Investigating Landscape Preference Using Fractal Geometry

Agnès Patuano

University of Edinburgh, Scotland/UK · apatuano@exseed.ed.ac.uk

Abstract: This paper presents the second half of an exploratory study looking at the use of fractal dimensions of landscape photographs as predictors of preference judgements. An online survey was prepared and disseminated in both the UK and France to collect demographic and preference data. By comparing different types of preference (aesthetic, cognitive and affective), it was found that the fractal dimensions of the images were most reliably correlated with participants' desire to explore a scene. This correlation was strongest using the fractal dimension of the image's extracted edges, and for British participants who grew up in peri-urban or rural environments.

Keywords: Preference, fractal analysis, fractal dimension

1 Introduction

Ever since its first systemized description in 1975, fractal geometry has been of much interest for those studying the aesthetics of natural forms. In a previous paper, five methods of fractal analysis of landscape images were presented (PATUANO 2018). Two of them, based on the silhouette outline and the extracted edges of landscape images, were shown to be linked with, respectively, the levels of naturalness (correlated with the type of scene depicted, such as forests or fields) and the complexity of the image (correlated with the size of the digital file and the quantity of information stored).

However, the link between these fractal dimensions and our preference judgements remained unclear. Therefore, this paper addresses several research questions: Are our preferences for different scenes and settings related to their fractal dimension? If so, are the different values of fractal dimensions extracted from the same image equal in their ability to predict preference? Moreover, is this preference universal?

Indeed, landscape preference, the study of where people like to go or where they choose to live, often relies on the existence of a universal trend. Many of the best-known theories in this field of research, such as Biophilia or the Kaplans' Information Processing Model, have explained our preferences as the result of an evolutionary process, taking place over the millions of years of our shared history (KELLERT & WILSON 1993, KAPLAN 1985).

Within these theories, preference is considered a universal human construct and landscapes can be studied as typologies rather than a particular human experience. In other words, instead of studying a specific landscape within its own geographical and social context, scenes of a particular type (forests, parks, meadows, etc.) are studied as a group and their attributes pooled together. Similarly, statistical procedures applied to preference ratings allow the extraction of general perceptual categories (KAPLAN 1985).

Journal of Digital Landscape Architecture, 4-2019, pp. 76-83. © Wichmann Verlag, VDE VERLAG GMBH · Berlin · Offenbach. ISBN 978-3-87907-663-5, ISSN 2367-4253, e-ISSN 2511-624X, doi:10.14627/537663008.

1.1 Fractal Geometry

Sometimes nicknamed "The Geometry of Nature", fractal geometry defines principles that allow the detailed description and quantification of organic patterns such as coastlines, rivers or trees, using numerical parameters. Its core concept, the fractal dimension (noted D), is often related to complexity (PATUANO 2018, MANDELBROT 1982).

Soon after its discovery, fractal geometry was studied for its aesthetic value. Specifically, following the innate positive reaction to organic objects proposed by the Biophilia Hypothesis, it was found that people universally tend to prefer fractal patterns over non-fractal ones (SHORT 1991).

Specifically, a mid-range value of the fractal dimension, thought to express medium complexity, was preferred overall (TAYLOR 2006). This finding was linked with the demonstration that most natural shapes such as clouds and mountains exhibit fractal dimensions in that range, which could elicit a tuning effect whereby humans are more likely to respond positively to that particular level of complexity (TAYLOR 2005, AKS & SPROTT 1996).

1.2 Application to Landscape Images

However, these empirical studies tend to approach the question from a purely aesthetic perspective and in a digital context. It was therefore unclear whether their results could be extended to our multi-level perception of landscapes. Indeed, landscape preference is not purely driven by aesthetic concerns, as landscapes are not framed two-dimensional images existing only to be seen. They are settings to be experienced and lived in. Consequently, the importance of the aesthetic experience of a landscape for preference judgements is often mitigated by social and cultural factors such as age and gender (LYONS 1983).

Additionally, natural environments are well known for delivering a range of health-supporting benefits, such as recuperation from the demands of an urban life. It is still unclear whether landscape preference might be the cause of these benefits or whether the causal relationship operates in the other direction. Defining the articulation of that system has been the focus of many studies and it is also the framework within which this study takes place (VAN DEN BERG et al. 2003).

Within landscape research, only the landscape silhouette outline had previously been studied for its fractal properties. Indeed, the fractal dimension of the outline was shown to correlate with preference (HAGERHALL et al. 2004) and even elicit physiological responses similar to the ones that would appear when visiting natural spaces (TAYLOR et al. 2005).

