An integration of space syntax into GIS for modelling urban spaces

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ABSTRACT

In the past, many methods of spatial analysis have been developed for a better understanding and modelling of real-world phenomena. However there is still a need for exploration of new analytical techniques for modelling urban spaces. Space syntax models the spatial configurations of urban spaces by using a connectivity graph representation. Such a configuration of space identifies patterns that can be used to study urban structures and human behaviours. This paper proposes methodological and practical evaluations of the potential of the space syntax approach within GIS. We present the main principles that are the basis of space syntax, in addition to methodological perspectives for a closer integration with GIS, which should be of use for many GIS applications, such as urban planning and design.

INTRODUCTION

Spatial analysis is one of the key features that differentiates GIS from other forms of spatial information processing such as spatial databases, computer cartography and computer aided design (CAD). In the last decade, much effort has been put into developing Spatial Data Analysis (SDA) theories and methods to improve understanding and modelling of real-world phenomena [Fotheringham & Rogerson, 1994; Longley & Batty, 1996; Fischer *et al*, 1996; Timmermans, 1997; Fisher & Getis, 1997]. Recent research and applications in SDA have developed many sophisticated analytical techniques for studying spatial patterns and processes. However, it is widely recognised that GIS still needs integration of new analysis and modelling methods if it is to achieve its potential as a general-purpose tool for environmental and urban planning [Openshaw, 1996; Goodchild, 2000]. The current demand for analytical tools in GIS covers a wide range of applications, ranging from the study of environmental phenomena to the analysis of urban and regional systems [Fotheringham & Wegener, 2000].

Over the past two decades, space syntax theory has provided important computational support for the development of spatial morphological studies, in particular for the analysis of urban systems. It has been widely used for pedestrian modelling [Hillier *et al*, 1993], crime analysis [Jones & Fanek, 1997], traffic pollution control [Penn & Croxford, 1997], and way-finding processes [Peponis *et al*, 1990]. Space syntax provides a configurational description of an urban structure and attempts to explain human behaviours and social activities from a spatial configuration point of view. Most space syntax studies concern issues related to urban patterns, but the method is also relevant for studies on the scale of urban design and architecture. It has been used to describe these 'non-discursive' patterns, or configurations, and to explain the morphogenesis of spatial patterns and their social implications. We believe that space syntax could provide an alternative view and model of space for the representation of urban systems within GIS. As such, an integration of space syntax into GIS would stimulate research oriented toward the analysis of urban systems at different levels of abstraction. GIS provides on the one hand a rich set of spatial data integration, analysis and visualisation capabilities that support urban studies. On the other hand, the principles that underlie space syntax theory can extend the modelling capabilities of GIS, particularly in terms of the dissemination of recent advances and experimentation throughout the analysis of urban systems. Such integration can be of value for GIS users involved in the management and planning of urban systems.

The objectives of this paper are three-fold: (1) to provide an introduction to the computational and cognitive perspectives of space syntax principles to support an alternative model of space within GIS; (2) to develop a comparative analysis of space syntax modelling concepts as against conventional GIS modelling capabilities, given relevant case studies at both city and architectural levels; and (3) to identify relevant applications of space syntax in urban science.

SPACE SYNTAX PRINCIPLES

Space syntax is a set of theories and tools used for spatial morphological analysis with particular applications in urban science. Empirical studies and applications using space syntax are well documented in the literature, *eg,* by Hillier & Hanson [1984] and Hillier [1996]. However, the underlying principles that support space syntax theory have not been completely explained and disseminated throughout the GIS community. We believe that space syntax can be considered both as an alternative model of space at the cognitive level, and as a practical computational method for the analysis of urban structures and patterns. This coincides with the scope of many scientific studies such as morphological analysis, and modelling studies oriented to the representation of dynamic urban behaviours. In this article, we provide an introduction to the cognitive and modelling principles of space syntax, in particular to the different computational parameters that underpin many of the empirical studies conducted so far.

