A digital image of the city: 3D isovists in Lynch’s urban analysis

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<tr>
<td>As Published</td>
<td><a href="http://dx.doi.org/10.1068/b34144t">http://dx.doi.org/10.1068/b34144t</a></td>
</tr>
<tr>
<td>Publisher</td>
<td>Pion Ltd.</td>
</tr>
<tr>
<td>Version</td>
<td>Author's final manuscript</td>
</tr>
<tr>
<td>Accessed</td>
<td>Wed Mar 20 17:50:29 EDT 2019</td>
</tr>
<tr>
<td>Citable Link</td>
<td><a href="http://hdl.handle.net/1721.1/55992">http://hdl.handle.net/1721.1/55992</a></td>
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Eugenio Morello
Carlo Ratti

A Digital Image of the City: 3-D isovists and a tribute to Kevin Lynch

Keywords
visual perception, environmental psychology,
Kevin Lynch, isovist, DEM

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A Digital Image of the City: 3-D isovists and a tribute to Kevin Lynch

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Abstract
New techniques to measure visual perception over urban spaces are presented in this paper. This study aims to extend the concept of ‘isovist’, i.e. the visible space from a vantage point, in three dimensions and examines how it could help in providing a quantifiable basis for Kevin Lynch’s urban analysis, as outlined in his book The Image of the City. Outputs of the analysis are stored in a voxel space, i.e. a three-dimensional matrix of urban visibility measures. The analysis of what we have called ‘iso-visi-matrix’ seems to allow a more useful interpretation of visibility from a visual perception point of view.

Keywords: visual perception, environmental psychology, Kevin Lynch, isovist, DEM.

Topic: Urban morphology and structural analysis

1. Introduction

In this study we extend the concept of ‘isovist’, i.e. the visible space from a vantage point, in three dimensions and examine how it could help to provide a quantifiable basis for Kevin Lynch’s urban analysis, as outlined in his book The Image of the City. Lynch’s visual elements will be reinterpreted through 2-D isovists, isovistfields and 3-D isovists, allowing the calculation of maps and qualitative indications about the visual experience through open spaces in the city.

Since their introduction to the planning community by Benedikt in 1979, isovists have been an active field of research. A number of authors have suggested techniques to calculate them over extensive urban areas and to describe their shape, thus gaining insights into urban morphology. However, this proliferation of analyses produces an endless number of outputs that are difficult to interpret from an architectural and urban standpoint. Furthermore, traditional calculation methods consider a model, which is too far from real human visual experience: first of all, it does not take into account the vertical dimension – the analysed space is two-dimensional; second, traditional methods do not consider the dynamic participation of moving through the space, which is a fundamental characteristic of visual knowledge.

The aim of this paper is twofold. First, it introduces, in addition to the well-known definitions of isovists and isovistfields, a three-dimensional description of visible space from any given vantage point and shows how it can be calculated. This has recently become possible thanks to increased computing power and new image processing techniques applied to very simple models of urban form, the so-called Digital Elevation Models (DEMs – see for instance Ratti and Richens, 2004). Outputs of the analysis are stored in a voxel
space, i.e. a three-dimensional matrix of urban visibility measures. The analysis of what we have called ‘isovisibility matrix’ seems to allow a more useful interpretation of visibility from a visual perception point of view.

Second, this paper aims to show how three-dimensional visibility analysis could help to reinterpret the visual elements defined by Kevin Lynch. Lynch’s theory emphasizes the "legibility" (and "imageability") of urban spaces for both practical tasks such as way finding and as a feature of physical and emotional well-being in the city. Our attempt is indeed to assess the environmental quality of urban forms. The commonly considered visual elements are: path, landmark, edge, node, and district. It is surprising that to date there have not been many attempts to translate these into quantifiable measures, apart from Conroy Dalton and Bafna’s work (2003) on the framework of Space Syntax. Revisiting Lynch’s theory seems appropriate, as it provides a perceptual framework to orient the definition of visibility parameters, without following technique-led investigations. A definition in terms of visibility is given for most of Lynch’s elements, and their calculation shown, thus providing a new quantitative way to describe and compare the spatial qualities of urban textures.

