Landscape Design and the Language of Nature

STEPHEN PERRY, ROB REEVES AND JEANNIE SIM

Recognition that we need to live in a more ecologically sustainable way and that the physical forms of designed landscapes are an expression of the social values and cultural drivers of the time has underpinned the call by some landscape design professionals for a new design aesthetic - one that reflects modern ecological concerns. However, for an 'ecological aesthetic' to be accepted, it must be capable of generating landscape forms that are pleasurable to the general public, as it is the general public who will be responsible for delivering ecological sustainability in the long term.

The growth in understanding of the mathematical properties of natural systems and processes has led some authors to suggest that fractal geometry, called the language of nature, could play a role in developing such an aesthetic. This is supported by recent research that suggests human perceptual systems have evolved to process fractal patterning and that we have a visual preference for images with certain fractal qualities. However, how fractal geometry can be used, and what form an aesthetic based on this geometry might take, remains elusive and undefined.

To develop an aesthetic based on fractal geometry it is necessary to understand why fractal geometry should be considered as a potential tool and whether the application of fractal analysis can differentiate between the types of landscape forms encountered every day.

INTRODUCTION

Recognition that western attitudes towards the non-human environment were a cause for concern was articulated in Aldo Leopold's powerful and beautiful book *A Sand Country Almanac*, first published in 1949 (Leopold, 1989), and in his call for a land ethic. Lynn White (White, 1967) mirrored Leopold's concerns that Judeo-Christian attitudes towards the environment were the root cause of its damage. However, our current conceptions of ecological sustainability primarily emerged from the environmental philosophies of the 1960s and 1970s based on popular books such as *Silent Spring* by Rachel Carson (Carson, 1962), and *GAIA: A New Look at Life on Earth* by James Lovelock (Lovelock, 1979). Similarly, in terms of landscape design, the powerful influence of Ian McHarg's seminal work *Design with Nature* (McHarg, 1969) still resonates within landscape design today.

Around the same period, discourse within the art and design professions on the aesthetics of nature, ecology and the environment began to grow, from Smith's concept of the 'aesthetosphere' (Smith, 1970; Smith, 1973; Bartuska and Young, 1975) to Nassauer's idea of wrapping 'messy ecosystems' within 'orderly frames' (Nassauer, 2002).[1]

This article is based on Stephen Perry's PhD research. Dr Rob Reeves amd Dr Jeannie Sim supervised the research.

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RESEARCH

The power of aesthetics to influence how we perceive the world around us has been recognised both by designers and psychologists (Nassauer, 2002; Richards, 2001; Tuan, 1974). Similarly, over the last few years, an awareness of the importance of aesthetics to ecologically sustainable designed landscapes has been growing. This has been reflected in the call by some landscape design academics and practitioners for a move towards a new design aesthetic for our ecological age (Howett, 1987; Bull, 1996; Koh, 1988; Nassauer, 2002; Spirn, 1988).

NATURE, AESTHETICS AND LANDSCAPE DESIGN

Aesthetics is not about superficial embellishment, but is a very powerful way of knowing and can have a profound effect on our relationship to the non-human environment (Nassauer, 2002; Richards, 2001; Carlson, 2001; Leopold, 1989). Therefore, it is important to understand the roots of these ideas, especially as they relate to nature and western landscape design traditions.

Susan Feagin (Feagin, 1999) has defined aesthetics as the 'branch of philosophy that examines the nature of art and the character of our experience of art and of the natural environment.' Art, aesthetics and beauty are concepts that have been the subject of philosophical discourse since Plato (427–347 BCE) and Aristotle (384–322 BCE) and quite probably before that. Our current conceptions of these terms are thought to stem from the ideas developed during the eighteenth century by philosophers such as Immanuel Kant (1724–1804), whose third *Critique*, the *Critique of Judgement*, was the first philosophical system to include aesthetic theory and is still considered important and influential today (Crawford, 2001). However, it was a little-known German philosopher, Alexander Baumgarten (1714–1762), who introduced the term 'aesthetics' in the eighteenth century, to describe the study of what he termed 'sensory cognition' (Goldman, 2001; Seeley, 2005), or how sensory information is turned into a conscious experience linked to the generation of emotion.

Baumgarten considered aesthetics, as a way of 'knowing' – very different from the knowledge gained from the study of abstract ideas and the rational logic that was derived from the early Greek philosophers. Baumgarten was also responsible for trying to define the aesthetic concepts of the 'sublime' and 'beauty'. He related the sublime to the physical sensations of pain and the emotions of fear and awe that can be felt when confronted by large-scale landscape forms that exhibit the immense physical power of natural systems – forms such as volcanoes, rugged mountains, canyons and ancient forests. These sublime forms possessed properties that were considered to be dark and brooding and exhibited dramatic changes in structural quality. He related the concept of beauty to pleasure and to smaller-scale landscape forms that displayed a sense of lightness, both in the quality of light and in their sense of mass. Beauty, then, was linked to forms that displayed softness, structural smoothness and where lines were sinuous rather than straight and rigid.

