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Automatic Speech Recognition (ASR) Systems for Learning Arabic Language and Al-Quran Recitation: A Review

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Abstract: This paper provides a literature survey about Automatic Speech Recognition (ASR) systems for learning Arabic language and Al-Quran Recitation. The growth in communication technologies and AI (specially Machine learning and Deep learning) led researchers in ASR field to thinking of and developing ASR systems which mimic humans in their understand of natural speech and recognition.

One of the most important applications in ASR is natural language processing (NLP). Arabic language is one of these languages. ASR systems which developed for Arabic language help Arabs and non-Arabs in learning Arabic language and so Al-Quran recitation and memorization in proper way according to recitation rules (Tajweed). This paper concentrate on ASR systems in general, challenges, PROS, CONS, Arabic language ASR systems and challenges faced them and finally Al-Quran recitation verification systems.

1- Introduction:

Automatic speech recognition (ASR) is the ability of a machine or program to identify words and phrases in spoken language and convert them to a machine-readable format or it is transcription of spoken utterance or sentence into readable format by computer [1]. In other words, it is a technology that helps and allows humans to communicate with computer by speech [2].

ASR techniques are used to develop automatic systems that can be used to voice and speech recognition and verification, natural languages learning and processing for different purpose and usage. ASR is still a challenging task due to the high viability in speech signals. For example, speakers may have different accents, dialects, or

pronunciations, and speak in different styles, at different rates, in different emotional states, presence of environmental noise and reverberation.

The goal of ASR system is to accurately and efficiently convert a speech signal into a text message transcription of the spoken words independent of the speaker, environment or the device used to record the speech (i.e. the microphone) [3].

The most important applications of ASR systems are learning of Arabic language (correct pronunciation) and Al-Quranic applications such as verification of Al-Quran recitation and Al-Quran memorization.

Arabic language is an official language in more than 22 countries. Since it is also the language of religious instructions in Islam, it is one of the languages that are often described as morphologically complex and the problem of language modeling for Arabic are multipart by the variation of dialectal.

Verification of recitation of Al – Quran is an important issue because Muslims (Arabs and non-Arabs) must recite Al-Quran correctly by pronounced letters correctly and applying the Tajweed rules (rules governing pronunciation during recitation of the Al-Quran).

As we know that Islam spreading and numbers of Muslims growing up every day and every moments from both Arabs and non-Arabs, so that we must avoid Al-Quran from Change, distortion, corrupted , altered and errors in recitation or writing and this leads to think of developing Computer-Aided Pronunciation Learning System (CAPL) to learn the correct way to recite Al-Quran (applying the Tajweed rules), to correct any mistakes in recitation without teacher and to help Muslims to memorize Al – Quran properly, correctly in easy and fast way.

The rest of the paper is divided into six parts, Section 2 presents ASR systems stages, Section 3 presents Arabic speech sounds and pronunciation, Section 4 explains ASR Systems of Arabic language, related and previous studies of Arabic language and Al-Quran recitation discussed in Section 5 and Conclusion in Section 6.

2- ASR system stages:

ASR process is consist of 4 main stages:

The following is the description of these stages [4]:

- **Pre-processing stage:** This is the first and very important stage. speech signal noise free, Determination of the boundary of each word in speech signal where it begins and where it ends and recognition of organized speech signal are done in this stage.
- **Feature extraction stage**: Discrimination uniquely between words is done in this stage by extracting important information in speech signal. There are many feature extraction methods which can be used to extract important information from speech signal, such as Linear Predictive Coding (LPC), Perceptual Linear Prediction (PLP), Mel-Frequency Cepstral Coefficients (MFCC) and Spectrographic Analysis as mentioned by[5] [6]
- **Training and Testing stage:**
  Training process involves entering new distinct word/s (speech sample/s) to identification system database, this is done by constructing a model of each new word based on the features extracted of each word from the previous stage. In other hand, in testing process the similarity of feature extracted from unknown word and stored model in the database is measured by computing a matching score between the unknown word and the stored one [4].
- **Feature classification and Recognition stage:**
  The classification and recognition is a process of making decision and classifying patterns. There are many techniques used in classification (pattern matching) such as:
    - Hidden Markov Model (HMM).
    - Vector Quantization (VQ).
    - Artificial Neural Networks (ANNs).

3- Arabic Speech sounds and Pronunciation:

Speech sounds are a set of Phonetics which are the pronunciation of words and a set of phonemes which represent speech sound with phonetic symbols [7]. Pronunciation is refers to the way in which we make the sound of words [8].

