Zürcher Hochschule der Künste
Zurich University of the Arts

Sound Colour Space – A Virtual Museum

SNF Project 105216_156979 – Scientific Report

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By investigating the conceptual field of sound, tone, pitch, and timbre in its relation to visual phenomena and geometrical concepts, the project *Sound Colour Space – A Virtual Museum* contributes to an interdisciplinary field of research and explores adequate modes of its representation and communication.
Many scientists and philosophers from antiquity to modern times have studied the relationships between sound, light and geometry. Many of their visualisations of acoustical, optical and perceptual topics speak to the eye and can be studied comparatively. These pictures are interesting because of their diagrammatic structure, the way in which they combine text, images and spatial structures on a flat surface and the way they address topological, philosophical and psychological questions. They often have an aesthetic value of their own.
The collection and study of these materials and the attempts to present them as a sequential text lead to the question of adequate forms of representation. Since a given picture or graphic can appear in various contexts and with different implications, a distinct network architecture permits forms of content representation free of redundancies in a way that is difficult to achieve in textual form. Therefore, a collection of scientific illustrations and diagrams (currently about 600 image files) together with related materials and findings is presented within an open, dynamic online publication. The metaphor «museum» is thus rendered as a place where people and objects meet and interact in various dynamic modes. Visitors gain access to the image collection and can compare and regroup the pictures, read explanations and interact with audio-visual applications, or just follow guided tours. Scientists and scholars use the museum as a research tool and add to the contents of the underlying database. The application is based on the Media Archive of the Arts developed at the Zurich University of the Arts and contributes to the further development of this online platform as a research tool.

In Part 1 the description of the virtual museum and its development is followed by a summary of the research done by team members during the project. Part 2 summarizes the contribution of the individual team members and the output of the project, especially the talks and workshops organized at the Zurich University of the Arts.

Part 1. The Virtual Museum “Sound Colour Space”

The final implementation of the virtual museum

In the following we will say *museum* or *virtual museum* to refer to the final implementation of the virtual museum “Sound Colour Space”. The term is used for both, the software and the way it presents itself to the users (visitors). By *media archive* we will refer to the Media Archive of the Arts of the Zurich University of the Arts, which is based on the software Madek. There are three types of semantic units or exhibits in the museum: *items*, *item groups* and *experiments*. An *item* consists of a picture (image file) and meta information. An *item group* consists of a set of items and meta information. An *experiment* is an audio-visual application with meta information.

The items are stored as *media* in the media archive, where they are given title, author, year, bibliographic information and keywords, and grouped into *sets*. This ensures for the data to be available in the longer term.

The museum uses the media archive’s application programming interface (API) to synchronize the items and item groups with their counterparts in the media archive.

Since the annotations of the items and item groups contain formatted text, formulas and cross-references, they are stored in the database of the museum. They have been prepared in rich text tables. [The assignment of the annotations to the items is realised through matching file names. The software ‘Directory List & Print (Pro)’ was used to create the lists of the names of the files that were imported into the media archive.]

The *Archive* of the museum accesses the items in a way similar to a library system with various search, filter and representational functions.

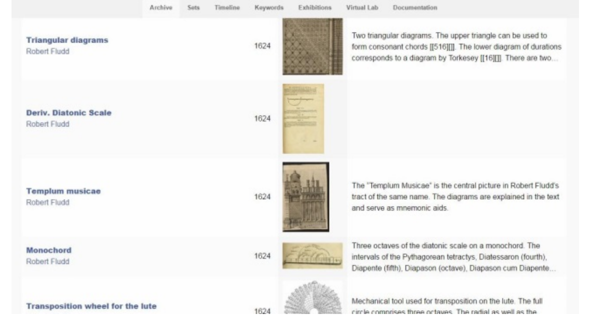
The *Timeline* visualizes the diagrams and their meta information on a time axis.

The menu *Sets* leads to the item groups – defined in the media archive as sets – and their meta-information.

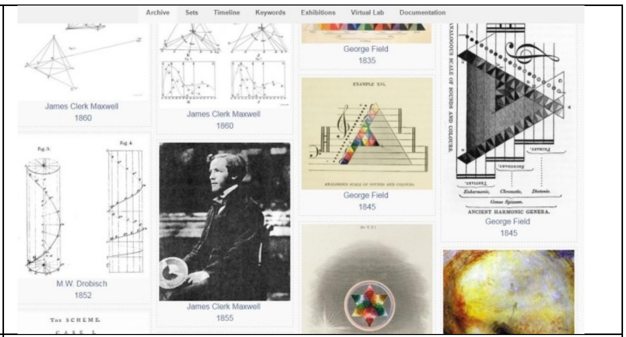
The menu *Keywords* opens a list of all the keywords that have been assigned to items. Selecting a keyword displays the related diagrams and an optional definition of the keyword.

Besides the presentation of the static contents the *Virtual Lab* offers an array of interactive audio-visual exhibits created for this project. They can be run directly in modern browsers.

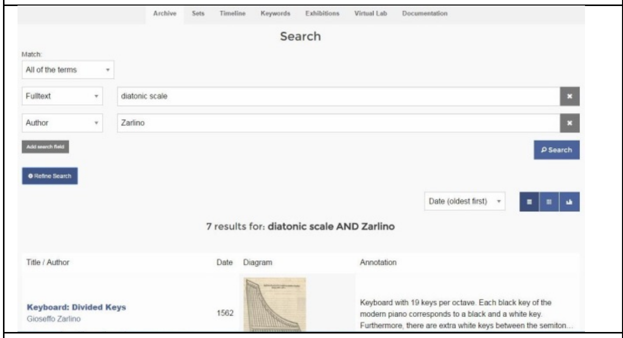
The menu *Exhibitions* contains a few paradigmatic exhibitions based on the collection of the museum.



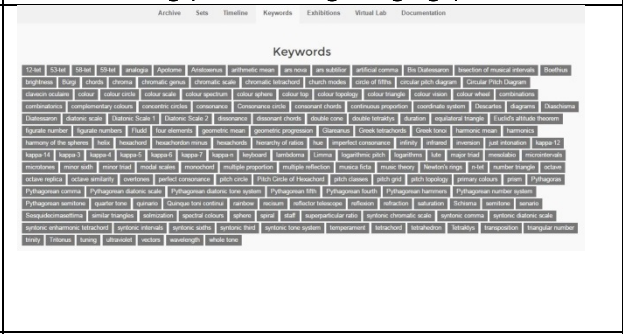
Archive: list view



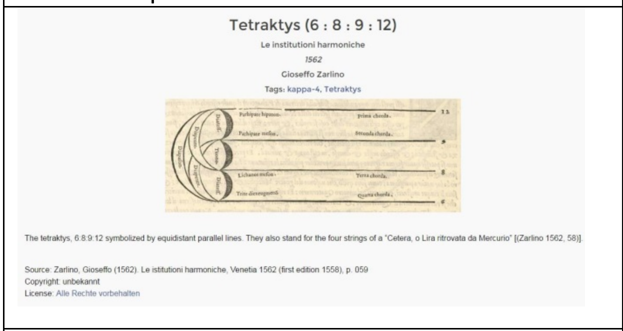
Archive: tiling (“Petersburg hanging”)



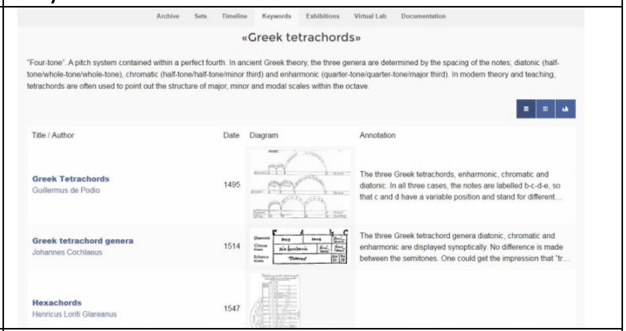
Archive: expert search



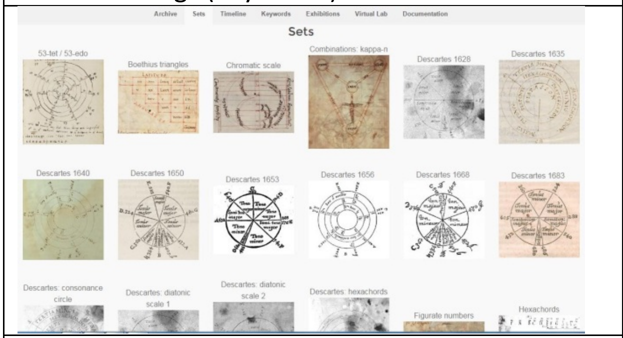
Keywords: overview



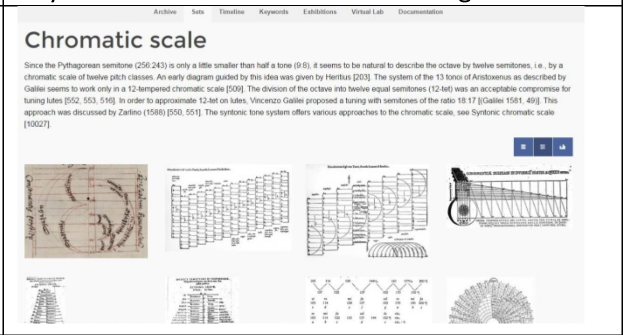
Item view: tags (keywords) and annotation



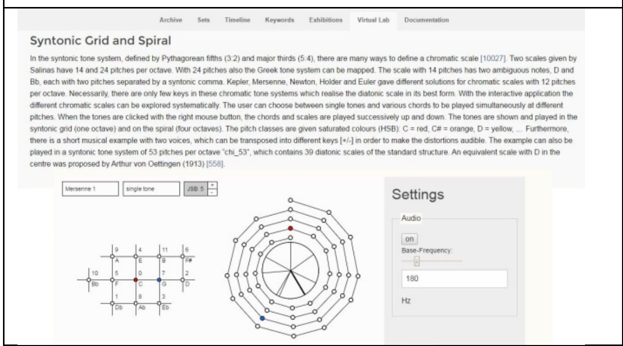
Keywords: definition with related diagrams



