Three Dimensional Isovists for the Study of Public Displays

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Abstract

During this paper, we suggest that the 3D isovists centered on a display have an impact on the 'noticeability' of the information presented on it. We compared the use of 2D and 3D isovists as methods of assessing display 'noticeability' applied to an environment in which a network of public digital displays has been installed, namely a university campus. We tested 2D and 3D isovists against observations, and experimental methods are employed in order to compare the observed recognition of display-content against the spatial attributes of the display. This paper introduces new software, 'Nebula', which analyzes real world scan isovists' point clouds using a number of different 3D, volumetric approximations. For the university campus we studied, we found that 3D isovist volume improves the correlation between the recall of display content (when normalized for the number of viewers), over 2D isovist area or other measures. On the basis of this research, we recommend the use of both 3D and 2D scanned isovists as a new analytical tool for the study of architectural environments.

Keywords

3d isovists, laser scanning, spatial cognition, visual representation, signage and displays.

1. Introduction

In the field of space syntax, isovists (Benedikt 1979) have long been one of the central pillars of representation. Isovist representations have been the basis of many advances in analysis, such as applying configurational measures to isovist arrays (Turner and Penn 1999). Montello (Montello 2007) and Meilinger (Meilinger, Franz, and Bnz, and BBITA both theorized that Isovists are the link between cognitive models of people's motion through the environment and space syntax abstract representations). However, by their very nature, isovists representations are highly reductionist:

taking a complex, three-dimensional world and reducing it to a two-dimensional model of part of it. While isovists have been very successful at synthesizing spatial qualities into objectively representational numbers, questions have been raised as to the validity of these representations. The current analytic process is to take a complex real-world spatial environment and to simplify this down into a CADD representation. The CADD representation is then sectioned at eye height to create a two-dimensional, approximating 'slice' of the three-dimensional scene around an embodied viewer. This two-dimensional polygon, created from this slice, is then processed analytically to yield a number of numeric factors, such as area and perimeter, which are then used to represent qualities of that space. Considering the computational abilities of the time, Benedict's two-dimensional isovist was a significant benefit to knowledge in the field. Advances in both computer processing and spatial capture permit a more direct and comprehensive process to be applied before the reduction to single factors. The contribution to knowledge of this paper is the combination of capturing three-dimensional isovists in real-world contexts, their analysis in three dimensions and reduction to familiar quantities. This paper is split into two parts; firstly the process by which the information is captured and reduced, then the paper will go on to know a sample analysis of these techniques in a real-world context.

2. Previous work

The term isovist was first mentioned in the work of Tandy (Tandy 1967), the concept, as it is used today, has more in common with the work of Gibson (Gibson 1986)(Gibson 1966) and his idea of "visual flow". Gibson's ideas were brought into the field of Architecture by Benedikt (Benedikt 1979) who defined an isovist as the "set of all points visible from a given vantage point in space and with respect to an environment". While the notion of the set of all points is an inherently three-dimensional one, it was Benedict who was the first to reduce this set of points from its three-dimensional reality to a two-dimensional planar equivalent. Benedikt's ambition was to capture experiential aspects of space (Wiener et al. 2007) and developments have been carried out in this direction (Wiener and Franz 2005); for example, relating a number of spatial factors back to their psychological analogues. At its most simple level, for example, a small isovist area represents a small space that may induce feelings of anxiety for those suffering from claustrophobia. Over the years, the initial spatial representation and the values that can be derived from it have been expanded upon by a number of authorities e.g. (Wiener et al. 2007) and Conroy, who introduced new isovist measures, such as drift. In his thesis, Dalton (NSC Dalton 2011) looks at changes in isovist properties as one moves through the environment creating isovist fields and introduces the concept of revelation or the change (first differential) in isovist properties. This notion of the isovist field was expanded upon by Morello and Ratti (Morello and Ratti 2009) who extend earlier work of Fisher-Gewirtzman et al. (Fisher-Gewirtzman, Burt, and Tzamir 2003) to create a three-dimensional model of buildings in an urban context. These three-dimensional urban models are centrally concerned with the properties of inter-building visibility and 'openness' or measures of the proportion of visible sky. Suleiman (Suleiman, Joliveau, and Favier 2011)(Suleiman, Joliveau, and Favier 2013) performs similar processing but, in this case, using vector-based GIS models. One significant aspect of both of these urban-based approaches is the lack of any attempt to compare the algorithmic results against empirical findings.

