

The Fractal Pattern of Cities

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***Abstract:** The paper adds another layer to usual descriptions of colour in cities, which is fractal order patterning, across a multi-scale analysis in relation to human perception of space and time and to cultural meaning. The paper examines the fractal patterns of colours in cities that belong to different civilizations, with a special focus on Venice, and explores their multi-scale colour patterns.*

***Keywords:** urban, colour field, fractal patterns, color, pattern, harmony*

1 Introduction

Historical writing on cities continues to stress the Cartesian dominance of form and space and to underplay the role of colour in city patterns. This stems from attention being focused too little in colour in architecture and the social world. To understand the value of colour in cities, it is necessary to include building materials, mosaic, outside frescoes, in the enquiry. It is possible to comprehend then the scale free patterns of colours that derive from the system of values of different civilizations. In cities colour is substantial and meaningful rather than mimetic. The polychrome fabric of ancient Athens, ancient Rome, Byzantium, Venice, Samarkand, Isfahan constructs and signals at all scales differences and distinctions. Chromatic value in material and pattern builds a world before it imitates one [1].

This world was fractal. A fractal has been defined as a rough or fragmented geometric shape that can be split into parts, each of which is (at least approximately) a reduced-size copy of the whole, this is self-similarity. But a fractal is more than that, it is the hidden order and harmony of nature founded on a form of symmetry, scale symmetry, meaning more generally that through a series of scales we find at each scale complex patterns of order. Our key hypothesis is that colour in historical cities is not distributed randomly but according to fractal patterns. This hypothesis follows in the wake of the body of work in our recent book *Cities and Forms* [2], which demonstrates that the spatial order of historical

cities is fractal and that the distribution of elements in historical cities follows inverse power laws characteristic of fractal structures.

In this paper, we will consider the fabric of the city at all scales, the layering and sedimentation of colours within the city fractal structure. Such an approach reveals patterns of repetition and reinforcement of the urban information field in optical, informational, and architectural discrimination. It also reveals patterns of ambiguity and specific powers of colour notably on time perception.

2 Fractal Patterns of Order

2.1 Colour and the Urban Information Field

“Urban space, as Salingeros points, is more sophisticated mathematically than we are used to thinking. At the other extreme from a collection of static, non-interacting simple forms and voids, in reality we have a complex system tied together by both static and dynamic interactions [3].” Colour is a key part of this fractal structure of the information field.

According to Salingeros: “The use of urban space is linked to the information field generated by surrounding surfaces [4].” In historical cities, this urban information field is usually concave and fractal. According to Salingeros, concavity and fractal structures optimize visual and acoustical information. The role of colour has not been integrated in the analysis. We will show in this paper that colour, contrary to form and shape, is not limited to its physical support: it is a radiant quality, like light, which extends into space beyond shapes and surfaces. It enriches considerably the information field and has been used very subtly by architects and associated with texture, with light and shade, with brilliance of marbles and matte coarse grain of stones, with encrustation and contrejour. As a perceptual phenomenon, colour creates a much more complex information field than simply the manipulation of shape.

The information field originates in the surrounding urban surfaces: it permeates space and connects it to human consciousness. Colour is more complex than shape as it varies endlessly according to time and weather changes, the thickness and movement of the air, and above all it is reconstructed in the mind’s eye through an interpretation of the texture and orientation of surfaces. In a complex fractal coloured urban information field, urban space is enhanced by the relationship between the human mind and the field. When colour enters into the city fabric, the human receptor creates the field as much as it is influenced by the flow of information. In a coloured field, the solid boundary of the city surfaces dissolves and the human experience becomes more temporal than spatial.

2.2 A Rhythmic Experience in Time

Colour in cities is a three-dimensional experience unfolding in time. We experience the urban colour dynamics in fleeting scans peppered with momentary fixations. If these scans don't reconstruct a higher form of order, the city appears alienating and meaningless. Meaningful patterns of colours perceived into sequences make the city a four-dimensional experience.



Figure 1: Colour unfolds in the rhythmic beat of time of Venice lagoon (photo: Serge Salat).

