SPATIAL POLYPHONY: *Virtual Architecture Generated from the Music of J.S. Bach*

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Abstract. This paper documents the process and outcomes of a digital design project with the aim of translating music into architecture. Parametric software has been used to generate 48 virtual forms from the preludes and fugues of Book I of *The Well-Tempered Clavier* (BWV 846-869), by Johann Sebastian Bach. The paper discusses historical connections between architecture and music in the Western tradition and in relation to contemporary thought and practice.

Keywords. Architecture: music; digital; parametric.

1. Introduction

For centuries, architects in the West have been interested in the correlations between architecture and music. This project uses new technology to explore this age-old relationship. The project conceives of architecture in purely formal terms, to the exclusion of program, materiality, circulation and so forth. The formal structure of the music is of concern, not the sounds produced by a particular performance. The musical score is the starting point, providing the 'blueprint' from which virtual forms are generated.

Music can be experienced by listening to the sound or by reading the score. When listening to a complex piece, it is helpful (and pleasurable) to follow the score with one's eyes, in order to 'see' the structure. However, musical notation is limited in its ability to show the music as it truly is. This project aims to create another way of experiencing musical structure.

Spatial Polyphony refers to a virtual representation of the rich structure of Baroque music, as exemplified in the work of Johann Sebastian Bach (1685-1750). A fugue is a complex musical 'game' in which two or more melodic lines, known as *voices*, are woven together to form a harmonious whole. Bach is considered the greatest exponent of this form of music, known as *polyphony* (literally 'many sounds').

Bach's music is known for its sense of completeness. The composer wrote collections of works that seem to exhaust the potential of the instrument or compositional form. *The Well-Tempered Clavier* (BWV 846-857) is no exception. Composed in 1722, its two volumes contain preludes and fugues written in all 24 keys. In order to preserve this sense of wholeness, all 48 preludes and fugues of Book I have been translated. This has resulted in the creation of a family of forms, aiding comparison and improving the depth of analysis possible.

2. Literature Review

There is a long tradition of musical analogy in Western architecture. A wide variety of approaches to expressing the reciprocal relationship are documented, ranging from the use of underlying principles to literal translations.

In Ancient Rome architecture and music were considered branches of the mathematical sciences (Ham, 2005). At this time, an understanding of music was considered indispensable to the architect. In *Ten Books on Architecture*, the Roman architect Vitruvius states,

> "Let him be educated, skilful with the pencil, instructed in geometry, know much history, have followed the philosophers with attention, understand music, have some knowledge of medicine, know the opinions of the jurists and be acquainted with astronomy and the theory of the heavens."
>
> (Vitruvius, 1999)

The inclusive nature of architecture led to an interest in the underlying principles of other fields of study, including music. Renaissance architects created proportional systems based on the principles of musical harmony established in Ancient Greece, grounded in the belief that the same universal principles of beauty are manifest in art, architecture and music. In *De re aedificatoria,* Alberti discusses the correlation between music and architecture, "the numbers by means of which the agreement of sounds affects our ears with delight, are the very same which please our eyes and our minds" (Wittkower, 1973).

Translations of musical principles into architecture continued in the 20th Century. Cross-fertilisation was encouraged by new developments in media and technology. Le Corbusier and the composer Iannis Xenakis collaborated on the *Phillips Pavilion* at the 1958 Brussells World Fair. The design of the pavilion referred to the principles and techniques of serial music, and the interior incorporated a multimedia show of lights, projected images and specially composed music (Bandur, 2001).

Architects have used music in their work both literally and metaphorically. Opinions vary as to the validity of each approach. Harvey (1998) describes two contemporary buildings with a relationship to music: Daniel Libeskind's *Jewish Museum Berlin* (1989-2001); and Steven Holl's *Stretto House* (1990-92). The author criticises Holl's literal approach and argues that Libeskind's building is more successful as it explores, "the underlying philosophical concerns of the composer". Other commentators consider the literal approach to be sound. Martin (1994) describes *Stretto House* positively as a study into the inherent "multi-layered" nature of architecture.

