

Exploring the Sound Tapestry – The Role of Space in *Nomos Gamma*

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Space has been one of the major topics in the work of Iannis Xenakis throughout the decades, but a first climax can surely be found in the 1960s. At that time he started exploring space in the concert hall with several compositions that introduced completely new arrangements of musicians. The focus of this paper lies on *Nomos Gamma* (1967/68) for 98 musicians shattered among the audience, where Xenakis deals with the group theory, thus creating a very complex system of groups in different combinations, to which he subordinates every musical parameter. Due to the spatial arrangement, the position of the single musician, that means space, is involved in this system as well. As opposed to *Terretektorh* (1965/66) Xenakis here comes back to an apparently more traditional way of orchestral treatment which re-implements the four established families of instruments and uses them independently, even confronts them with one another. But simultaneously the spatial disposition inevitably creates a superposition and combination of these sections or layers. This paper does not deliver a mathematical approach to this work by just revealing details of the group structures but rather relies on the function of space in this system and its practical acoustic effect for the listener. In the first part some typical composition techniques that Xenakis uses in this piece and that could be referred to as "techniques of spatial composing" are examined with a few examples. Following this, one can draw conclusions on the overall structure of *Nomos Gamma*. The last part is illustrating experiments with the technique of Wave Field Synthesis and its possibilities to reproduce and throw new light upon this composition and on spatial contemporary music in general.

Nomos Gamma for 98 musicians shattered among the audience is supposed to be one of Iannis Xenakis' most formalized works. It was composed in 1967/68 and premiered on the 1969 festival in Royan by the *Orchestre Philharmonique de l'O.R.T.F.*, conducted by Charles Bruck. The recording of this performance still seems to be the only one available on disk. Just as little has been published in textual form on this piece up to now, in contrast to *Nomos Alpha* for solo violoncello where Xenakis introduced the group theory and which has been analyzed repeatedly and extensively. In the context of a scientific project which I am going to present later on, I had the chance to assist one of the rare performances of *Nomos Gamma*, this time by the BBC symphony orchestra. My impression was that – in spite of the underlying complex composition techniques – *Nomos Gamma* is a very impressive and approachable work, an effect that is to a high degree due to its spatial disposition. So I came across the question how space contributes in detail to this global impression.

Spatial composition and organisation in *Nomos Gamma*

How are the instruments distributed in space? Figure 1 shows the seating plan: We have a large orchestra with 60 strings, 14 woodwinds and 16 brass distributed inside and 8 percussionists with four tom-toms arranged outside of a circle. This disposition was invented in a very similar way a few years ago for *Terretektorh*. Now 5 percussionists have been added to complete a full circle, furthermore 2 contrabassoons, 2 french horns and one trumpet. The distribution was made very evenly as it can better be seen by giving each orchestral group its own colour (Figure 2). As opposed to *Terretektorh*, the function of the eight circle segments and also their numbering does not become obvious in the composition. It might be a reminiscence to the former piece which is also supported by the fact that the disposition of *Terretektorh* was turned by 90 degrees.

Nomos Gamma is characterized by a strong separation of the traditional orchestral families: strings, woodwinds, brass and percussion. Most often the instruments of a family are treated in a mutual structure that does not correspond to the other families. I would like to call such a common structure a layer. There are only few instrument combinations across the families but many superpositions of independent layers. The seat and the spatial position of each individual instrument does mainly affect inside its family, giving the layer an internal spatial structure.

