Evaluation of Quran Recitation via OWL Ontology Based System

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Abstract: *The Linguistic miracle in the Holy Quran leads to many challenges in Automate Quran recitation evaluation. This paper considers one of suggestions of how natural language processing can benefit from using ontology. In this paper, we proposed a general automatic system to evaluate Quran recitation according to Hafs reading. That is via integration the ontology based as artificial intelligent knowledge representation method and Automatic Speech Recognition (ASR) technology as a way of interaction with computer. Our proposed system solves the problem of evaluating all intonations (Tajweed) in the same time in addition to evaluate set of Quran segments in the wright arrangement of reading. The system uses Mel-Frequency Cepstral Coefficients (MFCC) and Vector Quantization (VQ) respectively in feature extraction and dimension reduction on Arabic speech. Also, we construct Quran ontology based for Quranic speech and integrate it with information retrieval system. Quran ontology based is the first version to merge Quran meaning" Tafseer" and its recitation in the Universal oral exam to take advantage of semantic property of ontology. Experimentally, our system gives good accuracy for Quran recitation evaluation.*

Keywords: *Holy Quran, ontology, automatic speech recognition, feature extraction, Information retrieval system.*

Received January 2, 2017; accepted March 11, 2018

1. Introduction

Quran is not prose, discrete verses or poetry. It is rather Quran and it cannot be called by any other name. Quran is the Linguistic miracle. Quran achieves the unique literary form. Quran is a unique fusion cannot be found in any Arabic text.

In Automatic Quran Recitation recognition, we need to evaluate right words in right place and right sound “good applied for Tajweed rules”. That is for each segment in Quran which have 114 chapters with 6236 verses each verse has number of segments.

Arabic is important language, spoken by more than 422 million [4]. Arabic language is more difficult than English in Automatic Speech Recognition (ASR). Generally Arabic speech recognition faces many challenges. For example, Arabic is a semantic language with a composite complex morphology. Also, Arabic has short vowels which are usually ignored in text but make different in meaning when reading an Arabic text. There are differences between write and read Quran as a special case. Also, Quran recitation must follow Tajweed rules. Therefore, any application developed for Quranic verse recitation recognition faces these challenges.

Even though Quran oral exam through the conventional method is may be the best and accurate but need more time allocation and proper arrangement for the exam. So, Muslims need to automate the Quran oral exam. That is important for e-learning systems.

Recently, researchers attempted to solve the problems which faced automate Quran recitation.

Some researchers build Ontologies for Quran as in [1, 2], but there is no specific Quran ontology based on Quran audio clips features'.

Also, despite the existence of several researches related to automatic Quran recitation recognition as [9] and [8], there is no online automated application to manage Quran oral exams that can evaluate Quran recitation with all Tajweed rules in the same time and can evaluate recitation a set of consecutive segments from the Holy Quran, only evaluate each segment separately.

Our proposed solution based on two main concepts ASR and Ontology.

ASR process is a special case of supervised pattern recognition [5]. Mel-Frequency Cepstral Coefficients (MFCC) technique is one of the most popular feature extraction techniques used in speech recognition. MFCC is less Complex and it is the most method suitable for Arabic language.

In Artificial Intelligence field, there are many definitions of Ontology. One of these definitions is an explicit specification of a conceptualization. Ontology uses for analyzing and reusing knowledge. Ontology explicit description of individual, classes, attributes, relations, restrictions, rules, axioms and events. Individuals represent objects or instance in the domain. The relation is binary on individuals; i.e., the relation links two individuals together or two classes together. Class is the concept or type of objects. Attribute is property, feature, and characteristic. The function is complex structure formed from relations between two individuals can have used them in a statement.

Restrictions represented formally stated descriptions use in some assertion. The rule is statement used in logical inference to draw from assertion. An axiom is assertion in logical form. The rules and axioms are used together for comparison the all theory that the ontology describes in the domain of application. The event is changing of relations. The previous Ontology definition and structure were summarized from reference [15].

In our proposed system, we use Ontology Web Language (OWL) ontology based to represent and classify Quran acoustic features. Using OWL to create ontology based is suitable for e-learning and online application.

The semantic was assigned to the verses or chapters, the segments inherit the verse or chapter concepts in the right arrangement of Quran reading. Using ontology decrease processing time and retrieve features of verse segments in right arrangement.