Literal translations of music into architecture are founded on the formal parallels between each discipline. Walton (1934) discusses the "reciprocal values" shared by the two art forms. Counterpoint and harmony – the 'horizontal' and 'vertical' aspects of music – are given architectural equivalents, the Renaissance palazzo and Gothic cathedral, respectively. These comparisons are somewhat idealized; every rule has its exceptions. Nevertheless, the use of 'spatial' terms to describe music supports the notion that significant formal parallels exist between the two disciplines.

The polyphony of a Bach fugue is an ideal example of the integration of horizontal and vertical music. In 1928, a Bauhaus student designed a sculptural monument based on one of the composer's fugues (Figure 1, left). The monument's designer, Heinrich Neugeboren, explained at the time that he was not concerned with "an emotionally personal reinterpretation, but rather with a scientifically exact transformation into another system" (Wingler, 1969). However, Neugeboren felt that his creation was flawed, as the sonically powerful bass was insignificant in the sculpture, its lesser stature allowing it to be smothered by a "towering monumentality".

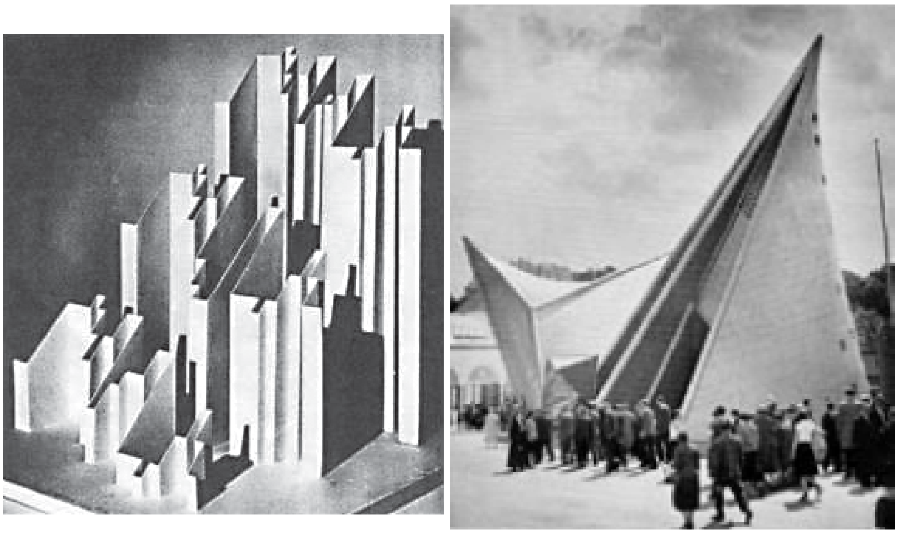

Figure 1. Left: Monument to Bach by Neugeboren, note the bass. (Wingler, 1969) – *Right:* Phillips Pavilion, based on compositional principles from serial music (Bandur 2001)

Neugeboren's "scientifically exact" translation is strikingly similar in spirit to the contemporary process known as `Data Representation Architecture`, where architectural form is generated using data from an external source, such as music. In *Real and Virtual Spaces Generated by Music*, sounds and melodies are translated into architectural form. Data derived from sampled sounds is manipulated to generate geometries, creating a mapping between musical and spatial parameters (Levy, 2003). Data manipulation is crucial in this process. The human operator of the machine is the mediator between raw data and outcome, and must exercise their judgment in the selection of the data and the design of the system itself.

Digital processes can be used in architectural education to challenge notions of what architecture is and to enhance students' creativity. In *The 'Musitecture' Game* students explore the relationship between music and architecture, creating digital representations of architectural form directly from musical compositions using parameters such as dynamics, tempo, meter and rhythm (Ham, 2005). One of the lessons students learn from *The 'Musitecture' Game* is that extra-architectural sources can inform architectural design. The process of translation from one medium to another can enhance creativity and lead to solutions or forms that would otherwise not emerge. Steven Holl's description of *Stretto House* illustrates this point (Figure 2, left):

> "As boundaries between disciplines collapse, new channels suggesting thought and development open up... A move away from compartmentalizing and mental closing is a move toward an open future." (Holl, 1994)

This here presented project seeks to break down the boundaries that surround architecture, in the hope of discovering new connections. Architecture and music share a strong tradition, indicated by the wealth of literature on the subject. The advent of digital design technologies and the emergence of the notion of 'virtual space' have opened up new avenues for the exploration of this relationship. Parametric design techniques allow establishing dependencies between design rules of music as well as architecture. This juxtaposition of acoustic parameters with spatial ones allows a redefining of both, the music as well as the architectural form.

