A Timbral and Musical Performance Analysis of Saxophone Multiphonics Morphings

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ABSTRACT

This work presents a study of the multiphonics of the saxophone from the points of view of timbral analysis and musical performance. A multiphonics categorization into four groups was previously proposed, starting from a musical analysis and further validated by psychophysical experiments and spectral analysis tools. This classification served to identify relevant timbral attributes of the studied multiphonics, such as modulation frequency, spectral center of gravity and roughness. The present work extends the analysis to the spectral morphing of multiphonics, generated by the continuous modification of the playing parameters. These morphings are studied in a comparative view as trajectories in a timbral space, based on the aforementioned attributes, and in terms of their feasibility in the instrument. From this comparative analysis a dynamic characterization of the proposed multiphonic groups is derived.

1. INTRODUCTION

The multiphonic sonority constitutes an idiomatic part of the language of contemporary music. Unlike in the past, when their use had a decorative or accessory character, nowadays this type of sounds has gained a structural space in the musical composition. Many pieces are constructed "from" the multiphonics, starting from their mixed sonority of timbre and harmony as a poetic-musical trigger element. In this context, the saxophone provides a wide range of multiphonics that have been approached from multiple perspectives[1,2,3,4].

In a previous work, we have studied a timbral categorization for the multiphonic tones in the saxophone from a musical, psychophysical and acoustical point of view [5]. This work served to establish a space defined by acoustic parameters that allowed to assign each of the proposed categories a given region in a two-dimensional space. Although this study was performed on static sounds, it was suggested that each multiphonic is rather a dynamical structure capable of traversing different stages. As a consequence, it is possible to think of timbral modulation trajectories, or morphings, between the different sonorities, even for the same multiphonic.

The present work is focused on the study of multiphonics morphings. For this purpose, a set of morphing trajectories, presenting significant changes both at the spectrum level and in other timbral attributes, will be studied. These trajectories, once defined in a two-dimensional space determined by the acoustical parameters, will display the timbral evolution of a multiphonic across the different sonorities. In this way, it is sought to establish a systematization for multiphonic morphing that contemplates the plurality of aspects involved.

2. MULTIPHONICS MORPHINGS

We can say, roughly, that *morphing* is the process during which a sound progresses from one timbre to another. Since timbre is multidimensional in nature, a morphing process does not take place along a single dimension, and entails the modification of many sound parameters in an interdependent way: pitch, dynamic envelope, spectral envelope, degree of roughness, harmony, etc. It was proposed [6] that a morphing process, in order to be perceived as such, must meet three basic requirements: (a) gradualness, which refers to the degree of smoothness of the timbral change, taking into account the gradualness of the timbral differences between the different states, the temporal separation, the duration and the rate of change; (b) directionality, which points out to the relationship between the starting timbre, the arrival timbre and the type of trajectory between both; and (c) time continuity, which reflects how the intermediate states of this modulation take place in time, and whether this occurs continuously or discontinuously.

We will also establish certain guidelines for our study. In the first place, we will be focused on the multiphonics of the alto saxophone as a solo instrument, *i. e.*, we will leave aside the morphing processes that include more than one instrument. In the second place, we will restrict our study to those processes that can be realized in a single gesture (a single *fiato*) discarding those that imply the need to attack the sound more than once[1] . We will therefore undertake the study of multiphonics morphings in the alto saxophone that can be performed by a single instrument, in a single phase and that meet the requirement of being gradual, directed and continuous.

Seven multiphonics of the alto saxophone were selected for the analysis. This choice was made taken into account each particular attribute of the multiphonic, not only based on its sonority but also on the possibilities of tímbrical and dynamical evolution. In order to qualify these attributes, the analysis carried out in the typology previously proposed was considered [5]. This typology consists of four sets of sonorities, or classes, that can be summarized here: (a) *Bichords:* multiphonics with a stable sonority, and a first interval that is around a 3rd, with a velvety quality of surface, and dynamics ranging between *pp* and *mf*, (b) *Complex multiphonics*: have a relatively stable sonority, with emphasis on the higher

[1] We do not discard here the use of circular breathing, as long as we understand it as a single gesture, a continuous sonority that is not interrupted in its evolution by breathing or silence.