Colour defines but does not separate like form. Thus it unfolds in time and in the rhythmic beat of time produced by the smallest changes of weather. This rhythmic universalizing power of colour comes from the atmospheric effects of ambient light that establish an affinity amongst the lights and another affinity amongst the shadows. Such affinities cut across the entities in the city that line and shape may separate. Islamic ornament for example is a green and blue tide of colour, which submerges any structural distinction in the architectural forms.

2.3 Order and Urban Ritual Meaning

But colour in historical cities was even more than that: it was a true polychromatic medium expressing social order and urban ritual meaning. Colour plays a key role in the inhabitant's sense of being at home in the city social space. Colour has a social meaning based upon cultural and semantic classifications. By harmonies of colour, the city fabric creates the myth of political serenity amongst city and citizens. Venice, Isfahan, ancient Beijing by their patterns of colours transcending

the boundaries of individual architectural objects create a unique relation between the citizen inhabitant and the city as a complex work of art and a socially meaningful pattern. Colour plays a role in this cultural meaning of cities, operating both at a conscious level in the distribution of colours (yellow for the emperor in China, blue and green for the mosque vault in Islam) and at a subliminal level of shared common experience. Colour is manipulated in cities, as well as seen, and every citizen possesses colour and is born into colour.

For example, in classical Beijing, imperial yellow, and red, as opposed to the general greyness of the private houses expressed the large-scale fractal order of the city, with the Forbidden City, in the centre, and the grey maze of private siheyuan (quadrangle houses). This was the large-scale colour pattern of the city. If we now zoom in into the urban fabric, there are many subtle differentiations in bright yellow, red, blue and green inside the imperial areas, as well as a symphony in different matte greys in the residential fabric. At each scale of the city, from the large-scale order to the minute detailing, patterns of colour appear but they play subtly on the reduced palette belonging to each scale, like in Japanese gardens the endless variations in green of the moss colours or in ochre of a mud clay wall.

This is also true but ordered differently in Islamic cities, especially in Iran, where the blue and green Iwans of the mosque, are images of paradise hidden in the maze of the monochromatic white or ochre residential areas. Distinguishing coloured patterns of Islamic architecture have always been ordered repetition, radiating structures, and rhythmic patterns with scale symmetry but no translation symmetry (Penrose tiling). In this respect, fractal geometry has been an ordering pattern, especially for mosques and palaces. But the residential areas in Islam are monochromatic only on outsides and enclose hidden richly colour patterned courtyards in a reduced palette than the mosque and palaces. Here the urban ritual distinguishes between public space and intimate interior family space. The fractal colour urban order of Islamic civilization is more linked to an inside/outside, public/private, hidden/revealed pattern that permeates the urban fabric through its different scales.

This fractal order is extremely clear in civilizations like China or Islam where the usage of urban colour was regulated. It nevertheless exists in Medieval and seventeenth century Europe, where colour is not distributed randomly but obeys fractal patterns such as in Venice, Delft, or Prague and Tallinn in Estonia. We will now focus on one city and investigate Venice patterns of urban colours at different scales in order to show how subtle was the interplay of colour and form in a European Medieval city.



Figures 2 and 3: Venice lagoon changing colour field (Photo: Serge Salat).

3 Venice Fractal Colour Field

3.1 The Lagoon and the Fractal Information Field

In Venice, the lagoon is by itself an ever-changing fractal information field sensitive to the tiniest weather change. On Venice lagoon, boundaries are not rigid, tides raise and lower; the baseline from which architecture arises is variable. The jade-green patterns of colour of the lagoon are endless, imbued with latent energy. Colour manifests itself by turns as a phenomenon adhering to surface, or spreading into a film, or filling a volume [5]. Colour adds a layer of ambiguity and fleeting movement to the city: “It may bound, may veil or may defy limit and definition, opening to the abyss and chasm of space [6].”

