The Question Does Compute

the role of the computer in space syntax

42

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42.01

1 What is space syntax?

Space syntax is a kit of tools with a theory attached. The tools are about the 'configurational' analysis of space, and seek to analyse spatial complexes in such a way as to identify structure at the level of the whole 'configuration'. For example, if we represent a street network as its least set of longest lines, and analyse it according to the least number of lines that must be used to go from each line to all others (the simplest route, as opposed to the shortest route - though the two will often be the same), then the set of lines with lowest totals will form a pattern which we call an 'integration core'. This core will normally - though not always - connect edge to centre and identify the main 'structure' of public space in the network.

The theory of space syntax proposes that, in general, the form-function relation in cities and buildings passes through these structural properties of whole configurations. For example, movement along the streets making up a network is more influenced by the position of each street within the whole network, than by the immediately local qualities of that street. Because this is so, land use decisions which are sensitive to movement are indirectly sensitive also to spatial and locational factors, and 'integration cores' tend to become dominant patterns of public space through their role in movement-sensitive activities such as retail.

Methodologically, there are two distinctive ideas in space syntax. The first is its approach to spatial representation and how it answers the question: what is a space ? The answer it proposes is that spatial elements must be defined variably, according to the purposes of the investigation. The reasoning behind this is that different human activities have their own 'natural geometry', and what we find in any real spatial complex is not one thing but a series of potentials for reflecting different aspects of what people might seek to do in space. For example, in so far as people move around, they will treat the spatial complex as a matrix of potential lines of movement, and not, for example, as a series of convex lumps. Thus for movement studies, space is usually represented by the least matrix of lines of potential movement in the complex - the 'axial map' - one of the key elements in syntactic studies of urban space.

The second methodological key is the distinctive concept of 'configuration'. In space syntax terms, configuration means relations which take into account other relations. For example, if we cut a link in a street network, its effects will usually extend well beyond the two spaces whose link has been cut, and may have effects throughout the system, depending on the importance of the link. This reflects a basic property (and difficulty) in relational systems of all kinds. When we consider them as whole complexes, removing or changing one element or relation can have effects on the whole

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structure, which are often quite hard to foresee. It is these effects that are vital to the space syntax method, because spatial patterns work as wholes, not as accumulations of local relations, and it is the relation between the local linkages and the global pattern that must first be understood

Oddly, perhaps, this means that in quantifying the properties of spatial complexes, space syntax concentrates on the 'extrinsic' properties of spaces, that is their connections, position in visual fields, topological relations to all other, even remote, spaces in a system, rather than on their 'intrinsic' properties, such as shape, scale, and texture, even though the latter dominate our experience of space. Eventually, the theoretical justification of this counter-intuitive strategy is that space is always a 'strongly relational system', meaning that the interrelations amongst elements are more important to the structure and functioning of the system than the properties of individual spaces, and its greatest sensitivities are to changes in the structure of relations amongst spaces.

The essential research strategy of space syntax is to use these ideas as flexibly as possible in searching both for structure in space and for how that structure relates to observable function. The usual study pattern is to observe a functioning system of space, then try to find a spatial representation combined with a configurational measure - a model, we might say - which captures the functional logic of that system. To the degree that we find consistent representations and measures for different phenomena, as we do for example in studies of movement, then the results begin to look more like a theory.

2 The role of the computer

In the early days in the 1980's much of this was done 'by hand'. However, it soon became clear that analysing complex configurations required computation. Computation in space syntax research is the subject of this special issue, specifically how the use of computers has led to theory about the form-function relationship in cities and also, as computer technology has advanced (more speed, memory and access to information), so have the problems under investigation and the empirical results and applications. This has had a profound impact on the triad of activities in which space syntax is applied worldwide - main line research, design consultancy and teaching. We have noticed the development over the last ten years of a dynamic feedback process whereby theory and methodology from one feeds into the other on an everyday basis. The latest main line research findings are applied in practical design solutions in consultancy with architects, planners and local authorities. At the same time the findings of the main line research and design consultancy are taught on postgraduate courses worldwide, forming the basis for a burgeoning cohort of doctoral researchers using space syntax. It is amongst these students that we most often encounter computer technology being used to stretch the boundaries of research and, on occasion, to break through them in a completely unforeseen way. It often happens that when a new computer software package based on space syntax is developed, or existing software is updated, the students will immediately seek out the technological limits of that software. This tendency is not exclusive to in-house software but also includes commercial software packages. This often leads to new methods for graphical and statistical representation which are then applied in main line research and

design consultancy projects. It also leads to the definition of new problems to investigate, and new hypotheses about the way cities function which are then tested to destruction and eventually give rise to new theory.