In the first part of this study, this measure was also found to discriminate accurately between images depicting forests or fields (PATUANO 2018). This finding was soon replicated by STEVENS (2018) who linked it to measures of biodiversity. It was therefore expected to be the best predictor for preference as well.

2 Collecting Preference Data

The design of this study was inspired by previous experiments and attempted to replicate their results. Specifically, it follows the work of HAGERHALL et al. (2004), who previously explored the correlation between the fractal dimension of landscape images and preference.

However, rather than re-using images from previous studies, which might introduce biases, a decision was taken to collect original data using an online survey. This in turn allowed the comparison of cultural and demographic factors, as well as maximizing the amount of data which could be gathered in a limited time frame. Furthermore, rather than only looking at a single value of fractal dimension for each image, several methods of fractal analysis were applied, and their values compared for their ability to predict preference (PATUANO 2018).

2.1 An Online Survey to Compare Cultural Variations

A bilingual online survey was prepared and disseminated in the United Kingdom and in France, through mailing lists and personal contacts.

In total, twenty-six images were picked from the picture set previously presented in PATUANO (2018). Of these, 13 were photographs of forests and 13 were photographs of meadows or fields, all courtesy of the Forestry Commission Scotland (Figure 1). The majority were views from within the landscapes, while three images pictured elevated views. The extent of topographic variation was broadly constant within the set, from flat grounds to slight hills. Images displaying elements of landscapes known to influence preference, such as water features, buildings or animals, were excluded (HAGERHALL et al. 2004). However, due to the limited availability of images, some of the photographs presenting subtle cues of man-made interventions, such as wooden fences and electrical poles, were kept.

The images were mainly chosen in order to cover a wide range of fractal dimensions (D = [1.00 - 1.55] based on the fractal analysis of the silhouette outlines conducted with the software BENOIT™) and to respect the distribution of the values of D within the scene type, including the mean and standard deviation.

Additionally, to reduce any bias linked to weather conditions, seasonality or colours, and because of the current state of development of fractal analysis methods, the landscape preference data were collected using photographic images in black and white with the sky area removed. The complete protocol for the segmentation and preparation of images can be found in PATUANO (2018).

2.2 The Demographic Predictors of Preference

Demographic factors, such as age, gender, occupation and residential experience have been found to contribute significantly to differences in landscape preference ratings (LYONS 1983).

Additionally, as the survey was intended for a wide distribution, factors like nationality, country of residence and the geographical situation of the participants at the time of the survey could not be controlled despite their potential influence on the pattern of results.

Fig. 1: Survey set showing the 13 images of forests (top) and 13 images of meadows (bottom)

Therefore, demographic variables were also collected, such as the participants' age, gender and field of work/study. Questions about their previous experience of landscapes were added, as well as on their location immediately prior to the survey. This was considered a precaution against the lack of control on the conditions in which the survey was completed, but also to prevent any tuning effect which would happen for participants located in the countryside at the time of completion.

2.3 Three Preference Scales

Preference ratings were recorded on separate scales in order to cover different aspects of landscape preference: aesthetic, interest and affective. In an attempt to collect preference data, which would also record potential health-benefits, the questions were all inspired by the Perceived Restorativeness Scale developed by HARTIG et al. (1996).

1. The aesthetic scale measured a scene's' attractiveness in the viewer's mind, following the claims of the powerful aesthetic value of fractal patterns apparent in the literature.
2. The interest scale measured participants' willingness to explore a scene based on the hypothesis that complex scenes would be more attractive to viewers and more able to hold their attention. This measure additionally intended to contextualise the photographs as three-dimensional environments instead of mere patterns.
3. The affective scale measured the general liking for a scene, which corresponds to the more traditional aspect of landscape preference. In this case participants were asked to rate the landscape as a view from their holiday house.

2.4 Statistical Analysis

Once cleaned up and all outliers dealt with, the preference data obtained through the survey were correlated with the ten values of D previously measured for each image, using non-parametric correlation tests. A control for the type of environment being assessed (forest or meadow) was also applied, as that variable was found to correlate with values of D estimated from the silhouette outline.

The methods of fractal analysis that yielded the D values which correlated most strongly with preference were identified. Several models of prediction of landscape preference were then developed, for each type of landscape studied, and the main populations of participants in the survey.

3 Results

After three months live, the on-line survey had collected responses from 177 participants, with ages ranging from 18 to 80 years old, and a clear majority of women (72.8 %). The large majority of participants were French (62 %, for 16 % of British nationals).