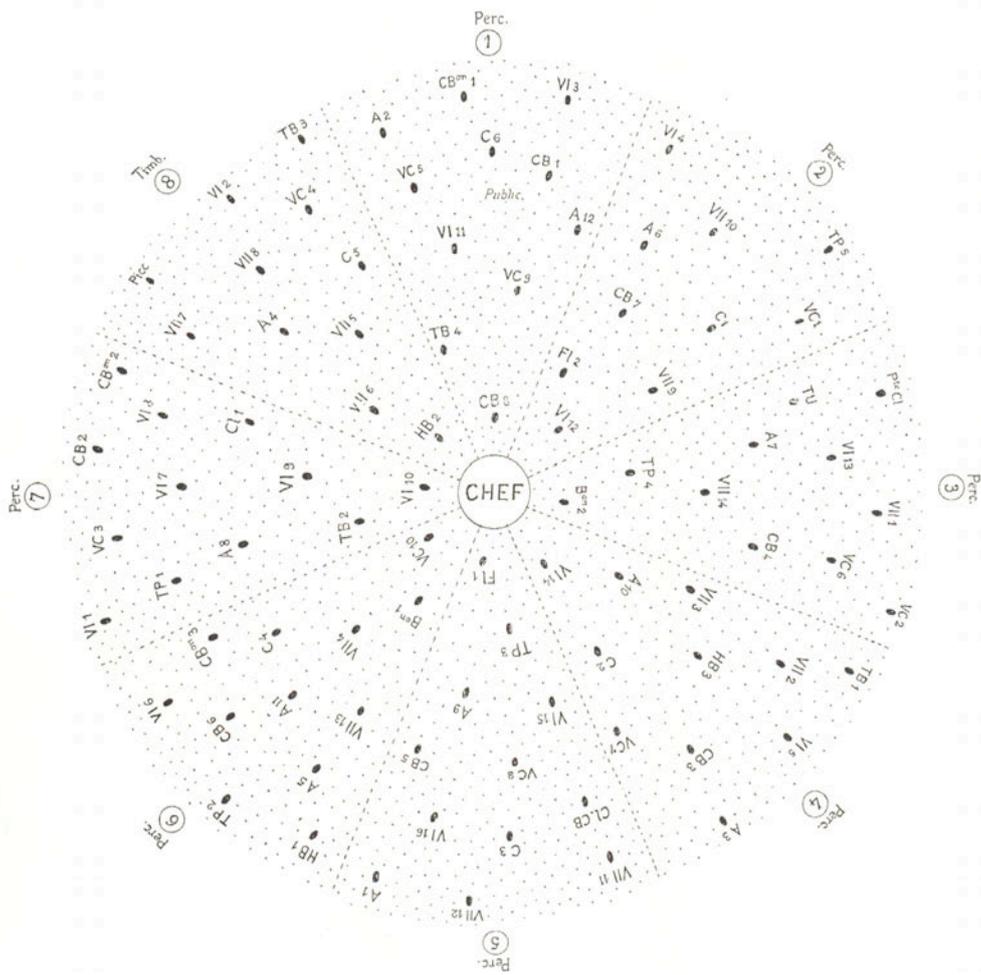


Figure 1. *Nomos Gamma* – Seating plan (Éditions Salabert)

