OmniVista

An Application for Isovist Field and Path Analysis

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25.1

Abstract
This paper briefly describes the software application OmniVista written for the Apple Macintosh Platform. OmniVista is essentially an isovist generating application, which uses the 2d plan of a building or urban environment as input data, and then can be used in one of three modal ways. Firstly, point isovists can be generated by 'clicking' onto any location in the environment. Secondly, all navigable space can be flood-filled with points, which may then be used to generate a field of isovists. Finally, a path of points can be used to examine how isovist properties vary along the path - the results of this can either be output as numerical data, or exported as a series of pictures, which may be combined to form an animation of the varying isovists along the route. This paper will examine all three modes of use in turn, starting from the simplest (point) to the more complex (the path). A description and equation for all isovist measures used in the application will also be given as an appendix to the paper.

OmniVista[1] was first developed in February 1999 and completed by mid March 1999, it is not, therefore, a new piece of software. It is based on the concept of the isovist, most widely associated with Benedikt (Benedikt 1979; Benedikt and Burnham 1985). Since this paper is a software paper, we will assume that the reader is familiar with the concept of an isovist, suffice to say it is a 2d polygonal representation of visible space as generated from a single vantage point. OmniVista is a privately written piece of software with no institutional affiliations.

OmniVista's functionality may usefully be held to divide into three possible 'modes'. The first mode is that of generating a single point isovist. This is used to examine the properties of the field of view from a single, or number of distinct, locations. The second mode in which OmniVista may be used is to flood-fill all navigable space with a grid of vantage points and to generate an isovist at each of these locations. The final and third mode in which the application may be used is to generate isovists along a path. Each of these three modes will be presented in this paper, along with an appendix containing definitions of the measurements used by OmniVista.

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1 The name OmniVista is derived from the Latin Omnis = all and the Italian Visto and Latin videre = view.

OmniVista's Functionality

Single Isovists

This is the very simplest of OmniVista's three modes. OmniVista will generate a single isovist at any location in the scene. Click anywhere on the screen (on the plan view) and OmniVista will generate the isovist from that specific location and then calculates the following isovist attributes:
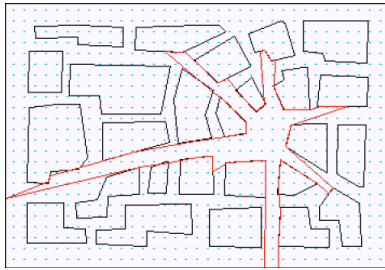
- area
- perimeter
- minimum radial
- maximum radial
- average radial
- standard deviation of radials

The resultant isovist is represented as a single polygon drawn upon the plan view of the environment, see figure 1. The numerical values of the isovist's area, perimeter, minimum radial length, maximum radial length, average radial length and standard deviation of its radial lengths are displayed along the top of the screen. The standard unit of measurement in OmniVista is the metre.

Copy or command C will copy the numerical data constituting the points of the isovist onto the computer's clipboard. This can then be pasted into any other application, for example a spreadsheet. The first two points (i.e. the first row of the list) represent the (x, y) co-ordinates of the centre of the isovist. The following rows contain pairs of numbers and are the (x, y) co-ordinates of the polygon's vertices (a polygon is defined by a stream of points). The number of points may be changed, but as a default is set to 256^2 representing radial lines of sights constructed from the vantage point and distributed at 1.4" intervals. An example of such numerical data is shown in figure 2 below.

If these points are copied into a spreadsheet application, they may be further analysed. For example, the following isovist, in figure 3, was copied into excel and plotted as a xy-scattergram, resulting in a familiar looking, isovist polygon.

However, this data may be represented in many different ways, for example as a line plot representing the varying lengths of the isovist's radials. If the above dataset is visualised in this manner, then the following line-plot, illustrated in figure 4, may be produced.

