Journal for Geometry and Graphics
Volume 9 (2005), No. 2, 169–176.

Experiments on Relations between Geometry, Architecture and Music

Cornelie Leopold

University of Kaiserslautern
P.O. Box 3049, D-67653 Kaiserslautern, Germany
www.uni-kl.de/AG-Leopold, email: leopold@rhrk.uni-kl.de

Abstract. This paper presents some results of an interdisciplinary project where we brought together geometry, architecture and music. This combination enables a visual and audible approach to the formal thinking of sciences. Geometry has the role of formalization and mediation of the relations between architecture and music. Pythagoras' ideas about harmony and proportion impressed the formation processes in music over many centuries. In architecture Le Corbusier and Xenakis for example stand for corresponding creations in architecture and music compositions. In the interdisciplinary project we worked together with students of architecture and mathematics of the University of Kaiserslautern and with students of music composition of the Music Academy of Cologne in Germany. The theoretical and historical analyses formed the basis for their own creative works in interdisciplinary groups. The results of the students' creative works were presented in a concert with visual presentations and geometrical objects with the title "Sound-Sights. Seeing Music – Hearing Geometry". Some examples of the student projects will give an impression of the interdisciplinary experiments.

Key Words: Interdisciplinary Project, Geometry, Architecture, Music, Art, Proportion, Space, Sound

MSC 2000: 00A99, 51N05

1. Introduction

The experience of a complex reality has led us today to be aware of the importance of interdisciplinary studies. They can provide to give new impulses to the arts and sciences. With the help of the arts it is possible to experience scientific coherence in a sensory way. In our interdisciplinary project we brought together geometry, architecture and music. Students from the faculty of Architecture and Mathematics of the University of Kaiserslautern worked together with students of Music Composition from the Music Academy of Cologne in interdisciplinary groups. The students were supported and directed by the composer Johannes

ISSN 1433-8157/$ 2.50

Fritsch from Music Academy of Cologne, by Norbert Christmann, Department of Mathematics, and Cornelie Leopold, Department of Architecture, both from the University of Kaiserslautern. The cooperation was initiated by Andrea Edel, director of the cultural office of the city of Kaiserslautern.

Besides theoretical and historical studies on the relationships between geometry, architecture and music it was necessary to reflect on the differences and similarities of audible and visual perception. Excursions to exhibitions and concerts completed our preparations for the workshops and their own projects. The creative works of the students were developed in common workshops and then completed in the interdisciplinary project groups. Finally the results were presented at a concert with visual presentations and geometrical objects with the title *"Sound-Sights. Seeing Music – Hearing Geometry"* in October 2003 at the "Fruchthalle" concert hall of our city [2].

2. The theoretical basis

Research on the relationship between geometry and music starts with the ancient understanding of the *"artes liberales"*. The seven "artes liberales" in antiquity and the middle ages were grouped in the "trivium" with grammar, rhetoric and logic whereas arithmetic, music, geometry and astronomy were brought together in the "quadrivium". Architecture was assigned to practical arts *("artes mechanicae")*, where harmony and proportion are applied to principles of creation. With new ideas of interdisciplinarity of arts and sciences we should refer to this classical understanding. Pythagoras' ideas on harmony and proportion impressed the formation processes in music and architecture over many centuries. Geometry was given the role of formalization and mediation of the relations between architecture and music.

Figure 1: *Pythagoras with Monochord*, sculpture by Wilfried Koch, University of Kaiserslautern, and *Pythagoras with Tetraktys*, Raffael's School of Athens, Rome [3]

2.1. Pythagorean harmony and concepts in Renaissance

According to Pythagoras (570-480 BC) all things and principles of being can be grasped by integers and mathematical regularities. Thus he also expressed harmony by using relations on integers. He found that musical intervals are reached by the division of a string as well as

the relations between the number of sound oscillations. All harmonic proportions are expressable by the numbers of *"Tetraktys"*, the integers 1,2,3 and 4. In the four directions north, south, east, west and the four elements water, fire, air and earth he supposed a cosmological reason for the number four. The sound experiments were developed by PYTHAGORAS using his *"monochord"*, a simple instrument with one string tightened over a resonance box. By halving the string we get the octave (1:2). The proportion 2:3 stands for a fifth and 3:4 for a fourth. The proportion 4:5 for the major third was not included as a harmonic interval in the Pythagorean system. Later on, in the Renaissance the "Tetraktys" was enlarged by ZARLINO (1558), so that the major and minor third (4:5 and 5:6), the second, and the sixth were also included as consonant proportions. During the Renaissance relations between architecture and music had been very close. ALBERTI explained that the rules for harmonic proportions in architecture have to be borrowed from the musicians because they are used to working with the numbers.