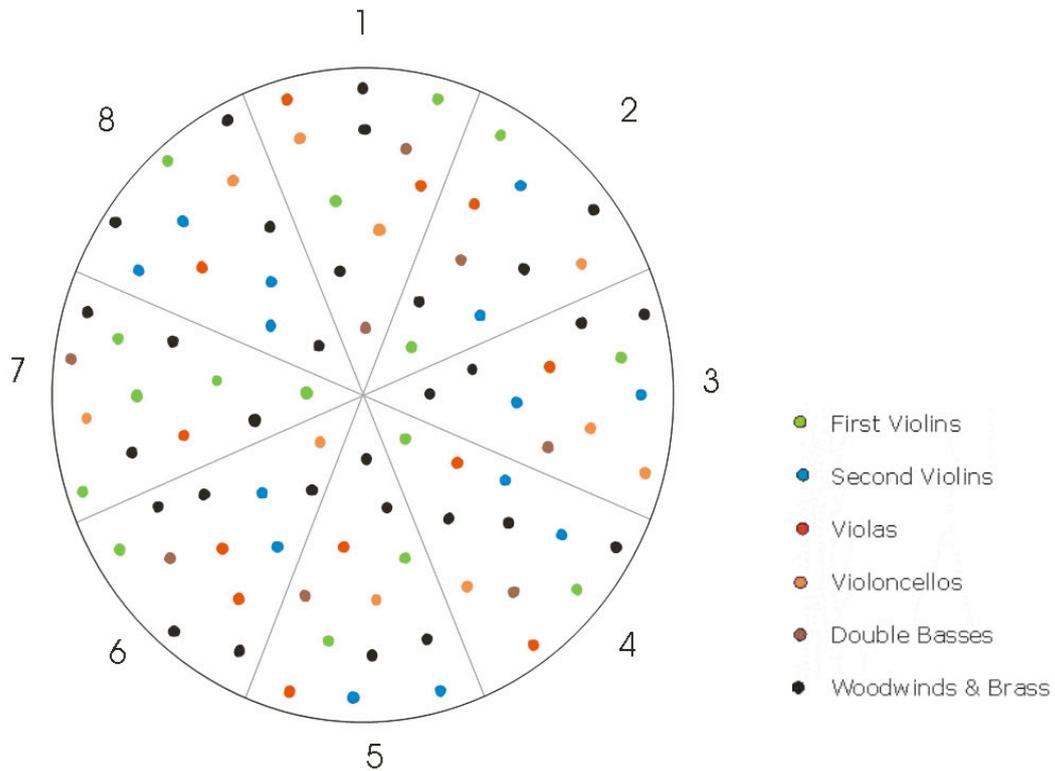


Figure 2. Seating plan with specified orchestral groups

The percussion layer and its spatial dynamics

This structure becomes most obvious with the layer of the eight percussionists whose position at a maximal distance from one another is enhancing the spatial phenomena. There are various composition techniques for the percussion part: Nearly every entry has its own structure: There are rhythms and regular pulsations in unison as well as sound clouds of beats that seem to be stochastically distributed. But apart from these more compact ways of percussion treatment Xenakis is conferring to the percussion layer spatial dynamics as well.

The most impressive example takes place at the end where a drum roll is constantly rotating counter-clockwise for about three minutes with the eight percussionists passing the roll to one after another in a fast tempo. (Figure 3) This layer has an internal movement in space and also internal dynamic irregularities by occasional accents. Besides the roll is played alternately on all the four tom-toms. The percussion layer is characterized by a strong circular energy and has been the precursor of the famous "tourniquet" or revolving door effect in the last part of *Persephassa* for six percussionists where not less than seven distinctive rotations are superposed. But its overall form remains unchanged up to the end, apart from some interruptions of mutual "sound clouds". It is superposed now and then with one or several other layers of other families. But the layer itself is nevertheless static as there is no development in the whole passage, apart from the last measures where strings and brass are playing simultaneously and are switching to a sudden triple forte to create a kind of conclusion effect, with a final sound cloud in the percussion.

The image shows a musical score for a percussion roll, consisting of seven staves. The notation is dense and rhythmic, with many notes and rests. Dynamic markings such as 'pp', 'mf', and 'simile' are used throughout. The score is written in a standard musical notation style with a treble clef and a key signature of one sharp (F#).

Figure 3. Percussion roll in bar 445-449 (Éditions Salabert)

The other layers do not dispose of internal spatial dynamics in this final section. But may I recall the three-dimensional spatial model that I presented in my PhD¹ and that is adding a vertical axis for pitch or frequency to the two-dimensional plane where the musicians are placed. According to this the layers have a distinct separation in the vertical direction: We have clusters of a maximum interval of a fourth each that are not overlapping even though their pitch is constantly decreasing slowly. (Figure 4) The brass cluster that is situated underneath the string cluster at first is then switching above the string cluster. So the listener is immersed in several layers of sound which are superposed but at the same time situated one above another. With the rotation and the downward movement the impression of a whirl to the bottom could arise.

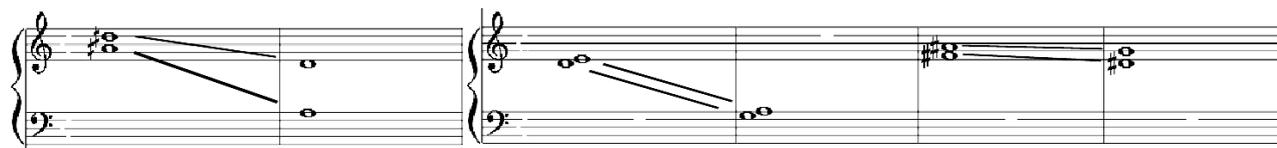
The image shows two musical staves, labeled 'a' and 'b'. Staff 'a' shows a string cluster with notes on the treble and bass clefs, connected by lines indicating a downward pitch movement. Staff 'b' shows a brass cluster with notes on the treble and bass clefs, also connected by lines indicating a downward pitch movement. The notation is in a standard musical style with a treble clef and a key signature of one sharp (F#).