In Arabic language there are two classes of phonemes, Vowels and Consonant. The Arabic alphabet is composed of 28 letters and 34 phonemes. There are 25 consonants and three vowels. Vowels are three type short vowel signs "Haraka", "Alif, a, Fathah", "Ya, I, Kasra " and "Waw, u, Damma "which are not a part of Arabic alphabet but they are merely oral, long vowels "aa" "ii" and "uu" one of their functions is to slightly lengthened the short vowels which called "maad" and Diphthongs and the rest of the letters are consonants [9].

4- ASR Systems of Arabic language:

People need language tutor to help them learning the correct pronunciation of the language and to correct them when they are wrong, Computer Aided Language Learning System (CALL) such as ASR is playing this role.
ASR technology earned notable success and gave promising results in English language and other languages such as Arabic language. In Arabic language different speakers may pronounced the same word in different ways (pronunciation variability) and mispronunciation of confusable phonemes are some of the difficulties faced ASR systems of Arabic language [10].
Many Arabic language texts are fully diacritized by diacritical marks ("Harakat", Fathah, Kasra and Damma). These diacritics gives the right meanings of the words in phrases and helps in transcription of written text into sounds in both classical Arabic and Modern standard Arabic (MSA) language. Therefor specific pronunciation rules must be followed for diacritized texts specially in Quranic texts.

5- Related and previous studies

There are many studies in the field of ASR for Arabic language and Al-Quran verification systems, these studies helped in learning the correct pronunciation of the Arabic language, recitation of Al-Quran correctly according to Tajweed rules (Tajweed rules ensures that there is no difference in recitation in spite of difference of readers) and verification of the recitation of Al-Quran verses.

5.1 ASR systems of Arabic language:

According to [11] who developed Automatic Arabic Speech Segmentation System which classifying speech into speech regions (vowel letters, consonants letters) and non-speech regions (pause and noise) in a speech signal based on Quranic Arabic (Classical Arabic), the study identifying phoneme boundaries (start and end of phoneme) by using many cues such as zero crossing rate (ZCR), power spectral density (PSD), formant transitions, rhythm of consonants and vowels and vowel duration. ZCR, PSD and formants were generated in numerical format by using Praat tool (speech processing tool). Many experiments done by using different combinations of cues. ZCR and PSD gave best results for phoneme level segmentation. Samples for experiments are recorded in a noise free environment by 8 highly trained speakers in Quranic recitation rules, and each speaker had 2 minutes to recorded recitation. The system accuracy was about 89% for correct segmentation of phonemes level (vowels and consonants).
Another system developed by [12] to generate Phonetic Dictionaries for Arabic language SR system using a rule based technique, the phoneme set used for the experience based on previous Arabic text-to-speech systems experiences [13, 14 and 15], and on the corresponding phoneme set in the English ASR [16]. A set of rules developed by using these phonemes set to generate the pronunciations (how the words or letters actually spoken) for Arabic words and letters automatically. Rules are provided for each Arabic letter available in the Unicode listing. Rules defined were covered all possible letters (Consonants, Semi-vowels, Tanween) and a lot of these rules match the letters to their corresponding phonemes correctly, but there were letters required additional rules such as vowels. Arabic broadcast news was used to train the system which consist of 249 news stories (5.4 hours of speech) and the test was done using the remaining set of the broadcast news (1 hours of speech). CMU toolkit was used to build a statistical model for the system, system accuracy was 92.84% for recognizing words with WER about 9.0%
A hybrid method implemented by [17] for continuous Arabic speech recognition by applying SVM (Support Vector Machine), HMM (Hidden Markov Models) and MLP (Multi-Layer Perceptron) approaches to categorize Arabic vowels to short vowels and long vowels. The system trained with 620 statements for six speakers (3 males and 3 females).
The study proved that the hybrid technique SVM/HMM was the best and more efficient technique than HMMs and the hybrid technique MLP/HMM, the results obtained by the system based on triphones was 74.01% for

SVM/HMM hybrid model, 72.39% with MLP/HMM and 64.68% for HMMs. The speech recognizer was evaluated with ARABIC_DB corpus and performs WER at 11.42% as compared to 13.42% by triphones mixture-Gaussian HMM system and 11.92% by MLP/HMM hybrid model.

A review paper by [18] presents different approaches that ASR systems use to recognize speech such as Acoustic phonetic approach which is a rule-based approach deals with sounds that transmit from speaker to listener and gives an opportunity to study the nature of speech signal from different sounds. Because expressing the phonatic rules is difficult the performance of this Approach is poor and a Pattern Recognition Approach which divided in to tow steps training of speech patterns and recognition of pattern using pattern comparison. The study mentioned some difficulties of ASR systems as speaker variability and channel variability (microphone and background environment).