2. The research context

The first attempts to assess the environmental quality of urban spaces based on perception were presented in the late fifties and in the sixties as result of interdisciplinary studies in architecture, psychology, anthropology and sociology. The introduction of the discipline of proxemics by the American anthropologist Edward T. Hall (1960, 1966) opened up a series of applications in architectural and urban design. Proxemics is defined as the study of spatial interrelationships between people as they interact. Hall investigates the cultural aspects that involve human behavior in space. In his theory the ‘social field of vision’ determines human behavior and communication in social spaces. The key-descriptors for this discipline are the ‘social distances’ that enable different types of human activity and different levels of intimacy in the interrelationship between human beings.

Many attempts to translate visual perception research into architectural and urban design theory followed. The best known contribution in urban planning studies is perhaps Kevin Lynch’s ‘The Image of the City’ (1960). This book deals with the look of cities and recognizes that giving visual form to cities is a design problem. “We are continuously engaged in the attempt to organize our surroundings, to structure and identify them. Various environments are more or less amenable to such treatment. When reshaping cities it should be possible to give them a form which facilitates these organizing efforts rather than frustrates them.” (p. 90). Everyone builds environmental images, helpful in the process of way-finding. These ‘city mental maps’ contain many elements that can describe our experience and the image of the environment; they can explain our tools for orientation and memorization, and represent an evaluation of the ‘legibility’ of a built context as well. ‘Legibility’ is the clarity of the cityscape, “the ease with which its parts can be recognized and can be organized into a coherent pattern” (1960, p. 2). As well as this concept, Lynch introduces the derived notion of ‘imageability’, which is “that quality in a physical object which gives it a high probability of evoking a strong image in any given observer. It is that shape, colour, or arrangement which facilitates the making of vividly identified, powerfully structured, highly useful mental images of the environment” (1960, p. 9). An important point in Lynch’s work is that he does not make a judgement on the value of different urban spaces, but he
refers to ‘legibility’ and ‘imageability’ as evaluating parameters. In other words, Lynch attempts to determine the degree of orderliness of an urban structure, moving his attention away from other criteria for evaluation.

It seems that Lynch’s approach could benefit from the analysis of urban texture in terms of visibility and lines-of-sight. Different parameters are commonly used and they are outlined below.

**isovists**

Originally the notion of ‘isovist’ was presented by Tandy (1967) in the field of landscape geography, but it was Benedikt (1979) who first introduced the concept in architectural studies. Isovist is defined as the field of view, available from a specific point of view. An isovist can also be understood as the area not in shadow cast from a point light source. Usually, in the scientific literature, the isovist represents a horizontal slice through this field of view taken at eye height and parallel to the ground plane. In general, the isovist is a closed 2-D polygon. Complementary definitions have been given more recently: the isovist “is defined as a set of points or vertices of a graph, \( j \in Z_i, j = 1,2,\ldots, n_i \), where \( Z_i \) is the generic field associated with the vantage point or vertex \( I \), and \( n_i \) is the total number of points in \( Z_i \), including the vantage vertex \( I \)” (Batty, 2001, p. 125). Or, translated into Space Syntax theory, “an isovist is the sum of the infinite number of lines-of-sight (or axial lines) that pass through a single point in space (usually at eye height) and occupy the same plane (usually parallel to the ground plane)” (Conroy Dalton and Bafna, 2003).

Many characteristics and indicators describe an isovist. A proliferation of many indicators and analyses around isovists were proposed by Benedikt (1979), De Floriani et al. (1994), Batty (2001), Turner et al. (2001), etc. If we concentrate our attention on more pragmatic applications of these studies, then the field of investigation decreases dramatically. As reported by Stamps (2005), only a few geometrical variables would be significant for distinguishing between isovists. Our interest is in those identifiable characteristics that influence the use of space. Although isovist computation has mainly been used for analyses at the scale of buildings, and Space Syntax as a suitable technique to quantify environmental and spatial indicators at the urban scale, we argue that isovists can also be successfully used for architectural open spaces and large-scale spatial configurations.