LARGE-SCALE VERSUS SMALL-SCALE SPACES VIEW

From the point of view of cognitive perception, space can be considered at two scales, *ie*, either large or small scale [Montello, 1993; Egenhofer & Mark, 1995]. Large-scale space is beyond human perception and cannot be perceived from a single vantage point; while small-scale space is presumably larger than the human body, but can be perceived from a single vantage point. The perception of small-scale spaces while moving through a large-scale space provides a prerequisite for the perception of large-scale environment (in general, the geographic space). As human beings, we perceive a small-scale space throughout interacting objects that constitute the structure of the physical environment and the empty space that support its perception. For instance, a room may contain some furniture, such as a table and chair, but one can perceive the room's structure without any difficulty. Small-scale spaces are continuous (not discrete) and interconnected. For example, when we are walking along a street, at every moment we perceive our surrounding environment as a small-scale space.

Small-scale space perception is very important for reasoning in large-scale spaces. Downs & Stea [1977] assumed that "larger units must be built upon smaller units, that an 'atom' of experience must generate 'molecules' and so on". They further assumed that the cognition of small-scale spaces must inevitably precede the cognition of large-scale spaces. For instance, a child must fully comprehend his room before he can understand the surroundings of his house, and this spatial understanding must come before an understanding of his village, and so on. A similar assertion has been made based on empirical studies that judgement of whole spaces might be predicted from averaged judgements of their parts [Garling, 1969]. When a tourist recalls a visit to a place, he/she will most likely present a sort of sketch map, something like a plan that includes, for example, his home and sights visited, which are all inter-connected in space and time. As such, a large-scale space can be represented as an infinite number of inter-connected small-scale spaces. Such a dynamic cognitive representation may be interpreted as a navigation–learning process in large-scale space. This cognitive environment offers scope for the application of space syntax to navigation knowledge representation.

These concepts and observations provide valuable insights into the space syntax model being elaborated in this article, *ie,* that of a large-scale space being modelled as a set of individual small-scale spaces. The computational space syntax model that integrates the small-scale space perspective is based on a two-step approach. The first step is the representation of the large-scale space as a finite number of small-scale spaces. The second step is to link these individual small-scale spaces to form a connectivity graph. For instance, Figure 1 shows various closed building plans, and their related connectivity graphs, with each room or corridor represented as a small-scale space. A connectivity graph supports the computation of important spatial properties, *eg*, how each node links to its immediate neighbours, and how each node links to every other node. Answers to these questions help us in understanding a large-scale space (here a building) from the perception of its small-scale spaces.
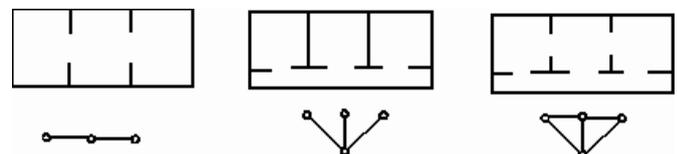

FIGURE 1 Closed building plans and their connectivity graphs

SPATIAL DECOMPOSITION

An urban environment consists of two parts: spatial obstacles such as buildings, and free space within which human beings are able to move from place to place. The notion of free space, defined as the parts of an urban space available for movement of people (thus excluding by definition physical obstacles) is particularly important for space syntax approach. Space syntax focuses on free space and decomposes an entire area of free space into small pieces of space, each of which can be perceived from a single vantage point. As such, this representation constitutes the cognitive fundamental modelling reference of the space syntax approach. In other words, a visual distinction between different forms of the perceived space (free space versus physical obstacles). These modelling concepts differ from those generally used in GIS modelling: *ie,* object- versus field-oriented para-

digms, since the concept of free space is not represented as such by these models.

Several space syntax representations can be applied, depending on the degree of linearity of the free space. The first space-syntax representation is oriented toward environments which are relatively linear. This linear property represents the fact that the built environment is relatively dense, so that the free space is stretched in one orientation at most points. Common examples of this type of urban environment are a city, a town, a village or a neighbourhood. When humans are walking in this type of free space, at most points (if not all) such a free space is perceived as a 'vista' that can be approximately represented as an axial line. The first representation, a so-called axial map, is defined as the least number of longest straight lines (Figure 2a). According to how each line intersects every other line, a connectivity graph, taking axial lines as nodes and line intersections as links, can be derived.

In contrast, the second representation is more oriented toward environments in which the free space is non-linear. A typical example of this type of environment is a building's internal layout, where most rooms are stretched in two ways, although corridors may have linear characteristics. Therefore, the second representation partitions the free space as a finite number of convex spaces, which is represented by a convex polygon in 2D maps. A polygon is said to be convex if no line drawn between any two points in that polygon goes outside the polygon. For a standard building layout, each room or corridor can be approximated as a convex space (Figure 2b). So the second representation, a so-called convex representation, should comprise the least set of the broadest spaces that covers the whole free space. A con-

nectivity graph is derived by taking rooms as nodes and door connections as links.

