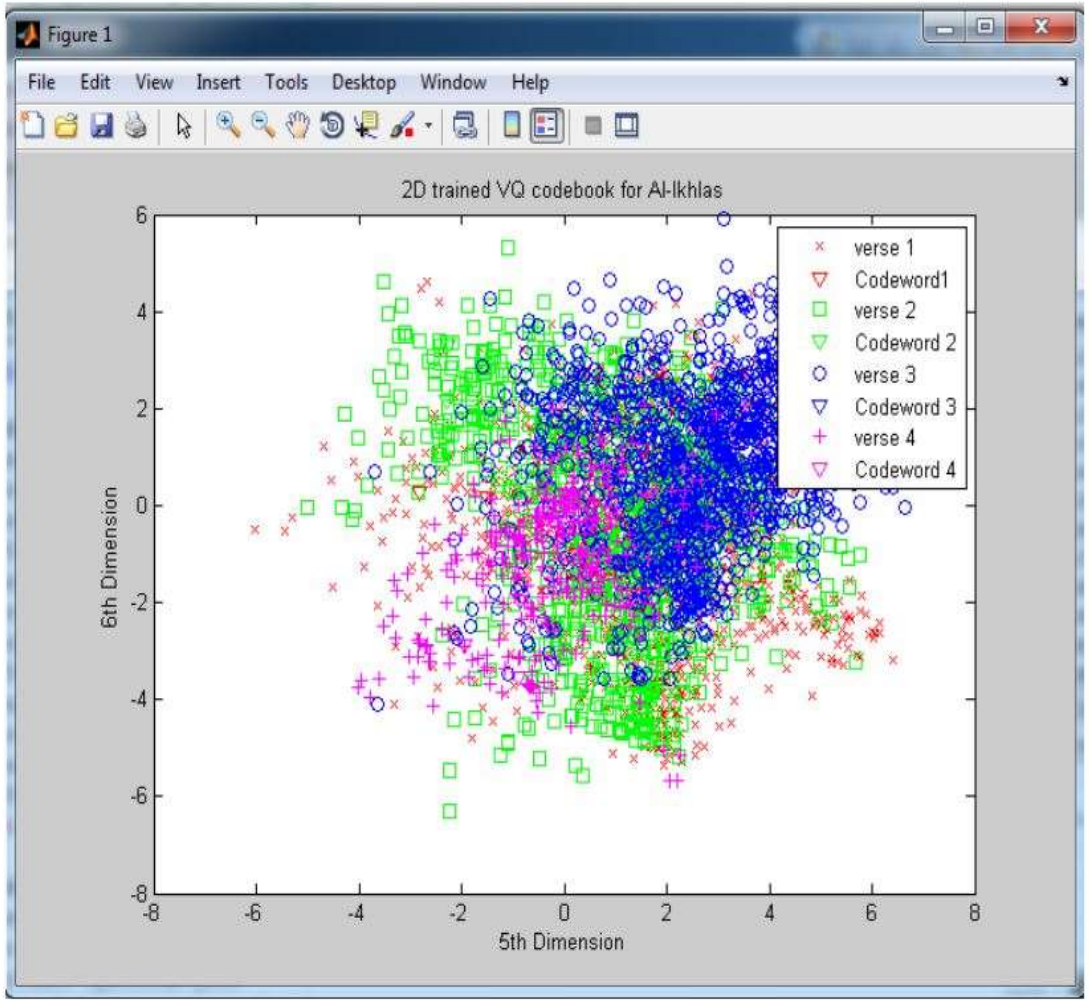


Fig. 7.The 2D VQ codebook for *Al-Ikhlas*.

