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Sound–Sights
An Interdisciplinary Project

An interdisciplinary project between geometry, architecture and music resulted in a concert and exhibition with sound installations. Professors and students of architecture and mathematics of the Technical University of Kaiserslautern worked with a professor and students of music composition of the Music Academy of Cologne in Germany. The theoretical and historical analyses of the relationships between geometry and music formed the basis for original creative works in interdisciplinary groups. Music was composed according geometrical-architectural concepts and geometrical images, forms and processes were developed after musical ideas. Geometrical forms are combined with the music into a kinetic, visual and acoustic work of art. Through such interdisciplinary art projects it is possible to experience scientific coherence in a sensual way. The combination of geometry, architecture and music enables a visual and aural approach to formal thinking of sciences.

Introduction

Exploring the relationships between geometry, architecture and music formed the background of an interdisciplinary project with students and professors of architecture, mathematics and music composition. The aim of the project was a concert and exhibition with sound installations entitled "Sound–Sights. Seeing Music – Hearing Geometry" [Leopold 2003a; Leopold et al. 2004] held in the concert hall of the city of Kaiserslautern, Germany. The project was initiated by Andrea Edel, director of the cultural office of the city of Kaiserslautern. Theoretical and historical analyses of the relationships between geometry and music preceded the students' creative works in interdisciplinary groups. The groups were organized during a common workshop week where each student presented his/her first ideas. It was not possible in all cases to bring together interdisciplinary groups. Finally the various individual or group projects were arranged in the concert and exhibition program.

Fig. 1. Projects: "Space-Sound-Sphere", "Balanced Sound Sculpture" and "Abacus"

Music was composed according geometrical-architectural concepts, and geometrical images, forms and processes were developed according to musical ideas. Geometrical forms were combined with the music to a kinetic, visual and acoustic works of art. Multimedia computer technologies were used for the connection of image and sound in some projects. But the human being behind

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the creative process always remained visible. Combining the sense of seeing and the sense of hearing underlined the differences and similarities between audible and visual perception.

With interdisciplinary art projects such as this, it is possible to experience and mediate scientific coherence in a sensual way. The combination of geometry, architecture and music enables a visual and aural approach to formal and structural thinking in art and sciences.

Theoretical and historical background

The idea to look for the relationships between geometry, architecture and music goes back to the ancient understanding of the sciences where the seven *artes liberales* were grouped in the *trivium* (grammar, rhetoric, logic) and the *quadrivium* (arithmetic, music, geometry and astronomy). The study of harmony is a common element of the quadrivium. Architecture was seen as a mechanical art, in which harmony and proportion were applied to the principles of creating a building. Geometry and music were developed on the basis of the Pythagorean concepts. Especially in the European development of the sound systems, mathematics and music were closely linked. The development of the musical scales and the geometry of elaborating motifs shows the relationship between mathematics and music.

Pythagorean Harmony. For the Pythagoreans, music, arithmetic, geometry and astronomy were very closely related. "Harmony" had an extensive meaning and was related to philosophy, arts and sciences. It was understood as regularity, order and regular arrangement of many parts. The word "harmony" is derived from Greek *harmos*, which means combination, adaptation, connecting different or opposite things to a ordered whole. "Harmonia" is also a mythological person, the daughter of Ares, god of war, and Aphrodite, queen of love and beauty. She therefore represents the union of two opposites.

