SPHERICAL INSTRUMENTATION FOR THE URBAN MORPHOLOGY ANALYSIS

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ABSTRACT

This paper introduces and discusses several analysis techniques for the quantitative assessment of urban morphology. A new instrumentation, based on spherical projections, was developed in order to address more directly the urban open space three-dimensional characteristics so often obliterated by traditional urban planning standards.

1. INTRODUCTION

Since the decline of the reliance on traditional zoning schemes, urban open space quality has been raised as a major issue in the Urban Agenda *(Expert Group on the Urban Environment, 1996)*. The urban open spaces are the empty spaces left apart the built (filled) elements. It comprises urban public spaces such as streets, city squares and the environment around monuments, a variety of green spaces, including formal and informal parks, remnants of natural systems such as along watercourses etc. All these spaces typically constitute the actual arena of urban life, e.g. in terms of meeting places, and their amenity value includes a contribution to quality of life and aesthetic enjoyment. That is to say they should be truly considered as basic urban components rather than as the "space left over after development". Awareness of this necessarily meaning shift has been the main motive for "urban design" emergence in the early 90ies.

Urban design is commonly defined through two different ways. First, through its scale which is considered as intermediate between architecture and traditional land planning. It is also defined through its scope. Urban design would specifically focus on the three-dimensional interactions between buildings and open spaces *(Punter & Carmona, 1997)*.

As such, it is characterised by a number of specific properties. For instance, the number of objects to be considered in urban design is usually much larger than in architectural design. Furthermore, these objects are quite complex (3D volumes) when compared with land zoning ones (2D zones and networks characterised by limited attributes). Finally, urban design is also uncommon through its basic procedures. Political, judicial and technical considerations are interwoven in such a way that none of these three aspects can be neglected for the effective implementation of any urban design scheme.

This being said, urban design shares at least one common aspect with all other design fields, namely it requires some instrumentation for the various alternatives to be specified, compared and evaluated. In this perspective, some computers models were already developed for the assessment of specific urban design issues, i.e. visual integration *(Hillier & Hanson, 1981)*, solar energy availability *(Teller & Azar, 1999)* or morphological analysis.

The present paper will focus on this last aspect. Morphological analysis typically addresses the urban forms intelligibility through a set of procedures mainly based on geometrical and/or typological considerations. Intelligibility should be understood as some quality of urban patterns that makes them easy to identify, describe and remember. It is usually assumed to rely on certain urban pattern attributes, like a clear delineation of open spaces, proper connections with surrounding spaces or similarity with recognisable geometrical figures.

Our basic hypothesis is that such spatial attributes can be somehow formalised and elicitated (if not measured) through spherical projection analyses. The specificity of our approach, when compared with other existing methodologies (ground ratio f.i.), is that it fully considers the three-dimensional form of urban open spaces. As such, it is well fitted to dense urban environments, e.g. historical centers., where the empty space appears to be the dual component of the built pattern.

The presentation of spherical instrumentation is based on a worked example dealing with the analysis of Place Saint-Lambert in Liege (Belgium). To be brief, this place has long been a 70ies "urban disaster", located in the core of Liege historical center. After a long period of political troubles, Liege municipal authorities finally decided to rehabilitate the place according to simple, but very clear principles. Amongst these principles, the intelligibility of urban open spaces was presented as a major priority and, following, an urban design project was established by an independent team. We'll try to discuss how this project matched the municipality intelligibility objectives. In this perspective, section 2 briefly states what we mean by urban open space and the way it is addressed by our instrumentation. Section 3 applies some simple techniques, based on Euclidean parameters, to characterise the projected urban open space shape. In section 4, we introduce and discuss spherical projections methods by a close examination of the future Place Saint-Lambert morphological performances.

2. THE URBAN BOX

Urban open spaces are ‘virtual’ by nature : they are not a material element of the physical world. Furthermore, a place limits are often quite fuzzy, or contestable, given that the open space is continuous (at the opposite of discrete built elements) even if there may exist some exceptions to this statement. The Pompei Forum for instance was entirely enclosed. It could thus be easily defined as a discrete urban fragment whose limits were as ‘material’ as can be a building ones.