The third representation is also oriented to non-linear free space, but with a more precise spatial representation. This representation is based on the notion of isovist, which is defined as a visual field that is wholly visible from a single vantage point [Benedikt, 1979] (Figure 2c). As an observation point moves through the environment, the pattern of light reflected to that point changes continuously, creating an optic flow, which is the key concept in Gibson's direct perception theory [Gibson, 1979]. Benedikt & Burnham [1981] made a claim, based on an experiment, that isovists in some sense are a simplification of an optical flow that determines people's movement behaviour in the environment. According to the representation, a building plan is partitioned into a finer grid [Turner & Penn, 1999], *eg*, 100 × 100. Each cell at the finer level represents a single vantage point and its associated isovist. Then a connectivity graph can be created depending on how each isovist overlaps each other isovist. For the purpose of illustration, Figure 2 introduces a 3 × 3 grid with its associated isovists.

Theoretically the second and third representations are also applicable to the representation of a linear free space (first representation). However, due to the expense of computing large spatial configurations, so far they have only been applied to non-linear free spaces.

SPATIAL ANALYSIS PARAMETERS

For urban morphological analysis, space syntax provides a range of spatial property parameters derived from the connectivity graph. First, connectivity is the most apparent parameter for morphological analysis. Connectivity is defined as the number of nodes directly linked to each
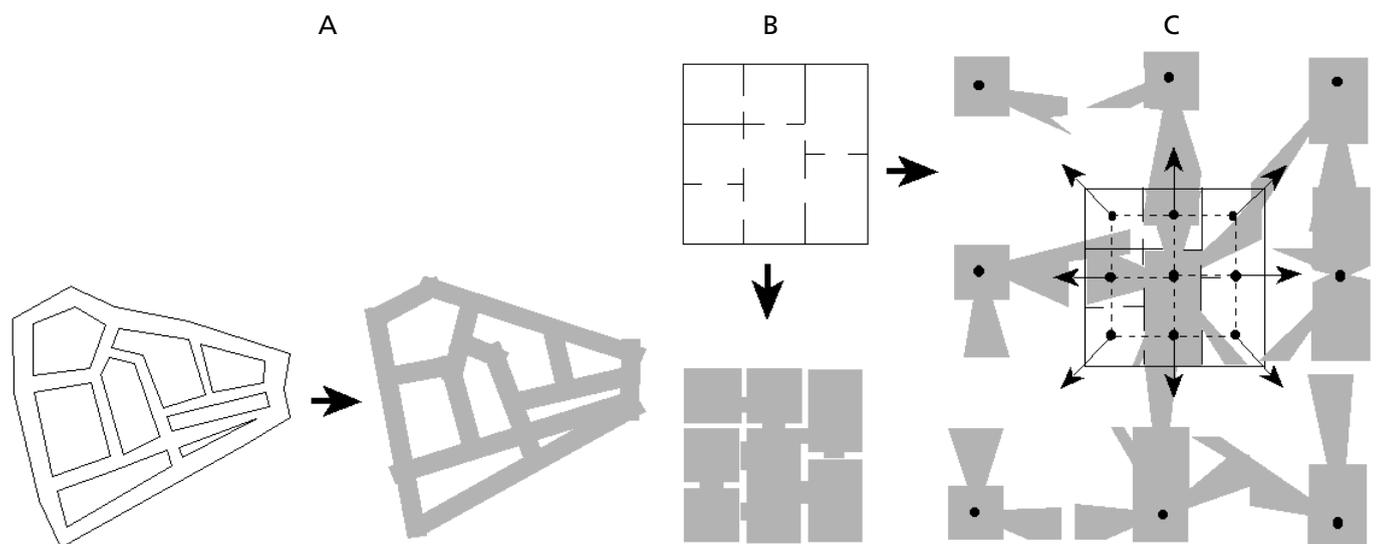

FIGURE 2 Discretisation of free space into small-scale spaces, which are (a) vista spaces, (b) convex spaces, and (c) isovists (note: isovists have been relocated for presentation purposes)

individual node in the connectivity graph,

$$C_i = k$$

where k is the number of nodes directly linked.