Figure 4. a. String cluster ranges bar 452-559, b. Brass cluster ranges bar 458-559

Figure 5. Percussion rotation in bar 354-356 (Éditions Salabert)

This regular and complete drum rotation appears like an aiming point as it is anticipated at several moments of the piece: Most obvious in bars 354 to 356 where a clockwise rotation of tom beats is running with a constant speed of five beats per second. (Figure 5) There are other sections with fragmentary rotations of tom beats like the one starting right in bar 7 with percussionist 1. (Figure 6) His regular pulsation with a periodicity of 9/10 bars is soon joined by percussionist Nr. 3, then by Nr. 7, thus performing a kind of cross-shaped movement. Later in this section there are clockwise rotations of single hits and of short rolls, that are gradually growing to a full turn before getting fragmentary again with some players pausing. One can find, as well, rotating percussion rolls with accelerating and decelerating movement which reminds of the archimedic, logarithmic and hyperbolic spirals that Xenakis already introduced for the sound rotations of *Terretektorh*. So the diversity of techniques in the percussion layer becomes obvious.

Figure 6. Fragmentary rotation of tom beats bar 17-26 (Éditions Salabert)

But space does contribute to the other layers as well. For example, in two large sections there are extended clusters changing their timbre and colour due to a variable consistence. From bar 71 to 80 a cluster of brass, low woodwinds and Double Bases is, as Makis Solomos calls it, revealing step-by-step its structure when its components are played successively which causes a changing so-to-speak spatial timbre from chord to chord. This passage is enhanced later on with another cluster and a similar proceeding, but this time including the whole orchestra, thus being the only section of the piece with the orchestra really treated as a unity.

The treatment of the strings

In *Nomos Gamma* the 60 strings are always playing simultaneously and are treated like a unique mass (apart from the Double Bases that are sometimes playing a special role). But inside of this layer we have a high complexity of different sound events whose distribution is made by Xenakis strictly according to the group theory as he explains in *Formalized Music*, talking of a "powerful deterministic and finite machinery"². The most extensive appearance of this string layer goes from bar 404 to 441 and is named "sound tapestry" by the composer. With the help of Xenakis we can verify here several levels of assignments of the 60 players. They are divided into six teams of eight players each, not according to their register but according to their seat or position. As six times eight is 48, there are 12 players left who are joining one of the teams in their proximity.

The principles of the group theory have been broadly described by Xenakis himself³ and other authors⁴, illustrating the permutations of eight elements by the possible turnings of a cube. Concretely, Xenakis is mapping different musical parameters onto single players or teams, for example eight ways of playing (Table 1) or three sets of eight different intensities (Table 2). The assignment is done on four levels: On level 1 the eight ways of playing are mapped onto the eight players of each team (or respectively the ones sitting in proximity). Furthermore the three sets of eight intensities are mapped in a similar way one-to-one onto 3 teams and their eight players.

1. On the bridge tremolo
2. On the bridge tremolo and trill
3. Sul ponticello smooth
4. Sul ponticello tremolo
5. Smooth natural harmonic notes
6. Irregular dense strokes with the wood of the bow
7. Normal arco with tremolo
8. Pizzicato-glissando ascending or descending

Table 1. Eight ways of playing for the strings

ppp <	mf <	p >
ppp >	mf >	p <
pp <	f <	mp >
pp >	f >	mp <
p <	ff <	mf >
p >	ff >	mf <
mp <	fff <	f >
mp >	fff >	f <

Table 2. Three sets of eight intensities for the strings

The same thing is done on level 2 with three pitch ranges and on level 3 with three so-called macroscopic types. On level 4 Xenakis does the assignment to the six teams in different modes: What he calls compact I is in fact grouping two times three teams together. The result is a division of the whole seating area by six. The same for compact II (Figure 7). There is another "dispersed" mode with six teams as well where the players are mixed all over the area so that there is no dependency on space. These modes are applied one after another with the dispersed mode being the intermediate stage between the two cases of the compact mode.