Even if this specific event still remains an outstanding one in the whole urban history, morphological analysis postulates that most traditional open spaces could be assimilated to “urban rooms”. This analogy with architectural design simply states that we tend to mentally organise our visual environment into discrete entities, whose limits can be logically inferred from real world elements. Otherwise, most street and place names wouldn’t make any sense at all. In this perspective, the continuous open space is considered as a combination of distinct "urban boxes", delineated by walls (the enclosing façades), a floor (the ground) and a ceiling (the sky beneath the space).

3. EUCLIDEAN PARAMETERS

Once open spaces are assimilated to effective volumes, they can easily be applied simple geometrical analysis techniques in order to characterise their shape. The ground area surface and aspect ratio for instance are interesting information about the absolute dimensions and global shape of an urban box. As such, Euclidean parameters afford with a first measuring instrument for comparing various urban open spaces. For the exercise, we selected the Grand-Place in Arras as an appropriate reference for Place St-Lambert morphological analysis. The Grand'Place of Arras is indeed a critical case since it is usually considered as a remarkable medieval urban reference, easily intelligible, despite its very large dimensions (175 x 100 m).

It can be seen from Table 1 that the Place Saint-Lambert is characterised by a greater surface area than the Grand'Place of Arras. Following this, it can be argued that the open space would probably require a specific design in order to adjust it to the relatively small scale of the urban pattern it is inserted in. The design should thus seek to further subdivide the ground surface into smaller units by taking advantage of the general declivity of the place and appropriate ground elements (walls, pavement, vegetation).

3.1 Urban box compactness

The compactness is another simple Euclidean parameter. It's been hereby defined as the ratio between the urban box volume and its equivalent sphere volume. The equivalent sphere is a sphere whose area is equal to the one of the box. It is not the only possible definition, but we think it already fits some basic analyses. Analytically, for a parallelepiped of surface Sb and Volume Vb, this ratio is given by :

$$K_b = \frac{3V_b}{4\pi \left[\frac{S_b}{4\pi}\right]^{3/2}}$$

The compactness of the Place Saint-Lambert is exposed in Table 1 along with the one of Grand'Place of Arras. Despite the ground area of Place Saint-Lambert is larger than the one of Grand'Place in Arras, its 3D shape is slightly more compact. It is a first indication that the proposed urban design scheme complies with the explicit demand for an increased open space intelligibility : the place shouldn't be considered out of scale by its future users.

	Spl (m2)	Kb
sphere		1
cube		0,725
Place Saint-Lambert	18 757	0,351
Grand'Place d'Arras	17 500	0,310
"Squared" Place Saint-Lambert	18 757	0,355
"Squared" Grand'Place	17 500	0,314

Table 1: Place compactness.

The last two lines of Table 1 give compactness values for the urban box when the aspect ratio of the two places ground is assimilated to a square. It can be seen that the resulting values are almost unchanged when the ground aspect ratio is higher. It means that the difference between the compactness of Place Saint-Lambert and Grand'Place in Arras is mostly related to the relative height of the buildings. As the ratio between the height of surrounding buildings and the mean length of the surface area [h/mean(L*l)] is very low, the ground surface aspect ratio is not really determinant in the 3D shape compactness.

It should be recognised that the compactness parameter has to be understood as a very simple way to characterise a space shape. Obviously imprudent applications of this parameter could lead to important aberrations. So the point of defining additional indicators that would not necessarily be Euclidean ones.

4. NON EUCLIDEAN PARAMETERS - SPHERICAL ANALYSES

Despite simple and quite efficient, Euclidean parameters are limited. They do not cope with important aspects of urban open spaces like topological characteristics. It is nevertheless commonly admitted that spatial relations may well play an important role in an urban open space intelligibility, through elements like nodes, landmarks, glimpses etc that actually participate to the imagibility of a space *(Lynch, 1960)*. Furthermore the urban box has to be decided a-priori for the Euclidean parameters to be applied. As such they can not distinguish between poorly enclosed spaces and very enclosed ones. We'll try to illustrate how spherical analyses allow for a better consideration of these aspects.

