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Statistical Machine Translation from Arab Vocal Improvisation to Instrumental Melodic Accompaniment

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Vocal improvisation is an essential practice in Arab music. The interactivity between the singer and the instrumentalist(s) is a main featureof thisdeep-rooted musical form. As part of the interactivity, the instrumentalist recapitulates, or translates, each vocal sentence upon its completion. In this paper, we present our own parallel corpus of instrumentally accompanied Arab vocal improvisation. The initial size of the corpus is 2779 parallel sentences. We discuss the process of building this corpus as well as the choice of data representation. We also present some statistics about the corpus. Then we present initial experiments on applying statistical machine translation to propose an automatic instrumental accompanimenttoArabvocalimprovisation. Theresults with this small corpus, in comparison to classical machine translation of natural languages, are very promising: a BLEU of 24.62 from Vocal to instrumental and 24.07 from instrumental to vocal.

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1. INTRODUCTION

Vocal improvisation is a primary musical form in Arab music. It is called Mawwal in the eastern part of the Arab world and istikhbar in the Maghreb. It is a non-metric musical practice that shows the vocalist's virtuosity when singing narrative poetry. It is tightly connected to the sense of saltanah, or what can be referred to as modal ecstasy. In performance, an instrumentalist set the stage for the singer by performing an improvisation on the given Maqam of the Mawwal. Then, the aesthetic feedback loop between the singer and the accompanying instrumentalists goes on. The Instrumentalists interact with the singer by playing along with him or her throughout every vocal sentence, then by recapitulating that sentence instrumentally upon its completion [1][2]. The audience takes part of this loop of aesthetic feedback especially by reacting to performers' expressiveness and virtuosity. This can be expressed by clapping or other means of showing excitement. Early contributions toward automating the instrumental musical accompaniment started in the mid-eighties [3][4]. However, researching automatic accompaniment in the context of Arab music started just recently [5], and has not yet been introduced to the capabilities and complexities of machine learning. Toward proposing an improved automatic accompaniment to Arab vocal improvisation, we studied the part of the

accompaniment in which the instrumentalist recapitulates, or translates, the singer's musical sentence upon completion[1]. To handle this challenge, we imagined it as a statistical machine translation problem, and then make use of techniques previously used in computational linguistics. Accordingly, our experiments require a parallel corpus consisting of vocal sentences and corresponding instrumental responses. Building our own corpus has been a necessity due to the lack of available transcriptions of accompanied Arab improvisations, also because selecting accompanied improvisations from the web and transcribing them automatically can be challenging for a variety of reasons. In our work we applied automatic transcription indeed, but on our own recordings performed by our singers and instrumentalists in equipped recording rooms. This was to ensure decent machine transcription. The remaining of this paper is organized as follows: we present related work in section two. In section three we discuss the idea of looking at the challenge of automating the melodic accompaniment from the perspective of statistical machine translation. In section four we present out corpus, and we apply machine translation experiments on it in section five, then results are presented in section six.

2. RELATED WORKS

Several harmonic accompaniment models have been proposed for different musical styles, such as jazz [6] and chorale style[7]. More generic models were also proposed, such as [8], which considered rock and R&B, among others. Several techniques were applied in the context of harmonic accompaniment, such as musical knowledge, genetic algorithms, neural networks and finite-state methods [9]. Fewer contributions considered non-harmonic accompaniment, including [5] and [10], who proposed Arab and Indian style melodic accompaniment, respectively. These last models used musical knowledge rather than machine learning methods. The model in [5] suggested a knowledge-based accompaniment to Arab vocal improvisation, Mawwal. The melodic instrumental accompaniment lines were very simple and performed slightly modified, or simplified, versions of vocal figures, all in heterophony with the vocal improvisation. Then and upon completion of each vocal figure, there was an instrumental imitation that repeated a full or partial parts of the vocal figure at a speed that could vary slightly from the speed of the vocal. In [11] and when analyzing scores of vocal improvisations along with corresponding oud accompaniment, it was illustrated that, although at times the melodic lines of the instrumental accompaniment might follow the progression of the vocal lines, the particular melodic contour might twist in a way that is challenging to model. Indeed, such results encourage experimenting with corpus-based approaches to improve the automatic accompaniment.

