The Morphology of Public Open Spaces as Visual Opportunity Fields

A space syntax approach based on Revelation and VGA maps customization with SalaScript

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This paper explores the visual dynamics of the morphology of public open spaces. Resorting to space syntax concepts, visual graph analysis (VGA), and the innovative use of its standard tool Depthmap, a set of case studies is analysed under the perspective of visual opportunity fields and building upon the established concept and metrics of Revelation. A series of related novel measures and visualizations are developed, which are only possible, in Depthmap environment, by the advanced use of its scripting language: SalaScript. Despite Depthmap being the standard tool among the space syntax community, there is a lack of references to the explicit use of SalaScript. One major objective of this paper is to illustrate, and document, its possibilities to a broad audience by extending, customizing and introducing a more interactive approach in handling VGA maps. We present SalaScript functionalities and its use in the development of visual analysis scripts that allow the study of revelation, which we then apply to a set of real public open spaces case studies.

Keywords: *Visibility graph analysis, Space syntax, Public open space, Depthmap SalaScript, Revelation*

INTRODUCTION

The formal analysis of visibility of architectonic and urban spaces is one of the main lines of research in space syntax theory. Visibility plays a major role in the theoretical grounding of its spatial partitioning nuclear elements: convex spaces and copresence as inter-visibility, axial lines and movement as long lines of sight, and isovists and visual affordances as viewsheds (Al-Sayed et al., 2014). In space syntax the visuo-spatial analysis of the built environment implies the passage from empirical point/localized or path analysis, to field analysis, into graph analysis where its configurational structure can be explored. Although, the interplay between local ego-centric and global systemic approaches is of most importance, and both may be studied resorting to visibility graphs. A comparative study of the use of graphs in space modelling in both cognitive sciences and architecture can be found in (Franz, Mallot, & Wiener, 2005).

Franz & Wiener (2005), exploring isovist-based correlates of spatial behaviour and experience, identify four main theory-based spatial qualities: *spaciousness*, *openness*, *complexity* and *order*. These were translated into isovist measures, and for that purpose they developed the concept of *revelation*, which they associate to *openness* (prospect, opportunity and defensible space). Revelation, and its associated measure revelation coefficient , expresses the affordances in terms of new visible space if one moves to a neighbouring location, potentially increasing visual information and possibility of movement or social interaction. It is a dynamic and *more behaviourally oriented measure*, not part of the standard space syntax set of measures, nor implemented in its standard tool Depthmap. The focus of Franz & Wiener is in interior architectural space and, in this paper, we apply this concept to public open spaces by its implementation in Depthmap.

Our objectives are: (i) to document the possibilities of SalaScript and show the implementation of existing and novel revelation related metrics in Depthmap, (ii) to investigate the morphology of public open spaces as visual opportunity fields analysing a set of case studies in the perspective of revelation, and (iii) investigate the relations between space syntax and revelation measures.

Next, we will expand on the background of the used theories and concepts; expose methodological aspects on both SalaScript and the implementation of revelation metrics; introduce our case studies and process; present some commented results, and final conclusions.

BACKGROUND

Space syntax is a well-established architectural morphologic theory rooted in a set of concepts, methods and tools for the spatial analysis of the relationship between society, human behaviour and the built environment at all scales. Idealized in the 1970s by Bill Hillier and colleagues at The Bartlett, University College London (UCL), it was formalized in the seminal book "The Social Logic of Space" (Hillier & Hanson, 1984), and further developed in (Hillier, 1996) and (Hanson, 1999). Its approach is said to be configurational in the sense that the focus is on relations, or more specifically on the analysis of *relations taking into account other relations*, and in (Hillier & Hanson, 1984) it is already formalized in terms of graph theory. This mathematical tool had, by the time, a resurgence in the scope of natural sciences and sociology, with the study of networks. An early introduction of the subject into the architectonic field can be found in (March & Steadman, 1974).

Space is analysed as a graph of the spatial relations (physical adjacency, intersection/connection, visibility) between the discrete elements in which the spatial continuum is partitioned. Founded upon a solid theory, space syntax typically defines three nuclear spatial elements: the convex space, the axial line/segment and the isovist; along with the related 2D maps and analysis techniques. In this paper we explore the last, which came at a later stage into space syntax theory, establishing a new strand of investigation more deeply-rooted in visibility and spatial cognition than in social inferences.

