A method for the visual analysis of the streetscape

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Abstract

This paper outlines an interdisciplinary approach, utilising architectural knowledge and computer imaging, to develop an analytical tool that describes the physical characteristics of a street scape. Techniques for connecting the urban texture at the scale of the individual, with the urban character of precincts within the city are difficult to find. One theory that does appear to be able to make such a connection is space syntax. By considering the open spaces generated by the existence of an interdependent built boundary extending in scale from the individual house through to the streets that form cities, space syntax attempts to explain human behaviour as it occurs in those spaces. Describing the visual character of a streetscape through analysis of its spatial configuration might then provide an objective measure within a planning field that is dominated by qualitative methods. A method of analysis is developed using an algorithm, based on the Hough transform, which provides a global measure of the geometry within the convex space of the streetscape. This image processing technique segments an image at a fine scale on the basis of discontinuity and similarity, allowing the edges that define features within the built surface to be detected. The density of edges within the textured surface then provides a measure of how visual detail is distributed throughout an image at different scales, a concept that is closely related to fractal geometry.

The approach is conceptually related to the theory of description retrieval, facade configuration and the facade isovist discussed by Hillier (Hillier 1996:p238; Hillier 2003). The streetscape is considered as a convex space where the visual field is constructed of elements that can be studied as an objective reality. The interrelationship of the elements or as Hillier describes, the way they are synchronised, might then provide an insight into how the street is understood at an experiential level.

Keywords: streetscape, visual analysis, Hough transform

1. 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. Yet, planning authorities throughout Australia use the character of a streetscape as one means of determining the appropriateness of a future development for any given site (VicD.I. 2001; DIPNR 2004). 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 affect of proposed building works within a streetscape this definition becomes a critical and potentially costly factor. 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.

With a reliance on expert evaluation, the analysis of a streetscape is essentially an individual's interpretation of what appears to be visually significant. Without a consistent approach within and between localities, the information derived about the character of streets and neighbourhoods lacks an objective basis for the discussion of a development's appropriateness (Alexander 2003). This paper posits that the application of image processing tools, using algorithms developed for refining computer visualisation, is one possible way of describing the optical and associated physical attributes of a streetscape. The intention for developing such software is to provide those involved in the planning process with a visual measure that is comparable across a variety of urban conditions and geographic regions. Specifically the software provides a measure of the form and complexity of the vertical surface of urban spaces that can be used in concert with more established planar methods of urban analysis including space syntax.

2. Key theories of visual character and streetscape

The assumption that some collective qualities must exist is in part supported by the proposition that the majority of people experiencing a particular city street or park must have shared some experiences in order for them to enter and use the space, and live in close proximity to it. Lynch showed that such resonances do actually exist and that these are, in part, a result of similar interactions between the physical reality of the space (street, park or square) and our basic human physiology (Lynch 1960).

The presence of common or shared meanings in the image of a streetscape suggests that it is possible to create or design environments that will be used and experienced by many people in comparable ways (Lynch 1960). From this research Lynch developed the concept of imageability; an ability for the shape, colour and arrangement of elements within an urban environment to evoke a strong image for an observer. Imageability is related to streetscape character in the way in which both are concerned with the visual arrangement of elements within the environment. Where Lynch shows how a city can be expressed diagrammatically as the combination of elements that differentiate parts of the urban fabric (Lynch 1960), streetscape character analysis attempts to do this at a much finer scale (DIPNR 2004). This is because streetscape character is specifically shaped by the boundaries between the elements that constitute the street wall or fa?ade, and how those elements relate to each other in patterns that are consistent within a specific urban or suburban built environment (Kropf 1996).

Various scholars have independently concluded that the amount of perceived complexity within a streetscape is an important variable that determines whether or not a person might find it appealing (Berlyne 1974; Imamoglu 2000; Stamps III 2003). The perceived number of elements within a streetscape, and particularly the "noticeable differences" (Rapoport 1990: p269) between them, provides a measure of visual complexity. Visual complexity 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). The way that the differences are gradually revealed, while walking down a street, determines the extent to which such a passage might feel monotonous, surprising or familiar.

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. The streetscape is also the home of a reciprocal relationship wherein the individual owner of a dwelling has some right to view the public and in doing so exert their influence over common space. This realisation affirms the importance of streetscape in debates concerning notions of privacy and separation (Fiske 1987). Thus the relationship between public and private spaces, expressed visually in the complexity of a streetscape, is an important determinant of its character (Alexander 2003).