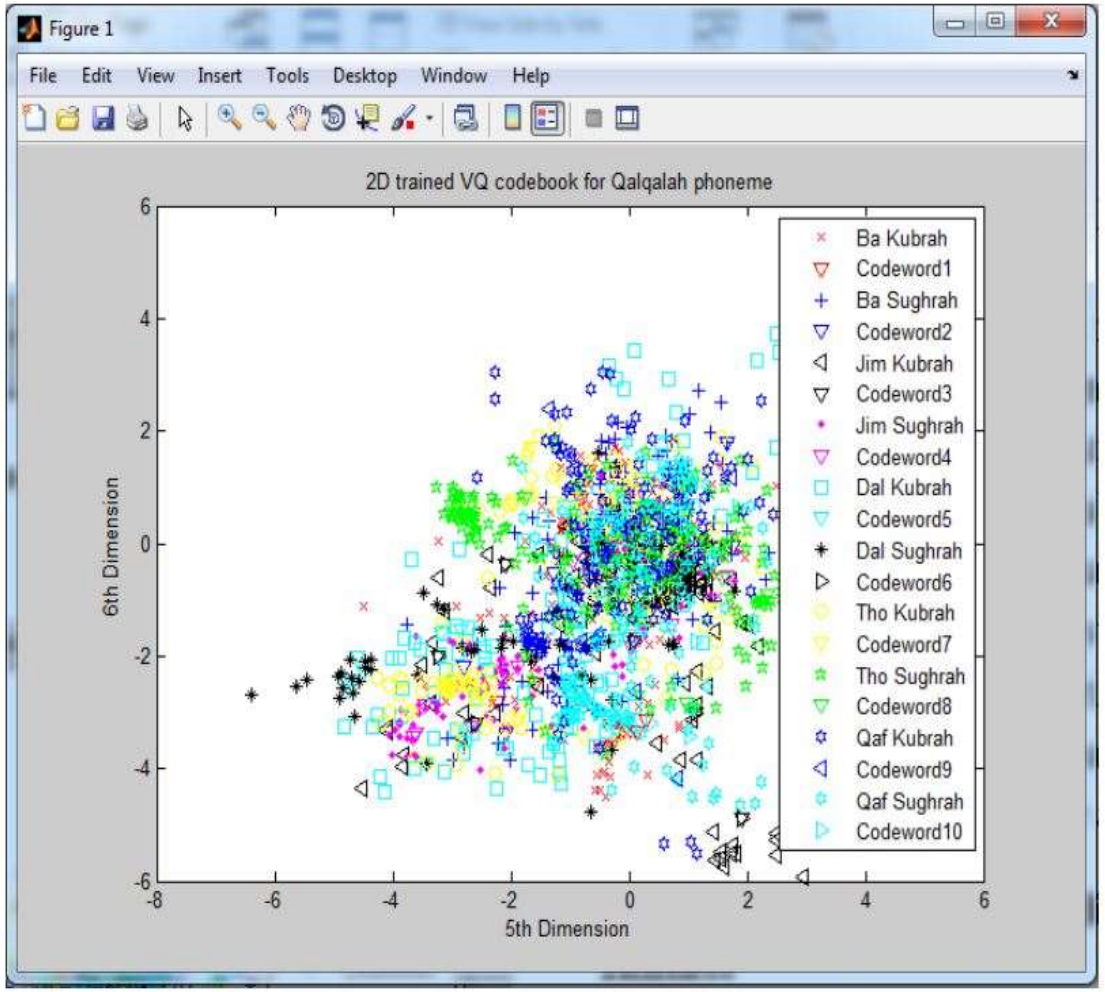


Fig. 8. The 2D VQ codebook for *Qalqalah* phoneme.

Paper s:previous related work

Table 5. Performance of Quranic Recitation using other hybrid methods.

Hybrid Method	Dataset Tested	Accuracy	Real-Time Factor
MFCC and MSE [29]	*Makhraj*	100%	Non Reported
MFCC and MLP [6]	*Tajweed Qalqalah Kubrah*	95-100%	Non Reported
MFCC and HMM [27]	*Tajweed* in Sourate *Al-Fatihah*	86.4 - 91.95%	Non Reported
MFCC-VQ (proposed method)	*Tajweed Qalqalah Sughrah* and *Kubrah* in Sourate *Al-Ikhlas* and *Qalqalah* phoneme	82.1-95%	0.156-0.261
MFCC and ANN [41]	*Tajweed* in Sourate *An-Nas*	72-93%	Non Reported

Paper 5: [Results]

- Faster by 86.928% for male, 94.495% for female and 64.683% for children real-time factor.
- Accuracy achieved was 83.9%, 82.1%, and 95.0%.(for males, females, children)
- Can be used in recognition of Qalqalah Sughrah and Kubrah for males, females, children.
- MFCC-VQ better than the MFCC in terms of speed performance.