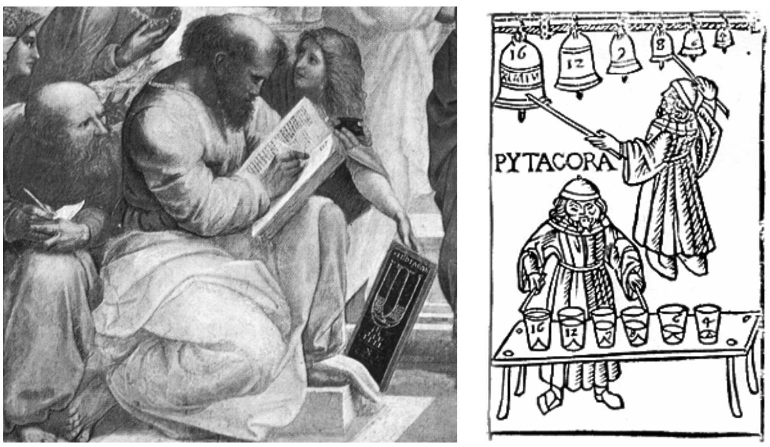

Fig. 2. Pythagoras with the tetraktys, from Raffael's *School of Athens* (Stanza della Segnatura, Rome) and Pythagoras with experimenting with sound [Hay 1968, 150]

According to Pythagoras, harmony and all things and principles of being can be expressed by integers and mathematical regularities. It is said that Pythagoras overheard the sounds and harmony of blacksmiths' hammers, leading to experiments with the division of a string. He found that musical intervals are achieved by the division of a string as well as the relations between the number of sound oscillations. The integers 1, 2 , 3 and 4 form the "tetraktys," which is the basis of all harmonic proportions. The sound experiments were developed by means of the monochord, a simple instrument with one string tightened over a resonance box. The proportion 1:2 is the octave, the proportion 2:3 stands for the fifth and 3:4 for the fourth. Pythagoras transferred these proportions to astronomy as well. He believed that the stars stand also in these proportions and they produce divine music, the sphere sounds. Later on, in the Renaissance, the tetraktys was expanded by Zarlino. The relationships between architecture and music were very close in the Renaissance. Alberti wrote that the rules for harmonic proportions in architecture should be borrowed from musicians [Naredi-Rainer, 1982; Wittkower 1971].

Inspired by the Pythagorean ideas and combined with new technologies, the projects "Abacus" as well as "Point and Line" were created by our students.

Transformational Geometry. Another background for the creative work was found in investigations about applications of transformational geometry in music and the geometrical analyses of musical motifs. Transforming musical motifs according some rules is a method often used in musical composition. If we illustrate the transformations by pitch-time diagrams, we can interpret the transformations as geometrical transformations: transposing as translating in direction of a second axis, retrograde as a reflection at the vertical axis, inversion as a reflection at the horizontal axis and the retrograde inversion as double reflections, which can also be interpreted as point reflection [Christmann 2003; Leonhardt and Willenbacher 2003]. In this way concepts of symmetry are applicable to musical composition. Through this geometrical interpretation of musical motifs we perceive relations between music and patterns. Motifs with translations are for example interpretable as frieze ornaments. Fig. 3 shows such an example.

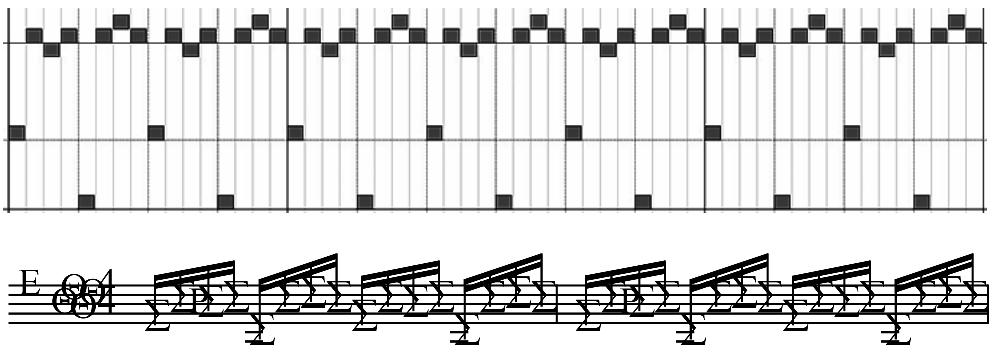

Fig. 3. Frieze ornament by translation, after B. Smetana, *Moldau*, bar 1+2, left hand, piano arrangement

The music of Bach especially lends itself to interpretation by transformational geometry. There exist many experiments through history of art to express the music of Bach visually.

Looking for geometrical structures in music by translating it into visual elements or by applying musical structures to visual material was another inspiring source in the students' projects; one example is "Ball," described below.