It was Uvedale Price (1747–1829) in *An Essay on the Picturesque* who defined the enduring concept of a 'picturesque' landscape as a third aesthetic sitting midway

between that of the sublime and the beautiful (Hunt and Willis, 1988). The picturesque aesthetic – derived from the artistic compositions of landscape paintings by artists such as Claude Lorrain (1600–1682), Nicholas Poussin (1573–1665), and Salvator Rosa (1615–1673) – took advantage of the visual beauty of the natural environment when coupled with the emotive power of ancient ruined buildings. This combination was considered a powerful design form expressive of the landscape owner's social standing, knowledge and cultural sensitivities. It went beyond Baumgarten's initial definition to include far more knowledge and understanding of the information content in the landscape. However, the concept of the picturesque gradually evolved to include any landscape where attention could be given to its scenic and picture-like qualities, based on a detailed foreground, a middle ground and an indistinct background.

As art, in its own right, grew to become more influential during the later part of the nineteenth century and the early twentieth century, the perceived aesthetic value of nature and the landscape diminished. At this point the philosophy of aesthetics and the philosophy of art merged. Carlson points out that this position continued until around 1966, with the publication of a paper entitled 'Contemporary Aesthetics and the Neglect of Natural Beauty' by Hepburn (Carlson, 2001, p 426).

Since then there have been a number of approaches to understanding environmental aesthetics, ranging from the sociobiological approaches of Appleton and Bourassa (Appleton, 1996; Bourassa, 1991), to the environmental psychological approaches of Kaplan and Kaplan (Kaplan and Kaplan, 1989). More recently, Carlson has argued, on the basis of Hepburn's deductions, that the aesthetic appreciation of nature will range from the trivial to the serious. The trivial aesthetic response is based on the formalistic[2] qualities of an environment and its emotional impact, while the serious response requires a cognitive and much deeper knowledge and understanding of the underlying properties and workings of the natural world or the environment under consideration. However our current concepts of the natural world are derived from many sources and are therefore layered with multiple meanings. Thayer identified the core problem: 'today's complex, multi-valent mental image of the natural world has thus far outstripped the semiotic limits of typical landscape architecture to describe it' (Thayer, 1989, p 104). Phillips supports Thayer by asking the question: 'Does sustainability have a visual validity that can be expressed as an aesthetic?' (Phillips, 2003, p 174). In other words, what does an ecologically sustainable environment look like?

The form of ecologically healthy landscapes can range from the relatively homogeneous, with few distinguishing features, to landscapes of incredible complexity. Nassauer's concept of care within modern western culture has highlighted the problem that many of these landscapes would not be considered aesthetically pleasing (Nassauer, 2002). Another problem is that the majority of the natural processes that are responsible for creating these healthy landscapes are normally hidden from human perception and cognition. Thayer makes it clear that design principles traditionally used to create form – such as contrast, emphasis,

balance, unity, movement and rhythm – cannot be easily adapted to designs that signify ecological health. Jusack Koh examined this problem and proposed three new principles based on the traditional design principles of unity, balance and contrast, but incorporating a more holistic approach to the design of human-environment systems (Koh, 1988). However, Koh also recognises that: 'An ecological theory of environmental design must be based on ordering principles in nature and on human perception and cognition' (Koh, 1988, p 180). Treib supports this when he states that it is the form and space of an environment that triggers our perceptions and that sensory perception, coupled with cognition, is the primary vehicle for understanding (Treib, 2002).

FRACTAL GEOMETRY – THE LANGUAGE OF NATURE

The complexity of aesthetic theory and its associated philosophy makes it clear why a practical realisation of an ecological aesthetic has shown itself to be elusive. To address this, some authors have suggested various theoretical frameworks for the development of an ecological aesthetic.[3] Within these frameworks there is a related underlying theme – the potential for the patterns and processes of natural systems to form the basis for a new aesthetic for landscape design.

Natural forms, as inspiration for design, are evident in art, architecture and landscape throughout history. However, until recently, it was not understood that many natural forms and processes possess a common ordering characteristic – a characteristic described by the mathematics of fractal geometry (Gisiger, 2001; Mandelbrot, 1977). Although Baird (2002), and Spirn (1988), have suggested that fractal geometry could form the basis of a new aesthetic, no indication is given about how this might occur. Thayer identified this problem and implied that a new visual and spatial language needs to be developed for landscape design to be able to articulate the complexity of nature (Thayer, 1989).

Benoit Mandelbrot was the first to articulate and name the reality of fractal geometry (Mandelbrot, 1977), although many people had studied mathematical precursors to this through their work in the field of Chaos Theory (Gleick, 1998). What is now understood is that many natural systems, entities and processes have an underlying order that displays a property known as scale invariance or self-similarity. In its simplest terms, scale invariance can be identified where features within a pattern are repeated across different scales of magnification. The mathematical Cantor set, an abstract construction created by the nineteenth century mathematician Georg Cantor, that is shown in Figure 1 on the next page, demonstrates this concept.

The Cantor set is created by repeatedly deleting the middle third of a set of line segments. Here, the dashed borderline in the figure indicates the next level of magnification. It can be seen that as you zoom into the pattern, the features are reproduced exactly. If expanded to the same size, they would be geometrically identical.