There are many problems facing Arabic Speech Recognition systems, as example due to differences of dialects (words are pronounced differently) more confusion will be added to the Arabic Speech Recognition system. Arabic phonetics, diacritization problem which cause more ambiguities for pronunciations and meanings due to non-diacritized Arabic scripts, grapheme-to-phoneme relation, absence of short vowels in written Arabic text and morphological complexity are the main problems of Arabic Speech Recognition that mentioned by [19] [20] [21].

A self-learning mobile application created by [22] which can detects mispronounced words and helps to correct pronunciation for Arabic language and also helps users to learn Al- Quran recitation. MFCC was used as a feature extractor and DWT used to measure similarity between extracted features and stored one (feature matching). The last 20 verses of Quran were used for system experiments. Two experiments was done to test system accuracy, the second experiment (using modified version of DWT algorithm) was more accurate than the first one. Each word used in the system was recorded about 10 to 15 times by different users and saved to system database and the similarity measured between the user spoken word and the recorded one to determine which word was pronounced correctly and which was wrong pronounced, finally the experiments concluded that the MFCC method and DWT algorithm were robust in features extraction and features matching respectively.

The system developed by [23] which constructs and implements Arabic phonemes recognition system to recognize classical Arabic letters sounds. The speech signals for the system were collected from Holey Quran (Holey Quran reciters) because all classical Arabic sounds (31 Arabic phonemes) are found in it, and the system implemented using HTK and 16 Gaussian Mixture Models (GMMs). The overall system accuracy was 98% and this accuracy enhanced by around 1% by implementing HSMM (hidden semi-Markov model) instead of standard HMM to reach 99%. The main contribution of this system is it's help on learning Arabic language and recitation of Quran in easy and a fast way and in another side has drawback is that it tested on a small number of verses.

Improving performance of Arabic language speech recognition system by exploiting phonological properties of the Arabic language was system implemented by [24]. The objective of this study was to find solution of within-word and cross-word pronunciation variation problem in MSA speech because this problem leading the recognition engine to misclassifying speech. Context sensitive phonetic transcription was generated using a grapheme-to-allophone algorithm. Instead of predefined dictionary the study predicted allophonic variations of speech by using a set of language-dependent grapheme-to-allophone rules. The dataset size is around 2.13 hours and was generated manually by 23 Arabic native speakers. The experiments of the system were done by 3 developed systems, the first system developed using a fixed-dictionary with a single pronunciation for each word, second system uses a multi-entry pronunciation dictionary that gives different pronouncing of the words and the third system uses generated transcription. The performance of the system was tested by comparing the performance of these 3 systems and the result obtained was 63.68%, 69.1% and 71% respectively. The system experiments confirms that using generated transcription dictionary was the best one than the single pronunciation dictionary and multi-entry pronunciation dictionary.

5.2 ASR systems of Al-Quran recitation

Here is some related works of Al-Quran recitation verification systems that introduced by many researchers to overcome challenges faced Al_Quran recitation. However, they do not attempt to cover the verification of Al-Quran recitation for Arabs and non-Arabs to all Tajweed rules, which is an important issue for reciting Al-Quran in proper way according to Tajweed rules. Some of difficulties in the traditional teaching of Al_Quran recitation (face to face teaching) mentioned by [25] :

- One teacher teaches many students, so he/she cannot care to every student.
- Students find difficulties in asking teacher due to shyness and fear.
- Teachers don't have full information about students background.

- Difficulties and time shortness in accessing Tajweed books.
- Material is delivered with same teaching method for all students irrespective of various altitudes of understanding.
- Not all learners understand with the same style of teaching, some are visual learners, others are audio learners.
- Non availability of teachers in every time and everywhere.

Due to all these problems researchers in the field of ASR systems introduced many available automated system that help users to verify their recitation in easy and faster way in any place at any time.

The work done by [25], Tutoring system helps in teaching and learning Tajweed rules, the main objective of this study is to overcome the difficulties faced in learning Tajweed, this system covered the first level of Tajweed with Rewaya Hafs from 'Aasem. The system tested by 2 group of users, students and teachers, these groups reported that the system overcome most problems of traditional teaching, the average satisfaction of teachers and students was 94.5 % and 94 % respectively

The work that done by H. Tabbal [26], an Automated delimiter, which extracts verses from the audio files, this research taking into account the special ways to recite AL-Quran with Tajweed rules, the goal of this thesis was to achieve new approach that uses speech recognition techniques to find and delimit verses in audio recitations automatically regardless of the reciter. The study use the Sphinx Framework as a research environment which is based on HMMs and used the SphinxTrain as a tool to develop the acoustic models. The feature extracted to the system by using MFCC algorithm, the Sphinx engine and acoustic models were used for recognition process.

