CHAPTER 5

MAQAMAT ONTOLOGY FOR QMR KNOWLEDGEBASE CONSTRUCTIONS

5.1 Introduction

This chapter provides a thorough description and formalization of the proposed MPS system, which aim is to discover those features modelled as an ontological input that can be found in QMR audio files. The QMR signal that have been applied to the feature extraction and spectral descriptors wherein a certain number of spectral descriptors that will be extracted per input frame. Extraction, representation, organisation and application of metadata about audio recordings are in the concern of semantic audio analysis. As explained literally in Chapter 2, semantic analysis techniques are important for analyzing and identifying users' topics of interest. Aligned with recent developments in the field, includes methodological aspects of semantic audio, such as those related to information management, knowledge representation and applications of the extracted information, has been the main focus of this chapter.

The first section includes system design and module description that have been covered. Feature selection is introduced in the next section which mainly focused on the peak ratio. In particular, it explained the proper ontologies design principle may be used to enhance audio information management practices. The later part of this chapter discuss the implementation of designed framework which deduce the relationship between ontology-based audio features of QMR content. Then, briefly discussed data analysis and experimental evaluation in the last section.

5.2 Work process

The presented work described previously in chapter 4 involved extractions of 7 types of maqamat which will be used as entities and attributes to design a unique ontology for QMR. It also described mel frequency function that select variables by ranking them with correlation coefficients. It also includes wrapper methods that assess subsets of variables according to their usefulness to a given predictor. The models provide the basis for content annotation as well as the construction of the knowledge base. There is various consideration level of proposed framework thus these are being proposed as new ontology in later section as the attributes for the ontological theme of the QMR content. Figure 5.1 depicted various stages of the whole process starting from unstructured database creation to classification phase. Initially a training database of classified and non-classified QMR audio files using features from spectral descriptors and W-DFT is created. During this stage, various features of an audio file are identified. Then a range of data numerical values of each time frame are extracted from individual audio files for creating feature vector prior the data analysis stage. After that range of each feature for every maqamat class is identified by calculating the mean, standard deviation and peak to RMS ratio to identify the unique identifier as attribute. In the final step will be the classification of audio files from testing database with result analysis and calculation of successful classification and rate of error.

5.3 Audio Features Classification

For QMR audio files, the initial step is to create a training model from the database. Total of 28 unstructured *.wav QMR audio files from primary data set for each maqamat have been used for creating the training model. Extracted numerical values from the selected QMR audio files are stored in a dataset. The data values of individual features of classified audio files are plotted and analyzed in a waveform and linear values. MATLAB function for Peak-Magnitude-to-RMS-ratio, mean and standard deviation are used for classification analysis.