A basic element in the formal analysis of visibility, the isovist is a spatial unit corresponding to the potentially visible space from a vantage point. It is traditionally represented as a two-dimensional star-shaped polygonal section of a 360 degrees visual field, charting the directly visible or physically unobstructed accessible space. The rationale is that we navigate space through ever-changing visual fields. It was popularized by (Benedikt, 1979), inspired by Gibson's ecological approach to visual perception (Gibson, 1979). Isovist analysis may be carried out empirically using localized or path isovists, or, more systematically (and abstractly), using *isovist fields* by covering the spatial system by an unbiased regular grid of points (isovist roots) with a certain resolution (e.g. Batty, 2001). Introduced by Turner et al. (2001), space syntax developed a configurational approach to visibility, based on isovist fields analysed as visibility graphs: visual graph analysis (VGA). The VGA visibility graph is a dense graph of intervisible locations, and the isovist corresponds to the neighbourhood of a vertex in graph terms.

Space syntax analyses the graphs according to a set of measures developed over time, resting upon graph-related notions of adjacency, step, minimal path, depth and several distance functions (topologic, angular, metric). These can be global or local measures, and computed at several radii, and most of them have a counterpart in centrality and small-worlds measures in network theory. For VGA analysis, the main standard measures are Connectivity (degree centrality), Visual Integration (closeness centrality), Control and Cluster Coefficient (Al-Sayed et al., 2014).

Dalton (2010) adapts and make extensive use of the *revelation* concept in his thesis on the spatial grounds of neighbourhood places, generalizing this concept to axial analysis and relating it with space syntax notions of *synergy* and *intelligibility*. This author also claims that revelation, as a measure of how new information unfolds in space, is closed linked with Benedict's "new space" idea: the production of paths of greater visibility gain if moving to neighbouring locations, and with Peponis (1997) stable visual information spatial partitions. Revelation also addresses the notions of first and second-order relations between isovists (Turner et al., 2001) and the *dynamic* notions of *embodied-situated vision* (Psarra&Mcelhinney, 2014) , meaning that observers can anticipate *how relations seen from a position can be seen from other regions*.

METHODOLOGY

Depthmap and SalaScript

Although there are more recent tools, the standard tool in space syntax is still Depthmap (Turner, Varoudis, UCL). Originally developed by Turner (2001) for syntactic visibility analysis, it also allows the analysis of convex, axial and segment maps, and in general of any graph that can have a 2D geometric expression. In Depthmap the graph, itself a collection of subgraphs, has a double representation: one geometric (as a coloured map), and other in tabular form, each line corresponding to a spatial-geometric element (a grid point in VGA), and each column to an attribute. Usually restricted to one-line formulas or query selections, SalaScript is a full flagged scripting language that can run several line algorithms. Using graph object functions, program control, looping statements and standard math, it is possible to elaborate new measures and representations of diverse complexity. SalaScript has a pythonic feeling and while being restricted to an imperative programming style, it directs a set of powerful *C* libraries, allowing fine resolution studies.

Depthmap features a specific graph object that have geometry, attributes, and connections to other graph objects. SalaScript is meant mainly to explore pre-existing graph objects and these (and their associated geometry) cannot be created or edited with it. Variables can only be assigned to existing objects and data recorded in pre-existing columns, created manually beforehand. We don´t intend to present a full description (refer to Turner, 2007) but some important, mostly undocumented, findings and remarks on VGA graphs and the innerworkings of SalaScript are important to comprehend how the presented cases may be crated within Depthmap:

1. Complex SalaScript algorithms are preferably written using a text editor, or a source code editor, and pasted into the Depthmap's *update column window* (the expression interpreter window), staying attached to that column. Columns are not dynamically linked, and updates must be done by rerunning the script. The script runs like an unnamed function applied sequentially to all (or the selected) vertices of the graph, getting or setting current and/or other existing columns values. The data in the graph is updated "in the fly", so the values set by the script may change values set by itself in the same run. This calls for extra attention when doing "in-place" editing and more complex looping.

2. User defined columns may be used to create data mappings for the classification or weighting of map elements. For example, to perform localized analysis a column that maps the inclusion in a set of points, lines or areas of interest can be filtered by an *if* statement. For VGA maps, complex selections may be attained by using Depthmap GIS like capabilities of pushing values between shape and point maps.

3. In SalaScript the list of neighbouring points (the isovist) is retrieved by calling the *connections()* function on a graph object. These points are partitioned into 32 radial binning lists (starting 0 degrees to the right) which can be accessed by passing its index i [0, 1, ...,31] as an argument to the function call (i.e. *connections(i)*). By trialling we found that the 8 adjacent points of a Moore neighbourhood are in the index 0 of the binning lists [0, 4, 8, 28] and the index -1 (the last element) of the lists [12, 16, 20, 24]. The same logic may be applied to the 4 points of a von Neumann neighbourhood: index 0 of binning lists [0, 8], index -1 of lists [16, 24]. This allows to create a *window* around a root point and to perform *sliding window* analysis, and, for instance, to determine the edges of a VGA map or the closed and open edges of a graph-isovist.