**isovistfields**

Enlarging these latter considerations to the ‘isovistfields’ would give much more significant results in analysing large open or interior spaces. For instance, starting from the concept of isovist we can derive the concept of ‘isovistfield’, first introduced by Benedikt (1979): it represents a collection of views accumulated at each point in an open space. It shows what is contained within each view-shed - or isovist - at every viewpoint in the space. In other words, it describes calculated values of isovists and assigns this value to each analysed vantage point: for example the areas of the isovists, the perimeters, etc. “Insofar as the fields represent potential experience, philosophically one might lean towards the ‘idealist’ view of reality as nothing other than the union of all possible experiences” (Benedikt, 1979, p. 63). For instance, isovistfields sum all single visual perceptions and offer an objective and unique characterization of an environment.

In fact, the description of open spaces through maps visualising isovistfields allows the character of the space to emerge clearly. We have made the calculation for all the previously defined properties of isovists, grouped in three macro-categories: fundamental properties; elongation properties and the radial variances, as classified in many studies.
In Table 01 we have conducted a comparative study over two isovists on two different design schemes of open spaces proposed for the redevelopment of the Milan Trade Fair in central Milan. We have computed fundamental properties for both isovists. More interesting for the analysis are the isovist fields calculated for the public spaces on the winning design scheme shown in Figure 01 and in Table 02: diverse characters of spaces emerge, thus contributing to better understanding of the possible uses by people.

<table>
<thead>
<tr>
<th>Property of the 2-D isovist</th>
<th>Isovist with viewpoint=[630,530]</th>
<th>Isovist with viewpoint=[730,700]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fundamental properties</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area of isovist $A$</td>
<td>119104</td>
<td>178644</td>
</tr>
<tr>
<td>Perimeter of isovist $P$</td>
<td>6824.00</td>
<td>7224.50</td>
</tr>
<tr>
<td>Solid Perimeter $P_S$</td>
<td>2506.10</td>
<td>2840.50</td>
</tr>
<tr>
<td>% Solid Perimeter $P_S / P$</td>
<td>36.7250</td>
<td>39.3171</td>
</tr>
<tr>
<td>Occluding Perimeter $P_o$</td>
<td>4317.90</td>
<td>4384.00</td>
</tr>
<tr>
<td>Maximal radial distance $d_{max}$</td>
<td>524.3892</td>
<td>604.7942</td>
</tr>
<tr>
<td>Minimal radial distance $d_{min}$</td>
<td>72.0278</td>
<td>99.2975</td>
</tr>
<tr>
<td>Average radial distance $d_{ave}$</td>
<td>260.8405</td>
<td>287.6694</td>
</tr>
<tr>
<td><strong>Elongation properties</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compactness $\Gamma_i$</td>
<td>0.4974</td>
<td>0.4756</td>
</tr>
<tr>
<td>Convexity – Cluster index $\Psi_i$</td>
<td>0.1793</td>
<td>0.2074</td>
</tr>
<tr>
<td>Concavity $P^2/(4A^2\pi)$</td>
<td>31.1132</td>
<td>23.2497</td>
</tr>
<tr>
<td>Ratio of eigen values $\lambda_1/\lambda_2$</td>
<td>2.5454</td>
<td>2.1746</td>
</tr>
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<td><strong>Radial variances</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entropy $H$</td>
<td>7.6276</td>
<td>7.5785</td>
</tr>
<tr>
<td>Radial standard deviation stddev</td>
<td>112.1557</td>
<td>112.2225</td>
</tr>
<tr>
<td>Radial variance $m^2$</td>
<td>40.541.818,0381</td>
<td>40.073.812,7485</td>
</tr>
<tr>
<td>Radial skew $m^3$</td>
<td>1.815.692.803,6319</td>
<td>3.042.853.616,2578</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.3997</td>
<td>0.6772</td>
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</table>

Table 01 – Calculation of isovist properties from two different vantage points in the open spaces of the Milan Trade Fair masterplan.
Fig. 01 – 2-D isovist fields for different properties computed on the open spaces of the Milan Trade Fair masterplan.

