A DESIGN CHECKING TOOL BASED ON AESTHETIC PROPERTIES FROM DESIGN THEORIES OF ARCHITECTURE: Focused on Musical Harmony in Architecture

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Abstract. This paper proposes a way how a semantic aesthetic property from architectural theories in the Western world can be integrated into a computer-aided architectural design (CAAD) system. It starts from the premise that computer-aided design tools are mostly aimed at serving as drawing tools which are used only after a design formal solution has already been established by the architect. To support an early design solution in a computer-based environment, a design checking tool was developed and tested in a real building project. This tool gives various design alternatives from the early design phase to the final stage of design details, according to musical harmony. Finally, this paper shows that an aesthetic property from architectural theories can be calculated with the aid of a computer-based design tool, and the used tool played its role as a design assistant in supporting the architectural design.

1. Introduction

Aesthetic traditions from which the architectural design evolved have roots that can be traced back to some of the earlier expressions of European civilization. In ancient Greece, the concept of harmony was given a musical and mathematical treatment by Pythagoras and his followers. Pythagoras' idea of the centrality of music and its mathematical expression to human's understanding of the order of nature became a key concept in music and architecture for many centuries afterwards. During the Renaissance, the proportion derived from musical scales was pervaded much greater than before in building designs by the fact that from the beginning Alberti himself expounded musical theory in architecture. Indeed, the influence of the musical proportion is felt even in modern times as an attempt to find a rational order behind the chaos in a design. Many of the questions asked regarding architectural use of the musical proportion have been discussed, but topics relating to practical application of this proportion appear to be lacking. Therefore, we will propose a design checking tool based on the musical proportion for modern application in this paper, using a current AutoCAD system. This tool will show one way how the traditional musical proportion can be integrated into a CAAD system.

2. Analysis of Musical Proportion

In the Western world, some of the earliest known reflections on music are those of the Pythagoreans. Music is defined in terms of ratios—the science of relative numbers or numbers in ratio (Dorfman, 1986). For the Pythagorean, the blending of two musical tones into a harmony, known as the Perfect Fifth, is a manifestation of the harmonious blending of two qualities of number, 2:3. In the opinion of Plato, the basis of harmony and the cosmos are the progressions: 1, 2, 4, 8 and 1, 3, 9, 27. The integer series of these progressions show that the ratio of successive terms in the horizontal direction is in the octave ratio, while the left-leaning diagonal represents the musical fifth ratio and the right-leaning diagonal exhibits the musical fourth ratio, as shown in Figure 1:

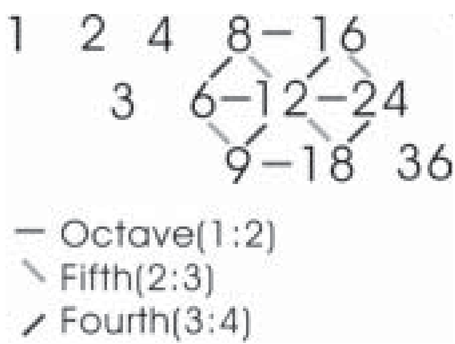


Figure 1. Integer series of musical ratio.

In this sense, the term “ratio” refers to a harmony that relates to the various melodic and harmonic relationships by which tones fit together (Lippman, 1964). Figure 2 shows division for some musical relationship, which represents the fundamental tone into segments corresponding to musical fifth (2:3), fourth (3:4), octave (1:2) and so on:

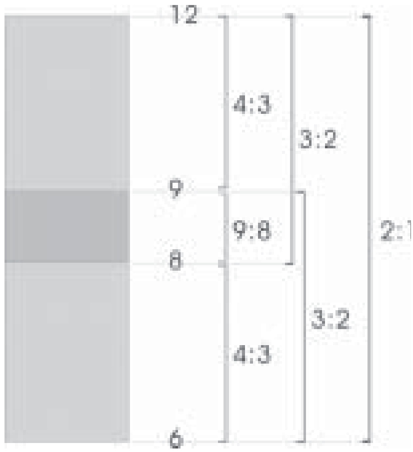


Figure 2. Musical consonance between the sequences 6, 8, 9, 12.

