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Exploring isovists:

The egocentric perspective

Beatrix Emo
ETH Zurich
b.emo@gess.ethz.ch

Abstract

Isovist analysis is useful tool for understanding how individuals perceive and act in space. It is often used in space syntax research as part of a set of techniques that examine users' visibility of space. Traditionally, isovists represent the optimal viewshed from any given location; when working with real-world spaces, however, there may be obstacles that obscure the optimal isovist. This paper explores the relevance of first-person isovists that are drawn from what is actually (and not only theoretically) visible in the scene. A candidate measure, termed "choice zones", is evaluated. The paper argues that for real-world studies examining the social use of space, it may be desirable to complement traditional viewshed analyses with ones that take an egocentric perspective.

Keywords

Isovists, egocentric spatial geometry, behavior, real world, individuals.

1. Motivation

The art of architectural representation is to depict the 3D properties of a space in a 2D form in such a way, that they aid people to imagine what a space may look or feel like. People with high spatial abilities (eg. architects) find it easy to switch between different drawings projections (eg. plan vs. section) and between drawings viewpoints (eg. allocentric vs. egocentric). Viewsheds can be a useful way for analysing the geometric properties of a space, as they are a simple abstraction: they represent the boundaries of any space as a 2D polygon, measured from a generating location. In their traditional form, viewsheds tend to be an allocentric form of analysis. This paper examines the merit of representing viewsheds from an egocentric perspective. It discusses what the drawbacks of the traditional allocentric form are, and how these can be addressed by using an egocentric approach.

The paper begins with a discussion of existing representations and measures. It goes on to discuss a newly proposed measure, "choice zones", as a way of defining the first-person isovist. The paper ends with a discussion of the value of such a measure for the space syntax community.

2. Background

Viewsheds are often used in architectural analyses to convey what can be seen at any given point. A particular type of viewshed, or vista, has proved especially relevant for the analysis of the built environment: an isovist is a 2D polygon, taken at a stated height (commonly either floor level or eye-height) that represents the visible area from a point (the generating location of the isovist) (Figure 1). The aim of this section is to give an overview of some of the key concepts and measures used in viewshed analysis to date.

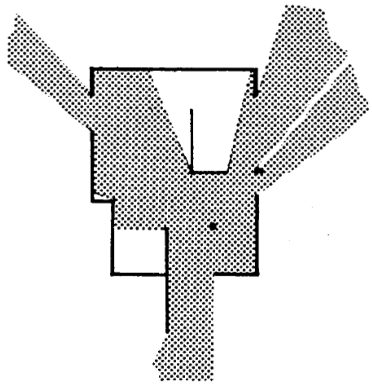

Figure 1: Example of an isovist. Source: Benedikt (1979)

The concept behind isovists was initially discussed in relation to landscape architecture by Tandy (1967). A seminal paper by Benedikt (1979), who initially described these as Minkowski models, pushed the theoretical boundaries, thus paving the way for future research. Benedikt was heavily influenced by the ideas of the Gibson, who proposed a novel approach in the field of environmental perception (1979). For Gibson, a moving observer in the environment is subjected to an ambient optic array which is comprised of variant and invariant information. The invariant properties are of particular interest as they can be held to be part of the underlying structure of the environment; an understanding of those invariant properties is invaluable to designers of the built environment. Benedikt's approach was to propose the physical properties of the structure of the environment as the invariant properties, measured through isovists.

Various aspects of the isovist hold a key to the physical properties of the environment; some are derived from the way in which the isovist is generated eg. i) its generating location (which Benedikt called its vantage point), ii) the radial lines needed to define its resulting edges, and iii) those same edges which can be closed or open edge (depending on the whether it corresponds to a real surface or occluding radial). Other properties are derived from the resultant polygon; either from simple mathematical measures eg. i) the length and number of radial lines and ii) its perimeter and area or from a mixture of measures eg. eccentricity, compactness, drift.

The importance of movement for visual perception led to a deliberation on overlapping isovists, or the properties of isovist fields. How isovists relate to each other is an intriguing question, especially for wayfinding. A number of different approaches have been developed, such as identifying significant surfaces in an environment and deriving informationally stable units from these - e-spaces and s-spaces (Peponis et al., 1997; 1998); relating isovist fields (Batty, 2001); the ``route vision profile'' which examines how the individual properties of isovists vary along a route (Conroy, 2001); the measure of revelation in Franz and Wiener (2008); and the combination of a depth profile together with depth edge detector (Wiener et al., 2012).

