8.3 Spatial Analysis for Museum Design

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The paper describes how a specially written customisation of AutoCAD enables students of Architecture to use the method of spatial analysis called Space Syntax developed by Professor Bill Hillier of the Bartlett School of Architecture, London, to examine a number of existing museums, to compare the findings against other criteria, and to draw conclusions about the strategy adopted in museum design. Simple interactive graphics enable plans to be entered and compared, so that they may be evaluated during the design process, with decisions supported by objective tests. This improves both design decisions and the learning process.

Introduction

At the Department of Architecture at Edinburgh College of Art, Heriot-Watt University, Edinburgh we have found that the method of analysis called Space Syntax is useful in many ways. The technique's ability to *predict* how pedestrians will make use of the choices offered them in a building or a series of urban spaces, besides being useful to Urban Designers and Architects, is especially valuable to inexperienced designers: our students.

Large public buildings need to be designed so that visitors may either be channelled into major through routes, steered away from areas which do not concern them, or led to the most urgent, interesting or popular parts quickly. For example, hospitals, schools and hotels have public areas but also areas which should have limited access, while still being easily found by "residents", however temporary. Similarly, galleries and museums may either wish to protect their most precious objects or lead visitors to see them without intrusive signing. In both cases security may be a factor, so that supervision of either "risk areas" or access to private areas becomes important. While experienced Architects should be able to achieve their intentions, it harder to succeed with larger and more complex buildings. Later alterations which block off areas may change the pattern of routes. By enabling quantification, Space Syntax can prove a useful tool to teach students the consequences of their designs and for checking the results of proposed alterations.

Space Syntax

Space Syntax is the name given to a method of representing, quantifying and interpreting spatial configurations in settlements and buildings; it was developed by Professor Bill Hillier and his colleagues at the Bartlett School of Architecture, University College, London Hillier and Hanson 1984). Space Syntax provides us with a way of interpreting plans which give a number of entities whose relationships may be measured, and thus give us an **objective** test of the social implications of spatial form.

A **convex space** is defined as a space within which all points are directly visible from all other points. That is, there are no hidden corners. A complete plan can be divided into a series of convex spaces.

Figure 1 (a) An arbitrary system
(b) Its Depth Diagram, showing that line 4 is more integrated than line 7. (Aspinall 1994)

Axial maps are constructed from **axial lines**, the fewest longest intersecting straight lines which can be drawn across the convex spaces to cover the plan. These usually correspond to sight lines, and often link several convex spaces of varying width along the length of the axial line.

It is possible to represent the **integration** of an axial line with the rest of the system by means of a **Depth Diagram** (figure 1). Having numbered the lines (so that they can be identified), we place at level 0 in the Depth Diagram the line whose integration is being sought (figure 1 b), then place at level 1 all the lines which it intersects , then repeat the procedure for each level 1 line in turn to produce level 2, and so on until all the axial lines have been referenced. During this procedure no line is placed in the Depth Diagram more than once. In figure 1, line 7 needs four levels to connect it to all the other lines, whereas line 4 only needs three levels to connect it to all the other lines. The fewer the levels required the more integrated into the whole system is that axial line. The **mean depth** for each line is a measure of its integration into the whole system. The **integration value** of an axial line or space on the axial map is the inverse of the mean depth. The mean depth for every line in the system can be calculated and the lines ordered accordingly, so that the lowest 10% or 25% (for small systems) - i.e. the lines with greatest connectivity - will show the “core” of the system.

The second global measure, **traffic,** indicates how often a line is likely to be used in a journey across the system. The local measures of **Control** and **Connectivity** are also calculated.

For a full description of the calculations required, see page 108 of Hillier and Hanson 1984.