This paper organizes as the following: section 2 shows the related work for recognition of Quran recitation and Quran ontology. Section 3 presents the proposed method for Automatic evaluation of Quran recitation and its phases. The analysis of results was discussed in section 4. Finally, section 5 presents the conclusion and further work.

2. Literature Review

2.1. Automatic Speech Recognition (ASR) on Quran Recitation Application

There are many researches in speech recognition in general. The important and complexity of Quran recitation recognition system tends to find a few researches on it.

Authors in reference [14] provides a research related to Quran. Where, they can assist and ensure correct pronunciation, readings and interpretations in true Quranic recitation rules. That is based on the speech recognition for "Warsh".They used database to store the recitation features of true sample collected from expert reciters. MFCC used in features extraction, and Hidden Markov Models (HMM) used in classification.

Also, researches in [13] used MFCC and HMM on another type of recitation for Holy Quran.

Also, "E Hafiz" system in [11], and system in reference [10] used MFCC for feature extraction and Vector Quantization (VQ) for feature classification. Systems stored the trained features in codebook.

Authors in reference [9] proposed automated tajweed checking rules engine for quran learning. That is by using MFCC to extract features of verse recitation and trained verse samples calculated and stored in HMM database. But, the engine of the system tested only on selected Tajweed rule of "Al-Fatihah".

Ismail *et al.* [8] investigated a speech recognition system for Tajweed Rule Checking Tool to help students to learn and revise proper Quran recitation by themselves. They used also MFCC as feature extraction technique and vector quantization VQ as classification technique and data reduction technique. From the result, it shows that the MFCC-VQ achieves better results in terms of speed performance than conventional MFCC. Vector quantization is used in this work to cluster the coefficient vector extracted from the speech samples on their sound class for each of "Qalqalah letters (ق ط ب ج د)". The accuracy was about 82.1-95 %.

But the system applied only on "Tajweed Qalqalah" rule. Also, features of trained Quran verse samples calculated and stored in VQ codebook. The proposed system in this reference evaluates one verse or word contain "Qalqalah letter" at once.

2.2. Using Ontology with Quran Applications

In Islamic world, researchers interest to study Quran in all fields. In computer science, Ontology used to capture knowledge from Quran in some domains of interest by describing concepts in these domains and relationships that are held between those concepts. Many researches have been done in retrieving knowledge from Quran using semantic search.

Reference [2] proposed a search tool called a semantic search tool for Quran based on Qur'anic ontologies and surveys most existing Quranic ontologies and what are their deficiencies as ontologies in references [1, 12]. Where, reference [12] extracts verses according to the concept. Reference [1] is the Quranic Arabic Corpus which is the first manually verified and computationally analyzed Quran corpus morphology.

Reference [7] reports an experience of developing ontology on Quranic text for "Juz' Ammi". This Quran ontology supports contextual information and represents authentic information from the Quran but not support acoustic features of Quran recitation.

Briefly, there exist Desktop and Web applications have been developed to retrieve knowledge from Quran. Most of these applications use keyword search techniques. However, some researchers have proposed frameworks for a Quranic semantic search tool based on concepts. But no ontologies include acoustic features of Quran words or sounds of segments.

A good resource for Quran Ontology is available but, we can't use any Quran Ontology was prepared. Because our Quran ontology developed for different aim, so we propose Quran ontology represents acoustic features of Quran recitation.

3. Proposed System Architecture

In this section, we propose a system to evaluate Quran recitation in correct pronunciation and Holy Quran Tajweed rules according to "Hafs from Asim reading".

- **The creation of the proposed system has four main phases:** The first phase is building Quran lightweight ontology using protégé as ontology editor.

The second phase is training phase, which is data preparation, features extraction using MFCC and VQ of the training set.

The third phase is inserting phase, which is to insert the result of analysis from the training phase in Quran lightweight ontology result from the first phase to get the heavy ontology.

When user uses the system to test his reading, the system passes through other two phases: analysis phase and evaluation phase.

The analysis phase is to prepare date, extract features from the user speech and applying VQ.

The evaluating phase is by comparing between certain selected classes that is retrieved using SPARQL from ontology and the result of the analysis phase.

In the following subsections, we explain the proposed system phases in more details.

