Optics, arts, and sound - celebrating 100 years of Kaluza's 5^{th} dimension in a geographically distributed interactive hybrid exhibition

Cornelius Hahlweg[a] and Witold Stypa[b]

[a]bbw Hochschule - University of Applied Sciences
Leibnizstraße 11-13, D-10625 Berlin, Germany
[b]Gallery Museum of Future
Schliemannstaße 25, D-10437 Berlin, Germany

ABSTRACT

From the remains of the planned contribution of our department to the *Night of Sciences 2020* in Berlin, which was cancelled due to the pandemic conditions at the time, a new concept in cooperation with the privately owned *Gallery Museum of Future* in Berlin and the *Foundation for German-Polish Cooperation* was drawn. Based on an idea by artist *Witold Stypa*, who's work is seeking to visualize multidimensional spaces in paintings and sculptures, a hybrid exhibition entitled *Shapes, colours and sounds in the world of mathematics - 100 years Theodor Kaluza's 5^{th} dimension* was designed. It comprises paintings and sculptures with special optical effects and musical elements, which are derived from investigations on optics and sounds as discussed in previous SPIE papers. It is dedicated to the work of Theodor Kaluza, mathematician and physicist of german and polish descent. He is known for his paper *On the problem of unity in physics*, which was presented by *Albert Einstein* on December 8^{th} 1921 to the *Prussian Academy of Science* and which is the origin of the *Kaluza-Klein* theory. The physical parts of the exhibition are spread over various locations in Germany and Poland, including *Kaluza's* place of birth, *Opole*, which are interactively linked via video conference tools. In addition to the impact in outreach for the Department of Electrical Engineering of the *bbw University* and the artists involved, the project provided new unexpected insides into effects of human perception effects, which are roughly discussed in the paper.

Keywords: outreach, hybrid exhibition, acoustical and optical stimuli, coherence, flicker, chords, light show, perceptibility, harmonics, arts and music, Theodor Kaluza, colour perception, just intonation

INTRODUCTION AND MOTIVATION

The paper is dedicated to an ongoing project on art and science, hosted by the Department of Electrical Engineering of the *bbw University* Berlin. Partners are the *Gallery Museum of Future*, both located in Berlin, Germany, Polish artist *Irena Imanska*, Polish-German artist *Witold Stypa*, and the Faculty of Arts of the University of Technology and Humanities Casimir Pulaski, Radom, Poland. The project is supported by *Foundation for German-Polish Cooperation*[*].

For several years the electrical engineering department of the bbw University Berlin has been working in the field of cross-disciplinary interactions of art and science. Especially combined optical and acoustical effects of human perception were investigated. For the *Night of Sciences 2020* in Berlin an interactive exhibition, involving optical sound generation devices and paintings by *Stypa* and *Imanska* was planned. The pandemic conditions of the time not only lead to almost zero participation of students, but finally to the cancellation of the event.

In the aftermath of the failed preparations and during the ongoing pandemic, ways to revive and enable the project were sought. The primary scope was to resume public relations work and to offer the artists involved a stage under lockdown conditions, when there was almost zero direct audience contact.

Further author information: C.H.: cornelius.hahlweg@bbw-hochschule.de, W.S.: info@witold-stypa.de

[*]web: www.sdpz.org; e-mail:sdpz@sdpz.org; German office: Stiftung für deutsch-polnische Zusammenarbeit, Büro Berlin, Schillerstraße 59, D-10627 Berlin.

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We found that 2021 marked the 100^{th} anniversary of the publication of *Zum Unitätsproblem der Physik/ On the unity problem of physics* by German-Polish mathematician and physicist *Theodor Kaluza* [†] at the *Preußische Akademie der Wissenschaften/ Prussian Academy of Science* in 1921.[2] *Kaluza's* work was supported and presented by *Albert Einstein* on 8 December 1921. In his paper, *Kaluza* introduced a 5^{th} dimension. It is the origin of the later so-called *Kaluza-Klein* theory[‡].

An interactive hybrid audio-visual art exhibition with musical accompaniment in honour of *Theodor Kaluza* was proposed. Galleries in Berlin and Radom with art exhibitions and informative video projection were to be connected via video conference systems, so interactive online admission was possible under pandemic conditions. Also the production of an artistic documentary was intended. The original title was *Colours and forms in the multidimensional world of geometry – Pictures at an Online Exhibition* with an obvious reference to *Modest Petrovich Mussorgsky's* piano suite *Pictures at an Exhibition* from 1874. The funded budget was EUR 23.000 with 20% own contribution, due 2021.