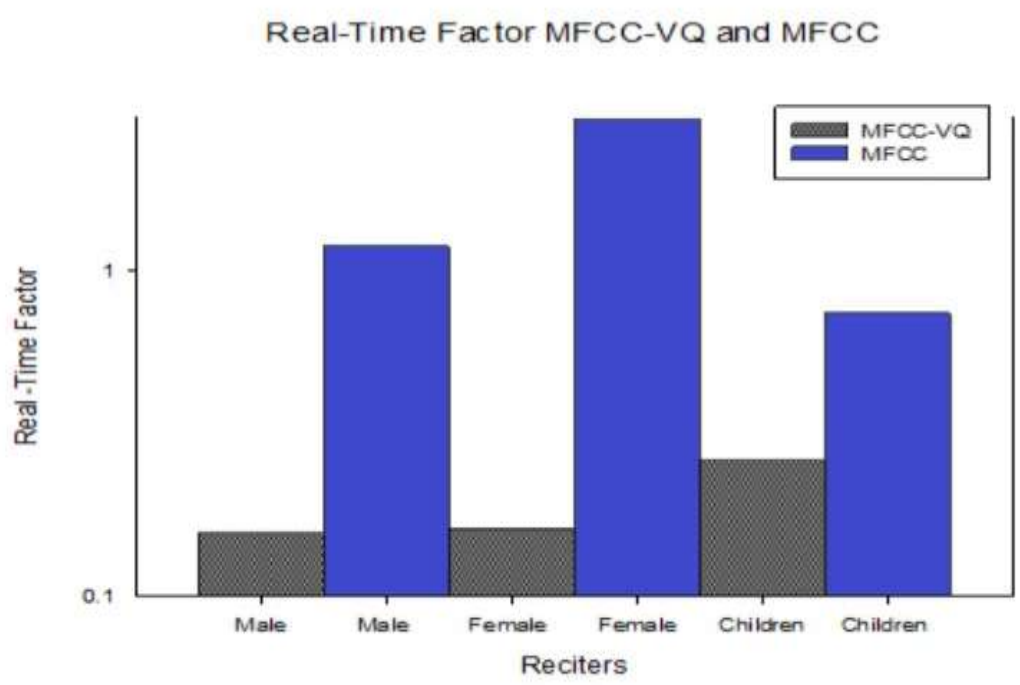


Fig. 9. Comparison graph real-time factor for MFCC-VQ and MFCC.

