The visual qualities of liveable streets

Chris Tucker[1], Michael J. Ostwald[1], Josh Marshall[2], Stephan Chalup[2]
[1]University of Newcastle, School of Architecture & Built Environment, Newcastle, Australia
[2]University of Newcastle, School of Computer Engineering, Newcastle, Australia

Abstract: The visual character of buildings is often associated with the style of its construction - a set of visual characteristics that a group of buildings might share. These characteristics include the relationship of the parts of the building to each other and to the building as a whole, the use of ornament and visible textures, and the scale of elements within the composition. Alexander (Alexander, 2002) and Rapoport (Rapoport, 1990) have discussed how these visual features affect urban coherence, and the way that people behave in public spaces. Using algorithms developed within robotic research that enable a computer to interpret a visual environment (similar to those used in medicine and facial recognition for instance), this paper outlines how algorithms can be used to study the visual properties of the built environment. The paper discusses how the urban texture of houses within the streetscape, at the scale of the individual, relates to the urban visual character of precincts within the city. The architectural drawings of a house designed by Le Corbusier and the street frontages of post war and federation houses are visually analysed using Archimage, software developed by the authors for this type of analysis.

Conference theme: Effective tools: design, assessment, operation
Keywords: Streetscape, visual analysis, architectural style

INTRODUCTION

Planning authorities use words like sympathetic, compatible, historically significant, sense of place or identity when evaluating streetscape character. However such descriptions are necessarily subjective and qualitative, leading to extensive debate and limited objectivity.
How new buildings relate to existing urban settings has become an important point of debate in architectural, planning and public policy forums (Groat, 1988).
In deference to new buildings within the natural landscape, or those that are visually removed from the public space of the street, buildings that infill urban and suburban streets visually relate to nearby buildings and become part of the existing streetscape.
In a legislative or policy sense the definition of streetscape, as described in the Environmental Planning and Assessment Act is: the character of a locality defined by the "spatial arrangement and visual appearance of built and landscape features when viewed from the street" (Env. Planning Act, 1979). For parties in dispute over the effect of proposed building works within a streetscape, this definition becomes a critical and potentially costly factor (DIPNR, 2004; VicD.I., 2001). Such policies and practices signal the importance of determining some measure or dimension that could be used for describing or defining the visual character of a streetscape. Only by defining these processes more clearly can creative solutions be found for new buildings in areas with a well-established street character (RAIA, 2004).

1. VISUAL CHARACTER OF THE STREETSCAPE

1.1 Qualitative Measures

The character of a street, or its *genius loci,* is a unique and distinguishing quality that differentiates one place from another (Norberg-Shulz, 1963). From the perspective of a resident, it can represent a collective identity (Smith, 1997) and be valued for more than its purely functional quality would suggest. Part of this value is found in the meanings local communities attribute to features or elements within the street.
Specifically streetscape is defined as either the transition space between the private and public realms or the delineating zone between an individual and society (Fiske, 1987; VicD.I., 2001). By understanding that the space outside a dwelling is used differently from the space inside, the transition zone becomes a formal representation of the coexistence and co-dependence of internal and external areas. The publics' right to look—and indeed to share symbolic possession through active or passive surveillance—suggests that the owner of a private space has some obligation to provide a public front to their personal dwelling
While planning diagrams concentrate on the functional and formal requirements of the built landscape, little attention is given to obtaining information about the visual character of the urban environment which is what people experience.
Quantitative measures such as the height of a proposed building and other density measures can be determined quickly and accurately. Fisher-Gewirtzman, Burt and Tzamir (Fisher-Gewirtzman, 2003a) states that physical and psychological "qualitative parameters" such as texture, privacy, colour, and nostalgia also play an important part in making places liveable. However these aspects of the built environment are difficult to measure as they are open to the interpretation of the individual. Hull states that this can result in changes that disassociate residents from their "place based communities" (Hull IV, 1993). In cases where the character of a street or locality requires improvement, the challenge is to identify the

physical attributes of the preferred character while developing the broader infrastructure and amenity within the locality (Townsend, 2001).

1.2 Analysing Visual Character within the Streetscape

When new buildings are proposed in heritage conservation areas, development is regulated by Development Control Plans (DCP) that provide guidelines about the shape, form and detail that new houses, alterations and additions should take (DIPNR 2004). For buildings to be approved, planning authorities must assess these qualitative aspects of existing urban areas such that decisions can be made about proposed changes

By understanding that the visual amenity of streets within a city plays an important role in creating a sense of place and community for its citizens (Lynch 1960) they attempt to sustain, through regulation, an urban pattern that has become valued by the community.