4. Vertices in the graph have a non-editable ID attribute ("Ref number") that follows a 2d modular grid logic. Relative *i* and *j* position in the grid can be retrieved by querying "Ref number"\65536 and "Ref number"%1024 respectively, where "\" and "%" are integer division and the modulus math operations. This permits to treat VGA maps as raster maps, and to introduce distance metrics (Euclidean, Manhattan, angles, etc) in their analysis. In this way it is possible to: adapt to SalaScript raster-based algorithms, easily control the radius of a window, and use real Euclidean distance (defining the VGA grid spacing as a scaling factor) or real angles (instead of bins discretization).

With the abovementioned information, it is possible to gain access to the graph behind each VGA

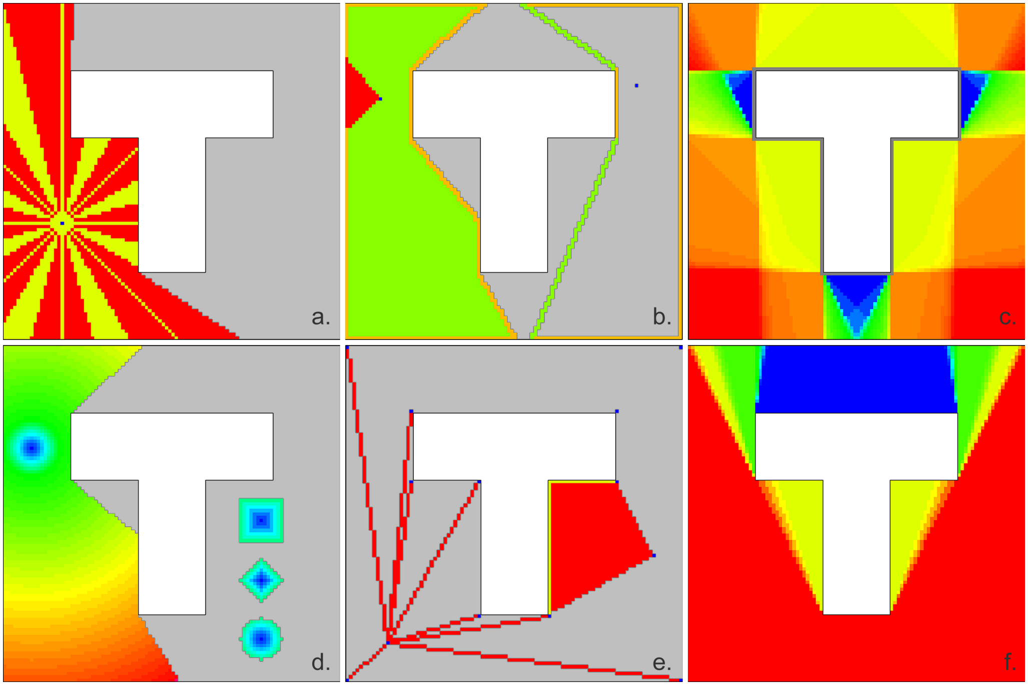

Figure 1
SalaScript examples in a "T" toy model: a. isovist bins; b. point isovists, isovist polygon kernel (left) and open/closed edges (right); c. visibility of an area of interest (the T edges); d. distance functions and windows (Moore, von Neumann and Euclidean); e. Bresenham's raster lines and a visibility cone; f. aggregation by the maximum of connectivity in neighbours.

map and to produce new analysis and visualizations (Figure 1), namely: (i) create point, line and area isovists; (ii) quantify the visibility of areas of interest; (iii) introduce Euclidian distance, angles and cellular automata like neighbouring analysis; (iv) restrict isovists by radius and determine isovists intersections or kernels; (v) apply raster-based algorithms (find boundaries, make sliding window interpolation, blurring or sharpening, draw lines of sight with Bresenham's raster line algorithm); (vi) map isovist based statistical aggregations at different radii; (vii) find local visual maxima and minima of attributes; and (viii) traverse the graph and customize existing or produce new visibility measures, as shown in the case studies.

Implementing revelation related metrics

Revelation coefficients and gradient. The concept of *revelation* was originally operationalized by Franz & Wiener (2005) by a measure called *revelation coefficient*, defined by them as:

"[...] a more behaviourally oriented measure was designed called revelation coefficient that was calculated on the visibility graph as the relative difference between the current and the adjacent isovist areas. Similar to the clustering coefficient, a high revelation coefficient indicates an area of low visual stability and potential information gain by moving further." (Franz & Wiener, 2005).