A model for the composition of melodies using fuzzy logic was presented in[12]. Automatically generated melodies were used to accompany a musician playing chords. This was considered an approach to represent the emotions of the musician, this is because the composition process benefited of the previously captured emotional intentions. In [13] the advantage of applying computational approaches for the analysis and study of audio musical corpora was demonstrated. The study revealed details on rhythmic and tempo patterns in Hindustani music through applying spectral processing and reference beat annotations, respectively, on a large corpora.

In [14] a corpus for arab-Andalusian music was built for computational musicology. The corpus consisted of audio materials, metadata, lyrics and scores. The contribution accented on the importance of the task of determining the design criteria according to which corpora are built. In [15] a research corpus for computational musicology was presented and consisted of audio and metadata for flamenco music. The contribution stressed on the idea that the distinctiveness of melodic and rhythmic elements, as well as its improvised interpretations and diversity in styles, are all reasons making flamenco music still largely undocumented. In [16] a parallel corpus of music and corresponding lyrics was presented. Crowdsourcing was used to enhance the corpus with notes on six basic emotions, annotated at line level. Early experiments showed promising results on the use of such corpus for song processing, particularly on emotion classification.

3. MELODIC ACCOMPANIMENT AND LANGUAGE MODELS

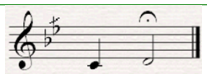
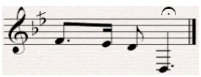
Statistical Language Models work toward estimating the distribution of a variety of phenomena when processing natural languages automatically. These models seek regularities as a mean to improve the performance of applications [17]. In this contribution we investigated applying techniques common in statistical machine translation to handle the problem of automating the accompaniment to Arab vocal improvisation. In other words, we investigated translating the vocal improvisation into an instrumental accompaniment. We handled this translation problem sentence by sentence. Each vocal idea – whether as short as a motive or as long as a sentence – was considered a distinct musical sentence. The same was applied to instrumental responses; each response to the singer's previous sentence was considered one instrumental sentence. Indeed, In the Mawwal practice, the singer separates vocal sentences with relatively long rests, and accompanying instrumentalists fill these rests by recapitulating the singer's previous sentence. This type of instrumental response is referred to as "tarjama," literally meaning "translation" [2].

In general, each musical sentence consists of several musical notes, and each note has two main features: pitch and duration. In our proposed approach we represented them as scale degree and quantized duration, respectively. Section 5 justifies this choice of representation with further clarification. For each sentence, whether vocal or instrumental, we considered the degree as an element and the quantization step as another element. Elements might also be called words, as in natural languages. Table 1 shows notations of a short vocal idea (or sentence, as in natural languages) and its corresponding instrumental response, or translation. The performance is on the maqam bayati with the note D as its tonic. The vocal idea is an ascending two-note motive. The scale degrees of this short sentence, respectively, are: 7th degree (octave lower) and 1st degree. The instrumental response is a descending four-note

[1]This article is an extended version of a contribution to ICNLSSP 2017.

motive. The scale degrees of this sentence, respectively, are: 3rd degree, 2nd degree, 1st degree and 1st degree (one octave lower). In our approach we neither document nor process musical sentences in traditional Western graphical music notation, which is commonly used among professional practitioners of Arab music. We rather use textual representations in order to apply statistical techniques, common in natural language processing, directly to text files. For the textual representation of the vocal idea, or sentence, the first two elements are (dg_7) and (dr_7), both belong to the first note and tell its scale degree and quantized duration, respectively. This means that the scale degree of this note is 7, and the duration is of rank 7. The full textual sentence for this vocal sentence is: $(dg_7)(dr_7)(dg_1)(dr_8)$. Now for the textual representation of the instrumental idea, or sentence, in the same figure: the first two elements are (dg_3) and (dr_6). They both belong to the first note and tell its scale degree and quantized duration, respectively. This means that the scale degree of this note is 3, and the duration is of rank 6. The full textual sentence for this musical sentence is:$(dg_3)(dr_6)(dg_2)(dr_3)(dg_1)(dr_5)(dg_1)(dr_8)$.