During the Italian Renaissance, Alberti and Palladio developed a system of architectural proportion based on proportions inherent in the musical scale. Alberti compiled a list of the ratios between the lengths and sides of rooms. These consist of the ratios 1:1, 2:3 and 3:4 for short rooms, 2:1, 4:9 and 9:16 for medium rooms, and 3:1, 3:8 and 4:1 for long rooms. The following Table 1 gives the musical intervals to which these ratios correspond: all of these ratios correspond to musical consonances except two, 16:9 and 9:4, which are equal respectively to (4:3)2 and (3:2)2:

TABLE 1. Alberti's recommended proportions for each area.

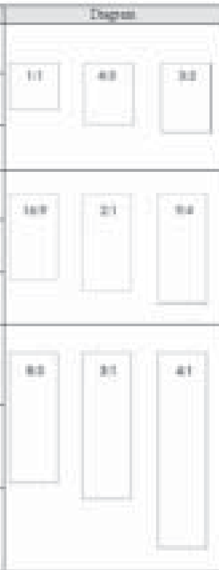
Ratio	Musical Interval	Diagram	Areas
1:1	Unison		Short room
4:3	Fourth		
3:2	Fifth		
16:9			Medium room
2:1	Octave		
9:4			
8:3	Eleventh		Long room
3:1	Twelfth		
4:1	Fifteenth		

Figure 3 proves that Palladio used musical ratios in the proportioning of his buildings. Each proportion used in the floor plan of Villa Malcontenta corresponds to those proportions that Alberti proposed.

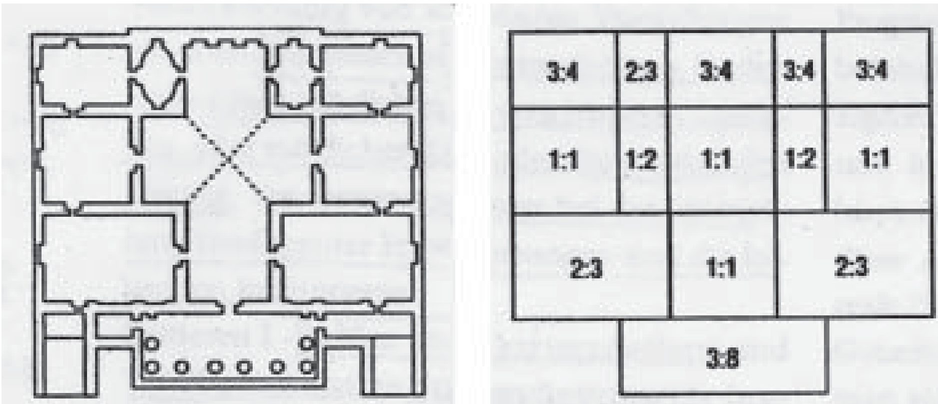


Figure 3. Floor-plan and analysis of proportion system in Villa Malcontenta (Source: Schmitt, 1993, p.39).

This musical theory of architectural proportion seems to have originated in the sixteenth century, and has continued up to the present day (Scholfield, 1958). As above mentioned, one of the most dominant proportions used by Renaissance architects was the musical theory of proportion, which Professor Wittkower (Wittkower, 1983) dealt with and which Alberti himself had originated. The musical analogy starts with the fact that groups of notes in music produced, for instance, by strings whose lengths are simply commensurable please the ears. It has been discussed as “the value of musical proportion in architecture”. Perrault was attracted to this theory by the fact that the ear is not able to pass on to the mind any information about mathematical ratios at all (Scholfield, 1958). Therefore, to him there was no foundation for any analogy between proportion in architecture and harmony in music.

However, if we decide that the aim of proportion is a formal ordering-system in which the specific mathematical ratios are used, in order to create unity and harmony in a design, it becomes a comparatively elementary matter to explain the value of musical proportion. Furthermore, the fact that the above mentioned musical relationships are directly determined by numeral ratios shows a possibility to computate the complex musical harmony in the architectural world.