A different way of relating isovist fields is through a graph generated from the mutual visibility of all generating locations (Turner et al., 2001). This type of analysis is termed visibility graph analysis (VGA) – for an example see figure 2. The generating location is set arbitrarily, often at one metre, which is close to the length of the average stride at 0.8m. VGA has been readily adopted by the space syntax community because of its efficiency at conveying the changing visual properties of spaces, allowing also for an analysis at different scales. This paper discusses an egocentric approach to representing isovists, and does not discuss how to relate these viewsheds ie. the changing properties reflected in VGA analysis – this is an important issue that will be addressed in future work.

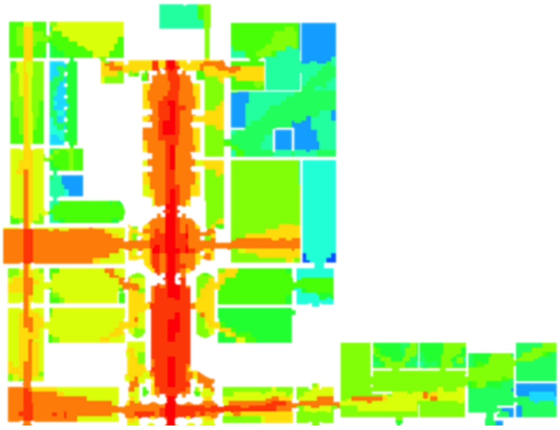

Figure 2: Example of visibility graph analysis. Source: Turner et al. (2001)

The above measures are mostly carried out on a 2-dimensional plane, following the arguments of Benedikt (1979) and Hillier (1996), who state that our experience of space can adequately be approximated at a 2-D level. However there is a real need to be able to incorporate the third dimension into such analyses. A number of such efforts have already been proposed, both for isovists (Morello and Ratti, 2009; Suleiman et al., 2013) and visibility graph analysis (Varoudis and Psarra, 2014). The measure proposed in this paper is also a 2D measure, although it addresses some of the concerns relating to the lack of information on a 3-dimensional plane; this is achieved by incorporating a parameter based on the sky line (see below). Further work should expand the measure to be fully 3-dimensional.

3. An egocentric alternative

Whilst isovist analysis and visibility graph analyses provide an accurate measurement of the geometric properties of viewsheds, they tend to be based on the architectural representation of the environment. For studies undertaken in a virtual environment, the viewsheds match the perceptual information the participant is presented with. However, in the real world, the different forms of isovist analyses may not match a subject's sensory information; street furniture, moving obstacles, contrasting light conditions and overhead obstructions are all examples of how the structural properties of a real-world viewshed might differ from the viewshed drawn off an architectural representation of the environment. This paper considers the egocentric isovist, that is based on what can actually be seen, as opposed to what could be visible in a scene from a theoretical point of view. Instead of depicting the traditional, allocentric vista on a horizontal plane, an effort is made to translate as much relevant information from a subject’s viewshed into a new type of polygon.

One challenge in proposing a first-person-view isovist is the question of what is the most relevant information in the field of view. This paper discusses a new measure termed “choice zones”, as proposed in Emo (2014). The representation of choice zones draws on data from an eye tracking experiment and is therefore closely linked to the visual attention of individuals. To the author’s knowledge, choice zones can be considered the first candidate definition of a first-person isovist; this paper discusses the merit of such a concept for the space syntax community.

A choice zone is an irregular polygon that represents an individual’s egocentric viewshed (Figure 3). Choice zones are areas of high spatio-geometric information that are the focus of visual attention during spatial cognition.