harmonics, a high degree of dissonance, a compact and rough surface quality, dynamics between *mf* and *ff* and a first interval that is around a 9th. (c) *Multiharmonics:* are unstable multiphonics from the point of view of their production, they do not present activity in the upper part of the spectrum and their dynamics range between *ppp* and *mp*; also their surface quality is remarkably smooth, with a first interval corresponding to a 7th or a 9th. (d) *Tremolos:* present a homogeneous distribution of the spectral energy, with a surface quality marked by the beat and type of grain typical of a tremolo sound, and a degree of consonance relative to the tuning of its first interval that is close to the octave.

These classes have been proposed for stationary fragments (a three-second cut was made in which the multiphonic was stabilized) from a reduced listening[2] and further validated by a psychophysical study [5]. However, each fingering that produces a multiphonic determines a structure of pitches that the performer must stabilize from the intonation and use of the vocal tract. From modifications in the mouth, air column and intonation, it is possible to obtain different sonorities with the same fingering. In this way, we can say that a multiphonic must be considered a dynamic structure capable of traversing different stages [7]. From a signal analysis point of view, the saxophone multiphonics could be considered as modulated tones, hence having intrinsic property, which is the modulation frequency. This modulation is produced by the superposition of the different pitches and their nonlinear interaction in the reed [8], and is a determinant parameter of the timbre.

A sound morphing is a continuous phenomenon that presents intermediate stages, as well as a visual morphing [9], so that each of the static classes proposed in our typology can be either the starting point, the point of arrival or some of the intermediate points in a multiphonic morphing. In order to perform a multiphonic morphing on the saxophone, the interpreter must control the pitch changes in order to have continuity in each of the intermediate stages.

For the present work we selected representative multiphonics spanning the four proposed classes (see Figure 1). Multiphonics 1 and 4 when played *pp* behave like a Bichord, while as the intensity is increased a third pitch becomes audible and a general timbral change is observed. Multiphonics 5 and 6, belonging to the set of Complex Multiphonics, present a greater degree of roughness when reaching the *mf*, which increases when reaching *ff*. Sounds 2, 3 and 7, although not exclusive to tremolo sonority, have a greater spectral activity, since they include, in contrast to previous cases, a partial sound in the bass record of the instrument. At the same time, as they grow in dynamics they present different evolutions of internal beat and roughness.

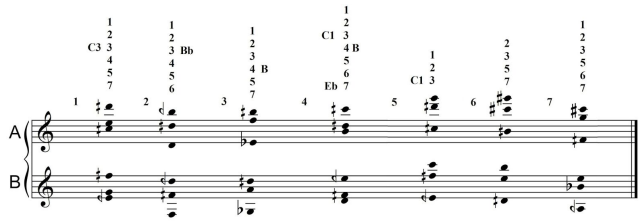

Figure 1. Musical notation for the seven multiphonic alto saxophone under study. Staff A displays the notes transposed to Eb and the digitation that produces that multiphonic. In staff B the pitches are presented in concert pitch.

All the selected multiphonics, starting from *pp* present a sonority close to the Multiharmonic type, while as they evolve spectrally they approach the aforementioned classes. In musical notation (see Figure 2) all the examples start from *pp* and go to *ff*. The phonation of the multiphonic is maintained during the entire fiato, but the partials rise as the intensity of the blow increases. For that reason, we decided to add to the traditional notation a crescendo colored on the score, giving the notion that the number of different pitches increases along with the intensity. The linkage between intensity and the number of different pitches is also apparent when inspecting the spectrogram of the multiphonic morphing, as displayed in Figure 3.

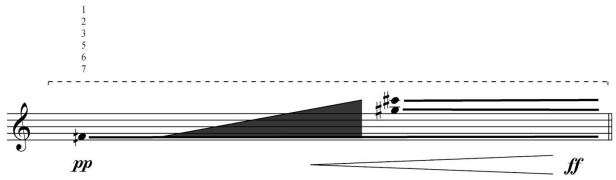

Figure 2. Musical notation of a multiphonics morphing (Multiphonic 7 of Figure 1). As the same fingering is used throughout the entire playing, the structure of pitches of the multiphonic is maintained. Increasing the intensity increases the number of pitches, and a transition between a smooth sonority with little spectral activity (Multiharmonic) and a sonority with a much larger mass and great roughness (Tremolo) take place.