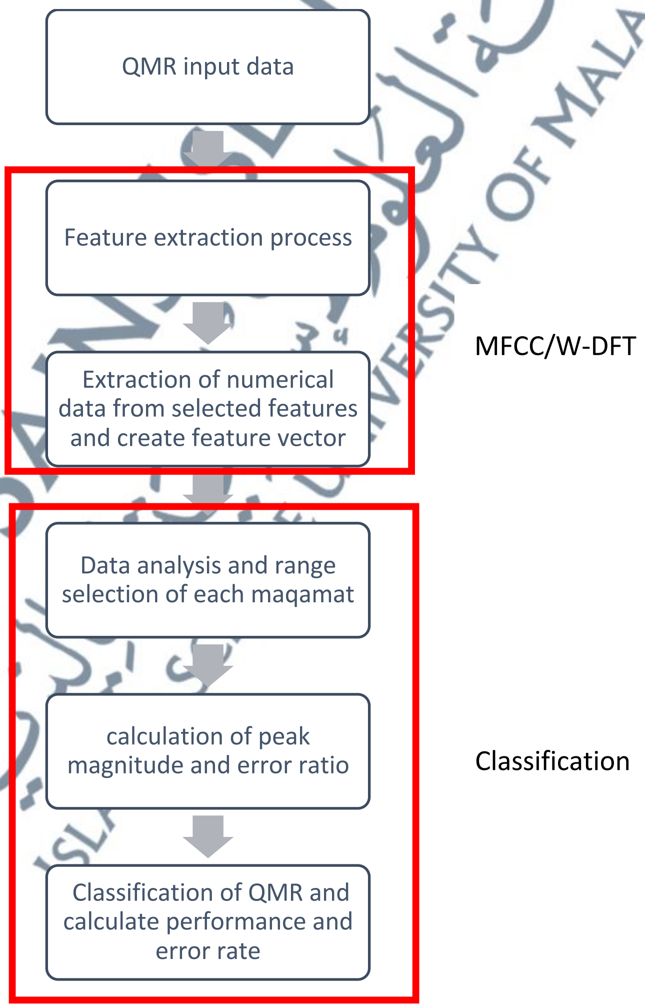


Figure 5.1 Work process for MPS model

5.3.1 Peak-magnitude-to-RMS-ratio

In MATLAB function, *peak2rms* gives output, y = peak2rms(x) which returns the ratio of the largest absolute value in x to the root-mean-square (RMS) value of x.

$$\frac{\left||X|\right|_\infty}{\sqrt{\frac{1}{N}\sum_{n=1}^{N}|X_n|^2}} \tag{5.1}$$

where the infinity-norm and RMS value are computed along the specified dimension.

5.3.2 Classes

For evaluating the performance of the proposed technique in these experiments, the MATLAB Classification Learner Toolbox was used to train and test with various classifiers. The toolbox has the advantage that it can train multiple classifiers using parallel pool. Using this toolbox, the dataset can be explored and performed many analyses such as feature selection, specify validation schemes, train models, and assess results. It also performing automated training to search for the best classification model type, including decision trees, discriminant analysis, support vector machines, logistic regression, nearest neighbors, naive Bayes, and ensemble classification. 9 extracted features as input data and classes of maqamat as the responses. In each of the training and testing data, signals are arranged in sets, and each set having one signal of each maqamat type is labelled with numerical attributes 1 to 7 as presented in Table 5.1. The numerical attributes

Table 5.1 Attributes for maqamat type

Maqamat Type	Attributes
Bayyati	1
Hijaz	2
Jiharkah	3
Rast	4
Nahawand	5
Siqah	6
Soba	7

5.4 The Maqamat Ontology

In this section will be discussing knowledge representation issues arising in selecting ontologies and precautious steps to be taken in dealing with QMR, and introduce the Maqamat Ontology (MO) framework for describing and sharing detailed information about producing QMR quality standard in the recording studio. The primary motivation for creating this ontology is to facilitate the record production by providing an insight attributes within the studio environment. The proposed ontology model used is to describe real-world recording scenarios involving machine hardware, and production procedures by the involved machines. The models provide the basis for content annotation as well as the construction of the knowledge base. There is various consideration level of proposed framework thus these are being proposed in MO as the attributes for the ontological theme of the QMR content.

5.4.1 Motivations

One of the issues that commonly arise in maqamat area among the reciters is that they do not have structured and insight knowledge base for all the QMR audio files. Most of the audio files exist in web are random and generalized in terms of the digitizing formats and standards. The motivations to create an ontology for maqamat based on studio production are focused on the following standard and applications:

1. Formal standard and guidelines

   Setting a set of standard and guidelines for experts and learners of QMR to develop more systematic and professional learning module in maqamat. Most of the maqamat exist worldwide are created without quality of standard of audio engineering background. This will lead to unsynchronized and mismatched when reciting the Quranic content without specific theme or expressions.

2. Audio engineering notation

   Appreciating the creative work contributed by audio the engineer or producer to a recording work and exploiting production data based on studio environment recommendation which follow the basic audio engineering practice (Huber and Runstein, 2005).

3. Intelligent audio editing and recording

   Provide a knowledge representation model that supports intelligent audio editing systems to facilitate information management through the collection of production information for archival, search and educational applications.

5.4.2 Selecting of ontologies

Before discussing the methodology, ontological modelling aims to enlist the concepts of a particular domain in a hierarchical manner so that superclass-subclass relations can be specified accurately. It also aims to specify the relations among these concepts. This is a form of knowledge representation which ultimately leads towards logic-based formalism and reasoning about the concepts in the ontology. To model the Maqamat ontology, it needed to be design based on the concepts related to holy Quran with the help from the experts in Quranic content field. The work has been divided into the following steps:

1. Work with group of experts among professional *qaris* to get clear descriptions of maqamat type and features.
2. Finding all the related verses that are in relation with expression domain in holy Quran.