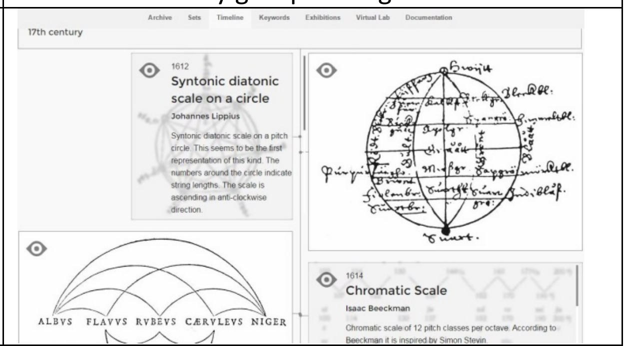
Sets: overview



Sets: thematically grouped diagrams



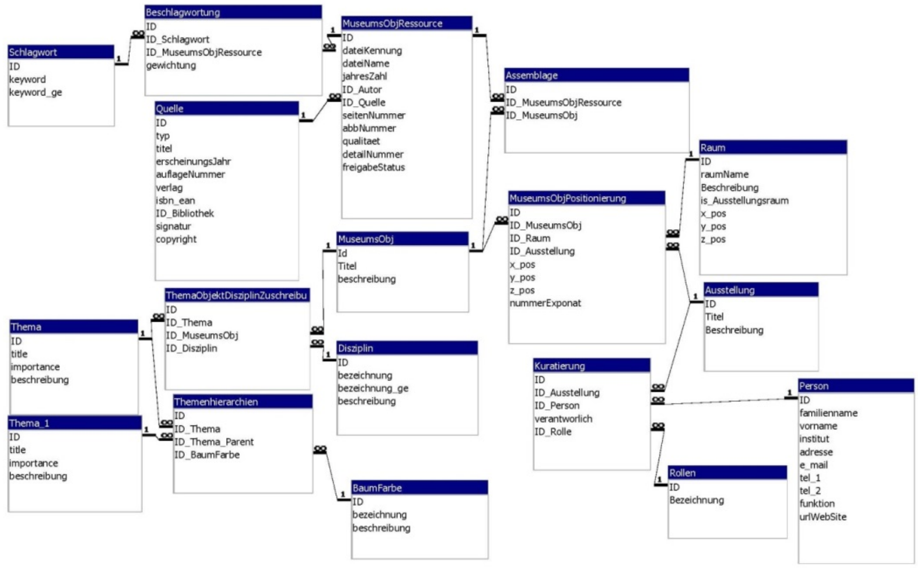
Virtual Lab: interactive experiment



Timeline

Data modelling and prototype

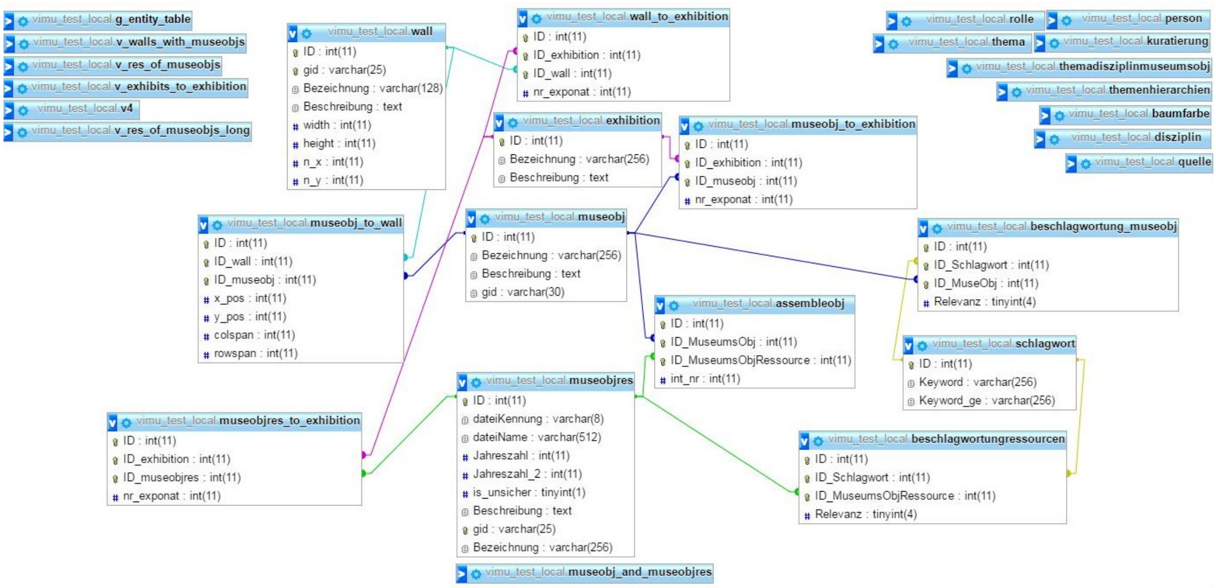
In collaboration with Christoph Reuter a first data model was created in February 2015.



ER-model [25.2.2015]

The many-to-many relationship ‘Assemblage’ between the central entities ‘MuseumsObjRessource’ and ‘MuseumsObj’ links the resources (media, files, typically diagrams) to semantic units or exhibits. The ‘MuseumsObj’s are similar to the sets of the media archive, however there is no further structure that would bring them into a network or a hierarchy. Keywords are assigned to the resources, but no additional semantic context. The lower left part of the model describes a kind of ontology where the network of topics related to the ‘MuseumsObj’s could be explored by means of “differently coloured trees”.

In summer 2015, the data model was partially implemented into a prototype by Daniel Muzzulini. The prototype used a mySql-database and was programmed with php, JavaScript and jQuery/Ajax. This early draft of the museum holds 150 diagrams (partially with realistic meta-data). There are no interactive exhibits in the prototype.



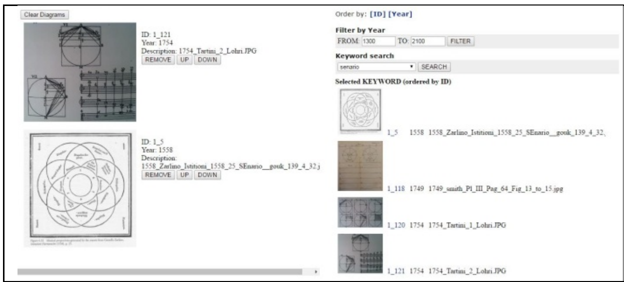
It turned out that many resources form semantic units in a natural way, so that no further documents are needed to turn them into exhibits. In the following we use the terms ‘item’ for these simple resources (‘museobjres’) and ‘item groups’ for the grouped resources (‘museobj’).

A semantic context (‘Bezeichnung’ (title), ‘Beschreibung’ (description)) as well as keywords can be assigned to both, items and item groups, in the form of metadata.

In the archive view of the items, the collection of diagrams can be filtered through time spans and keywords. By selecting items from a list they are shown together with their meta-information in a simple lightbox, where they can be moved up and down or removed.

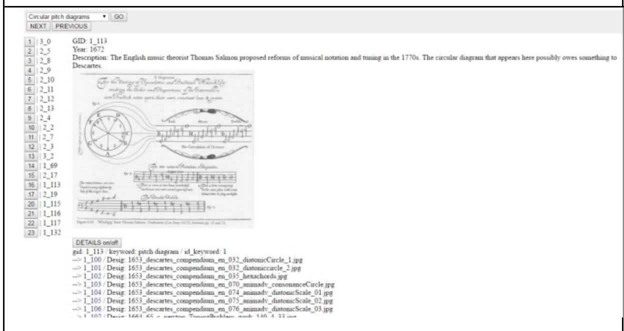
In the archive view of the item groups, an item group can be selected from a list, so that all its diagrams and related meta information is shown.

An *exhibition* is an ordered collection of exhibits. There are three types of exhibits: single *items*, *item groups* and *walls* holding one or several item groups in a matrix arrangement.

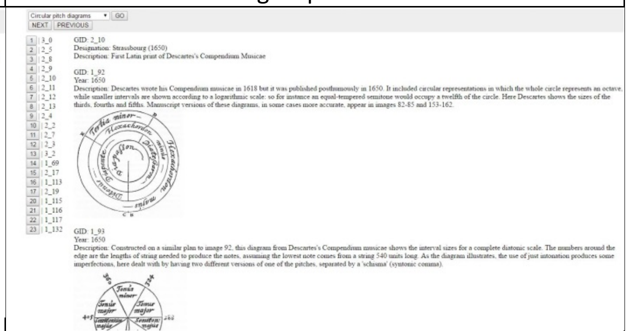


Archive view for items

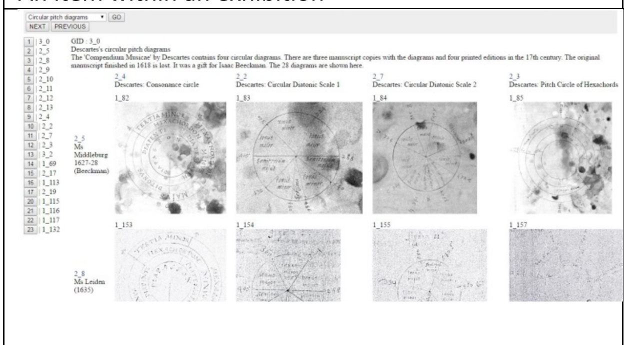
Archive view for item groups

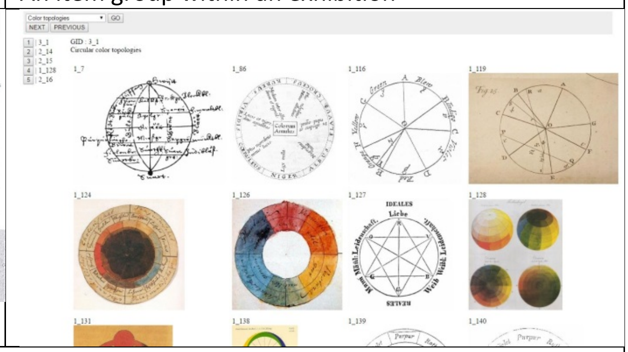


An item within an exhibition



An item group within an exhibition





Two examples of matrix walls as parts of an exhibitions.