Formalisation of Aesthetics. Symmetry concepts have always played an important role in aesthetics. By interpreting symmetry with the help of transformational geometry we have already taken a step towards the formalisation of aesthetics. Reflections about proportions and developing scales of proportions with the golden section, such as the "Modulor" of Le Corbusier, are other examples of developing formal systems in aesthetics. Architect and composer Iannis Xenakis (1922 –2001) worked to find mathematical solutions for artistic problems.

Xenakis worked in the atelier of Le Corbusier in Paris from 1948 to 1959. He applied the "Modulor" to architecture and to music. The rhythmical structure of his *Metastasis* was composed with increasing and decreasing density according the "Modulor"; in like manner the facade of monastery "La Tourette" was an application of the "Modulor" in the *pans de vers ondulatoires* [Leopold 2003b].

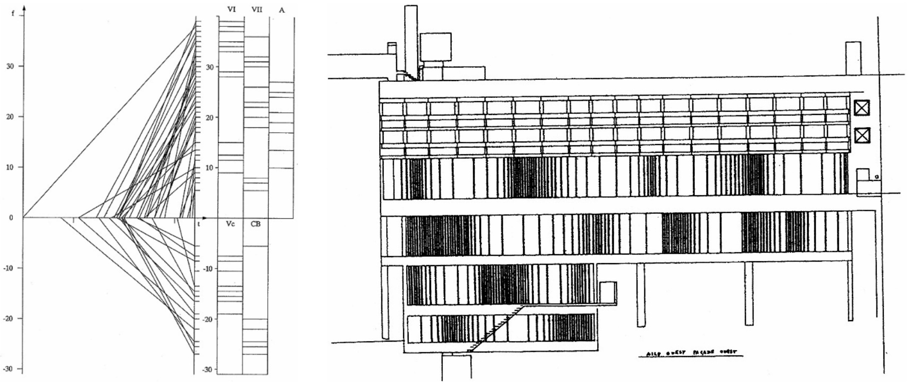

Fig. 4. Scheme of "Ondulatoires" in Xenakis's *Metastasis*; the west facade of "La Tourette"

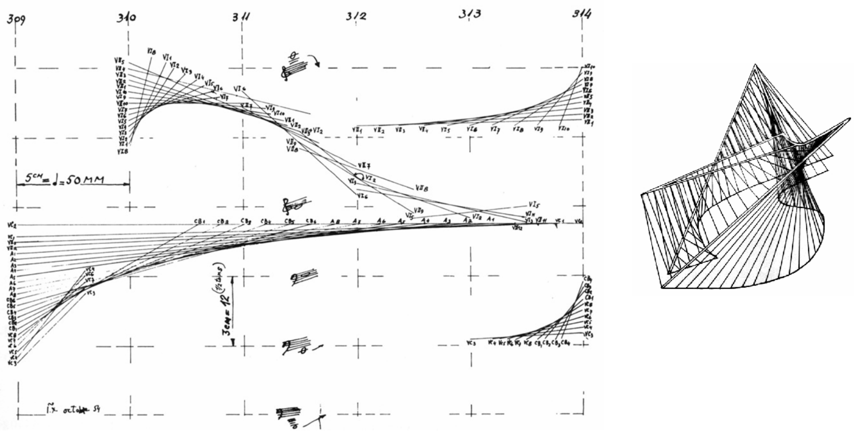

Fig. 5. *Metastasis*, graphical score, bar 309-314, and a design model of the Philips Pavilion.

Xenakis used geometrical abstractions as ordering principles in music and architecture. For example, ruled surfaces were applied to music as clusters of *glissando*. The new technical developments of steel-reinforced concrete led to the development of new forms of architecture, such as the ruled surfaces of hyperbolic paraboloids. The form of the hyperbolic paraboloid is another example which was transferred to architecture as well as music in the work of Xenakis. Glissandi in *Metastasis* appear in graphical scores, and we can see the correspondence of the musical form with the architectural form of the Philips Pavilion designed by Xenakis and Le Corbusier for the 1958 world exhibition in Brussels. Later Xenakis founded the "Centre des Etudes Mathématique Automatiques Musicales," where he continued working on the formalisation of aesthetics.