3.1. Building Quran Lightweight Ontology

Quran is the immortal miracle from God for humans. Quran consists of 30 divisions (Juz), 114 chapters (Surah), 6236 verses (Ayah), and less than 80,000 words. The verse contains one or more sentences to form the verse. A group of verses form a chapter with a given unique name e.g., (Al-Baqarah, Ali-Imran, An-Nisa, Al-Ikhlas).Quran Content Hierarchy is as shown in Figure 1.

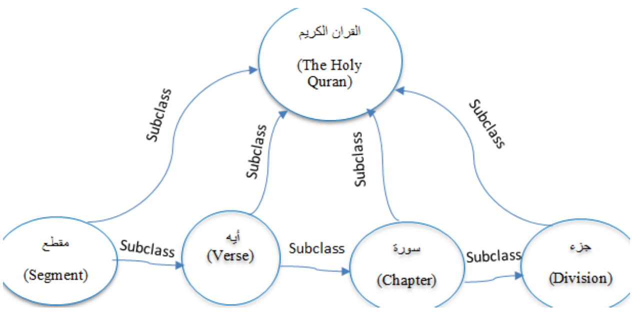

Figure 1. Quran contents hierarchy.

The advantages of using the Quran normal classification in the Quran Ontology based are:

- The uniqueness of the words and segments.
- Respecting constrain of the arrangement between verses.
- Ability to refinement the ontology to cover the meaning.

Quran recitation consists of many rules needed to be considered when any one read Quran verse these rules named with Tajweed rules. Mistakes in recitation of Quran are forbidden. These errors may include missing words, verse, misreading vowel pronunciations, punctuations, and accents. Also, the characters in the Quran may have a diacritic written either above or below a character. This diacritic can change the pronunciation and meaning of the word. Tajweed rules ensure that the recitation is performed incorrectly pronunciation and at a moderate speed without changing the meaning. The pronunciation and recitation for each letter of Quran should follow its right and its due. The rights of a letter are the characteristics that are always connected to it. The due of a letter is characteristic that is present sometimes but not always, such as prolongation "Madd", shorten "Istifāl", thinning "Tarqeeq", thickening "Tafkheem" and other such phonetic methods of a merging "Idghaam", clearly mentions "Idh-haar", change "Iqlab", hide "Ikhfa" [6].

The spread of the Quran printed "Hafs" is one of the reasons of publicity and the many who read them confirmed by this fact so, the proposed Quran ontology based on "Hafs reading".

The components of Quran ontology are as shown in Figure 2. The two main concepts are "Quran" and "Tajweed rules". Chapter "surah" and division "Juz" are the subclasses of Quran. Qurandivision "Juz" subclass classifies into thirty subclasses, and chapter "Surah" subclass classifies into one hundred and fourteen. Each chapter has different number of verses as subclasses. Finally, each verse has different number of arranged segments as individuals.

Properties we are used to describe resources; they give more description to a class/concept or subclass:

a) Data property that used for relationship between class and its literal are:

- mfcc_matrix_value: datatype property that relates Quran segment to his MFCC voice features.
- Segment_text: datatype property that relates Quran segment to his Arabic text.
- threshold_distance_value: datatype property that relates Quran segment to the distance value between the segment MFCC features value and other true recitation of the same segment. Therefore, when user recite segment, it is compared with the stored one.

b) Object property describes the relationship between classes are "belongs to".