Dalton (2010) adapts the original measure by exploring different weighting, the use of absolute values, which makes the measure insensitive to the sense of movement, and proposes a new one, *revelation gradient*, that maps the directions of greater visibility gain and treats the revelation field as a gradient. Using SalaScript we start by implementing the revelation measures as in Dalton (2010):

f-revelation (*Rev_coef_f*), same as original Franz & Wiener and Dalton's f-revelation:

$$\text{Rev coef f} = \frac{1}{\mathsf{A}_{(\mathsf{r})}} \sum_{\mathsf{i=0}}^{\mathsf{n-1}} \left(\mathsf{A}_{(\mathsf{i})} - \mathsf{A}_{(\mathsf{r})} \right) \tag{1}$$

s-revelation (*Rev_coef_s*), same as Dalton's s-revelation:

$$\text{Rev coef s} = \frac{1}{\mathsf{A}_{(\mathsf{r})n}} \sum_{\mathsf{i=0}}^{\mathsf{n-1}} \left(\left| \mathsf{A}_{(\mathsf{i})} - \mathsf{A}_{(\mathsf{r})} \right| \right) \tag{2}$$

b-revelation (*Rev_coef_b*), same as Dalton's b-revelation:

$$\text{Rev coef b} = \frac{1}{n} \sum_{\mathsf{i=0}}^{\mathsf{n-1}} \left(\left| \mathsf{A}_{(i)} - \mathsf{A}_{(\mathsf{r})} \right| \right) \tag{3}$$

Revelation gradient (*Rev_gradient*), adapted from Dalton's revelation gradient. Instead of angular bin indexing, the values are continuous (in degrees). It is necessary if using different radii.

Where *A(r)* is the area of the root isovist, *A(i)* the area of the isovist of the i's point in an 8-point Moore window, and *n* the total number of existing points in that window.

New Old and Lost Spaces. Building on Benedikt's concept of "new space", and the importance of accessing how visibility measures change with *arbitrarily small motion of the observer* (Benedikt, 1996), we conceptualize the spatial phenomena of *small motion* by dissecting the visual field of the root-window isovist set of points into: **New Space**, space only visible from the neighbouring locations; **Old Space**, space that remains visible from the neighbouring locations, and **Lost Space**, space no longer visible from the neighbouring locations, defined as disjoint areas and assigned to the root point (Figure 2). The relations between these three Spaces encodes a sort of visual information economy of movement: new information gets available at the expense of eventually losing previously assessible information. In closed convex spaces there is no New nor Lost Space and, in most locations, small displacements do not produce Lost Space, although New Space gets available, and so not all types of these Spaces may be present at the same time. The questions of how small the motion should be, and what should be considered a change of the visual field, are open to discussion. We restrain ourselves to the granularity of the VGA map that we keep in the bounds of human scale (with a grid spacing of 1m).

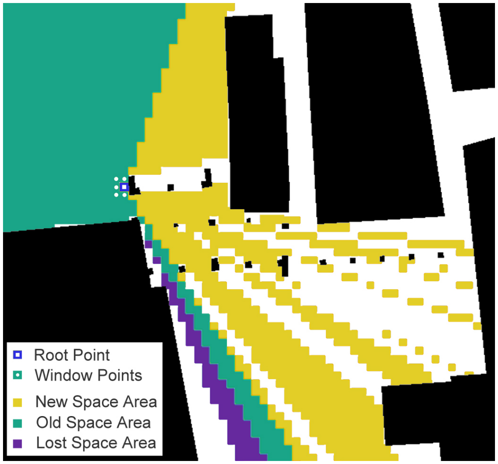

Figure 2
New, Old and Lost Space Areas in the centre of Guimarães case study urban setting (where the two squares are connect by an archway, see bellow). These basic relations may be attained: (i) Root Isovist = Old Space + Lost Space; (ii) Window Isovist = Old Space + New Space.

The following novel measures were defined, which are only possible by querying the connections of the graph:

New Space Area (*Rev_sNewAr*), number of vertices of the neighbourhood of the window points not present in the neighbourhood of the root point;

Old Space Area (*Rev_sOldAr*), number of vertices of the neighbourhood of the window points present in the neighbourhood of the root point;

Lost Space Area (*Rev_sLostAr*), number of vertices of the neighbourhood of the root point not present in the neighbourhood of its window points;

Revelation New-Old Space Area Ratio (*Rev_-sNOArRatio*), ratio between New and Old Space Areas:

$$\text{Rev sNOArRatio} = \frac{\text{New Space Area}}{\text{Old Space Area}} \quad (4)$$

Using these concepts, we adapted the revelation coefficients formulas presented by Dalton, resorting to New Space Area, which is a unique set of points, and not the statistical aggregation (summation of differences in area between neighbouring and root isovist) as defined there (see above). The adapted measures are: **f-revelation New Space** (*Rev_coef_f_-sNew*), **s-revelation New Space** (*Rev_coef_s_sNew*), **b-revelation New Space** (*Rev_coef_b_sNew*).