Table 1. Short example of a vocal idea and its instrumental response, or translation.

	notation	Textual representation
Voc.		$(dg_7)(dr_7)(dg_1)(dr_8)$
Instr.		$(dg_3)(dr_6)(dg_2)(dr_3)$ $(dg_1)(dr_5)(dg_1)(dr_8)$

4. THE CORPUS

We built our own corpus with initial size of 2779 parallel sentences (vocal and instrumental). The goal is to use it to construct a statistical language model and apply a statistical machine translation paradigm. In this section we justify the need for building our own corpus and explain the procedure of building it. We also present some statistics about our corpus.

A. Why build it ourselves?

There are two main reasons that led us to build the corpus ourselves. Firstly, there is a lack of available transcriptions of Arab vocal improvisation, and it is much more difficult to find instrumentally accompanied improvisations. This is while taking into consideration that machine learning usually needs thousands of musical figures, not tens nor hundreds even. Secondly, although there are plenty of recordings of accompanied Mawaweel (plural of Mawwal) available on several audio- and video-sharing websites, transcribing such Mawaweel automatically is very challenging for a variety of reasons, including:

- The challenge of automatically transcribing the vocal improvisation with several instrumental melodic lines that are improvising accompaniment in a non-metric context.
- This musical form is highly interactive; so clapping and shouting from the audience can make the process more challenging.
- Arab music has many different Maqamat, and the same Maqam can have differences in microtonal tuning across different regions, especially for neutral tones. It is also common for the Mawwal to include modulations from a particular Maqam to others. Transcribing unknown audio files would require a robust Maqam-finding algorithm. This is a different research problem that is tackled, yet not completely solved, by other researchers [18]. Indeed, automatically selecting and transcribing quality Mawaweel performances with instrumental accompaniment from YouTube and other online sources is a research challenge that needs further research. Unfortunately this was not within the scope of this project. For the reasons above, neither relying on available transcriptions nor transcribing Mawaweel from the Internet could have been a viable solution for building our parallel corpus at this time. We therefore decided to build our own corpus with our own singers, MIDI keyboard instrumentalists, and equipped recording rooms. Standardizing the recording process allowed us to avoid the issue of transcription quality in this research.

B. Procedure of building the corpus

To build the parallel corpus, we decided to use live vocal improvisation and Arab keyboard accompaniment. Indeed, the keyboard can emulate Arab instruments to a sufficient degree, and many singers today are accompanied by keyboardists rather than acoustic instruments. Moreover, transcribing keyboard accompaniment has perfect accuracy. This is because we only export the MIDI file that includes the transcription details, such as pitch and duration, as opposed to applying signal processing tasks to convert audio to transcription. In the latter approach, accuracy is decent, yet not perfect. In other words, when we sequence a MIDI score derived from a keyboard instrument, we hear the exact transcribed performance, but when we sequence a score of automatically transcribed audio, we are more likely to hear a deformed version of the original performance. Our choice reproduced the real-life scenario of the desired Mawwal automatic accompaniment, where the input is a vocal signal transcribed with a decent, yet not perfect, accuracy, and the output is an instrumental accompaniment that recapitulates the vocal input and its score is generated and reproduced audibly with perfect accuracy. Accordingly, building instrumental corpora using MIDI instruments would allow for incorporating instrumental accompaniment signals without deformity caused by transcription inaccuracy.