2.2. LE CORBUSIER and XENAKIS

In modern times LE CORBUSIER was one of the protagonists for renewing close relationships between architecture, music and mathematics. *"Music is time and space like architecture. Music and Architecture depend on measure."* [5, p. 29]. In *"Le Modulor"*, first published in 1950, he introduced the measuring system "Modulor" for architecture as a system of proportions in a music theoretical context. The "Modulor" can be understood as a scale of proportions. LE CORBUSIER inspired Iannis XENAKIS, who worked from 1948 to 1959 in his office in Paris on corresponding creations in architecture and music. He applied the "Modulor" to both. At the same time he worked as a music composer and an architect. XENAKIS composed *"Metastasis"* in its rhythmical structure with increasing and decreasing density according the "Modulor". Then he applied these proportions to the facade of the monastery *"La Tourette"* by creating the *"pans de vers ondulatoires"*.

Architecture as well as music are founded on the geometry of proportions and forms. Later on in XENAKIS' *"Centre des Etudes Mathématique Automatiques Musicales"* he also worked on the formalization of esthetical problems.

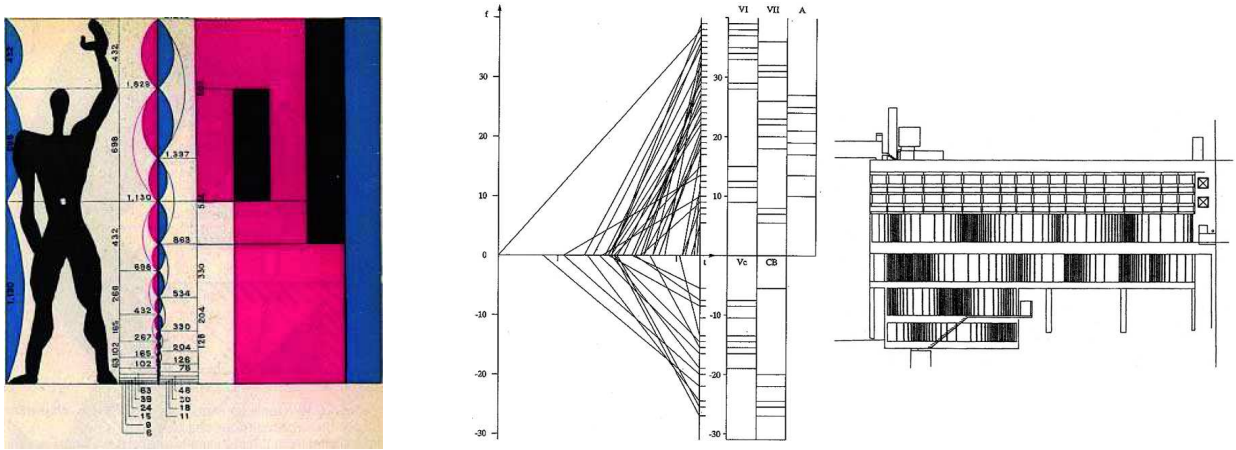

Figure 2: LE CORBUSIER's "Modulor" [1] and Scheme of "Ondulatoires" in "Metastasis" and west facade of "La Tourette" [6]

2.3. Sound-space experiments by Leitner

Studying the extensive sound and space experiment of the Austrian architect Bernhard Leitner, born in 1938, formed another theoretical basis for the students' projects. In his work we found reflections on the differences and common points of an audible and visual perception. His sound spaces create new esthetical perceptions where visual and acoustic sense are combined. He experimented with real spaces but also with spaces created by sounds, for example *"Headspaces"* 2003. The soundcube was presented at *Dokumenta 7* in 1982, where he experimented with the perception of sound spaces by the whole body. With the help of the instrument *soundcube* different sound spaces can be composed. Leitner's work inspired the students to think about the relations between sound, space and perception.

