Analysis of performances and computational modelling of *maqam* improvisations

Mondher Ayari, Olivier Lartillot

We study the influence of cultural knowledge in the way *maqam* improvisations are perceived and understood by listeners from various cultures. Due to complex interactions between the dynamic process of segmentation and the influence of cultural knowledge (Ayari, 2008), intercultural perception needs to be observed from different perspectives including music analysis, cognitive ethnomusicology and computer modelling, in order to describe the real-time potential of music understanding. Our research started with the study of Tunisian *maqam* and progressively extends towards a larger range of musical traditions of the Mediterranean Basin.

Listening experiment. An *Istikhbâr* (a traditional improvisation style in Tunisian music), performed on the *Nay* flute by the Tunisian master Mohamed Saâda, was analysed by three classes of musicians: 20 Tunisian traditional musicians ('**t**' in Figure 1), 20 European jazz musicians ('**j**') and 20 European non-jazz musicians ('**n**'). The individual listening strategies followed by those expert musicians from various cultures were explored with the help of an experimental protocol (Lartillot and Ayari, 2009) based on identification of musical material, recognition of mode and modulation, three segmentation tasks: free segmentation into large segments (black triangles above the score), and their subdivision into smaller segments (white triangles) and a directed segmentation based on modulations, i.e., on transitions from one *jins* to another (grey triangles). Segmentations were clustered across subjects, according to the underlying heuristics guiding their segmentation they indicated. An interview was also carried out with each participant in order to interpret more precisely their reactions, to understand the difficulties they faced during the experiment, to contrast diverse listening strategies and to compare multiple analytical approaches.