These ideas influenced the student projects "Space-Sound-Sphere", "Balanced Sound Sculpture", "Sphere Music" and "Motion".

"Sound–Sights" projects

The following projects will give an idea of the interdisciplinary working of the student groups and the results presented in the concert and exhibition on 31 October 2003 in Kaiserslautern and later presented in video on a DVD. The concert hall in Kaiserslautern is a neo-Renaissance building built by August von Voit in 1843-46. In one of the projects the students analysed the proportions and history of the building and transformed it in music and visual impressions.

The students were supported and directed by composer Johannes Fritsch of the Music Academy of Cologne, by Norbert Christmann from the Department of Mathematics of the University of Kaiserslautern and Cornelie Leopold from the Department of Architecture of University of Kaiserslautern. The various projects were brought together under the idea of hearing and seeing, music and geometry, combined by signals and short pieces for flute entitled *Pirinore* (Korean for "flute tunes"), according the dramaturgy of the "Sound-Sights" projects. Some of the compositions by Eunshin Jung referred to each other symmetrically in time and space, while others served as bridges for combining several pieces.

Space-Sound-Sphere. The form of music was brought together with the form of an architectural object in this interdisciplinary project of students of architecture and civil engineering together with a student of musical composition. Kim Ngoc Tran Thi composed the pointed sounds for the instrument "Chan". The idea was to contrast the pointed music with a round and smooth spatial form. It had to be possible for a visitor to enter the form and hear the music, so that the experiences of seeing and hearing form are parallel. By contrasting the pointed form of the music to the rounded form of the architecture, the perception becomes more intense. The students decided to build a spherical surface. Several construction and design concepts had been discussed in reference to the costs and possible realisation in a short time as well. Students Philipp Jünemann, Artur Jungiewicz, Jochen Gross and Tobias Wittig developed a concept for building the sphere as a hollowed cube out of Styrodur, sponsored by the chemical company BASF. They built the hollowed cube out of layers, calculated the radius of the circle for each layer and cut the material with by compasses made with a hot wire. The "Space-Sound-Sphere" was built up in the exhibition area of the concert hall so that each visitor was able to experience it individually.

Fig. 6. Building the "Space-Sound-Sphere"

Balanced Sound Sculpture. Another sound installation combined geometric solids with experimental music. Twelve transparent solids were built with speakers inside. Each solid was assigned to corresponding music, bringing the solid into motion. “Music is sound moving form” was the basic idea for this project. The music compositions by Yoon-He Suhmoon, consisting of six motifs for guitar, were assigned to the coloured geometric solids by architecture students Leyla Dal and Filiz Tunc. The moving coloured solids with their shadows produce aural and spatial impressions.


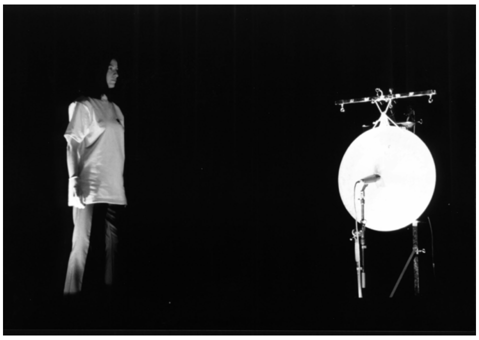

Fig. 7. “Balanced Sound Sculpture” in the Concert Hall and scene from “Sphere Music”

Ball. The most fascinating Euclidean figure is the sphere, which suggests movement through its curved form. The short film project “Ball 2,7” by Dominik Susteck and Joan-Ivonne Bake put a ball in the focus of the film. This object is brought into relation to many other everyday things. The film produced in this way was cut according to certain musical procedures such as repetition, retrograde, inversion, augmentation, etc. The music composer worked with the visual material as he works normally with musical motifs.

