# Auditory Fusion and Holophonic Musical Texture in Xenakis's *Pithoprakta*

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## ABSTRACT

One of the most important factors, which affect the perception of textures, depends on the fusion of separate components of the musical passage. The possibilities of such fusion occurring are almost certain in some cases. This is due to the way our auditory system is constructed and the way it functions. The main properties, which promote fusion in a music passage, include the high density of attacks and the timbral similarities of the sounds being played. The latter element includes various spectral features of the sounds. In addition the register of the instrumental parts and their dynamic range promotes textural fusion. This paper uses this set of properties to evaluate and quantify one instance in Iannis Xenakis's *Pithoprakta* (1955-56) where two or more simultaneous sound streams are easily perceived as forming a coherent whole.

## 1. INTRODUCTION

*Pithoprakta* [8] is a highly textural piece. Based on Xenakis's assertion in his program notes [9], the goal of *Pithoprakta* was to lose the individual players' contributions in one single mass of sound, to fuse the individual sounds into a coherent whole. However, there are several challenges in serving this assertion. What is the degree of interaction that the composer expects between conductor/musicians/audiences in the concert hall and what is the delay time occurring during the performance? How much information is written on the score about the 'sound quality' of the textures? How far can the conductor go from the score with his own interpretation?

This paper focuses on bar 15 (shown right) of *Pithoprakta* by Xenakis. In the following chapters, it will be explained the methodology and the analysis tools used in order to classify and measure the fusion achieved in this section of the score. Bar 15 is comprised by non-pitched tapping sounds on the bodies of the string instruments with the flat of the hand. Bar 15 has been chosen for this analysis because it is the beginning of the densest part of this texture before the introduction of fortissimo pizzicato notes that break the single holophonic texture and add one more structural element. Following the paradigm of this paper one can analyse other parts for the piece. Chapter two will give a brief definition of Holophonic Musical Texture [1] and chapters three and four and five will further examine how time timbre and interpretation can influence the fusion of the texture in Xenakis's piece. It is out of the scope of this text to analyse in detail how textural fusion influences the register of the instrumental parts and their dynamic range.



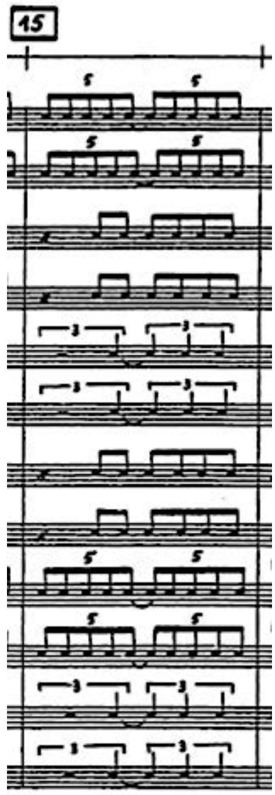


**Figure 1**. The first twelve part from Violin I of bar 15 of *Pithoprakta* by Xenakis.

## 2. HOLOPHONIC MUSICAL TEXTURE

The word Holophony is derived from the Greek word holos, which means 'whole/ entire', and the word phone, which means 'sound/ voice'. In other words, each independent phone (sound) contributes to the synthesis of the holos (whole). Holophonic musical texture is best perceived as the synthesis of simultaneous sound streams into a coherent whole. The Holophonic music is music whose texture is formed by the fusion of several sound entities, which lose their identity and independence in order to contribute to the synthesis of a whole. In a holophonic musical texture you cannot separate the rhythm from the pitch and the instrumental timbres. A holophonic musical texture is not consisting of parts and cannot be partitioned. It exists as wholeness. In particular a holophonic musical texture has one or more of the following characteristics:

a) Granularity (rhythm complexity)
b) Density
c) Timbre similarity (homogeneity)
d) Space singularity
e) Sound continuity

This musical texture aims to create a musical context with various morphoplastic qualities through the process of morphopoiesis [2].[1]

## 3. TIME

The rate of the sound events and their contribution to a fused texture has to do both with the interpretation of the written score and with the performance as an interaction between musicians, conductor, audiences and the concert hall's acoustics. Due to the fact that the balance is very delicate and that the borderline can be easily crossed, the performance plays an important role in determining how fast, how loud, how *sull ponticello* a passage can be performed. All the parameters can dramatically influence the degree of fusion.