<table>
<thead>
<tr>
<th>Fundamental properties</th>
<th>1. CITIlife</th>
<th>2. ProLIVE</th>
<th>3. Bieanamonto</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean isovist area</td>
<td>81.200.000</td>
<td>160.600.000</td>
<td>93.389.5569</td>
</tr>
<tr>
<td>mean isovist perimeter</td>
<td>4.391.100</td>
<td>5.861.300</td>
<td>5.437.347</td>
</tr>
<tr>
<td>mean solid perimeter</td>
<td>1.924.9000</td>
<td>2.614.6000</td>
<td>2.145.5615</td>
</tr>
<tr>
<td>mean solid perm to perm</td>
<td>41.3458</td>
<td>42.6731</td>
<td>39.7436</td>
</tr>
<tr>
<td>mean occluding perimeter</td>
<td>2.776.4000</td>
<td>3.886.1000</td>
<td>3.391.3079</td>
</tr>
<tr>
<td>mean maximum distance</td>
<td>333.7059</td>
<td>675.0484</td>
<td>639.2803</td>
</tr>
<tr>
<td>mean average distance</td>
<td>2.800.8076</td>
<td>303.6352</td>
<td>263.7458</td>
</tr>
<tr>
<td>mean minimum distance</td>
<td>25.4629</td>
<td>45.6610</td>
<td>36.5505</td>
</tr>
</tbody>
</table>

| Elevation properties   |            |            |              |
| mean compactness       | 0.4311     | 0.4564     | 0.4169       |
| mean convexity         | 0.2199     | 0.2156     | 0.2030       |
| mean concavity         | 0.7672     | 0.7034     | 0.6129       |
| mean eigenvalues ratio | 4.2536     | 3.7193     | 4.2403       |

| Radial values          |            |            |              |
| mean entropy           | 5.3921     | 6.0661     | 5.3443       |
| mean standard deviation| 129.1906   | 141.7478   | 143.2150     |
| mean m2                | 10.390.000 | 18.277.000 | 14.809.687   |
| mean m3                | 745.200.000 | 1.716.000 | 1.583.153    |
| mean skewness          | 0.4400     | 0.3452     | 0.4988       |

Table 02 – Mean values obtained for the 16 isovist field maps computed on three different design solutions proposed for the redevelopment of the Milan Trade Fair site. The values are obtained as the weighted arithmetic averages resulting for each map.
3. Isovists in space

3a. 3-D isovists

Another branch of research that aims to measure the qualitative experience of human perception, tries to quantify the visual experience in the third dimension. Fisher-Gewirtzman and other researchers at the University of Haifa (Fisher-Gewirtzman, 1998; Fisher-Gewirtzman et al., 2000) develop a more realistic model for the translation of Benedikt's isovist in space. They introduce the Spatial Openness index (SO) (Fisher-Gewirtzman and Wagner, 2003), defined as the volume of the part of a surrounding sphere which is visible from a given point of view. In other words, the visual perception is given through a spatial conical angle. The SO measures the net volume of open space. The aim of this index is to describe the quality of perception and of comfort. In fact, it shows the openness to natural light, air, near and distant views and is correlated to the concept of “perceived density”. To support their studies on the SO index, the researchers evaluated the perceived density by people responding to alternative spatial configurations, starting from the same built masses and comparing results with the SO index.

The SO index is a scalar, whereas our definition of isovist in space is a shape in 3-D. In fact, a ‘3-D isovist’ defines the 3-D field of view, which can be seen from a vantage point with a circular rotation of 360 degrees and from the ground to the sky. In comparison to the definition of a 2-D isovist, which considers a plan parallel to the ground, this new definition refers to the real perceived volumes in a 3-D space. Adding the vertical dimension helps to better simulate the physical environment observed from the vantage point.