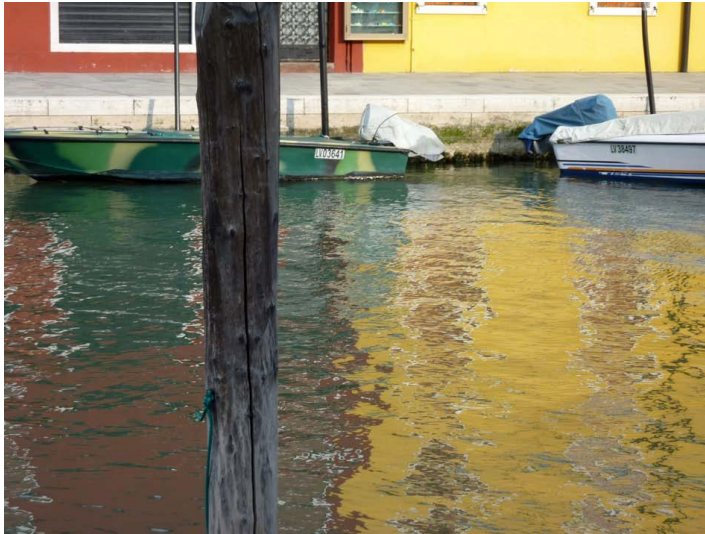


Figure 4: Venice lagoon changing colour field defies limit and definition (Photo: Serge Salat).

3.2 Fractal Patterns on the Palazzo Ducale



Figure 5: Marble encrustation on Basilica San Marco wall near the entrance of Palazzo Ducale (Photo: Serge Salat).

But not only the lagoon is an ever-changing surface. Buildings in Venice interweave colours in fractal patterns. The façade of the Palazzo Ducale on the Piazzetta for example consists of tiles of white Istrian and orange-red Verona stone set in an interlocking pattern of lozenges. The longitudinal slabs are set

horizontally, each row overlapping by half to create a regular pattern of red and white that zigzags diagonally across the wall in stepped rhythm. The shared interface of red marble between each diamond does not quite become a continuous diagonal because of the extra width of the step at their junction, which creates a ripple in the colour as it runs across and up the wall. Seen from the ground, this shift is just enough to maintain a teasing ambiguity as to whether the diamonds should be read as locked into a mesh, subordinate to a large design, or whether the larger design is simply the aggregate of the individual motifs. Once again the fractal patterning in urban colour is subtler than plain self-similarity. Fractal patterns in city colour fields are ambiguous enough to stimulate the visual perception of time, space and movement. They are based on perceptual effects for the eye in motion and on enhancing the movements of air and light rather than on mechanical repetition. At the centre of each lozenge of the Palazzo Ducale façade are crosses of grey marble with some squares in Veronese red. The configurations vary, adding an element of surprise to the overall pattern. This use of lozenge shapes is close to Islamic sources and is reminiscent of the Persian decorative tradition. The pattern is non architectonic and covers the building like a textile beginning and ending seemingly at random like a cut from a huge roll of textile. The size and sequence of the diamonds are not gauged according to the vertical or horizontal edges or the spacing of apertures.

3.3 San Marco Basilica Fractal Marbles and Mosaics



Figure 6: Basilica San Marco porch (Photo: Serge Salat).

In the pavement of San Marco Basilica, many patterns, especially the circular ones, are constructed with a “field” of pale grey marble rhythmically interspersed by the “figure” of coloured marbles. Figure and field may interchange, but tonal contrast remains. In the sections of polychrome infill, the regular juxtaposition of

porphyry and serpentine is typical of opus sectile floors. These polychrome areas of larger opus sectile alternate with areas of smaller opus tessellatum made of a predominantly black and white with some red denser mesh of dice-like cubes. Quite often some black and white checker work is included within the area of figure creating an effect of diaphanous cells through which the light of the ground shines. This conjunction between the two scales of mesh in opus sectile and opus tessellatum is by essence an ambiguous fractal pattern and the pavement shows no rigid self-similarity but rather an astounding invention in self affinity (a fractal process with changing patterns when scale changes) allowing to insert incrustations of light patterns into coloured patterns.

This complex colour and light fractal pattern is the archetype of the general pattern of encrustation and perforation that unfolds in all Venice surfaces. A Paul Hills remarks, “Florence is the city of stone, Venice of encrustation [7]”.