Study done by [27], Computer Aided Pronunciation Learning (CAPL) system HAFSS© for teaching Arabic pronunciations to non-native speakers and also to teach correct recitation of Al-Quran, this system is a helpfully system because it gives the user a suitable feedback of his/her errors in recitation if found, in addition to how can correct that errors.

The HAFSS© system architecture consists of:

- **Verification HMM models:** Is the acoustic HMM models for the system.
- **Speaker Adaptation:** Is used to adapt acoustic models to each user acoustic properties in order to boost system performance.
- **Pronunciation hypotheses generator:** This generates all possible pronunciation variants to test them against the spoken utterance.
- **Confidence Score Analysis:** analyzes the scores of the best decoded word sequence to determine the result
- **Phoneme duration analysis:** Recitation Rate Normalization (RRN) algorithm developed to overcome recitation speed variability by using phone duration to determine if phonemes have correct lengths or not
- **Feedback Generator:** produce useful feedback messages to the user by analyzing results from the speech recognizer. A database of 663 rules of pronunciation errors was connected with 2 other database to generate the suitable feedback (readable feedback or audible feedback) and to connect the recitation error with correct recitation rule. The system evaluated according to system judgment accept correctly pronounced phones or report same pronunciation error as the human expert. The diagram below demonstrate the architecture of HAFSS©