Since the intended production of the musical accompaniment lead to severe problems, endangering the whole project, the musicians involved had to be removed from the list of contributors, the title was changed to *Forms, Colours and Sounds in the Multidimensional World of Mathematics – 100 years Kaluza's 5^{th} Dimension* to ensure that no rights could be claimed.

As a result, the focus on the anniversary was sharpened. It was decided not to replace the musicians by new partners, but to produce experimental sounds and music, purely based on mathematics. These should fit the idea of art and science. Investigations done in recent years on the combined perception of sound and light were to be used.

In earlier publications the composition of chords and harmonies by superposition of discrete periodically power modulated light sources, producing periodical patterns in time and space, was discussed.[3] At that time we ended up with speculation on uses for emotionally reinforcing multi-media oriented entertainment, training support for musicians, and implications for occupational medicine. Further, the extraction of acoustical rhythm patterns from these flicker signals was investigated,[4] especially when modulation is applied near perceptible flicker frequency. It could be shown that major and minor chords deliver certain specific behaviour.

For the project presented here, the above mentioned mechanics of rhythm generation from chords transposed down to flicker frequency range was used to generate the sequencing of the chords themselves in audible frequency range. The results are best illustrated via portions of the documentary film, which are attached to the paper.

STYPA'S PAINTINGS

Witold Stypa, Berlin based German-Polish artist and founder of the Gallery *Museum of Future*, is known for abstract paintings. He uses special pigments, glass, metallic particles and other materials for his multi-layer colour landscapes, achieving various angle depending scatter and reflection effects. He is influenced by *Hans Holbein the Elder*[§], who used glass as major component in his colours for his sacred paintings.[5] *Stypa* is inspired by physics and science in general. His goal is to make multidimensionality visible and comprehensible, and to translate it into artistic concepts.

Figure 1 gives an example of such light effects. The painting is shown under diffuse and direct illumination. The use of sub-millimeter glass spheres, embedded in the colour, produces strong retro-reflection, making the painting change its character completely, revealing its hidden dimensions.

MUSICAL CONCEPT

In earlier publications the composition of chords and harmonies by superposition of discrete periodically power modulated light sources, producing periodical patterns in time and space, was discussed.[3] We ended up with

[†] 9 November 1885 in Wilhelmsthal, Oppeln/Opole – 19 January, 1954 in Göttingen.[1]

[‡] Interestingly, the original proceedings are a crossdisciplinary collection: in the proceedings, the *Kaluza* paper is followed by a work on antipope *Clement III* by *P. Kehr*.

[§] ca. 1465 Augsburg – ca. 1524 Basel

Figure 1. Example of painting with embedded glass spheres, producing dramatically changing impressions, depending on directivity and angle of illumination. Left: under diffuse light. Right: direct illumination. Painting: Witold Stypa.

speculation on uses for emotionally reinforcing multi-media oriented entertainment, training support for musicians, and implications for occupational medicine. Further, the extraction of acoustical rhythm patterns from these flicker signals was investigated,[4] especially when modulation is applied near perceptible flicker frequency. It could be shown that major and minor chords deliver certain specific behaviour. For illustration of the effects, an impression, two examples are cited in figure 2 with sound samples. The transient sound emulating some percussive instrument is not derived from the chord, but chosen for convenient reasons. For the project presented