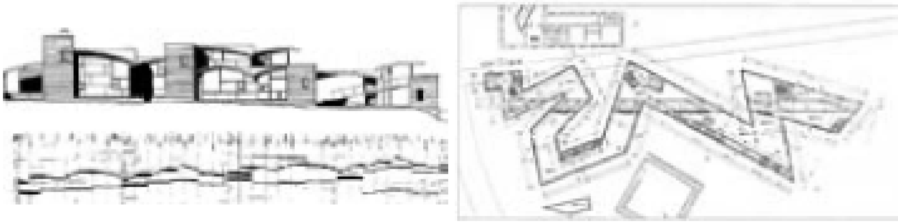

Figure 2 Left: Steven Holl's Stretto House, a literal translation of music – *Right*: Daniel Libeskind's Jewish Museum Berlin, a conceptual translation of music (www.pbs.org)

3. Process

3.1. DESCRIPTION

The process consists of four stages, each representing a different manifestation of the same data.

3.1.1. Step 1: MIDI (music)

The process begins with electronic music in the form of MIDI files. A MIDI file (Musical Instrument Digital Interface) is not a sound file, but a set of instructions that tells a device, such as a synthesizer or desktop computer, which sounds to play and when. Each MIDI file contains a number of tracks, corresponding to the different voices of each prelude or fugue. The MIDI files used in this project were downloaded from `The Bach Connection`, an online database of the composer's work:

(www.classicalmidiconnection.com/cmc/bach.html: April 2007).

3.1.2. Step 2: ASCII (text)

The MIDI files are converted into ASCII text files using a digital script. The resulting file contains a list of all the notes in the MIDI file, providing information on the variables or parameters associated with each note:

- *`Pitch`*: The note to be played, expressed as a roman character (C, C#, D, E, etc)
- *`Position`*: The location of each note in the musical sequence, expressed as a fraction
- *`Duration`*: The length of each note in time, expressed as a fraction
- *`Velocity`*: A quality of the note analogous to 'hard' or 'soft', expressed as a decimal number
- *`Tempo`*: The speed of the music, expressed as a decimal number

3.1.3. Step 3: EXCEL (numerals)

The parameters in the ASCII text files are displayed as roman characters (pitch) or fractions (position and duration). Parametric software can only read numerals, so the data must be converted from text into decimal numbers. This step is automated using a macro in *Microsoft*

Excel. For each track of the MIDI file, five Excel files are created. These *design tables* enable associations to be made between the musical and spatial parameters (Table 1).

TABLE 1: Design Tables

DESIGN TABLES	MUSICAL PARAMETERS	SPATIAL PARAMETERS
DT_offset.xls	Location in musical sequence	Location in spatial sequence
DT_duration.xls	Length of each note	Length of each block
DT_frequency.xls	Value derived from pitch of note	Height of each block
DT_wavelength.xls	Value derived from pitch of note	Width of each block
DT_note number.xls	Number of notes in track	Number of blocks

3.1.4. Step 4: CATIA (form)

The virtual forms are created in parametric design software *Digital Project*. Two types of file are created:

- `CATPart`: For each voice, contains the musical notes
- `CATProduct`: For each prelude or fugue, contains CATPart files

Each musical note is represented in the CATPart-file by an extruded rectangle, referred to as a ‘pad’. The pitch of the note determines the dimensions of the rectangle, and the length of the note determines the depth of the extrusion in time. These rules and parameters are the base of the spatial exploration of the music.

3.2. ‘WAVELENGTH’ AND ‘PITCH’

The pitch is split into two parameters, notionally referred to as ‘frequency’ and ‘wavelength’. With time, these form the three musical parameters to map onto the spatial parameters of length, width and height.

The actual frequency and wavelength of each note are not used, as the values are too extreme. Instead, an indexing system has been devised where each note is assigned two numbers ranging from 1 to 64, the number of notes used by Bach in the *Well-Tempered Clavier*. The numbers for frequency ascend while those for wavelength descend, reflecting their inverse relationship. These values determine the height and width of the extruded rectangles that make up the virtual forms. Tonal difference is expressed by height and width, not height alone, so the bass is not “smothered” as in Neugeboren’s sculpture.