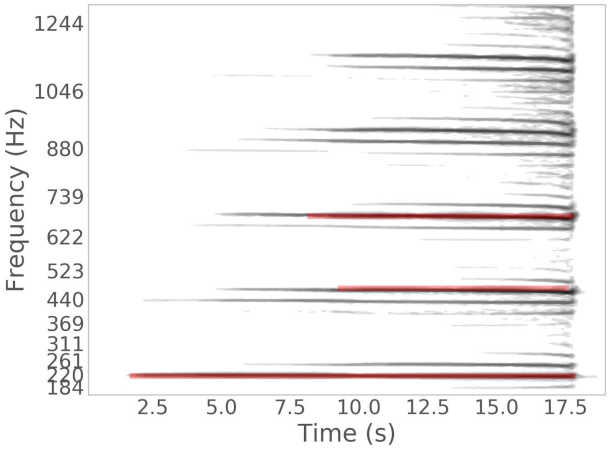

Figure 3. Spectrogram of Multiphonic 7 displayed in Figure 2 in musical notation. The evolving pitches are depicted as shaded lines and were detected by a pitch extraction algorithm [10]

[2] The reduced listening is a concept proposed by Pierre Schaeffer (Schaeffer, 2003) and is a type of isolated listening in which the auditory analysis of a sound object is made independently of the source.

3. RECORDINGS AND ANALYSIS

The multiphonic tones were played with a Selmer Super action 80 Serie III alto saxophone tuned at A = 440 Hz, with a Selmer Serie 80 C* mouthpiece and Vandorem 3½ reeds. The recordings were made using an acoustical measurement microphone (DBX TRA-M) and a Focusrite Sapphire external sound card at a sampling rate of 48 kHz with a resolution of 24 bits. The multiphonics were selected and performed by one of the authors (MP)[3]. The samples were recorded in a room with sound isolation and acoustic treatment (noise floor 19 dBA, reverberation time T60 @ 1 kHz 0.3 s). Recorded samples have an average duration of 19 seconds, minimum of 15 and maximum of 22 seconds.

In order to perform the timbral analysis of the recorded trajectories, first a set of relevant acoustical features must be selected. We will circumscribe this first study to only three parameters: spectral centroid, modulation frequency and roughness. The selected acoustical features are those that showed a higher correlation with the coordinates of a multidimensional analysis performed over a psychophysical study of discrimination of the proposed multiphonic classes [5]. Feature extraction was performed taking frames of 85 ms length, with steps of 42 ms for the roughness and centroid and 1360 ms length and steps of 680 ms for the modulation frequency. For each frame roughness was measured from spectral peaks using the method from [11]. Spectral centroid was computed as the first moment of the spectral power distribution. Modulation frequency was extracted by computing the autocorrelation of the spectrum and identifying the largest and lowest in frequency peak.

For these multiphonics morphings, the intensity, the roughness and the centroid are highly correlated. The main reason of this strong correlation is the following: as the blown intensity is increased more partial components are added to the sound, thus pushing the centroid to higher frequencies and increasing the roughness at the same time. Nonetheless, the spectral centroid is also affected by the pitch structure of each multiphonics setting, where the pitches are higher. In addition, the modulation frequency reflects the average frequency distance between partial components, which also affects the roughness.

In the following figures we display the timbre space trajectories of the multiphonics morphings. Figure 4 depicts the timbral space of roughness vs. modulation frequency. Most morphings, beside Morphing 3, start at low intensity with a low amount of roughness and as they evolve, the roughness is progressively increased (diamond markers indicate the end of the trajectories). Morphing 3 is an example of a sound where the number of partial components remains roughly constant along the trajectory although, at the same time the modulation frequency declines and the roughness displays a slight increment, as the trajectory evolves.