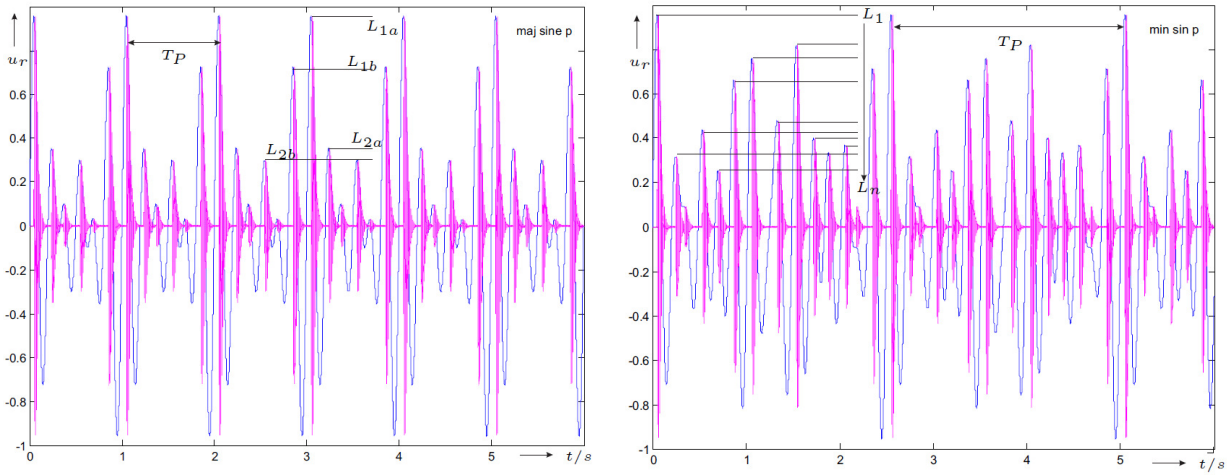

Figure 2. The beat patterns of a majo (left) and a minor (right) chord with sound samples.[4] Significant peak levels of basic beats are identified and marked. The corresponding sound files (*.wav) are indicated in the upper right corners. Audio 1 http://dx.doi.org/doi.number.goes.here; Audio 2 http://dx.doi.org/doi.number.goes.here .

here, the above mentioned mechanism of rhythm generation from chords transposed down to flicker frequency range was used to generate the sequencing of the chords themselves in audible frequency range.

The audible sounds are generated as unmodulated sets of periodical signals with correct integer based frequency relations according to the just intonation scale as derived from the natural overtone series, and deterministic and stiff phase relation over time. The amplitude-modulation with the sub-audible beat-patterns is applied on the existing precalculated signal sets, so the arrangement emulates non-causal signals, which stay coherent in phase. So the chord textures, or even the resulting music, generates itself, other than being composed by a musician.

Further, every audible chord is modulated and sequenced using its own beat pattern, resulting in the fact that every chord has its own texture. For some experiments, the unmodulated phase-stiff chords and their components were used.

The results are best illustrated via portions of the documentary film, which are attached to the paper.

EXHIBITION

For the final exhibition, the concept of self-sequencing or self-generation of the musical elements was applied to the presentation of the paintings. Videos of camera flights over the illuminated paintings as seen in the original gallery (which could not attract audience) were filtered and distorted, and finally projected onto the paintings. It should be stated that the projected videos are not connected to the sounds, although one might get the impression, that they are generated from each other. Video 1 shows the original gallery at the bbw Academy

Figure 3. Sections from the documentary 1. Left: Video 1 http://dx.doi.org/doi.number.goes.here; Right: Video 2 http://dx.doi.org/doi.number.goes.here .

in Berlin in February 2021. Still there is was physical audience possible. The scene is shown in original and in inverted mode, which produces completely new paintings. Sound: actual rhythm sections derived from E minor chord and coherent chord sections with modulation. Video 2 is an original painting overflight; coherent chord sequence convolved with white noise, but without modulation. Natural geese included. Videos 3 and 4 show

Figure 4. Sections from the documentary 2. Left: Video 3 http://dx.doi.org/doi.number.goes.here; Right: Video 4 http://dx.doi.org/doi.number.goes.here .

distorted overflights. Video 3 is based on a *Stypa* painting, video 4 on a *Imanska* work. The sounds are coherent self-sequenced triad progressions from a major and a locrian scale. The characteristics of the chords transition to the presented sequence. Videos 5 demonstrates the combination of sound and projection of paintings onto

Figure 5. Sections from the documentary 3. Left: *Kaluza* portait by *Stypa*. Video 5 http://dx.doi.org/doi.number.goes.here; Right: Rufus in Video 5.

paintings, here at the *Museum of Future* gallery. Usually the combination is perceived as harmonious, some visitors described the impression as healing. For comparison, there is a high tension sequence based on the track from video 2 with added slide guitar included. As soon as the coherent chord progression kicks in again, the tension dissolves. Video 6 contains the credits. It gives an impression on the idea, that guests in presence or

Figure 6. Sections from the documentary 4. Essential credits. Video 6 http://dx.doi.org/doi.number.goes.here .

online could actively take part in exhibition by contributing music or video material.