Another novel measure of revelation is presented, **Revelation Probability** (*Rev_probability*), which measures the probability of (positive) gain if one moves to an adjacent window point, as the fraction of points in the window with greater visibility than the root point. Some anonym derivate measures were calculated in parallel and recorded for testing purposes: *Rev_wPtsQty*, the number of points in the window; *Rev_sNewSum*, *Rev_sOldSum* and *Rev_sLostSum*, sum of the New, Old and Lost Space Areas defined per window point; *Rev_sNO_SumDifs* and *Rev_sNL_SumDifs*, sum of the differences between neighbouring New-Old and New-Lost Space Areas per window point.

Although not a novel concept in the space syntax field, revelation is not implemented in Depthmap. Using SalaScript and VGA maps we were able to implement established measures, adapt and generate new ones in a script where shape and radius of sliding windows may be customizable.

CASE STUDIES AND PROCESS

The presented case studies are three urban settings focused in squares (Portuguese: Praças/Largos) of the historical centres of the middle-sized cities of Guimarães (Largo da Oliveira and Praça de São Tiago), Coimbra (Praça do Comércio) and Évora (Praça do Giraldo) (Figure 3). These cities span across Portuguese mainland and their medieval cores are mainly pedestrian carefully preserved, representative and leisure places, where car circulation is not disruptive of their tourist and civic event activity. The three case studies comprise squares of essentially informal genesis, located in the cities' consolidated fabric.

We produced 120m radius ground floor *Nolli plan* like models of the three urban settings, including galleries and open floorplans. These were excluded from the definition of the working square boundary drawn from the façade plans of the adjacent buildings. This boundary is used to classify VGA points into two merged datasets: an *all points* and a *inside squares* points dataset. These 2D model, representing more precisely physical accessibility than

Figure 3
Case studies, from left to right: Guimarães (a. Praça de São Tiago, b. Largo da Oliveira), Coimbra (Praça do Comércio) and Évora (Praça do Giraldo). Praça de São Tiago, a medieval market square, and Largo da Oliveira, a church forecourt, form a system connected through the archway of the open floorplan of a medieval building; Praça do Comércio, and Praça do Giraldo, are examples of ancient "rossios": large multifunctional spaces contiguous to the external side of a city gate and historically urban expansion irradiation points.

strict visibility, were used to produce 1m resolution grid visibility graphs in Depthmap, resulting in VGA maps of about 11000 points. These graphs were analysed for standard Isovist and Visual VGA measures, and used to run a SalaScript script that implements the revelation measures described. The script runs in a working column that updates a series of other columns (one for each new attribute). In this way the code is centralized, and changes to several attributes can be committed in one run, taking maximum advantage of the traverse of the graph. Maps were created for a qualitative study and data exported for a systematic correlation analysis.

RESULTS

The qualitative analysis of the produced maps shows that most of the implemented revelation measures address the same visuo-spatial phenomena, concentrating values in the same location, although with different degrees of clarity (Figure 4). High values tend to display where one would expect: in places near or with more obstructing objects like galleries and underpasses, in crossings and around sharp convex corners. Edges incident in these, and long lines of sight connecting high value locations, get highlighted across open spaces in which most locations present low values.

From the different definitions of revelation coefficient, the most expressive to use in urban space seems to be b-Revelation. Dalton´s b-revelation is less sensitive to extreme values, while b-revelation New Space presents sharper revelation edges (Figure 4a, b and c). The other revelation coefficients that rely on New Space also present better sharpness. New Space Area (Figure 4d) and New-Old Space Area Ratio are a good proxy of b-Revelation and though Lost Space Area doesn't convey much information *per se*, its sum (Rev_sLostSum) depicts both the revelation distribution and area convexity (Figure 4e). Similarly, Old Space Area doesn't carry more information than Connectivity, but its sum (Rev_sOldSum), as well as New-Old Space Sum of Differences, highlights large open spaces on urban plans (Figure 4f).

Not surprisingly, high values of Revelation Probability tend to concentrate alongside the edges of spaces, and in channel winding spaces in opposite sides from low value edge locations, separating concave from convex boundaries. High and low values produce thin chains of points that cross spaces along long lines of sight, and low values tend to follow the centre line of more wider channel spaces (Figure 6, left). Similarly, tied to the presence of obstructing elements, Lost Space Area tend to form straight lines spanning open spaces where virtually there is no Lost Space. The appearance of these artefacts must be subjected to deeper analysis.