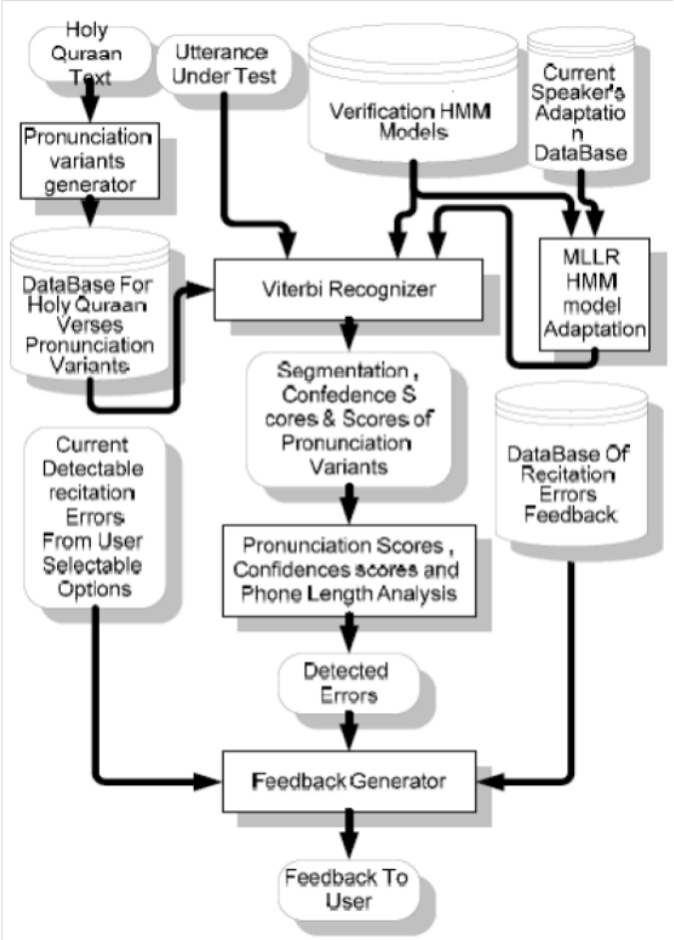

Fig 1: Architecture of HAFSS©

The study by S. Hamid [28] who develop an ASR system by implementing Computer-Aided Pronunciation Learning (CAPL) System. This system used many algorithms to detect and cover all user mistakes in recitation and gives a feedback to the user by the mistakes and the type of that mistakes and also give him/her the correct recitation. A Recitation Rate Normalization (RRN) algorithm was used to overcome the variability in recitation speed which may mislead the phone duration classification module, and HMM-based acoustic model speech recognition engine was implemented to detect the types of recitation mistakes and to segment input utterance, this system reducing the syllable error rate less than 5% for more than 50% of the speakers. The system was developed to Arabic language speakers only and those who have previous knowledge about recitation rules. Another related work done by Sherif, M. A., Samir, A., Khalil, A.H. and Mohsen, R., CAPL for Al-Quran recitation learning [29], which introduced to enhance the (CAPL) system HAFSS© which was developed for teaching Holy Qur'an recitation rules and Arabic pronunciations to non-native speakers. The verification done by using HMMs, the MLLR techniques used to increment the system performance by adapting the acoustic models. The system was time consuming process because the baseline system used all data collected from certain user to create the new transformation. M. S. Abdo, A. H. Kandil, A. M. El-Bialy, S. A. Fawzy [30], introduced system to enhance usability of CAPL system for Al-Quran Recitation Learning focused on detection of the non-proper pronunciation of a chosen set of uttered letters, new approach developed (MFCC) for automatic segmentation of the phonetic unit ,also two algorithms applied, the first for verification of the speech phonetic unit that have an uttered recitation rules and the second was for automatically detecting the phonetic unit from the input utterance. The system accuracy was 100% in distinguishing between correct recitation and predictable errors.

The research that done by Hamid, S. E., and Rashwan, M. [31], which was introduced for Automatic Diagnosis of Pronunciation Errors it was use CAPL system with HMMs to generate the most probable pronunciation error hypotheses to test them against the spoken utterance from the user. HMMs was used as a detection tool for errors

types. The system achieved good accuracy and less error rate. Focusing on Arabic speakers only was the limitation of this system.

Automated Tajweed Checking Rules Engine for developing Quranic recitation with Tajweed rules was system introduced by N. J. Ibrahim [32], to support Quranic learning process in effective and attractive way. This engine implemented and tested with the j-QAF students at primary school in Malaysia. MFCC algorithm used as feature extraction technique and HMMs used as a classifier. The speech samples were collected from 5 different reciters and saved as (.wav) files. The input of the system was the speech signal and phonetic transcription of the speech utterance. The recognition rate was 91.95% (ayates) and 86.41% (phonemes), after been tested on Sourate Al-Fatihah. The advantages of this engine is that it can help in learning and reciting Al-Quran in a proper way without a teacher. However this engine was focused on one Quranic chapter (Sourate Al-Fatihah).

The proposed study by Ismail, A., Idris, M. Y. I., Noor, N. M., Razak, Z., & Yusoff, Z. [33], for speech recognition, which introduced Checking Tool for Tajweed which concentrated on the Qalqalah Kubrah and Sughrah Tajweed rule for each (ق ,ج ,ب ,د ,ط) Qalqalah letters by using hybrid algorithm Mel-Frequency Cepstral Coefficient and Vector

Quantization (MFCC-VQ). The MFCC has been used as feature extraction techniques that convert voice signals to acoustic feature vectors and Vector Quantization (VQ) used as data reduction technique to reduce the data and this lead to speeds up the system by reducing the computational time. The dataset collected by recording recitation from 45 reciters in three categories of reciters which are 20 males, 20 females and 5 children. The study observed that the speed performance of the hybrid algorithm MFCC-VQ is better than conventional MFCC by 86.928% for male, 94.495% for female and 64.683% for children. The study compared between hybrid algorithm MFCC-VQ and conventional MFCC and concluded that the MFCC-VQ was better in term of speed performance. However the study focused on Sourate Al-Ikhlas and Qalqalah phoneme only.

A new application of recitation verification of Al-Quran based on correct makhraj, introduced by A. Wahidah and M. Suriazalmi [34], as a new way to learn reciting Al-Quran in proper way and to reduce the duration time of learning from the expert. To obtain the correct makhraj the system used combination of the sound of hijaiyah letter (there is 29 basic Hijaiyah letter used in the Holy Quran) as the input data. The input speech was taken from people who are expert in makhraj utterance between the ages of 21 and 23, voices has been saved in (.wav) files by using Audacity Version 1.3 Software . Mel Frequency Cepstrum Coefficient (MFCC) used as feature extraction technique and Mean Square Error (MSE) used as a pattern matching technique. The system used False Reject Rate (FRR) and Wrong Recognition (WR) to measured the accuracy to compute system performance The system performance was 100% accuracy which is high accuracy. However the system focused on recitation based on Rasm 'Uthmani.

An interactive multimedia system Implemented by [35] to learn Al-Quran recitation correctly (according to Tajweed rules) and to overcome learning process problems of Al-Quran recitation (limited time and limited number of teachers). The system consist of 3 levels: correction in makhraj(Hijaiyah letters), law of recitation and combination of recitation law and correction in makhraj/pronunciation. MFCC was used as feature extractor. The accuracy achieved by the system was 90%, 70% and 60% for the three levels respectively.