5. Analysis and Interpretation

The family of forms produced by the translations consists of 48 instances of one parametric form. The shape of this ‘ideal’ form is a sum of all the decisions made in the course of this project, including the mapping of parameters and the choice of shape. The form of the translations is determined by the system, not the music. However, the consistent use of the same system to generate all 48 forms means that comparison within the set reveals the unique identity of each piece.

The project has revealed the shape of Bach's music in a direct visual way. The spatial representations allow one to see the whole piece of music simultaneously, impossible when listening. In *Prelude No. 1* the music begins in a high register and steadily moves down towards its resolution. This can be seen in the side view, as the height of the forms diminishes from left to right (Figure 3).

Figure 3. Side view of form generated from Prelude No. 1.

The virtual forms can be contrasted with one another to illustrate facts about the music. For instance, the preludes tend to be more rhythmically regular than the fugues. This is shown in the virtual forms, which are simpler and feature more repeated formal patterns. The fugues, on the other hand, tend to be less regular and more complex (Figure 4).

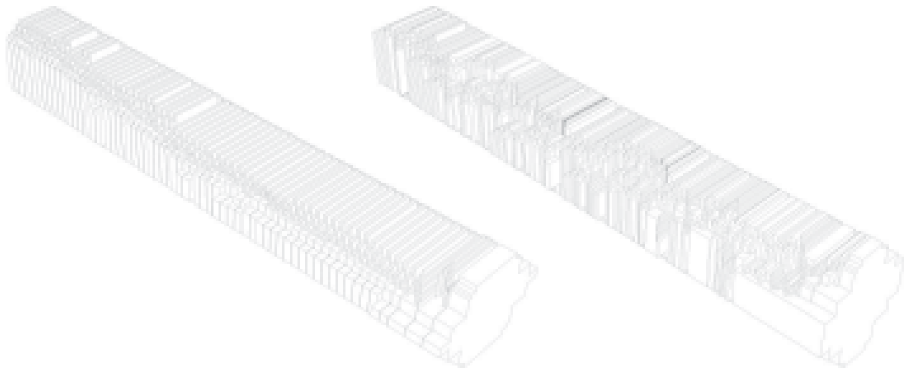

Figure 4. Prelude No. 1, left, and Fugue No. 1, right.

Each piece has been arranged in space horizontally; reflecting the linear nature of the music and leaving the forms open to multiple readings. This avoids the obvious architectural connotations that arise from a vertical, tower-like orientation. The virtual forms display a high degree of symmetry: two-fold in the side views and four-fold in the end views. This is the result of a decision to avoid any unnecessary eccentricity, which would distract from the pure form of the music.

The start and end views of each virtual form reveal the vertical aspect of the music. In Figure 5, five rectangles overlap to create a crucifix-like form. Each rectangle represents a different note. When heard, these five notes combine to form the final chord that provides resolution at the conclusion of the fugue. The two-dimensional shape is a visual representation of this harmony. This shape bears a striking (and accidental) resemblance to a 'Greek cross' church plan (Figure 5).

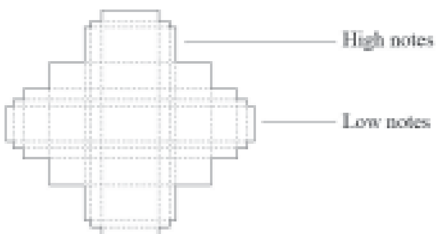

Figure 5. Visual representation of the final chord of Fugue No. 1.

Spatial Polyphony seeks to represent the construction of Bach's music. However, the greatness of the music lies not only in its intricate structure, but also in its profound emotional beauty. Abstract beauty cannot be translated as easily as concrete structure. The intangible defies definition and is impossible to quantify. Architecture, like music, has the power to move and inspire. However, this is not the purpose of *Spatial Polyphony*. The virtual translations are intricate and intriguing structural forms, not exercises in profundity.