3. Design Rule and Structure of Design Checking Tool

3.1. BASIC MECHANISM OF THE TOOL

The programming language employed in AutoCAD is AutoLISP. As this language retains most of the general LISP (LIST Processing Language)-functions, it is a symbolic manipulation-based, interpreted language that provides a simple mechanism for adding commands to AutoCAD. For example, this interactive programming language in AutoCAD allows users to program external applications, using the AutoCAD drawing generation and manipulation functions for 2D geometry, 3D wire-frame structures and 3D curved surfaces. Therefore, customizing AutoCAD into a more useful tool for a particular application for users can be carried out using AutoLISP programs. The AutoLISP program is normally written by “text editors” and then is saved as “text only” with the “.lsp” extension; i.e. musicalproportion.lsp. An example is shown in the following Figure 4, which is concerned with the musical proportion and is programmed by this author.

For implementation, users must load AutoLISP-files into a computer’s memory before using them. There are various ways of loading them. For instance, they can be loaded by typing the instructions in the command prompt in AutoCAD, as follows:

COMMAND: (load “c:/LISP/musical proportion”)

C:MUSICAL-PROPORTION

The choice of AutoLISP in this work has been made for several reasons: this author’s amount of experience with both AutoLISP and AutoCAD; the reliable graphic control/output in AutoCAD and the worldwide usage of this system in architectural offices. This program can be used as soon as it is needed and simultaneously the user can obtain some design advice from his own computer for a quality assessment of the particular design qualities. This tool demonstrated here operates in MS-Windows XP and in the AutoCAD 2000 environment.

3.2. RULE OF MUSICAL PROPORTION IN THE TOOL

The first person to make the connection between mathematics and music was Pythagoras, as mentioned in Section 2. His theory was that pleasing sounds resulted from frequencies with simple ratios. What we now call octaves, perfect fifths, and major thirds have ratios of 2 to 1, 3 to 2, and 5 to 4 respectively. These ratios correspond to the frequency-relationship. For example, if A note is tuned to a frequency of 440 hertz, then a perfect fifth above that note has a frequency of 660 hertz, because the ratio of 660 hertz to 440 hertz is 3 to 2. In this way, musical structure can be demonstrated in the octave starting with C, using Pythagoras’ ratios by which most of the notes are tuned to a scale, such as the following Figure 5:

```
(defun c:musical-proportion()
(prompt "\nWelcome to the musical facade program with tacs by Mr. Choo!")
(setq txt0(getstring "\nEnter key, please!!:")
(if (= txt0 "")
(progn
(command "layer" "make" "ornament" "color" "yellow" "" "")
(setq osm(getvar "osmose"))
(setq fr "fr")
(setq nr 0)
))
(dtrl)
(setq opl(opet "D:/lisp/mozart/datamusik.dat" "w"))
(setq  txt(getstring "\nSelect the musik(Don_Giovanni-long=DL/Don_Giovanni-
        short=DS):"))
(if(=(strcase.txt) "DL")
(progn
(while fr
(setq op(open "D:/lisp/mozart/Don_Giovanni-long1.dat" "r"))
(setq rl(read-line op))
(setq titel rl)
(dtr3)
(set1 x (/wl hap))
(dtr4)
(setq txt3(getstring "\nFurther work?(Y/N):"))
(if(or(= (strace txt2) "Y") (=txt3 ""))
  (progn
  (setq txt3(getstring "\nWere the measures changed or not??(Y/N):"))
  (if(or(= (strace txt3) "Y") (=txt3 ""))
    (dtrl)
    (progn
      (setvar "osmode" osm)
      (setq bp(getpoint "\Specify the base point of the ornament:"))
      (setq dbp(list (+ (car bp) 1) (+ (car bp) h)))
      (command "retangle" bp dbp)
      (setq oss1(ssget "1"))
      (command "hatch" "solic" oss1 "")
      (setq oss2(ssget "1"))
      (setq intp(list (+ (car bp) (/12)) (cadr bp)))
    )))
  (setq fr nil)
))))
  .
  .
  .
(setvar "osmode" osm)
(setq fr nil)
(setq chk nil)
(prompt titel)
```

Figure 4. Example of AutoLISP-program.