3b. Calculation of 3-D isovists with DEMs

All visibility calculations performed with the above techniques were implemented in this study with the technique based on the Image Processing of DEMs using Matlab (Figure 02). Although many other computation programmes seem to have great potential and easy interfaces and are specifically dedicated to isovist calculation, the technique we used permits many indicators to be analysed with great flexibility and in a very short time: ‘2-D isovists’, ‘isovistfields’ and ‘3D isovists’ can be generated using simple algorithms based on the calculation of lines-of-sight. Lines-of-sight are calculated passing through the viewpoint and with circular rotation covering 360 degrees. From the viewpoint, a series of arrays are generated and stop when they find built pixels (pixels with value >0). Once the visible area is determined we can derive all other indicators presented above with simple mathematical formulae.
Fig. 02 – A 2-D isovist calculated through Image Processing with Matlab. On the left, the isovist visualized in its urban environment; in the center, the isovist with increasing distance from the vantage point; on the right, the perimeter of the isovist with the distance values highlighted.

We choose a viewpoint based on the open space of the DEM we want to analyse. A large number of lines-of-sight passing through the vantage point are calculated, in order to obtain a good approximation for covering all visible pixels from this point. For each line-of-sight we compute the required information and store the results into different arrays (see Figures 03 and 04). Namely, we calculate an array containing the heights of the objects through the line, and an array with the distances from the viewpoint. We then compute the tangents of the heights to the distances, which is another way to consider the urban horizontal angle (UHA). Starting from the vantage point along the array, we store just the tangent which is bigger or equal to the one calculated on the previous point of the array. This step allows buildings that are shaded by other buildings inside the visual cone to be discarded. In the 3-D isovist we then store the maximum values between the product of these maximum tangents with the corresponding distances to the viewpoint and the height of the buildings at the same point. This final step allows those buildings that are behind others but still visible inside the visual cone to be visualized, because they are higher than the tangent falling on their façades. Now we can distribute the heights in a voxel space, assigning to each z-layer the corresponding values.

In Figure 03 the isovist was computed from a vantage point located in the square in front of the three towers designed for the Milan Trade Fair masterplan. The calculated isovist distinguishes pixels that are hidden from the view of the observer and pixels that are visible.

Fig. 03 – Calculating the 3-D isovist on a DEM: left, the axonometric view of the Milan Trade Fair masterplan and on the right the 3-D representation of the isovist from a vantage point on the ground.
This process can be repeated at every vantage point in the open space in a very short time. In so doing we obtain a 3-D matrix, a sort of 3-D field, where we store and sum all visible and hidden voxels from each viewpoint. For instance, a voxel space is a three-dimensional matrix made by superimposed horizontal matrices taken at different heights. In this example, we collect in the voxel-space all visibility measures inside a volume. In other words we have calculated the ‘iso-visi-matrix’ which contains the values of visibility of each voxel in space weighted on the considered viewpoints in the open space, usually the vantage points at street level.

The calculation of the ‘iso-visi-matrices’ over the design projects for the Milan Trade Fair masterplan reveals itself to be very useful for understanding the visual impact of tall buildings on the urban surroundings. In Figure 05 a section through the towers represents the rate of visibility for the intersected façades, considering all computed vantage points at ground level.
3d. Calculation of iso-visi-matrix

The computation requires summing all 3-D isovist values into a new 3-D matrix in voxel space and weighting results depending on the number of open space pixels. In other words, for every voxel contained in the 3-D matrix, we assign a value that assesses the percentage of times this voxel is visible from street level. For instance, this is possible if we translate all \( z \)-values contained in every pixel of each isovist into voxels assigned to the corresponding \( z \)-levels in the 3-D matrix.

Our interest is mainly to determine the rate of visibility of buildings. In order to do that, we have to discard voxels of open spaces and hold only built pixels. Results can be visualized by simply slicing the voxel space and highlighting those buildings that we want to analyse as shown in figure 05.

4. Lynch’s five visual elements: from qualitative to quantifiable indicators for defining environmental quality of urban structures

Through isovists, isovistfields and 3-D isovists it is possible to reinterpret Lynch’s parameters for characterizing the ‘legibility’ and ‘imageability’ of the urban form. Criteria to assess the ‘legibility’ of an urban environment are based on five well-known visual elements, “the building blocks in the process of making firm, differentiated structures at the urban scale” (Lynch, 1960, p. 95). The following five visual elements show different qualities that make them easily identifiable (1960, pp. 46-83): paths, nodes, districts, edges, landmarks.