So the acoustic result is a big diversity of the string layer which, as a whole, has a constant maximum extension on the horizontal plane and in the frequency domain but nevertheless a permanent internal movement and transition.

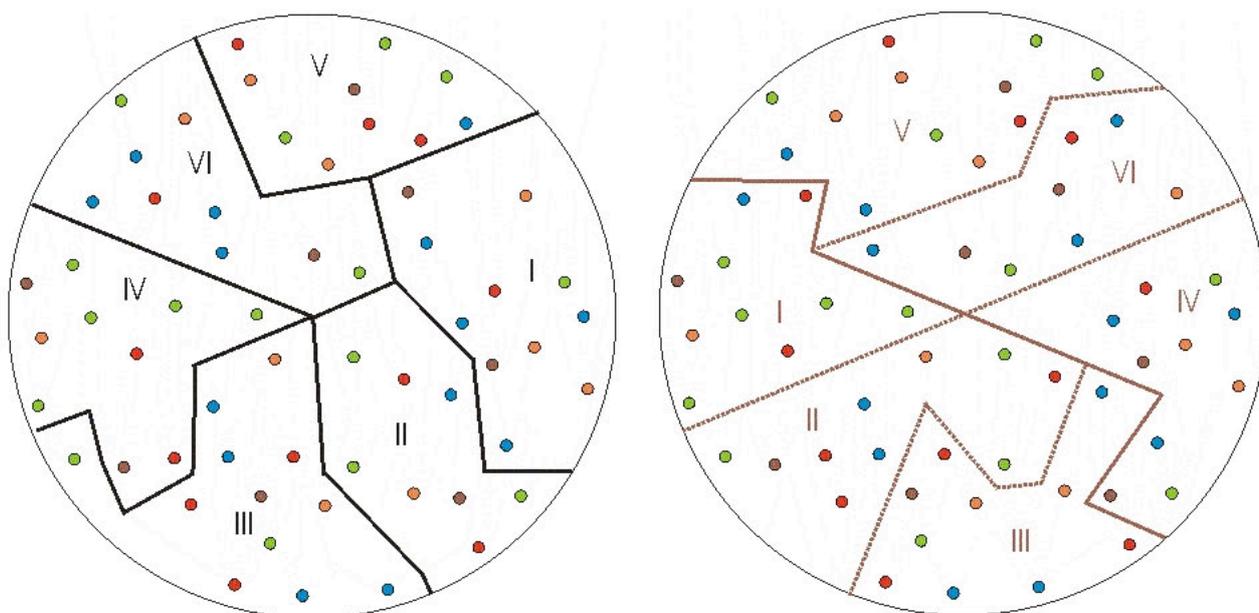


Figure 7. Divisions of the strings: Compact modes I and II

On the overall structure: Interaction of layers

Looking at the overall construction of the work it can mainly be regarded as the sum of its parts. As it is typical for Xenakis, the piece does not have a stringent development over the whole time but is rather a collage of sections with a very high differentiation. As mentioned before, the superposition of the four layers and families is the main organisational technique in *Nomos Gamma*. Figure 8 shows a graph of the overall structure with this superposition. In total one can see an equality with each layer once being dominant for a longer time: starting with the brass, then the woodwinds, the strings and the percussion. The other layers do not get beyond short appearances: There is a certain opposition between them, due to their mostly strict separation and their completely different internal structure. But at the same time there is a combination and superposition because of the spatial disposition of the players.

In view of the previously shown spatial content of the string and mainly of the percussion layer one can come to the conclusion that there is a process of increasing spatial dynamics in this piece, ranging from irregular and incomplete movements of the beginning to the final percussion rotation.