All musical proportions are expressed as specific ratios, as shown in Figure 6, so that these ratios can be applied to a CAAD system. The basic shape for implementation of the design tool based on the musical proportion is illustrated as follows:

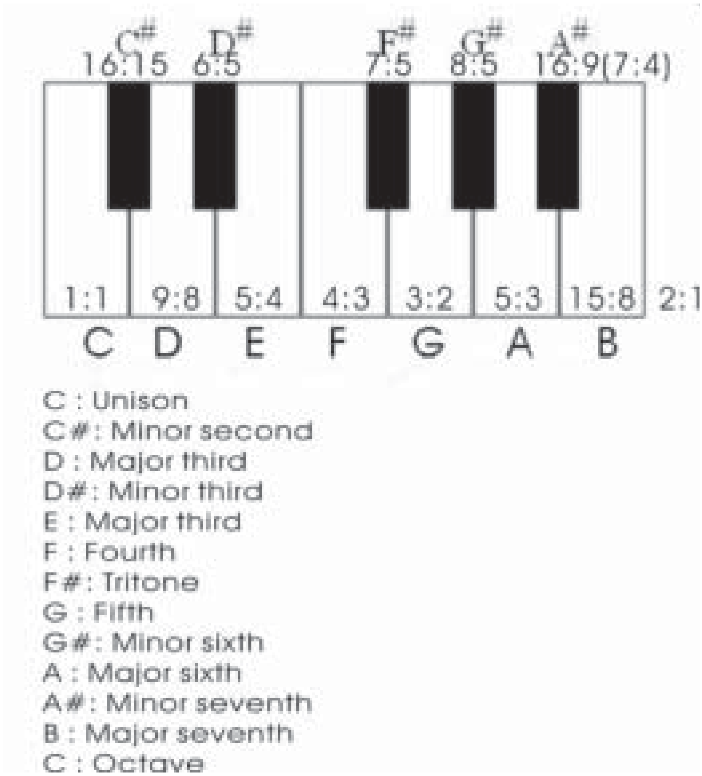


Figure 5. Musical tones and corresponding Hz.

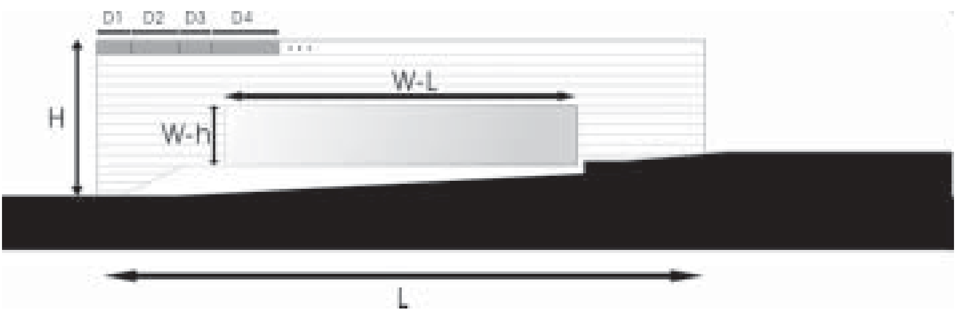


Figure 6. Basic shape for implementation of the tool.

In Figure 6, each distance of joint-surfaces, die Fuge in German, and each spacing distance of columns on a façade is illustrated as D1:D2:D3:D4. This formula can be calculated automatically through the computer, according to either musical ratio or melody. So, the rule applied to the tool is illustrated as shown in Figure 7.