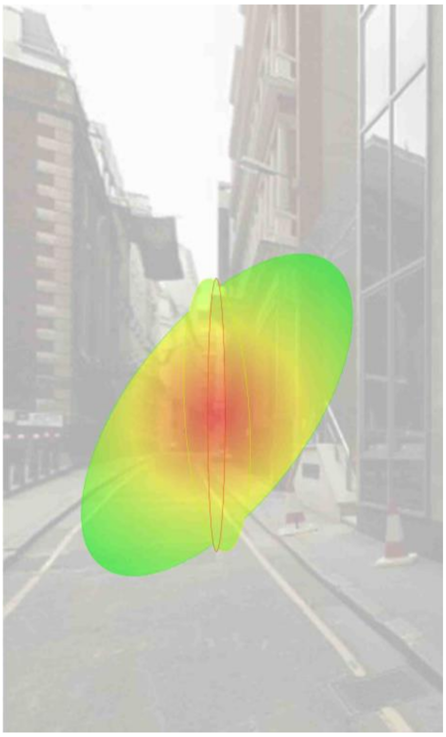

Figure 3: An example choice zone

4. Defining choice zones: Three space-geometric measures.

The definition of choice zones is based on three space-geometric measures that are measured directly from the scene, either in situ or from a representation eg. a photograph.[1] The three measures are based on floor area, sky area, and depth of view (Figure 4). The recording of the three parameters is affected by the exact standpoint of the generating location; future work should devise a way of standardising the parameters. This is possible given that the parameters work with varying horizon lines and can be applied to scenes with different reference classes (eg. sky and horizon lines).

The floor area refers to the amount of walkable surface visible from the current standpoint. It is represented as a 2D polygon; three sides of that polygon are rectilinear, whereas the last is formed by the floor line that separates buildings from the street. The side that separates buildings from the street is made up of several linear segments that follow the structure of the buildings: these are known as "floor line segments". Floor area is not used as a standalone measure in the identification of choice zones, but allows the floor line segments to be defined, which are pivotal in the definition of the line of sight parameters.

The floor area measure is related to depth of view; a line of sight is simply a straight line orthogonally connecting the bottom of the picture to the floor line directly above. A change in direction in the floor line is equal to a notable change in the depth of view. The highest point on the floor line is the longest line of sight of the stimulus; this is one of the parameters used in the definition of choice zones. Line of sight is measured in real-world meters. Sky area sky refers to the amount of visible sky. It is represented as a 2D polygon that outlines the sky area from buildings. Sky area is not directly used in the identification of choice zones, but its lowest point is the sky line which is one of the parameters used in the definition of choice zones. It has been suggested that the amount of visible sky is a relevant factor during wayfinding (Teller 2003).

[1] The choice zones described in this paper are applied to photographic stimuli; for a description of how each parameter was standardised and recorded refer to Emo (2014).

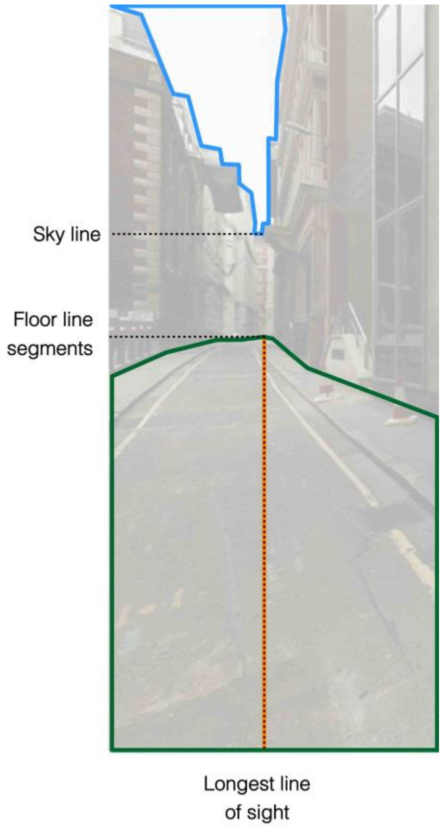

Figure 4: Three space-geometric measures: floor area (green), sky area (blue) and depth of view (orange).

Figure 5: A choice zone is made up of 3 ellipses (shown in red, yellow and green) based on three floor line segments (black lines)

A choice zone is the resultant polygon formed by a series of three overlapping ellipses. All of the ellipses share the same centre, but are of different sizes. Each ellipse is based on the spatial structure of the scene, around the longest lines of sight (Figure 5). The choice zone polygon is visualised as having a strong core (depicted in red), fading to an area that corresponds to less spatial intensity (green). The three ellipses are not directly visible in the final choice zone, but are the only way of computing them. The centre of the choice zone defines the centre of each ellipse: this occurs half way between the floor and sky lines, at the point of the longest line of sight. Each ellipse is based around a floor line segment taken from the floor area (green line in Figure 4). The x- and y-axis values of each floor line segment define the width and height of each ellipse.[2]

The "choice zone" representation draws on data from an eye tracking experiment that showed where participants looked during navigation at street junctions. Participants were shown photographs of binary choice street junctions, and made directed and undirected wayfinding choices; the full experimental procedure is given in Emo (2014). The eye movement patterns showed evidence of clustering around each path alternative. Choice zones were used to define those areas of interest, using the space-geometric parameters mentioned above (Figure 6). The resultant measure is a form of viewshed analysis that differs from traditional isovist analysis because of its egocentric approach.