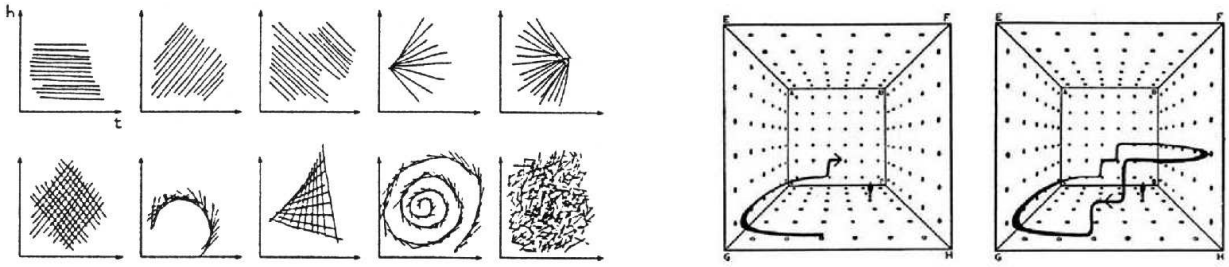

Figure 3: *"Champs sonores"* developed by Xenakis [6] and *Soundcube* by B. Leitner [7]

3. Projects from "Sound-Sights"

The theoretical and historical analyses formed the basis for their own creative works in interdisciplinary groups. Music was composed according to geometric-architectural concepts and geometrical images, forms and processes were developed on the basis of musical ideas. Geometrical forms are combined with the music to a haptic-visual and acoustic work of art. Multimedia computer technologies are used for the connection of image and sound in some projects. But the human creator of the creative process always remains visible.

3.1. The project "Space-Sound-Sphere"

The sound installation was inspired by the idea to contrast the pointed sounds of the old Vietnamese instrument *"Chan"* with the smooth form of the sphere surface. For the construction of the sphere it had to be considered that it should be possible to go into the sphere; the sphere has to be transportable; inside the sphere you should concentrate on the music, played through speakers.

After discussing several construction and design concepts the students of architecture and civil engineering Philipp Juenemann, Artur Jungiewicz, Jochen Gross and Tobias Wittig decided to build the sphere as a hollowed cube out of Styrodur, sponsored by the BASF company. The student of music composition Kim Ngoc Tran Thi composed the pointed sounds for the instrument "Chan" so that the visitor in the sphere was able to experience the space form in contrast with the music form.


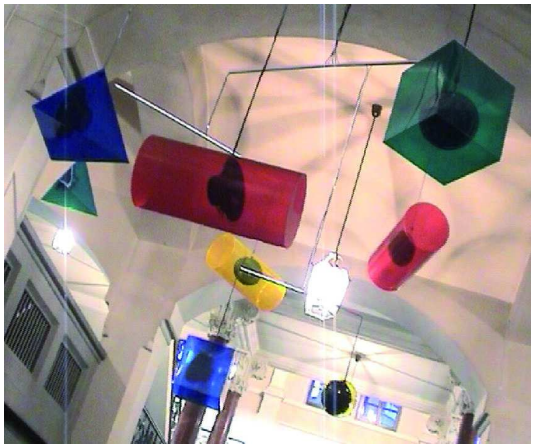

Figure 4: Building the hollow sphere in the exhibition area and colored geometric solids containing speakers

3.2. The project "Balanced Sound Sculpture"

The sound installation *"Balanced Sound Sculpture"* combines geometric solids with experimental music. Twelve transparent solids in various colors contain speakers. Each solid is assigned to the corresponding music, which brings the solid into motion. The idea was derived from the definition *"Music is sounding moved form"*. The mucic composition by Yoon-Hee Suhmoon consists of six motives for guitar. The students of architecture Leyla Dal and Filiz Tunc assigned colors and music motives to the geometrical forms. The solids were lit up by spotlights so that the solids were projected onto a screen. The moving colored solids with the image, produced by the projection, achieve a new impression of space.

3.3. The project "Point and Line"

This project is based on the idea of reducing musical and visual structures to the most elementary geometric elements point and line. The student of urban and environmental planning Martin Wisniowski and the student of music composition Jihyun Kim built their own instruments, five *"superstrings"* (design by Rolf Gehlhaar, Feedback Studio 1971).

"Superstring" is a simple instrument similar to a monochord with two strings over a wooden board and a electromagnetical pickup. The musicians improvised in the concert according to graphical notation of points and lines. The sounds produced by the superstrings were visualized by an interactive computerized graphic system and projected onto two screens.