Sphere Music. Composer Manfred Ruecker developed his “Sphere Music” from the idea of generating a sphere through a virtual rotation of the area of a tamtam with a diameter of 55 cm. In the rotation process the area was assigned to a volume, and the flat disc became a sphere by rotation. These virtual processes of the sphere formation was converted into musical parameters. Norbert Christmann calculated eleven slices of the sphere with the same volume. These eleven slices of the sphere and eleven relevant pitches of the tamtam formed the basis of the composing process.

Abacus. The “Abacus” picked up the idea of Hermann Hesse’s novel *The Glass Bead Game*, in which mathematics and music are joined together by numbers. The name “Abacus” is derived from its outward similarity with the Asian calculators. Architecture student Philipp Jünemann and music composition student Oxana Omeltschuk constructed the “Abacus” with the help of bottles of different sizes. The pitch, timbre and oscillation period of each bottle depends on its form, weight and consistency. The pitch was regulated with aid of the fill height. Coloured water at various fill levels added a visual component to the instrument. An improvisation on the “Abacus” of a composition by music composition student Simon Rummel was performed in the concert hall. There was a second “Abacus” installed in the exhibition area where the visitors were able to try out the instrument on their own.

Point and Line. Points and lines as the basic elements of Euclidean geometry were the musical and visual elements of this project. Built objects, music and graphics expressed points and lines at various sensual layers. Urban and environmental planning student Martin Wisniowski and music composition student Jihyun Kim built their own instruments, five “superstrings” [Gehlhaar 1971]. The superstring is a simple instrument similar to a monochord with two strings over a wooden board and an electromagnetic pickup. Graphical notations of points and lines supported the musical improvisation. The sounds of the superstrings in the concert were visualised in real time by an interactive computer graphics system. The point and line graphics were projected onto two screens to visualise the sounds of the instrument.

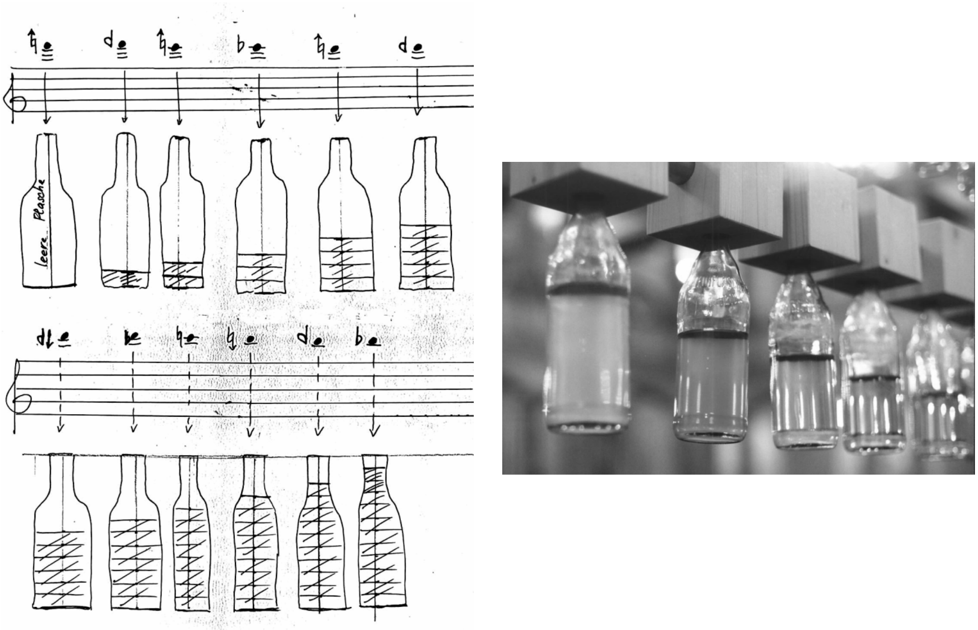

Fig. 8. Realisation and concept of “Abacus”