5.4.3 Entities and annotation

Contemporary ontologies share many structural similarities, regardless of the language in which they are expressed. Most ontologies describe individuals (instances), classes (concepts), attributes and relations. Common components of ontologies include individuals, classes, attributes, relations, and rules. In Table 5.2 describes the main components contained in MO describing entities and its annotation in MO.

Table 5.2 Entities and its annotation in MO

Entities	**Annotation**
Individuals	QMR audio files
Classes	Type of maqamat
Attributes	Audio features extracted from QMR
Relations	Ways in which classes (maqamat type) and individuals (QMR audio files) can be related to one another
Rules	Standards of feature elements describing the logical inferences that can be drawn from audio features extraction
Events	The changing of attributes or relations

5.4.4 Attribute Tagging for Rule Matching

For attribute tagging, certain rules need to be specified for the best result. Table 5.3 shows some examples of rule matching for attribute tagging. Figure 5.2 shows screenshot of command line used in MATLAB as preliminaries rules before executing AFE algorithm. The aim is to detect matching elements between features and maqamat type. For instance, frequency sampling must be in 44100Hz based on studio environment, time duration for QMR recording should not more than 15 second due to system limitations. Furthermore, numerical data value must be matched with significant signal pattern for each maqamat type during classifications stage.

```
%% PRELIMINARIES
    % Ensure correct number of inputs
    if( nargin~= 10 ), help mfcc; return; end;

    % Explode samples to the range of 16 bit shorts
    if( max(abs(speech))<=1 ), speech = speech * 2^15; end;

    fs = 44100;                       % frequency sampling is set to
 44100Hz
    Nw = round( 1E-3*Tw*fs );         % frame duration (samples)
    Ns = round( 1E-3*Ts*fs );         % frame shift (samples)
    nfft = 2^nextpow2( Nw );          % length of FFT analysis
    K = nfft/2+1;                     % length of the unique part of FFT
    LF = 3;                           % lower frequency limit (Hz)
    HF = 8000;                        % upper frequency limit (Hz)
```

Figure 5.2 Screenshot of command line used in MATLAB as preliminaries rules

Table 5.3 Some examples of rules applied in rule matching for attribute tagging

Rules	Justification
Frequency Sampling, Fs = 44100Hz	Sampling frequency must be in the value of 44100Hz for optimum extraction
Time duration, Ts >= 15s	The total time duration for QMR recording should not more than 15second
Data range for spectral features	Numerical data value to be matched for each maqamat type

5.4.5 Workflows, Events and Timelines

Audio engineering workflows concern the manipulation of sounds and signals. For example, the manipulation of audio signals by digital signal processing (DSP) devices as common case. The Maqamat Ontology provides a concept where the workflow process is a description of who (or what) produced what, when, and how, using what. For example, a male reciter has made recording of QMR with studio environment using sound recording equipment. Such a description requires a conceptualization of entities existing at various stages of the workflow. In the case of MO, the audio features (mo:AudioFeatures) extracted from QMR audio files through DSP (mo:DSP) has element of mo:FrequencySampling and mo:TimeDuration. The mo:AudioFeatures is derived from mo:maqamat to defined maqamat type (mo:type) and theme (mo:theme) based on mo:extractElement as attributes which composed of mo:spectralCentroid, mo:spectralSpread, mo:spectralRolloff, mo:MFCC and mo:WDFT. Figure 5.3 depict the overview of Maqamat Ontology and its subclasses. The designed and proposed ontology will be used as fundamental guidekines in construction the QMR knowledge base and the implementation will be presented and discussed in next section.