An attempt to translate Lynch’s theory into digital automatic parameterisation was done using the Space Syntax technique by Conroy Dalton and Bafna (2003). Lynch’s visual elements are redefined using spatial notations, basically the axial line and the isovist. As well as the concepts of ‘legibility’ and ‘imageability’ introduced by Lynch, the Space Syntax theory adds the notion of ‘intelligibility’, which represents the “quality of an environment as being comprehensible and easy navigable” (Conroy Dalton and Bafna, 2003). The notion of intelligibility was defined by Hillier (1996, page 129) as a key concept for space syntax: “Intelligibility […] means the degree to which what we can see from the spaces that make up the system – that is how many other spaces are connected to – is a good guide to what we cannot see, that is the integration of each space into the system as a whole. An intelligible system is one in which well-connected spaces also tend to be well-integrated spaces. An unintelligible system is one where well-connected spaces are not well integrated, so that what we can see of their connections misleads us about the status of that space in the system as a whole”.

To strengthen the meaning of accessibility in the isovist analysis, Conroy Dalton and Bafna (2003) suggest a stronger relationship between the two concepts of imageability and intelligibility. The study by Conroy Dalton and Bafna (2003) is based on the reduction of Lynch’s visual elements through 2-D syntactical variables. This approach is shown to be lacking, because Space Syntax theory does not consider the visual character and tries to translate visual features into structural features. For instance, some discrepancies emerge in the results, where the maps produced through Space Syntax differ from mental maps provided in the same case study of Boston analysed by Lynch. Some paths which are not highly intelligible in Space Syntax theory play a major role in the visual maps provided by Lynch. This means that
the agreement between well-connected spaces and visual character is not always verified. The same considerations can be seen with other visual elements, especially for those elements which are not properly geo-referred, such as edges and landmarks.

But the authors acknowledge that spatial representation using isovists could potentially be useful to overcome the simplifications due to one-dimensional axial lines. Isovists allow the consideration of the spatial character and the boundaries of what can be seen from vantage points, enlarging simple results based only on connectivity of lines-of-sight.

For instance, all analyses can be conducted on the DEMs, calculating the isovists along specific directions. To interpret Lynch’s visual elements it is necessary to better understand their meaning and try to apply specific calculations for each element.

Some analyses might require, for example, calculations based on simple 2-D isovists (nodes and districts), others (edges and landmarks) require a more complex voxel space. In any case, we provide calculations on 3-D isovists, which seem to be more faithful to actual visual experience and do not imply a more time-consuming computation. In Table 03 all five visual elements are characterized and for each an example based on the case study of the Milan Trade Fair and a calculation method are presented. A brief explanation for each element follows.
<table>
<thead>
<tr>
<th>Visual Elements: definitions and examples from Lynch (1960)</th>
<th>Analysis on DEMs</th>
</tr>
</thead>
</table>
| **paths** | **Questions:**
- channels for potential movement (p. 47)
- strong visual character
- kinesthetic quality
- the destination toward which it goes, clear focuses of origin and destination |
- What is its rhythm? Does it present some symmetry or reversibility in both directions?
**Analysis** (on static and motional views)
- longest axial lines
- lines of high integration
- verify the sense of motion along the path; the dynamic shaping of the movement lines will give its identity and will produce a continuous experience over time
- verify the visibility of the focus along the street. The continuity of the view is a characteristic of a clear position in a place for the observer. |
| **Examples:** Main streets and boulevards | **nodes** | **Questions:**
- Lynch distinguishes two types of nodes: at major intersections and those characterised by concentration with a thematic activity
- clear shape
- key points in way-finding
- contribute to the sense of orientation in the city
- points with crucial route choices |
- Does such a space have a sufficient identity to contain and promote these functions?
**Analysis** (on static views)
- verify homogeneity or fragmentation of the boundaries
  1) concave shaped nodes (star shaped) and proximity to highly integrated axial lines
  2) convex shaped nodes (compact shaped)
- area to perimeter ratio
- mean isovist length
- circularity (Benedikt, 1979)
- entropy (Turner at al., 2001) |
| nodes with strong visual character, distinctive in their surroundings and intensifying some of their characteristics (p. 77) | **districts** | **Questions:**
- clear edges of districts |
- Is this district coherent? Has it a clear structure?
**Analysis** (on motional views)
- verify the homogeneity or the fragmentation of the boundaries
- for internal character of districts, verify the uniform distribution of isovists values, in particular the length of average radials
- for external character of districts, verify if the supposed boundaries of a district act as paths or as edges (isovists along boundaries) |
| **Examples:** The central square, the park, a place of urbanity, where more functions happen simultaneously | **edges** | **Questions:**
- “Linear elements not considered as paths” (p. 62)
- “Boundaries between two kinds of areas” (p. 62)
- “Visually prominent, … continuous in form and impenetrable to cross movement” (p. 62)
- “Tend to fragment [the environment]” (p. 63) |
- Is the edge continuous? Is it readable as a strong element in its surroundings?
**Analysis** (on motional views)
- verify the uniform increase or decrease in the radial length (distribution of radial variances) |
| edges with strong visual character, distinctive in their surroundings, and intensifying some of their characteristics (p. 77) | **landmarks** | **Questions:**
- primary quality: ability to be visible over long vistas (far and near), where easy to be seen |
- Is the landmark located in the correct position?
**Analysis** (on motional views)
- verify the visibility (occlusivity) from far and from near distance (at the base)
- verify the homogeneous visibility of the object from far away |
| **Examples:** Paradigmatic buildings, monuments | |