4.1 Alternative Graphical Representation Methods of Urban Open Spaces

As the urban box is an empty shape, it can not be as easily "projected" nor "represented" from an outside point of view as can be a filled volume (through traditional pictural perspectives for instance). Basically, empty volumes wholly surround their observer at a panoramic 360° angle. It raises some serious representation problem, especially since the human visual field is known to be limited to some 150 degrees laterally. We proposed an original solution to this conceptual dilemma. It consists in considering the human "visual world" instead of his visual field. Visual perception research effectively unveiled that our material environment perception rely on a very large number of instantaneous visual stimuli. The mental integration of these stimuli produce a stable, unbounded "visual world" that forms the basis of open space intelligibility.

Instead on trying to tackle visual stimuli, we propose to address the properties of the human visual world itself through spherical representations. The advantages of spherical representations when compared to other projection methods have already been discussed in another article *(Dupagne & Teller, 1998)*. Basically a spherical projection consists in projecting all the 3D-world elements on a sphere centred on the observer's viewpoint. It is a convenient way to represent the whole physical environment visible by an observer from a given point in any view direction. The next step, projection from the sphere to a plan, is typically characterised by specific properties according to the mathematical transformation method used therefore (f.i. gnomonic, equidistant, cylindrical etc.).

4.2 The Sky Opening

Any observation point located in an urban open space "sees" a fraction of sky unobstructed by the environmental mask. The environmental mask is constituted by natural obstacles (ground surfaces) and artificial obstacles (buildings, infrastructures, etc.). This fraction of visible sky is itself characterised by a solid angle whose vertex coincides with the observation point and whose generating line is given by the 3D-polyline constituted by the points of maximal visual height.

In isoaire projection method, the solid angle can be directly measured in the projection plane by the ratio of unobstructed surface area upon the circle area. This solid angle is strictly independent of the open space global dimensions : homothetic spaces would be characterised by a similar sky solid angle when measured along homothetic points. Its value may thus deserve dimensionless comparisons of different urban open spaces. It is a convenient way to characterise an open space "opening" relatively to existing urban references, whatever may be their Euclidean comparability.

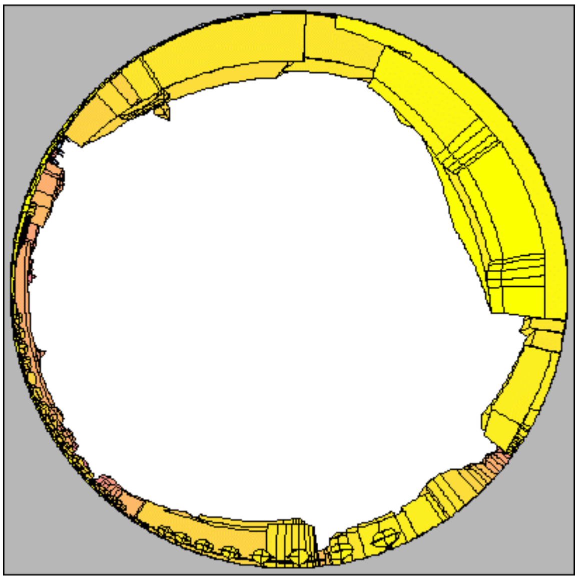
	S.O.	M.V.L.	C.V.L.
Place Saint-Lambert	80 %	74 m	361 m
Grand Place d'Arras	87 %	75 m	565 m

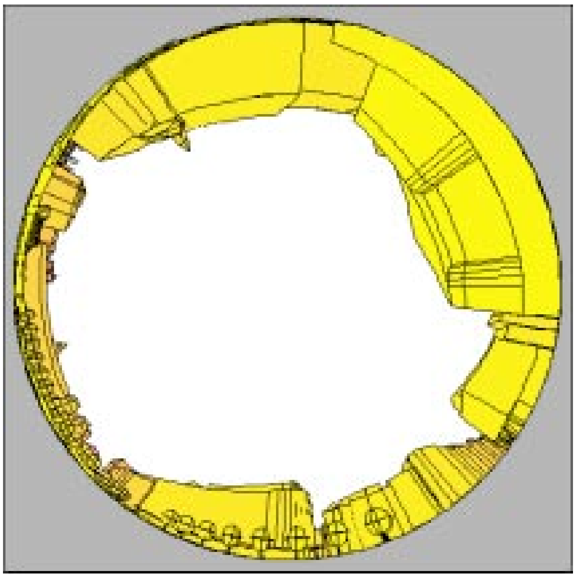
Table 2: View length comparison.