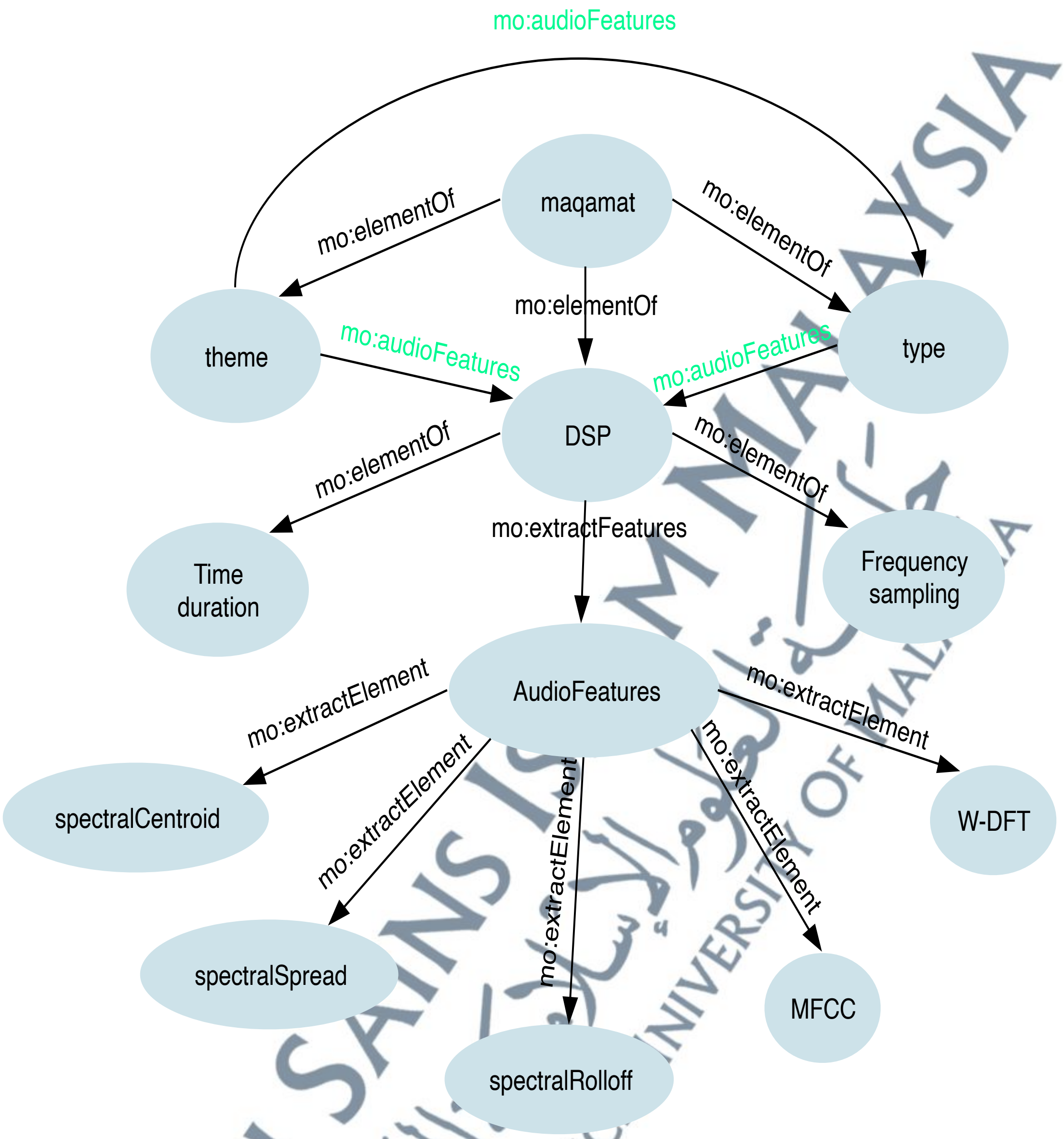


Figure 5.3 Overview of Maqamat Ontology

5.5 Framework for QMR Knowledge Base Construction

In this section develops a framework to construct a knowledge base for QMR semantically based on which includes the pre-design Maqamat Ontology, to build an insight knowledge base for the analysis of content from extracted information of QMR.

There is various consideration level of proposed framework to suit the requirements. Based on the framework proposed, 3 layers have been identified as the (1) pre-processing, (2) profiling and (3) post processing. The Maqamat Ontology framework is builds during profiling stage based on selected entities for knowledge representation and knowledge sharing.

The rest of this section is to provide some motivating examples and discuss some design criteria and outline the foundational and core elements of the Maqamat Ontology. Figure 5.4 shows the framework, which includes the relationships among sentiment analysis, semantic analysis, ontology, and knowledge base.