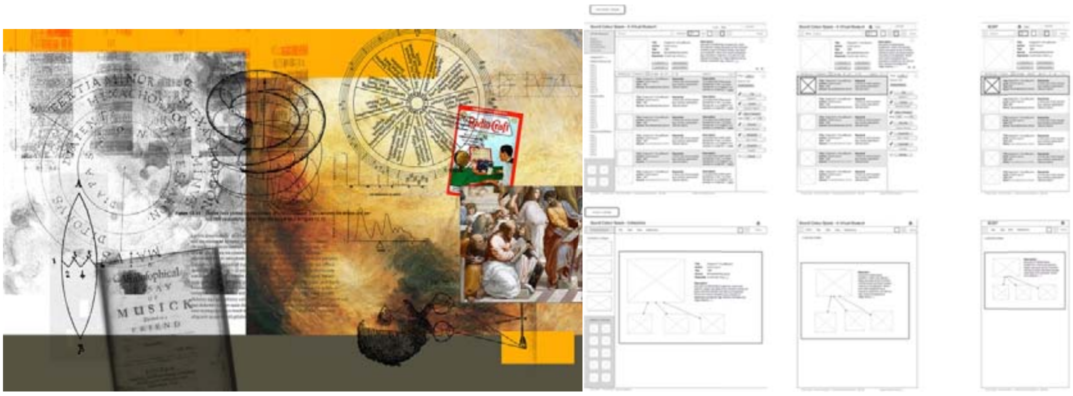
The prototype showed that the data model works well and that there was enough know-how in our team to implement a virtual museum according to our ideas and needs.

Topics, information technologies and research practice

Virtual Museum and Virtual Lab (Raimund Vogtenhuber)

Conception of the Virtual Museum

For the conception and functionality of the application the metaphor and terminology of a museum was helpful. The application addresses primarily researchers and scientists in the areas of music theory and diagrammatics. Although there is a close connection to the media archive of the Zurich University of the Arts, the access through a separate interface with special features for searching, sorting and viewing is essential for experts and visitors. For the development of the frontend interface several layouts, mood boards and sketches of the virtual museum were created and were helpful in building a responsive design.



Mood board and wireframe, Raimund Vogtenhuber

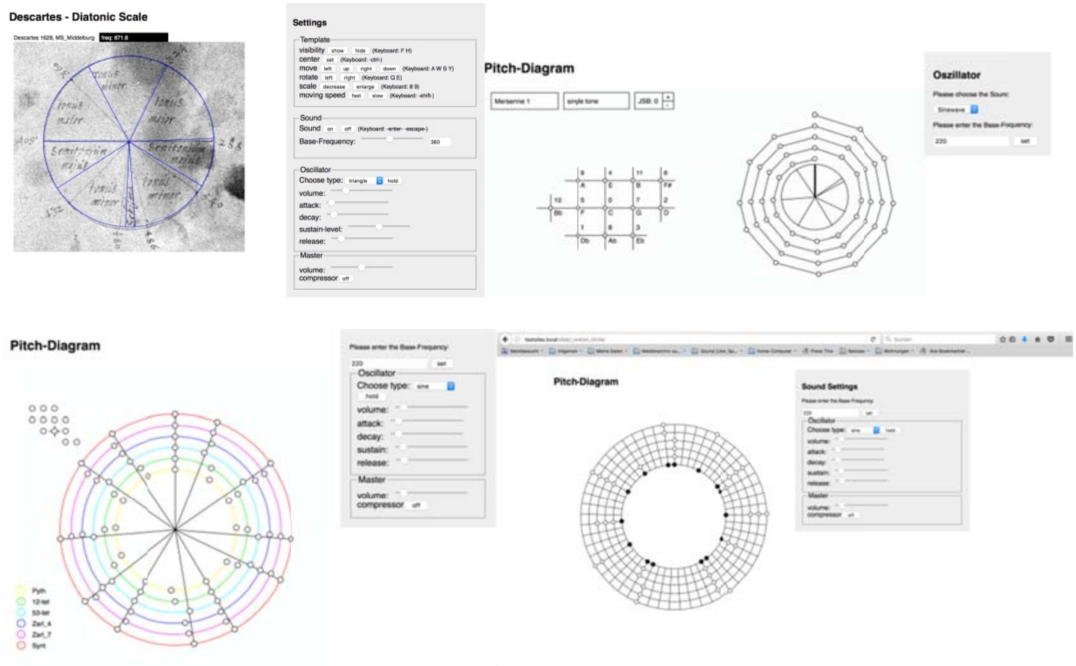
Besides the archive and the access to its contents through a database, exhibitions should be a part of the museum. According to Sybille Krämer's theory of "the culture of flattening" (Krämer 2016) diagrams in web technologies can be used to generate knowledge through flattening multidimensional information to a two-dimensional level. Following this idea, a collection of exhibits, the exhibition itself, can be seen as a network of information, which is presented by an "operative image" (Krämer 2009), a diagram itself. This concept naturally leads to navigation tools for exhibitions. As Gerhard Dirmoser emphasizes, a digital realization of an exhibition is like a tour of a museum. His theories and layouts were helpful in designing new exhibitions.

Layout for an exhibition by Gerhard Dirmoser and for "Chromatic Scales"

Virtual Lab

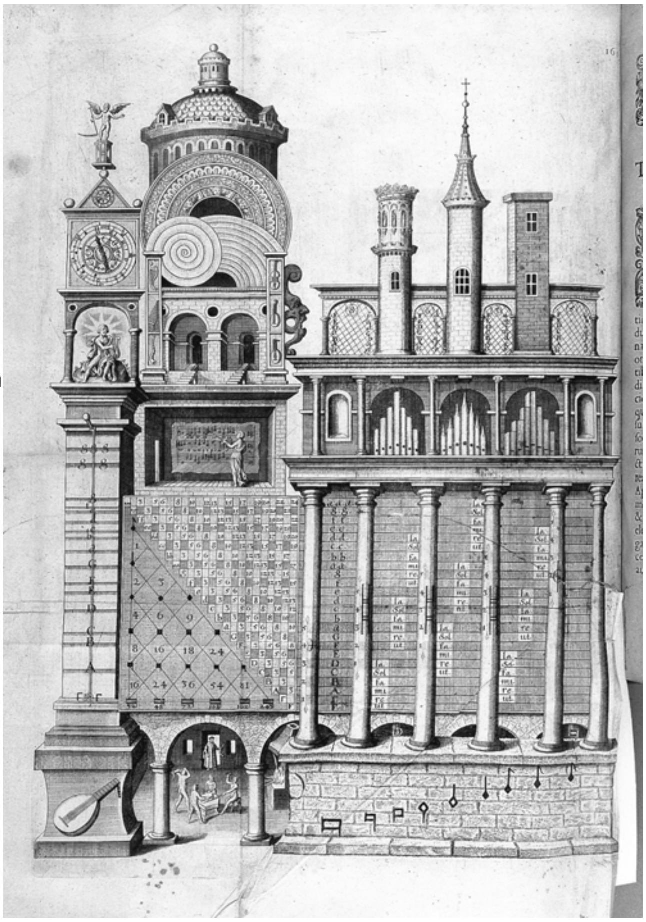
It was necessary to evaluate the possibilities of web technologies for the interactive audiovisual applications. The abilities of HTML5 and the diversity of JavaScript libraries led to the idea of a virtual lab as a space where different experiments with interactive applications can take place in the web. In an early prototype a first example was developed, which can be changed and edited directly in the browser. The applications consist of two parts: a layer in which the interactive diagram is generated and a separate layer where the settings and the synthesizer can be placed. A Web Audio library was developed, which is used by all the examples and can be adjusted according to the needs of the example.

For these experiments different strategies were used: Existing pitch diagrams can be made audible through Web Audio, so that they can be used in demonstrations and education. Some examples create new diagrams, which help to compare musical scales defined by different authors. Other examples create an exact graphical template of the scales being discussed, which can be compared to the historic diagrams. These interactive exhibits are programmed with p5js, a JavaScript library and a project of processing.org, offering the same functionality as Processing. Processing is used by many media artists, and so it is possible to convert their programs for the web. The examples from the virtual museum are also collected at https://github.com/Virtual-Lab.



Interactive audiovisual examples from the virtual lab

Fludd's Temple of Music as a conceptual starting point (Jeroen Visser)



A conceptual introduction

As an example of the content and the potential of the collection of musical pitch diagrams - and at the same a virtual museum "avant-la-lettre" , an analysis of Robert Fludd's "Temple of Music" was chosen for a first presentation of the project. The "Temple of Music", which was published in 1618, contains, in a mixed order of iconic and graphematic themes, a guide through rhythmical, harmonic and melodic compositional elements as input on the left side, which find their combinations in practical compositional output on the right side of the diagram.

As Fludd's intentions were more or less aimig at acceptance in scientific circles of the time, they were not directly based on contemporary musical thought. Therefore, some musical concepts were included which were not 'fashionable' anymore at the time of publishing, but date back to earlier periods (Hauge 2008). His efforts can however be considered as one of the first in which the concept of "Klangfarbe" can be discovered, preserved in the form of the organ pipes, which themselves represent the three hexachords duris, naturalis, and molle.