There are two stages in defining the nature of existing visual character of a streetscape. The first is an objective analysis of visual elements within the streetscape that may provide a measurable outcome. The second stage involves a decision about the importance of the patterns of elements in relation to others (Alexander, 2003; DIPNR, 2004; VicD.I., 2001).

It is this first stage that our research is concerned with, and in particular how the visual properties of a streetscape might be interpreted without first having to interpret its 'style'.

Fisher-Gewirtzman (Fisher-Gewirtzman, 2003a) points out that while density measures might be relevant to planning at the scale of the city or region they are of little use when considering the degree of enclosure or openness within a particular urban space. She reflects that understanding the relationship between the built form of the street and surrounding urban space is fundamental, "appropriate thorough work is needed to develop sharper evaluation, control methods, and predictive tools, conditioned to the human perception of space."

When evaluating the effect of changes to the streetscape, changes to the façade of a dwelling for instance, Alexander (Alexander, 2003) suggests that the analysis be undertaken at different scales and include; views of the locality or neighbourhood; views within the street (the character precinct); and views from the front of adjacent properties. At the scale of the neighbourhood, elements such as the topography, street pattern, vistas and the prevailing character of the urban space are to be examined.

The character precinct is conceived as a fundamental unit of streetscape character as it attempts to find elements that have a strong visual relationship to each other within an urban scene (Alexander, 2003). Elements to be examined at this scale include street fixtures and furniture, patterns of lot widths, outline, composition and any symmetries of the built form, extent of light and shade within the built form and on the ground. At the scale of the adjacent properties, elements to be examined include the built form (including solid and void), horizontality and verticality of the elements within the façade, the intricacies of line within the street façade, colour and texture of the materials.

1.3 Surfaces and Boundaries Of The Streetscape

While Hillier (Hillier, 1984:p1) states that a building's purpose is to transform space, Salingaros (Salingaros, 1999b) asserts that it is the information within the surrounding surfaces of the open space that is perceived, and is of greater importance than an analysis of a plan that is not perceived at all.

Differentiations in the surface of the open space caused by colour, texture and ornamentation are considered significant subdivisions within the surface of the streetscape even when their effect on its form may be minimal (Moughtin, 1999; Salingaros, 1999b).

Visual diversity relates to the rate at which usable information is made available to the viewer, or by the rate of change of the "noticeable differences" (Rapoport, 1990:p269). Depending on the way that the differences are gradually revealed, the experience of walking down a street might then feel in turn monotonous, surprising or familiar. For instance where the streetscape is visually consistent with a "strong order" (Rapoport, 1990:p269) minor variations become *noticeable* against a *familiar* background and contribute to its complexity. While noticeable differences may occur within any of the five senses, this study is only concerned with those of a purely visual nature. These visual differences will form a boundary of an "element", and it is the term that will be used when describing the visual diversity within a surface.

Importantly the perception of an element is a condition of the surface that surrounds it and is perhaps reinforced by the juxtaposition of nearby elements (Rapoport, 1990:p273).

The boundaries of the elements then remain an important consideration, while the surface within the element is of less consequence. Streetscape character is specifically shaped by the boundaries between the elements that constitute the street wall or façade of the urban space. How those elements are organised and perhaps related in patterns within a specific urban or suburban built environment defines it visual character (Kropf, 1996). Surfaces of the open space that are orientated perpendicular to movement create a local spatial boundary (Salingaros, 1999b); Theil, Harrison and Alden (Theil, 1986) state that the visual boundaries within the surface of a space define its degree of enclosure in a more significant way than simply determining how large it is.

Research undertaken by Al-Homoud and Natheer (Al-Homoud, 2000) supports this by finding that vertical objects 'determine our perception of spatial enclosures' more than horizontal elements within urban spaces do.

1.4 The Significance of Detail within the Façade of Buildings

Many researchers have shown that the character of, and preference for a building often depends on the detail within its façade (Stamps III, 1999). Moughtin *et al.* (Moughtin, 1999:p25) suggests that decoration, ornamentation and articulation within a building's façade is the 'means by which a variety of visual experiences are introduced to the viewer'. Brolin (Brolin, 2000) adds that the 'small scale details' of visual texture are the most critical factor to consider when locating a new building within an existing built context. Hull et al (Hull IV, 1993) finds that decorative style valued highly by residence, possibly because it creates a sense of identity by distinguishing one place from another.