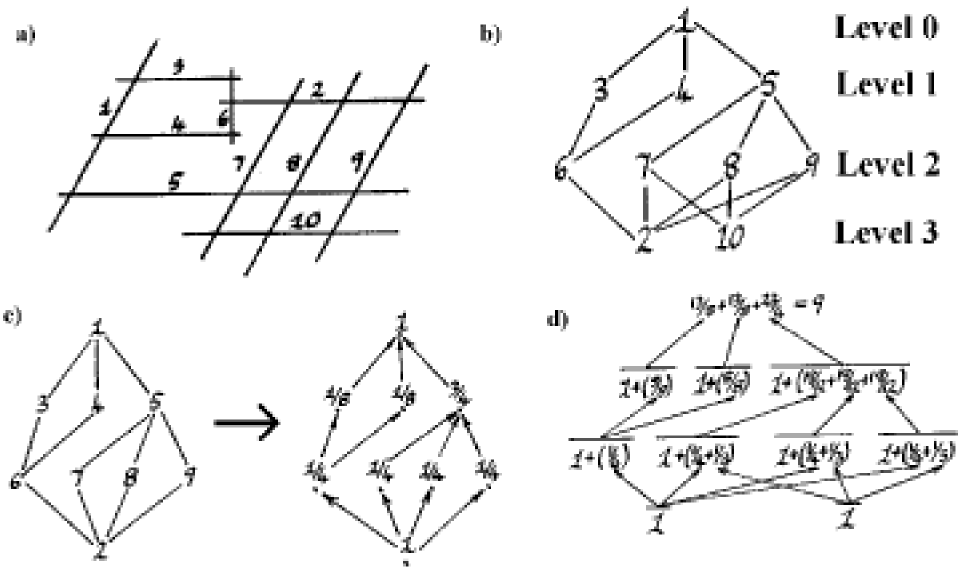

Figure 2 (a) A simple plan
(b) Starting at Space 1, link it to all other spaces
(c) Taking the path from 1♉2, if one step in a level equals 1,
assign proportions of the next possible step to each choice of route
(d) Assign proportionate values to all possible routes. (Ireland 1987)

The Edinburgh College of Art Implementation

The method by which our implementation calculates probable routes through the system from every line to every other line is outlined in Figure 2 (a)-(d), so that the integration value for each space may be calculated, giving us its inverse, the Mean Depth. Having assigned values to routes through the system it is possible to calculate all of the Space Syntax Measures for all of the axial lines. These are values are written into the data structure, along with the linked structure so that a variety of displays may be generated as the user requires.

Our first implementation, a package written in C on a UNIX system, provided an interactive tool with graphical display and digitiser input to record existing or proposed maps or plans, calculate the Space Syntax measures and plot the results. This was successively ported to two other machines. However we decided that by using AutoCAD to provide the graphical interface, a platform-independent system could be achieved.

The interface depends on the AutoLISP language. A pull-down menu offers commands corresponding to the various stages of the process; they are mainly implemented by means of AutoLISP routines, although Compute shells out to a C program based on the original calculations of our first implementation (Ireland 1984). See figure 3.

```
***POP8
[Space Syntax]
[Axial Line]^c^c(create-axial-lines)
[Bridge]^c^c(create-axial-bridge)
[Connects]^c^c(check-axial-connex)
[Orphans]^c^c(sizer) (axial-orphans)
[Delete]^c^c(delete-axial-line)
[--]
[Reset Display]^c^c(reset-display)
[Labels OFF]^c^cLAYER s syn-lines f syn-labels
[Labels ON]^c^cLAYER t syn-labels
[--]
[Compute]^c^c(syn-out) SPCOMP ;(syn-in)
[--]
[Re-intersect]^c^c(re-intersect)
[--]
[Tabulate]^c^c(if (syn-uptodate ) (syn-table)  (prin1))
[Correlate]^c^c(if (syn-uptodate ) (syn-correl) (prin1))
[Display Measures]^c^c(if (syn-uptodate) (select 1 ax-list) (prin1)
```

Figure 3: Space Syntax Pull-Down Menu (in AutoLISP)

The menu choices provide the means to create the data-structure for an axial map, add bridges, check the system's integrity, and delete lines from the data structure. Sometimes labelling the lines is useful if a table of measures for each line is required (Tabulate). In order to compare one axial map with another, the Correlate function prints out the **Integration Value** for the current system**,** calculated using the Pearson Correlation . The Display Measures function colours proportions of the measures, e.g. the lowest 10% Mean Depth lines, should indicate the most integrated parts of an axial map; that is, its most frequented routes.

```
[File]
[New...]^C^C_new
[Open...]^C^C_open
[Save...]^C^C(syn-add-xdata) _qsave
[Save As...]^C^C(syn-add-xdata) _saveas
[Recover...]^C^C_recover
[--]
[Tablet calibrate]^c^ctablet cal \\\\;limits \\z a
[Plot...]^C^C_plot
[--]
[Configure]^C^C_config
[--]
[Exit AutoCAD]^C^C_quit
```

Figure 4: Amended File Menu (in AutoLISP)

An amended version of the File menu (figure 4) is provided, partly to add the necessary data, but also because many users need to digitise plans, so that an easy access to calibrating a tablet is useful. Using scanned images of plans is also possible, using the TIFFIN command for on-screen digitising, which is a bonus due to the flexibility of working through the AutoCAD interface.