3.1 Demographic Predictors

Following some of the best-known findings on the cultural and demographic predictors of landscape preference, the main variables influencing the ratings between participants were found to be their nationality (e. g. French or British) and the environment they reported growing up in (e. g. rural, periurban or urban). There was no correlation between these two demographic variables.

3.2 Correlation with Fractal Dimensions

Overall, the fractal dimensions of the patterns extracted from the landscape photographs correlated most reliably with participants' desire to explore particular settings (Table 1).

Since previous studies had only looked at the silhouette outline of a landscape as a predictor of preference, it was expected that this variable would yield significant results on all three preference variables. Instead, the average preference correlated most strongly with the fractal dimension of the extracted edges. For this measure, higher fractal dimensions, rather than a single value, were generally preferred (Figure 2).

4 Discussion

Previous claims that specific fractal dimensions can incite innate positive aesthetic responses could not be supported by this experiment.

Firstly, the values of the fractal dimension of the extracted edges were all above the mid-range threshold defined by AKS & SPROTT (1996) and TAYLOR (2005). Most importantly, no single value was preferred overall. Instead, a linear regression model could be defined, expressing preference as a function of the fractal dimension of the silhouette outlines (or the landscape type) and of the fractal dimension of the extracted edges.

Table 1: Correlation table, between methods of fractal analysis and preference ratings, without accounting for population or environment type. (N = 26). Correlations marked with a * are statistically significant ($p < .05$).

		Average rating (Aesthetic)	Average rating (Interest)	Average rating (Affective)
Fractal dimension of the silhouette outline	Correlation Sig. (2- tailed)	.234 .094	.312* .026	.173 .217
Fractal dimension of the extracted edges	Correlation Sig. (2- tailed)	.444* .001	.435* .002	.413* .003
Minimum fractal dimension from greyscale	Correlation Sig. (2- tailed)	.243 .085	.333* .018	.187 .185
Maximum fractal dimension from greyscale	Correlation Sig. (2- tailed)	-.143 .310	-.183 .193	.143 .310
Average fractal dimension from greyscale	Correlation Sig. (2- tailed)	.164 .242	.149 .289	.108 .440

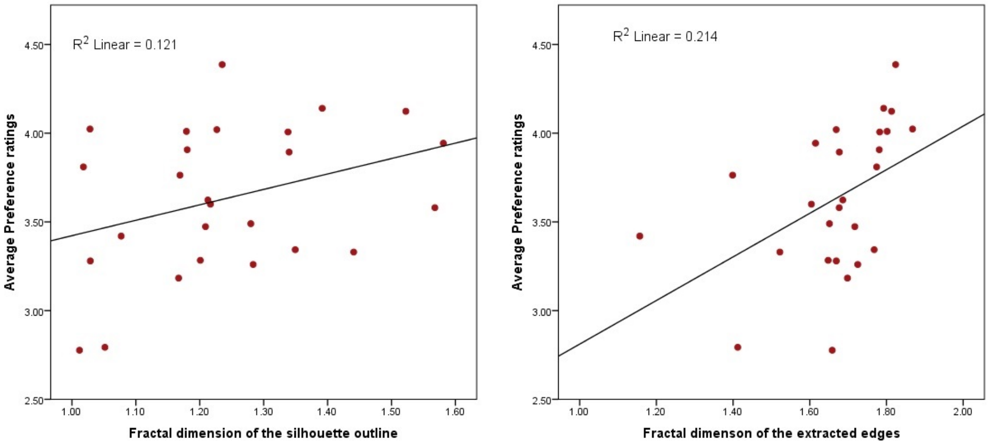

Fig. 2: Comparison of the two scatterplots showing the relation between fractal dimension and preference, depending on the method of fractal analysis. The relationship is stronger with the fractal dimension of the images' extracted edges (right), suggesting this method is better for predicting preference.

4.1 Difference in Preference Judgements

Although fractal patterns have extensively been studied for their aesthetic value, the preference scale most strongly correlated with fractal dimensions was not measuring aesthetic preference.

Instead, the correlation was strongest on the Interest scale, measuring participants' desire for exploration. This result could be assimilated with a cognitive preference such as the one described in the Kaplans' Information Processing model, which defines "complexity" as an important factor for its ability to hold our attention. In this case, the link between the fractal dimension of extracted edges, previously presented as an indicator of complexity, and preference as recorded here is coherent with claims made in the literature.