### 3.1 Time on Score

As Mountain [4] explains, previous research into aural perception has revealed that humans have a perceptual threshold in separating sound events. When sound events occur at intervals faster than about twenty per second, that is one event every fifty milliseconds, they will inevitably fuse into a single sound. Events happening at slower rates of around ten sound events per second have been traditionally used in music for trills, tremolo, ornamentation, arpeggiation and so on.

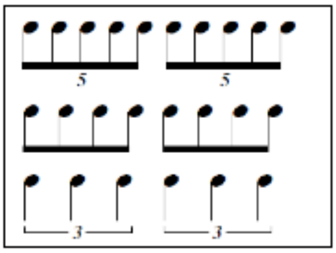


**Table 1.** Superimposed rythms in bar 15.

The In *Pithoprakta,* the texture in bar 15 has time signature and tempo at 2/2 52 per half note. Using a beats per minute (BPM) millisecond calculator,[2] a bar of 2/2 52 per half note has duration 2307ms. Considering the human perceptual threshold of twenty events per second, 46.13 sound events can fit into 2307ms. Bar 15 is composed of a combination of 5/4/3 tuplets per half note (*see* Figure 1). That is, 24 sound events per 2307ms. However, this rate is almost half of the required 46.13 events per 2307ms. In a simulated version of bar 15 using midi computer software that triggers pizzicato sounds, instead of knocking in an absolute synchrony, the result (listen to sound example 1) is clearly far away from the desired mass of sound.

| | |
|---|---|
| Duration of bar 15 | 2307.69 milliseconds |
| Number of events | 24 |
| Desired number of events | 46.13 |

**Table 2.** Bar 15 requires an event rate of 46 per 2307.69ms.

As a result, at first sight the score does not give a number of events close to the fusion threshold for onsets. What happens in the 1965 recording [9]? Is fusion achieved? What creates the fusion, since the attack rate is far below the threshold according to the written score? The next sections will explain the methodology followed to answer these questions.

### 3.2 Time in space

Part of the answer to the questions posed above may lie in the way acoustics affect music performance. Studies by Rasch [5 & 6] showed that a typical delay between the first and the last attack between performers who are playing a single note was approximately 40 milliseconds for large ensembles. For example, if a symphony orchestra were to play a single note simultaneously, the entry time between the earliest musician and the latest musician would be approximately 40 ms. [3] Traditionally, the first stand, in an orchestra's string section, will probably have performers who are the best players in the section; they are the leaders for those sitting behind them and will likely have more accurate timing and, being more confident performers, will play slightly more prominently. Additionally, the sound of these players will be the least delayed and subjected to air absorption since they are seated closest to the audience. Finally, the sound of each stand will be slightly filtered and delayed due to air absorption and distance from the audience [11]. This might sound as an oversimplification but it is part of the orchestral sound.

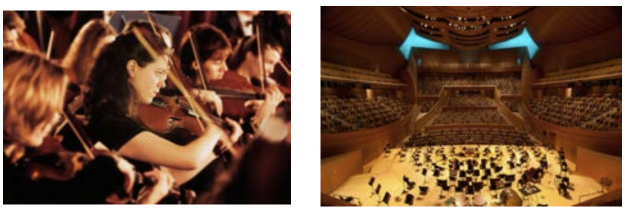

**Figure 2**. Orchestral chorus effect and concert hall delay lines are part of the audiences experience.

[1] The term implies the intention to see the development of musical/ sonic structures as they are formed.

[2] The Beats per minute (BPM / Tempo) Millisecond Delay Calculator is an online application by Time_Spiral <http://www.dvfugit.com/beats-per-minute-millisecond-delay-calculator.php>

[3] Note that a delay of about 40 milliseconds at a tempo of 52 per half note is close to a 64th note.

In the case of *Pithoprakta*, there are 46 string players on stage who play the 26 events in groups. According to Rasch, among the 46 players, the first from the last musician will have a delay of 40ms. That is, although in bar 15 violin I and violin X have exactly the same passage their sound will not arrive to the audience's ears exactly at the same time. Especially for sounds with very short attack like the knocking sound in bar 15 even the slightest time shifting from one instrument to another will be audible. The same happens in various degrees to the rest of the string players and therefore each and every one of the 46 string musical lines could potentially diverge up to 40ms from the written score. As a result the 26 events could be increased, up to the number of players, at 46 events. In sound example 2, a simulated computer generated version of bar 15 (used earlier in sound example 1) has been edited with delay lines up to 40ms, panning and a concert hall reverb with 5secs reverb time. The example 2 is closer to the original recording from the 1965. In bar 15 the time contributes to achieve a holophonic texture with sufficient degree of auditory fusion for two reasons:

- complexity by creating a highly polyrhythmic texture
- event rate by assigning forty six separate instrumental parts

There remains a question of why Xenakis did not choose to notate his score with proportional notation to indicate when the density should by high. This type of proportional spacing of note in the score could clarify the complex rhythmic relationships directly in the score. Another way could be to mention in the performance notes that the synchronism should be tried flexibly, or what he assumes the delay time of an acoustic space for orchestra is. Such a note could provide significant information for the resulting sound in reference with the degree of fusion.