C. Corpus statistics

Statistics on the parallel corpus as a whole are presented in Table 2. As shown in the table, the vocal improvisation is in general longer than the instrumental accompaniment. This is although the number of instrumental notes is bigger. This is normal because the keyboard instrument imitated a plucked string instrument, the oud. Thus, the sound does not sustain for a long time, and this requires the instrumentalist to keep plucking in order

to keep the instrument sounding. For both vocal and oud, the ranges of durations of notes are very wide. The table also shows that the overwhelming majority of vocal sentences lay within one octave; also half of the instrumental sentences lay in this pitch range.

	Vocal	Instrumental
Total duration	17907 s	13787 s
Note count	35745	55667
Total number of sentences	2779	2779
Percentage of sentences with tone range within octave	83.62	49.44
Maximum note duration	7.7 s	4 s
Minimum duration	0.14 s	0.002 s
Mean of durations	0.5 s	0.24 s
STD of durations	0.45	0.21

Table 2. Statistics on the parallel corpus as a whole

Table 3 presents corpus statistics at sentence level. For both vocal and instrumental sentences, it is clear that the sentence length may vary extremely. The sentence can be as short as one note or as long to have tens of notes.

	Vocal corpus	Instrumental
Maximum note count	82	140
Minimum note count	1	1
Averages note count	12.86	20.03
STD of note count	10.70	17.96

Table 3. Statistics on the parallel corpus within one sentence

Table 4 presents the number of parallel sentences for each maqam in the corpus, depicting a wide range. As the table demonstrates, maqam ajam had by far the highest number of parallel sentences (1310), whereas hijaz (495), bayati (287), kurd (243), rast (205), and nahawand (138) were less represented. Overall, however, huzam and saba had the smallest number of parallel sentences, with only 51 and 50, respectively. There are a number of reasons for the difference in representation of maqamat: first, each singer's repertoire may focus on some of the maqamat rather than others due to the particular contexts of their training. Second, they may personally prefer to sing in particular maqamat for aesthetic reasons. Third, they may have mastered or feel most comfortable in selected maqamat, perhaps due to common audience requests and expectations, or for other reasons. It is worth mentioning here that both improvisers and accompanists were asked to avoid modulation to other maqamat when performing on a particular maqam. However, they were allowed to apply some coloration, such as chromatic ornamentations.

Table 4. The count of parallel sentences for each maqam in the corpus.

Maqam	Count of parallel sentences
Ajam	1310
Hijaz	495
Bayati	287
Kurd	243
Rast	205
Nahawand	138
Huzam	51
Saba	50
Total for all maqamat	2779

Table 5 Shows the distribution of the corpus over the singers and instrumentalists. Three singers and three instrumentalists contributed to the corpus. All the performers were professionals with excellent command of Arab maqam theory. The three vocalists performed 1207, 1125 and 447 sentences, and the three instrumentalists performed 1347, 985 and 447.

Table 5. Counts of sentences performed by each musician.

	1st singer	2nd singer	3rd singer	Total
1st instrumentalist	222	1125	0	1347
2nd instrumentalist	985	0	0	985
3rd instrumentalist	0	0	447	447
Total	1207	1125	447	2779

5. DATA REPRESENTATION

The development of quality NLP models requires very large corpora. Our corpus, however, is both small and diverse. It is important, then, to represent this musical data with minimal letters and words from our two proposed languages, vocal improvisation and instrumental response. Yet it is also crucial that such minimization not deform the essence of the musical data. We analyze two main musical elements in this corpus, pitch and duration, and represent them as scale degree and quantized duration. The following two sub-sections discuss this process in detail.