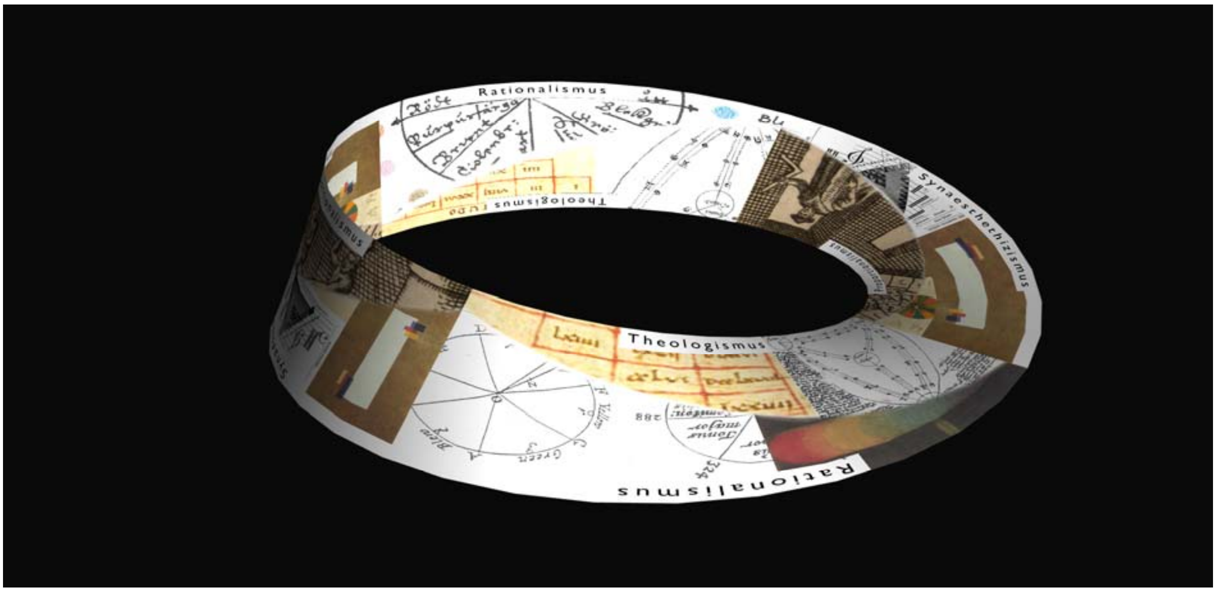
Definition of needs for the Virtual Museum

Having defined the technical outline in terms of database needs, an inventory of several possible implementations for the virtual museum was made. The use of newly available Javascript Web Libraries, turning the exhibition into a virtual 3-D experience was considered, so as to accomodate the "Space" keyword of the research group. As this was originally meant to describe the mathematical space inhabited by the diagrams, the virtual museum seemed to suggest an approach containing virtual 3-dimensional exhibitions. However, the epistemological input of Sybille Krämer (in her talk followed by a colloquium, and in Krämer (2012)) underlined the extended possibilities of 2D representation. To gain some more exemplary insight, a talk and a colloquium with IT specialist and artist Gerhard Dirmoser was arranged, whose ontological approach has proven pivotal in the final design of the virtual museum.

With the output methods of the museum in place, methods for the generation of an exhibition, or in other words, a toolbox for an exhibition's curator, had to be defined. This toolbox should include tools to define a library of diagrams according to specified parameters, and a choice of output aesthetics to represent the diagrams and their accompanying text. An experimenting area was defined using Web Audio and other JavaScript technologies in order to supply a curator with the necessary tools to show a 'hands-on' implementation of chosen diagrams, the representation of which can also be included in the exhibition

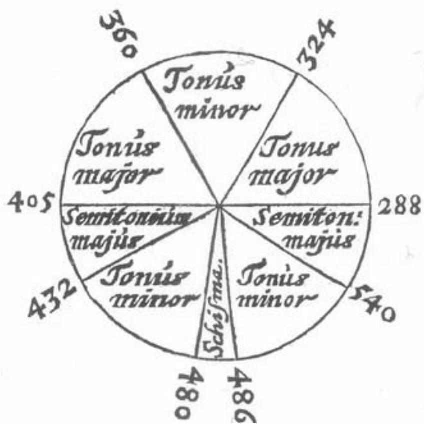
The Moebius Model

In order to put the issue of the connection of sound spaces and colour spaces into a historical/philosophical context, an inventarisation concerning this relationship was made starting with the Proportionalism of the Antiquity and ending with the Synestheticism of the Modernity. According to Jewansky (1999), the interpretation of this connection has varied greatly over the centuries and even within centuries. With the Modern Synestheticism seeming to reconnect to the Proportionalism of the Antiquity a model was developed based on the Moebius band. This model was presented at the final conference and is intended to be one of the museum’s exhibits.

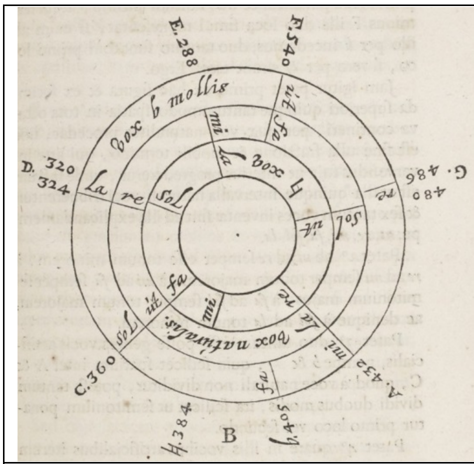
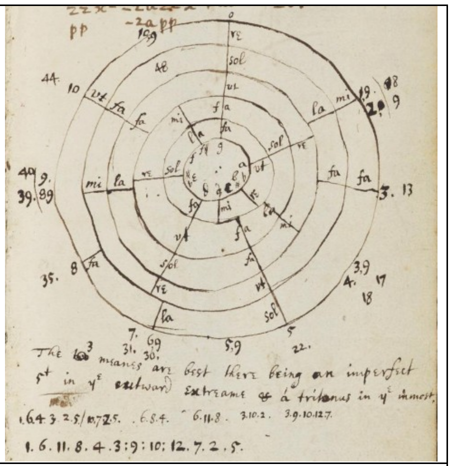


Diagrammatics of pitch (Daniel Muzzulini)

The beginning of my preoccupation with diagrams related to the topics complex sound-colour-space was marked by a pair of diagrams by René Descartes (1650) and Isaac Newton (1704), cf. Muzzulini (2012).

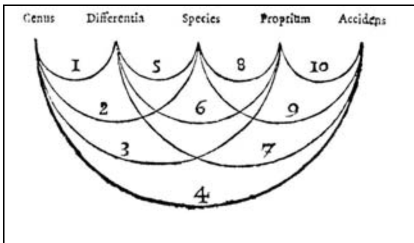
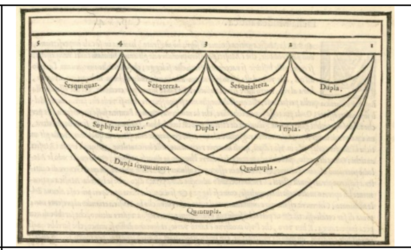
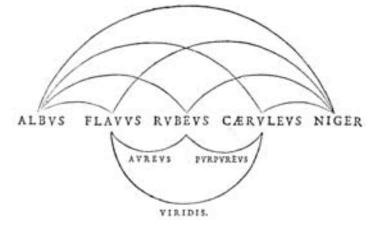


The similarity of the diagrams might obfuscate the fact that Newton gives the interior of the circle a meaning in terms of colour. Descartes’ diagram shows the pitch classes of the syntonic diatonic scale in a circular arrangement, whereas Newton's diagram represents a two-dimensional perceptual colour order with the dimensions hue (angle) and saturation (radius): point z is a weakly saturated orange close to red. At the same time, the radiuses separating the colours define the pitch classes of the diatonic scale.

	
Descartes (1650)	Newton (1665)

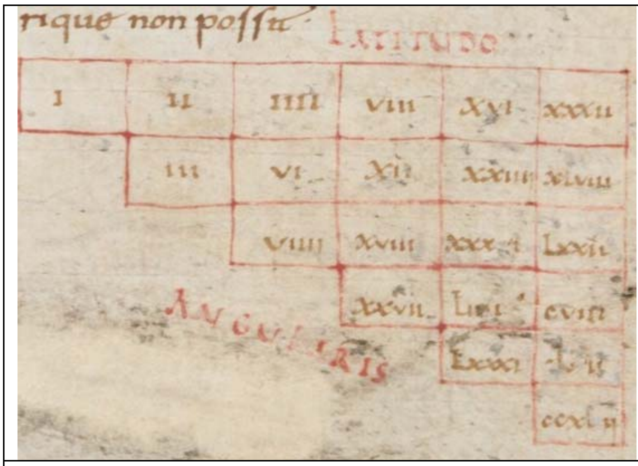
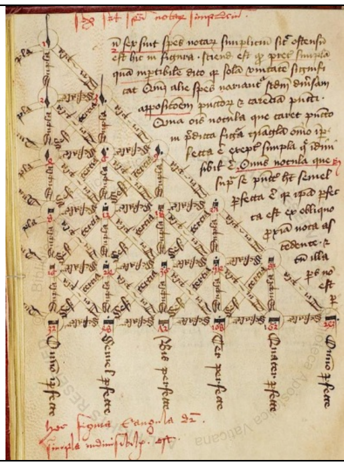
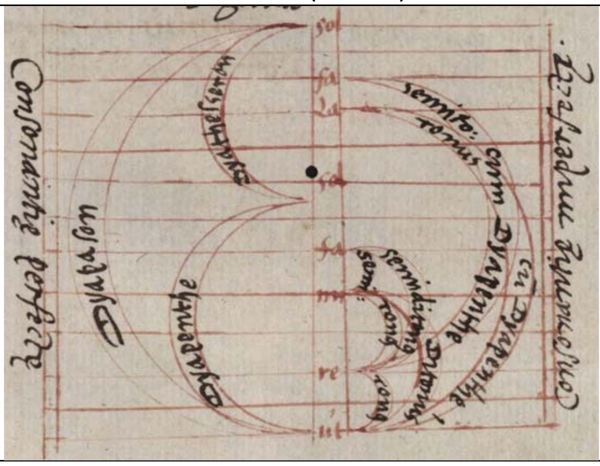
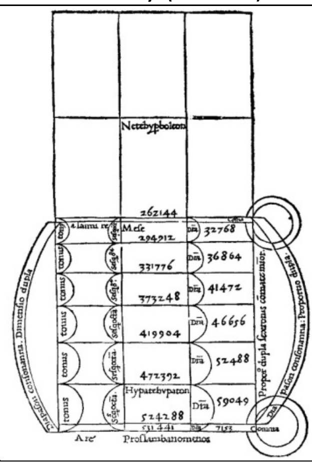
In a notebook from 1665, Newton generalized one of Descartes' circular pitch diagrams. This shows that he was familiar with Descartes' *Musicae Compendium* (1650) when he devised the circular colour topology for his *Opticks* (1704).