Methods used in architecture to determine scale within a building include massing, where the largest scale is usually defined by an outline of the building itself (Salingaros, 2000b).Elements within the façade such as openings, detail, trim and the material itself will then successively identify smaller scales.
Symmetry is a condition of massing and is manifested through the recurrence of shapes in a regular way, and can help connect elements forming a single element at a greater scale (Salingaros, 2000b). Once formed, this arrangement can be thought of as modular, repeated through the 'economy of thought and action' (Salingaros, 2001).
Salingaros (2003b) reflects that successful building facades within an urban space feature a 'continuous swath of high-density visual structure that the eye can follow in traversing their overall form'.

1.5 Texture Of The Streetscape

Texture is a property of all surfaces and is one of the characteristics used to identify visual regions bound by edges within an object. It can be described as the 'structural arrangement of a surface and the relationship that one arrangement has with others surrounding it' (Schira, 2003).
Salingaros (Salingaros, 1999b) comments that contemporary building materials and methods used to replicate traditional façade styles might 'minimize the information field' and subsequently not provide the visual field associated with the traditional building. The replication of an existing style is considered an acceptable and often desirable solution from a planning perspective (Alexander, 2003) regardless of the characteristics of materials used. However it is important that the visual qualities of contemporary buildings are understood in relation to the existing visual context even at this scale.

1.6 The Visual Properties of Style

Alexander suggests that good design consists of certain definable properties including, Levels of Scale, Strong Centres, Boundaries, Positive Space, and voids to contrast with surrounding information (Alexander, 2002).
According to Alexander, shapes within a composition must express a number of levels of scale in order to make them coherent with one another. Individual parts within a composition are intensified by their position within the structure and by their relation to a focus point which he calls a centre.

> 'I use the word centre to identify an organised zone of space – that is to say, a distinct set of points in space, which, because of its organization, because of its internal coherence, and because of its relation to its context, exhibits centred-ness, forms a local zone of relative centred-ness which respect to the other parts of space.' (Alexander, 2002:p84)

Zucker and Terzopoulos similarly describe texture as 'a global pattern arising from the repetition, either deterministically or randomly, of local sub-patterns. The structure resulting from this repetition is often important in discriminating between different textures.' (Zucker, 1980)
Alexander states that 'Boundaries do the complex work of surrounding, enclosing, separating, and connecting in various different geometric ways..' (Alexander, 2002:p159) They should exist at various scales through the composition. The boundaries weight should correlate with the scale of the shape it is binding, for example larger shapes require larger borders, smaller shapes require smaller borders. Newman states that boundaries contribute to defensible space, and can be real or symbolic Whether the boundary is a high wall or the change in surface texture, they both serve to indicate a transition from public to private space 'where one's presence requires justification' (Newman, 1972 p63).
Furthermore, Gehl observes that conversations in streets occur more frequently when a yard is delineated by a boundary such as a low wall (Gehl, 1996:p192). These boundaries create resting places which Gehl states are important in enabling people to stay longer in the semiprivate area in front of their house increasing the possibility for interaction with passers by. This activity on the street is an important factor in making places liveable 'people come where people are.' (Gehl, 1996:p27). He has observed that these characteristics are more likely to keep people in the public realm for longer periods.' These areas might be what Alexander calls positive spaces (Alexander, 2002:p173). This concept could also be applied to the façade of a building. A positive space or shape is one which surrounds another shape or space and is able to be considered as a shape or space in its own right. The whole composition is then considered so 'there is not a single place which is leftover' (Alexander, 2002:p176). According to Alexander, a void can unify the structure of a composition by providing a focal point for surrounding details and elements (Alexander, 2002:p222). The porch of a bungalow could be read as a unifying void for the façade of a house. The uniform shade made by this space can create a place for the eye to rest, and contrasts with the higher levels of visual information in the rest of the façade.
Factors determining the perception of a buildings character are not limited to the building itself. As Alexander points out a view of the building as a whole means that we see it as 'part of an extended and undivided continuum'. The façade is not an image in itself, but part of the streetscape which includes the 'gardens, walls, trees, streets beyond its boundaries and other buildings beyond those' (Alexander, 2002:p80). Tree lined streets are more visually complex, and been found to instil positive emotional responses when compared to streets with no trees. (Nelson, 2001). Moreover studies have shown that a tree is preferred in terms of how full its canopy is, with a full canopy being the most preferred (Nelson, 2001)

2. ASSESSING THE VISUAL PROPERTIES OF ELEMENTS WITHIN THE STREETSCAPE

2.1 Introduction

Algorithms are being used to understand the visual properties of physical environments in a number of fields including biology, medical diagnostic imaging, remote sensing, space exploration, defence and security. Analysing the built environment is an extension of these applications and might show if there are consistent visual characteristics to why some environments are highly valued, safe or sustainable. A tool that was also able to consistantly analyse the visual characteristics of the environment might also assist the assessment of buildings by planning authorities.