4.2 Difference Between the Methods of Extraction of the Fractal Dimensions

In previous studies, the fractal dimension the silhouette outline of a landscape was found to correlate with the type of landscape being studied (PATUANO 2018) and general preference (HAGERHALL et al 2004). However, the results obtained here show that these two effects might in fact be due to confounding variables such as the height of vegetation present in the scenes. Indeed, in the present study, once the correlation between fractal dimensions and preference were controlled for landscape types, the silhouette outline was no longer correlated with preference.

Instead, the rarely-studied fractal dimension of the extracted edges of an image performed much better as a predictor for preference, correlating with all three scales of preference regardless of landscape type.

4.3 Difference in Sub-populations

Another original contribution to knowledge offered by this study is the exploration of demographic differences within fractal preference. Indeed, although a medium correlation could be observed between the average rating scores and some measures of the fractal dimension, this correlation varied for different sub-populations. For example, the preference ratings of French participants were less likely than those of British participants to correlate with any measure of D. Similarly, participants who grew up in urban areas were less likely to correlate their preference with the fractal dimensions than those raised in peri-urban or rural areas.

4.4 Limited External Validity

Although the use of landscape images as surrogates for landscape experience has often been shown to be a reliable method of research, it is clear that it cannot cover every perceptual aspect of being immersed in an environment.

Furthermore, the use of grayscale landscapes without skies to collect preference data, although limiting the possibility of external biases, also decreases the external validity of the study. Consequently, it is difficult to assert that the results obtained here could be extended to physical sites. Instead, the fractal dimension values estimated are intrinsically specific to the image and the segmentation method used (PATUANO 2018). However, the results on the Interest scale are specific to the exploration of 3-dimensional scenes and imply they could be replicated *in situ.*

5 Conclusion

The findings of this study are in sharp contrast with most of the literature on the topic. Although there is a link between preference judgements and fractal characteristics, it is a complex one, which depends as much on what is assessed as on who is doing the assessing. By using a rigorous methodology comparing different methods of fractal analysis and different socio-demographic profiles, this study significantly furthers our understanding of landscape preference as it relates to elements such as naturalness and complexity. Specifically, it demonstrates the existence of a quantitative measure of complexity able to predict cognitive preference expressed through participants' desire to explore a scene. For landscape planners and designers, this might mean using ecological diversity as an incentive for exploration and as a way to attract more visitors.

References

AKS, D. & SPROTT, J. C. (1996), Quantifying aesthetic preference for chaotic patterns. Empirical Studies of the Arts, 14, 1-16.

HAGERHALL, C. M., PURCELL, T. & TAYLOR, R. P. (2004), Fractal dimension of landscape silhouette outlines as a predictor of landscape preference. Journal of Environmental Psychology, 24 (2), 247-255.

HARTIG, T., KORPELA, K., EVANS, G. W. & GARLING, T. (1996), Validation of a Measure of Perceived Environmental Restorativeness. Journal of Environmental Education, 32 (1), 1-64.

KAPLAN, R. (1985), The analysis of perception via preference: A strategy for studying how the environment is experienced. Landscape Planning, 12 (2), 161-176.

KELLERT, S. R. & WILSON, E. O. (1993), The Biophilia Hypothesis. Island Press, Washington, D.C.

MANDELBROT, B. B. (1982), The Fractal Geometry of Nature. 3d Ed. W. H. Freeman.

LYONS, E. E. (1983), Demographic correlators of preference. Environment and Behavior, 15 (4), 487-511.

PATUANO, A. (2018), Measuring naturalness and complexity using the fractal dimensions of landscape photographs. Journal of Digital Landscape Architecture, 3-2018, 328-335.

STEVENS, P. (2018), Fractal dimension links responses to a visual scene to its biodiversity. Ecopsychology, 10 (2), 89-96.

SHORT, L. (1991), The aesthetic value of fractal images. British Journal of Aesthetics, 31 (4), 342-355.

TAYLOR, R. P. (2006), Reduction of Physiological Stress Using Fractal Art and Architecture. Leonardo, 39, 245-251.

TAYLOR, R. P., SPEHAR, B., WISE, J. A., CLIFFORD, C. W. G., NEWELL, B. R., HAGERHALL, C. M., PURCELL, T. & MARTIN, T. P. (2005), Perceptual and physiological responses to the visual complexity of fractal patterns. Journal of Nonlinear Dynamics, Psychology and Life Sciences, 9 (1), 89-114.

VAN DEN BERG, A., KOOLE, S. & VANDERWULP, N. (2003), Environmental preference and restoration: (How) are they related? Journal of Environmental Psychology, 23, 135-146.