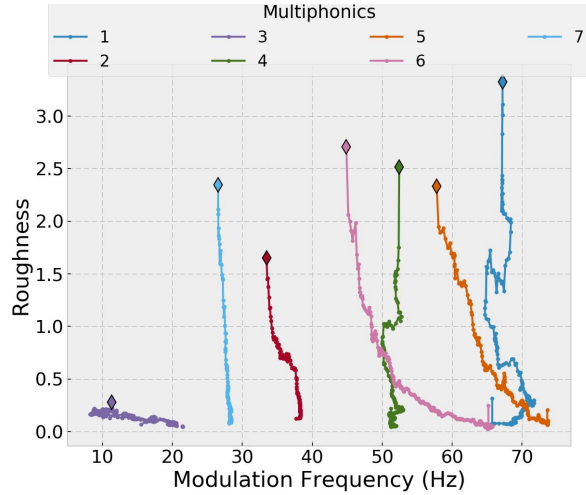

Figure 4. Trajectories of the seven multiphonics morphings in the roughness / modulation frequency space. The diamond marker indicates where the trajectory ends.

In Figure 5 we display the same trajectories unfolded in the timbral space of spectral centroid vs. modulation frequency. The trajectories are somehow similar to those exhibited in the previous figure, but Multiphonics 1 and 5 show different behaviors relative to the maximum values of roughness and spectral centroid. In this Figure we also overlay the timbral space regions that characterize the four multiphonics classes introduced before. These regions were estimated from a set of 118 categorized multiphonics, as described in [5].

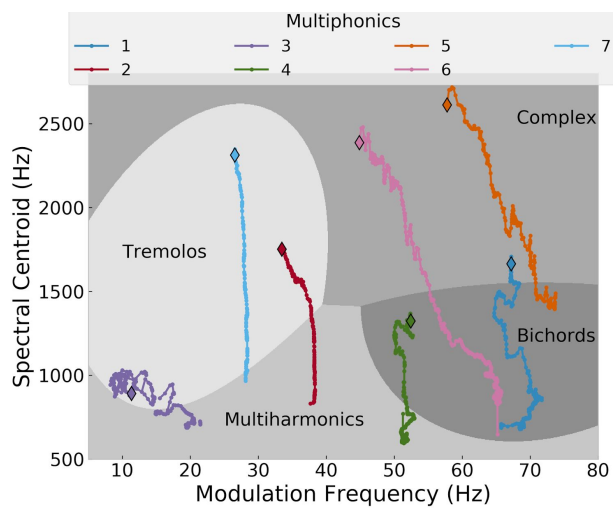

Figure 5. Trajectories of the seven multiphonics morphings in the spectral centroid / modulation frequency space. The diamond marker indicates where the trajectories end. The shaded region indicate the timbric space portion for the multiphonics of the four classes described in the text.

[3] The recordings are available at http://www.lapso.org/multiphonics.html.

We could say that, in general, as the dynamics increases, the spectral centroid rises while the modulation frequency decreases. The first effect is mainly due to the fact the more energy is imprinted to the multiphonic, the higher the stimulation of new partials sounds. As for the modulation frequency, we can conjecture that by increasing the velocity of the air column, in order to keep the sound stable, the player must loosen slightly the embochure, causing a decrease in the beat rate and therefore in the modulation frequency.

4. CONCLUSIONS

In this work, we studied saxophone multiphonics morphings from a dynamical perspective, using a previously proposed classification as anchors in timbral space. These morphings were obtained in most cases by starting from a low blown intensity and ending near a full blown intensity. This technique creates sounds that have clear trajectories in simple timbre spaces made from a small set of acoustic features. As the intensity increases, the sound not only gets louder but also richer in partial components, thus increasing the roughness and its spectral centroid. These changes entail a substantial timbre modification. In addition, the modulation frequency is not static and suffers perturbations produced by variations in the embouchure.

Timbre space trajectories studies often include many different types of acoustic features and dimensionality reduction techniques [12]. In this work we focused on a relative small set of features that capture the essential timbre properties and dimensionality reduction was not necessary.

Sound morphings are a common practice in contemporary and electronic music, however, studies of timbre space trajectories [13,14] have been done mostly with standard instrument techniques and familiar sonorities. The method presented here could be useful for the analysis of musical pieces that make use of these kind of sounds.

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