Accompanying the general coloured encrustation of surfaces with veneered coloured marbles (over layering porphyry against verde antico), Venice shows a distinctive gothic fenestration perforated with light. This distinctive contrejour fractal patterns contrasting darkness and sharp light of Venice gothic fenestration is echoed in the black and white opus tessellatum of San Marco’s pavement.

3.4 Marbles, Gold, the Floating Lightness and the Eye in Movement



Figure 7: Round marble columns dissolving the surface at the entrance of Basilica San Marco (Photo: Serge Salat).

The coloured marbles of San Marco Basilica dissolve the visual boundary between the hard surface of the wall and the ample space of the interior. By touch and sight the marble veneers are located on the surface of the walls, yet their fractal patterns, mobile and undulating, seem to pulse, contract and expand beyond the

surface. The veneers of marble demonstrate symmetry through the visual litany of answering patterns due to the cleavage of two halves. But they also demonstrate fractal scale symmetry when, moving closer to the wall, marble reveals its very process of igneous formation in a narrative of veiling and unveiling: in serpentine, for example, splinters of pale green glow, embedded within the darker matrix of green.

Other veneers – particularly the Greek grey marbles – open depths as between layers of clouds. “From a distance the butterfly patterns read as an opening of the heart of things and the spreading of what was inside upon the surface [8].”.



Figure 8: Basilica San Marco marble patterns (Photo: Serge Salat).



Figure 9: Venice floor patterns (Photo: Serge Salat).

The general encrustation of marbles and the golden surfaces of San Marco in Venice and Hagia Sophia in Constantinople deny the weight of structures, a quality admired by the Byzantine Procopius in his account of the sixth-century: “Rising above this circle is an enormous spherical dome, which makes the

building exceptionally beautiful. It seems not to be founded on solid masonry, but to be suspended from heaven by that golden chain and so cover the space. All of these elements, marvellously fitted together in mid-air, suspended from one another and reposing only on the parts adjacent to them produce a unified and most remarkable harmony in the work, and yet do not allow the spectators to rest their gaze on anyone of them for a length of time, but each detail readily attracts and draws the eye to itself. Thus the vision constantly shifts round, and the beholders are quite unable to select any particular element which they might admire more than all the others [9].”.

3.5 Colour as Slowing Time and Motion

The patterns of marble discourage the fovea vision and invite the broader visual awareness of peripheral para-foveal vision. Within the space of San Marco, between the nave and the revetments of the aisles, are the unfluted marble cylinders of the columns. With the rhythm of waves of the rounded patterns of the columns on the larger symmetries of the wall slabs, the air itself seems thickened with colour: “Indeed when orientation of surface is understated, uncertain even camouflaged, colour may float detached from surface, hang in the air [10].”.

In a monochrome urban field the configuration of edges of three-dimensional objects changes as the observer moves and the visual system correlates the changing configuration of objects with the shifting angle of vision. But in a coloured complex field such as San Marco or Hagia Sophia, the patterns in gold or in veined marble are slow to change with the angle of vision. When somebody moves slowly in this type of field, time seems to slow down as the viewer becomes relatively unaware of the change of his angle of vision. This creates a feeling of slower motion within a larger unfolding than in real life.



Figure 10: Light and shadow, rose and grey floating colours on a Venice palazzo facade (Photo: Serge Salat).

4 Conclusion: Modernism and the Loss of Colour

As Venice, all medieval cities were extremely rich in colours and Central Europe Baroque cities were also colourful information fields. Yet in 20th century the disappearance of urban colour (replaced by a dull grey or a universal glass) has been parallel to the extreme reduction of the urban information field. For modernist urbanism, defined by large-scale geometry, empty volume exists only in an abstract, mathematical sense.

With the modernist movement, our cities started to loose their fractal patterns of order. With modernism, cities also lost the order in space crated by their fractal patterns of colour. They became grey. Colour was a key element to relate human beings to the various scales of the built environment and to make the city legible and understandable. Becoming grey is not just loosing tone and hue, vibrancy and pattern. It is loosing differentiation and scaling order. It is also loosing rhythm and meaning in urban rituals.

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