The second parameter is the control value, which is defined as a parameter which expresses the degree of choice each node represents for nodes directly linked to it. The control value $(ctrl_i)$ of a node (i) is determined according to the following calculation:

$$ctrl_i = \sum_{j=1}^{k} \frac{1}{C_j}$$

where k is the number of directly linked nodes of a considered node (i), and C_j is the connectivity of the jth directly linked node.

The notion of depth can be defined as the number of steps from a considered node to all other nodes. A node is said to be deep if there are many steps separating it from other nodes. By contrast, a node is said to be shallow if only a few steps separate it from other nodes. Depth is not an independent parameter of the space syntax. However, it is an important variable for calculating the integration of a node. Let d_{ij} be the shortest distance between two points i and j in a graph G, then the total depth of node i is the sum of distance

$$\sum_{j=1}^{n} d_{ij}$$

and accordingly mean depth is defined by

$$MD_i = \frac{\sum_{j=1}^{n} d_{ij}}{n-1}$$

where n is the number of nodes of a whole graph.

The third parameter is integration. Integration of a node is by definition expressed by a value that indicates the degree to which a node is integrated or segregated from a system as a whole (global integration), or from a partial system consisting of nodes a few steps away (local integration). It can be measured with either Relative Asymmetry (RA) or Real Relative Asymmetry (RRA):

$$RA_i = \frac{2(MD_i - 1)}{n-2} \quad \text{and} \quad RRA_i = \frac{RA_i}{D_n}$$

where $D_n = 2\left\{ n(\lg_2^{((n+2)/3)-1} + 1) \right\} / [(n-1)(n-2)]$ is the D-value, which is intended to provide the standardised value for the integration parameter (see Kruger [1989] for details).

These parameters can be used to describe both local and global properties of a spatial configuration in the sense of integration or segregation. A space (ie, small-scale space) is said to be more integrated if all the other spaces can be reached after traversing a small number of inter-

vening spaces; it is less integrated if the necessary number of intermediate spaces increases. This concept is measured by global integration. Similarly, connectivity and local integration measure the degree of integration or segregation at the local level. Basically there is a correlation between these local and global parameters.

Such correlation is 'intelligibility', which is used to describe the part–whole relationship within the spatial configuration. It is defined by the coefficient of correlation between local and global parameters. A local area is said to be intelligible if its coefficient value is higher than the one of global area as illustrated in Figure 3. The large oval represents the cluster of all spaces of a whole area, while the small oval represents the cluster of a selected local area. The global parameter characterises the global integration, while the local parameter denotes either the connectivity or local integration.
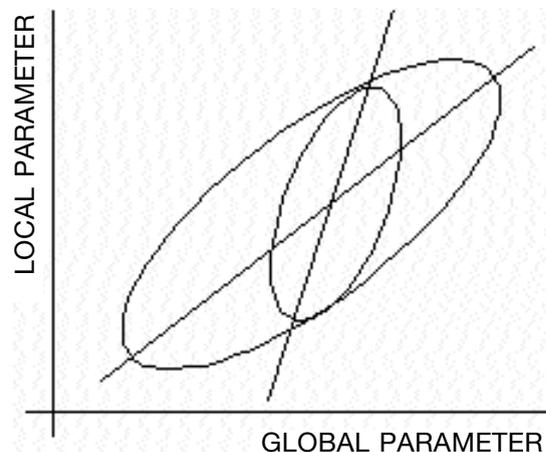

FIGURE 3 Illustration of intelligibility

INTEGRATION OF SPACE SYNTAX INTO GIS
SPACE SYNTAX AS A MODELLING CONCEPT FOR GIS
Within GIS the relative and absolute views of space are the two main concepts used for the representation of environmental and urban systems, ie, space perceived as an attribute of objects or space perceived as a container, respectively [Peuquet, 1988; Couclelis, 1992]. These concepts support two different perceptions of space: the relative view considers space as a collection of objects, since the objects themselves are the space; the absolute view considers space as the content of things [Nunes, 1991]. At the data representation level, two main spatial data structures have been developed and are currently used within GIS: raster and vector data structures (note that raster and vector data structures can represent either cognitive relative or absolute perceptions of space [Nunes, 1991]). The emerging field of Naïve Geography intends to develop new models of space that reflect how people intuitively or spontaneously conceptualise geographic space and time [Freundschuh & Egenhofer,

1997]. Naïve Geography concepts integrate a more experience- and sense-based representation of space [Johnson, 1987; Lakoff, 1987]. For instance, the representation of navigation knowledge can be modelled and represented by the concept of mental maps [Claramunt & Mainguenaud, 1996]; relationships between these mental maps are identified throughout semantic connections [Portugali, 1996].