Returning to the field of architecture (Bhatia, Chalup, and Ostwald 2012) analyzed CAD models of the Villa Savoye using an isovist array built by sending rays out from a point in the model in three-dimensions, using a polar coordinate system. By sending a number of rays spaced evenly over changes in azimuth (α) and altitude (θ), Bhatia was able to effectively build up a three-dimensional isovist. While this work was a significant advance in the field, it failed to explore experimentally the relationship between the isovist matrix captured from the CAD model and the reality of exploring experiencing space.

What the previous work in the field has failed to identify is whether a three-dimensional isovist captures any more salient information from the world. Now it is computationally possible to process three-dimensional isovists and equipment now exists, which can capture the actual isovist information within a building, we are left with two questions. Firstly, does a three-dimensional isovist capture information that is substantially more informative than the previous two-dimensional methods? Secondly, if three-dimensional isovists are used to present different information, does this invalidate the previous two-dimensional isovist methods?

3. Method

To explore our questions it was necessary to conduct a case study involving real world isovists. To this end, the objective of our experiment was to capture three-dimensional information from real-world settings and to relate the results derived from measures of these three-dimensional isovists back to empirical observations in the world. Our study was based on the exploration of isovists to look at the discoverability of public displays (N. S. Dalton, Marshall, and Conroy Dalton 2010). We became interested in whether or not spatial attributes influenced whether people noticed displays in everyday settings.

Our methodology was to compare the number of times people reported seeing specific content on a display, against a number of isovist values for a number of spaces. To do this we used 13 displays set up around a large university campus in the UK. These displays had been set up previously as part of an information portal for campus staff and students (Clinch et al. 2013). Each display could be individually programed to display assorted information. The displays presented information full screen and for 30 second periods before moving on to a different information screen. Our screens consisted of single words and pictures which had been taken from a standard set of memorable words (Paivio, Yuille, and Madigan 1968) and pictures (Szekely et al. 2004). We displayed these words interleaved with other information for one week (5 working days and 1 weekend), and after the pictures were removed from the screens we sent out a questionnaire to assess how often people remembered seeing individual screens. The survey was sent to staff and students at the university trying to include as many of those who were on campus at the time as possible. The survey was discretionary but we did offer a prize for those who got the most right, and a second prize awarded to a randomly selected person who took part. The survey showed words which were presented on the displays, along with a number of similar distractor words. Our reasoning was that if a word was seen on a display, it would be more likely to be remembered by those taking the survey. Thus, words that were presented on screens which were in better orientations and spaces to make them noticeable would be better remembered and recalled than those which were harder to notice. Given that different words were presented in different locations, it would be likely that words would be recalled and reported to a higher degree not because of the space, but due to the sheer volume of people passing by the screens or sitting or standing in front of them.

Many screens were in sight of places to sit, or in spaces where students were likely to stand and converse. To counter the uneven numbers of people sitting and passing each screen we performed gate count observations on the number of people passing a display. After a 1 min, 5 min or 10 min gate count was concluded, we also counted the number of static people sitting or standing. These gate counts were repeated at different times of day and on a number of different days. With the average of these gate counts, it was then possible to divide the number of positive responses to seeing the words on a display by the average number of people passing the display and the average number of people sitting near the display. This would give the number of positive responses for a particular display normalised for the number of people sitting or walking past the display. This could then be compared against a number of spatial variables describing the position and orientation of the display to uncover any correlations.

One practical problem we encountered was the difficulty of getting correct CAD information for each location. We discovered that due to the operational organization of the campus, different buildings came under different building managers. Each manager may or may not have digital building records and we had no way to compel the local building manager to give us the records if they existed. To counter this we developed a way to scan each isovist using 3D scanner technology (N Dalton, Dalton, and Peverett 2015). By scanning we could get ‘as built’ or ‘as used’ measures of the three dimensional space. Scanned isovists are more representative of the actual conditions that the displays were present in. While scanning would entail the development of completely new software to derive measures from the real world, it would also give high intra-scan site consistency, which processing a number of different CADD file formats drawn to different standards and purposes with different digital provenances would not. This scanning process would also include any as-built changes or any spatial interventions which had been made and not recorded on the CADD drawings. The scanning process would give a number of three dimensional scans, making it possible to evaluate three dimensional interpretations of a real isovist for the first time.