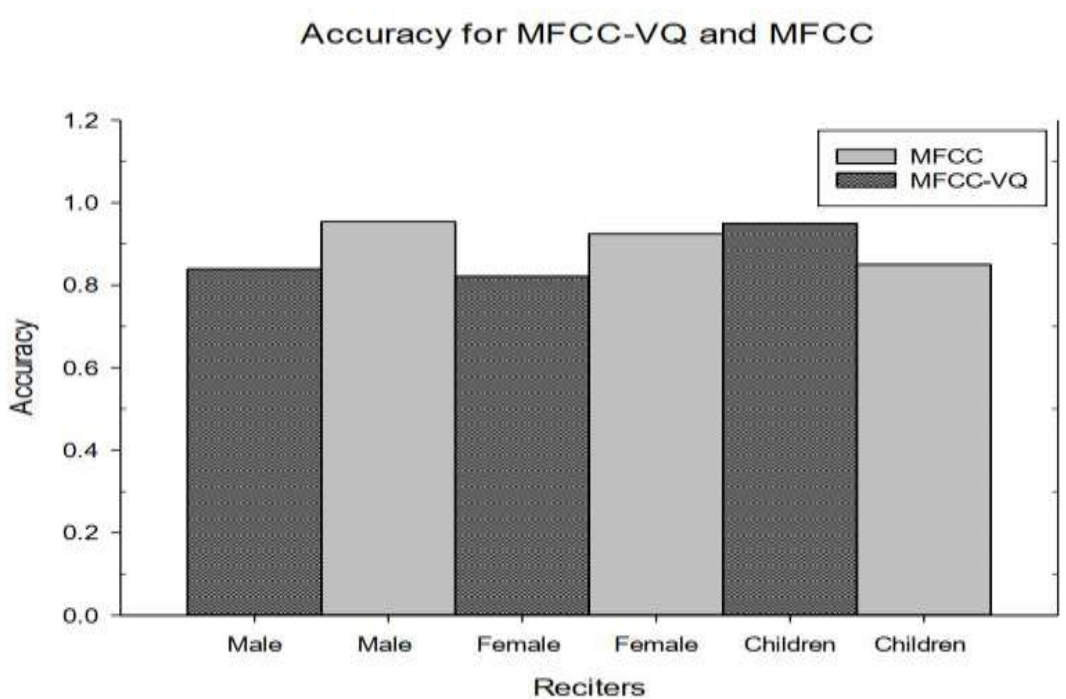


Fig. 10. Comparison accuracy graph for MFCC-VQ and MFCC.

Paper 6:

Speaker-dependent live Quranic verses recitation recognition system using Sphinx-4 framework

- Development of speaker dependent Quranic recitation recognition system.
- Used [CMU] Sphinx-4 based on HMM.
- Published: Dec,2014
- To recognize and evaluate of recitation of some verses of Quran.
- Data: from expert reciters and from users too. [Training Data]
- CMU used on English language so transliteration mechanism for the Arabic language.
- This system tested with 4 different ways Arabic word with Arabic alphabets, transliteration word with syllable, transliteration compound word with syllable, transliteration syllable with syllable.

Paper 6: [Results]

- **Accuracy:**
  - -67% for Arabic word with Arabic alphabets.
  - -96% transliteration word with syllable.
  - -94% transliteration compound word with syllable.

Paper 7:

Automated tajweed checking rules engine for Quranic learning

- Developed an engine for recitation rules of Quran for the purpose of helping students to read Quran well with Tajweed rules.
- Developed software, tested on primary students in Malaysia.
- Provide interactive method of learning.
- The input of the system is the speech signal and phonetic transcription of the speech utterance.
- Students read Quran, their recitation is processed and revised and corrected by the system in real time.
- Used MFCC in features extraction , Hidden Markov Model [HMM] in classification.
- Training Data: [Surat Al-Fatihah]

The whole system:

-Feature vector of output is compared to codebook.

-Score is obtained to evaluate the recitation.