As already mentioned, space syntax approach provides another, different view of space. From a computational point of view, it is based on a graph-oriented representation of a geographical space that models the free spaces of an urban system (Figure 1). In other words, space syntax models an urban system by concentrating on free spaces. The distinction between the free spaces and spatial obstacles is generated by the existence of boundaries between streets and the built environment, *ie,* both are interdependent as they share a common physical boundary. In fact such a property is similarly, but more formally, defined by emerging boundary theories [Smith & Varzi, 1997].

Within urban systems, a free space is explicitly represented as the centre of interest when dealing with the displacement of human subjects within it. In fact, spatial obstacles implicitly create various free spaces for human/vehicle movement. Space syntax is generally concerned with a computational representation of the free spaces to achieve the analysis of urban structures. Free spaces provide a unique view for understanding the configuration of an urban system [Jiang & Claramunt, 1999]. They also allow the detection of the skeleton/structure of an urban system and the derivation of the 'configuration knowledge'. If spatial decomposition methods that we have already described are applied on free spaces, they provide various skeletal representations of an urban configuration and a reference for analytical parameters. So both space syntax and GIS are complementary in many aspects, and we believe that their integration could offer promising possibilities for the analysis of urban systems.

AXWOMAN[1]: AN IMPLEMENTATION OF SPACE SYNTAX WITHIN GIS

The implementation of an analytical space syntax tool within GIS provides some important advantages from both computational and user points of view. Incorporating space syntax in GIS promotes both GIS and urban morphology research. Furthermore, it enhances GIS functionality in spatial analysis into the domain of urban morphological analysis. On the other hand, GIS provides rich geo-referenced data, spatial data analysis and visualisation capabilities for urban morphological

research. The development of the prototype Axwoman is based on the vector data structure of a GIS in order to represent the graph components of the space syntax. The analytical tool is implemented as an ArcView extension (Figure 4). ArcView was chosen because of its user-friendly GUI and its potential to extend spatial analysis by using the built-in Avenue language.
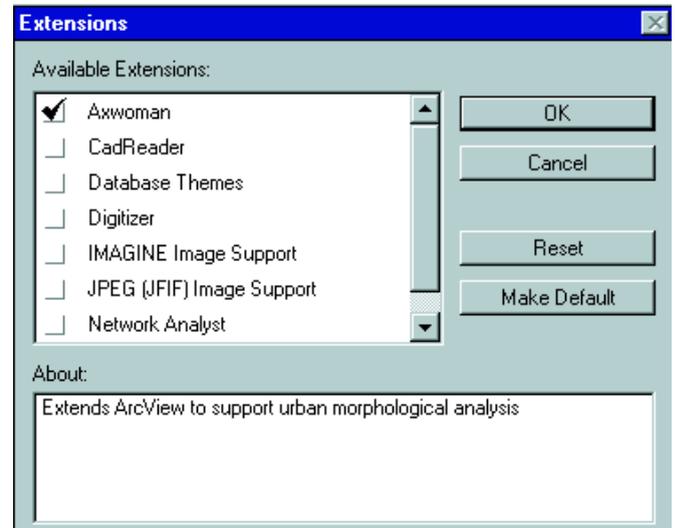

FIGURE 4 Axwoman extension based on ArcView 3.0

The structure of the space syntax implementation in GIS is illustrated in Figure 5, where three main functions are emphasised, *ie,* drawing, computation, and analysis. The three functions are implemented using Avenue scripts with different interface modules: drawing with view, computation with view and table, and analysis with table and chart. All these Avenue scripts are packed as an extension named Axwoman (Axwoman.avx), using Extension Install, Extension Make, and Extension Uninstall (refering to ArcView's script library). A set of icons is created and linked to respective Avenue scripts, and an online help is implemented using Microsoft Help authoring tools.