Review paper of Al-Quran recitation verification automatic systems was mentioned by [4]. The paper described speech recognition systems and its phases (Pre-processing, Feature Extraction, Training and Testing and Features Classification (Pattern Recognition) and structure of Al-Quran recitation verification automatic systems in details (as example Verification HMM models, confidence Score Analysis and phoneme duration analysis.). Also the paper mentioned some systems that helped users in learning, memorizing and verifying Al-Quran recitation such as E-Hafiz system. The paper also presented a proposal for an automated system to verify the reading of the Holy Quran correctly. This system will use MFCC for extracting features and HMMs for recognizing and matching features which are robust technologies in Arabic speech recognition.

Lip speech recognition system introduced by [36], depends on a lip movement during pronunciation of Arabic letters to recognize speech without hearing.

The system compare lip movement between expert reciter and novice reciter to determine if novice reciter pronunciation was correct or not. High speed camera was used to record the data from expert reciter for 4 times (28 alphabets of Al-Quran) in audio visual studio room at University of Malaysia (IIUM). Width and height of the lips were used to extract features of each frame to extract relation between them to determine the position of the mouth during pronouncing letters which categorized in four groups (Normal, Agape, Open and Stretched).

Graph of lip movement and position of the mouth during recitation of the expert reciter was used as model reference of the system and the system tested by comparing between the two graphs (expert graph and novice graph) to check if the pronunciation was correct or not. Also the study presents that the pronunciations of Quranic letters rely on two major things: points of articulation and attributes (Sifaat) of the letters. The study explained the main

places of articulations in the vocal tract: empty space in the mouth and throat, the throat, tongue, two lips and the nasal passage, There are difficulties in the pronunciation of letters that share the same point of articulations or its articulations are close to each other but these letters can be differentiated by attribute (Sifaat) of these letters.
The below diagram shows the articulation points and the alphabets that are related to these articulation point.

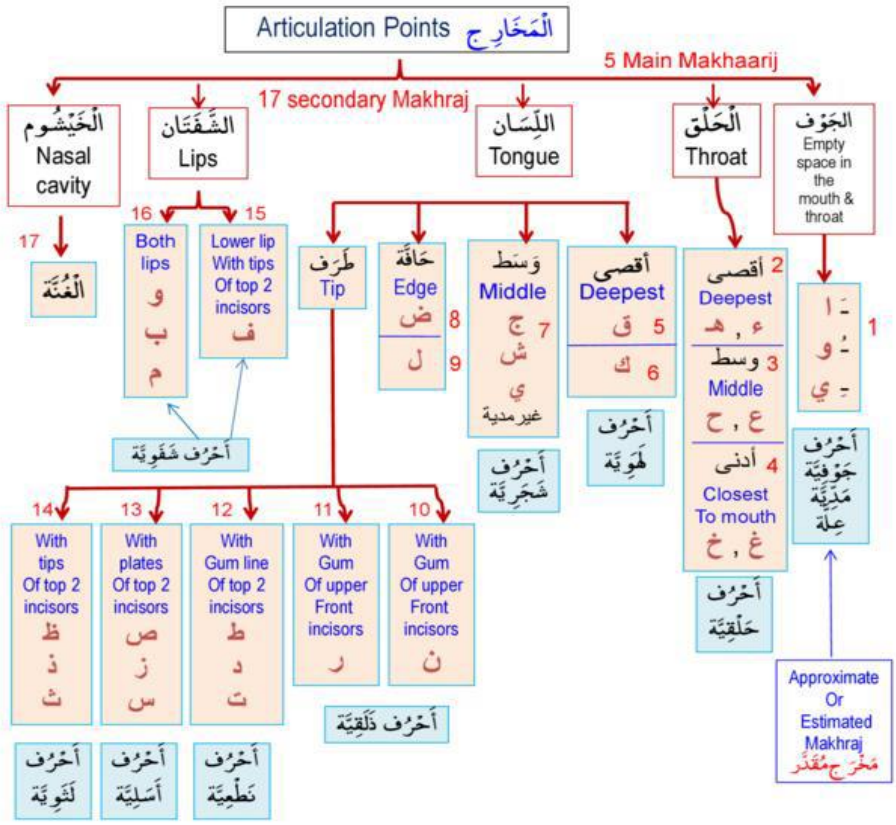

Fig2: Articulation points and the alphabets that are related to each articulation point

Correctness of user recitation automatically according to Tajweed rules was a system implemented by [37] to overcome the limitation of individual learning. The system was based on a CMU Sphinx tools which is an open-source tool, due to its flexibility in creating pronunciation dictionary for Arabic letters. The acoustic model for the system built by 10 reciters for two chapters of Al- Quran. HMM which is robust technology was used to extract features from wave signals, these input signals were decoded in 3 parts, acoustic model part, language model part, which created using Quranic text, and the pronunciation dictionary part. The system accuracy was calculated by aligning the identified words against the correct word of verse.