I hoped in vain to find more historical diagrams relating sound and colour with comparable sophistication. In both fields, colour theory and music theory, there are multifarious diagrams visualizing pitch, timbre and colour geometrically, however, synesthetic presentation usually does not go beyond arranging pitches and colours on a circle line, as for example Joseph Matthias Hauer (1918). One exception is the "acoustical colour solid" by Gerhard Albersheim (1939), see below Christoph Reuter (p.19-20). Another exception is the use of the same graph type in Aristotelean philosophy, music theory and colour theory, a graph in which five nodes arranged on a line are pairwise connected by arcs to form the full kappa-5 graph:

		
Aristotelian predicables (1597)	Zarlino (1562): consonances	Aguilonius (1613): colours

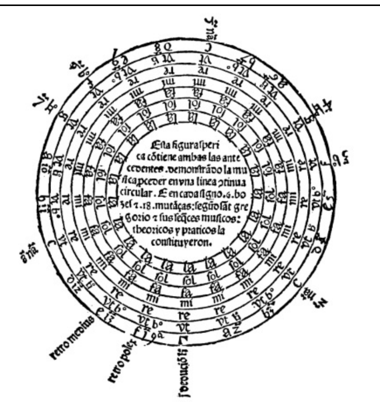
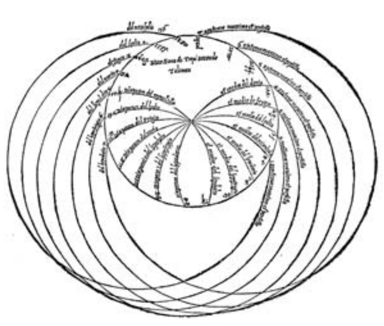
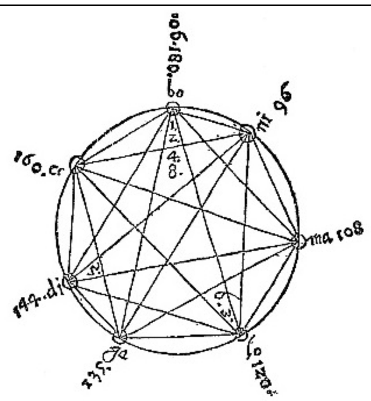
Therefore, I focused my research on the dyad *sound-space*, where *space* stands for geometrical approaches to pitch and intervals. The focus was on spatial and diagrammatical representation of a seemingly one-dimensional concept.

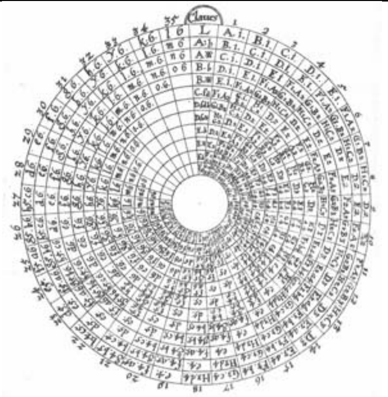
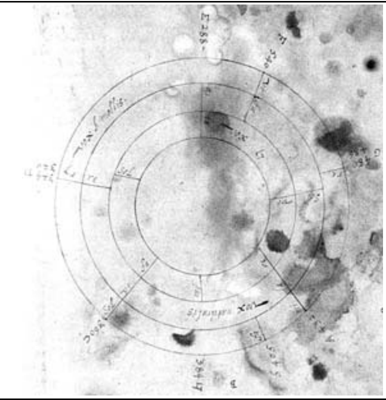
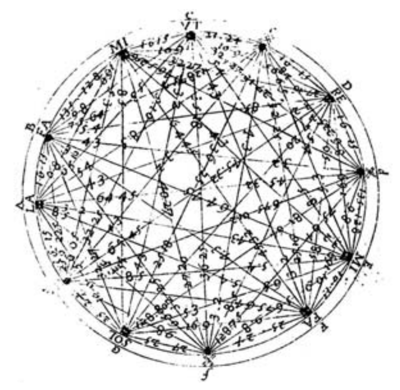
Applied to music theory, the number triangles by Boethius provide an early two-dimensional logarithmic representation of pitch, where equal discrete vectors correspond to equal number ratios, i.e., equal musical intervals. These diagrams were adopted by Johannes Torkesey (14th c.) and Robert Fludd (1618) to describe the duration system of the ars nova/ars subtilior period and are the base for the pitch grids by Jean-Philippe Rameau (1726) and Leonhard Euler (1739). Early logarithmic pitch representations in one dimension were found in Erasmus Heritius (1498) and in Vincenzo Galilei (1581).

	
Boethius (10th c.)	Torkesey (14th c.)
	
Erasmus Heritius (1498) – logarithmic pitch	Gaffurio (1518) – string length

Early circular pitch diagrams

René Descartes' *Compendium musicae* written in 1618 included circular representations in which the whole circle represents an octave, while smaller intervals are shown according to a logarithmic scale: so for instance an equal-tempered semitone would occupy a twelfth of the circle. We found precursors and possible sources for Descartes' diagrams.

		
Domingo Marcos Durán (1492)	Vincenzo Galilei (1581)	Johannes Lippius (1612)

		
Robert Fludd (1618)	Descartes / Beeckman (1628)	Marin Mersenne (1636)

Before the project we only knew of the circular diagrams shown above the one by Robert Fludd. The diagram by Domingo Marcos Durán was found by Gerhard Dirmoser. It shows an extension of Guido of Arezzo's system of hexachords. The diagrams in Beeckman's manuscript copy of Descartes' *Compendium musicae* give evidence that the circular diagrams must have been part of Descartes' lost manuscript from 1618 (cf. Muzzulini 2015). The diagram of the syntonic diatonic scale by Lippius (1612) is the earliest circular diagram we know that uses logarithmic pitch over one octave. Possibly, the diagrams by Durán and Lippius were sources for Descartes' own diagrams and most probably, Mersenne (1636) knew Lippius' *Synopsis musicae novae* from 1612.

Syntonic chromatic scales

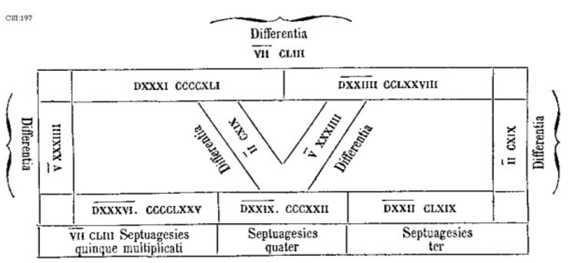
By *syntonic tone system* we refer to the infinite set of pitch classes defined by fifth of the ratio 3:2 and major thirds of the ratio 5:4 modulo octave. The task of defining a chromatic scale in the syntonic tone systems has many different solutions. Furthermore, since C# and Db are different pitches in the syntonic system, it is even not a priori clear that a chromatic scale should consist of twelve pitch classes. Models by Lodovico Fogliano (1529) and Francisco Salinas (1577) suggested 14, 15 or even 24 different pitches per octave. Various chromatic scales with twelve notes were given by Johannes Kepler (1619), Marin Mersenne (1636), Isaac Newton (1665), William Holder (1694/1731) and Leonhard Euler (1739). The problem with these scales is that most of the diatonic scales in different keys are distorted forms of the original C-major scale: they contain fewer perfect major triads (4:5:6) and perfect minor triads (10:12:15). Put positively, the different keys have a specific interval structure ('Tonartencharakteristik'). [For example, Holder's chromatic scale contains seven structurally different major triads.] The virtual museum hosts an interactive audio-visual exhibit, which allows the comparison of the various chromatic scales and an exhibition on chromatic scales.

Measuring musical intervals

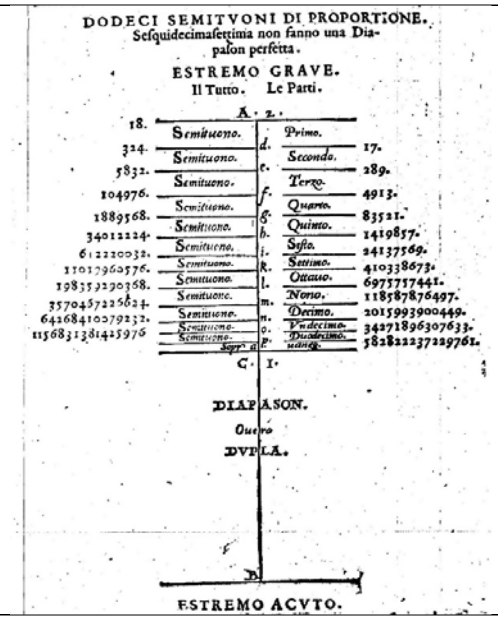
Boethius knew the ratio 531,441:524,288 of the Pythagorean comma, the small intervallic difference of six tones (9:8) and an octave (2:1). One way to compare the sizes of musical intervals is to express them in terms of a unit interval. For the Pythagorean tone system the Pythagorean comma seems to be a natural unit. Boethius found that the Pythagorean semitone of the ratio 256:243 lies between three and four Pythagorean commas. This estimation of the Pythagoeran semitone implies that the octave is between 41 and 53 Pythagorean commas and closer to the upper bound (the correct result is 51.15).

With the spreading of the syntonic tone system, other unit intervals were taken into account. Johannes Lippius (1612) and Marin Mersenne (1636) estimated the size of the octave in terms of syntonic commas of the ratio 81:80. Using logarithms, Nicholas Mercator (c. 1660) and Isaac Newton (1665) went the opposite way. In order to define a unit interval or "artificial comma", they divided the octave into a predefined number of equal intervals and expressed the intervals of the syntonic tone system as approximate multiples of this unit. Mercator opted for a division of the octave into 53 equal parts, Newton tried out 29, 53, 120, 59 and 612 equal parts of the octave.