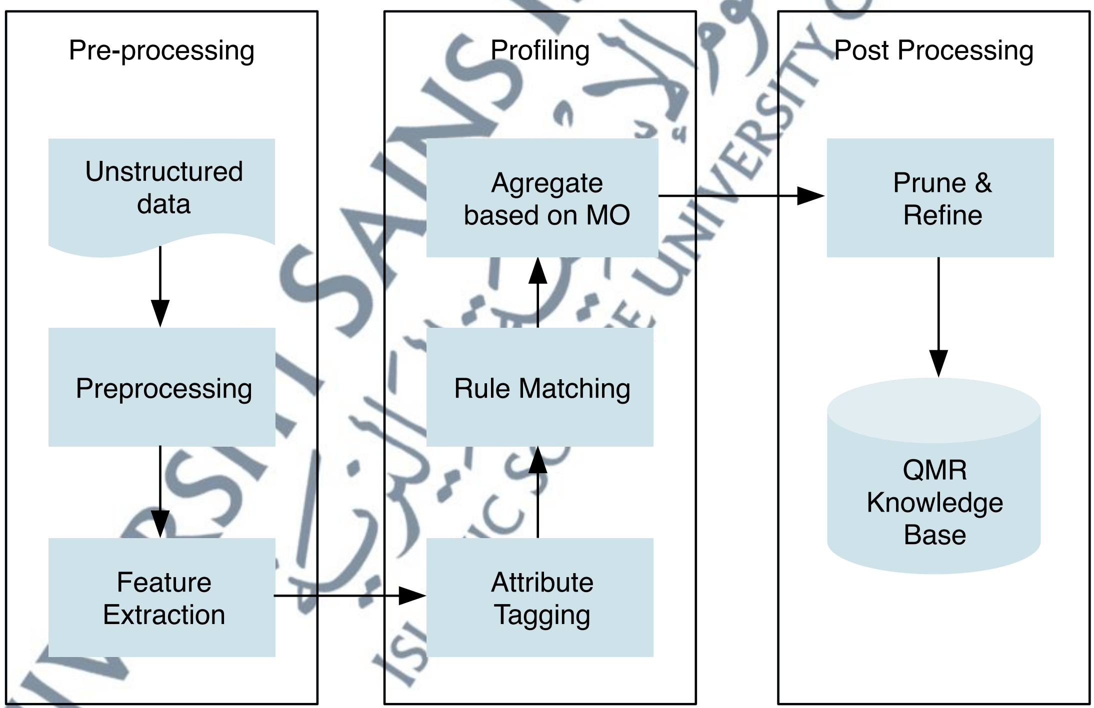


Figure 5.4 Design framework in constructing QMR Knowledge base

5.5.1 Pre-processing

The pre-processing stage includes data collection of the unstructured data, trimming the voice and unvoiced scene. Then, the data is applied with feature extraction process which already been discussed detail in Chapter 4 and 5 as validation.

5.5.2 Profiling

In profiling, the extracted features will be performed with profiling techniques with attribute tagging, simple rule matching and aggregation of ontology based on QMR. In this section, new ontology will be introduced known as Maqamat Ontology (MO) and its entities relationship between classes. The fundamental purpose of MO is for describing and sharing detailed information about QMR production in the recording studio. Detailed process has been discussed in previous section.

5.5.3 Post-processing

The post processing involved pruning and refining the datasets before storing in structured QMR knowledge base. Pruning techniques are the most important part of the process of constructing and effective classifier with high accuracy standard. Recently there are many different pruning methods that have been proposed which shows effective class association rule mining yields a classifier that reduces error possibility and increases the accuracy rate that can be deployed for use in big data analytics and data science (Parashu et al., 2019). Pruning QMR data after profiling process is to remove unnecessary and historical background data which does not match with the criteria and rules in MO and prior storing in separate database.

5.6 Experimental Result and Discussion

The QMR samples from the database are divided into training and testing samples. The training data consists of 28 samples (4 samples of each maqamat) and the testing data consists of 42 samples (6 samples of each maqamat). Corresponding target matrices are constructed for training and testing data. Table 5.4 shows the example of numerical attributes from extracted spectral descriptors.