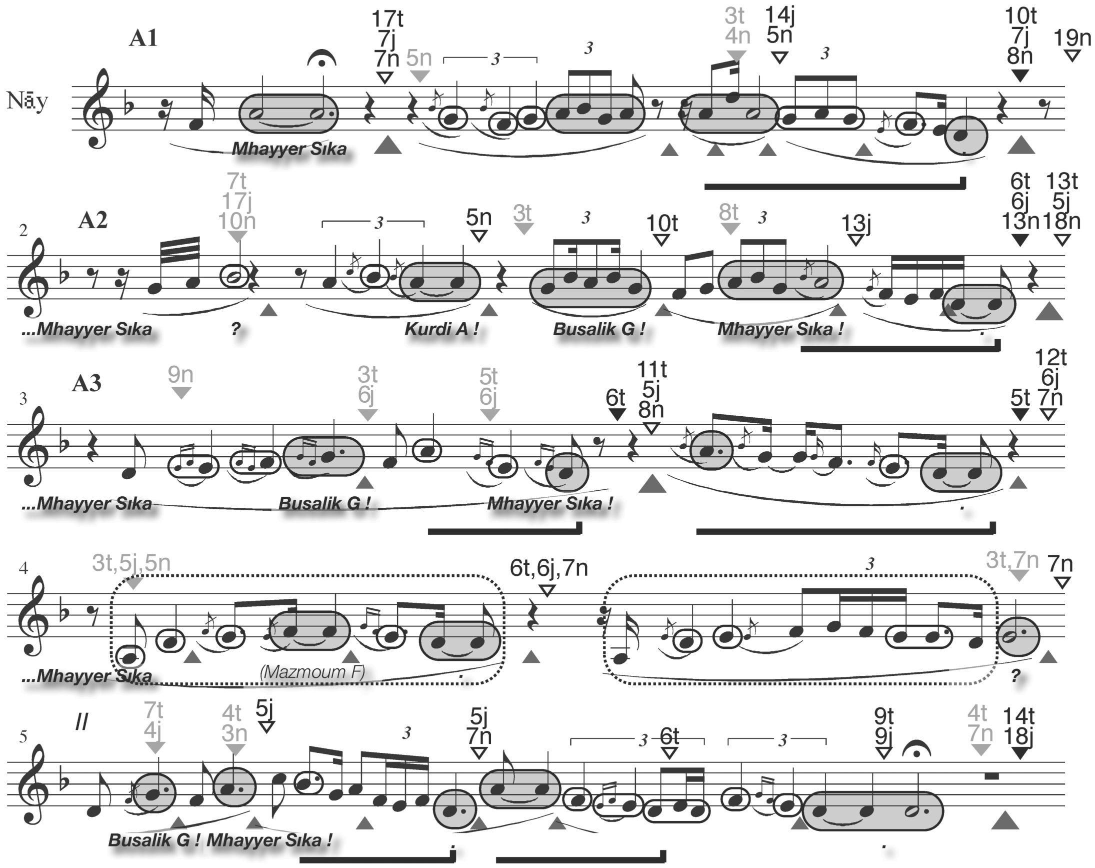

Figure 1. An *Istikhbar* improvisation, as segmented by different groups of listeners (indicated over the staves) and by the computational model (on and under the staves). See the text and (Lartillot and Ayari, 2011) for explanations.

Cognitive modelling of *maqam* structure

The main question in this study is to understand what is happening in the listener's mind when listening to a *maqam* improvisation. In order to study in details important structural aspects of the modal structure of *maqam* in general, we need here to apply a systematic and rigorous methodology requiring a reductive focus on mainly ***technical*** aspects of *maqam* music: namely, the organisation of the modal scale into *ajnas*, the organisation of the temporal flow of music into pivotal notes and ornamentation, the progressive structuration of the improvisation based on those aspects. Consequently, we will *not* consider here more subtle aspects related to, among many others, the global formal construction of *maqam*, the style of each improviser and each particular culture, the semantic aspects of the music and the lyrics, the underlying emotions, the social representations associated to *maqam*, etc. This ***reductive*** approach to structural aspects is a necessary step in the establishment of a coherent and detailed cognitive model of *maqam* understanding, the taking into account of more complex and subtle configurations is planned for future stages of our research projects.

Our aim is to reveal commonalities in the way listeners built some kind of structural understanding while listening to an improvisation. In order to describe these listening strategies in a complete and detailed way, we propose to establish a set of basic rules, of heuristics, describing in detail the modal characteristics of *maqam* and how listeners understand them, that we try to describe as precisely as possible. The cognitive rules are modelled as computer algorithms, in order to automate the structural analysis. In this way, these abstract rules can be tested by comparing the results given by the computational model with the reactions given by the listeners during the experiments we described in the previous section. These comparisons enable to validate the model and to guide its progressive improvement. The cognitive modelling of the segmentation strategies is conceived as a complex articulation between purely perceptual rules and cultural knowledge, which are structured into a list of heuristics presented in the following paragraphs.

Modal structuration of maqam. This study focuses on how listeners perceive the modal development of the Tunisian *Mhayyer Sîkâ* maqam developed in the *Istikhbar* improvisation. The modal structure of *Mhayyer Sîkâ* is defined by a main scale (first stave in Figure 2) as well as two secondary scales (staves 2 and 3). Each scale is further decomposed into *ajnas*: each *jins* is made of a series of 4 or 5 successive notes of the scale, highlighted in Figure 2, where the names of each *jins* is also given (*Mhayyer Sika*, *Mazmoun fa*, *Busalik sol*, etc.). Each *jins* is also characterized by the presence of pivotal notes, circled in Figure 2. For instance, the main *jins* of the *Mhayyer Sika* mode, called also "*Mhayyer Sika*", is composed of the series of notes *ré mi fa sol la*, with the two extreme notes *ré* and *la* being the pivotal notes.