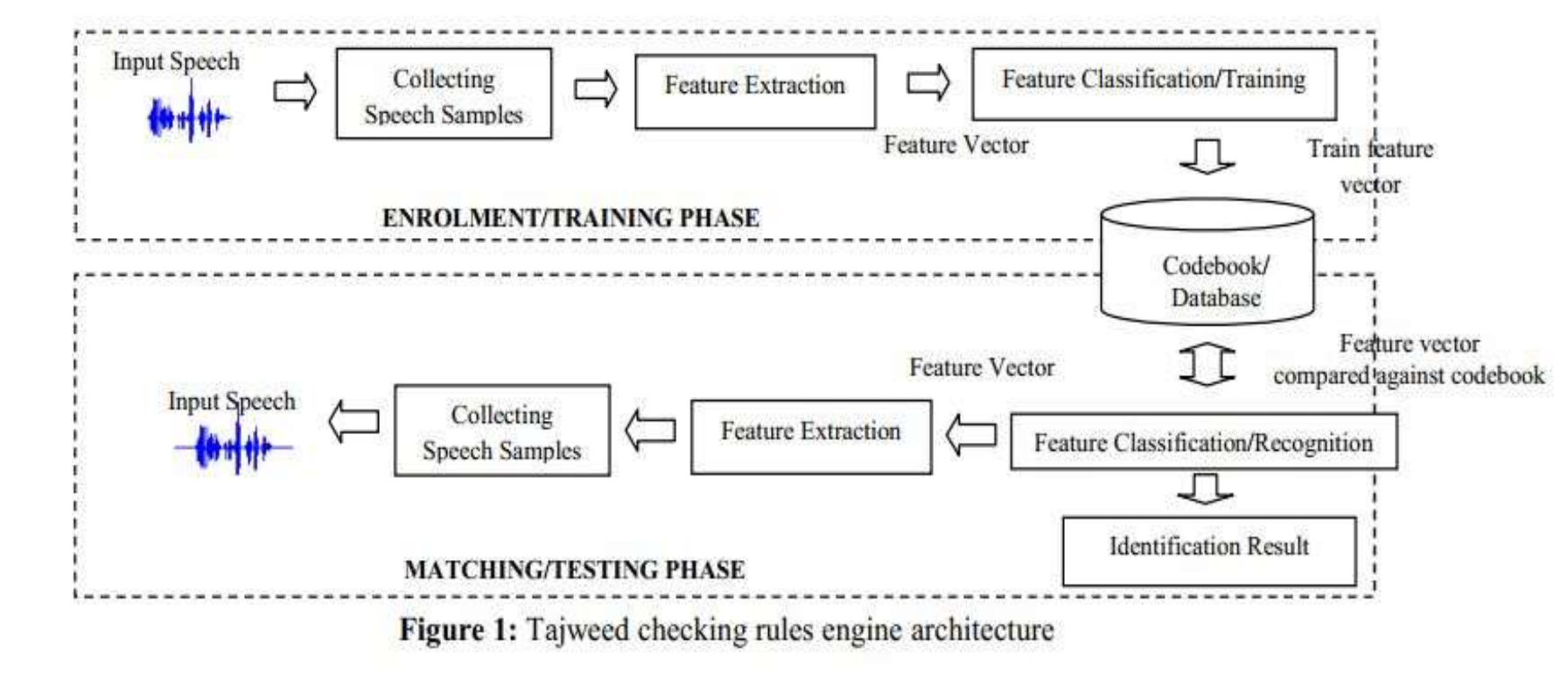


Figure 1: Tajweed checking rules engine architecture

Recognition task:

Two Parts:

1-**Identification:**

Words recognized from observation vector of feature analysis of words.
The word selected which has highest probability, [Maximum Likelihood]

2-**Verification:**

Input feature is compared to stored database and threshold is used to verify if recitation is correct or wrong.