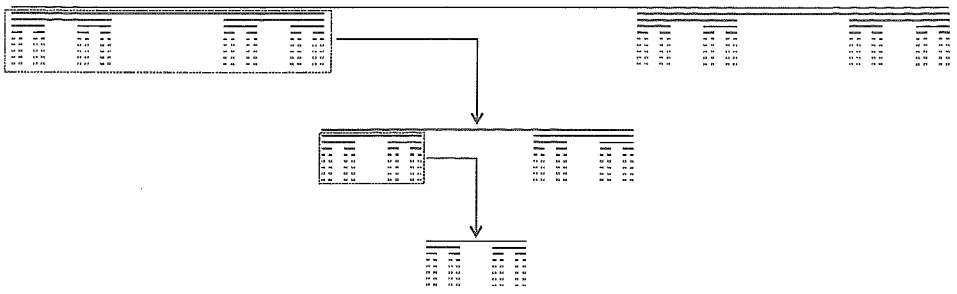


Figure 1: The Cantor Set

These scale invariant patterns can be generated in various ways, either by nature (Mandelbrot, 1977; Briggs, 1992; Gleick, 1998; Jurgens, et al, 1990; Pentland, 1984; Ruderman and Bialek, 1994; Spehar, et al, 2003; Li, 2000), or through mathematical processes (Mandelbrot, 1977; Briggs, 1992; Gleick, 1998), or by human endeavour (Benguigui, 2000; Bovill, 1996; Briggs, 2005; Crompton, 2001; Lorenz, 2003; Ostwald, 2001; Taylor, et al, 1999). Mathematical fractals can be considered as ideal fractals in that they exhibit scale invariance at all scales. This means that as you magnify a mathematical fractal it will still exhibit a degree of similarity, no matter what the scale of magnification. Human-produced fractals can be either statistically self-similar (such as those produced by Jackson Pollock in his drip paintings (Taylor, et al, 1999)), or involve the repartition of a single form at different scales (as in some architectural forms (Ostwald, 2001) and art forms (Briggs, 2005)). Natural fractals however, typically exhibit scale invariance over a limited range of scales.[4] They are classified as having statistical self-similarity, which means that the patterns will not be geometrically identical, but statistically similar. This property can be seen when looking at cloud formations, the flames in a fire and the structure of plants. The patterns always seem similar, but always slightly different. If these entities are examined over a defined range of scales, the same fundamental patterns are encountered.

The scale invariance of a fractal pattern is described by a characteristic number known as the fractal dimension 'D', which quantifies the visual complexity of a pattern by measuring the ratio of the number of features at one scale to the number of features at another. Unlike the three integer dimensions normally represented by Euclidean geometry,[5] the fractal dimension can be considered as 'a measure of the extent to which a structure exceeds its base dimension to fill the next dimension' (Hagerhall, et al, 2004). Thus, for a fractal line, D will have a value greater than one and less than two. Similarly, for a fractal surface, D will have a value between two and three.

The statistical self-similarity of natural patterns can be identified in the four photographs shown in Figure 2. These are photographs of a section of *Eucalyptus tessellaris* bark, where the pale section in the centre of each image represents the area of the following image as the camera zooms in. These images display a natural fractal patterning produced by processes that act over space and time. This

form of patterning produces a very similar fractal dimension at different levels of magnification. However, the features contained within digital images of an entity are much more complex than the Cantor set above and are related to the spectral qualities of the entity captured by the image, rather than any specific, geometric element. Even so, the fractal self-similarity is apparent. A small section of the 800% image, excluding the large fissures, could appear to come from any of the four magnified levels.

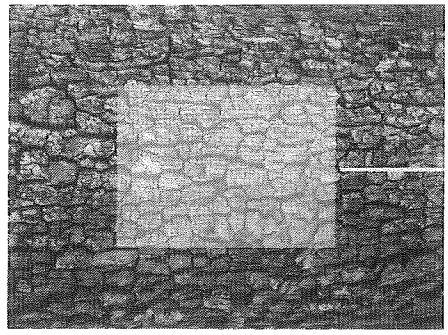


Image 100% - Fractal Dimension = 2.20

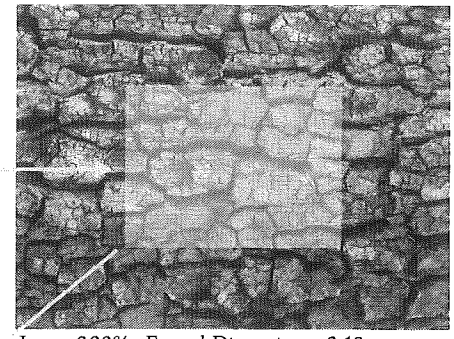


Image 200% - Fractal Dimension = 2.19

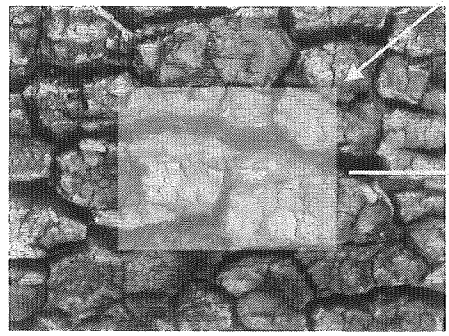


Image 400% - Fractal Dimension = 2.14

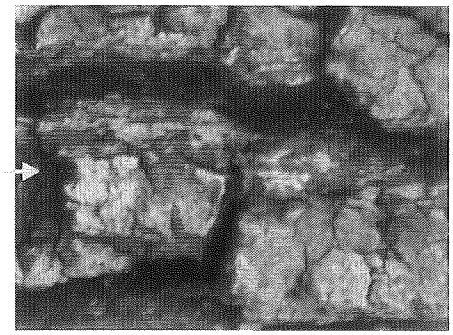


Image 800% - Fractal Dimension = 2.07

Figure 2: Details of Eucalyptus tessellaris Tree Bark

FRACTAL GEOMETRY AND LANDSCAPE DESIGN

The measure of fractal dimension has been used to analyse various types of landscapes from an aerial perspective (Xu, et al, 1993), and certain types of natural objects, textures and pictorial scenes (Ruderman, 1994; Ruderman and Bialek, 1994; Taylor, 2002). Other research has shown that human discrimination of images is higher for images with a fractal dimension similar to that of natural terrain surfaces (Knill, et al, 1990) and that humans prefer images with a fractal dimension in the mid-range from 1.3 to 1.5 (Spehar, et al, 2003).[6]