The y-axis represents the length in metres of the isovist's radials. The act of representing an isovist in this manner, may be imagined as 'unfurling' or 'unwrapping' the isovist. Once this has been achieved, further methods of analysis may be applied. Although this is not performed in OmniVista, the ability to copy and export the numerical data so easily is a particularly useful feature of the application.

Figure 1 Point Isovist Generation


```
Centre of isovist
            203        138
         0.6353     25.8795
        0.874771    17.8062      Points conti
         1.00201    13.5839
```
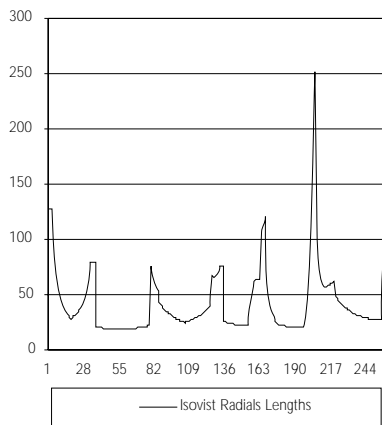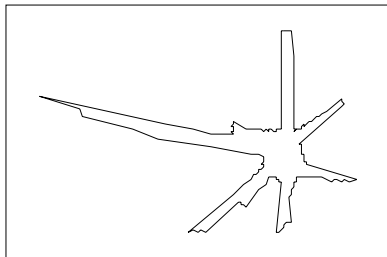

Figure 2. Top. Numerical Data Output from OmniVista

Figure 3. Middle. Isovist Generated in Excel as Scattergram

Figure 4. Bottom. Isovist 'Unfurled' as a Line-Plot

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2 The reason that the default number of radials was originally set to 256 was to enable Fast Fourier Transform analysis of the distribution of the isovist's radial lengths
3 Pict is an Apple Macintosh 2d vector/image file format.

As an alternative method of data export, 'Copy Picture' (under the 'Edit' menu) may be used to copy a pict[3] image of the world and isovist onto the clipboard. In this manner, single images of isovists may be created, in order to use elsewhere.

Grid Isovists

In order to process grid isovists, the grid must firstly be established. Since MiniCad also employs the concept of a grid (as do most CAD applications), the default grid in OmniVista is always set to be the grid used in the original MiniCad File. This is particularly useful, since the grid may first be visualised in MiniCad, by being superimposed on the plan of the environment (urban or building) to be analysed. It is not only the spacing of the grid points that is taken from the original MiniCad file, but also the location of the grid's origin (the point from which the grid is generated).

If however, the grid was not set in MiniCad, or an alternative grid is to be used, then the grid may be altered by choosing 'Set Up Grid' under the 'Control' menu. The user can specify different horizontal and vertical grid-intervals and a grid origin. There is no limit to the number of times that a user might alter the grid. It is particularly useful to be able to process an environment using a 'coarse grid', for example set at ten metre intervals and then to leave it processing a much finer grid once satisfied with the results of the coarser grid. Figure 5 shows the 'Set Up Grid' dialogue box.

Each grid location is represented by a blue dot. An example of a coarse and fine grid displayed in a very simple environment may be seen in figure 6.

Once the grid has been set, the user may choose 'Build Grid Isovists' from the 'Control' menu or Command D. This will construct an isovist centred upon every grid location. Once calculated, each isovist will be represented by a circle or square (the size and shape of which can be altered using commands at the bottom of the 'Colour' menu, see figure 8).

In figure 7, the isovists' vantage points are represented by circles (upper left) and squares (upper right). The size of the circle or square can be set to large (upper left and right), medium (not illustrated) and small (bottom left and right). The bottom right image illustrates an array of small circles calculated using a fine grid. The colours of the circle/squares are set by any one of number of different isovist attributes (the diagrams above represent the attribute isovist 'area'). The available isovist attributes by which the circles/squares may be coloured are;