## 4. TIMBRE

As mentioned above, one of the main properties, which promote fusion in a music passage, is the timbre. Because of the way our auditory system is constructed and the way it functions, two or more simultaneous sound streams that have timbral similarities are easily perceived as forming a coherent whole. The timbre similarities of bar 15 are probably evident as all of the musicians play a percussive sound by striking the back of their instruments with the flat of the hand.

### 4.1 Timbre in Score

Xenakis describes in detail the notational issues of this technique providing practical information such as the precise place to strike or the hand position to be used. There is even a particular instruction specifically for the double bass. This information is important because not all knock sounds are similar. A strike at a different part of the instruments' body, or the part of the hand that strikes, such as the finger nail, fingertip or finger knuckle, can produce a significantly different sound that will break the fusion.

Xenakis in his performance notes provides the following description for the knocking sound "…the instrument is to turned over and struck with the right hand upon the center of the back of the instrument, or better, with the flat of the hand (without turning over the instrument), upon the front, close to the shoulder, or beneath the bridge in the case of the double bass [8]." With a simple 'ear testing' it seems that three of the different places have similar sound. That is warm, rich, low woody sound. It seems Xenakis did not want bright, sharp sound that could easily be achieved by using fingernails or knocking at the sides of the instruments. Sounds like those would be harder to fuse, as they are more distinctive.

Clearly there are no cues on the score about the quality of the textures. Expressions like "Dense, Fused, Ethereal, and Frozen" to mention a few could provide extra information to the conductor and the musicians. The only indication about the type of textures remains the description in his program notes "with a large quantity of pointed sound spread across the whole sound spectrum, a dense "granular effect" emerges, a real cloud of moving sound material, …" and second and most at important quotation from his program notes "…the individual sound loses its importance to the benefit of the whole, perceived a block in its totality."sound.

### 4.2 Timbre in Space

At this stage of the research, the sounds used in bar 15 were fed into an analysis and classification algorithm[4] and a 2D timbre space was extracted.

The classification algorithm is driven by a C.A.S.E. (Computer Aided Sound Exploration) engine, a sophisticated suite of algorithms that analyse and intelligently classify an audio collection. The extractor computes more than 600 features from each audio sample. The search interface analyses the audio samples and compares it against the feature database generated by the extractor. This is a common prictice among sound desinger inorder to identify similar sound with in a large sound library. For the classification of the timbres, first each instrument recorded the particular sounds of this section before the sound was fed into the system segmented into single sound events. Then, the segmented sound events of the instrumental parts were analysed by a computer classification algorithm and displayed on a 2D plot. For the paradigm bar 15, a number of eight to twelve knocks for each instrument was recorded. The classification in Figure 2 displays the degree of similarity between the individual sounds.

The plot displayed as Figure 2 clearly shows that the striking sounds are formed all together contributing to the fusion. Also, the woodblock, xylophone and trombone sounds are separated from the striking cluster. The last three sound clusters are not part of bar 15 but they are

[4] Accessive - Tools C.A.S.E. <http://www.accessive-tools.com/projects/audiosimilarity/>

used in the piece at different sections and therefore provide a good reference in relation to the striking sounds.

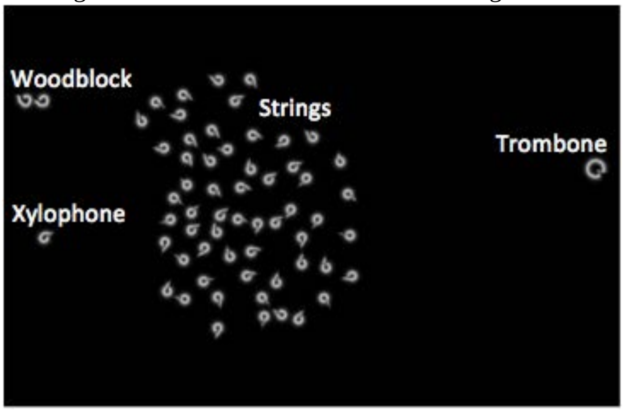


**FIGURE 2.** The striking sounds from bar 15 of *Pithoprakta*. The xylophone is shown centre left and two woodblock sounds top left; centre right is a pp trombone sound. The central strings crowd is a mixture of vln, vla, vc and db knock sounds.