An example is the development of the space syntax software Axman and the construction of the axial map of Greater London within the north and south circular roads. This was the first large scale axial map constructed after the development of the Axman software. Until this time, most axial models were hand drawn and therefore very limited in 'size' (i.e. number of axial lines). Axman was written by Nick Dalton of University College London (with funding from the Engineering and Physical Sciences Research Council) specifically to cater for the digitising and analysing of axial maps of the type already being made by hand. However, in 1991 Hua Yoo - a PhD student at UCL - decided to construct an axial map larger than anything which had preceded it by a factor of thirty. This axial map was drawn by hand, scanned into the computer in sections, digitised and then painstakingly pieced together like a jigsaw puzzle. When this was completed, it took nearly three days to process due to the lack of computer power in 1991. When it had finished processing the resulting pattern of global integration was revealing. It showed that the most globally integrated line was Oxford Street, the busiest shopping street in London. Although it was based only on the topological relationship of each axial line to every other and no additional socioeconomic data such as land use, building height or population density had been added it seemed to confirm the intuitively obvious, that Oxford Street was the most strategic alignment in London. This led to a new problem to investigate. One's intuition was that Oxford Street is busy because that is where the shops are, but the new research question became: why are the shops there? The research question originating with this axial model generated a new avenue of research which eventually led to the 'theory of natural movement' (Hillier et al, 1993), the 'movement economy' theory of the city (Hillier, 1996) and an answer to the question: why are the shops on Oxford Street? Because that is where the movement is.

Recently, another axial map was constructed which we suspect may signal another shifting of the problem-definition for space syntax research. Last year two MSc students at UCL, Shinichi Iida and Masaki Nishibori, mapped the network of routes in metropolitan Tokyo (see Figure 1). This axial map was further modified to incorporate the entire public transportation rail network of the metropolitan region. Both were constructed in little over a month using digital maps of the Tokyo street system and urban blocks over which the axial map was drawn directly into the computer. This reduced the labour required to build the axial map by a factor of three since the computer technology and initial map data allowed for two steps, in the normal way of making a map, to be bypassed. Additionally, the technological limitations of the Axman software were exposed by the size of the Tokyo axial map resulting in the software having to be rewritten (leading to a faster, more reliable version of the software). We suspect that this axial map may lead to new questions about the emergent global structure of cities and about the differentiation of urban areas at the metropolitan level. Finally, the pattern of global integration of the combined map of ground level routes and the, mostly underground, rail network (which were connected via station entrances) shows that global integration shifts when these two modes of movement are considered as a single system. First, the strategic importance of the central busi-

ness district is reinforced for integration and second, several areas peripheral to the CBD and characterised by high-rise mixed use office/retail developments are picked out by integration. Many of these areas of Tokyo have been identified in the architectural and planning press as 'edge cities' and this analysis suggests that there may be a more subtle way of defining the spatial and functional characteristics of the 'edge city'.

42.04

These two examples could be thought of as broadly in the stream of 'conventional space syntax' and are based firmly on the facilities provided by axial analysis and the Axman software. Although the most recent makes use of GIS software to make the process of map building more efficient, the core analytic software is based on a quite different conception of space. It treats space not as the cartographer's 'as the crow flies' two dimensional homogeneous surface, but as the space we all use and move around every day - perhaps 'lived in space' would be the appropriate term. 'Lived in space' is constrained by buildings and fences, by glass and water, and modulated by design or urban evolution in a way that carries social potential. The power of this approach is evidenced both by the range of theoretical applications to which space syntax has been put, and by the range of practical design applications in which it is now being used as a predictive tool. As Ian Hacking said, theoretical entities become real when you can 'spray them' (Hacking, 1983). Syntax seems close to making that grade.

Figure 1: Pattern of global integration in the axial map of metropolitan Tokyo, Japan.

We believe that at least part of that power lies in the unifying effect of space in social, economic and environmental issues. All aspects of society are lived out in spatial systems, and space provides a natural framework for bringing all of these aspects together within the ambit of a single research enterprise. Although it was one of the hopes of GIS that it could bring about this unification, we think that it is only really possible if the move is made away from 'as the crow flies' space and towards 'lived in space', and this is where the contribution of space syntax computation lies.

3 The scope of the work

At the research end of the activity, space syntax is now in use by researchers from universities around the world and, as the first symposium has shown, flown the UCL nest. It is continuing to evolve and develop at a greater and greater pace as its use spreads and it is interesting to note that this development seems to be in two main directions. First to increase the range of applications and to create hybrid forms of analysis with other approaches, and second to move into more 'egocentric' forms of analysis, concentrating on visual aspects of intelligibility and the third dimension for instance. Each of the papers in this special issue were presented at the Space Syntax - First International Symposium held in April 1997 at University College London. They have been chosen to demonstrate some aspect of this relationship between the triad of activities space syntax research is applied worldwide, with the way the computer is being used to investigate new problems and generate new empirical results, and how this has led to the development of new computer applications to handle more complex forms of phenomena and data.