Isovist grid perameters

Horizontal Isovist spaceing (pixels)   10
Vertical Isovist spacing (pixels)   10

Vertical Isovist starting distance   0
Horizontal Isovist starting distance   0
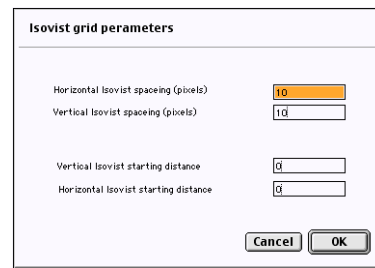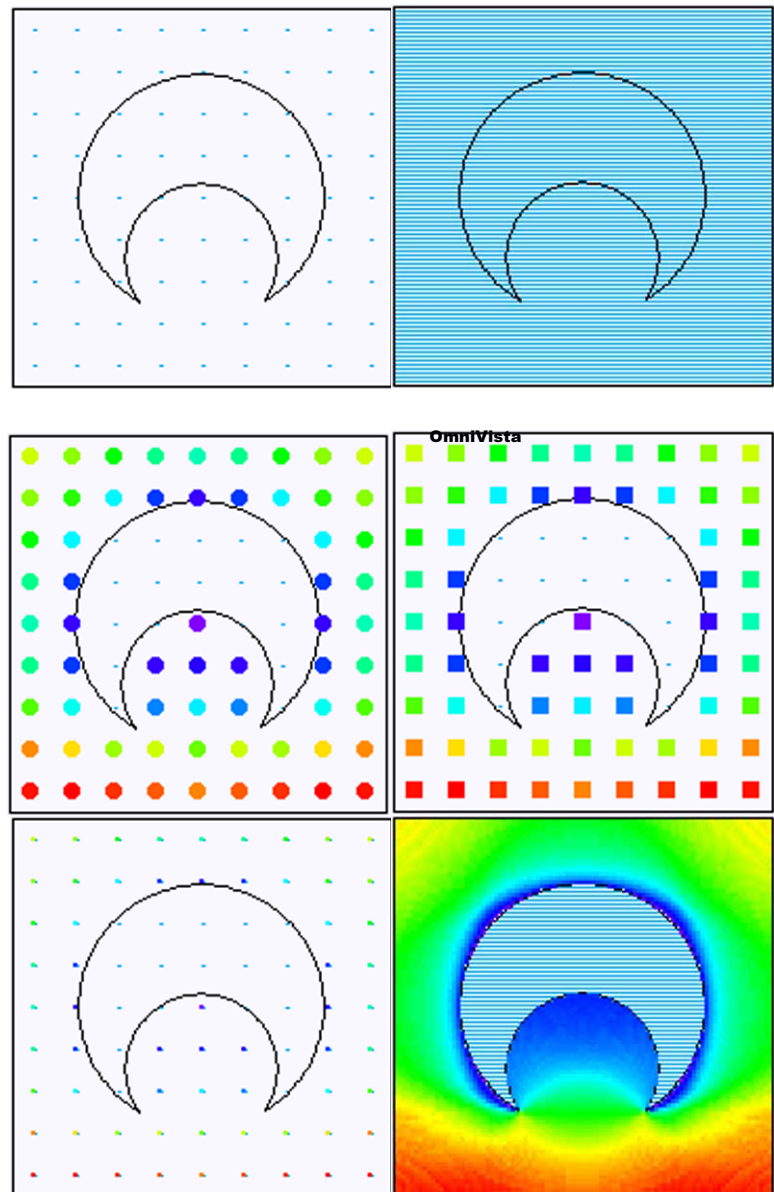
Cancel   OK