Although there has been significant interest in the application of fractal geometry as a tool for form creation in the fields of architecture and art, there has been no corresponding development in the field of landscape design. However, it seems that the unconscious use of fractal patterning by some designers may play a role in the aesthetic response a particular designed landscape evokes. Research by Gert van

Tonder and Michael Lyons has shown that fractal patterning is embedded within the dry landscape garden of the Ryoanjii Temple in Japan (Tonder and Lyons, 2005). Using a technique know as medial-axis transformation,[7] they have shown that the overall structure of this dry garden is based on a spatial form similar to that of a branching tree. They determined that the connectivity pattern of the branches is self-similar and the trunk of the tree form converges on the main viewing area for the garden. By changing either the placement or number of rocks within the garden,[8] they found that the self-similar tree form and convergence on the main viewing area was removed from the corresponding medial axis. From this analysis they concluded that the structure defined by the visual ground was not accidental, and that the ancient designers of these sophisticated, minimalist gardens may have had an intuitive understanding of the fractal properties of nature. In their discussion, Tonder and Lyons suggest their work uncovers a new link between the structure of the Ryoanjii Temple garden and its aesthetic appreciation - a link based on the self-similar structure of the garden.

Because fractal geometry is the basis for many of the patterns found in nature, we may hypothesise that the fractal dimension can be considered a measure of the naturalness of something (Hagerhall, et al, 2004). This is supported by Li when he suggests that the visual patterns produced by natural systems and processes may be important factors in identifying ecological diversity, stability and function (Li, 2000). This, coupled with the results of Tonder and Lyons, Knill and Spehar, et al, begs the question: does the fractal dimension of a designed landscape influence people's preference for it? However, unlike previous work that has examined the fractal dimension of individual natural entities or specific landscape scenes, designed landscapes are structurally very complex, consisting of both natural and built elements arrayed in multiple visual planes. Similarly, these landscapes are not viewed from a single position at a single point in time, but viewed from multiple positions over time. Therefore, analysing the fractal dimension of a single, pictorial, view of a particular landscape is not appropriate. What is needed is an understanding of the overall, or composite, fractal dimension of an environment. This is a prerequisite to understanding whether fractal geometry can be used as the basis for the development of an ecological aesthetic. However, as the central fractal concept of scale invariance might not be valid for these complex landscapes, the first step to answering this question is to determine whether the measurement of fractal dimension can be used to differentiate between different landscape forms.

PILOT STUDY

To determine whether the fractal dimension can be used to differentiate between different landscape forms, a pilot study has been undertaken that analyses seven different landscape types commonly encountered within south-east Queensland, Australia. These landscapes range from a relatively undisturbed natural environment, to a highly modified central urban streetscape.

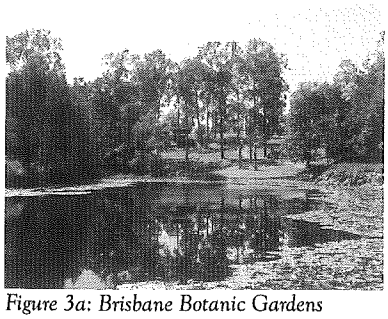


Figure 3a: Brisbane Botanic Gardens

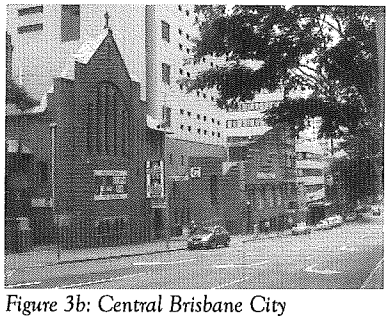


Figure 3b: Central Brisbane City

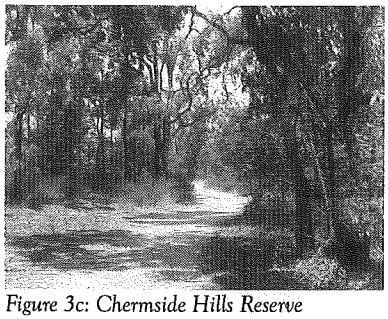


Figure 3c: Chermside Hills Reserve

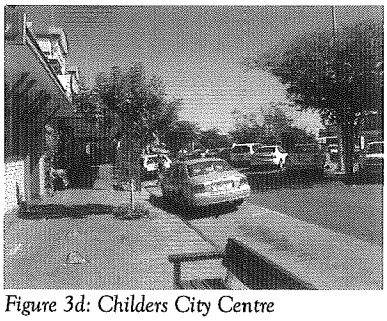


Figure 3d: Childers City Centre

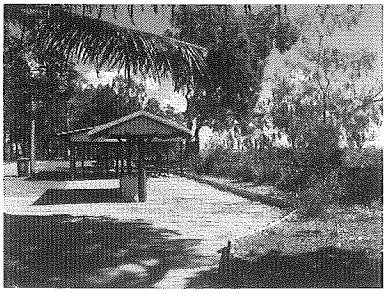


Figure 3e: Hervey Bay Esplanade

They are:

1. Brisbane Botanic Gardens, Mount Coot-tha: A relatively new botanic garden established in the 1980s.
2. Central Brisbane City: A cental urban city streetscape of high-rise offices, apartments and street vegetation.
3. Chermside Hills Reserve: A remnant bushland reserve, now relatively undisturbed, in the northern Brisbane suburbs.
4. Childers City Centre: An historic rural town split by a major highway.
5. Hervey Bay Esplanade: A major tourist environment characterised by its low-rise residential and commercial development on one side and its remnant vegetated foreshore on the other.
6. Old Brisbane Botanic Gardens: An historic public garden on the Brisbane River.
7. Toowoomba City Centre: A major regional town, characterised by low-rise buildings and wide paved streets.

METHOD

The fractal dimension of an entity can be determined in many ways, from a simple divider-compass method for measuring the fractal dimension of a coastline, to highly complex mathematical and statistical methods for determining the fractal dimension of both temporal and spatial entities.[9] It has been shown that the luminance intensity of the surface of a photographic image will exhibit the same fractal dimension as the surface photographed (Pentland, 1984). Luminance refers to the quality of light reflected or emitted by an object. One advantage of analysing the luminance properties of an image of a landscape is that it conveys information that relates to the texture (or roughness) of the landscape and it has been shown that there is a high correlation between fractal dimension and perceived roughness (Pentland, 1984). Therefore, from this we can deduce that a photographic image will be an acceptable surrogate for the fractal analysis of landscapes.

To obtain a composite fractal dimension for each of the landscapes chosen, multiple photographs were taken from different viewpoints over a period of several hours, using an Olympus E300 digital camera, set on automatic mode, with an image resolution of 2560 x 1920 pixels. The number of photographs taken for a particular landscape ranged from 32 to 77. All photographs were taken in landscape format. These different landscape types are shown in Figure 3a–g.

To determine the fractal dimension of each photograph they are first converted to an eight bit greyscale image, which gives luminance values for each image pixel in the range 0 to 255, where 0 represents black and 255 represents white. If the values for each pixel within a row or column are plotted on a graph, a line with a specific frequency signature is obtained. This process is demonstrated in Figures 4a–c.

From Figure 4c it can be seen that adjacent pixel values that are similar result in a relatively smooth signal, while adjacent pixels of very different values result in much more variation. Each row and column of the image is then Fourier transformed (F) to determine the amplitude of the individual frequency components (f) contained within the row or column. From this the power spectrum p(f), which is proportional to the square of the amplitude for each frequency component, is calculated, indicating the relative magnitude of the different frequency components contained within the signal.

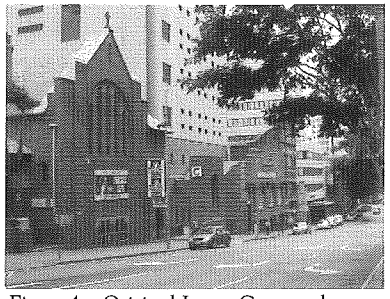


Figure 4a: Original Image Converted to Grey Scale

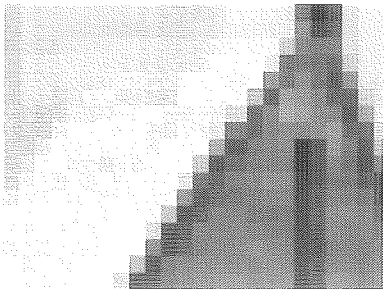


Figure 4b: Magnified Section Showing Grey Scale Pixels

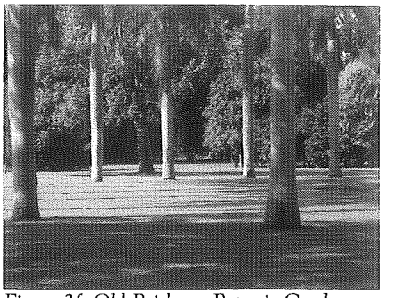


Figure 3f: Old Brisbane Botanic Gardens

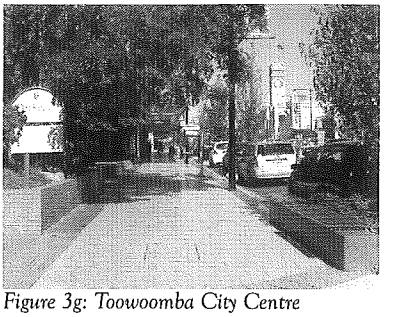


Figure 3g: Toowoomba City Centre

This process is illustrated in Figure 5, for the first four component frequencies contained within a simple square wave.