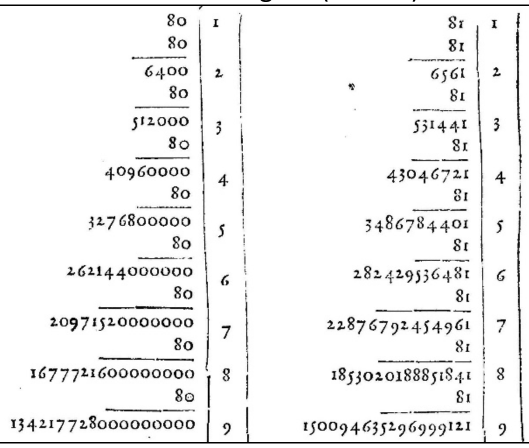
The equal divisions of the octave were studied systematically with a computer program, so that the excellent quality of the division of the octave into 53 and 612 equal parts can be objectively confirmed. Eventually, a reconstruction of Newton's considerations behind his particular choice of octave divisions was attempted, cf. Muzzulini 2017.



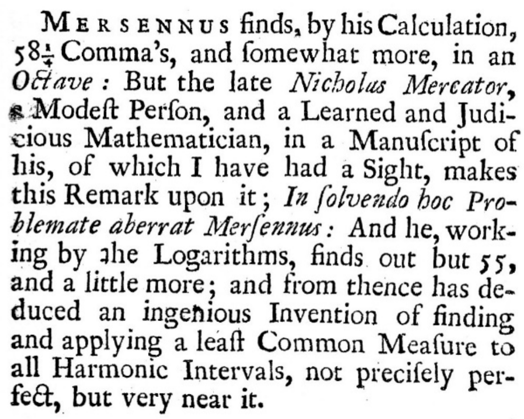
Walter Odington (14th c.)



Gioseffo Zarlino (1588)

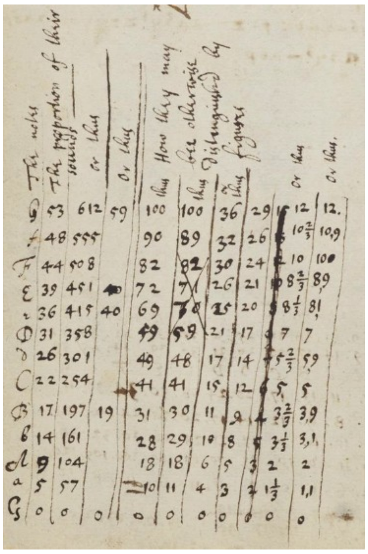


Marin Mersenne (1636)

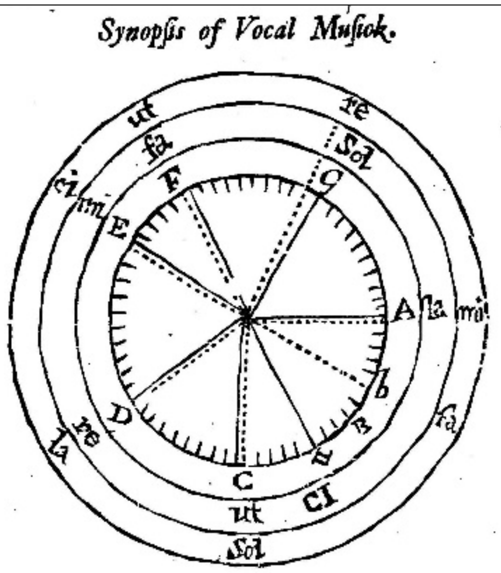


MERSENNUS finds, by his Calculation, 58¼ Comma's, and somewhat more, in an *Octave*: But the late *Nicholus Mercator*, a Modest Person, and a Learned and Judicious Mathematician, in a Manuscript of his, of which I have had a Sight, makes this Remark upon it; *In solvendo hoc Problemate aberrat Mersennus*: And he, working by the Logarithms, finds out but 55, and a little more; and from thence has deduced an ingenious Invention of finding and applying a least Common Measure to all Harmonic Intervals, not precisely perfect, but very near it.

William Holder (1731)



Newton (1664-1665)



A.B. Philo-Mus (1680)

Diagrammatic knowledge practices (Susanne Schumacher)

In the project «Sound Colour Space» a wide range of diagrams are both analysed and created. The historic diagrams depicting tone and colour systems by René Descartes, Isaac Newton and others are the scientific subject of the project – they are musicologically and mathematically analysed. In the course of the project, a great number of new diagrams were created and programmed as part of the scientific and artistic processes. The functions and contexts of these new diagrams allow for a better understanding of project members' work techniques and knowledge practices, the members coming from disciplines such as musicology, mathematics, composition, art history and software engineering.

The outcome of these diagrammatic working techniques can be grouped as follows:

1. Diagrammatic artefacts: Hand drawn, computer drawn and programmed diagrams resulting from conceptual work and from computer based analysis («Data Modelling and System Architecture», «Data Visualization», «Diagrams as Think Tools», «Programmed Diagrams», «Explanatory Diagrams»).

2. Diagrammatic models of the virtual museum: The virtual museum allows the visitors to explore the collected content along predefined patterns. Among these are accesses by «Timeline», «List View», «Keywords», «Sets» and so on. These diagrammatic models of representation result from the data structure of the museum.

3. Reinterpretation of diagrams: A more intuitive access to the historic diagrams was used in a related artistic project (shown at the Showroom Z+ of the ZHdK), involving graphical collages, by an interactive table and by sound performances («Diagrams as Artistic Material», «Playful Interactivity with Historic Diagrams», «Mood boards to Historic Diagrams»).

The multitude of approaches to working with diagrams seen in this project might be due to three reasons: First, the variety of professional backgrounds of and methods used by the project members did not provide an overarching common language and thus made diagrams an ideal medium for communication and exchange of ideas and concepts. Second, the virtual museum as a digital publication form was for all project members a new medium of representation. As this medium is based on a technical paradigm and the definition of entities and their relationships, diagrammatic concepts shared by all contributors were necessary. Third, the integration of mathematical thinking as a basis of musicology and electroacoustic composition turns diagrams into a natural form of conceptualization. The transformation of a historical research topic into a computer based representation supports a diagrammatic conceptualization and provides a new level of abstraction for the topic under consideration.

These diagrammatic knowledge practices facilitated the discussion of ideas and concepts provided that the diagrams follow conventions in terms of notation and visualization.

The diagrammatic artefacts are collected, grouped, described and tagged in the media archive: https://medienarchiv.zhdk.ch/sets/socospa_diagrammatic_artefacts

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Part 2. Organization and Results

The contribution of the team members

Daniel Muzzulini

Daniel Muzzulini conceptualised and managed the research project. Together with collaboration partner Christoph Reuter he created a first data model and he implemented a prototype of the virtual museum. He selected the historical exhibits. More than 550 diagrams from his collection and their metadata were filed in the media archive by him and Susanne Schumacher. He wrote most of the related annotations. Some diagrams and annotations were provided by collaboration partner Benjamin Wardhaugh. Daniel Muzzulini also programmed some of the virtual exhibits, which were adapted and included in the Virtual Lab by Raimund Vogtenhuber.
He organised the talks by Christoph Reuter, Sybille Krämer and Benjamin Wardhaugh and the final project conference in October 2016 at the ZHdK, which was also supported by the SNF (10CO12_171126).
Together with Raimund Vogtenhuber and Jeroen Visser he presented the project at the "Tag der Forschung 2015" of the Zurich University of the Arts. At the final conference, he gave a talk about historical diagrams. At the "Jahrestagung der Deutschen Gesellschaft für Musikpsychologie 2016" in Vienna, he was present with a poster „Diagrammatik der Tonhöhen – Von Boethius bis Newton". He composed two exhibitions for the museum and wrote two scientific papers.

Raimund Vogtenhuber

Raimund Vogtenhuber designed and programmed the project website and was responsible for the Virtual Lab. He actively contributed to the discussion and research about the conception of the virtual museum. He created interactive audiovisual exhibits and adapted Daniel Muzzulini's programs. He developed the examples with JavaScript and Web audio, so that they can be played through internet browsers. Together with Christoph Stähli and Jeroen Visser he represented our project in the "Showroom Z+: Kollaborationen". For this purpose, he designed the installation and posters and made video interviews with Susanne Schumacher and Daniel Muzzulini. He made an artistic performance related to the developed database. He programmed and adapted the exhibitions "Chromatic scales" and "Circular pitch diagrams" by Daniel Muzzulini and an exhibition by Gerhard Dirmoser for website.

Christoph Stähli

Christoph Stähli implemented the virtual museum in its current form, which comprises the programming of the API to the media archive, the mapping of the data structure, the search and representation functions in the archive, the access to sets and keywords as well as a timeline.

Jeroen Visser

Representing ZHdK's Institute of Theory in the research group 'Sound Colour Space', Jeroen Visser has been actively contributing to the discussion about the terminology to be used, to outlining the museum's exhibition paradigm in general, and more specifically to promote the invitation of Gerhard Dirmoser, specialist in IT and diagrammatic art.
Furthermore, he took the initiative in putting the question of the connection between colour-space and pitch-space into an historic perspective. As a composer, Visser was honoured to contribute a work of art to the final conference at the ZHdK, a composition for sine tones and coloured light, based on the Pythagorean Tetractys.

Susanne Schumacher

Susanne Schumacher contributed essentially to the planning and conceptualisation of the virtual museum. She helped to define the data model and metadata schema with regard to the interplay of the virtual museum and “Madek”, the Software behind the media archive of the arts. In doing so she tried to figure out how the exhibitions of the prototype could be transferred into a final technical layout. In her suggestions, she took a long term perspective and advocated the collection of the historic diagrams in the media archive of the arts in addition to the online-publication of the virtual museum.

Additionally, she analysed the diagrammatic knowledge techniques of the project members. For this purpose, she collected, analysed and categorized their diagrammatic artefacts and made them accessible in the media archive of the arts in the form of a commented collection.