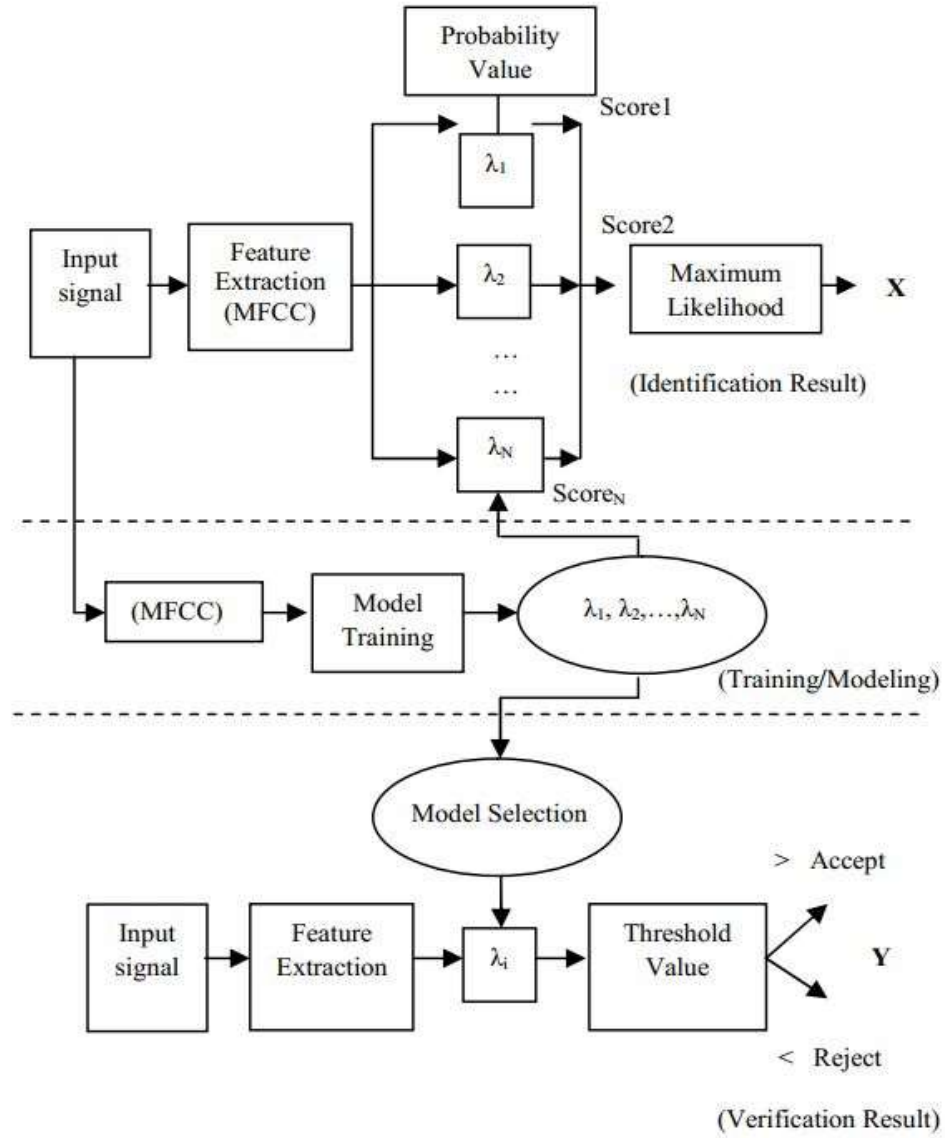


Figure 2: Automated Tajweed Checking Rules engine structure

Paper 7: data

-5 different reciters.

-52 Ayates,82 probable samples of phonemes for all Quranic collected samples.

Table 2: Except from the dictionary of *Sourate Al-Fatihah*

The word in the dictionary (Wave file assigned)	The utterances (Phonemes)	The ayates in Quran
Bismillahirrah manirrahim *(Bismillah.wav)*	*Bismi Llahii Rraohimani Rraohiiim*	بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ
Alhamdu lillahi rabbi alAAalameen *(fatihah1.wav)*	*Allhamdu Lillahhirabbil A'alamiinna*	ٱلْحَمْدُ لِلَّهِ رَبِّ ٱلْعَٰلَمِينَ
Arrahmaanirrahiim *(fatihah2.wav)*	*Alrrahmani Alrraheemi*	ٱلرَّحْمَٰنِ ٱلرَّحِيمِ
Maalikiyawmiddiini *(fatihah3.wav)*	*Maaliki Yawmi Alddeeni*	مَٰلِكِ يَوْمِ ٱلدِّينِ
Iyyakana'Abudu waiyyaka nastaeen *(fatihah4.wav)*	*Iyyaka naA'Abudu waiyyaka nastaAAeen*	إِيَّاكَ نَعْبُدُ وَإِيَّاكَ نَسْتَعِينُ
Ihdinaassiratholmustakiim *(fatihah5.wav)*	*Ihdina Alssiratho Almustaqeema*	ٱهْدِنَا ٱلصِّرَٰطَ ٱلْمُسْتَقِيمَ

Paper 7: [Test/Matching stage]

1-Word[ayates]like-Template:

Extracted features of 8 ayates of *Sourate Al-Fatihah* (compared to the Word-based Templates) is perfectly reached to 91.95%, 8.05% WER

Ayates/Articulation	# of utterances	Correct	Wrong	% Accuracy	% Word Error Rate
بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ	5	5	0	100	0
ٱلْحَمْدُ لِلَّهِ رَبِّ ٱلْعَٰلَمِينَ	5	5	0	100	0
ٱلرَّحْمَٰنِ ٱلرَّحِيمِ	7	7	0	100	0
مَٰلِكِ يَوْمِ ٱلدِّينِ	6	6	0	100	0
إِيَّاكَ نَعْبُدُ وَإِيَّاكَ نَسْتَعِينُ	9	8	1	88.89	11.1
ٱهْدِنَا ٱلصِّرَٰطَ ٱلْمُسْتَقِيمَ	9	9	0	100	0
صِرَٰطَ ٱلَّذِينَ أَنْعَمْتَ عَلَيْهِمْ غَيْرِ ٱلْمَغْضُوبِ	6	4	2	66.67	33.33