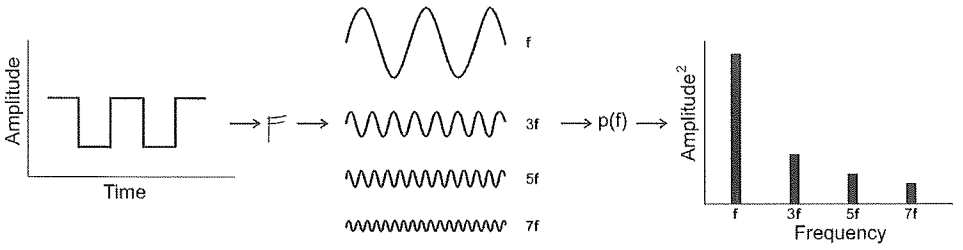


Figure 5: Frequency Signal to Power Spectrum

The 1-dimensional fractal dimension of any row or column within an image is related to the slope of the 'line of best' fit when p(f) and f are plotted on a log-log graph (Turner, et al, 1998). This is shown in Figure 6. The fractal dimension for each row or column can be calculated from the formulae:

$$D1 = (5-b)/2$$

Where b is the slope of the line shown in Figure 6, and D1 is the 1-dimensional Fractal Dimension for each row or column. The overall fractal dimension of each image is then calculated by vertical slice averaging (Turner, et al, 1998), using the formula:

$$D2 = 1 + D1$$

Where D2 is the overall 2-dimensional fractal dimension of the image, and D1 is the average 1-dimensional fractal dimension of all rows and columns. The composite fractal dimension for a particular landscape is then determined by calculating the mean of all the sample images of that landscape.

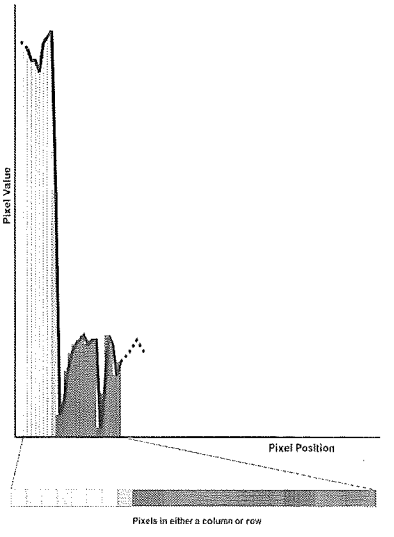


Figure 4c: Pixels Values of Bottom Row of Figure 4b Converted to a Frequency Signal.

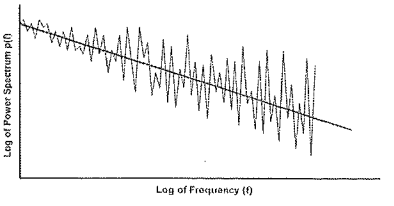


Figure 6: Power Spectrum vs Spectral Frequency

RESULTS

The results of this pilot study are shown in Figure 7, which compares the histograms of occurrence of each range of fractal dimension for the seven different landscape types.

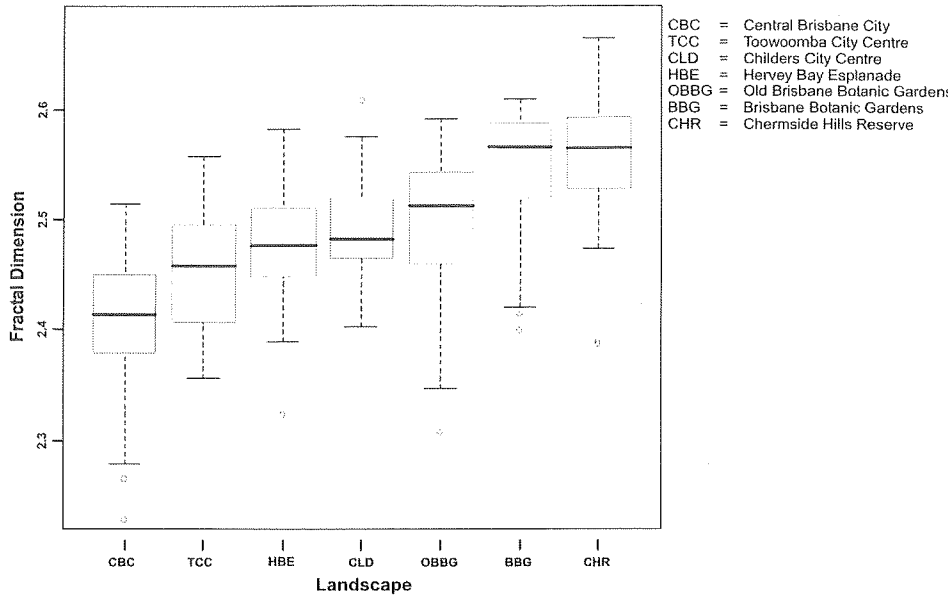


Figure 7: The Fractal Dimension of Different Landscapes

Table 1 shows the mean fractal dimension and the standard deviation for each landscape type.

Landscape Type	Number of Photographs	Mean Fractal Dimension	Standard Deviation
Central Brisbane City (CBC)	74	2.41	0.0608
Toowoomba City Centre (TCC)	51	2.45	0.0521
Childers City Centre (CLD)	52	2.49	0.0434
Hervey Bay Esplanade (HBE)	58	2.48	0.0500
Old Brisbane Botanic Gardens (OBBG)	32	2.50	0.0671
Brisbane Botanic Gardens, Mt Coot-tha (BBG)	32	2.55	0.0545
Chermside Hills Reserve (CHR)	77	2.56	0.0503

Table 1: Mean Fractal Dimensions

It can be seen from Figure 7 and Table 1 that highly urban landscapes appear to have a lower overall fractal dimension than the more natural landscapes, whereas landscapes composed of both urban and natural elements lie somewhere between the two.