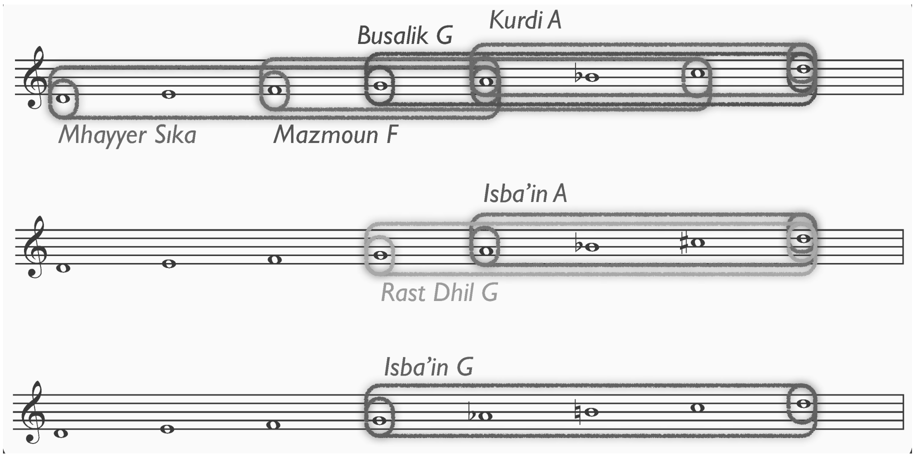

Figure 2. Scale structure of the Tunisian maqam mode *Mhayyer Sika*. Each series of 4 or 5 notes highlighted is a *jins* with its corresponding name. Pivotal notes of the *jins* are circled.

Typically, a maqam improvisation is made of a succession of moments, each focussed on the use of a particular *jins*. Our hypothesis is that listeners (especially expert listeners) perceived this succession of *ajnas*. In the cognitive model described below, we attempt to formalize the principles underlying the listeners' capabilities in understanding this modal development. This study focuses on the particular *maqam* structure developed in the *Istikhbar* improvisation under study. In future work, we plan to generalize the model to a larger set of *maqamat*.

Ornamentation filtering. First, a distinction is made between short notes that mostly play the role of ornamentation and longer notes that constitute the important steps in the melodic phrasing. The simplest method consists in filtering out notes whose temporal distance with subsequent ones (or inter-onset-interval) is shorter than a given constant threshold (for instance, 400 ms). A more refined heuristic has been designed that take into consideration the gross contour profile: an ascending line, for instance, made of a succession of ascending intervals with short durations, followed by a descending interval, enables to highlight the highest pitch, climax of that ascending line, even when its actual temporal duration is short. A significant amount of work will be required in the future in order to enrich this modelling of mechanisms of ornamentation and reduction and to take into consideration a large range of techniques, their cognitive justifications as well as their cultural background.

In the transcription of the piece (cf. Figure 1), important notes, which remain once ornamentation has been filtered out, are circled. When two successive important notes relate to the same pitch height, they are fused into one single note. In Figure 1, this corresponds to circles grouping a series of notes, the first and last one considered as the main single event.

Pivotal note detection. Once notes playing a role of ornamentation are filtered out, what remains are notes whose pitch height values play a role in the modal structure. Amongst those notes, a further distinction is made in order to highlight notes of particularly long durations that play a role of melodic punctuation, and whose pitch height values corresponds to pivotal points in the modal structure. A simple way of defining those important notes is based on a simple constant threshold related to the note duration (or more precisely inter-onset interval): notes whose duration exceeds that threshold (for instance, one second) will be considered as possible candidates for the detection of pivotal points in the modal structure. Pivotal notes are indicated on the score by circles filled with grey colour.

***Jins* modelling.** With each *jins* is associated a numerical score that varies throughout the improvisation under analysis. This value represents a degree of likelihood, or activation, of the given *jins*, and allows a comparison between *ajnas* and the selection of the most probable one at each successive step of the improvisation. This score is represented as a value on a numerical scale referenced by a threshold value: score above this threshold indicates that the *jins* can be considered as a plausible candidate, whereas score below the threshold negates the significance of that particular *jins* for the given musical context.

Each successive note in the improvisation implies an update of the score associated to each *jins*. Four general rules have been proposed concerning the determination and update of *ajnas* scores:

***Jins* reinforcement.** When the pitch height value of a note currently played belongs to a particular *jins*, the score of this *jins* is slightly increased. If the score is below the threshold, the score increases, but remains still below the threshold.

Pivotal activation. When a long note currently played corresponds to a pivotal note of a particular *jins*, the score of this *jins* (if inactive) is significantly increased, exceeding the detection threshold, thus confirming the given *jins* as a possible candidate for the current context.

***Ajnas* competition.** When several ajnas are activated, the *jins* with highest score is selected as the currently prominent *jins*.