Figure 1: Scanner being setup up in context.

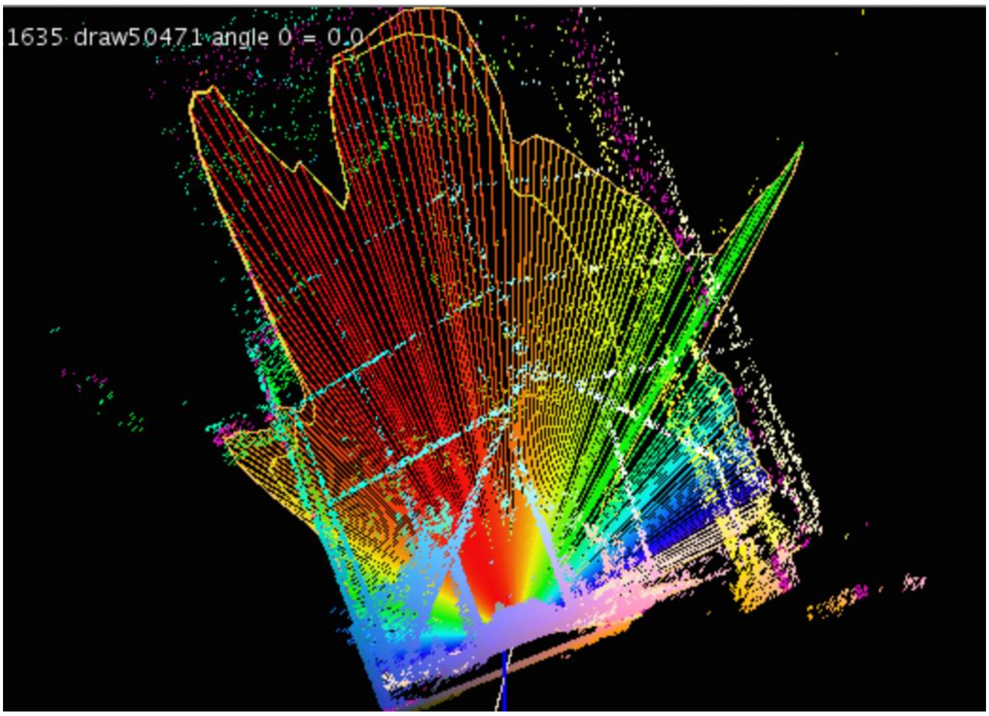

Figure 2: Scan of isovist shown in Nebula software

Scanning occurred prior to the experiment, out of term time, when the building would not be occupied and the scans would be free of occupants. We used a Faro Focus 3D laser scanner, using a laser beam with a vertical range of 305° and a horizontal range of 360° and a Range Focus of 60m to collect the data. Each scan produced approximately 9 million coordinates from a view point just in front of the display in choice. For more information on the process of using 3-D scans see (N

Dalton, Dalton, and Peverett 2015). This produced a cloud of x,y,z points in three-dimensional space. Data files for each scanning location were then transferred to a computer to be processed by specifically written software called Nebula. This software computed both two-dimensional and three-dimensional isovists. The three-dimensional computations were based on the polar coordinate system similar to that of Bhatia(Bhatia, Chalup, and Ostwald 2012) using the camera as the center of the scan.