Visibility analysis supported by computer algorithms makes it useful for a comparative analysis because the representational and symbolic meanings attributed to a building play no part. The organisation of the elements can be analysed without having to interpret them at the beginning of the process, and any part of any streetscape can be assessed using the same processes. This is not to say that representational meanings are not important to the visual character of a streetscape, but that an interpretation of these elements might follow an algorithm derived visual analysis.

2.2 Analysis using Archimage

Computer software, named Archimage, has been developed that utilises algorithms to analyse the visual properties of architectural images. The diagrams on the following page show how the architectural drawings of the Maison Canneel in Brussels, a project house designed by LeCorbusier, can be analysed using Archimage.

Figure 1 is a drawing of the east elevation of the Maison Canneel that has been scanned from a book containing the drawings and models of many of LeCorbusiers houses (Laboratory, 2001). Archimage first processes the image by converting the original image into a diagram where edges, or areas of high contrast between adjacent pixels, are highlighted (Tucker, 2006). This process eliminates pixels within the image that are not detected as edges. This diagram, called the **Line Image**, can then be processed using the Hough Transform (HT).

Figure 2 shows the Hough acculumator, the resulting graph after the HT has been applied to the **Line Image**. The Hough Transform is an algorithm that detects the likely direction of a line (or edge) that any pixel in the image might be part of (Tucker, 2005a). It shows the angle and distance of all pixels within detected lines from a predetermined origin. Lines with the greatest number of edge pixels within them appear as 'bright' points within the array. In **Figure 2** the top 40 'bright' points have been highlighted with a small red square. The HT finds edges that are continuous; such as the drawn lines of the walls, and also those that are discontinuous; edges that appear to form a line but are separated by gaps. Detecting lines that are discontinuous, but perceived by humans as an edge, is an important part of Gestalt psychology (Chalup, 2007; Guy, 2002) and necessary for a visual analysis of existing buildings (Tucker, 2004). The HT also translates edges or lines of two dimensions within the image into points of one dimension, making the array a diagram that can be more easily compared with others (Song, 2005). Finding similarities and differences between the HT arrays enables them to be clustered, and can show where dwellings of the same or dissimilar architectural styles might share particular visual characteristics (Chalup, 2007). Fo instance determining whether an image of the streetscape exhibits more horizontal or vertical lines can be related to feelings of privacy (verticality) or publicity (horizontality) (Al-Homoud, 2000).

Figure 3 is called the HT Polar array, where the Hough accumulator array explained above is expressed as a polar graph. The HT Polar array locates the angle and strength of the top 40 lines found lines in relation to the centre of the image – the size of the bubble relating to its strength. Like the HT array graph in **Figure 2** the graph allows comparison between images.

Figure 4 shows a calculation of the fractal dimension using the box counting method. The automated technique develops the work undertaken by Bovill and Weidemann (Bovill, 1996) and uses methods developed by Fouroutan, Dutilleul and Smith (Foroutan-pour, 1999) to determine the best approximation for the fractal dimension. Salingaros et al (Salingaros, 1999a) has discussed the relationship between a higher fractal dimension and successful urban spaces.

Figure 5 shows the inverse Hough Transform where the top forty lines found within the image that have the greatest strength are placed back over the original image. Because the lines are now drawn over the image from mathematical formula they are at infinite length (not bound by the pixels that created them).

Figure 6 is a diagram called the *Line Strength*. By considering that every pixel in the *Line Image* is part of a possible line, the Archimage software successively counts detected lines that contain only 3 pixels, then 4 pixels and so on until all lines of all pixel lengths have been counted (greater Line Strength relates to lines that have a greater number of pixels within them). The number of lines for each angle are added together and the value recorded as a point in the graph. The *contour lines* within the graph represent line counts at 50 pixel intervals (y axis) against the angle of the line (x axis). Horizontal lines are shown as peaks in the centre of the graph, vertical lines peak at the edges of the graph. This method allows a single pixel to be recorded in any number of discreet lines and can show the relative *connectedness* of a pixel in relation to others.

By successively counting the number of detected lines the graph shows how line length is distributed within the image. As there are many lines within an image that can be formed by aligning a small number of pixels, the first contour line tends to be a near horizontal line at the top of the graph. As the required number of pixels within a line gets larger (eg 100) the number of detected lines reduces and the orientation of more significant detail within the image is revealed.