Figure 5. Above. Setting the Grid in OmniVista

Figure 6. Middle. Resolution of Different Grid Settings

Figure 7. Bottom. Flexibility of Representation in OmniVista
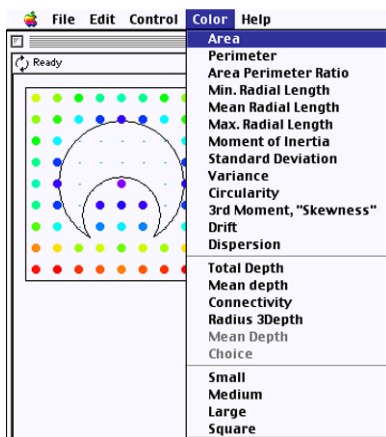
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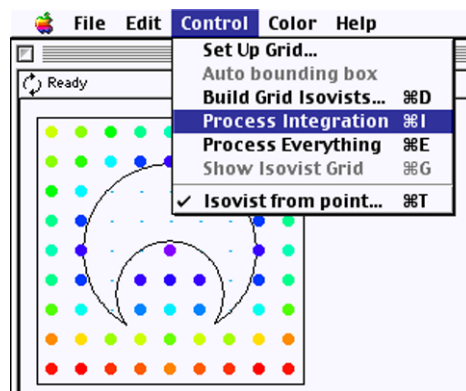**Figure 8. Above. Screenshot of Isovist Attributes (Colour Menu)**

Figure 9. Above right. Screenshot of the Control Menu

- Area
- Perimeter
- Area Perimeter Ratio
- Minimum Radial Length
- Mean Radial Length
- Maximum Radial Length
- Moment of Inertia
- Standard Deviation of Radial Lengths
- Variance of Radial Lengths
- Circularity
- Third Moment/'Skewness' of Distribution of Radial Lengths
- Drift
- Dispersion

Figure 8 shows how easily each of the isovist properties may be selected from a pull-down menu.

The colour of the dot is assigned using the value of each measure. A rainbow spectrum is employed where red denotes the maximum value of a measure and blue represents the minimum value of a measure. The colours orange, yellow and green are assigned respectively for the intermediate values. Each distinct measure of the geometrical property of an array of isovists can therefore be illustrated in a single diagram. (See the Appendix for full details of how the measures are calculated).

Once the grid isovists have been calculated, then the measure isovist integration can be calculated. If the grid isovist stage has not been processed, then the 'Process Integration' or Command I command can not be selected (it is grey).

Upon selecting 'Process Integration' or Command I (see figure 9 above) the relationship between each isovist point and every other isovist point are examined and a graph representation of intervisibility, or the 'visibility graph' is constructed. There are two possible types of connection, the first is where the viewpoints themselves are mutually visible (i.e. two people standing at each isovist location can see each other). The second type of connection is where the isovists generated at any two points overlap, but neither viewpoint is located inside the isovist of the second view point (since this would be case one). In this scenario any two people standing at two viewpoints would not be able to see one another directly, but both could see a third person standing in the region of the union of the two isovists. The calculations performed by OmniVista are based upon first order visibility relationships, see (Turner, Doxa et al., 2001).

Once the visibility graph has been generated, this set of relationships can be used to develop a set of 'syntactic' measures (see the Appendix for full details of how the measures are calculated). In essence, the relationship between every viewpoint and every other viewpoint in the system is calculated, and the distance (in graph terminology) is calculated between every possible pairing of points. The isovist viewpoints are then represented as nodes in the graph while the relationship of mutual visibility is represented as links between these nodes. The values calculated are shown below.

- Connectivity
- Mean Depth
- Radius Three Depth
- Total Depth

Path Isovists (Minkovski Models)

The third mode in which OmniVista may be used is one that sets it apart from a number of other similar applications. This mode may be used to analyse 'path isovists' which are similar to Minkowski Models. In other words, instead of analysing a single point isovist or a grid of isovists, in this mode a path through an environment may be used as the generator of a series of isovists. At every step along a path, an isovist is generated. In this manner the fluctuating properties of isovists can be analysed from the perspective of an individual moving through an environment.

OmniVista can import input paths generated from a VR headset (from people moving through immersive environments) or from a path or paths drawn in MiniCad. Once OmniVista has read in an input file (representing the path through the environment) it can produce one of two possible outputs. Firstly it can output a text file containing the full range of isovists attributes appended to the (x, y) location of the isovist. This can then be read into a spreadsheet and any single isovist may be represented as a line graph. This representation of the variation of isovists along a route may be termed a 'route vision profile'.