3.4. The project "Abacus"

The *"Abacus"* and the composition based on its tone spectrum try to pick up the idea in Hermann Hesse's novel *"The Glass Bead Game"*. The name "Abacus" is derived from its outward similarity to Asian calculators. The glass bead game and the abacus join mathematics and music together by numbers. The sound installation "Abacus" embodies this idea. Instead of glass beads the architecture student Philipp Juenemann and the student of music composition Oxana Omeltschuk took bottles of different sizes which stand for different pitches. The pitch, the timbre, and the oscillation period of each bottle depends of its form, weight and consistency. The pitch is regulated with aid of the fill height. Colored water gave an added visual impression.

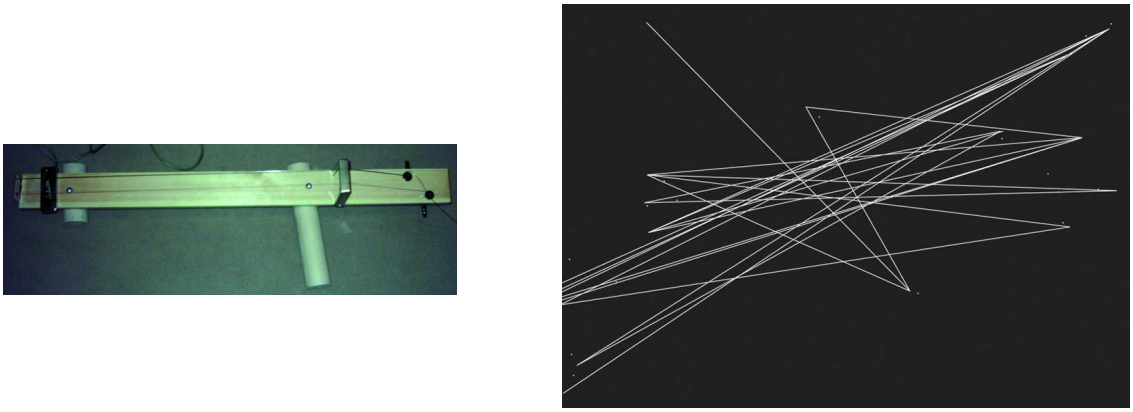

Figure 5: Music instrument "superstring" and interactively produced graphic by the music

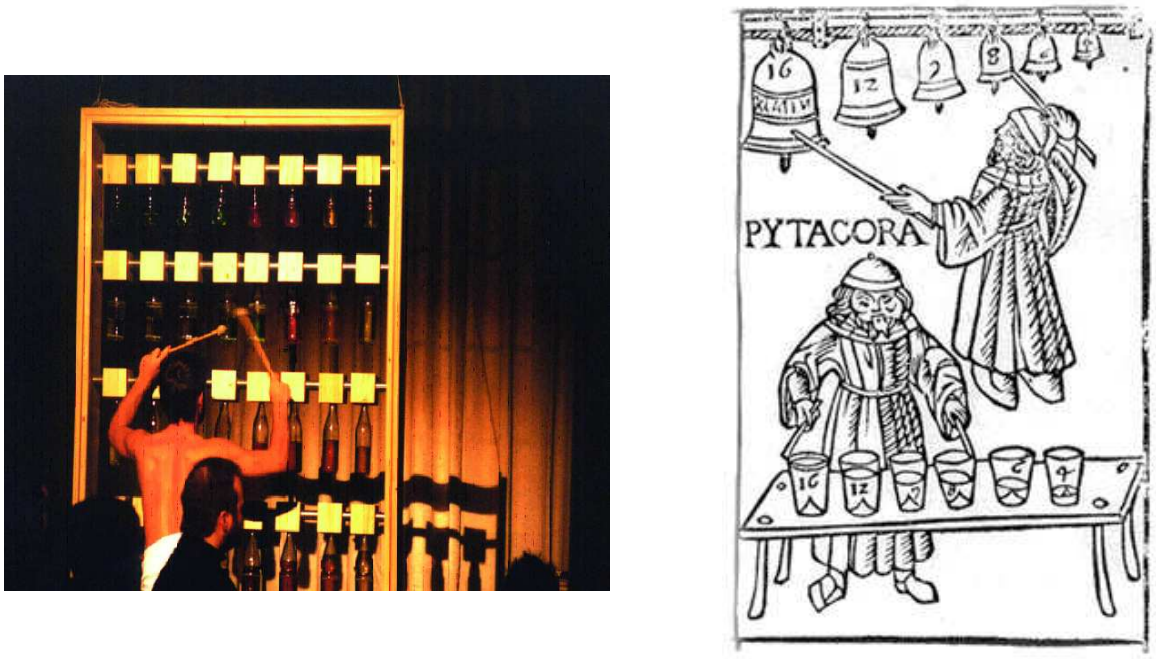

Figure 6: Abacus created using bottles, filled with different amounts of water and Pythagoras with a similar experiment [8]