The *terrain* of the developed graph (for example shown in **Figure 14**) shows the distribution of line length as *gradient*. The gradient implied within the graph shows; how evenly line length is distributed throughout the image; and what the dominant orientation of lines within the image is. When comparing traditional dwellings, such as a federation terrace, and a modern suburban dwelling this density of visual information can differentiate the two styles.

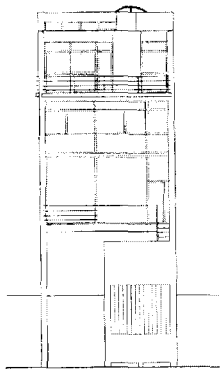

Figure 1 East elevation

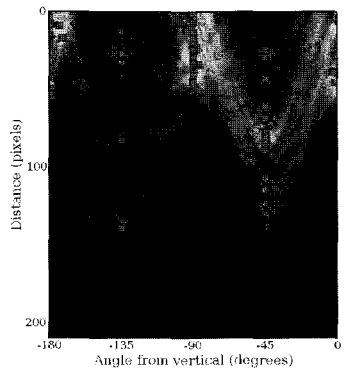

Figure 2 East elavation HT array

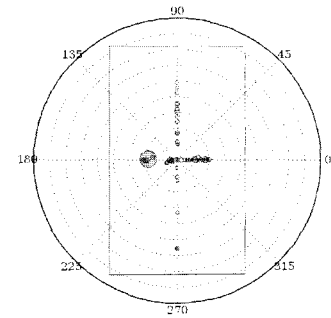

Figure 3 East elavation Polar HT array

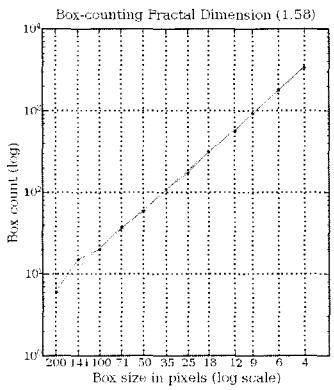

Figure 4 East ele. Fractal Dimension

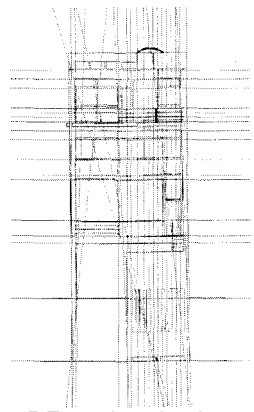

Figure 5 East elevation Inverse HT

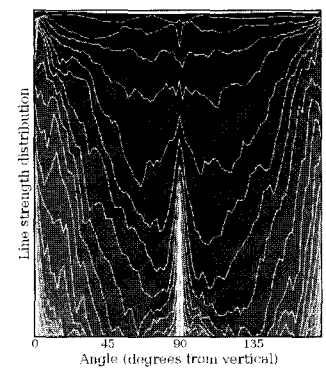

Figure 6 East elavation Line Strength

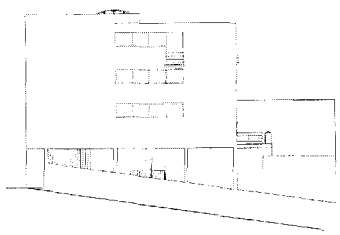

Figure 7 South Elevation

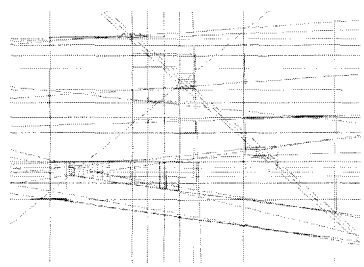

Figure 8 South elavation Inverse HT

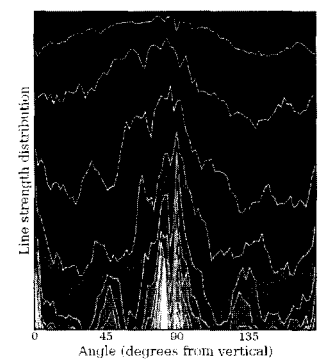

Figure 9 South elavation Line Strength

Figure 10 Bungalow 1 image

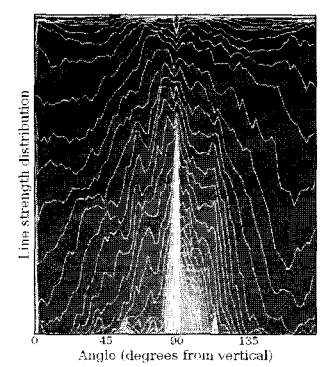

Figure 11 Bungalow 1 Line Strength

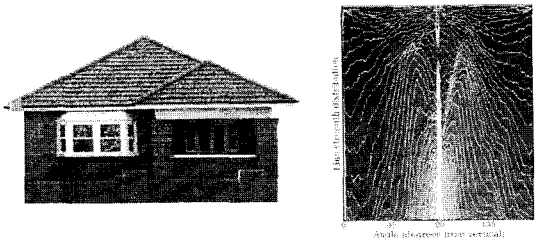

Figure 12 Post war style 1 and Line Strength diagram

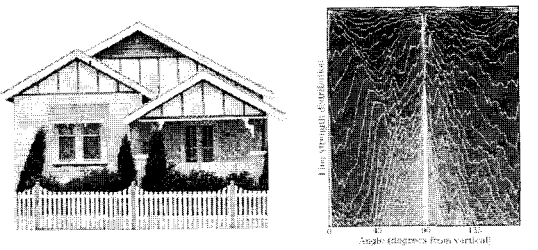

Figure 13 Federation style 1 and Line Strength diagram

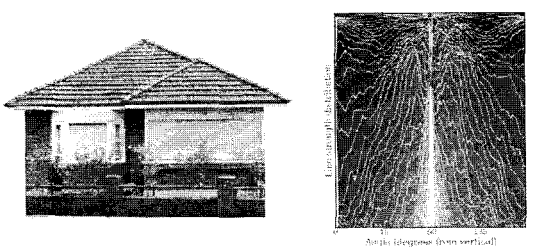

Figure 14 Post war style 2 and Line Strength diagram

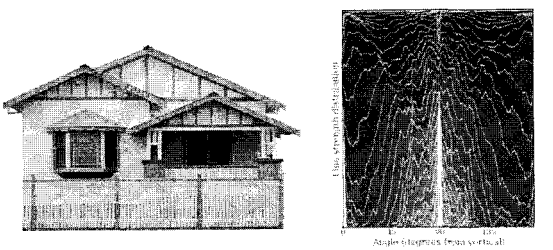

Figure 15 Federation style 2 and Line Strength diagram

3. ARCHIMAGE ANALYSIS OF THE MAISON CANNEEL ELEVATIONS

A study of the elevations of the houses of LeCorbusier is presently being undertaken to test and understand how the Archimage software functions when analysing architectural drawings. From this study the Maison Canneel has been shown as an example.

3.1 Fractal Dimension calculation (*D*)