STATISTICAL ANALYSIS

To test the hypothesis that all landscapes will have the same mean fractal dimension, an ANOVA test was performed on the mean fractal dimension for landscape type. A very small p-value of 2.2e-16 showed strong evidence to reject the hypothesis that all landscape types have the same mean fractal dimension.

To determine which landscapes are significantly different from each other, Tukey's honest significance difference method was used, giving a 95 per cent confidence interval for the mean difference between each pair of landscape types. This gave the results shown in Table 2 below.

Landscape	Difference	Lower	Upper
CBC-BBG	-0.138813688	-0.17256401	-0.105063368
CHR-BBG	**0.012598959**	**-0.02095229**	**0.046150209**
CLD-BBG	-0.057806109	-0.09364700	-0.021965218
HBE-BBG	-0.070286816	-0.10541438	-0.035159248
OBBG-BBG	-0.049914616	-0.08979468	-0.010034554
TCC-BBG	-0.095468891	-0.13144339	-0.059494390
CHR-CBC	0.151412647	0.12544437	0.177380919
CLD-CBC	0.081007579	0.05214178	0.109873377
HBE-CBC	0.068526872	0.04055169	0.096502054
OBBG-CBC	0.088899072	0.05514875	0.122649392
TCC-CBC	0.043344796	0.01431327	0.072376323
CLD-CHR	-0.070405067	-0.09903785	-0.041772279
HBE-CHR	-0.082885775	-0.11062047	-0.055151083
OBBG-CHR	-0.062513575	-0.09606483	-0.028962324
TCC-CHR	-0.108067850	-0.13686771	-0.079267992
HBE-CLD	**-0.012480708**	**-0.04294538**	**0.017983963**
OBBG-CLD	**0.007891492**	**-0.02794940**	**0.043732383**
TCC-CLD	-0.037662783	-0.06910026	-0.006225307
OBBG-HBE	**0.020372200**	**-0.01475537**	**0.055499768**
TCC-HBE	**-0.025182075**	**-0.05580382**	**0.005439673**
TCC-OBBG	-0.045554275	-0.08152878	-0.009579774

Table 2: Mean difference and 95 per cent confidence interval for the mean difference between each pair of landscape types.

From this analysis it can be determined that the mean fractal dimension for the landscape types analysed were all significantly different, except the following five pairs:

- Chermside Hills Reserve and Brisbane Botanic Gardens
- Hervey Bay Esplanade and Childers City Centre

- Old Brisbane Botanic Gardens and Childers City Centre
- Old Brisbane Botanic Gardens and Hervey Bay Esplanade
- Toowoomba City Centre and Hervey Bay Esplanade

Chermside Hills Reserve and Brisbane Botanic Gardens are the most naturalistic of the landscape types analysed and appear indistinguishable through the analysis method used in this pilot study to determine their overall fractal dimension. Likewise, this analysis cannot differentiate between Hervey Bay Esplanade, Childers City Centre and the Old Brisbane Botanic Gardens. From the point of view of mean fractal dimension, these three landscape types were indistinguishable in our analysis. They all appear to occupy an intermediate zone between completely urban and completely natural landscapes. While Toowoomba City Centre is distinguishable from Childers City Centre and the Old Brisbane Botanic Gardens, which appear more towards the natural end of the spectrum, there is not a clear ability to distinguish it from Hervey Bay Esplanade, which appears towards the more urban end of the spectrum. The smallest mean fractal dimension was attributed to Brisbane City Centre, the most urban of the landscape types and the highest mean fractal dimension was attributed to Chermside Hills Reserve, the most natural of the landscape types.

The fractal analysis undertaken in this pilot study indicates that in our sample:

- the lowest mean fractal dimension was associated with the most urbanised landscape, while the highest mean fractal dimension was associated with the most natural landscape;
- intermediate landscape types having both urban and natural forms have an intermediate fractal dimension;
- it is possible to differentiate between landscape types based on their overall fractal dimension; and
- some urban landscape forms exhibit fractal dimensions similar to natural forms, and vice versa.

Considering the similarity in fractal dimension between different natural and different urban landscape forms, it seems reasonable that similar relationships can be expected to hold for other examples of these landscape types.

DISCUSSION

There has been a considerable amount of research undertaken on people's preferences for different landscape types. The study by Tanja Simonič (Simonič, 2003) is typical of this work, which uses photographs as surrogates for environments and semantic-differential scales to estimate preference based on cognitive indicators. The results from her study indicate a preference for landscapes designed as naturalistic, whereas, purely natural landscape forms and landscape forms based on rigid linear geometric properties were not rated as highly. Similarly, Purcell, et

al, have also shown that natural landscapes are rated higher than built landscapes (Purcell, et al, 2001). In their discussion they suggested that this preference might be associated with the fractal geometric properties of these landscapes.