Eventually, she took care of the extensive documentation of the project under the aspects of a good visibility of the project findings at the ZHdK and on the Internet. She fitted the research data management of the project to the digital preservation guidelines of the ZHdK.

Philippe Kocher

Philippe Kocher took part in the project as an advisor. He was involved in discussions concerning the museum's structural organisation and the possibilities of novel forms of presentation as well as in discussions about the programming and the evaluation of technical means to be implemented in the museum.
For the final conference he took some of the diagrams that had been collected for the museum (mainly those by Robert Fludd) as a starting point to consider the relationship between pitches and durations and their representation as numerical ratios. For this purpose, he compared medieval music theory with serial composition techniques of the 20th century.

Lucas Bennett

In order to facilitate consultation of the diagrams and annotations within the virtual museum for non-specialists, explanations for a selection of essential keywords are given in short abstracts. Lucas Bennett provided the definitions and kept an eye on the English of the other team members.

Output of the project

Talks and workshops organised at Zurich University of the Arts

Christoph Reuter (Universität Wien)

"The Colourful Life of Timbre Spaces – Klangfarbenmodelle vom akustischen Farbenkörper bis zum Meta Timbre Space", Vortrag, 4. Juni 2015, ZHdK.

Christoph Reuter’s talk addressed a specific interpretation of the triad “sound colour space” by reading “sound colour” as “timbre”.
If one tries to describe musical timbres or their similarities, it soon becomes clear that sounds are comparable in many ways and that sonic features such as brightness, roughness, vocality, attack, etc. can be aligned with various dimensions. Long before Joseph C. R. Licklider (1951) called timbre a "multidimensional dimension", Carl Stumpf (1890) tried to describe timbre with polarities on several dimensions. The talk tracked the development from early timbre descriptions by Hermann von

Helmholtz (1863) and Stumpf to the multidimensional models by Gerhard Albersheim (1939) and Gottfried von Bismarck (1971) and the various timbre spaces since 1975.

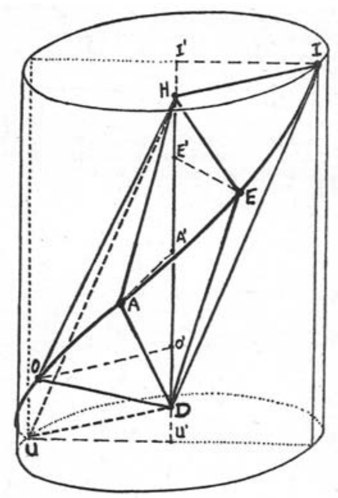
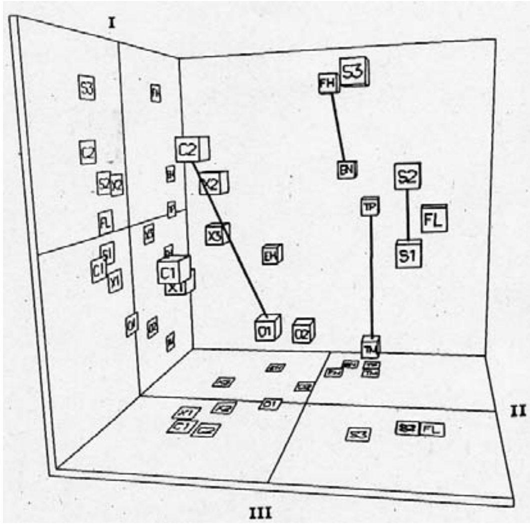


Fig. 23. Der Farbenkörper.



Albersheim (1939, p. 353) Grey & Gordon (1978, p. 1496)

The limits of these concepts become evident if the current timbre spaces are embedded into a meta-timbre space. On the other hand, timbre spaces calculated on the basis of timbre descriptors known from music information retrieval make new applications possible (audio logos and noise description) and might pave the way to a stable timbre conception adapted to human perception and independent of pitch and loudness.

Gerhard Albersheim, Zur Psychologie der Ton- und Klangeigenschaften (unter Berücksichtigung der "Zweikomponententheorie" und der Vokalsystematik. Strassburg: Heitz 1939

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Carl Stumpf, Tonpsychologie, Zweiter Band, Leipzig: S. Hirzel 1890, 514-549

Sybille Krämer (Freie Universität Berlin)

"Diagrammatologie", Vortrag und Kolloquium, 7./8. Januar 2016, ZHdK.

In our living world, we are surrounded by pictures, diagrams, writings, graphs, maps, display boards, computer screens, tablet computers etc. Creative artistic and scientific work can hardly get along without using inscribed and illustrated surfaces. The use of representing surfaces is part of a "cultural technique of flattening" ("Kulturtechnik der Verflachung"), which forms the basis of our symbolic and technical universe. What particular form of spatiality is given by this "artificial flatness"?

Diagrammatology, understood as the theory of the productive use of writings, diagrams and maps, examines the cognitive implications, e.g., the power of cognition of the line. It is not simply their visuality, but their spatiality that constitutes these forms of representation, so that time sequences can be spatialized (and vice versa). Each graphical configuration can be reconfigured. Therefore, inscribed surfaces not only bring about spaces of representation but also spaces of action, in which one can experiment with the represented objects and situations and in which they can be constructed, composed and examined. And most notably they create "play spaces". But what is the meaning of the cultural phenomenon of the artificial flatness for music, the art of time par excellence? Like speech sounds, musical sounds only exist in their disappearance. Why does the invention of graphically treated surfaces nevertheless have an important impact on the performance and analysis of music and everything related to music?

In her talk, Sybille Krämer discussed six characteristic features of the intermediate world of diagrams:

(1) Inscribable surfaces of solids which realize a topographical order (a) in their two-dimensionality, (b) through formatting and scaling, (c) through alternation of void and marking.

(2) Simultaneity: the two-dimensional arrangement on a surface makes synopsis and comparison possible.

(3) Hybridity: diagrams are pictures which make an assertion. Saying and showing, the discursive and the iconic coalesce/fuse.

(4) Referentiality: other than in artistic pictures external reference is essential for diagrams

(5) Operativity: diagrams have a cognitive and communicative dimension. The surface is a space for operative thinking.

(6) Lack of independence: no diagram interprets itself.

She exemplified these aspects with examples from Plato and Descartes.

Keywords: Plato: simile of the line, diairesis, Descartes: Musicae compendium: arithmetic and geometric proportion, octave similarity. Géometrie: construction of the multiplication. Les météores: particle theory. Regulae ad directionem ingenii (XII): colours as two-dimensional patterns.

Sybille Krämer, Diagrammatologie (Thesenpapier), https://medienarchiv.zhdk.ch/entries/socospa_kraemer_diagrammatologie_thesenpapier_2016

Sybille Krämer, Figuration, Anschauung, Erkenntnis – Grundlinien einer Diagrammatologie. Berlin : Suhrkamp, 2016

Benjamin Wardhaugh (All Souls College Oxford)

"Lines, angles, wheels: The geometry of musical sound from William Brouncker to Robert Smith", Talk, February 2 2016, ZHdK.

In early modern Britain, the physical nature of musical sound remained a matter of dispute. As a result, attempts to describe it mathematically or depict it graphically produced a range of different results, starting with versions inspired by the work of René Descartes, which reached England in the 1640s. Isaac Newton was among those who experimented with musical 'wheels' in the 1660s; he also attempted to correlate the notes of the scale with the colours of the rainbow. Following Newton, other writers in and around the Royal Society tried to devise 'sound wheels' that would divide up the octave while revealing its structure to the eye, presenting projects with titles such as the 'Musical Compass' or the 'Tonometer' of Ambrose Warren (1725). Among the most heroic of such attempts was that of Robert Smith. In his 1749 Harmonics, he placed himself in a Newtonian tradition while attempting to quantify and illustrate the elusive quality of harmoniousness.

Benjamin Wardhaugh, Musical logarithms in the seventeenth century: Descartes, Mercator, Newton. In: Historia mathematica 35 (2008), 19-36, http://www.sciencedirect.com/science/article/pii/S0315086007000341

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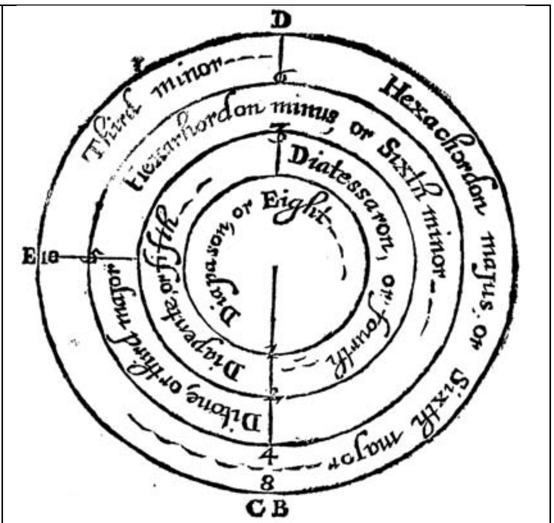
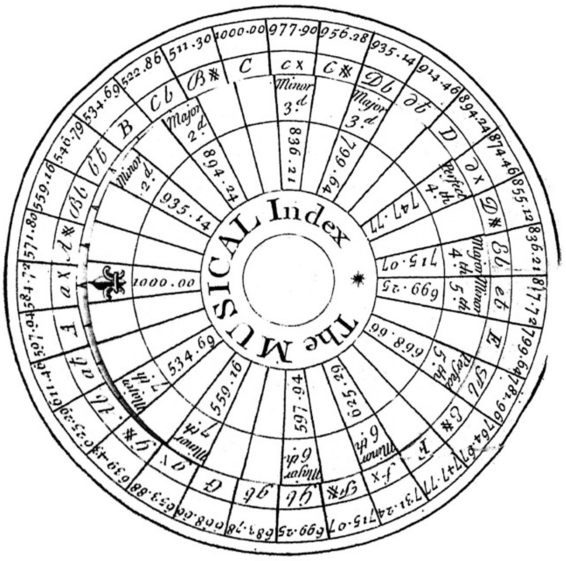
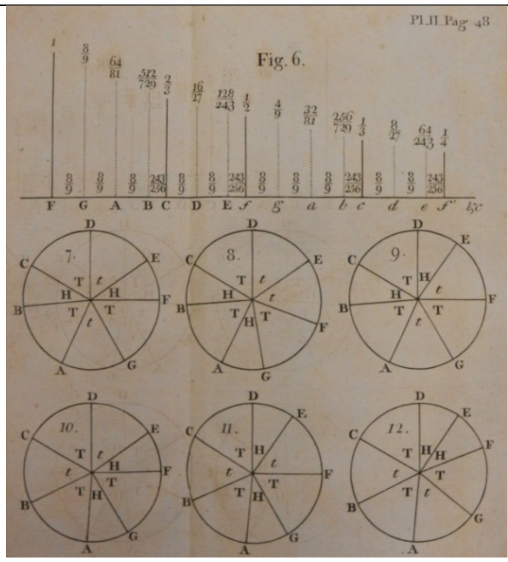


A diagram from Descartes' Musicae Compendium (1650) and its distorted version in the English translation (1653).