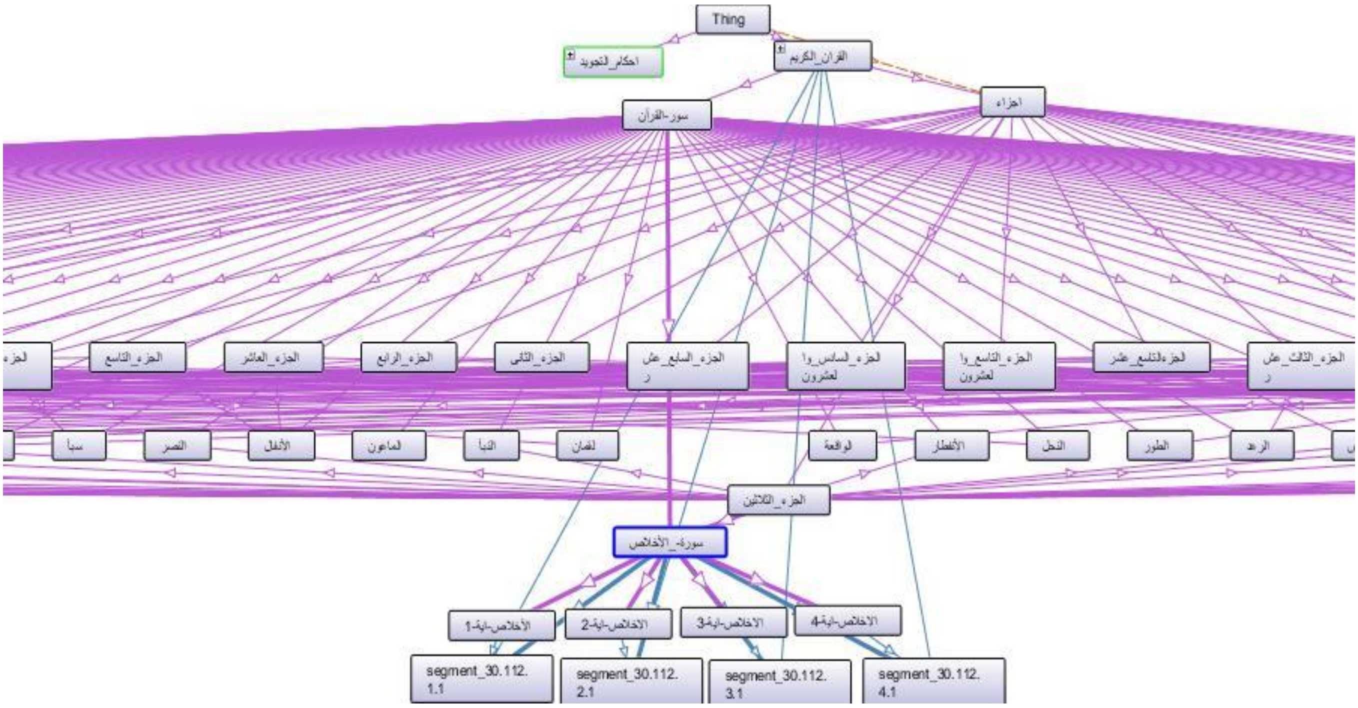

Figure 2. Quran ontology graph.

We will use Quran ontology to support speech recitation recognition of Quran. That is via store speech features of Quran segments as data property of Quran recitation segment.

3.2. Training Phase

Training phase is a process of enrolling a new speech sample of a distinct verse to the Quran ontology based. That is by constructing a model of the verse based on the features extracted from the verse's segments speech samples.

In This phase, we analyze the Quran speech using the MFCC because it is based on human perception experiments.

We start by samples of five recorded audio files of Quran to different good Quran reciters in "Hafs reading" i.e., reciters were chosen based on the commitment 'Tajweed rules' which called "He has Ejaza". That is because an appropriate speech corpus of the Quranic sounds is rare available. We record the sample in wave format.

The three stages of training phase are data preparation, feature extraction, and vector quantization, and then inserted the output of training phase into Quran ontology are shown in Figure 3.

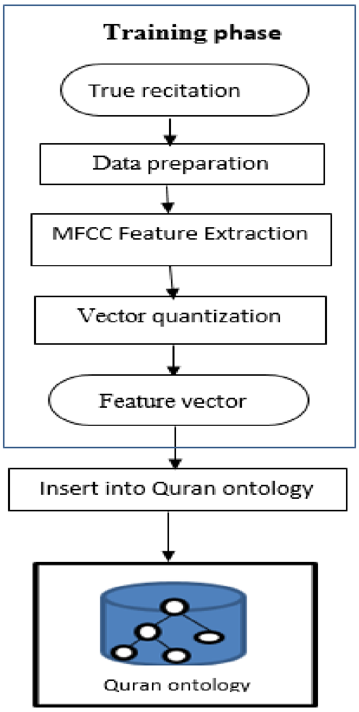

Figure 3. Training phase.

3.2.1. Data Preparation

For more accuracy result, in data preparation step we delete noise from the audio sample set. That's by detecting the end points to delete the unnecessary frame. That is removing silence parts. Then we need to cancel the noise from signals of each segment in Quran. That's by using pre-emphasis filter. To perform the pre-emphasis process, the application of first order Finite Impulse Response (FIR) filter is applied on digitized signal. The equation used to apply FIR filter is Equation (1).

$$Y[n] = X[n] - \alpha \cdot X[n-1] \quad (1)$$

Where, $Y[n]$ is the output of the signal $X[n]$ is a speech signal. And α represents the pre-emphasis factor.

