PERFORMING PALLADIO

Matthew Swarts  
Georgia Institute of Technology  
College of Architecture  
247 4th Street, Atlanta, GA 30305-1055, USA  
gte017u@mail.gatech.edu

Marietta Monaghan  
Georgia Institute of Technology  
College of Architecture  
247 4th Street, Atlanta, GA 30305-1055, USA  
marietta.monaghan@arch.gatech.edu

Athanasios Economou  
Georgia Institute of Technology  
College of Architecture  
247 4th Street, Atlanta, GA 30305-1055, USA  
athanos.economou@arch.gatech.edu

Abstract

The idea of harmonic ratios in Renaissance architecture has been a highly debated subject in the realm of architectural theory and criticism. Palladio’s Villa Capra has been used extensively as an example to test these ideas. This paper describes four mathematical mappings of space to sound and color to bring forward these relationships and provides a brief account of their computer implementation with game engines technology. The modeling of these spaces along with their corresponding sounds and colors suggests a whole new range of interpretations of Palladio’s work as well as new and diverse performances of Palladian spaces.

1. Introduction

Palladian villas have long been termed harmonic. This has been discussed by many critics beginning soon after Palladio completed his designs. In his _Quattro Libri_, Palladio simply remarks that man is a microcosm that reflects the macrocosm of nature and that the rules of architecture refer to the rules of nature (Boucher, 1998), but Alberti, upon whose authority Palladio relied heavily, took his rules for proportion “from the musicians” and this is the general conception of what is meant by harmonic (Alberti 1998).

Wittkower, in 1949, argued that Palladio used proportions derived from music in his architecture on the theory that if harmonic proportions are beautiful to the ear, they will also please the eye and mind (Wittkower 1971). March discussed the classical proportionalities and the musical theories of Palladio’s contemporary, Zarlino, in his analysis on Villa Emo (March 2001). The designs most closely tied with harmonic proportions come later in Palladio’s oeuvre and were designed for patrons who were themselves interested in musical or architectural theory (Howard and Longair 1982).

An educated man of the Renaissance era would have interpreted the musical and visual arts very differently than we do today (March 1998). For him, the geometrical and numerical codes contained in works of art would not always be instantly evident, but certainly present to be inspected, puzzled out, and discussed among friends and colleagues. Whether Palladio really used musical ratios in his buildings we will probably never know; it still possible though to reconstruct their sounds and their harmonies and suggest ways to inquire to what extent they might be considered harmonic or not. In this paper we chose Palladio’s Villa Capra, otherwise known as Villa Rotunda, as the main instrument through which we will do our inspection. A diagrammatic representation of the Villa Capra is shown in “Figure 1”.

Figure 1: Plan of Palladio’s Villa Capra..
2. Sound of space – Color of space

In our paper we use color as an interface between space and sound; color makes visible the sound which makes audible the ratios of the rooms. The literature of mapping ratios and numbers to frequencies of color and sound is rich and complex (Itten 1997, Economou 1998). Here the model we use is the sRGB color space, the mathematical model of color implemented in computer graphics (Foley et al 1996). The sRGB color space has 1530 possible hue values. For $a$ and $b$ whole numbers, red, green, and blue components are explicitly combined based upon the hue location according to formula (1).

\[
\frac{\log_2 a}{\log_2 1530} = h_{\text{max}}
\]

(1)

For instance if the ratio is $a:b$ is 3:2, then (1) becomes:

\[
\frac{\log_2 3}{\log_2 1530} \approx 0.895
\]

(2)

895 is equivalent to an RGB of (0,125,255), producing a light blue. The hue values of sRGB space are shown in Table 1 below.

Sound scales can be easily constructed based on this model. Utilizing a 1530 tone scale, we can link a color in sRGB to one of 1530 intervals within one octave. We use a chromatic multiplier of $\frac{1530}{\sqrt{2}}$ to calculate the intervals, which are matched as closely as possible to a given space and its frequency value. It must be noted that overlapping sounds are processed by the ear differently than the mixing of color and light is processed by the eye. When two lights of different color overlap, their color values are added, but when two sounds overlap, they are distinctly heard with the addition of some overtones and beat frequencies. Despite these combinational differences in sound and light, we can compare the frequency of light to the frequency of sound and by shifting a light frequency many octaves down, we can bring a usable tonic frequency to an audible range such as, say, the range of a cello.

Rectangular spaces can be easily associated with this model too. For $a$ and $b$ numbers equal to the length and the width of a room, and $a>b$, the ratio $a:b$ can be multiplied by a tonic frequency to produce a harmonic or proportional sound with respect to the tonic frequency. The computation then of the sine waves of each of these frequencies is a straightforward task. Two rooms of the same ratios may have the same sound frequency, but the larger of the two is louder in a proportional relationship. These multimodal mappings for the Villa Capra are shown in Table 2.

3. Partitions and mappings

The mapping of ratios of rectangles to frequencies of color and sound provides a nice dataset to correlate these media but still it says nothing about the ways these media may relate to each other and in particular how they relate to an observer within this space. Various methods for conveying relationships related to perception of space exist and all are based on specific decompositions of polygons that comprise the configuration. Here we propose four models for integrating space, color and sound all with respect to a situated observer. A brief
account of those follows below.