The fractal dimension of the east elevation (**Figure 1**) is 1.58 and the South elevation (**Figure 7**) is 1.33. The higher fractal dimension of the east elevation is due to the greater spread of visual information at different scales across the elevation. For instance, the windows in the east elevation are broken down into smaller framed units of varying sizes, while the windows in the south elevation are of a similar size and are placed within a larger expanse of flat wall. Salingaros (Salingaros, 2000b) has discussed how the visual properties of a buildings façade that provide higher fractal dimensions are preferred by people who interact with them (see also section 1.4). As the east elevation is the street facing façade of the Maison Canneel, the higher fractal dimension might help the building relate better to the street. As the study continues this relationship between the different facades of his buildings will be analysed.

3.2 Line Strength diagram

The line strength distribution within the east elevation (**Figure 6**) is more even than that found in the south elevation (**Figure 9**), reflecting the higher fractal dimension found within the image. The Line Strength diagram of the south elevation also shows some peaks around the 45 and 135 degree angles. These lines are not drawn within the image but are implied by the arrangement of the elements within the façade. They may also relate to the regulating lines that Le Corbusier has discussed as being an important part of façade composition (LeCorbusier, 1954 p34).

4. ARCHIMAGE ANALYSIS OF DWELLING FACADES

4.1 Introduction

The following is a discussion of how Archimage software is being used to visually segment images of the streetscape. The intention with the software is that it will provide a numeric analysis of the visual environment incorporating the distribution of; length and relative size of visual boundaries, colour and contrasting elements. At this stage of the study we are assessing how different algorithms analyse the visual environment, and whether this analysis might be useful for the goals we have of the software. Our methodology is to proportionally combine the analysis of different algorithms, providing an insight into how the built environment is visually structured. To test our method and analysis we have compiled a photographic database of around one thousand images of the street facing façade of dwellings within the Hamilton South Conservation Area (HSCA) in Newcastle. The conservation area has a number of houses of a number of identifiable styles, allowing groups of facades to be analysed using Archimage.