3.2.2. MFCC Feature Extraction

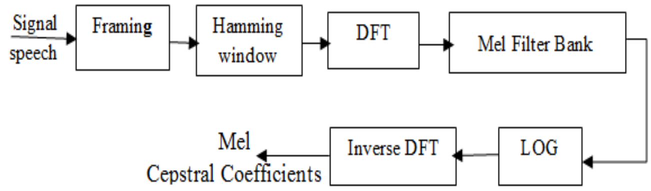

Figure 4. Steps involve in MFCC Feature extraction.

The feature extraction process transforms the raw signal into feature vectors. MFCC is one of the best techniques that used for speech feature extraction purpose and give good results in the field of voice content matching systems. In our proposed system, we use MFCC twice in training phase and testing phase. The MFCC feature extraction technique consists of six steps as shown in Figure 4 which are:

1. Framing: After pre-emphases filtered input speech is framed, each segment's signal is segmented into the small frames with the time length 23msec. frames to convert non-stationary signals into qui-stationary format. Also, theses frames are further blocked overlap, every frame contains the 11.5 msec. of its previous frame's data. It performs overlap to reduce the chances of losing information lies at the end of each frame that may be crashed during segmenting of speech.
2. Windowing: Performing windowing means multiplying each frame with Hamming Window. This shrink the signal values toward zero level at the boundaries of each frame. For each speech signal framed is windowed to minimize the signal discontinuities at the start and end of the frame. The Hamming Window is defined by Equation (2).

$$w(n) = 0.54 - 0.46cos(2\pi n/ N - 1) \quad (2)$$

Where, N is the total number of speech sample in each frame, n is any value from range 0 to N-1, $(0 \leq n \leq N - 1)$.

Thus, the result of the windowing can be shown based on Equation (3).

$$Y(n) = X(n) * w(n) \quad (3)$$

Where, $Y[n]$ is the windowing signal and $X[n]$ is a speech signal.

3. Discrete Fourier Transformation (DFT): It is applied on windowed signal obtained from previous step, by using of Fast Fourier Transform (FFT) algorithm to transfer each windowed frame from time domain to frequency domain. The output of this transformation is a complex number, representing each frequency band (0 to N-1) having magnitude and phase of that frequency component in original signal to frequency domain. The DFT is performed by Equation (4).

$$Y_2[n] = \sum_{K=0}^{N-1} Y_1[K]\, e^{-2\pi jKn/N} \quad (4)$$

Where, k= 0, 1, 2, 3, …, N-1 and $Y_2[n]$ is the output of Fourier Transform of $Y_1[k]$.

4. Mel Filter Bank: it uses to emphasize the low frequency components because low frequencies in speech signal contain useful and important information compare to higher ones. Mel scale is applied by the Equation (5) to compute the Mel frequencies for a frequency f in Hz:

$$Mel\ Scale(f) = 2592 * log10(1 + f/700) \quad (5)$$

5. Reduce Mel filter bank values: that is by taking the natural logarithm of the Mel filtered speech segments. The effect of taking natural log is reducing the values of Mel filter bank.
6. Inverse Discrete Fourier Transformation (IDFT): It converts the speech signal from frequency back to time domain.

Finally, we can get the output of the MFCC in the form of feature vector by using this Equation (6).

$$Y[n] = \sum_{K=0}^{N-1} X[K]\, cos\left[\frac{n\left(K-\frac{1}{2}\right)\pi}{N}\right] \quad (6)$$

Where n=1,2, 3…., L

$X[k]$ is the logged value of each Mel filtered speech segment. L is the required number of Mel Cepstral Coefficient taken from N filter tapes of each frame.

3.2.3. Vector Quantization

For mapping vectors from a large vector space to a finite number we use the VQ technique. VQ gives different size of matrix as the output. Experimentally, we choose a matrix of 12×16 for each segment which gives high accuracy.

This step is performed in features training and in features matching/ testing.