3. Methods and approaches to streetscape analysis

Any attempt to describe the urban environment requires a study of organized complexities on many scales (Batty 1994). Techniques for connecting the urban texture at the scale of the individual with the urban character of precincts within the city, are difficult to find (Ratti 2004). One theory that does appear to be able to make such a connection is space syntax (Hillier 1984). The proponents of space syntax attempt to model an urban system by concentrating on free spaces between buildings (Jiang 2000). The shape of the free space is generated by the existence of a defined boundary (Norberg Shulz, 1965); an interdependent planar surface that can extend from an individual house through to the streets that form cities (Jiang 2000). Using a configurational description of an urban structure, such as a streetscape, space syntax attempts to explain human behaviour as it actually occurs in those spaces. Its premise is that the configuration and character of urban space has a major influence on the perception and subsequent conduct of people who use it (Hillier 1996; Fisher-Gewirtzman 2003).

In terms of streetscape, Hillier proposes that configurations of building facades may be viewed as an arrangement of shapes which are orientated "to and away from the ground on which they stand" (Hillier 1996: p120). He represents a building's facade as both a "metric tessellation" (which is then investigated to provide a measure of connectivity) and as a diagram of "the dominant elements in the facade, as a pattern of convex elements" (Hillier 1996: p122). Using an example of the facade of a classical temple he shows that both diagrams are visually in opposition, creating a tension that is possibly alluring. For Hillier this is "what the human mind 'reads' when it looks at the form of a building is, or at least includes, the pattern of integration at more than one level, and the interrelations between the levels." (Hillier 1996: p122).

The concept of information retrieval (Hillier 2003) discusses the way in which a visual scene is understood simultaneously as both a relationship between elements and as a whole. Thus the processes of visual perception may be embedded within spatial morphology (Turner 2003); or as Hillier claims, space itself may be the machine. This suggests that the viewer "may merely need to determine the humanly accessible topology as invoked through the process of inhabitation" (Turner 2003) to determine the merits of proposals within the urban fabric. In this way a measure of the salient geometry within a streetscape or "small scale spaces" might reveal a topology that is useful in the analysis of larger urban areas (Jiang 1999).

Instead of increasing the complexity with which the streetscape is visually or otherwise recorded, perhaps a study that could establish a topology or patterns may prove more useful. Turner developed this method specifically as a configuration that could be studied in plan, where agents that assess the visual dynamics of the spatial morphology govern the process of visual inhabitation. This paper maintains that it is possible, in parallel to such an approach, for an analysis of the topology of the streetscape to take place. In such an elevational (rather than planar) approach it is the arrangement of the streetscape elements that are seen as a configuration.

The concept of an isovist; a set of points visible from another point in space (Batty 2001), could also be enhanced by a consideration of the three dimensional surface of the urban scape. The isovist analytical technique has developed (Benedikt 1979; Hillier 1996; Batty 2001; Batty 2004; Carvalho 2004) largely as representation of planar arrangements with little consideration of the volume of the urban space. The concept of a facade isovist (Hillier 1996) which describes the planar area of urban space that a facade is visible from appears to be a measure which would be enhanced by an evaluation of the facade itself. Considering the spatial complexity within urban systems and the increased speed of computers, research that considers all three dimensions has recently been developed by a number of researchers. Fisher-Gewirtzman who considered a three dimensional viewpoint and the volume of visible space as a measure of spatial openness (Fisher-Gewirtzman 2003). While requiring considerable computational power to develop accurate three dimensional models of urban areas, this type of analysis is becoming more prevalent in the field of computer vision. Teller similarly examined the three dimensional openness of streetscapes and town squares by creating a two dimensional image from a wide angle view looking vertically towards the sky (Teller 2003). This method, despite its lack of true three-dimensionality, was nevertheless an important step towards incorporating the street elevation within a study.

Researchers have also studied the geometric qualities of the streetscape in an attempt to understand what characteristics are considered to be the most desirable. For example, Oku and Cooper have separately attempted to determine the fractal dimension (a measure of complexity across multiple scales) or character of city skylines (Oku 1990; Cooper 2003). Salingaros and Crompton have discussed the question of the significance of detail at different scales within building facades and the success of associated urban spaces (Salingaros 2000; Crompton 2001). While Stamps (Stamps 1999) used a theory of visual septaves (detail that occurs at a seventh of the facade size) to show that decoration and trim within a fa?ade were desirable attributes within the streetscape. Another related technique places regular grids over streetscape images, either to recognise the boundaries between surfaces (Bovill 1996), or to allocate a value to a particular surface type (Krampen 1979). Generating this for the whole facade, both methods then provided a measure of how boundaries might change throughout the image. An alternative method uses the human eye to separate a streetscape into formal elements and groups of elements. The frequency of the elements can then be considered as a measure of visual diversity (Stamps 1999; Malhis 2003; Stamps 2003). In contrast, Nasar relied on design professionals to quantitatively assess images of streetscapes to determine the prominence of built form, shape and material quality for each of thirty images (Nasar 1988). In other studies houses within a street scape were analysed using three scales of decomposition; overall massing, secondary massing, and differentiation of elements such as doorways and windows (Elsheshtawy 1997). Malhis and Elsheshtawy both similarly attempted to segment the streetscape into meaningful elements in order to provide an objective measure of the visual character of a street. However both

rely on time-consuming, skilled, manual techniques in the segmentation process; a practical as well as s possible methodological problem.