Pythagoras had also made similar sound experiments by filling glasses with water. The student of music composition Simon Rummel improvised on the "abacus" instrument during the concert and the visitors were able to test the instrument for themselves in the exhibition area.

3.5. The project "Motion"

The *"Motion"* project develops relations between motion, music and geometry. The interactive stage system "Motion" was designed by the students of architecture Nils Hueckleкemkes and Pierre Wettels. Together with the student of music composition, Oxana Omeltschuk, they developed this system where a dancer, Oxana Omeltschuk, is able to produce sounds and images in real time. The motion of the dancer becomes visible on a screen and audible through speakers. This instrument achieves a visual and audible work of art. The stage as

a representation unit of space and time is extended by an interactive interface. The motion of the dancer is translated in music and image by video tracking. The dancer is at the same time the composer.

Figure 7: Dancing creates and changes images and
the "Fruchthalle" concert hall in Kaiserslautern with its proportions

3.6. The project "Musical Architecture"

For this contribution the "Fruchthalle" concert hall in Kaiserslautern, where our concert took place, was analyzed by architectural proportion theories based on musical harmonies. It is a neo-renaissance building and was built (1843-46) by August von Voit as a concert and market hall. The analysis of the proportions and the history of the building was transformed in music and visual impressions. Finally both together was presented as a visual and audible contribution. Music of several centuries, styles and functions as well as sounds of the environment are joined together by the music composition student Eunshin Jung. The architecture students Kerstin Dauenhauer and Hamire Kaya produced a movie where an analysis of the architecture, the perception and the history of the building were combined with music.

4. Conclusion

In our project we explored a large interdisciplinary field. By studying the relationships between geometry, architecture and music, historical background and actual research were brought together in a structural way of thinking. The extraordinary experience of the project was the realization of the ideas in the concert and the exhibition "Sound-sights". In the realization process the interdisciplinary field was even expanded. In addition questions of perception and computerized visualization technologies became important by creating the projects.

Working in such interdisciplinary groups was not easy but it was challenging and stimulating. Prejudices had to be cleared up on both sides, ways of communication had to be found and different positions and points of view had to be mediated. The project showed the importance of geometry in different sciences and presented the experienced coherence between them in a sensory way to a large non-academic audience. The concert, the exhibition installations and the workshop are documented in movies and published on a DVD [9].

Acknowledgements

The project was supported by the Foundation Rhineland-Palatinate for Culture and the cultural office of the city of Kaiserslautern. Many companies helped us by sponsoring material and technical equipment. Many thanks for the extensive support. Finally I want to thank Jane Bensch for correcting my English.

References

[1] C. Leopold, N. Christmann (eds.): *Geometrie, Architektur und Musik*. University of Kaiserslautern, 2003, ISBN 3-936890-18-8.

[2] C. Leopold (ed.): *Klangsichten 311003. Musik sehen — Geometrie hoeren*. University of Kaiserslautern, 2003, ISBN 3-936890-19-6.

[3] D. Hay: *Die Renaissance*. Droemer Knaur Muenchen/Zuerich 1968, p. 150.

[4] R. Wittkower: *Architectural Principles in the Age of Humanism*. W.W. Norton and Company, 1971.

[5] Le Corbusier: *Der Modulor*. Deutsche Verlagsanstalt Stuttgart, 7th Edition, 1998.

[6] A. Baltensperger: *Iannis Xenakis und die stochastische Musik*. Verlag Paul Haupt, Bern 1996.

[7] B. Leitner: *Sound:Space*. Cantz Verlag, Ostfildern 1998, ISBN 3-89322-411-4.

[8] http://music.washcoll.edu/

[9] C. Leopold, J. Fritsch, A. Edel (ed.): *Klangsichten 311003. DVD*. University of Kaiserslautern, 2004, ISBN 3-936890-53-6.

Received August 1, 2004; final form January 25, 2006