CONCLUSION AND OUTLOOK

An art and science exhibition project was conducted, away from the original intention, but finally more focussed on the subject. The project should have received intense contributions from students from our newly established master course in electrical engineering, which started successfully in autumn 2021 as hybrid part time course with a regular contingent of 75% online time. This course became possible as a positive result of the sad circumstances mentioned above. The students, who are located all over Germany, should have been responsible for IT infrastructure and technical installations, which was planned as a contribution to an interdisciplinary seminar, which is an integral part of their academic course. Unfortunately, due to the lack of physical availability and later of motivation, there was only minor contribution to IT problems with the video conference links. Also, none of the musicians among our students could be motivated to help out with the soundtrack.

On the other hand, the project revealed new aspects to the flicker chord investigations cited here. In an earlier paper[4] we stated, that it might be of more than only academic interest, that *Ohm's Law*[¶], stating that

[¶]Georg Simon Ohm, 1787 - 1854[6]

the human perception of the colour of sound, often called tone, is independent of the phase relation of harmonic components, and only depends on the amplitude spectrum, cannot be applied to the optical flicker perception. This emphasizes the trivial fact that the physiological mechanisms of acoustical and optical are different. With the presented project we went the other way round: while the sound perception for the single tone might be independent from phase, the textures realized by modulating the chord components with their own beat structure are not. The technique would not work in tempered scales. The key or mode are essential here. Further, many visitors observed a certain well-being while watching the performances. On the effect of the coherence of the music investigations might be conducted in the near future. It is even harder to evaluate the combination of the visual and the acoustical stimuli; they might follow a similar concept, but one should not follow metaphysical assumptions and leave this to the artist. Meanwhile, *Kaluza's* place of birth, Opole in Poland, became interested

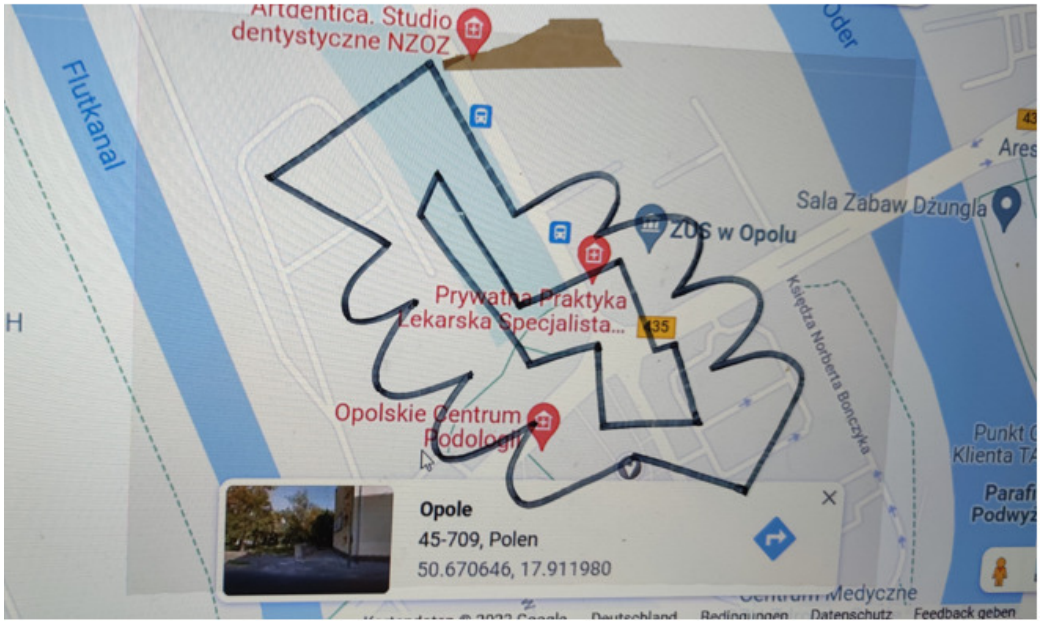

Figure 7. Artist's conception of a virtual scuplture spread over *Kaluza's* place of birth, Opole, Poland. The sculpture is realized using QR codes on buildings, places, and landmarks. They refer to internet content, like video, audio, and text.

in the project. There is ongoing activity by *Stypa* and *Imanska*, making Opole's little-known son more popular. Figure 7 shows an artistic concept of a virtual statue, which is spread over the whole town of Opole. The virtual sculpture consists of QR codes, refering to artistic and informative web content.

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