Supporting these results, and from the correlation analysis between revelation and VGA measures, for the abovementioned two datasets (Figure 5), some findings may be stated:

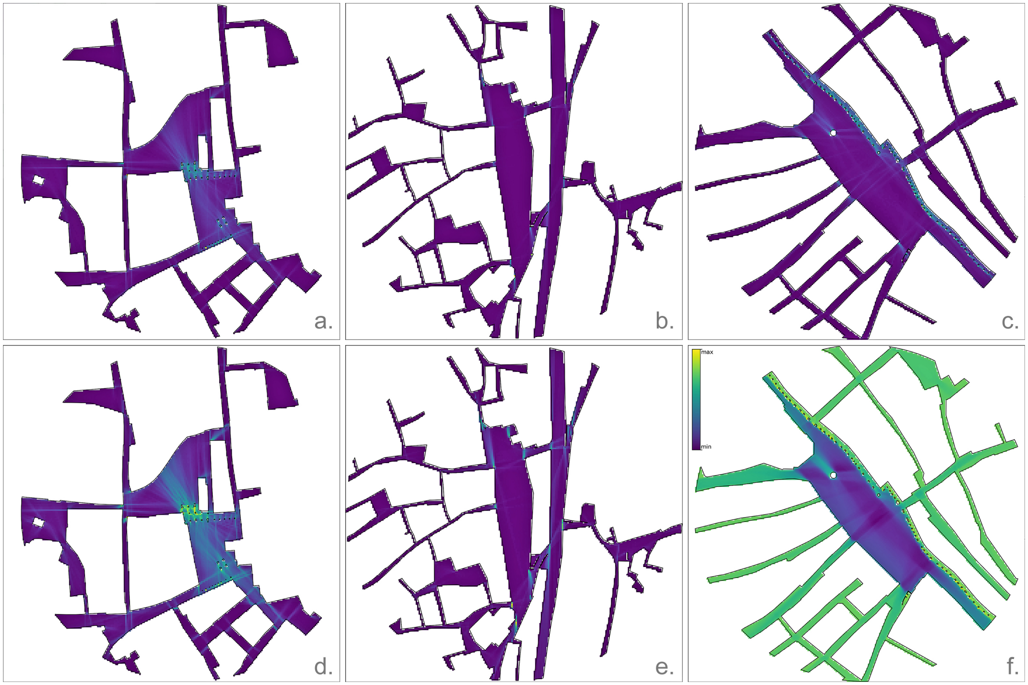

Figure 4
Results:
b-revelation New Space (a. Guimarães, b. Coimbra and c. Évora); d. New Space Area (Guimarães); e. sum of Lost Space Area per window point, Rev_sLostSum (Coimbra); f. New-Old Space Sum of Differences, Rev_sNO_SumDifs (Évora).

1. b-Revelation Coefficient via New Space Area is the only revelation coefficient that bears correlation with VGA measures in the all points dataset, albeit a moderate one (|0.4 - 0.59|). In the points inside squares, also the other New space Area revelation coefficients present a similar correlation to Visual Controllability. This illustrates the importance of measuring true New Space Area, and not to solely depend on statistic aggregation, and may allow to relate revelation with established space syntax findings on VGA measures;
2. The number of mostly high positive correlations between revelation coefficients, and between them and New, Old and Lost Space Area related measures, is increased from the all to the inside squares point data set. Different ways of measuring new space and weighting the revelation measures, decreases of importance when studying more stable and convex spaces;
3. Revelation Probability and New-Lost Sum of Differences present medium correlation with standard f-Revelation coefficient in the all points dataset. The relating factor is their sensitivity to the sense of movement;
4. Lost Space Area does not correlate in a significant way with any other measure, but its sum (Rev_sLostSum), along New Area Space, besides displaying high correlation with b-revelation coefficients, presents a moderate or medium correlation with both Visual and Isovist measures in both datasets. This captures their long-range scope and capacity to aggregate simultaneously local and global spatial descriptors;

Figure 5
Correlation table for attributtes with any correlation of absolute value >= 0.4 (_ indicates absolute values bellow 0.4; zcsore>4 outliers were removed).