3.3. Inserting Data Property into Ontology (Inserting Phase)

The output of VQ - a features vector- of Quran speech converts to a character vector. We insert a character vector into the OWL ontology based of Quran as "mfcc_matrix_value".Speech vector was extracted for each segment in Quran verses for five different good readers of Quran. Threshold distance value for each segment that determine in training phase also inserted into Quran ontology based "threshold_distance_ value". Text of each segment inserted as "segment_text".

We create another two processes to test the user reading. They are the analysis phase and evaluating phase. Figure 5 shows the relation and details of the system analysis phase and the evaluation phase.

3.4. The Testing Phase

3.4.1. The Analysis Phase

In this phase, we prepare data, extract features and applying VQ of each segment user' reading in the same steps as training phase.

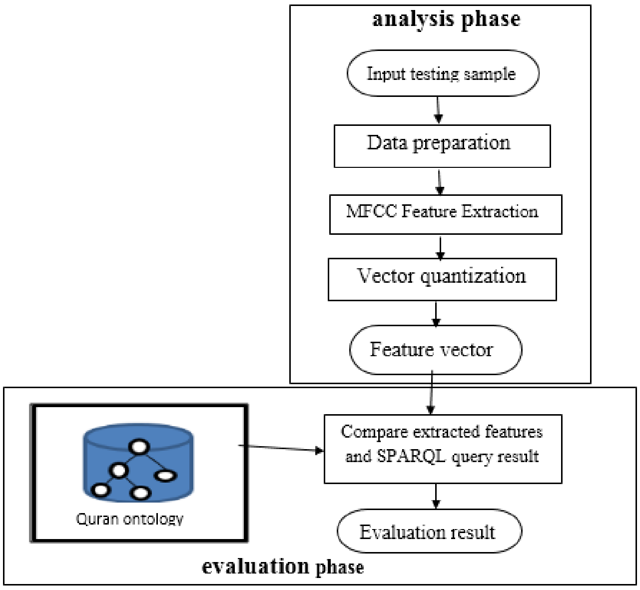

Figure 5. System analysis and evaluation phase(testing phase).

3.4.2. The Evaluation Phase

The main process in this phase is comparing process between the output of analysis phase and the selected part of Quran Ontology. This phase needs connection between MATLAB (2015) framework, and formal Ontology which solved in reference [3] in computer vision. We use the similar idea in speech recognition. That is by SPARQL query Language with OWL Ontology based. The way of building Quran ontology allows evaluating recitation of any Quran part. The advantage of this phase is supporting easy evaluation in the right arrangement.

To evaluate segment, the output of analysis phase is compared with "mfcc_matrix_value" data property of the correspond segment verified recitation where 5 stored features vectors for each segment stored in Quran ontology and retrieved using Sparql. Then comparing the result distances with threshold distance. For each segment recitation considered true if distances greater than the threshold distance value at least for 2 stored features vector else it considered mistakes.

The score is calculating by adding one mark for each right segment then calculate the percentage between the sum of right segments and the sum of all segments in each verse. The result inserts in student database in e-learning system or reported to user directly.

Although of segment consists of number of words, the comparison is performed on segment level. That is because of two reasons:

1. To evaluate all Tajweed rules include Tajweed rules that found in two consecutive words as example in verse 4 of Sourate "Al-Ikhlas" "يكن له ", where merge letter "ن"and "ل" without nasal tone.
2. The problem of automatic segmentation in Arabic language specially segmentation in Quran.

4. Case Study and Result Analysis

To implement the proposed system, we create OWL Quran Ontology based by Protégé 4.2 editor. The training samples according to "Hafs reading" are five Audio files of good reciters. Then to test the system, we apply it on some samples of ten readers.

The two biggest challenges of our system are the accuracy and speed performance. The obtained result is good considering constrains of recording.

First, in our case, the True Positive (TP) is a right recitation considered evaluated as right, False Positive (FP) is a wrong considered evaluated as right, True Negative (TN) is for the wrong recitation considered evaluated as wrong, and False Negative (FN) is a right recitation considered evaluated as wrong. These four values are used to compute accuracy parameters like recall, Precision and F-measure. We used Formula7 to compute our system recall, 8to compute Precision and Formula9 to compute F-measure.

$$recall = \frac{TP}{TP+FN} \quad (7)$$

$$precision = \frac{TP}{TP + FP} \quad (8)$$

$$F - measure = \frac{2*precision*recall}{precision+recall} \quad (9)$$

The recall achieved in our proposed system on selected chapter as "Al-Ikhlas" is about92%, precision about 81% and F-measure about 86%.