Xenakis in the case of timbre uses mostly the string section of the orchestra with the exception of the two trombones and two percussion instruments. In particular in bar 15 the use of timbre contributes to achieve a holophonic texture with high degree of auditory fusion for two reasons:

- singularity of timbre with the predominance of the strings
- homogeneity by the use of a single timbre technique

A third parameter could be the addition of dynamic indications. However Xenakis chooses not to include that information on the full score. The register in this case has no significant role since the sound is rather percussive and noisy.

## 5. THE CONDUCTOR

It is evident, a number of factors can influence to the experience of a musical performance and consequently the way a musical ideas is conveyed. The acoustic spaces, the musicians' performance practice, the score, are all part of the performance. Another factor that one should mention is the role of the conductor and his collaboration with the composer.

Xenakis was alive during the first recording of Pithoprakta in 1965 at the Studios O.R.T.F in Paris. Up to the time of this paper it was not possible to confirm if Xenakis was present during the recording. Although by that time he was composing works such as Terretektorh, Oresteia, Nomos Alpha, and he would probably like to be present during the first recording of Pithoprakta. If it was not possible he would be able to give feedback at some point of the process. At last, he would be able to hear the master track and agreed with the whole approach to the piece. That is to say, Xenakis should have accepted the final result as representative to what he imagined for the piece.

Besides the first recording of the piece, Luxembourg Philharmonic Orchestra with conductor Arturo Tamayo recorded for second time Pithoprakta several years later between 2000-2006 at the Luxembourg Conservatoire Auditorium [10]. In this case Xenakis was probably not alive to offer his opinion on the recording. Although it is not necessary for a conductor to have the composer's opinion, it provides an indication in this paper that the composer is aware of the final recorded result and accepts the performance as in line with his intentions.

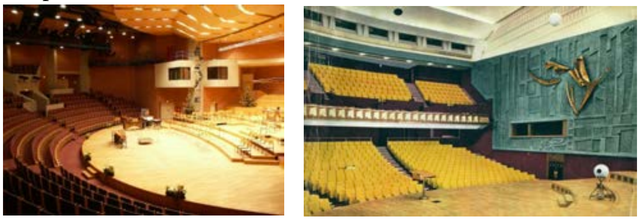

**Figure 3**. (left) Luxembourg Conservatoire Auditorium, capacity: 614 place, Average surface area: 150 m2. (right) Maison de la Radio Studio 104, Capacity 852 seats.

Pithoprakta consists of 269 bars at 2/2 52bpm and the absolute duration is 10:21 minutes. In the later recording the tempo is faster with total duration at 10:35. In addition the concert hall sounds much drier and more transparent. The First recording has 9:43 minute duration 38" seconds slower from the score and 52" seconds from the second recording. 52' seconds from one to another recording is quite a difference, which could result to different perception and interpretation of the piece. If the hypothesis is right and fusion is indented in bar 15 the conductor in the second recording might want to provide another perspective despite the composer's intentions.

| | |
|---|---|
| 0-269 bars, 2/2 52bpm | 10:21" |
| 1965 recording | 9:43" |
| 2006 recording | 10:35" |

**Table 3.** 1965 is 38" faster than the score, 2006 is 14" slower, whilst the second recording is 52" faster from the first recording.

## 6. CONCLUSION

A countable examination of this passage provides an interesting survey of a perceptual effect such as fusion and its musical implications as Holophonic Musical Texture. This kind of study can further contribute to the evaluation of the different types of musical texture used in *Pithoprakta* according to their degree of fusion or separation.

Further development of this methodology will include the analysis of the rest of the textures in *Pithoprakta* and a comparison of time and of timbral space.

Moreover, the results of this work could offer interesting insights to musicians and conductors in relation to the space in which the piece should ideally be performed and recorded, the tempo variations, the precision of the timbre techniques or the imprecision of the time synchrony if necessary, the relationship between manuscript and realisation of the piece and how it could dramatically effect the context of the piece.

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