All points dataset (_ absolute value of correlaction < 0.4)

revelation	Rev Coef B	Rev Coef B Snew	Rev Coef F	Rev Coef F Snew	Rev Coef S	Rev Coef S Snew	Rev Probability	Rev Slostsum	Rev Snewar	Rev Snl Sumdifs	Rev Sno Sumdifs	Rev Snoarratio	Rev Soldar
Rev Coef B		0.74	_	_	0.43	_	_	0.68	0.69	_	_	_	_
Rev Coef B Snew	0.74		_	0.48	_	0.43	_	0.71	0.95	_	_	0.44	_
Rev Coef F	_	_		0.78	0.65	0.81	0.42	_	_	0.61	_	0.74	_
Rev Coef F Snew	_	0.48	0.78		0.88	0.95	_	_	0.41	_	_	0.94	_
Rev Coef S	0.43	_	0.65	0.88		0.91	_	_	_	_	_	0.84	_
Rev Coef S Snew	_	0.43	0.81	0.95	0.91		_	_	_	_	_	0.91	_
Rev Probability	_	_	0.42	_	_	_		_	_	_	_	_	_
Rev Slostsum	0.68	0.71	_	_	_	_	_		0.77	-0.43	_	_	_
Rev Snewar	0.69	0.95	_	0.41	_	_	_	0.77		_	_	0.41	_
Rev Snl Sumdifs	_	_	0.61	_	_	_	_	-0.43	_		_	_	_
Rev Sno Sumdifs	_	_	_	_	_	_	_	_	_	_		_	-0.99
Rev Snoarratio	_	0.44	0.74	0.94	0.84	0.91	_	_	0.41	_	_		_
Rev Soldar	_	_	_	_	_	_	_	_	_	_	-0.99	_	
vga Visual													
Connectivity	_	_	_	_	_	_	_	_	_	_	-0.99	_	1
Visual Cluster. Coeff.	_	-0.41	_	_	_	_	_	-0.49	-0.43	_	_	_	_
Visual Control	_	_	_	_	_	_	_	_	_	_	-0.5	_	0.49
Visual Controllability	_	_	_	_	_	_	_	_	_	_	-0.49	_	0.47
Visual Entropy	_	_	_	_	_	_	_	_	_	_	_	_	_
Visual Integration [HH]	_	0.44	_	_	_	_	_	0.53	0.51	_	-0.84	_	0.87
Visual Mean Depth	_	-0.41	_	_	_	_	_	-0.47	-0.46	_	0.64	_	-0.68
Visual Relativ. Entropy	_	_	_	_	_	_	_	-0.47	-0.44	_	0.73	_	-0.76
Through vision	_	_	_	_	_	_	_	_	_	_	-0.83	_	0.81
vga Isovist													
Isovist Compactness	_	-0.41	_	_	_	_	_	-0.45	-0.44	_	_	_	_
Isovist Drift Magnitude	_	_	_	_	_	_	_	_	_	_	-0.45	_	0.48
Isovist Max Radial	_	_	_	_	_	_	_	_	_	_	-0.71	_	0.74
Isovist Min Radial	_	_	_	_	_	_	_	_	_	_	-0.66	_	0.62
Isovist Occlusivity	_	0.57	_	_	_	_	_	0.65	0.65	_	-0.74	_	0.78
Isovist Perimeter	_	0.5	_	_	_	_	_	0.61	0.58	_	-0.85	_	0.89

Inside squares points dataset (_ absolute value of correlaction < 0.4)

revelation	Rev Coef B	Rev Coef B Snew	Rev Coef F	Rev Coef F Snew	Rev Coef S	Rev Coef S Snew	Rev Probability	Rev Slostsum	Rev Snewar	Rev Snl Sumdifs	Rev Sno Sumdifs	Rev Snoarratio	Rev Soldar
Rev Coef B		0.72	_	0.56	0.65	0.5	_	0.71	0.66	_	_	0.54	_
Rev Coef B Snew	0.72		_	0.71	0.49	0.62	_	0.72	0.96	_	_	0.7	_
Rev Coef F	_	_		0.64	0.49	0.71	_	_	_	0.71	_	0.62	_
Rev Coef F Snew	0.56	0.71	0.64		0.85	0.95	_	_	0.63	_	_	0.97	_
Rev Coef S	0.65	0.49	0.49	0.85		0.89	_	_	_	_	_	0.84	_
Rev Coef S Snew	0.5	0.62	0.71	0.95	0.89		_	_	0.5	_	_	0.94	_
Rev Probability	_	_	_	_	_	_		_	_	_	_	_	_
Rev Slostsum	0.71	0.72	_	_	_	_	_		0.76	-0.46	_	_	_
Rev Snewar	0.66	0.96	_	0.63	_	0.5	_	0.76		_	_	0.64	_
Rev Snl Sumdifs	_	_	0.71	_	_	_	_	-0.46	_		_	_	_
Rev Sno Sumdifs	_	_	_	_	_	_	_	_	_	_		_	-0.98
Rev Snoarratio	0.54	0.7	0.62	0.97	0.84	0.94	_	_	0.64	_	_		_
Rev Soldar	_	_	_	_	_	_	_	_	_	_	-0.98	_	
vga Visual													
Connectivity	_	_	_	_	_	_	_	_	_		-0.98	_	1
Visual Cluster. Coeff.	_	-0.44	_	_	_	_	_	-0.51	-0.46		_	_	_
Visual Control	_	_	_	_	_	_	_	_	_		-0.51	_	0.51
Visual Controllability	_	-0.46	_	-0.52	_	-0.45	_	_	-0.45		_	-0.52	_
Visual Entropy	_	_	_	_	_	_	_	-0.4	-0.42		0.72	_	-0.77
Visual Integration [HH]	_	_	_	_	_	_	_	_	_		-0.86	_	0.9
Visual Mean Depth	_	_	_	_	_	_	_	_	_		0.81	_	-0.86
Visual Relativ. Entropy	_	_	_	_	_	_	_	_	_		0.79	_	-0.82
Through vision	_	_	_	_	_	_	_	_	_		-0.76	_	0.71
vga Isovist													
Isovist Compactness	_	-0.45	_	_	_	_	_	-0.49	-0.5		0.51	_	-0.56
Isovist Drift Magnitude	_	_	_	_	_	_	_	_	_		_	_	_
Isovist Max Radial	_	_	_	_	_	_	_	_	_		-0.8	_	0.83
Isovist Min Radial	_	_	_	_	_	_	_	_	_		_	_	_
Isovist Occlusivity	_	_	_	_	_	_	_	0.46	0.46		-0.74	_	0.78
Isovist Perimeter	_	_	_	_	_	_	_	0.42	_		-0.84	_	0.88