6- Conclusion

This paper has addressed ASR system stages, sounds and Pronunciation of Arabic language and previous studies of ASR systems of Arabic language and
Al-Quran recitation teaching, learning, memorization and verification and difficulties in the traditional teaching of Al_Quran recitation.
Muslims are required to recite Al-Quran based on proper pronunciation and Tajweed rules. This is because, even a little difference of sound in an Arabic word can lead to a different meaning of the word. Nowadays, there are several Quran learning software available in the market. Using these software, user only can listen and learn the correct pronunciation of the Al-Quran, but their pronunciation and recitation cannot be corrected like a teacher does, because they themselves sometimes cannot detect their mistakes in recitation.

References

[1]. Stuckless, R. (1994). "*Developments in real-time speech-to-text communication for people with impaired hearing*". In M. Ross(Ed.), Communication access for people with hearing loss (pp.197-226). Baltimore, MD: York Press.

[2]. Alsabaan, M. (2015). "*Pronunciation support for Arabic learners*". (Doctoral dissertation). Retrieved from https://www.escholar.manchester.ac.uk/api/datastream?publicationPid=uk-ac-man-scw:263831&datastreamId=FULL-TEXT.PDF

[3]. http://www.docsoft.com/resources/Studies/Whitepapers/whitepaper-ASR.pdf

[4]. Abdou Sherif Mahdy and Ahmed Ayat Hafzalla. "*Verification System for Quran Recitation Recordings*". International Journal of Computer Applications (0975 – 8887) Volume 163 – No 4, April 2017

[5]. M. Ursin (2002). "*Triphone Clustering in Finnish Continuous Speech Recognition*." Master Thesis, Department of Computer Science, Helsinki University of Technology, Finland

[6]. Ammar Mohammed 1*, Mohd Shahrizal Bin Sunar 2, " *Quranic Verses Verification using Speech Recognition Techniques*" Jurnal Teknologi (Sciences & Engineering) 73:2 (2015), 99–106.

[7]. Speech and Language Processing / Daniel Jurafsky, James H. Martin, September 1999

[8]. https://www.englishclub.com/pronunciation/what.htm

[9]. http://www.assidq.org/durusulQuran/articles/vowels-2.htm

[10]. H. Satori, M. Harti, and N. Chenfour. "*Introduction to Arabic Speech Recognition Using CMUSphinx System*". In Proceedings of Information and Communication Technologies International Symposium (ICTIS07), pages 115–139, Morocco, 2007.

[11]. Muhammad Jamil Anwar, M.M.Awais, Shahid Masud, and Shafay Shamail "*Automatic Arabic Speech Segmentation System*"

[12]. Ali, M., Elshafei, M., Alghamdi, M., Al-Muhtaseb, H., & Al-Najjar, A. (2008). "*Generation of Arabic phonetic dictionaries for speech recognition*". In The 5th international conference on innovations in information technology, United Arab Emirates, December 2008.

[13]. M. Elshafei Ahmed, "*Toward an Arabic Text-to-Speech System*", *The Arabian Journal of Science and Engineering*, Vol. 16, No. 4B, pp.565-583, 1991.

[14]. Mansour Alghamdi, Husni Almuhtasib, Mustafa Elshafei, "*Arabic Phonological Rules*", *King Saud* University Journal: Computer Sciences and Information. Vol. 16, pp. 1-25, 2004.

[15]. Moustafa Elshafei, Husni Almuhtasib and Mansour Alghamdi, "*Techniques for High Quality Text-to-speech*", Information Science, 140 (3-4) 255-267, 2002

[16]. Carnegie Mellon University. CMU pronouncing dictionary. http://www.speech.cs.cmu.edu/cgi-bin/cmudict

[17]. Zarrouk, E., Ayed, Y. B., and Gargouri, F. 2014. "*Hybrid Continuous Speech Recognition Systems By HMM, MLP and SVM: A Comparative Study*". International Journal of Speech Technology.

