Refining the Computational Method for the Evaluation of Visual Complexity in Architectural Images

Significant Lines in the Early Architecture of Le Corbusier

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Abstract: Past research over the last two decades has demonstrated that fractal analytical methods can be used to evaluate the visual complexity of architectural designs. Applying a computer program that has been developed specifically for the quantitative evaluation of architecture, the authors previously tested the fractal analysis method on several well-known architects’ works including those of Le Corbusier. However, while undertaking this research the computational method revealed unexpected results for the visual complexity of Le Corbusier’s early, highly ornamented, house designs. This paper examines these anomalous results and the proposition that they are a by-product of the data chosen for analysis. The fractal method relies on architectural drawings as raw “data” but little research has been undertaken into which elements should be chosen to represent the buildings or alternatively, which lines are “significant”. The present paper uses the results for ten of Le Corbusier’s house designs to examine the sensitivity of the method.

Keywords: Computational analysis; Le Corbusier; visual complexity; architectural evaluation.

Introduction

Fractal analysis is a quantitative computational method for evaluating characteristic visual complexity. Carl Bovill first applied this method, often known as “box-counting” to architecture in 1996. Since Bovill’s findings were first published, his method has been repeated, but has remained largely untested until recent years (Lorenz 2003; Ostwald, Vaughan and Tucker, 2008). Applying a computer program developed specifically for the evaluation of the fractal dimensions of architecture, the authors tested Bovill’s method and his original results. One of the architects Bovill used to demonstrate his approach on was Le Corbusier, and his design for the Villa Savoye. The authors have since re-examined the Villa Savoye and further examined an additional nine of Le Corbusier’s houses in detail. This research generally supports Bovill’s proposal however, unexpected results were produced from an analysis of Le Corbusier’s early, highly ornamented, house designs (Vaughan and Ostwald 2009). This paper examines these anomalous results for Le Corbusier’s house designs and the probable explanation for them. It is proposed that the selection criteria, used to decide which elements represent the building under analysis, are the reason...
for the anomaly. This methodological issue was identified by Ostwald and Tucker (2007) as “the problem of significant lines”, but has not previously been analysed or tested using real data.

**Computational analysis of architecture**

Past research has demonstrated that the application of certain pattern recognition and “box-counting” algorithms to architectural drawings can produce a quantitative measure of the characteristic visual complexity of a building. Inspired by Benoit Mandelbrot’s (1982), mathematical inquiry into complex systems, Carl Bovill (1996) published *Fractal geometry in architecture and design* in which the elevations of famous buildings are analysed using the box-counting method to calculate approximate fractal dimension (or $D$). $D$ is a non-integer value between 1 and 3 that indicates the characteristic formal or geometric complexity of an image or object. A comparison between the $D$ values of elevations and buildings is potentially a useful tool in architectural design and to support the propositions of architectural historians and theorists concerning architectural form. As one of a limited range of quantifiable approaches to the analysis of the visual qualities of buildings and landscapes, this computational method can assist architects to compare building complexities, can contribute toward studies in visual preference and help to determine the “contextual fractal fit” of buildings into particular locations (Stamps 2002).

In 2008 the authors developed a computational variation of the box-counting method and commenced the first comprehensive trials of this approach (Ostwald, Vaughan and Tucker). Their software, *Archimage*, was developed in order to automate the application of the box-counting method specifically for the evaluation of larger sets of architectural designs. Whereas Bovill, and most previous researchers, restricted their use of the manual variation of the method to analysing isolated architectural images, the computational variation can be used to develop a more comprehensive understanding of complete buildings, sets of buildings and architects’ bodies of work.

The computational process involves several steps. First, the building for evaluation is represented by its elevations. The elevations are drawn to a specific line weight and positioned on a blank background. Only the lines considered to be “significant” in terms of architectural form are selected for representation in the elevation. Following Bovill’s convention, the primary lines chosen for the analysis correspond to changes in shape, not changes in surface or texture. Thus, major window reveals, thickened concrete edge beams and steel railings are all considered, while brick coursing, control joints and glazing lines are not. In the second step, the prepared image is evaluated by the *Archimage* program which automatically places a large grid over the drawing and analyses each square in the grid to determine whether any lines from the façade are present in each square. Those grid boxes that have some detail in them are recorded. Next, a grid of smaller scale is placed over the same façade and the same determination is made of whether detail is present in the boxes of the grid. A comparison is then constructed between the number of boxes with detail in the first grid and the number of boxes with detail in the second grid; this comparison is made by plotting a log-log diagram for each grid size (Bovill, 1996). By repeating this process over multiple grids of different scales, using a combination of *Archimage* and TruSoft’s *Benoit* program, an estimate of the fractal dimension of the façade is produced. The lower the resulting fractal dimension, the less visually complex the building is. For example, the S House by the minimalist architect Kazuyo Sejima (Ostwald, Vaughan and Chalup 2008) has a $D$ value of 1.192 which is very low, whereas Frank Lloyd Wright’s more richly detailed Robie House has a high fractal dimension of $D = 1.550$ (Ostwald, Vaughan and Tucker 2008). Table 1 explains the various forms of information developed in this process and their abbreviations.
Anomalous results for Le Corbusier’s architectural works

Ongoing testing by the authors includes the computational analysis of a total of 112 elevations from 30 houses designed by well-known architects, spanning from the early twentieth century to the present day. The overall conclusion drawn from the results of continuing fractal analysis confirms that the results typically support and supplement the intuitive reading of these buildings. However, occasionally the results are unexpected and the problem can be traced to the selection of elements are lines which are considered ‘significant” for defining the architecture. This problem of significant lines is particularly evident in a comparative evaluation between Le Corbusier’s iconic modern designs of the 1920’s and his first, arts and crafts style works (1905-1912) (Vaughan and Ostwald 2009).