A route vision profile is a method for determining how individual properties of isovists vary along a route. This is not a particularly new concept, as it can be regarded as being related to Minkowski models, as illustrated by Benedikt in his paper (Benedikt, 1979). It can also be regarded has having some precedent in Lynch. In his paper (Lynch, 1965) he attempts to qualify the visual experience along a circular route, by graphically straightening out the route and representing it as a single line, with particularly 'interesting' views being indicated as arrows. Lynch is not using isovists (unlike this paper), but the desire to attempt to represent the visual experience of a route through an environment prompts both Lynch's paper as well as the OmniVista software application. What is novel in the approach taken by the route vision profile is that it is not the isovist itself that is being represented, but rather how a variety of isovist properties might vary along a route.

The route vision profile, is a graph representation of the visual experience of a journey through an environment. The journey time (or distance travelled) is plotted in regular intervals along the x-axis of the graph, whilst the magnitude of various isovist attributes are plotted on the y-axis. The type of graph used is a line graph. An individual journey taken through a world is used as the basis to generate a route vision profile. Using the application OmniVista it is then possible to take all points along the path, and to generate as series of isovists along the route. Each location that the subject passed through will become, in turn, the viewpoint generating an isovist. Each isovist generated will have a wide range of isovist

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Real and Virtual Routes - Isovist Area

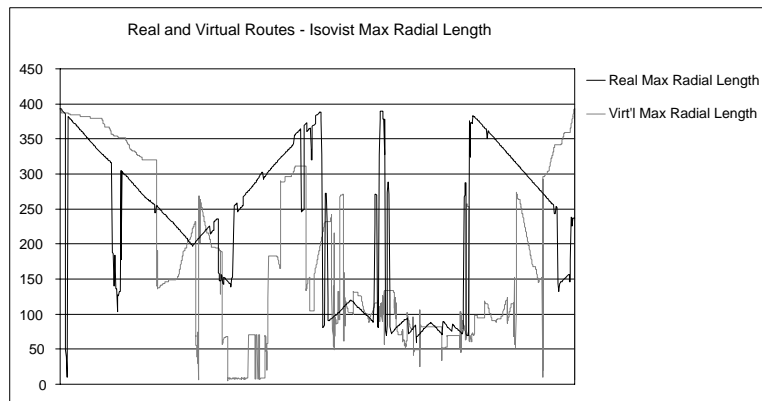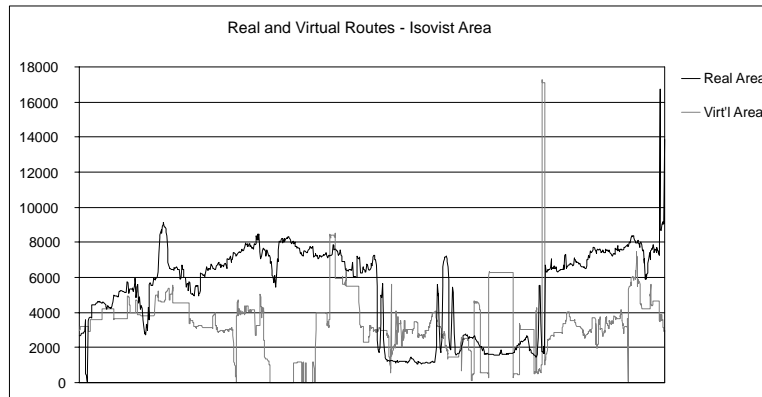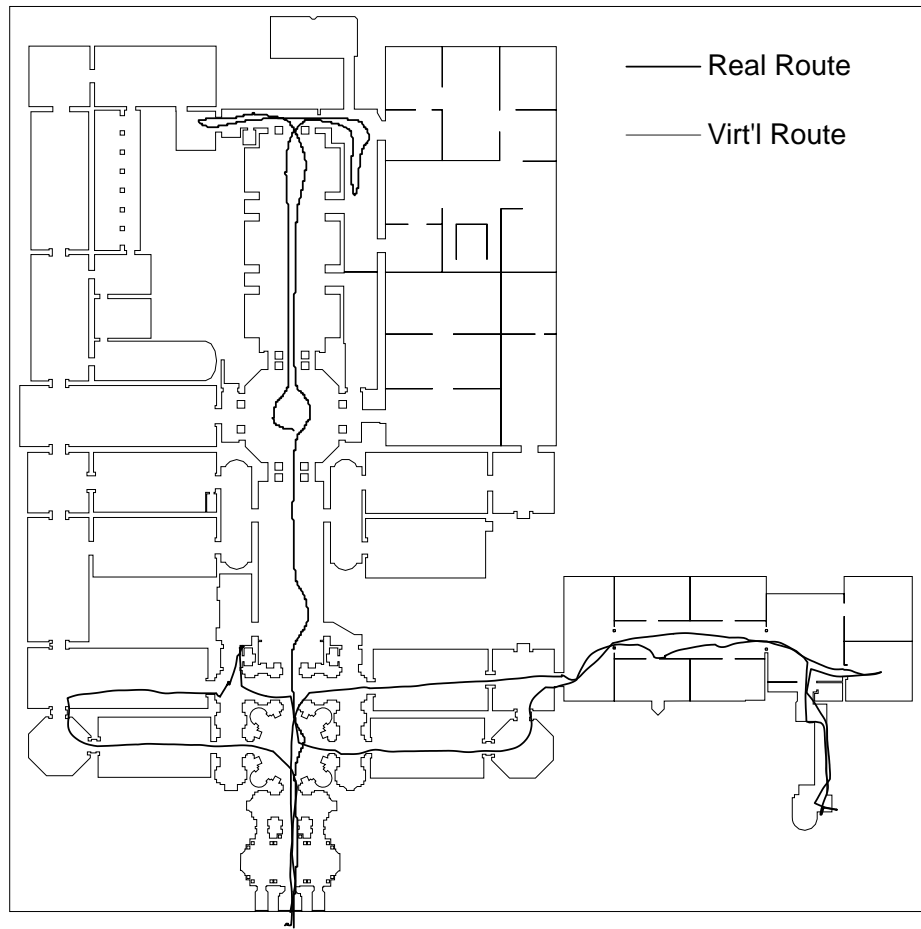Real and Virtual Routes - Isovist Max Radial Length