The parameters we are used shown in Table 1.

Table 1. Parameters were used in stages of our work.

Parameter	Value
Sampling Rate	16Khz
Pre-emphases Coefficient	0.935
Frame Size	23ms
Overlap Duration	11.5ms
Hamming Window	True
Number of Cepstral Coefficient	12
TP	52
FP	12
FN	4

Second, the speed performance improves using VQ as data reduction of MFCC features and using OWL ontology based to store and classify speech features. We used the Real-Time Factor (RTF) to measure the runtime speed. Where, it has been a widely-used metric system for measuring the speed of automated speech recognition. Real-Time Factor computed using Equation (10). In Table 2 the comparison between our proposed system (MFCC-VQ with OWL ontology based) and the same system when use codebook instead of using Quran Ontology in certain segment.

$$\textit{Real-Time Factor (RTF)} = \textit{execution time/ recording duratio} \quad (10)$$

Table 2. Comparison between our proposed system and MFCC-VQ with VQ codebook.

Metrics	MFCC-VQ with OWL ontology based	MFCC-VQ with VQ codebook
Execution Time (s)	0.341544seconds	1.044321seconds
Recording Duration (s)	3s 970ms	3s 970ms
Real-Time Factor	0.0860	0.2631

From Table 2, it can be observed that the speed performance to evaluate one Quran segment if correct or not of the proposed MFCC-VQ with ontology is faster than the MFCC-VQ with VQ codebook by 67.3% real-time factor improvement. Improvement Real-Time Factor computes by Equation (11).

$$Improvement\ (RTF)(\%) = (MFCC-VQ\ codebook(RTF) - Proposed\ system(RTF))/\ MFCC-VQ\ codebook(RTF) * 100 \quad (11)$$

Comparing with the performance between the proposed system and others. In reference [8], recognition accuracy achieved by using MFCC-VQ method were 83.9% for male and the real time factor obtained was about 0.156. This indicates that our proposed method which hybrid MFCCVQ with ontology is processed in a real time.

In further work we will integrate our Quran ontology to be in word level or phoneme level in evaluation process. That's needing to ameliorate Quran Ontology by merging with Tajweed rules Ontology as shown in Figure 6.

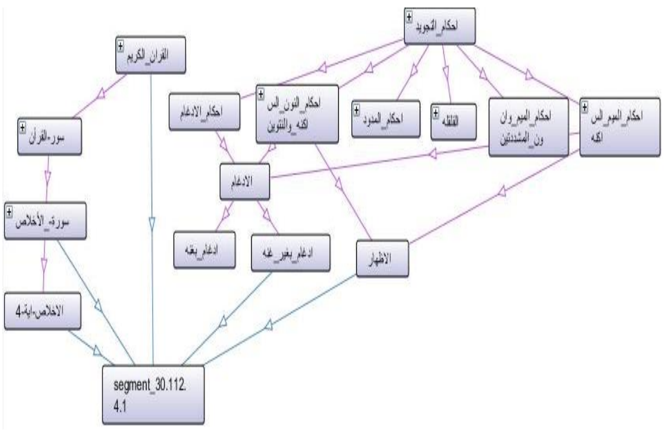

Figure 6. Tajweed Rules Ontology as a Part of Quran Ontology.

5. Conclusions

This paper proposed a system using ontology with Automatic Speech Recognition (ASR) in Arabic oral exam. This system connects ASR by MATLAB framework with formal ontology. VQ used as data reduction of MFCC features and OWL ontology based used to store and classify speech features. We apply the idea on the Holy Quran.

The proposed system can evaluate Quran recitation with Tajweed rules for any user. It can evaluate sequence of Quran segments recitation in right arrangement of Quran reading. From the results, it shows that the MFCC with Quran ontology achieves better results in terms of speed performance than conventional MFCC with VQ codebook.

Further works will generalize the process to ultimately cover all chapters of the Holy Quran to add more benefits from the ontology of Quran to the users. Weplan to complete the universal Quran Ontology by merging Quran Tajweed Ontology and Quran Tafseer Ontology. That is to enhance the electronic oral exam for all Islamic Religion subjects. Also, we will ameliorate the accuracy of the system by enhance the segmentation rule and increase the training set.

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