	
Anonymous (1684), The Musical Compass, British Library	Robert Smith, Harmonics, or, The Philosophy of Musical Sounds, Cambridge 1749

Gerhard Dirmoser (Linz)

"Frühe musiktheoretische Diagramme – Gestaltungsvorschläge für eine virtuelle Ausstellung", talk and colloquium, April 21/22 2016, ZHdK.

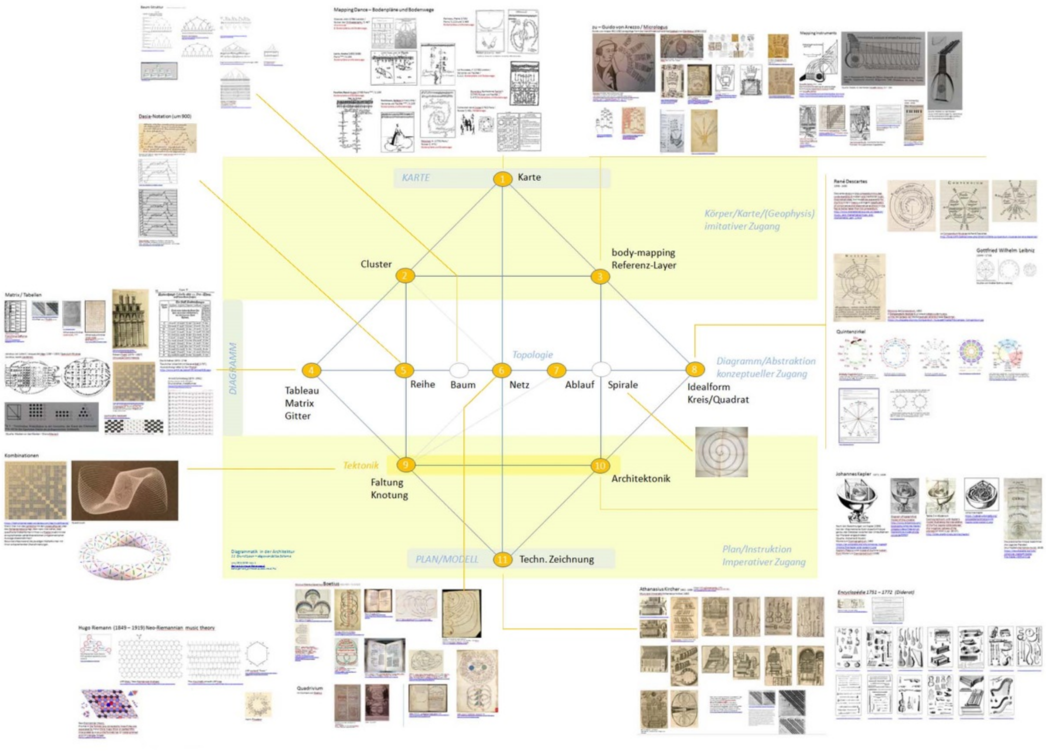
The information scientist and artist Gerhard Dirmoser talked about diagrammatical practices in science and art.

He highlighted the diagrammatical nature of archives, exhibitions and museums, and he discussed the various facets and functions of a virtual museum where diagrammatics play an essential role. They comprise the diagrammatics of time-based media and scores, archives, knowledge representation, the art of exhibiting (stage design), narration and correlation, interface design, typographical design/layout design within a frame of collecting, examining, imparting and exhibiting.

Dirmoser collected a large number of music theoretical diagrams (mainly from the internet) and he arranged them in core data sheets (“Stammblätter”) according to topics, authors and types of diagrams, a procedure leading to semantic, personal and pictorial networks. The author data sheets (each a power point presentation) can be accessed from a detailed pictorial time line (also a power point presentation). Thereby, Dirmoser actually created a valuable virtual museum, which he made available to the sound colour space team.

Furthermore, he pointed out that the related semantic networks should be dbase on weighted digraphs, which means that not only the nodes (e.g. the exhibits) can have attributes, but also the directed edges (e.g. the relationships between the exhibits).

Eventually, Dirmoser proposed the following typology of diagrams with related core data sheets.



Activities of team members

Tag der Forschung, Zurich University of the Arts (12.12.2015)

The presentation "Sound Colour Space – A Virtual Museum" by Daniel Muzzulini, Jeroen Visser and Raimund Vogtenhuber can be found at
https://medienarchiv.zhdk.ch/entries/socospa_tag_der_forschung_2015

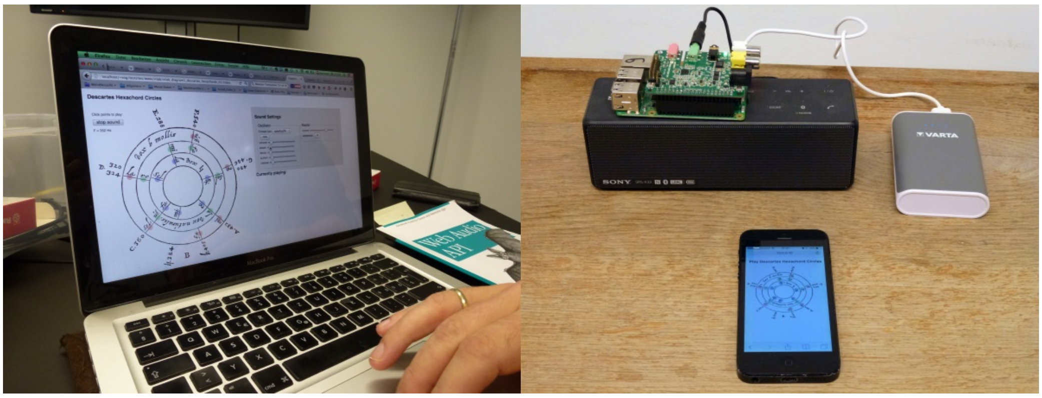
Tetractical Improvisation (Jeroen Visser)

As an artistic contribution to Sound Colour Space, this composition for sound and light is based on the Pythagorean Tetractys, a triangular arrangement of ten points defining the ratios of the Pythagorean consonances. The Tetractys model not only serves as an algorithmic aid to the composition by defining duration, pitch and colour, it also determines the inner construction of the sounds with elementary sine tones. As a tonal basis, a Pythagorean tetrachord is used.
A set of ten predefined colours produced by so-called RBGW Wall-Washer light fixture is controlled by the software which also controls the sound. To maximize colour intensity, a reference to white is presented by a video projection, showing a faint grey Tetractys on a white background.
The sonic harmonies and colours are brought into a 'polyphonic' setting where both qualities can be tasted independently as well as in combination.

“Tetractical Improvisation”, Zurich University of the Arts, 28.10.2016

Play Descartes (Raimund Vogtenhuber)

In order to explore its potential for art projects, an interactive audio-visual exhibit developed for the virtual museum was used in a performance. In this, scientific knowledge and its digital representation was an inspiration for a cross media project. The pitch diagrams were connected over a network to sound synthesis programs through Open Sound Control (OSC). In the performance Play Descartes, the diagram was used as an interface that can be controlled in the browser of mobile devices. By using their smartphones, the audience produced a collective composition.



Performance “Play Descartes”, Zurich University of the Arts, 29.10.2016

Showroom – installation (Raimund Vogtenhuber, Christoph Stähli)

For the “Showroom Z+: Kollaborationen”, an exhibition which took place at Zurich University of the Arts, an installation was created. A visual and haptic representation of the scientific content was created. On a desk the content of the database was used to generate postcards, which could be examined by the visitors.

Installation Showroom, Zurich University of the Arts, 4.11.2016

Publications / Poster

Daniel Muzzulini, The Geometry of Musical Logarithms, Acta Musicologica LXXXVII/2 (2015), 193-216; https://medienarchiv.zhdk.ch/entries/socospa_dm_muscical_logarithms

Daniel Muzzulini, Diagrammatik der Tonhöhen – Von Boethius bis Newton, Poster, Jahrestagung der Deutschen Gesellschaft für Musikpsychologie 2016, Wien
https://medienarchiv.zhdk.ch/sets/socospa_scientific_output

Daniel Muzzulini, Measuring Musical Intervals: from Boethius to Newton. Submitted for publication (Theoria, 2017)

Planned activities and publications

Susanne Schumacher, „The Virtual Museum «Sound Colour Space» and its Data Curators“, Vortrag, Swiss Data Days, Volkshaus Zürich, organisiert von HTW Chur und HEG Genf, 08.05.2017

Daniel Muzzulini, Philippe Kocher, Jeroen Visser, Robert Fludd’s musical diagrammatics

Internet links

The Virtual Museum
http://sound-colour-space.zhdk.ch

Documentation within the ZHdK Media Archive
https://medienarchiv.zhdk.ch/sets/sound-colour-space

Project presentation on ICST’s website
https://www.zhdk.ch/forschungsprojekt/426348

The final conference (SNF 10CO12_171126)
https://medienarchiv.zhdk.ch/sets/socospa_abschlusstagung