The package is simple enough for novices to use on its own because the error handling is efficient and unobtrusive; there is a routine invoked at certain points to check whether tiny unattached lines are interfering with the integrity of the data - as frequently occur while digitising. For experienced CAD users the full graphical package is available and axial maps can be created and analysed as designing and drafting proceeds.

Analysis of Museum Design

For some years now we have used Space Syntax in the analysis of museum and gallery design. Students still investigate aspects of galleries in other ways, e.g. they may look at lighting methods, or the proportion of space used for display, storage, conservation, circulation etc., but we have found that by adding Space Syntax to the palette of analytical tools a further dimension can be demonstrated, (Gray et al 1992). Novices in the field can check their own schemes as they design.

Space Syntax can predict how visitors will most easily find their way about a building, indicating which routes will be most frequented by them, making them well integrated into the axial map. The brief for each building will differ, e.g. if the valuable objects are a security risk, they must be placed in areas which are easily supervised so that they should not be found to be in poorly integrated areas of the axial map.

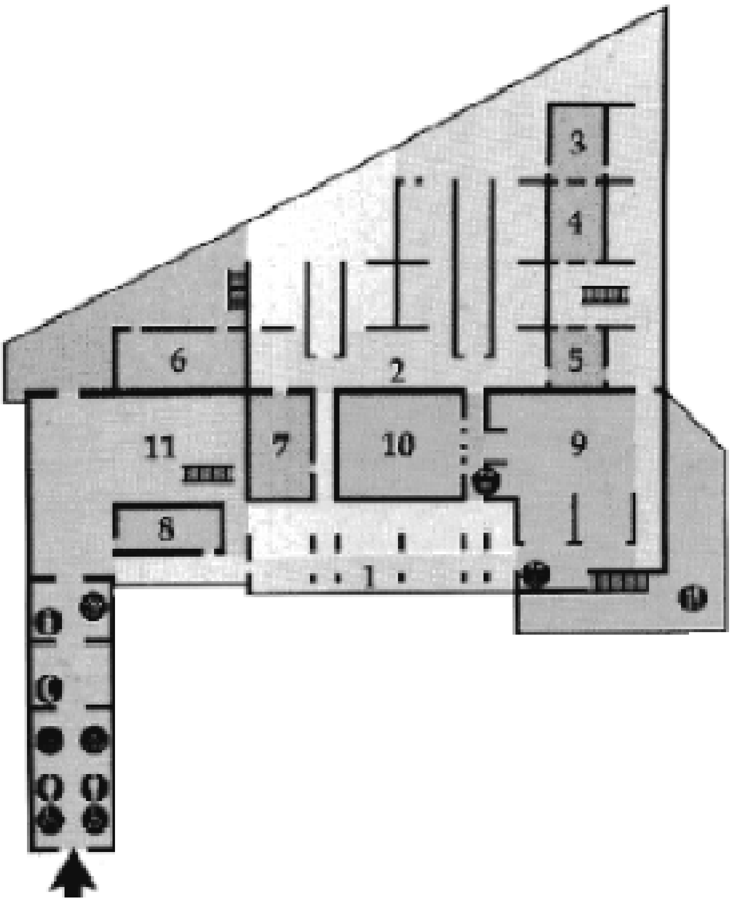

Figure 5 Ground floor plan of the Burrell Collection, Glasgow (Marks et al 1983)

One of many galleries investigated was the Burrell Collection at Pollok in Glasgow. Its Architect, Barrie Gasson, states (Marks et al 1983):

> "It was .. required that a means of easily viewing a succinct portion of the Collection should be made possible while still enabling those with the inclination to spend more time to explore the remainder"

He then adds that, in order to aid access and understanding:

> "A perimeter route was conceived to offer a line of reference around which different elements of the Collection could be arranged. A selection of the major pieces is displayed on this primary route. The perimeter is connected by two cross-routes, ... which offer short cuts, aid orientation and enable all parts to be seen as one whole."