4.2 Fractal Dimension calculation (*D*)

The fractal dimension of each of the two Post war style houses (**Figure 12 & 14**) is 1.65, and the fractal dimension of the two Federation style houses (**Figures 13 & 15**) is 1.73 and 1.61 respectively. The post war houses have similar form and method of construction, but it is the small scale detail that each have (in different forms) that is keeping their fractal dimension similar. Figure 12 has more detail within the windows while Figure 14 has rose bushes in the front yard. In comparison with the calculation of ***D*** for the 'line art images' (section 3.1), photographs of buildings of different styles tend to show less variation in ***D***. This is because more detail is captured within a photo that the line art image does not represent (eg shadow, texture, foliage, reflection) - this increase in visual information, particularly at smaller scales, produces higher values of ***D***, compared with the same building drawn as a line image. The parameters that control the

threshold for processing visual information within Archimage can be adjusted to reduce some of this noise, but it is unclear how much this information is important to the visual satisfaction of a building. As the study continues the variation in the calculation of ***D*** based on variations in the visual threshold can be discussed more thoroughly.
Calculating ***D*** for actual photographs of buildings, in difference to line images, appears to be the most beneficial in understanding the visual differences between buildings and streetscapes. A photograph more closely represents the actual visual qualities of standing within a street, and has the immediacy required by a tool for assessing the visual character of existing streets.

4.3 Line Strength diagram

The line strength diagram for each house of the same style shows similarities; the peaks and distribution of line strength (gradient) have similar characteristics. The diagrams show the differences between the two styles; the post war style houses have peaks either side of horizontal that become more horizontal as the line strength increases. It is the visual characteristics of the tile roof and masonry walls that are responsible for this. The federation style dwellings have more vertical lines, and the distribution of line strength is more even than the post war diagrams shown. How these diagrams can be compared with each other using other computer algorithms is currently being investigated.

5. Conclusion and Future work

Using algorithms to analyse the visual properties of the streetscape provides an insight in to the visual characteristics that define the style of a building, and provides an analysis of the visual environment that has previously not been possible. This analysis is particularly important for localities where the visual environment is protected by heritage controls, or has become valued by its residents. While planning controls attempt to sustain these visual environments, our photographic database of houses within a conservation area and has shown that much of the built work undertaken while the controls have been in place has not retained the visual character of the conservation area. There may be a number of reasons for this including; a preoccupation with the replication of the federation style even if the original building is a different style (see **Figure 16**); a misunderstanding of the visual requirements of a style; the use of modern construction materials and methods to replicate a style that requires other construction methods; and a lack of recognition by planning authorities that the detail within a buildings façade provides important visual information. Understanding the visual characteristics of the built environment within heritage conservation areas might also allow new buildings to be proposed that are of a different style, but none the less retain the visual character of the area. New requirements for houses to meet low energy design criteria is also effecting the form and detail within houses.

Figure 16 Images of houses within the HSCA that have undergone an upper storey addition in the last ten years.

REFERENCES

Act, E. P. a. A. (1979). Environmental Planning and Assessment Act.

Al-Homoud, M. A.-O., Natheer. (2000). Sense of privacy and territoriality as a function of spatial layout in university public spaces Architectural Science Review, v.43, n.4, p.211-219.

Alexander, C. (2002). The Nature of Order. Berkeley: The Center for Environmental Structure.

Alexander, N., Stark, P. (2003). Neighbourhood Characters - Multi- or Mono-Cultural. Paper presented at the Planning with Diversity: Adelaide 2003, Adelaide.

Bovill, C. G., A.E. Wiedemann, G. (1996). Fractal geometry in architecture and design. Boston: Birkhauser.

Brolin, B. (2000). Architectural ornament: banishment and return. New York: Norton.

Chalup, S., Clement, R., Marshall, J., Tucker, C., Ostwald, M. (2007, April 1- 4 2007). Representations of Streetscape Perceptions Through Manifold Learning in the Space of Hough Arrays. Paper presented at the IEEE Symposium on Artificial Life, Honolulu, Hawaii, USA.

DIPNR, N. (2004). Neighbourhood Character. Sydney: NSW Department of Infrastructure Planning & Natural Resources.

Fisher-Gewirtzman, D., Burt, M., Tzamir, Y. (2003a). A 3D visual method for comparative evaluation of dense built up environments. Environment and Planning B, Planning and Design, 30, 575-587.

Fiske, J. (1987). Suburban Homes: Goods to think with, Myths of Oz (pp. 26-52). Sydney: Allen & Unwin Pty Ltd.

Foroutan-pour, K., Dutilleul, P., Smith, D.L. (1999). Advances in the implementation of the box-counting method of fractal dimension estimation. Applied Mathematics and Computation, 105(2-3), 195-210.