Table 5.4 Example of Numerical data attributes of 3 spectral descriptors for (a) peak-magnitude-to-RMS-ratio (b) mean and (c) standard deviation

	Al-Asr			Al-Ikhlas			Al-Falaq			An-Nas		
	Centroid	Spread	Roll-off	Centroid	Spread	Roll-off	Centroid	Spread	Roll-off	Centroid	Spread	Roll-off
Bayati	4.17	4.45	4.10	6.72	6.13	6.04	6.24	4.89	4.70	4.66	4.31	3.66
Hijaz	4.58	5.01	4.19	6.26	5.46	5.36	5.75	5.17	4.81	4.30	4.48	3.68
Jiharkah	4.58	4.39	3.60	6.80	6.06	5.70	5.60	4.83	4.27	4.45	5.44	4.23
Nahawand	4.10	4.07	3.33	5.35	5.87	5.47	5.50	4.47	4.55	4.34	4.64	4.04
Rast	4.11	4.63	3.86	5.82	4.99	4.65	5.59	4.83	4.60	4.60	4.29	4.16
Siqah	4.24	4.34	3.82	5.65	5.61	5.34	5.37	4.28	4.08	4.34	4.39	4.13
Soba	4.30	4.31	3.57	5.42	4.85	4.76	5.68	4.23	4.59	4.46	4.44	3.61

(a)

	Al-Asr			Al-Ikhlas			Al-Falaq			An-Nas		
	Centroid	Spread	Roll-off	Centroid	Spread	Roll-off	Centroid	Spread	Roll-off	Centroid	Spread	Roll-off
Bayati	1125.11	811.81	2225.59	802.88	743.13	1874.45	1038.97	896.37	2480.31	1192.12	910.18	2618.06
Hijaz	1190.97	918.95	2680.39	980.24	748.19	1976.88	1172.63	916.87	2538.21	1354.93	949.76	2820.91
Jiharkah	1257.04	922.56	2681.95	914.08	744.12	1928.17	1181.58	887.05	2491.95	1347.20	954.70	2814.32
Nahawand	1399.44	955.94	2949.36	993.38	742.28	2042.46	1196.95	907.21	2539.12	1407.39	992.94	2949.94
Rast	1311.87	893.41	2632.63	1018.25	749.89	2059.03	1163.24	903.38	2503.24	1277.35	897.84	2671.15
Siqah	1267.66	881.67	2641.90	1052.04	742.38	2037.05	1220.27	899.05	2528.04	1351.30	949.32	2814.76
Soba	1248.60	908.58	2568.53	995.72	750.18	2077.11	1227.80	921.20	2536.16	1366.06	908.23	2672.86

(b)

	Al-Asr			Al-Ikhlas			Al-Falaq			An-Nas		
	Centroid	Spread	Roll-off	Centroid	Spread	Roll-off	Centroid	Spread	Roll-off	Centroid	Spread	Roll-off
Bayati	1648.18	546.64	2471.61	984.64	476.41	1886.33	1315.13	627.49	2320.66	1669.98	598.75	2657.19
Hijaz	1694.62	612.57	2606.85	1193.70	516.62	2104.89	1389.47	715.60	2497.03	1775.19	616.10	2708.90
Jiharkah	1843.55	669.70	2852.49	1150.04	488.20	2030.69	1522.11	619.90	2369.19	1836.86	596.02	2740.59
Nahawand	1962.69	662.35	2905.50	1092.90	515.90	1953.04	1358.09	642.94	2320.24	1854.81	624.71	2731.30
Rast	1901.01	636.33	2911.19	1070.03	481.03	1974.89	1285.13	666.74	2282.19	1801.16	604.81	2699.49
Siqah	1806.48	670.30	2866.04	1389.90	565.88	2282.33	1347.35	621.84	2257.12	1943.59	651.43	2904.90
Soba	1738.67	685.22	2863.78	1024.55	478.03	1969.33	1386.36	698.18	2501.39	1889.76	600.66	2790.64

(c)

Figure 5.5 below shows examples of output of the profiling system when tested with secondary data. Table 5.5 and tabulates the number of correctly predicted samples for each of the maqamat class, meanwhile Figure 5.5 shows bar chart showing intelligibility accuracy% from secondary datasets using MPS The proposed algorithm proves to be accurate and efficient in identifying the types of maqamat based on the spectral features. It works very well in identifying few maqamat with the highest score is Hijaz with 92% and average of 83% for Bayyati, Nahawand, Siqah and Soba. These types of maqamat give significant peaks value justifying a positive and neutral emotion within. The minimal value of accuracy is obtained in Rast with accuracy of 69% due to its elements of emotion being strong and affirmative. The significant changes happen in high frequency range thus less detection occurred.

```
maqamat type , filename , duration , sampling , output

'Bayyati' , 'C103B' , '5.4s', '44100Hz' , 'matched'
'Hijaz' , 'C103H' , '6.2s', '44100Hz' , 'matched'
'Jiharkah' , 'C103J' , '5.1s', '44100Hz' , 'not matched'
'Rast' , 'C103R' , '5.8s', '44100Hz' , 'not matched'
'Nahawand' , 'C103N' , '5.5s', '44100Hz' , 'matched'
'Siqah' , 'C103Q' , '5.9s', '44100Hz' , 'matched'
'Soba' , 'C103S' , '5.3s', '44100Hz' , 'matched'
```