A. Scale degree

Our corpus draws from a wide variety of Maqamat (musical modes), including Maqamat with neutral tones (tones with $\frac{3}{4}$ interval), and transpositions of Maqamat to less keys. Furthermore, the pitch range of both the vocal improvisation and the

instrumental accompaniment can exceed two octaves. When using pitches as letters in our proposed language, the total count of letters can exceed 48 (24 pitches per octave with a minimum interval of $\frac{1}{4}$). When using pitch-class representation, which equates octaves, the total count of letters does not exceed 24 pitches. This number remains high relative to the small size of the corpus. Given this issue, and the complication of incorporating different Maqamat in varying keys, we decided to use scale degree representation. Arab Maqamat are often based on seven scale degrees, allowing us to have the total number of letters as low as seven. One drawback to this method, however, is the inability to distinguish accidentals, the pitches that deviate from the given Maqam. Applying this configuration to the automatic transcriber of vocal improvisation, however, allows for a significantly improved transcription quality [10] that outweighs the necessity to track accidentals.

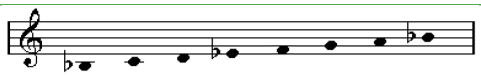
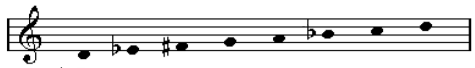
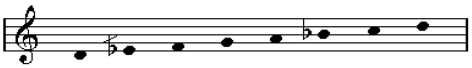
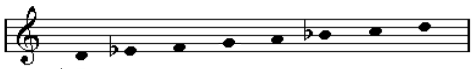
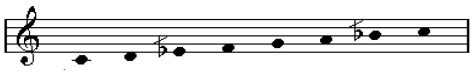
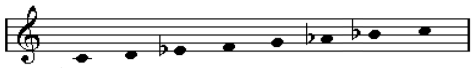
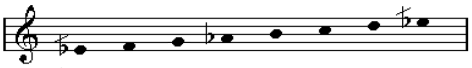
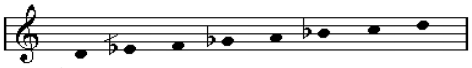
Table 6 presents notations of the maqamat used in the construction of the parallel corpus. The maqam is a group of notes with principles or traditions that mark out relationships among them, common melodic patterns and developments. Although the Arab maqam is best understood in the perspective of Arab music, the most related counterpart in Western music is a mode [19]. This is a selection of the most common maqamat, most likely to be used in performance. They are also in their most common keys. For all the maqamat in table 6, the first note in this ascending stepwise scale is the first scale degree, the second note is the second scale degree, etc. The last note in the scale, the eighth, is the eighth scale degree. In these examples, the eighth scale degree is the same note of the first scale degree but one octave higher, meaning the pitch has double the frequency of the first scale degree.

B. Quantized duration

Here we present two histograms of note durations, one for vocal improvisation and the other for oud accompaniment. Analyzing the histograms helps determine the best total number of quantization steps, and also the duration range of each step. We need to have as few steps as possible in order to have better translation results, but it is crucial to retain the quality of the translation. Figure 1 shows the histogram of note durations of the vocal improvisation. We adjusted the value of the pin size to 0.139 seconds, and this is the minimum note duration (MND) in our adopted solution for the automatic transcription of vocal improvisation. Figure 2 depicts the percentage of notes located within or below each pin in the vocal improvisation. As shown in this figure, 89.3% of the note durations are within or below the first 7 pins. The remaining durations, which are relatively very long, are concentrated along other upper pins. It therefore follows to group these long (upper) durations into two bigger pins, each of which holds about half of these long durations. While taking into consideration that the first pin is empty because no note can be below the MND of the transcriber, the total count of used pins, or language letters, for the vocal corpus is 8.

Figure 3 shows the histogram of note durations of instrumental accompaniment. We adjusted the value of the pin size to 0.07 second. This is half of the vocal pin size, because in our corpus, the average duration of oud notes is half of the average duration of vocal notes. Figure 4 illustrates the percentage of notes located within or below each pin in the instrumental accompaniment. As can be noticed from the figure, about 89.9% of the note durations are within or below the first 6 pins. The remaining durations, the relatively very long ones, are concentrated along other upper pins. We group these long durations into two bigger pins, each of which incorporates about half of these long durations. Accordingly, the total count of used pins, or language letters, for the oud corpus is 8.