This project uses digital architecture to represent music that is over 250 years old. This may seem inappropriate, but despite its age, Bach's music is well suited to digital representation. The keyboard, Bach's instrument of choice, is the digital instrument *par excellence*. Compare a harpsichord to a violin. The violin is analogue, allowing a continuous transition from one note to the next. By contrast, each note on the harpsichord is discreet. Unlike string instruments, there is no 'in-between' on the keyboard; every note is clearly defined.

It is apt that Bach chose to express himself using a 'digital' instrument – the keyboard is perfectly suited to the mathematical nature of his music. This mathematical clarity lends itself well to electronic performance. From the sleeve notes of an album of electronic versions of Bach's music,

> "Electronic music has a great deal to offer to Bach: Many Baroque characteristics, such as crisp, bright sonorities, terraced dynamics, and high relief of voices, are among the most idiomatic features of electronic music" (Folkman, 1968)

In the electronic performances of Bach, "every note and line can be heard." In the spatial representations, every note and line can be seen. The digital design process matches the "clarity of texture" which is the hallmark of electronic music (Folkman, 1968).

6. Conclusion

The purpose of this project is to explore the 'architecture' of music by translating the music of Johann Sebastian Bach into an abstract spatial form. The project has successfully translated Book I of Bach's *Well-Tempered Clavier* using a digital parametric process using digital representations of music and space (Figure 6). The full translation of various pieces of Bach's Well-Tempered Clavier can be found at Christensen (2007).

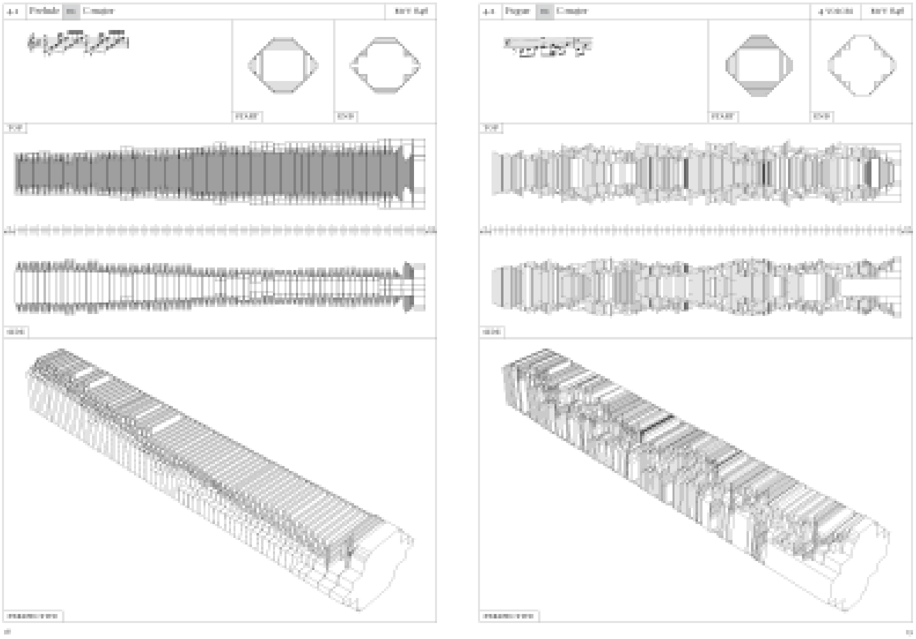

Figure 6. Representations of Prelude No.1 (left) and Fugue No. 1 (right)

A family of forms has been generated that provides a new way to experience music and spatial configurations. The parametric representations allow the entire music to be grasped as spatial shape as a whole without the need to listening to the time-based assembly of the music.

The project has focused on a translation into a form, to the exclusion of other architectural parameters. Future development could link musical parameters to architectural qualities such as light, colour or texture, to create a richer translation with more elements that relate closer to a realistic architectural design.

The project is also limited in its focus on ‘art music’ from the Western tradition, in particular the polyphonic music of the Baroque era. Other musical traditions–for instance, Asian or African, Folk or Pop–are outside the scope of this project. So too is the history of Western ‘art music’ post Baroque including classicism, romanticism, serial music, etc.

Translating different types of music could reveal more about the process, the music itself and the resulting spatial compositions. Comparing a representation of a Bach Fugue with a pop song by Britney Spears would be fascinating, and could help to clarify whether the shapes generated by the process are a result of the music itself, or the system of translation.

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