**Table 03** – Lynch’s five visual elements reinterpreted and computed using Image Processing on DEMs and calculations of 3-D isovists on the maps.
**Paths, nodes and districts**

Below we summarize the definitions given by Kevin Lynch:

- Paths (streets, walkways, transit lines, canals, railroads) are channels along which the observer, customarily, occasionally, or potentially moves. Paths are predominant elements and people observe the environment while moving through paths. They are characterized by: continuity, directional quality, gradients (for example: gradient of use intensity, prolonged curves).

- Nodes (junctions, places of break in transportation, crossing of paths) are points, strategic spots in a city into which an observer can enter, and which are the intensive foci to and from which he is travelling. Otherwise they can represent concentrations.

- Districts (city regions, neighbourhoods) are the medium-to-large sections of the city, conceived of as having two-dimensional extent. Districts have common character: shape, texture, class, ethnic area.

These first three geo-referred visual elements can be easily computed with simple analyses on 2-D isovists. For example, paths are characterized by different measures derived from each isovist: the areas, the perimeters, the maximum, minimum and average lengths of the radials, the compactness and the convexity indexes. All these values represent different arrays and can be displayed in the form of histograms (Figure 05) or can be superimposed on the plan (Figure 06). These diagrams and maps interpret the visual rhythm and character of the path: for instance, we can recognize paths with a regular and controlled rhythm; others with a crescendo effect due to the increasing visual openness; others with no controlled visual quality and high fragmentation. In particular, the cumulative opening of vistas can be displayed in the form of histograms or on a more diagrammatic plan (Figure 07), enabling a high degree of control on projects: in fact, we can easily define when a hidden object will reveal itself along a path or, in contrast, which objects we want to keep hidden from view.

In general we distinguish two types of analyses on sequences: sequences based on a motional view (paths, such as the analysis presented above) and sequences computed on a static view (for example a panorama of 360 degrees from a fixed vantage point). Static views can be evaluated calculating the maximum, minimum and average lengths of the radials of the isovist, and derived parameters from their sequences (standard deviation, etc.). This last typology of analysis based on static views is particularly indicated in dealing with Lynch’s nodes. The visual quality of nodes derives mainly from the analysis of the boundaries of these spaces.
Fig. 06 – On the top: In red the path which connects the subway station to the Vigorelli Stadium in the project proposed by architect Renzo Piano for the redevelopment of the Milan Trade Fair. Below, the histograms calculated for 43 steps along the path; from the top: the maximum and the minimum lengths of isovists’ radials; center: the areas and the perimeters of isovists along the path; below: the convexity and compactness of each isovist.
Fig. 07 – Isovists calculated along the path: the image clearly shows how the areas of the isovists are quite constant and regular in relation to the park.