In an attempt to overcome such problems Ratti used digital elevation models (DEM's) to show how a simple plan of an urban area might be used to store information about a range of variables including height or pollution (Ratti 2004). The method is computationally lean, using algorithms that are "independent of geometric complexity and relate linearly to the area under investigation" (Ratti 2004). While not directly applied to the streetscape the methods described show that useful information about the environment might simply be obtained through digital image processing. However in terms of understanding the surface of the urban environment in its vertical dimension or at the detail that users come into contact with that surface (Salingaros 1997) the technique has limitations. Hildebrand offers an interesting reflection on this when he maintains that successful architecture results from an abstract drive to impose patterns on surfaces that otherwise appear to be random acts of inhabitation (Hildebrand 1999). These patterns are then the physical attributes of buildings that help to identify visual regions of interest may make them appealing to us (Schira 2003). Capturing and analysing the texture of the vertical surfaces of the urban environment might then provide valuable information about how cities are inhabited. While the lack of computing power may have limited studies in the past, there are a number of current research projects that are using sophisticated methods to model the urban surface, and its form with a high degree of accuracy.

Ground based and air-borne laser sensing equipment provides the best methods for quickly and accurately constructing geometric and photorealistic models of individual buildings and entire urban regions (Stamos 2003). Freuh, Jain & Zakhor have developed automated methods that rapidly acquire the form and texture or an urban environment from the ground (Frueh 2005). Using fast 2D laser scanners that provide information about the shape of the urban surface and a digital camera that captures its texture and colour, with the equipment attached to their vehicle they drive at normal speeds to acquire the information they require to construct the models. The method also has the potential to construct protrusions from the surfaces of buildings such as awnings and to place urban fixtures such as signs and trees within the model. With urban spaces and surfaces so accurately constructed within a digital framework the potential for the analysis of how cities are inhabited and used appears to be vast.

4. A method for visual analysis of streetscape

An elevation of a streetscape was formed using a sequence of digital images that were taken on the ground by a hand held digital camera. The images were then "stitched" together to form a relatively seamless street facade. This image was then segmented into smaller images representing the boundaries of the private property in one set and in the other a standard street length of six metres. This process allowed for a measure of the geometry at discrete parts of the streetscape and ensured that elements within the street facade were analysed only once (Tucker 2004). The images were then processed using algorithms developed within computer vision to differentiate and segment the visual environment based on the boundaries formed by colour, texture and intensity levels (Boldt 1989; Gonzalez 1992). The developed software called Scape incorporates the Hough Transform, an algorithm that can establish the edges or boundaries within the image by considering the geometry within the entire image (figure 213). Through this method Scape is able to find



Figure 213: Detection of edges within an image, the perpendicular direction and magnitude of a possible line passing through a pixel is indicated by the arrows.

boundaries of low intensity and those that are discontinuous but of a sufficient proximity to be perceived by humans as a continuous edge (Boldt 1989; Guy 2002; Yang 2004).

For instance the side of a window that may be partially obscured by a tree is considered to be a continuous line, while the top of a row of timber battens of the same height will similarly form a line. All potential lines or edges are graphed as points in an accumulator array, each with a specific magnitude provided by the number of pixels within the line, an example is shown in figure 214 left.

By adjusting the peak threshold for accumulated lines, the number of lines that at least contain this user defined number of pixels will be counted. By incrementally changing the peak threshold, a series of line counts is produced that shows the number of lines of a particular length within the image. A number of images can be processed at once, the software resizing each image such that it contains the same number of pixels. Depending on the scale of detail within the image to be analysed, the image resolution can be set accordingly. Figure 215 graphically shows data from the processing of the image besided as the length of horizontal lines, vertical lines and a total of both (diagonal lines are defined as vertical or horizontal depending on the closer inclination).