[18]. Swati Patel and Nita Lokwani, "*Achieving Security Via Speech Recognition*", International Journal of Information Sciences and Techniques (IJIST) Vol.6, No.1/2, March 2016

[19]. Elmahdy M, Gruhn R et al (2009). "*Modern standard Arabic based multilingual approach for dialectal Arabic speech recognition*". In: Eighth international symposium on natural language processing, 2009. SNLP'09

[20]. Farghaly A, Shaalan K (2009). "*Arabic natural language processing: challenges and solutions*". ACM Trans Asian Lang Inform Process 8(4):1–22

[21]. Lamel L, Messaoudi A et al (2009). "*Automatic speech-to-text transcription in Arabic*". ACM Trans Asian Lang Inform Process 8(4):1–18

[22]. A. BASSEL, K. MOUHAMAD, A. AMMAR and A. RAMA, 2017. "*Building An Assistant Mobile Application For Teaching Arabic Pronunciation Using A New Approach For Arabic Speech Recognition*", Journal of Theoretical and Applied Information Technology Vol.95. No.3

[23]. Mohamed O.M. Khelifa, Y.O.M. Elhadj, Y. Abdellah and M. Belkasmi, "*An Accurate HSMM-Based System For Arabic Phonemes Recognition*," in proc. of The IEEE Ninth International conference on Advanced Computational Intelligence (ICACI 2017), Feb. 2, 2017, Doha, Qatar.

[24]. Alsharhan E, Ramsay A (2017), "*Improved Arabic speech recognition system through the automatic generation of fine-grained phonetic transcriptions*". Inf Process Manag**.**

[25]. Akkila, A. N., & Abu-Naser, S. S. (2018). "*Rules of Tajweed the Holy Quran Intelligent Tutoring System*". International Journal of Academic Pedagogical Research (IJAPR), 2(3), 7-20.

[26]. Tabbal, H., El-Falou, W. & Monla, B. Analysis and Implementation of a - "*Quranic" verses delimitation system in audio files using speech recognition Techniques*".in Proceeding of the IEEE Conference of 2nd Information and Communication Technologies, 2006. ICTTA '06. 2006.

[27]. Abdou, S. M., Hamid, S. E., Rashwan, M., Samir, A., Abd-Elhamid, O., 567 Shahin, M., Nazih, W., Sep. 2006. "*Computer aided pronunciation learning system using speech recognition techniques"*,18accepted manuscript 568. In: Proceedings of Interspeech 569 2006 - ICSLP, 9th International Conference on Spoken Language Process- 570 ing. Pittsburgh, PA, U.S.A., pp. 849–852.

[28].S. Hamid (2005). "*Computer Aided Pronunciation Learning System using Statistical Based Automatic Speech Recognition*". PhD thesis, Cairo University, Cairo, Egypt.

[29]. Sherif, M. A., Samir, A., Khalil, A.H. and Mohsen, R. 2006, "*Enhancing Usability of CAPL system for Quran Recitation Learning*," INTERSPEECH 2007, Antwerp, Belgium, 27-31 August

[30].M. S. Abdo, A. H. Kandil, and S. A. Fawzy, "Applied to Chosen Quran Sounds," pp. 6–9, 2010.

[31]. Hamid, S. E., and Rashwan, M., "*Automatic Generation of Hypotheses for Automatic Diagnosis of Pronunciation Errors*" Proceedings of NEMLAR International Conference on Arabic Language Resources and Tools, pp. 135- 139, Sep. 22-23, Cairo, Egypt, 2004.

[32].N. J. Ibrahim "*Automated tajweed checking rules engine for Quranic learning* ".2013

[33]. Ismail, A., Idris, M. Y. I., Noor, N. M., Razak, Z., & Yusoff, Z. (2014). *MFCC-VQ Approach for Qalqalah Tajweed Rule Checking.* Malaysian Journal of Computer Science, 27(4).

[34].A. Wahidah and M. Suriazalmi, "*Makhraj recognition using speech processing*," Comput. Converg. Technol. (ICCCT), 2012 7th Int. Conf., pp. 689–693, 2012.

[35].B.Putra , B.T. Atmaja , D.Prananto, "*Developing Speech Recognition System for Quranic Verse Recitation Learning Software*'', International Journal on Informatics for Development (IJID), Vol. 1, No. 2, 2012.

[36]. Tareq Altalmas et al. "*Lips Tracking Identification of a Correct Pronunciation of Quranic Alphabets for Tajweed Teaching and Learning"* IIUM Eng. J. vol. 18 no. 1 pp. 177-191 2017.

[37].A. Al-Baker, A.Basuhail. "*ASR for Tajweed Rules: Integrated with Self-Learning Environments"* I.J. Information Engineering and Electronic Business, 2017, 6, 1-9.