Figure 10. Top. Two Routes through the Tate Gallery

Figure 11. Middle. 'Area' Route Vision Profile

Figure 12. Bottom. 'Maximum Radial Length' Route Vision Profile

attributes associated with it, such as isovist area, isovist perimeter, and isovist mean radial length. If a Space Syntax analysis of the environment has been conducted (prior to processing the route), then for each point along the path, the nearest grid-isovist location will be sought, and its syntax measure appended to the path point. In this manner, it is also possible to determine how the isovist syntax-measures vary along a route. Two examples of route vision profiles are shown in figure 10. Two different routes may be used as input. In the example below, these paths are two paths taken through the Tate Gallery in London. The paths are quite different. The properties of isovists may be represented as they vary along the two routes.

The two properties that are illustrated below are the isovist attribute 'Area' and 'Maximum Radial Length'. The black line represents the path that moves up the main axis of the building, whereas the grey line-plot represents the path that explores a horizontal axis, which includes an exploration of the Clore Gallery (bottom right-most corner on plan). The route vision profiles for these paths and isovist attributes may be seen overleaf on figures 11 and 12.

25.7

It can be noted that the distinctive uniformly rising and falling gradients in figure 12 represent periods of the journey where the subject is walking along a particularly prominent line of sight (or axial line). It can be seen from the graph above that the black line represents behaviour that is more 'axial' than the grey line-plot.