Five houses 1922-1928

Characterised by machine-like, smooth, white planar surfaces and minimal surface detailing, Le Corbusier’s early Modern houses are iconic representations of his architectural philosophy of the 1920’s. It was in this period that Le Corbusier developed the five strategies for an architecture that would reflect the technological and social advances of its era. Initially published in the journal L’Esprit Nouveau and later collated in Vers Une Architecture, these strategies (pilotis, plan libre, façade libre, fenêtre en longueur and toît jardin) are found in their most refined form in the Villa Savoye. Representing this phase of Le Corbusier’s

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
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<tr>
<td>D</td>
<td>Approximate Fractal Dimension.</td>
</tr>
<tr>
<td>D(_{\text{Achil}})</td>
<td>(D) calculated using Archimage software.</td>
</tr>
<tr>
<td>D(_{\text{Benoit}})</td>
<td>(D) calculated using Benoit software.</td>
</tr>
<tr>
<td>D(_{\text{Elev}})</td>
<td>Average (D) for a set of elevation views of a house using a specified program.</td>
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<tr>
<td>D(_{\text{Comp}})</td>
<td>Composite (D) result (averaged from both Archimage and Benoit outcomes for all elevations) is a measure of the average characteristic visual complexity of the house (or average for the 2D visual qualities of the design).</td>
</tr>
<tr>
<td>D(_{\text{Agg}})</td>
<td>Aggregated result of five composite values used for producing an overall (D) for a set of architects’ works.</td>
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<tr>
<td>S</td>
<td>Significant line: Standard definition.</td>
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give little indication that they are the works of the future Modernist architect. The five houses from this period with previously published \( D \) results (Vaughan and Ostwald 2009), are the Villa Fallet (Pouillerel 1905), the Villa Jacquemet (Pouillerel 1907) (figure 3), the villa Stotzer (Pouillerel 1907), the villa Jeanneret-Perret (Pouillerel 1912), and the villa Favre-Jacot (Le Locle 1912) (figure 4). The results from the initial analysis ranged from a low of \( D = 1.458 \) (Jacquemet) to a high of \( D = 1.584 \) (Favre-Jacot) (see Table 2).

These results for the earlier houses are surprising because, from observation of the finished buildings, it would be expected that the ornate, highly decorative pre-Modern house designs of Le Corbusier would have a much higher fractal dimension than his later, Modernist works. However, counterintuitively, it would appear from results produced using the standard box-counting method that the early works of Le Corbusier are no more visually complex than his 1920’s houses.

### Five houses 1905-1912

While most architects will know that Le Corbusier produced several works before developing his Modernist aesthetic, few will be aware of how different these early designs were. Le Corbusier’s first buildings, constructed near his hometown in Switzerland, are surprisingly ornate, chalet-style houses which are reminiscent of the Arts and Crafts movement and

![Figure 3](image1.png)

![Figure 4](image2.png)
Significant lines?

One explanation for this anomaly is that the data or information chosen to represent a house has an impact on its $D$ result. In particular, the selection criteria for building elements which are considered ‘significant’ for computational analysis may have a noticeable impact on the results. As the actual lines generated by a material’s surface are not represented in the standard method, elements such as the stonework (which figure significantly in Le Corbusier’s early houses 1905-1907), stained glass windows (which reflected the overall design concepts of these early houses) and the decorative lines (such as those carved into the stucco or timber work of the Villa Fallet) are not considered in the typical analytical approach.

If the selection criteria for significant lines, for the purpose of analysis, are expanded to include a greater level of detail, the number of lines included in an elevation drawn to represent a building may change, and the resulting fractal dimension could increase. Thus, the early buildings of Le Corbusier (1905-1912) might contain a higher level of visual complexity if the individual stones in the stonework were represented, if the details in the glazing were included and if any timber detailing was shown. Importantly, for these designs, these details are an integral aspect of Le Corbusier’s early designs. Le Corbusier had studied the geology and ecology of the local area in great detail, and the progression of materials used in the design of the houses represents the locality and is a key concept behind the works.

In order to test the sensitivity of the method, the five early houses were re-drawn for analysis using an expanded definition of significant lines. The four existing elevations for each house were each augmented with a linear representation of the visual detail in the real facade, but which was not previously considered under the standard definition.

The expanded variation allows for the inclusion of the full details of the window and door timberwork, delineation of the stonework for each elevation which contains it, and any timber detailing. However, the carved stucco, and some of the ornate balustrade details and textures on roofing tiles, were difficult to accurately replicate and are not included. The different level of detail can be seen in figures 5 and 6.