2-Phonemes like-Template:

Accuracy : 86%

Table 5: Comparison between correct and incorrect Tajweed rules for ayates "Bismillahir *<rahmaanir>* rahimi"

	Correct Recitation	Incorrect Recitation
Ayates	بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ	بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ
The utterances (Articulation)	Bismillahir **RAHMAANIR** rahimi	Bismillahir **RAHMUUNIR** rahimi
Log-Likelihood (LLR)	**LLR:** 1.0e+003 * Columns 1 through 6 **-0.5685** -0.6033 -0.6398 - 0.6541 -0.6604 -0.7845 Columns 7 through 9 - 0.7968 -0.8684 -0.8995 - 1.0446 -1.0463 -1.1091 Columns 13 through 17 - 1.1624 -1.3030 -1.5521 - 2.1808 -2.2018	**LLR:** 1.0e+003 * Columns 1 through 6 **0.0544** -0.4929 -0.5621 - 0.7123 -0.7422 -0.7777 Columns 7 through 12 - 0.8362 -0.8738 -0.9155 - 0.9279 -0.9294 -0.9670 Columns 13 through 17 - 0.9958 -1.0265 -1.2703 - 1.4974 -2.2708
Tajweed Rules	-	Mad Asli Mutlak

Paper :7 [Results]

- Two references model were developed during this training process, which are ***Word based Model*** and ***Phoneme based Model*** .
- Performance/recognition rate:
  - 91.95% for *Ayates*
  - 86.41% for Phonemes
- Better results in [Ayates] than [Phonemes]:

Might because of the complexity in pronouncing the certain ayates, as well as difficulties in matching and recognizing the exact utterance properly.

Paper 8: Quranic Reciter Recognition: A Machine Learning Approach

- Published:2019,Publishers from colleges in Saudi Arabia
- They used database of 12 reciters of Quran, reading the last 10 Surah of Quran
- 120 Quranic recitations.
- Each reciter represent a class so total classes is 12.
- Audio Representation:1-Analysed in frequency domain 2-Treated as images through spectrogram
- Feature Extraction: 1-MFCC 2- Auto-correlogram
- Classification: Naïve Bayes,J48,Random Forest

THE GENERAL MODEL:

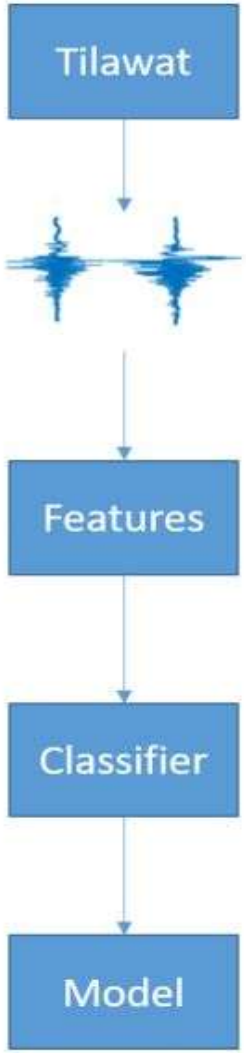


Figure 1. The classification model for Qari recognition

Paper 8: results

- Performance analysis of the **MFCC and Pitch features** with the three classifiers.