The peaks in figure 215 show a high number of lines of the same length within figure x At this processing resolution a door height is around 100 pixels, however as the side of the door corresponds with one above then the line will be detected as a line with at least 200 pixels. This characteristic of the Hough transform allows Scape to establish the visual structure of the image in a similar way to human perception which groups lines to



Figure 214: LEFT: An accumulator array from Scape, the brighter points indicate significant boundaries within the image. RIGHT: Image of a modern townhouse processed with a resolution of 307,200 pixels (640 x 480), together with a graph of the vertical, horizontal and total number of lines within the image, most detected lines are more than 10 pixels in length

form objects (Boldt 1989; Rapoport 1990: p269; Guy 2002). These longer lines are not represented in figure 215, with 11 of the total 251 lines found within the image greater than 85 pixels in length. As the pixel threshold for each line increases above 85 the changes in the number of lines decreases. The remaining lines reveal the primary structure of the building, bound by the ground, roof elements and other significant features.

It is the position and relationship of these lines that is potentially interesting, simply graphing their length has found to be of limited value. Lines existing in the finer scale of the image such as the textured wall surface are not represented in the graph, however high resolution images can be processed revealing this type of detail. Each image will vary in the proportion of vertical and horizontal edges; however for the purposes of this paper the total number of edges will be used for comparing streetscapes. The distribution of lines of different length and the location of significant changes in that length are of the most interest.

5. Application of Scape for the analysis of detail within streetscapes

To explore the application of Scape to an analysis of the visual quality of the streetscape, parts of three streetscapes typical of the eastern coast of Australia have been processed. Streetscape A (figure 215) is from an inner city street where dwellings have been occupied for the last 100 years, landscaping and fences are close to the front boundary, with no off street parking vehicles are often parked in front of the houses. Streetscape B (figure 215) is from a suburban street where detached houses are setback from the road with low-lying front yards and off street parking in the form of garages and driveways. Streetscape C (figure 215) if of recently constructed townhouses within a newly established suburb. They have little private open space at the public boundary with vehicles entering and being stored at the rear of each property.

Each similarly proportioned streetscape image was reduced to 153,600 pixels (a door being approximately 30 pixels high) and processed using Scape at increments of three pixels in length. The graphs produced are shown in figure 216, as overlays with each other. These graphs can be studied by looking at the distribution of the peaks at different



Figure 215: Streetscape A, Streetscape B and Streetscape C (Tucker 2004)



Figure 216: Streetscape A, B, C, (Tucker 2004),

thresholds.

When streetscape A and B and streetscape A and C (figure 216) are overlaid the difference between the lines indicates the number of lines of a specific length that are not present in streetscape B or C. This would suggest that the length of edges within streetscape B and C are less evenly distributed than those in streetscape A. When the peaks of each analysis are joined to form a line (figure 216) this can also be seen, Streetscape A has peaks distributed linearly, while streetscape B and C have peaks that diminish geometrically. Considering that streetscape B and C have little in common spatially it is interesting that their analysis should show such similarity (figure 216). There is perhaps no surprise in the fact that new and old streetscapes should be differentiated by the amount discernable edges within their facade (Salingaros 2000), however if this quality can be quantified then it might provide a basis for further discussion about the character of the streetscape.

6. Discussion

In this study it can be seen that digital image processing techniques can be used to provide a measure of the visual appearance of a streetscape. However there is a great deal that could be done to extend the effectiveness of the software. Many buildings are required to be processed to determine what aspects of the large amount of data produced will provide the most effective analysis. At this stage Scape is restricted to the analysis of the total number of edges within an image, but it is developing methods to incorporate colour and recognition of recurring patterns such as windows, doors and vehicles.

Considering the street as an arrangement of boundaries between elements at different scales has been regarded as a significant variable of the visual character of an urban space (Groat 1988; Imamoglu 2000; Stamps 2003). While current streetscape analysis techniques similarly rely on the determination of boundaries, the method has relied on the individual to establish them manually. Depending on the values that each brings to such an analysis the outcome lacks a basis for comparing streetscapes and localities with each other. Although the concept of providing a measure for the visual complexity of a streetscape is in its primary stages, the Scape software has shown that an automatic analysis of the length of edges within an image might be calculated. This measure appears to be a useful way of understanding how visual detail is distributed throughout an image at different scales; a concept that is loosely related to fractal geometry (Batty 1994; Salingaros 1999). How this measure might relate to the facade isovist has not as yet been evaluated, however the rate at which textural information of an urban space becomes available to a user would appear to be an important consideration (Hillier 1996:p236). As an observer moves from a distance towards a facade, different scales of built form and detail become evident. How this effect might be quantified and developed in parallel with other methods of urban analysis is an investigation that has just begun.¹.

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- ¹ Scape is able to provide an overlay of the detected lines with the original image, producing a diagram which has been used to calibrate and refine the software. However at this stage it is not able to compare these diagrams with others and provide information about the proportional qualities of streetscape images.

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