3.1. Weighted convex partition

The simplest partition of interior space is the convex partition (Peponis et al 1997). A convex space is one in which two points can be joined by a line fully contained within that space. Among all possible convex partitions the rectangular partitions and their ratios can be nicely mapped to corresponding colors and sounds. In our model we associate each convex partition with a color value that corresponds to the ratio of the rectangular partition and a pitch frequency that corresponds to this color. Each sound is bounded by the geometry of the room with which the sound is associated. The convex partition of Villa Capra is shown in “Figure 2”.

3.2. Extruded convex partition

The extruded convex partition is similar to the convex partition but it takes into account the height of the rooms. In addition to the colored convex spaces that signify bounded colored spaces, each edge of the rectangular partition is colored with a value that corresponds to the ratio of the spatial elements bounding the 3-dimensional box. The sound of each room is the sum of the three different ratios found in each space. The extruded convex partition of Villa Capra is shown in “Figure 3”.

3.3. Weighted isovist

The isovist is a polygonal representation of visible space based on an omniscient 360º field of vision (Benedikt 1979). This representation intuitively corresponds to what can be seen from one point in 2-dimensional space. In our model the continuous isovist is composed by colored zones that correspond to colors found in each room. The sound of each view corresponds to the sum of color fields found in each visual scan; each color field is computed for its ratio and its percentage of coverage in the polygonal configuration. An isovist of the Villa Capra is shown in “Figure 4”.

Table 2. Initial computation of frequencies, volume, and colors produced by room ratios in Villa Capra; tonic frequency is chosen as 160.619Hz.

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Frequency</th>
<th>Area</th>
<th>Maximum volume factor</th>
<th>Hue value out of 1530</th>
<th>sRGB (R,G,B) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>30:30 (1:1)</td>
<td>160.619 Hz</td>
<td>706.858</td>
<td>1.0000</td>
<td>0</td>
<td>(255,0,0)</td>
</tr>
<tr>
<td>15:11</td>
<td>219.026 Hz</td>
<td>165.000</td>
<td>0.2334</td>
<td>685</td>
<td>(0.255,175)</td>
</tr>
<tr>
<td>26:15</td>
<td>278.406 Hz</td>
<td>390.000</td>
<td>0.5517</td>
<td>1214</td>
<td>(194,0,255)</td>
</tr>
<tr>
<td>15:6 (5:2)</td>
<td>401.548 Hz</td>
<td>90.000</td>
<td>0.1273</td>
<td>2023</td>
<td>(17,255,0)</td>
</tr>
<tr>
<td>30:12 (5:2)</td>
<td>401.548 Hz</td>
<td>360.000</td>
<td>0.5093</td>
<td>2023</td>
<td>(17,255,0)</td>
</tr>
</tbody>
</table>

Figure 2. A weighted convex partition of Villa Capra.

Figure 3. A diagrammatic representation of an extruded convex partition of Villa Capra.

Figure 4. An isovist of the Villa Capra.
3.4. Extruded weighted isovist

The extruded weighted isovist is an extension of the isovist that takes into account the ratios of all rectangles bounding any space in the configuration; this extended isovist corresponds to the sum of colors seen in any direction and angle. In this model each sound is computed with respect to the color fields seen in a view. An extruded isovist of the Villa Capra is shown in “Figure 5”.

4. Opus Palladio

The Opus Palladio is the implementation of all these four models described above with game engines technology to simulate the synaesthetic effect of perception of space for a situated observed within the virtual environment of Villa Capra. After a series of experiments we focused on the last model because it suggested a nice correlation between expansions and contractions of the visual field with changes of intensity of sound fields; in other words, the model suggested a nice way to relate what the agent sees and what the agent hears within the virtual environment.

We investigated three methods in search of a successful model. All methods have to do with specific problems of representation within the games engines technology. In the first method, images are taken from the image dump of the game engine and processed through a secondary program that evaluates the histogram of the image. The histogram reveals the colors and amount of each color within the image. These values then are sent back into the game engine or to a third program to produce the sounds. This method is highly accurate, but has the disadvantages of not allowing the player to be visible, as he would interfere with the histogram, coupled with an intense level of processing and data transfer.

The second method breaks the 3-dimensional model into small squares; each holds information about its color and sound. When the square “sees” the player, the sound is activated. Though this method is much cheaper in terms of processing power, it requires that the user breaks the 3-dimensional mesh into small squares and creates an object from each one. Even with the use of external scripts to do this work it is complex and time consuming.

The third method uses a built-in function of the UnrealEngine2 Runtime to do simple ray tracing. Using a function called Trace(), a ray is defined to trace for collision. Information about what environment the agent inhabits (or specifically what the agent sees) is collected by sending out an array of rays from the player. This function returns the location of the hit, the normal to the face of that location, and the material of the face that is hit. By attaching specific sound loops to the player, the volume of those sounds can be adjusted based on the number of hits on a specific material. Some of the resulting representations of the space as perceived by a moving agent are shown in “Figure 6”.

Figure 4: A weighted isovist in Villa Capra.

Figure 5: A diagrammatic representation of an extruded weighted isovist in Villa Capra.

Figure 6: A sequence of views correlating spaces to sound to color within Villa Capra.
5. Conclusion

A range of alternative representations of Palladio’s Villa Capra has been given to correlate arithmetical and geometrical aspects of form to color and sound schemata. Sound and color have been mapped based upon the dimensions and the areas of each room to denote the relationships of these spaces as experienced by an agent moving from room to room. An augmented 3-dimensional model comprised of geometry, sounds and colors has been made to provide alternative methods for navigation into virtual spaces.

Acknowledgements

The authors are grateful for the use of the IMAGINE Lab at Georgia Institute of Technology.

References