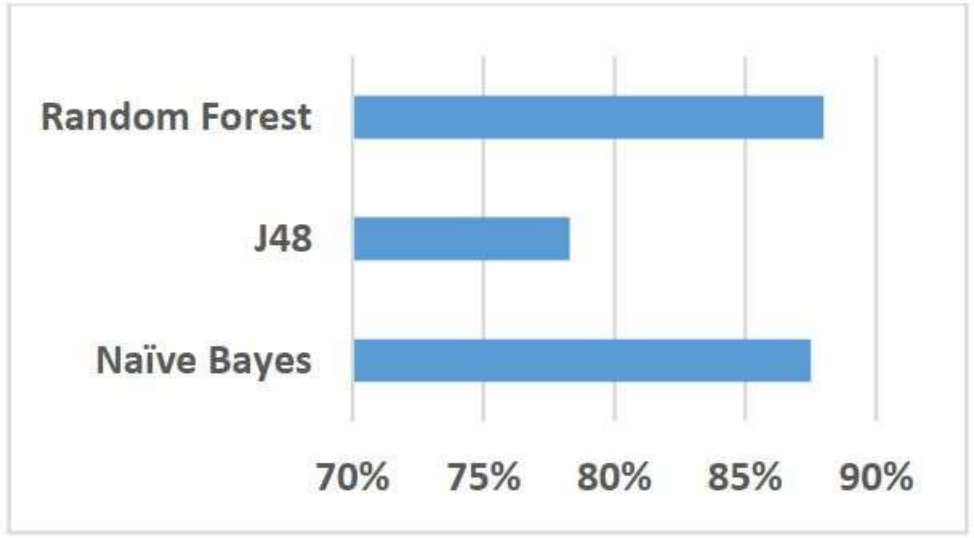


Figure 2. Accuracy of MFCC and Pitch with the three classifiers

Table 1: Performance analysis of the MFCC and Pitch features

Classifier	Accuracy
Naïve Bayes	88%
J48	78%
Random Forest	88%

Paper 8: results [cont.]

- Performance analysis of **the spectrogram-based** recognition in the three classifiers/models.

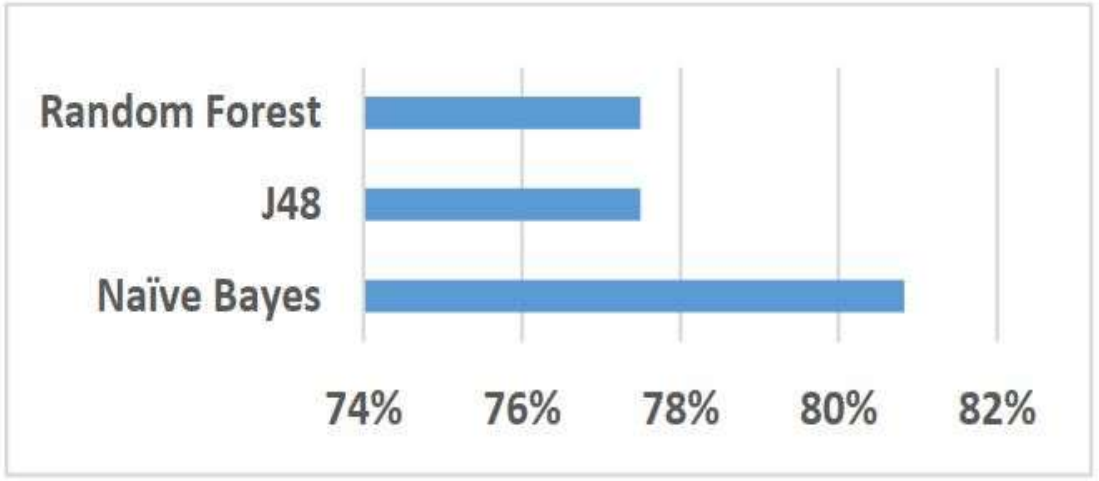


Figure 3. Accuracy of the spectrogram-based recognition models

Table 2: Performance analysis of the Spectrogram features

Classifier	Accuracy
Naïve Bayes	81%
J48	78%
Random Forest	78%

Conclusion:

- Automatic speech recognition is an open area of research now on Arabic language ,specially on Holy Quran.
- Recognition of Quran Recitation is an important thing so more **research and work in this topic is still needed.**
- There are **several previous work in this topic with promising results.**
- Different methodologies, Different models are implemented.
- There are advantages and drawbacks of each models but some of them achieve better results than others.

References:

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