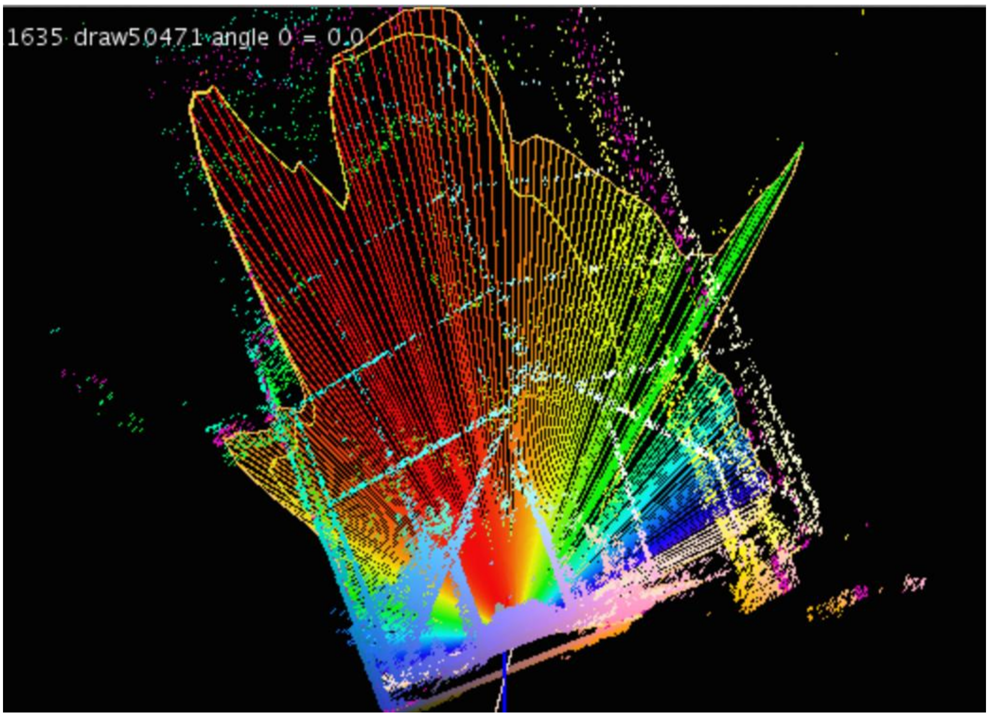

Figure 2 Shows The result of a scan for one of the display locations. The full scan of points creates a solid cloud of points in space. In order to visualize the data and interact with it a random subset of 1% is shown on the display(fig 2 above), but computations are always on the full data. Figure 2 also shows a 2D isovist from the centre of the display screen which is approximately eye height as a rainbow of lines. In this building the roof was made from glass like a conservatory. The blue grey lines of points are scanned of the opaque beams. This demonstrates one of the problems with indoor eye scanning. Light passes through glass to the sky therefore creates effectively infinite distances.