The sky opening percentage calculated in one point can be a valuable indicator of an empty volume characteristics as long as it is possible to select a specific point representative for the whole open space. The center of the space for instance is representative of regular spaces like squares, circles etc. Nevertheless, if the ground surface is not regular (as in some medieval places f.i.), it is not that obvious to select such a representative point a-priori. We'll discuss this aspect later on in this paper. Let's simply state that Place Saint-Lambert comparison with the Grand'Place of Arras indicates that its sky opening (SO) is quite large (Table 2), but still contained within acceptable margins. Here again, the Grand'Place in Arras should be thought as a "borderline case".

The spherical visual representation can also be used as a qualitative instrument to analyse an open space shape. It can be seen from figure 2 that the Place Saint-Lambert general shape can be identified from the reference point (figure 1), but it is not a dominant one. This partial conclusion strengthen the preliminary feeling we had by compactness analyses : given the low building heights relatively to the wide ground surface, the place is quite compact but still wide open to the sky. Its shape intelligibility would thus be possible, but weak.

The stereographical projection, from the same point (figure 2), is better fitted to a 2D-representation of the skyline. It is indeed a conform projection. It means that the relative view angles and 3D shapes are better respected in stereographical than isoaire projection. This is very obvious when one compares the figures 1 and 2 that were calculated in the same point. In stereographical projection, the skyline appears as a curvilinear pentagon whose plain angles result from the regularity of the façades heights. It demonstrates that the urban design option to foster some regularity in the building heights improves the intelligibility of the open space shape despite its large sky opening.





Figures 1 & 2: Isoaire & Stereographical projections of Place Saint-Lambert.

4.3 Iso Sky-opening Graph

When there is no single point representative of the whole open space, sky opening percentage can be repeatedly computed along a regular grid in order to produce iso-sky-opening graphs (see figure 3). We obtained thereby an iso sky-opening graph for the Place Saint-Lambert (figure 3). It has to be noted that the resulting maps are astonishingly similar to those intuitively proposed in 1978 by the Greater London Council *(GLC, 1978)* for an enclosure characterization.

Iso sky-opening graphs are an objective performance indicator for the buildings enclosure of an open space. They do not require any kind of a-priori definition from their users. By contrast with Euclidean parameters, the urban box doesn't have to be decided. It is rather inferred from the graph. Much the same can be said about representative points that were mandatory for punctual analyses.

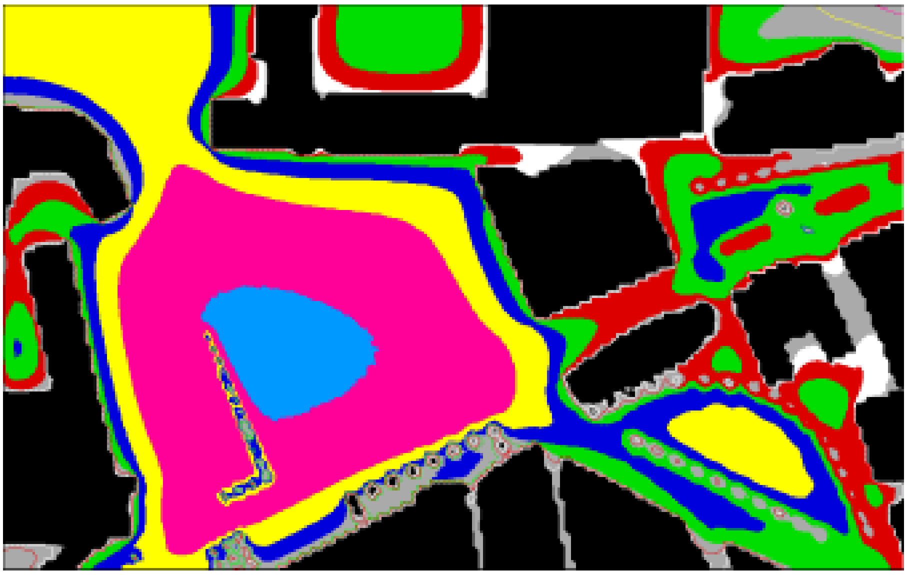


Figure 3: Iso sky-opening graph of the Place Saint-Lambert.