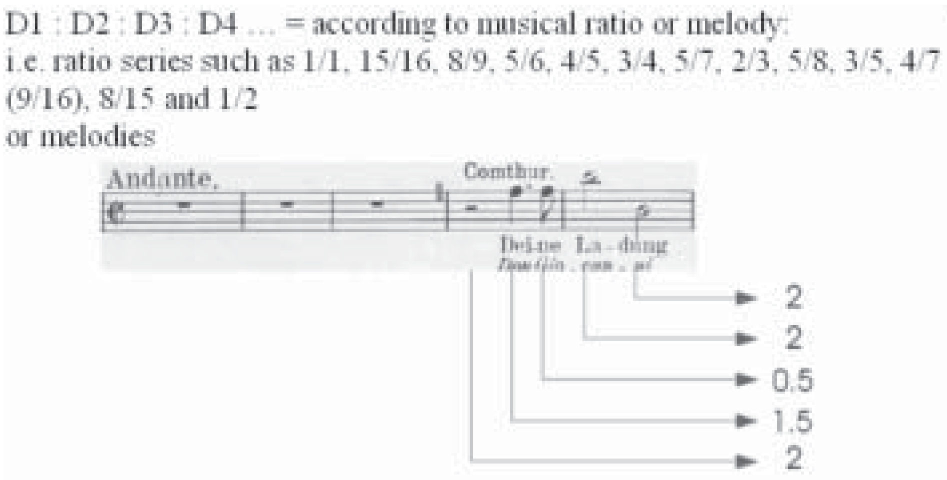


Figure 7. Rule for implementation of the tool.

4. Practical Application of Design Checking Tool

In practice, this tool was tested on a normal design project (Museum der Moderne Salzburg, Austria) in collaboration with the German architecture office “Friedrich Hoff Zwink Architekten” in 2003 (Figure 8).

Figure 8. Location (left) and model photo of the museum (right).

Figure 9 illustrates the east facade of the museum that consists of natural stones and joint-surfaces between them, before this tool was not applied.

The author received a design commission from one of the architects of that building, Stefan Hoff, to support the façade based on a familiar piece of music by Mozart, via the design checking tool. The function of this tool is to change either musical ratios or musical melodies in proportion to the distance between joint-spaces automatically. In this case, musical melodies are decided to be applied to the

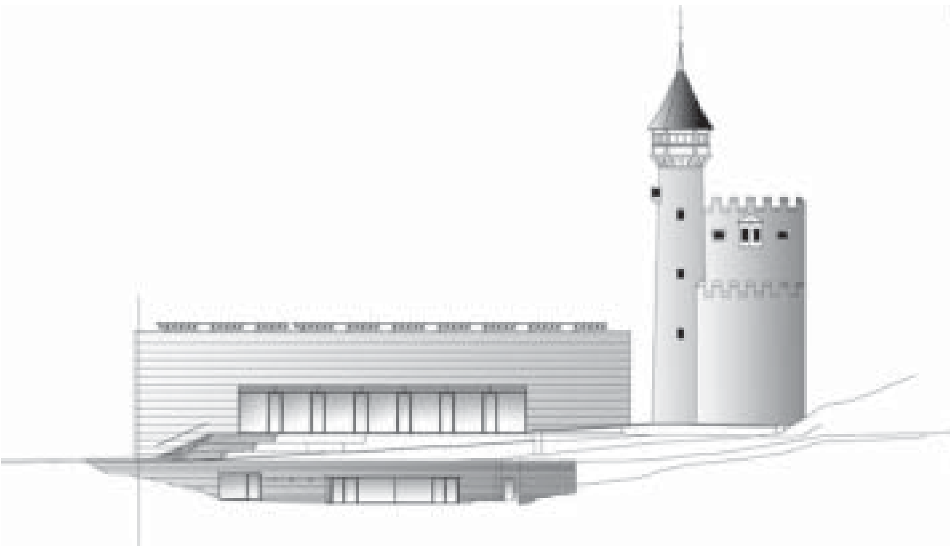


Figure 9. East façade of the museum.

façade through this tool, so as that observers of the museum can recognize the pattern of the façade listening to the corresponding music; if the musical ratios were used in the facade, the distance between the joint-spaces would express only the abstract meaning.

Figure 10. Applied musical notes and calculated data by the tool.

Figure 11 shows the applied façades that are based on Mozart's opera "Don Giovanni". When different notes of music are entered, alternatives are automatically created according to the corresponding music and then the user can choose his favourite one from them.