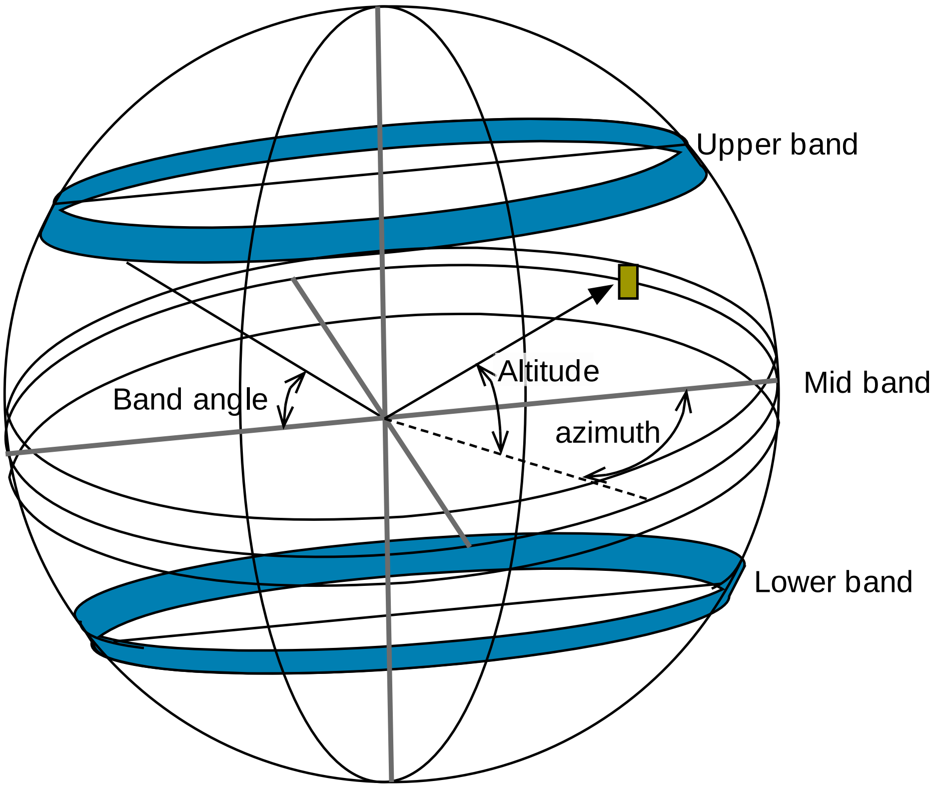

Figure 3 : Polar coordinate system for isovist

As mentioned in (N Dalton, Dalton, and Peverett 2015) it is possible to fire a virtual beam with a given altitude and azimuth and then use deviancy in angles with individual scan points to find those points in space clustered around the beam (see Figure 3). Effectively the beam collides with the point cloud and the average for the points around the point of collision becomes the distance of the isovist Ray. By scanning this beam along the azimuth it is possible to build up a two-dimensional polygon of points to form the two-dimensional isovist shown as a yellow line in Figure 2. In Nebula we experimented with two methods to approximate the volume of the isovist.

The first method called the three band method was to scan along the azimuth as in the two-dimensional case but then make two more scans raising and lowering the beam in altitude by 45°. This method was chosen as being relatively efficient and prioritizing the view about eye height. This had the additional effect of de-prioritising the less likely situation of looking straight at one's feet or straight above one's head. The volume was then computed as being an approximation of the areas of the three polygons scanned. The three-dimensional surface area was approximated by the perimeter of the three polygons.

The second more comprehensive method took a ray from the centre of the view to the scan point in space. By summing the distance from the centre to the Scanning point for all the rays the volume of the isovist could be approximated. Both methods were tested against standard shapes and appeared to have a reasonable correlation with known volumes. The surface area was computed by sorting all the coordinates so that it would be likely that two points would be in order. By looking at the separation (distance) between two squetial point in the array of scan points it was possible to approximate an isovist surface area in two dimensions. From these simple measurements it would be possible to derive many of the common measures of space including area perimeter ratio. By finding the average for all points it would be possible to compute values like drift(Conroy Dalton and Dalton 2001).

In summary for each display location it was possible to get the average number of times the words on display were correctly recognized normalized for the number of people sitting or standing nearby.

This could then be compared to the two-dimensional and three-dimensional isovist properties for each display. Given the number of displays it was then possible to compute the correlation between normalized recognition for display and an isovist measure. Table X to summarises these results giving me r squared value for Pearson's correlation coefficient and the Spearman rho coefficient used to check the results.

4. Results

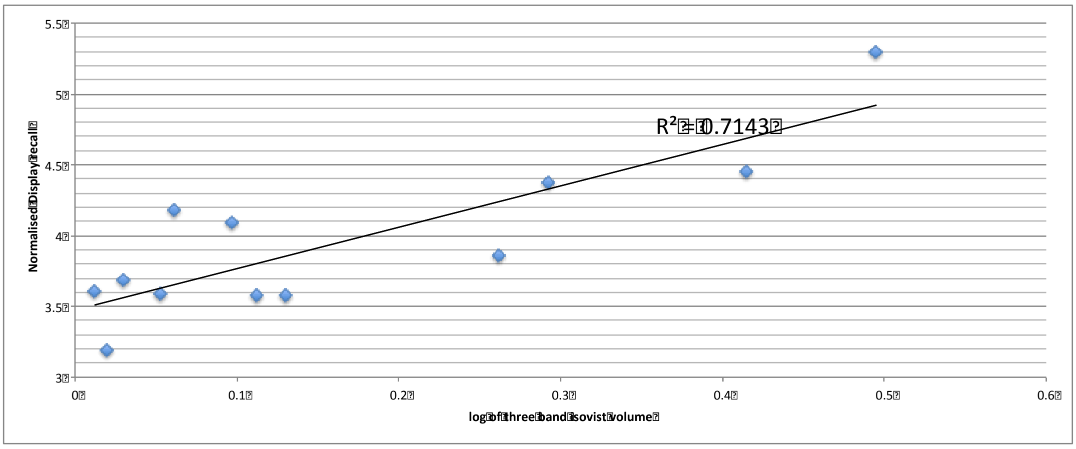

Figure 4: Correlation between Log of 3Band isovist volume against display recall

Figure 4 shows a scattergram showing the plot of log of observed 3 band isovist volume against the normalized number of observation. Each point represents a different location with displays near the entrances to lectures spaces typically occupying the upper right of the chart. Note these have already been normalized for the number of occupants.