It is interesting to note that the two last houses of Le Corbusier’s early period; the Villas Jeanneret-Perret and Favre-Jacot, do not contain any further visual detail to be represented under the expanded range of significant lines method. Previous analysis did find these houses to be significantly different from the first three houses, as there is a shift away from grand ornamentation to a much more subtle approach and Baker remarks that these “two houses that Jeanneret [Le Corbusier] designed in 1912 mark a turning point in his career”(1996: 209). Likewise, the elevations of the later, Modernist buildings of Le

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Figures 5, 6
Le Corbusier: Villa Fallet
south elevation with standard definition of significant lines (left), and expanded variation (right)
Corbusier (1922-1928) do not require redrawings for analysis, as no further level of detail would be reached for evaluation.

**Results**

The re-drawn elevations for the early houses were analysed and the results in Table 3 represent the updated $D$ values of the five early houses of Le Corbusier, analysed with the expanded definition of significant lines (E), and compared with the previously published results for the same houses, analysed with the standard method (S).

The results show, as a result of the inclusion of additional detail, an increase in the fractal dimension, or visual complexity, of the three Villas Fallet, Jacquemet and Stotzer. For example, the $D$ values for all elevations of the Villa Fallet are increased, and the $D_{(Comp)}$ result for the overall house changes from $D_{(Comp)} = 1.482$ to $D_{(Comp)} = 1.586$ using the expanded variation. In the initial analysis – using the standard definition of significant lines – this house showed the highest complexity of the first three houses. The current results, utilizing the expanded version, place its visual complexity at the lowest of the three. Inversely, the Villa Jacquemet, which had previously shown the lowest visual complexity of all five early houses, now displays the highest visual complexity in the present results, and its south elevation $D_{(Elev)} = 1.708$ has the highest fractal dimension of all Le Corbusier images measured thus far. The stonework on this southern elevation of the Villa Jacquemet covers much of the front of the building, dramatically increasing its visual complexity. The Villa Stotzer also has a higher measurement of visual complexity when the additional details of the timber detailing and stonework are included in the fractal analysis, its $D$ value increasing from $D_{(Comp)} = 1.466$ to $D_{(Comp)} = 1.592$. As can be seen from the results, the Villas Jeanneret-Perret and Favre-Jacot remain unchanged, and their $D$ values are now lower than the other three early villas, when using the expanded definition for determining significant lines.

**Discussion**

The re-analysis of these early, ornate houses by Le Corbusier using different significant line criteria produces results which come closer to supporting an intuitive reading of their visual complexity. Previous results using the standard method were unexpected, particularly when comparing Le Corbusier’s pre-Modern architecture to his later, Modern work. It would be anticipated, that the highly decorative pre-Modern house designs would have a much higher fractal dimension than his later, Modernist works. However, in the previous study, apart from the Villa Favre-Jacot, it appeared from the results...
using the standard significant lines definition, that the early works were typically no more complex than the 1920’s houses. The present results using the expanded variation of significant lines suggest otherwise (table 4) and match historical analysis of the architecture of Le Corbusier (Jencks 2000; von Moos 1979; and Baker 1996). This historical reading suggests the first three highly ornate Arts and Crafts or Art Nouveau houses of Le Corbusier (Fallet, Jaquemet, Stotzer) are the most visually dense of all ten houses; a proposition which is supported by the present results $1.586 < D_{(comp)} < 1.602$. The villas Jeanneret-Perret ($D_{(comp)} = 1.489$) and Favre-Jacot ($D_{(comp)} = 1.584$) with their plain white walls and minimal ornament, can be regarded as transitional designs. They were built only two years before Le Corbusier produced the maison Dom-in-o design; a precursor to his early Modernist work, which would be expected to have lower visual complexity; an assumption which is matched by the results for the Modernist villas 1922-1928 ($1.420 < D_{(comp)} < 1.515$).

By finding the average of a set of houses, an aggregate result is produced which indicates the overall sense of visual complexity for a period of an architect’s career. When the aggregate values for these two periods in Le Corbusier’s career are compared, they further support (for similar cases) the use of the expanded variation, the aggregate results clearly displaying a significantly higher level of visual complexity in the set of first five houses ($D_{(agg)} = 1.571$) compared to the early Modern houses ($D_{(agg)} = 1.481$).

**Conclusion**

The re-analysis of Le Corbusier’s early architecture using an expanded criteria show that significant lines have a definite impact on the computational method for the fractal analysis of architecture. Previous analysis using the standard definition of significant line selection produced questionable results, however, when analysed using the expanded variation, the levels of measured visual complexity in these ten houses more closely correspond to an intuitive and historical interpretation of Le Corbusier’s work over the twenty year period. The use of the expanded definition of significant lines should be considered for any future cases where ornamentation plays an important role in the building design.

This present research demonstrates that the parameters of the box-counting method need to be reconsidered with regard to the selection of ‘significant lines’. Further research is required to determine what the specific criteria might be, particularly when considering architects who may use smaller construction details in a specific way.

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