Fig. 08 – The cumulative opening of vistas along the path computed in 33 steps: left, the open areas discovered along the path (from blue to red); right, the histogram showing the square meters of discovered areas along the same path.

Edges

Edges (shores, railroads, cuts, edges of development, walls) are linear elements not used or considered as paths by the observer. In general they are represented by boundaries between two phases: barriers or seams, important organizing features.

Edges can be detected with the image processing of DEMs quickly by measuring their continuity along a motional view. This can be verified through the distribution of radial variances (regular increase or decrease) along a path.

Landmarks

Landmarks (buildings, signs, stores, mountains) are external reference points, where the observer does not enter. Landmarks are simply defined as physical objects, identified by uniqueness, specialization and singularity. They are often distant, and symbolise a constant direction. The visual element ‘landmark’ seems to be more complex to parameterise and the space syntax approach gave an inadequate description.
The main characteristic of a landmark, such as presented by Lynch, is the ability to be visible over long vistas (far and near); in other words a landmark must be easily intercepted by different viewpoints in its environment and must represent a clear reference point. More than other visual elements, the landmark is explicitly defined by its visual components in the surroundings. The analyses presented here and based on the use of 3-D isovist calculations are particularly suitable to our purposes.

First, we compute a ‘iso-visi-voxelspace’ which assigns to every voxel a value of visibility: voxels with 100% visibility are the ones which are see-able from all vantage points on the ground. We can therefore consider the voxels tangent to the façades of buildings and see which buildings have a major potential for visibility in their environments.

We can verify the homogeneity of the rate of visibility given by different buildings from the ground to the top, as well. The problem with many skyscrapers presented in Lynch’s case study is that they lose their role as a landmark from nearby, when the base is no longer identifiable and the building is mainly hidden to the pedestrian visual cone.

Another analysis aims to verify if the supposed landmark is easily visible from strategic points in the city. For example, we can investigate if the landmark can help people in way-finding in important places in the city (gates, mobility nodes). In short, we might ask if the building represents a constant reference or, on the contrary, if it is mainly hidden from view.

Conclusion

The implementation of the isovist field analysis considering the third dimension, could provide a more precise model, where the distinction of high vs. low buildings might open up stimulating architectonic arguments for planning studies. More powerful computers will allow entire districts to be mapped and general maps of visibility and visual accessibility of urban structures to be calculated.

In this paper we have introduced a technique to calculate ‘3-D isovists’ and ‘iso-visi-matrixes’. The technique reveals itself to be particularly efficient for visual perception analysis on open spaces and over large urban areas. We have thus proposed a reinterpretation of Lynch’s urban analysis on visual elements, highlighting how the use of 3-D isovists could provide a more precise interpretation of the visual elements.

Starting from these separate analyses on visual elements in the urban texture, further work should provide synthetic maps that can identify the prevailing character for each point in space, depending on the careful weighting of the main indicators at these locations.

As well as the identification of Lynch’s visual elements, we could provide maps with other indicators that can explain the use of space by people. For instance, we could distinguish the use of different areas in a public square, where the configuration of space defines different perceptions and different senses of control over the whole space, and where areas defined as ‘soft edges’, areas of high safety, areas of high visibility, areas of high legibility, etc., can easily be mapped. This kind of synthetic plot containing the prevailing perceived experiences could represent a very helpful strategic tool for urban designers.

In general, the techniques presented here could have many applications in design, predicting in advance the impact of a building on the urban form: the rate of visibility and the visual presence of a building intended as a ‘landmark’ could be evaluated depending on the initial targets of the project itself.
Finally, coming back to the general tasks of this work and as suggested by M.L. Benedikt at the conclusion of his paper, we should ask again, what would it be like if we could try to invert the process and “design environments not by the initial specification of real surfaces but by specification of the desired (potential) experience-in-space in the first place”? (Benedikt, 1979, p. 63). For instance, the visual perception as formgiver through the implementation of new tools for environmental prediction opens up a series of new strategies in the field of architectural and urban design and gives back a new central rule to people and their well-being in urban space.

References