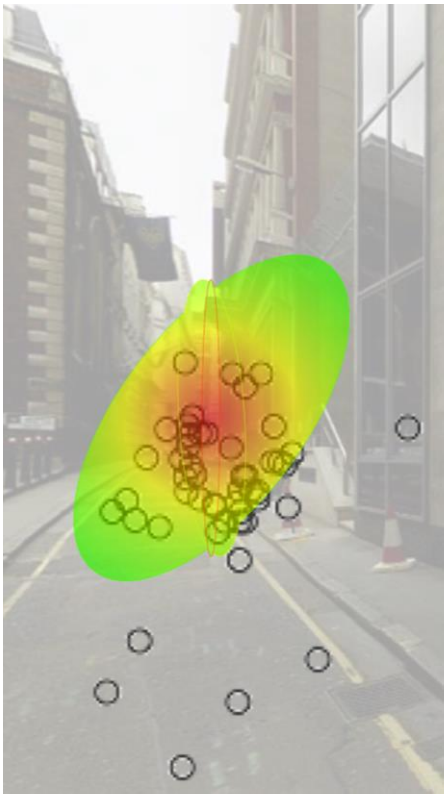

Figure 6: Choice zones are related to gaze bias

5. Evaluating choice zones

Viewshed analysis is a simple and effective way of examining how individuals might behave in space. Existing findings have suggested that spatial geometry play an important role in individual spatial decision-making. At a theoretical level, the role of viewsheds, and their associated properties, have been explored (eg. Benedikt, 1979; Conroy, 2001; Turner et al., 2001). An important finding suggests that isovists are, to some extent, linked to behaviour (Wiener et al., 2007). For studies conducted in the virtual realm, viewsheds match what is seen by an observer; however for behaviour in the physical world the visibility implied by traditional viewshed analyses is not always reached. This is because isovists reflect the optimal viewshed from any generating location; this optimal view, however, may be obscured for an individual located in that environment. This paper considers the

[2] The full algorithmic definition of choice zones is given in Emo (2014).

concept of an egocentric isovist, that takes the first-person perspective. It discusses the "choice zone" measure as a candidate definition for egocentric isovists; a choice zone is an irregular polygon that defines an area around the longest line of sight (this is the x-axis delimiter), and in between street and the sky line (the y-axis delimiters). A number of candidate definitions of choice zones are possible; identifying the most relevant and robust of these is the topic of ongoing research.

Egocentric isovists such as "choice zones" are especially relevant in research that links the behavioural aspects of human interaction with formal architectural representations of space. Often, traditional isovist or visibility graph analyses only partially address what it is that individuals see/act upon. When pairing viewshed analysis with behavioural data it may be necessary to resort to different types of viewshed analysis, including one generated from an egocentric perspective. There are some similarities between isovists and choice zones: both use the delimiting spatial information to form the resultant polygon. The main difference is the change of perspective: from allocentric (isovist & VGA) to a first-person approach (choice zones). This paper has evaluated just one method for calculating an egocentric isovist and is thus seen as a first step towards establishing this type of visual analysis. Furthermore, the realm of *changing* visual fields, accounted for in VGA analysis has not been considered here: this should be a topic for future research.

In conclusion, first-person isovists are a variation of traditional viewshed analyses; they offer a supplementary, user-centred visibility analysis that may be desirable in studies that focus on how individuals interact with their spatial surroundings. They can be implemented in a variety of ways, mapping directly onto behavioural data, and are especially relevant for real-world studies. A fundamental question underlying space syntax theory is to what extent spatial factors are understood by the individual (Penn, 2003); possibly one way to address this is to combine traditional techniques with specifically egocentric ones - the egocentric isovist being just one step in this direction.

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