Spatial configuration within residential facades

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Abstract
This paper outlines the preliminary outcomes of an interdisciplinary approach to describe the physical characteristics of urban residential facades. Utilising architectural knowledge and computer imaging, the spatial configuration of elements within a dwellings façade are shown to form patterns that are then repeated in other dwellings. The method relies on the visual analysis of a dwellings façade. Stylistic elements, textures and other features at a fine scale are considered in the same way that more formal elements such as doors and windows are considered at a larger scale. When the urban façade of a dwelling is studied as a composition of elements at different scales, the built form might be considered as a textured surface defining the open space of the street. This surface that dominates the visual field may play a critical role in the way that abstract information is retrieved from the city, as discussed by Hillier and Hanson (1984) as description retrieval. This paper shows that the facades of dwellings of similar styles have similar patterns of composition.

1. Introduction
This paper suggests that the use of image processing tools and algorithms developed for refining robotic visualisation is one possible way of describing the visual qualities of a residential facade. 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 the façade such that it might be used in concert with more established planar methods of urban analysis, including space syntax.

2. Visual Complexity
Various scholars have independently concluded that the amount of perceived complexity within a dwellings facade is an important variable that determines whether or not a person might find it appealing (Berlyne 1974; Rapoport 1990; Imamoglu 2000; Stamps III 2003). The perceived number of elements within the facade, and particularly the “noticeable differences” (Rapoport 1990) 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). 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.

Stamps states that while empirical work on architectural detail is sparse, it tends to support the hypothesis that "detail is an important part of preferences for buildings" (Stamps III 1999). Salingaros reflects that ornamentation "connects us to our environment" (Salingaros 2003b) and that successful buildings facades within an urban space feature a "continuous swath of high-density visual structure that the eye can follow in traversing their overall form, or focal points of intense detail and contrast arranged in the middle or at the corners of regions" (Salingaros 2003b). He has shown that ornament and decoration "subdivide building façades on many different scales" and that the most effective hierarchical scaling creates a fractal geometry (Moughtin 1999; Salingaros 1999b) which is independent of any associated scale. 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.

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 2000a; Crompton 2001). While Stamps (Stamps III 1999) used a theory of visual septaves (detail that occurs at a seventh of the façade size) to show that decoration and trim within a façade were desirable attributes.

Another related technique places regular grids over images of building facades, either to recognise and count the boundaries between surfaces (Bovill 1996), or to allocate a value to a particular surface type and form a sequence (Krampen 1979). Generating this for the whole façade, both methods provide a measure of how boundaries might change throughout the image.

An alternative method uses the human eye to separate a residential façade into formal elements and groups of elements. The frequency of the elements can then be considered as a measure of visual diversity (Stamps III 1999; Malhis 2003; Stamps III 2003). In other studies dwellings 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 residential facade into meaningful elements in order to provide an objective measure of their visual character (Figure1). However all methods tend to rely on time-consuming, skilled, manual techniques throughout the segmentation process; a practical as well as s possible methodological problem.
Other researchers comment that the elements within buildings of roughly the same size “couple strongly to become an element of the next-higher order in size”, single elements then have a role in linking elements together to form elements of a larger scale (Salingaros 2000a). Jacobs (Jacobs 1961:p234) similarly points out that diversity in urban uses can become a problem when the size of elements is of a disproportionate size. For a harmonious or contextual fit a building should have regions bounded by edges within a “hierarchy of scales” with the same “definition and connections as the building’s internal subdivisions” (Salingaros 1998). Salingaros (Salingaros 1999b) states that the buildings façade, pavement surfaces and other urban features such as trees and furniture can generate these regions. It is then the perception of these elements in terms of the organisation of form and the differentiations within the surface generates the “information field, which in turn determines the use of urban space” (Salingaros 1999b). The concept of a façade isovist (Hillier 1996) which describes the planar area of urban space that a façade is visible from appears to be a measure which would be enhanced by an evaluation of the facade itself.

Ratti has 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 elevation of buildings the methods described show that useful information about the environment might be simply 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.
3. A study of residential facades

The software we have developed, named *scape*, uses the Hough Transform to establish the visual boundaries within an image. By considering the geometry within the entire image, images are processed to differentiate and segment them based on the edges formed by colour, texture and intensity levels (Boldt 1989; Gonzalez 1992; Tucker 2004; Yang 2004). The histogram produced provides the number of lines of a specific pixel length within the image. A pixel within the image can then be given a size, allowing the length of a boundary to be expressed as a metric dimension; for instance, a 640 x 480 pixel image of a dwelling has a resolution where a single pixel is around 20mm in length. The metric length of a boundary is then multiplied by the number of boundaries of that length, providing the total length of all boundaries a given length. This information is then displayed in a graph, as shown in Figure 3. If visually similar facades are processed and displayed on the same graph, similarities can be seen between the graphs. Figure 4 for instance shows three modern terrace houses that have very similar designs, while the total boundary length of a given length may vary between images (as can be seen in the peaks and troughs within the graph) the essential shape of the graphs are quite similar.
Figure 5 shows another terrace in the same street that is again of similar design but includes a tall masonry element, the resulting graph is perhaps similar in shape, but the magnitude of boundary length is different (more). Figure 6 shows that the two dwellings with this masonry element again have similar graphs, and when this is overlaid with the graph in Figure 4 it can be seen that the now five dwellings can perhaps be differentiated by the shape of the graph alone.

Figures 7 and 8 show graphs of traditional dwellings of an Australian ‘federation’ style; while the images may appear visually different (Fig 8 - particularly detailing and material differences), the general shape of the graph does show some similarities. The other noticeable characteristic is that the graphs show more developed peaks and troughs over the extent of the graph, a characteristic of traditional buildings that has been discussed by a number of researchers including Salingaros (Salingaros 1999b), Alexander (Alexander 1977) and Bovill (Bovill 1996). The differences between the graphs generated by dwellings of different styles can be seen in Figures 9, 10, 11 and 12. By successively overlaying the graphs, the differences between them become obvious.
The study still has many more buildings to analyse and the software will continue to be developed to encompass other characteristics of the building façade such as colour, shadow and object recognition. The results presented in this paper however do show that the application of image processing to understand the geometric and visual characteristics of a buildings façade does appear to have substance.

4. Discussion

Visibility analysis is a seemingly attractive way to understand urban spaces as it appears to allow "mathematical certainty to the experience of urban and building environments" (Turner 2003). However by concentrating on visual relationships rather than an "interpretation of direct perception" (Turner 2003) the analysis will always require a level of interpretation based on how the information has been collected and how it will be used. Different cultural, and social backgrounds will necessarily interpret visual information differently (Turner 2003).

However one of qualities visibility analysis that makes it so useful for a comparative analysis is that the representational and symbolic meanings of a buildings style play no part. The organisation of the elements can be analysed without having to interpret them at the beginning of the process. This is not to say that representational meanings are not important to the visual character of a dwelling, but that both methods might work in parallel to provide a more thorough study of the urban environment.