Another way in which OmniVista may be used, is that instead of exporting the numerical data it may be used to export a series of pict files which can be combined into a movie using a third party piece of software such as Apple's QuickTime. This may be particularly effective for presentations, as it quickly conveys the varying field of view along a route, with little need for detailed explanation.

Finally, OmniVista also has the facility to produce a 'Restricted View' isovist path, for which it uses a smaller field of view, such as 180°, which can be set by the user (this is currently only implemented for VR headset data).

Conclusion

To summarise, OmniVista is a very simple and straightforward application to use, with many of the settings being selected by the user using pull-down menus. Although, at first glance it appears simple to use, its full functionality is quite extensive due to its three modes of use allowing for analyses of point, grid and path isovists. The possible outputs from each of the three modes are designed to allow for both visual and numerical (data) outputs, depending upon the further analysis that is required. It was decided that there was no need to incorporate sophisticated statistical analyses into the application. Instead it was assumed that a standard statistical analysis application would be used (such as Excel or StatView), therefore significant emphasis was placed upon the ease of numerical data export from OmniVista.

When visual rather than numerical outputs are required, care was taken to ensure that the user had maximum control over the resulting isovist visualisation. It was for this reason that the user was allowed to vary the size and shape of the graphic placed at the generating location of the isovist. Again, it was important to the authors that these could be set by the user by selection of options from simple pull-down menus. The ultimate aims of OmniVista were two-fold - simplicity and flexibility. In terms of these two criteria OmniVista may be held to have fulfilled its design aims.

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Appendix - The Calculation of Measures used in OmniVista

The geometrical properties calculated for each isovist location are listed below, with those measures also used by Benedikt in his paper (Benedikt 1979) marked with an asterisk. A brief explanation of how each measure is calculated is also included in this section of the paper.

1	Area*
2	Perimeter
3	Area/Perimeter
4	Circularity*
5	Dispersion
6	Dispersion (Absolute)
7	Drift
8	Maximum Radial Length
9	Mean Radial Length
10	Minimum Radial Length
11	Radial Standard Deviation
12	Variance of Radials
13	Skewness of Radials.

Area is simply the area of the isovist polygon generated, namely the sum total of all visible points (on a horizontal plane). The unit for area is square metres. Perimeter, as used in this paper, is not the same as Benedikt's measure of perimeter. Benedikt makes a distinction between two perimeter measures, real-surface perimeter, and occlusivity (the sum of the length of all occluding radials). Perimeter, as used in OmniVista, is simply the perimeter of the polygon representing the isovist. The connection between this measure and Benedikt's two measures is that perimeter in OmniVista is the sum of Benedikt's measures of perimeter and isovist occlusivity. Below is the equation used by OmniVista to calculate perimeter.

$$P = \sum_{n=1}^{n=m} \sqrt{\left(p_n^x - p_{n-1}^x\right)^2 + \left(p_n^y - p_{n-1}^y\right)^2}$$

Area/Perimeter, is the area to perimeter ratio. The most efficient area to perimeter ratio is produced by a perfect circle. As a circle is deformed and becomes more 'spiky' the perimeter of the shape increases at a greater rate than its area. As a consequence of this deformation the area/perimeter ratio becomes smaller and smaller. The area to perimeter ratio, therefore, can be regarded as a good measure of how 'spiky' or conversely how 'rounded' an isovist is. It should be noted that in order to compare isovists of different environments this measure should be normalised for the size of the world. The unit for Area/Perimeter is metres.

$$Area\ perimeter\ ratio = \left(\frac{A}{P}\right)2$$

Circularity is a measure from Benedikt's paper. Circularity is not only a measure of how well a space approximates a circle, but is also a measure of the viewpoint's position within the space. For this reason circularity is not only a measure of the shape of a space but also of the

25.8

centrality of the viewpoint within that space. It is determined by calculating the area of a perfect circle whose radius is set to the mean radial length of the isovist and then dividing this by the area of the isovist.