On the level of perception *Nomos Gamma* delivers a great variety of stimuli and combinations and at the same time a superposition of different listening spaces to attain a deep effect on the listener and to let him immerse into each of the single layers. So this is another example for Xenakis' ability to combine highly elaborated texture and immediate impact.

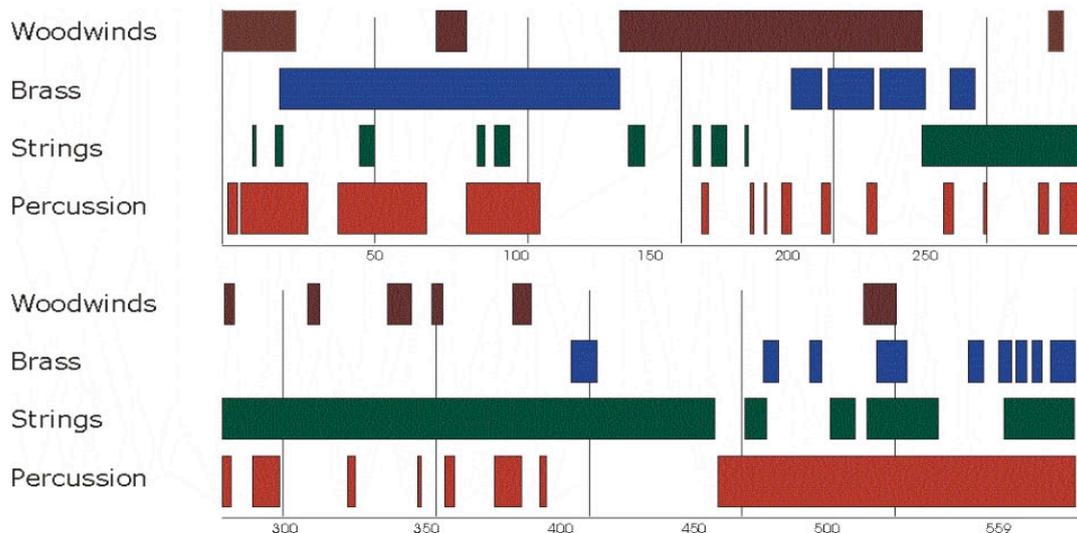


Figure 8. Overall structure: Superposition of layers

Wave Field Synthesis – an innovative technique to reproduce spatial music

Introduction and procedure

In the last part of this paper I would like to present an innovative technique for playing back or reproducing spatial music: Wave Field Synthesis. This is of special interest for me as a recording producer and sound engineer as I have occupied myself for a long time with the question how to record spatial contemporary music. Wave Field Synthesis creates virtual sound sources and acoustic environments, based on the Huygen's principle for wave fronts. The field of sound waves created by sound sources at any position in or outside a room is calculated and generated by a large number of loudspeakers. This technique has been invented 25 years ago at TU Delft in the Netherlands and has meanwhile come to some reputation by several large systems being installed, e.g. at the TU Berlin (Berlin institute for technology). There I had the opportunity to do research on two famous spatial compositions from the 1960s: *Nomos Gamma* and the *Requiem* by Bernd Alois Zimmermann. *Nomos Gamma* was recently performed by the BBC Symphony orchestra at Royal Albert Hall in September 2009.



Figure 9. Installation for *Nomos Gamma*, Royal Albert Hall London, 2 september 2009, © BBC

The multitrack files of the radio recording have been generously placed at my disposal. Figure 9 shows a photo of the installation, but without musicians and microphones. The original seating plan has been modified spreading the eight groups to so-called "petals". Listeners were allowed to sit not inside but at least between these petals. The colleagues of the BBC put a spot microphone on each of the eight percussionists, as well as two microphones on every circle segment or petal. For the mix I have distributed the signals of these altogether 24 microphones as virtual sound sources.

The mixing was mainly done in Berlin in the large lecture hall H104 with about 640 seats and the world-largest Wave Field Synthesis system with more than 2000 small loudspeakers, being installed in form of a line at face value all around the hall. Figure 10 with a screenshot of the XWONDER software for Wave Field Synthesis at the TU Berlin shows all the resulting 24 sound sources with a random colour. The underlying layout corresponds to the lecture hall. As the virtual disposition of the musicians should cover the whole size of the hall, the distribution of the sources was done according to this but was verified by listening.