Figure 5.5 Example of output when tested with Surah Abasa from secondary datasets

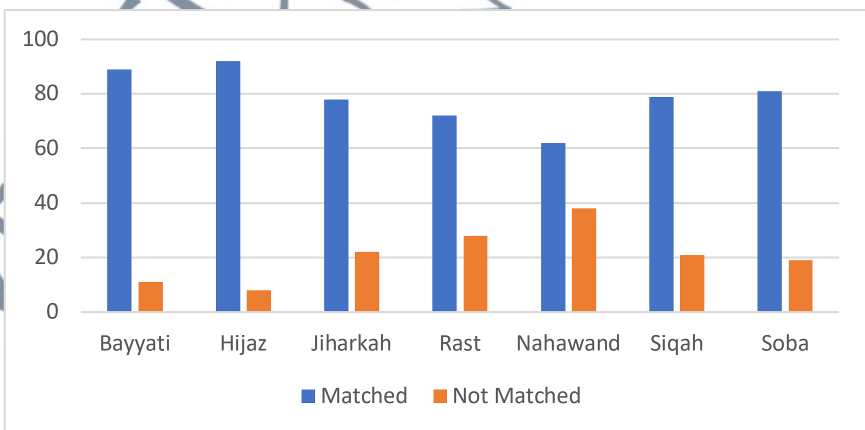


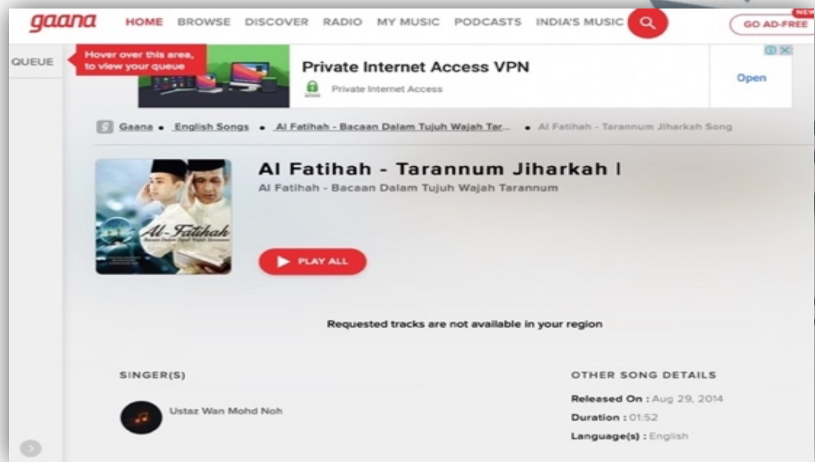
Figure 5.6 Bar chart showing percentage of intelligibility accuracy from secondary datasets using MPS.

Table 5.5 Experimental result of proposed technique tested with secondary datasets

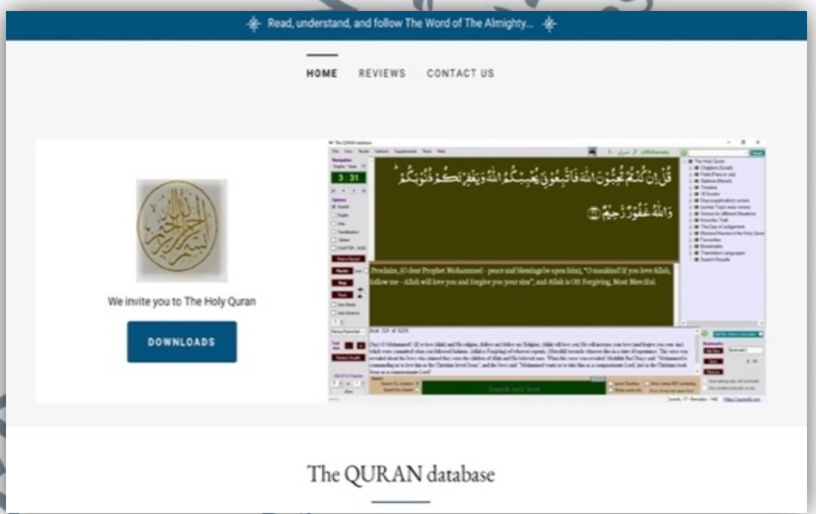
Maqamat Type	No. of samples - Matched	No. of samples - Not Matched	Intelligibility Accuracy %
Bayyati	38	4	89
Hijaz	39	3	92
Jiharkah	33	9	78
Rast	29	13	69
Nahawand	41	1	88
Siqah	40	2	79
Soba	41	1	81