The graph highlights three important properties of the open space.

1. A very homogeneous central area appears in the middle of the figure. The above-mentioned sky-opening percentage (80 % - Table 2) is thus quite characteristic of the whole place. Also, the precise location of computation point within the space was quite immaterial as long as it was selected in this central area (which was the case).
2. Lateral effects due to the façades surrounding the open space are contained in a very limited area when compared to the whole place area. The iso-lines are very dense at the perimeter of the open space. It means that the façades would produce a localised sharp gradient in sky-opening percentage. This property is very typical of wide open spaces.
3. The intelligibility of the open space is not too heavily perturbed by street openings. Evidence for this statement can be found in the fact that perturbation effects due to the surrounding streets connections are quite limited in scope and extend. This is an important point when we consider that these openings are very wide. The iso-sky opening lines containment has to be related to the positive effect of trees and plantations.

4.4 Urban Open Space View Lengths

All indicators presented just as now, may they be Euclidean or spherical ones, did deliberately obliterate the absolute dimensions of the open space. Such a standpoint was quite convenient for comparing the spatial characteristics of similar places with dissimilar sizes. It is to say that spatial intelligibility is, to some extend, related to the relative morphology of spaces and sub-spaces. Yet, as long as one considers that spatial intelligibility is not accessible through a single retinian image, it should also be noted that it can also require human motion. The urban pattern of European cities has indeed traditionally been organised along networks of semi-autonomous open spaces. Such a network organisation preserves open spaces enclosure while affording spatial intelligibility through appropriate visual clues (glimpses and landmarks). It typically maximise the "perceptive effects" for pedestrians through urban artefacts like doors, invitations, deflections etc *(GLC, 1978)*. In order to address such townscape issues *(Cullen, 1961)*, the open space global dimensions has to be reintroduced in our methodological framework.

We tried to develop a tentative "global indicator" that considers the view length distribution within the space. It mainly considers the distance distribution of the various faces surrounding an observer. The mean view length is given by the mean distance from the observer to surrounding faces weighted according to their respective visual obstruction. It is an absolute value, directly proportional to the dimension of the open space. In most simple configurations, this value would thus be roughly equal to half the dimension of the space, but this is generally not true given the common complexity of urban environments. The characteristical view length is given by the mean view length normalised according to the sky opening so as to properly consider the urban box effective enclosure. It is more theoretical but better fitted to urban open spaces comparisons. For rough they may seem, these two indicator nevertheless provide us with relevant information about the global urban open space characteristics.

Comparative view length analyses of Grand'Place in Arras and Place Saint-Lambert are summarised in Table 2 so as to give an idea of the differences between these two factors. It can also be seen from this table that Place Saint-Lambert and Grand Place of Arras are quite close to each other respectively to their mean view lengths (MVL). The lower sky opening of Place Saint-Lambert explains why its characteristical view length (CVL) is also much lower. It would mean that the confinment of this place is higher than the one of Grand'Place in Arras.

5. CONCLUSIONS

We presented a set of indicators to characterise an urban open space morphology. The specificity of our approach is to target directly the open space shape itself. These indicators were either based on Euclidean parameters or spherical analysis. The advantage of this last technique is that it doesn't require any a-priori definition of the open space shape.

Our intention is not to build some general “urban open space quality indicator”, blindly applicable to all cases from northern to southern latitudes. Our aim is rather to diversify the approaches for an urban open space analysis by proposing a number of alternate, complementary instruments. The way these indicators will be combined and levelled will always be specific to a given place, time and intents. In the same vein, the appropriate references along which to calibrate the instruments are also variable according to the political intents. For instance, in the Place Saint-Lambert analysis, avoiding excessive opening of the place once appeared as a clear demand from the local authorities. It is the reason why we selected the Grand'Place in Arras as our reference. Probably other references would also be helpful, especially in other situations where one would seek other performances (a high degree of confinment for instance).

Finally, it has to be noted that all these instruments are better fitted to traditional urban patterns where the built environment actually encloses and delineates the open space. Obviously, it is no longer the case in some present urban settlements, where the fabric is so much spread out that it can no longer shape the empty space. Other analysis instruments are required in these situations *(Dupagne & Teller, 1998)*.

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