***Jins* deactivation.** When the pitch height value of a note currently played does not belong to a particular *jins*, the score of this *jins* is set back to the minimum. When the pitch height value of a long note currently played does not correspond to a pivotal note of the *jins*, the score is simply decreased slightly.

Modulation segmentations. The aforementioned rules specify how scores are progressively assigned to each *jins* note after note. We also proposed few simple rules enabling to infer segmentation points from those *jins* scores: When the previously selected *jins* is not confirmed anymore, if a new *jins* is confirmed, this new modulation leads to a firm segmentation point (indicated by '**!**' in Figure 1); if on the contrary no *jins* is confirmed, we reach a point of indecision, leading to a possible segmentation (indicated by '**?**'). When instead the current long note corresponds to the stable note of the selected *jins*, the modal development reaches a state of stability, corresponding to a possible important punctuation of the phrase (indicated by '**.**' in Figure 1), leading to a candidate segmentation point.

Melodic pattern specific to each mode. Besides those considerations based on scales, subscales and pivotal notes, modes are also characterised by specific short melodic motifs. The termination of the archetypical *Mhayyer Sîkâ* motif, for instance, indicated by bold lines under the staves showing one vertical mark at their right ends.

Comparisons between listeners and the theoretical model

Both European and Arab listeners could perceive parts of the composition process developed in *maqam*, but the modulation from one *jins* to another is more strongly perceived by expert listeners as provoking a segmentation in the musical grammar. Each termination of the archetypical *Mhayyer Sîkâ* motif provokes a segmentation decision by expert listeners. Our study indicates that, whereas a cognitive model purely based on perceptual rules may offer some explanation of listeners' behaviours, the integration of cultural knowledge enables a deeper but in the same time clearer interpretation of the ways listeners construct a structural understanding of the improvisation (Lartillot and Ayari, 2011).

Conclusions

By implementing a new model describing aspects of music analysis, music perception and music cognition into a computational model, this enables to build a systematic model where theoretical hypotheses can be fully tested. The predictions suggested by the computational model based on the theoretical hypotheses, once they are confronted with concrete musical cases and listeners' judgments, enable to question those theoretical hypotheses and to improve both the theoretical models and the resulting computational algorithms. We obtained in fine a computational model that has been perception-tested, and that can be subsequently applied to the analysis of more complex pieces of music.

The resulting model will be made available to the research community in the form of a new computational environment called *CréMusCult*[1]. This tool will enable systematic analysis of maqam music, offering very detailed description of very large corpus of improvisations. This will also allow to test different hypotheses, and to model various cultural expertise. This could also be used for music pedagogy, in order to teach the principles of maqam music using interactive analyses of particular improvisations, played by expert musicians or by students themselves. In long term, the same computational environment will be generalized to the study of other style of music such as modern taqsim, jazz, etc. The cultural knowledge that has been added in the computational model is based on a set of general mechanisms (scales, set of notes, numeric

[1] This software will be one product of a new research project called *Creativity/Music/Culture* and funded by the French ANR research agency.

“activation” value associated to each mode and each jins, etc.) that might be considered as abstract rules of *maqam* music. For these reasons, its applicability to the analysis of related traditions, such as Azeri *mugham*, would be of particular interest.

A large spectrum of musical aspects need to be included into this computational modelling, in order to consider for instance rhythmical structuration, stylistic and formal analyses, specific gestures of each improvisers, formal schema of modern improvisations, etc.

References

Lartillot, O., & Ayari, M. (2011). Cultural impact in listeners’ structural understanding of a Tunisian traditional modal improvisation, studied with the help of computational models. *Journal of Interdisciplinary Music Studies*, 5(1), 85–100.

Lartillot, O., & Ayari, M. (2009). Segmentation of Tunisian modal improvisation: Comparing listeners’ responses with computational predictions. *Journal of New Music Research*, 38(2), 149–159.

Ayari, M. (2005). *De la théorie musicale à l’art de l’improvisation : analyse des performances et modélisation musicale*, Delatour-France, Sampzon, coll. « Culture et cognition musicales »

Ayari, M. (2003). *L’écoute des musiques improvisées : essai de psychologie cognitive*, L’Harmattan, Paris, coll. « Univers musical ».