To evaluate the performance of the implemented framework, some requirements need to be addressed and assessed based on the proposed ontology. The MO should be able to describe attributes of the digital signal formatting, for example, the number of channels, sample rate as well as attributes of the media storage such as bit rate and media format. It should also be able to allow the classification of audio content against multiple platforms for instance maqamat type and theme. Optionally, the system should be able to describe additional information of the audio production/publishing process. However, this additional information were not performed in this experiments due to recording took place in one location.

For further evaluation, the system need to be tested with the real-world database i.e. from Gaana.com database and Qurandatabase.org and other as shown in Figure 5.6. Gaana.com only having recording of surah Al-Fatihah for few maqamat whereas Qurandatabase.org is for unknown maqam type. Table 5.6 shows some promising result experiments of QMR from secondary datasets and some random web based datasets. The expanded two columns on the right are extracted from semantic analysis results. The detailed entities in the next lower-level ontology are extracted from terms using attributes tagging. Meanwhile all datasets from random web based give negative results. This is due to low quality audio with frequency sampling of 16kHz and unknown maqamat type. In order to have positive polarity, the input data should be from recording studio standard with optimum frequency sampling and media format.



(a)



(b)

Figure 5.7 (a) Gaana.com database and (b) Qurandb.com database

Table 5.6 Example of result from selected real-world datasets after implementing the framework

No	Surah	Verse	Source	Maqamat type	Frequency Sampling (Hz)	Result
1	Al-Fatihah	1-7	Gaana.com	Rast	16000	Not Matched
2.	Al-Fatihah	1-7	Gaana.com	Jiharkah	16000	Not Matched
3.	Al-Fatihah	1-7	Gaana.com	Nahawand	16000	Not Matched
4.	Al-Maun	1-6	Qurandb.com	Unknown	44100	Not Matched
5.	Al-Nas	1-6	Qurandb.com	Unknown	44100	Not Matched
6.	Al-Adiyat	1-5	Qurandb.com	Unknown	44100	Not Matched
7.	Al-Qari'ah	1-5	Qurandb.com	Unknown	44100	Not Matched

5.7 Summary

The chapter presents a proposed acoustic model for Quranic profiling based on ontological extraction audio features which facilitate the development of a well-structured database system that support studio environment for audio engineering. The technique for maqamat profiling based on QMR extracted features which aim is to discover those features modelled as an ontological input that can be found in QMR audio files. QMR knowledge base is generated semantically that associates the aggregated human affective information (emotions/theme) with corresponding real-world entities (content). The Maqamat Ontology has been designed to model the semantic approach for the profiling system. Its aim is to facilitate the integration and standardization of QMR audio, through an environment based on standard audio and multiple attributes and entities. The technique was tested with 9 features extracted from primary datasets and gives an optimal accuracy of 92% and the average of 83% for Bayyati, Nahawand, Siqah and Soba. These types of maqamat give significant peaks value justifying a positive and neutral emotion within. The minimal value of accuracy is obtained in Rast with accuracy of 69% due to its elements of emotion being strong and affirmative. The significant changes happen in high frequency range thus less detection occurred. These types of maqamat give significant peaks value justifying a positive and neutral emotion within. Further evaluation in real world data with most negative results shows that it is consistent with rule matching standard, and it is functional to the real world ecosystem. Furthermore, as the ontology is disseminated and the ecosystem expands, more input is expected in the near future which allow to evolve the ontology based on potentially unexpected use cases and conduct a more in-depth evaluation.