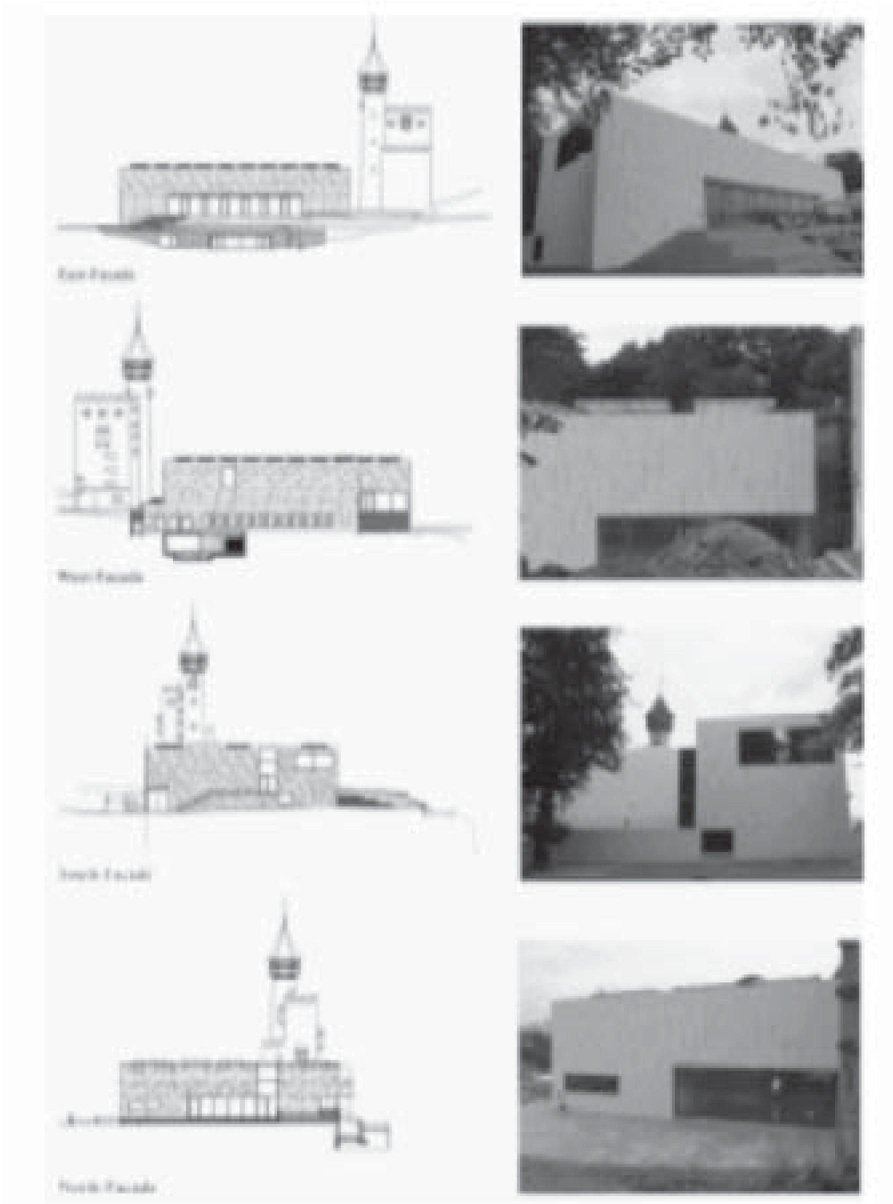


Figure 11. Applied facades of the museum, using the tool.

5. Conclusion

There has been an effort to apply musical harmony to an architectural façade, to the composition of the buildings' parts and to space. The proposed tool was developed as a practical application of the musical proportion for the façade. As shown in the previous examples, this tool is applied to explain and develop an aesthetic property of a design. One main goal of this tool is the improvement of the aesthetic property of a design, by incorporating one design aspect of proportion system based on music scale. This means that the proposed tool aims to support architectural designs, based on needs specified by architects and users.

Finally, the use of this design checking tool based on the musical proportion is a way to link an aesthetic property from design theories of architecture into a CAAD system.

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