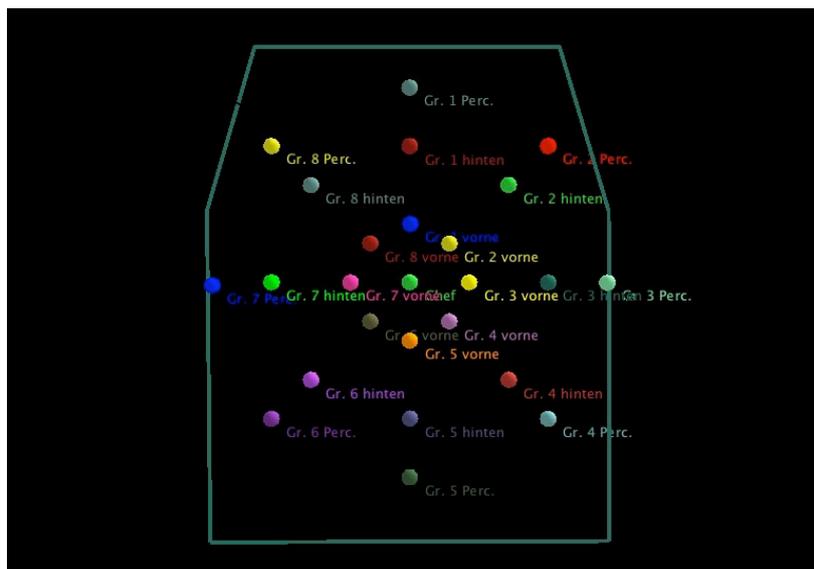


Figure 10. XWONDER: Distribution of sound sources

Results and conclusions

The acoustic result is rather striking and gives you the impression of being right inside the performance what was not possible with any other technical means so far.

For this piece Wave Field Synthesis can provide at least two big advantages:

- The presentation gives a rather similar listening experience compared to a live performance, but is temporally independent and can be repeated infinitely.
- The spectators are able to walk around in the venue and to choose every place for listening without disturbing players or the performance.

But there were problems with the used material as well: Even the performance itself is suffering from the fact that the balance of the instruments in the hall is not well equilibrated with mainly the brass being favoured. And so the localisation of the single instruments in the reproduction is very dependent of their type. It works well for the eight percussionists but becomes rather difficult for instruments with lower volume like the strings. But as the recording was made for radio purposes, one spot microphone was responsible to record at least five players in its neighbourhood, so some instruments have been closer to it than others. This leads to an even more difficult balance and no access to the volume of every single instrument.

At the present stage one could adapt the material carefully in a kind of studio mixing session, but for a crucial improvement of the balance it would be necessary to equip each player with his own microphone, in form of a pick-up. That would mean a large technical and

organisational effort with 98 microphones, but it could assure to treat every instrument individually as a single sound source, according to the concept of the piece. I am going to keep on working on this to realize such an experiment in the future, with more advantages:

- By technical means it could be possible to amplify or damp single sound sources, that means instruments in order to get a better balance than it could ever be possible at a live performance.
- The emancipation of each instrument could be achieved not only in the score but also in the acoustic impression.

At the moment Wave Field Synthesis seems to be the best technique to arrive at a satisfying reproduction of the Xenakian spatial compositions as well as of more recent works by other composers. To my opinion these experiences can be interesting and useful both for recording practice and for research of engineers or musicologists. There should be further research on other compositions to analyse and promote spatial music in general, but also to comprehend the influence that Xenakis with his concept of space had and still has on younger composers. Since despite from score studies the music by Xenakis is revealing its full content only in a live concert. So apart from the very rare performances of the pieces, Wave Field Synthesis can be a means to feature this content and to bring it to mind.

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Notes

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- ¹ cf. Hofmann 2008, 79 et seq.
 - ² Xenakis 1992, 237
 - ³ cf. Xenakis 1992, 236 et. seq.
 - ⁴ cf. among others DeLio 1980