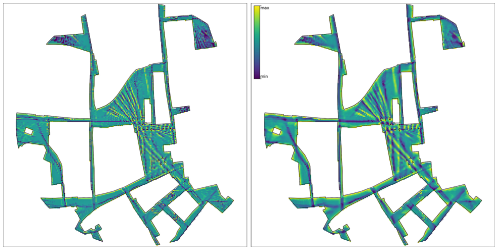

Figure 6
Revelation probability in Guimarães. Left: standard radius 1 Moore window, right: radius 3 Moore window.

5. Old Space Area related measures present high correlation between themselves and systematically correlate with VGA measures. This seems to happen through an extremely high cross correlation with Connectivity.
6. Isovist Drift Magnitude and Min Radial, which exhibit an average correlation with Old Space Area, when considering all points, disappear from the relevant correlated measures in the other dataset. These Isovist measures play a stronger role in revelation when considering street space.

We show the result of applying a radius 3 Moore window, which has a smoothing effect (Figure 6). Depending on the analysis, this may be of interest. Measures extremely sensitive to spatial idiosyncrasies and detail (e.g. Revelation Probability or Lost Space Area) may benefit from it. However, further studies must be carried out to assess the effects of window and grid sizes and shapes, besides frontier conditions and level of model detail.

CONCLUSION

The results of the new proposed measures based on our conceptualization of Benedikt´s "new space", depict some common aspects of the human-environmental *plexus*, objectifying spatial qualities not captured by revelation coefficients alone. In a qualitative assessment, they allow to (i) individualize places of higher cognitive impedance to movement (where directional decisions are made): high values of New Space Area; (ii) identify easier navigational paths: low values of Revelation Probability; and (iii) define areas of greater visual information stability (related to locations of static uses of space): low values of Lost Space Area. The presented investigation corroborates Franz & Wiener (2005) suggestion that revelation *might be especially relevant when actively navigating*, and allows us to unveil the local potential of movement and, thus, to model an eminently active cognitive process of spatial discovery (mostly of an unfamiliar site). This dynamic component, following (Psarra & Mcelhinney, 2014), is not captured by the systemic global measures of the pure syntactic approach, which discards local geometric (and symbolic) information in favour of overall static descriptions.

By exploring SalaScript, we show a way to introduce this dynamic component into Depthmap VGA analysis, along with other more empirical aspects of interactively dealing with VGA maps. Being a scripting language, SalaScript presents obvious limitations and, although our case studies show a fair complex example of its potential, other tools should be used for more complex projects. While of particular interest for Depthmap users, it may be of notice to other researchers, designers and non-specialists, and stimulate creative uses within and outside the space syntax community.

The effect of morphological and visuo-spatial characteristics of the built environment on human behaviour and experience, has been widely put to the test both by space syntax, cognitive sciences, and environmental and behavioural psychobiology and geography. Their findings on basic spatial qualities related with topics like wayfinding, spatial memory, sense of security, comfort and mystery, perceptive, aesthetic and emotional responses, represent a challenge to the design and decision-making processes balancing their normative bias with a more informed and evidence-based approach.

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