The successful intentions of the designer are amply illustrated by comparing the plan (Figure 5) with its axial map (Figure 6). The axial map shows that the most integrated lines (Mean depth 10% Low) are the "perimeter route", and the "cross-routes", as the designer intended.

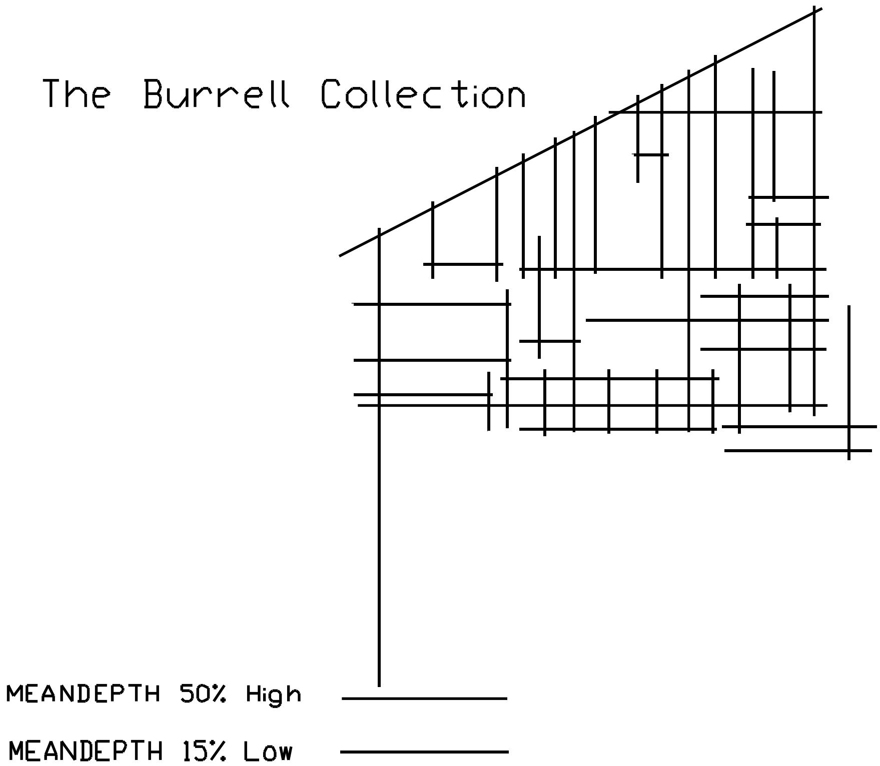

Figure 6 Space Syntax diagram of The Burrell Collection, Glasgow

Several other buildings have been interpreted in a similar manner, and this has always proved a starting point for animated discussion. This may be its ultimate benefit for student use, by making them stop to think, more even than supporting their design decisions.

Some Architects have problems with interpreting axial maps because of the 2-dimensional representation given. The varied topography of towns and the node connections between floors of buildings via lifts, stairs, and ramps, as well as visual links through glass and atria make a barrier to understanding the theory. An axial map looks too much like an echo of the plan, whereas it is in fact a diagrammatic representation of it - the length of each axial line is immaterial, it the intersections between what they represent which is significant. The linkages and changes in direction are the features that make people choose a particular route from the choices the system offers them. A stair or lift may be represented by an axial line, and bridges inserted where routes cross on the diagram but do not allow access. It is also possible to be mislead by some of terms used by Hillier. One expects Integration to be used in the sociological sense, but Hillier uses it to imply the relationship of a space with the whole structure (see Figure 1).

Conclusions

Space Syntax provides one of many tools which help student designers understand the design process and learn to make valid and justifiable decisions. By using this technique to look at Museum design we believe that our students obtain an aid to resolving the complex issues involved. By providing the means to make the calculations within a well-known graphical package, while at the same time keeping the procedure as simple as possible, we have found that students from a variety of backgrounds can use it at whatever level they wish. For the Department's benefit, using AutoCAD as the graphical interface has proved cost effective, since only a small amount of programmer's time was required to set up the package, and it will run on whatever equipment will run AutoCAD. As newer and faster machines become available, and different input and output devices are acquired, no re-implementation work needs to be funded out of meagre resources.

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