$$Circularity = \left(\frac{\pi |\bar{r}|^2}{Area} \right)$$

Dispersion (a new measure in OmniVista) is the difference between the values of the mean and the standard deviation of the isovist's radial lengths. This measure can take either a positive or negative value, whereas the measure absolute dispersion indicates purely the magnitude of the difference of the two values irrespective of the sign.

$$Dispersion = \left(mean\ radial\ length \right) - \left(standard\ deviation\ of\ radials \right)$$

Drift (a new measure in OmniVista) is an exceedingly interesting measure. It is the distance in metres between the location from which the isovist is generated and the 'centre of gravity' of the isovist. The centre of gravity of an isovist is calculated as if the isovist were a polygonal lamina of negligible but uniform thickness, as calculated in physics. This measure can only take positive values. Drift will tend to a minimum value in the centres of spaces and along the centre-lines of roads. For this reason there can be seen to be some similarities between areas of minimum drift and axial break-up of spaces.

$$Drift = \sqrt{\left(\left(d_y - c_y \right)^2 + \left(d_x - c_x \right)^2 \right)}$$

Maximum, mean and minimum radial length are calculated by using the lengths of isovist radials measured at specified intervals (for example every one-degree). These three attributes are generated by calculating the maximum length of any radial (or the longest line of sight), the mean length of all the radials (another measure of 'spikiness') and the minimum length of the radial (or the distance from the isovist viewpoint to the closest built edge). Mean radial length appears to be a good indicator of junctions in urban systems.

$$Maximum\ radial\ length = \left[\sqrt{\left(\left(p_n^x \right)^2 + \left(p_n^y \right)^2 \right)} \, \right]_{n-1}^{n=m}$$

$$Average\ radial\ length = \left(\left(\frac{1}{m} \right) \sum_{n=1}^{n=m} r \right)$$

$$Minimum\ radial\ length = \left[\sqrt{\left(\left(p_n^x \right)^2 + \left(p_n^y \right)^2 \right)} \, \right]_{n-1}^{n=m}$$

The standard deviation, variance, and skewness of the radials are also a family of measures based upon the distribution of the radial lengths of an isovist. Standard deviation is calculated by taking the sum of the differences between each radial length and the value for the mean radial lengths of the isovist, and then dividing this total by the number of isovist radials. Variance can be calculated by multiplying the standard deviation by itself. Variance can also be termed the second moment of the isovist, and is also a measure used by Benedikt. Skewness is the third moment of the radials, calculated by summing the cube of the differences between each radial length and the value for the mean radial lengths of the isovist, and

then dividing this total by the number of isovist radials. Skewness is also a measure used by Benedikt, who suggests that it is a good indicator of asymmetry of the perimeter of the isovist polygon.

$$Second\ moment\ (\sigma) = \left(\left(\frac{1}{m} \right) \sum_{n=1}^{n=m} r^2 \right)$$

$$Third\ moment\ (m^3) = \left(\left(\frac{1}{m} \right) \sum_{n=1}^{n=m} r_n^3 \right)$$

$$Variance = \sqrt{\sigma}$$

25.10

Connectivity, is simply a measure of how many other viewpoints are visible from a viewpoint. Each isovist will have its own connectivity value, which will be an integer number (since in this particular calculation two isovists are either connected or not, there are no gradations of connection). It should be obvious that there will be a strong relationship between an isovist's area and its visibility graph connectivity. If the distribution of generating locations is uniform then connectivity is a good approximation to isovist area.

The total depth of an isovist array is the sum of the distances of an isovist viewpoint from all other isovist locations in the array (distance in graph terms). Mean depth, however is the average distance from each isovist location to every other isovist location (in other words total depth divided by the number of isovists in the graph not including itself, i.e. n-1). This value is a real number. Radius three depth, is the sum of the distance of all points that are three or less steps (in the graph) from the isovist viewpoint.

$$Mean\ depth = \frac{1}{n} \left(\sum_{n=0}^{n=k} d_n \right)$$