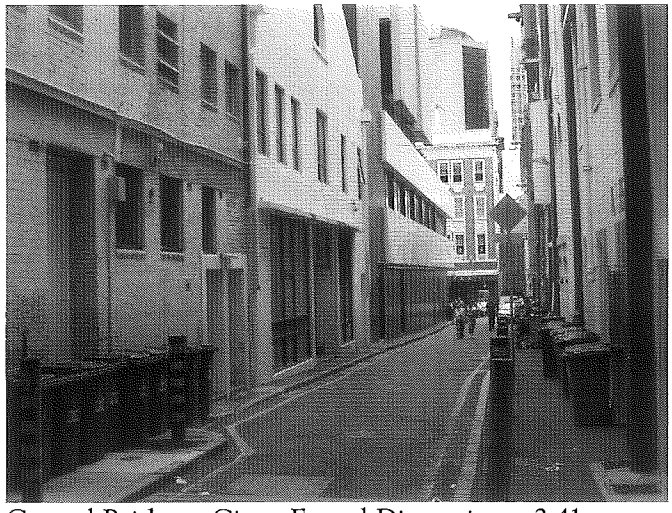
A recent paper by Taylor, et al, on fractal geometry and human perception reports that out of 120 participants, 113 preferred fractal patterns over non-fractal patterns (Taylor, et al, 2005). Also, as discussed above Spehar, et al, have shown that there is preference for fractal patterns that exhibit a fractal dimension in the mid-range (Spehar, et al, 2003).

The results of our pilot study confirms, for the first time, that different landscape types can be characterised by their mean fractal dimension. This result means that we can now progress with this research and undertake preference studies to determine whether there is a correlation between the mean fractal dimension of a landscape and its aesthetic preference.

However, our results also pose some interesting questions. Hagerhall, et al, have suggested that the fractal dimension can be considered an indicator of the naturalness of a pattern (Hagerhall, et al, 2004). This would imply that a higher fractal dimension indicates a greater degree of naturalness. Our results, shown in Figure 7, would seem to confirm this hypothesis, as the mean fractal dimension for the most natural landscape was 2.56, whereas the mean fractal dimension for the most built landscape was 2.41. However, when looking at specific scenes within a landscape this hypothesis fails to explain why urban images with no natural forms exhibit a fractal dimension similar to images containing all natural forms, see Figure 8.



Chermside Hills Reserve - Fractal dimension = 2.38



Central Brisbane City - Fractal Dimension = 2.41

Figure 8: Comparison of an Urban and Natural Image

Similarly, it is not clear why the landscape of Toowoomba City Centre, where the images are characterised, in general, by large vivid blue skies, wide roads, vehicles and predominantly built forms, could not be differentiated from Hervey Bay Esplanade, where the images contain much more natural vegetation, less built forms and dappled shadow on the road surfaces.

This pilot study represents the first stage of an ongoing research project to determine whether fractal geometry can underpin the development of an ecological aesthetic. Further analysis will now be undertaken to determine how the compositional elements within an image affect its overall fractal dimension. This will enable us to understand why landscapes that seem visually distinctive exhibit similar fractal dimensions. With this understanding, we will then be in a position to determine whether landscape preference corresponds to a particular fractal dimension and where this fractal dimension sits along the spectrum from natural to built forms.

This information will go a long way towards enabling the design of landscapes with a known composite fractal dimension that both reflects the underlying patterns of healthy ecosystems and pleases the aesthetic sensibilities of the general public.

NOTES

1 See Koh, J (1988) An Ecological Aesthetic, *Landscape Journal* 7, pp 177–191; Thayer, RL (1989) The Experience of Sustainable Landscapes, *Landscape Journal* 8, pp 101–109; Mozingo, LA (1997) The Aesthetics of Ecological Design: Seeing Science as Culture, *Landscape Journal* 16, pp 46–59.

2 Formalism is the theory that the aesthetic appreciation of an entity is based only on the relationship between the elements of that entity, such as notes in a piece of music, or the arrangement of lines, colours and shapes in a work of art. Formalism does not consider an entity's social or cultural context, its history or its relationship to its creator.

3 See Howett, C (1987) Systems, Signs, Sensibilities: Sources for a New Landscape Aesthetic, *Landscape Journal* 6, pp 1–12; Koh, J (1988) An Ecological Aesthetic, *Landscape Journal* 7, p 177–191; Spirn, AW (1988) The Poetics of City and Nature: Towards a New Aesthetic for Urban Design, *Landscape Journal* 7, pp 108–126; Mozingo, LA (1997) The Aesthetics of Ecological Design: Seeing Science as Culture, *Landscape Journal* 16, pp 46–59; Nassauer, JI (2002) *Messy Ecosystems, Orderly Frames* In *Theory in Landscape Architecture: A Reader,* S Swaffield (ed) Philadelphia: University of Pennsylvania Press, pp 196–206.

4 Avnir et al consider the use of the term fractal appropriate for these natural geometries as it 'provides a proper language and symbolism for the study of these ill-defined geometries' Avnir, D, Biham, O, Lidar, D and Malcai, O (1998) Is the Geometry of Nature Fractal? *Science* 279, pp 39–40.

5 Where lines are a shape element with an integer dimension of one (1), planes (squares, triangles) are shape elements with an integer dimension of two and volumes (spheres, cubes, cones) are shape elements with an integer dimension of three.

6 This measure is based on the 1-dimensional analysis of fractal lines rather than a 2-dimensional analysis of fractal planes.

7 The medial-axis transformation is a method for representing the shape of objects by finding their topological skeleton.

8 This was achieved by digital manipulation of photographs.

9 An overview of these methods is given by Kenkel and Walker (Kenkel, NC and Walker, DJ 2005).

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