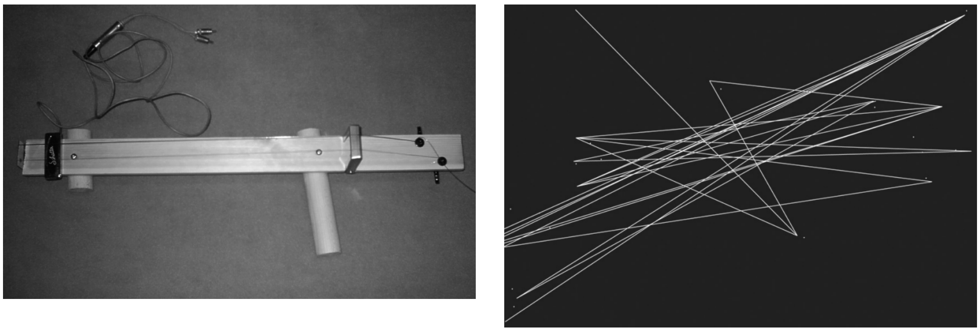

Fig. 9. The “superstring” and graphic “Point and Line”

Motion. Motion, music and geometry were combined in this project in an interactive stage system. Architecture students Nils Hücklekemkes and Pierre Wettels, together with music composition student and dancer Oxana Omeltschuk, developed this stage system, which was able to produce sounds and images in real time. The motion of the dancer on the stage generates music and images through video tracking. The dancer is the composer of music and images at the same time. The interactive stage system allows a dancer to produce sounds solely through his/her actions and at the same time to experience the motion geometrically. With this instrument a total audio-visual artwork was created.

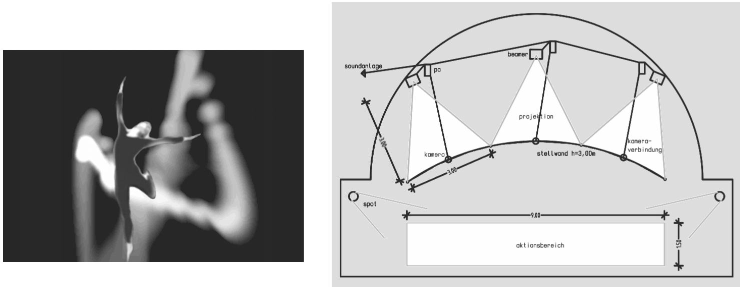

Fig. 10. Concept of “Motion”

Conclusion

It was a challenging task to combine theoretical and practical work and to realise the ideas 1:1 in the concert and the exhibition. The relationships between geometry, architecture and music were studied in theory and practice, realised between science and art, and translated into aural and visual perceptions. Geometry as a structural science is able to connect music and architecture, and music and art.

Working in the interdisciplinary groups made it clear that there are strong reciprocal misunderstandings about other disciplines. It was not easy to bring together the creative ideas of students from the various backgrounds and to mediate between them. Sometimes it was hard to bring the students to the point of being open to other ways of thinking, to understand each other and to combine the different ideas. We did not succeed in all cases in convincing them to work together on the projects. Some projects remained individual works, but were connected with the other projects through the process of the concert.

Fig. 11. People involved in “Sound-Sights” on stage

Finally the concert, the exhibition and the DVD offered the chance to present the projects to a large non-academic audience. Art and science turned out be partners in the mediation process. “Sound-Sights” was realised thanks to the help of many partners, sponsors and technical staff.

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Cornelie Leopold, Academic Director, is a Lecturer and Head of the Descriptive Geometry and Perspective Section of the Department of Architecture, Urban and Environmental Planning and Civil Engineering of the University of Kaiserslautern in Germany. She studied mathematics, philosophy and German at University of Stuttgart. She has published several books and articles on the relationships between geometry and architecture. Her book *Geometrische Grundlagen der Architekturdarstellung* (Kohlhammer Verlag Stuttgart 1999, second edition 2005) introduces the geometry of architectural forms and representations. She is president of the German Society for Geometry and Graphics (Deutsche Gesellschaft für Geometrie und Grafik). Her research interests are descriptive geometry and new media, geometric space conceptions and architecture, visualisation of architecture, development of spatial visualisation skills, and geometry and creation. More about her work can be found at http://www.uni-kl.de/AG-Leopold, and http://www.klangsichten.de.