Papers by Penn and Croxford, and Chang and Penn, describe the linking of existing space syntax programmes with new data sources to develop more robust models of the urban environment. Penn and Croxford describe the development of a new vehicular emission monitor which allows the collection of data on Carbon Monoxide (CO) concentrations at street level to a greater degree of resolution and sensitivity than previously possible. This data has been linked with the configurational variables commonly used in space syntax to demonstrate how we can begin to predict CO concentrations in the urban environment. Chang and Penn describe a methodological innovation of linking factors such as visual factors, major generators and attractors of movement, and effects of grade separation with configurational variables such as integration to develop a more robust model of pedestrian movement patterns in multi-level complex urban systems.

Taking a similar subject area as Chang and Penn but from a more theoretical point of view, Rashid examines a multi-level complex in Atlanta - John Portman's Peachtree Center - in order to understand how the reliance on conventional ideas such as magnets or attractor land uses in making design decisions has led to the creation of places which are confusing and unintelligible for the user. It is suggested that these factors provide only a partial explanation of the way they operate and that spatial configuration provides a more powerful explanation of the distribution of functional uses in these types of urban system. The findings of these two papers have profound implications for the way we design complex multi-level systems in the urban environment. They indicate that we must seek to better understand the relationship between 'extrinsic' spatial factors such as configuration, 'intrinsic' spatial factors such as visual

quality and grade separation, and functional factors such as attraction and land use to better design complexes which are easily understood and easy to use 'places'. Lessons such as these are now being applied on practical design projects where level changes and multiple land uses are components incorporated early into the design development, for example in the work of the Space Syntax Laboratory on proposals for the redevelopment of the South Bank Arts Centre in central London.

42.06

Another complex form of urban space comes under examination in Greene and Penn's study of four university campus in Santiago de Chile. This paper begins to unite together in one study the development of accurate space syntax models of space use and movement to factors which would appear to be external to spatial configuration itself: interaction and subjective perception. The collection of data on social interaction and students' and academics' subjective perception of the built environment via a questionnaire is detailed, and is then used to quantify the network of communications in the university campus, and their relationship to configuration. The questionnaire technique to quantify patterns of interaction and communication in complex organisations such as universities has recently found an extensive use in the evaluation of work environments and the impact of spatial configuration in either facilitating or retarding communication networks of the organisations which inhabit them.

The paper by Campos begins to question what makes some public squares 'places', and others not, by investigating how patterns of space use in public squares are shaped by the morphological properties of the urban grid. It is suggested that the urban morphology of public squares has a direct bearing on the whether they are well or poorly used public spaces. This is not expressed by degree of enclosure a square possesses (as has been commonly thought) but expressed by the ratio between the size of the square and the field of visibility available from it into surrounding urban context. As with the papers by Rashid and Chang and Penn, this has clear implications for the urban design. This idea formed a key principle in the recent Foster and Partners' World Squares for All proposals for Trafalgar Square, Whitehall and Parliament Square. Whereas the paper by Campos is primarily about the morphological characteristics of place-making at the micro-level, the paper by Karimi on the spatial logic of 'organic' cities is concerned with this at the macro-level. This paper examines the relationship between spatial and functional variables in the deformed grid cities of Iran and the United Kingdom. It is suggested that they, like other cities of the world, possess a global and local spatial structure which is fundamentally related to the distribution of functions that occur within them.

Finally, the paper by Penn et al describes Pangea, a new software workbench developed to enable the flexible analysis of multiple variables, configurational ones as well as the type of data external to configurational modelling mentioned earlier, at the level of the third dimension. This new workbench has been developed specifically to facilitate analysing the complex interrelationships between multiple variables than was previously possible.

Each paper in this special issue illustrates innovative and robust ways of using space syntax to represent a particular aspect of the relationship between form and function in cities using the computer. They also demonstrate effectively how the compu-

ter is continually being used not only to research today's problems but also in helping to define new ones for tomorrow. The key message from the range of these papers, we believe, is that theory advances in line with the ability to represent and quantify the phenomena of the real world. Hence computation is central to the advance of social and environmental theory. The space syntax kit of tools provides just one strand in this which we believe is powerful in that it is based on the representation of the geometry and topology of 'lived in' space. The new developments that will move this into the third dimension will allow the theory to broach not only lived in but perceived space as well. It remains to be seen how successful that enterprise will be.

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