Gehl, J. (1996). Life Between Buildings: Using Public Space (J. Koch, Trans.): Arkitektens Forlag.

Groat, L. (1988). Contextual compatibility in architecture: an issue of personal taste? In J. Nasar (Ed.), Environmental aesthetics: Theory, research, and applications (pp. 228-253). Cambridge: Cambridge University Press.

Guy, B. (2002). The Demystification of Character. Paper presented at the Planning Research Conference, Dundee.

Harries, K. (1997). The ethical function of architecture. Cambridge, Mass: MIT Press.

Hillier, B., Hanson, J. (1984). The social logic of space. Cambridge, NY: Cambridge University Press.

Hull IV, R., Lam, M., Vigo, G. (1993). Place identity: symbols of self in the urban fabric. Landscape and Urban Planning, 28, 109-120.

Kropf, K. (1996). Urban Tissue and the Character of Towns. Urban Design International, 1, 247-263.

Laboratory, A. T. (2001). LeCorbusier Houses. Tokyo: Mitsuo Kawagoe.

LeCorbusier. (1954). The Modulor. Harvard: Harvard University Press.

Moughtin, C., Taner, O., Tiesdell, S. (1999). Urban Design: Ornament and Decoration (Second ed.). Oxford: Architectural Press.

Nelson, T., Johnson, T., Strong, M., Rudakewich, G. (2001). Perception of Tree Canopy. Journal of Environmental Psychology, 21, 315-324.

Newman, O. (1972). Defensible Space. London: Architectural Press.

Norberg-Shulz, C. (1963). Intentions in architecture. Oslo: Universitetsforlaget.

RAIA. (2004). Development (Sustainable Development) Amendment Bill 2004. Adelaide.

Rapoport, A. (1990). History and Precedent in Environmental Design. New York: Plenum Press.

Salingaros, N. (1999b). Urban space and its information field. Journal of Urban Design, 4, 29-49.

Salingaros, N. (2000b). Hierarchical cooperation in architecture, and the mathematical necesssity for ornament. Journal of architectural and planning research, 17, 221-235.

Salingaros, N. (2001). Modularity and the Number of Design Choices. Nexus Network Journal, 3(2).

Salingaros, N. (2003b). The sensory value of ornament. Communication and Cognition, 36.

Salingaros, N., West, B. (1999a). A universal rule for the distribution of sizes. Environment and Planning B, Planning and Design, 26, 909-923.

Schira, G. (2003). Texture preference and global frequency magnitudes. Environment and Planning B, Planning and Design, 30, 297-318.

Smith, T., Nelischer, M., Perkins, N. (1997). Quality of an urban community: a framework for understanding the relationship between quality and physical form. Landscape and Urban Planning, 39, 229-241.

Song, J., Lyu, M. (2005). A Hough transform based line recognition method utilizing both parameter space and image space. Pattern Recognition, 38, 539-552.

Stamps III, A. (1999). Architectural detail, Van der Laan septaves and pixel counts. Design Studies, 20, 83-97.

Theil, P. H., Ean Duane; Alden, Richard S. (1986). The Perception of Spacial enclosure as a function of the position of architectural Surfaces. Environment and Behavior, 18(2).

Townsend, L. (2001). The evolution of neighbourhood character. Landscape Australia, 23 (4)(92), 11-16.

Tucker, C., Ostwald, M., Chalup, S. (2004). A method for the visual analysis of streetscape character using digital imaging processing. Paper presented at the Proceedings of the 38th Annual Conference of the Architectural Science Association ANZAScA and the International Building Performance Simulation Association, Launceston, Tasmania.

Tucker, C., Ostwald, M., Chalup, S., Marshall, J. (2005a). A method for the visual analysis of the streetscape. Paper presented at the Space Syntax 5th International Symposium, Delft, Netherlands.

Tucker, C., Ostwald, M., Chalup, S., Marshall, J. (2006, November 2006). Sustaining residential social space: a visual and spatial analysis of the nearly urban. Paper presented at the 40th Annual Conference of the Architectural Science Association ANZAScA - Challenges for Architectural Science in Changing Climates, Adelaide, Australia.

Venturi, R. (1966). Complexity and Contradiction in Architecture. New York: The Museum of Modern Art Papers on Architecture.

VicD.I. (2001). Understanding Neighbourhood Character. Melbourne: Victorian Department of Infrastructure.

Zucker, S., Terzopoulos, D. (1980). Finding Structure in Co-Occurence Matrices for Texture Analysis. Computer Graphics and Image Processing, 12, 286-308.