Table 6. The maqamat used in the construction of the corpus, notations from [19].

Name	Notation
Ajam	
Hijaz	
Bayati	
Kurd	
Rast	
Nahawand	
Huzam	
Saba	

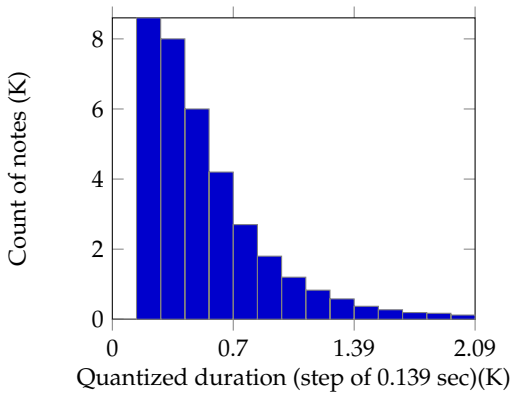


Fig. 1. Note durations of the vocal improvisation

6. MACHINE TRANSLATION EXPERIMENTS

Machine translation has been used to translate improvisation in both sides Vocal to Instrumental and Instrumental to vocal. In

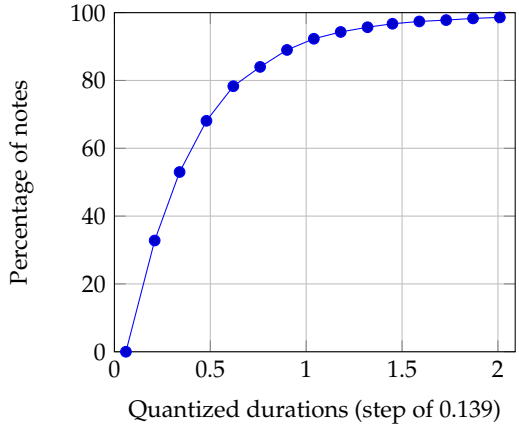


Fig. 2. Percentage of vocal notes with durations below or equal each quantization step

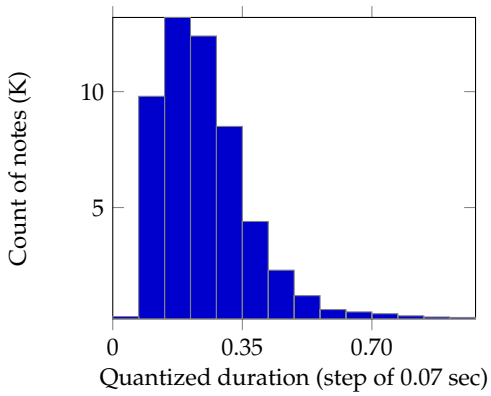


Fig. 3. Note durations of instrumental accompaniment

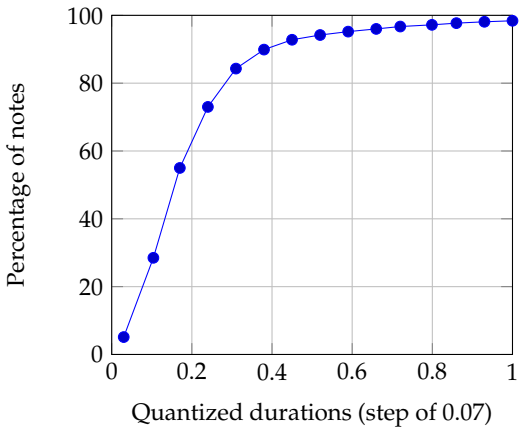


Fig. 4. Percentage of instrumental notes with durations below or equal each quantization step

order to find the best model, we tested several representations of the music format. The MT system is a classical one with default settings: bidirectional phrase and lexical translation probabilities, distortion model, a word and a phrase penalty and a trigram language model. For the development and the test we used corpora of 100 parallel sentences for each of them. We used the bilingual evaluation understudy measure (BLEU)[20] to evaluate the quality of the translation. The formats and the BLEU scores are given In Table 7. Each format has different settings of three types of choice:

- Score reduction: this means that the music score was simplified using the formula in reference [5] in order to make the musical sentences shorter (with less notes). We used two representations for the reduced score:
  - Reduced Sustain: means that each unessential note was removed and its duration was added to its previous essential note, i.e., sustaining the essential note.
  - Reduced Silence: means that adjacent unessential notes were replaced by anew silent note that incorporates the durations of these unessential notes.
  - Unreduced: means no score reduction was applied. Apparently score reduction did not give good results, possibly because the reduction oversimplifies the patterns of melodic sentences and makes regularity ambiguous.
- Merging adjacent similar notes:
  - Merged: replace each two similar adjacent notes by one longer note to minimize the size of the musical sentences.
  - Unmerged: do not apply merging adjacent similar notes.
- Note representations:
  - Scale degree
  - Quantized duration
  - Scale degree and quantized duration

The best results have been achieved by merging adjacent similar notes, but without applying score reduction. Results are promising as the BLEU is 19.03. We also listened to the automatic accompaniment, and we believe it does have potential. Audio examples and other information are available on the project page in ResearchGate [1]. Better BLEU score for this format was achieved when considering only one part of the musical information: either the duration or the scale degree, results were 21.27 and 24.62, respectively. The results of translating features separately (degrees alone and durations alone) could not be used to create accompaniment sentences, or translations, because creating a music notation need durations and degrees to have equal count. However, when separating the vocal sentence before translation into two parts, the number of resulting instrumental durations after translation does not necessarily equal the number of scale degrees. For example, when applying separated translation on a

[1] https://www.researchgate.net/project/Translating-Arab-Music-TRAM-Applying-Machine-Translation-on-Automatic-Accompaniment-to-Vocal-Improvisation

vocal sentence of 20 notes, i.e. 20 scale degree and 20 durations, the count of resulting instrumental translation can be 28 scale degrees and 32 durations. We cannot make a meaningful music notation in this case. Nevertheless, the results of translating musical features separately give an idea on where to apply more improvement in future research.

7. CONCLUSIONS

As part of efforts to improve the automated accompaniment to Arab vocal improvisation (Mawwal), in this contribution we considered the type of melodic accompaniment in which the instrumentalist(s) responses to, or translates, each vocal sentence after its completion. We built a relatively small parallel corpus; vocal and instrumental. We explained why we needed to construct this corpus ourselves. Then, we discussed data representation, also some statistics gathered from the corpus. After that we experimented with statistical machine translation. Results were positively surprising with a BLEU score reaching up to 24.62 from Vocal to instrumental, also 24.07 from instrumental to vocal. In addition, listening to translated music assured that this approach of automatic accompaniment is promising. Future work will include expanding the parallel corpus and introducing subjective evaluation side by side with the objective BLEU.

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Format of data	Vocal → Oud	Oud → Vocal
Unreduced Unmerged Scale Degree and quantized Duration	7.87	14.01
Reduced Merged Sustain Scale Degree	7.95	11.25
Reduced Merged Silence Scale Degree and quantized Duration	9.21	7.30
Reduced Merged Silence Scale Degree	9.94	15.92
Reduced Merged Sustain Scale Degree and quantized Duration	11.58	9.07
Reduced Merged Silence quantized Duration	14.10	8.40
Unreduced Unmerged quantized Duration	15.66	18.76
Unreduced Unmerged Scale Degree	15.66	24.41
Reduced Merged sustain quantized Duration	16.93	11.16
Unreduced Merged Scale Degree and quantized Duration	19.03	9.66
Unreduced Merged quantized Duration	21.27	22.38
Unreduced Merged Scale Degree	24.62	24.07

Table 7. BLEU score for each format data

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