Table 1 correlations between responses normalized for movement and display isovist measures

Method	Pearson P	r^2	P value	Spearman Rho	P value
2D Area	0.83	0.69	0.0009	0.76	0.01
Log 3Band Volume	0.85	0.71	0.0005	0.65	0.03
3D Volume (ray)	0.76	0.58	0.004	0.67	0.02

When looking at the isovist volume we found a strong correlation of $r^{2=}$0.85 (p=0.0005) between normalized response and the log of isovist volume. The correlation between 3Disovist surface (equivalent to perimeter in 2D) was $r^{2=}$0.479 but the correlation with Volume/Surface ratio was a weak $r^{2=}$0.134. While this work suggests that the 3D volume around the eye height possesses the strongest correlation the casualty cannot be inferred from these values. The correlation between 2D isovist area and the 3D approximations was strong (r^2=0.47), while the significance values were high (<<0.001) the small value for n makes it difficult to say with certainty that discoverability correlates with a large volume which correlates with a large area of vice versa. Certainly it appears that in the case of the discovery of displays isovist area or value has an important part of play after allowing for the numbers watching.

5. Discussion

We are fortunate to find a location with a large number of displays which could be individually addressed. It is rare to find a group of buildings with so many information dispays. We began with 14 displays but lost some due to technical faults or they being switched off during events. This reduced the number of observations which blurred the ability for statistics to declare one method a clear winner. Many of the displays were in public but specialized areas such as the entrance to particular departments. This made it difficult to assume that it was equally likely to see a particular display. Thus it was difficult to weight a survey respondents answers by their accuracy. Non the less we found that isovist volume $r^{2=}0.71$ was a reasonable predictor of how often a display was noticed (or noticed and remembered). This should make intuitive sense as the larger the isovist was from the display then the more likely the display was to be viewed.

It should be noted that all of our sites were practically planar; that is, the display could be seen from only one floor. A stronger difference between the 2-D and 3-D methods might have occurred if the locations had exhibited more complex volumetric spatiality. For example, if the displays were present in an atrium space where they could be seen from multiple floors, a different result might have occurred. This finding is most likely reflected in the fact that the three-band isovist approximation method correlated more strongly than the fuller 3-D ray approximation. The three-band method might be incorporating the visual sense while ignoring those aspects of vision that are less common during way finding.

6. Conclusions

Our initial hypothesis was that the orientation of the display would have an influence on the ability of passersby to notice the display, and this would affect their ability to recall words presented on the display. We found this to be true. The data we collected suggests that it was the number of people sitting that statically had the strongest influence on the ability to recall words on the display. Once the number of words recalled had been normalized for the number of static potential observers, we found that isovist volume seemed to most accurately predict the ability of people to recall the words presented. Given that we had already normalized for the number of people sitting, it seems natural that the larger isovist gives rise to more chances of viewing the display. One explanation for this is that people sitting statically are able to view the display over a longer period, and because they are not moving, they are better able to compensate for the orientation of the display than moving viewers are.

To our knowledge, this is the first paper to report on the use of three-dimensional isovists that had been collected in realistic conditions and compare these to real observations. In doing so, we found that three-dimensional isovists appear to function like two-dimensional ones, yet this might have been an unfair comparison as the screens occupied relatively simple spaces. Certainly the direct observation methods developed appear to use when applying isovist observations in a number of other real-world buildings. While we envisage that directly observed isovists are not going to displace isovists computed for CADD models soon, our experience was that directly observed isovists introduce a new faculty for research in buildings and structures (for example, caves or archeological sites) for which accurate CADD models do not exist.

Finally, we found that in our case the results from 3-D isovists correlate strongly with those of 2-D isovists, suggesting that while 3-D isovists have some potential for more nuance, there is no evidence to suggest that previous research using 2-D isovists should be discounted as too inaccurate.

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