Once the extension is specified by a single 'click', all these functions are added to ArcView. A series of mor-
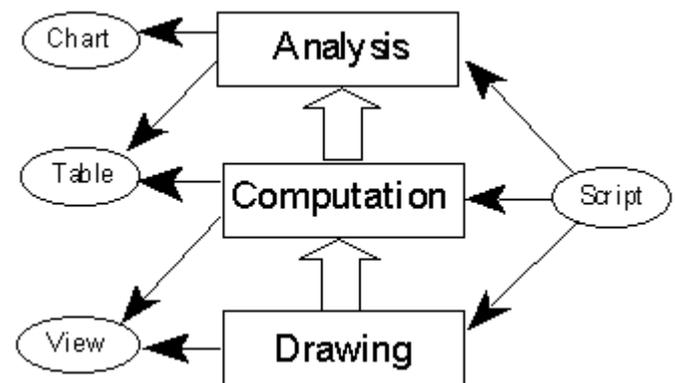

FIGURE 5 Schematic structure of Axwoman

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[1] The software is publicly available for downloading at
http://www.hig.se/~bjg/Axwoman.htm

phological analyses can be done with the extension module (cf. tool bar in Figure 6). *Axial line and polygon drawing tools* allow users to draw axial lines and polygons on a scanned map or an ArcView feature theme. *Doit tools* calculate various space syntax parameters, based on a connectivity graph, including connectivity, control value, and local and global integration. Computed results are stored in a table corresponding to the axial map or polygon theme. A user can explore data from different perspectives, or import observed data, *eg*, pedestrian or vehicle flow rates, which can be associated with the integration through regression analysis.
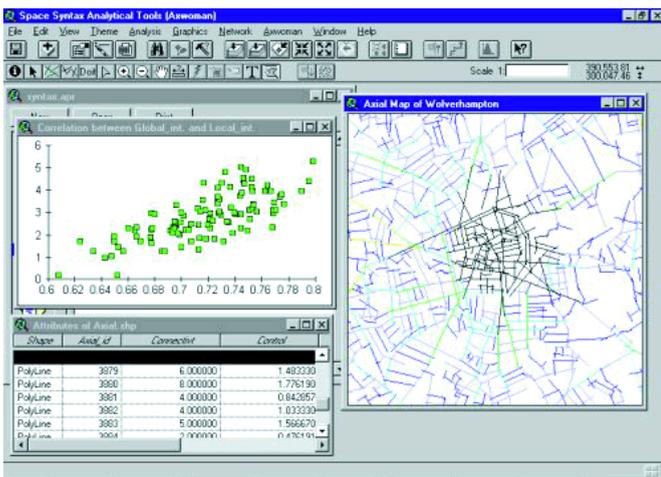

FIGURE 6 The Axwoman extension to the ArcView interface

Furthermore, local areas can be selected for intelligibility analysis. For this purpose, a range of *selection tools* are implemented with different polygon shapes. Worth noting is the software's exploration capability. In order to conduct the morphological analysis discussed here, a range of analytical components is provided such as axial maps, polygon maps, tables, charts, and so forth. All these components are dynamically linked to each other, so any action applied to one of the components will be propagated to any other. Figure 6 shows a typical interface.

IMPLEMENTATION DETAILS
Drawing an axial map and polygon map is a relatively straightforward task, since ArcView has a facility to draw geometric shapes, including straight-line segments and various geometric shapes. Before the computation, all axial lines or polygons should be stored in a graphic list. Each line or polygon has to be checked using request *Intersects* to see how many other lines or polygons intersect with it, which leads to the connectivity and control values given by the space syntax.

Using Avenue, the calculation of integration is rather difficult and time consuming as it involves the calculation of the total depth. The total depth has another name, *ie,*

'status', which was initially proposed for social networks [Harary, 1959; Buckley & Harary, 1990]. It shows the positional status of a node within a graph. Assume that the status $s(root, v_k)$ from the root to node v_k is stored in list s. Let V track nodes not yet visited; C records the current neighbourhood being processed; D accumulates next neighbourhoods; and $N(v)$ (w is an element of $N(v)$) denotes the adjacency list of node v. The following pseudo-code describes the algorithm for calculating status (or total depth), with which the global and local integration can be obtained. The main principle of the algorithm is the Breadth First Search (BFS) traversal approach, *ie*, to begin at the root and find its neighbours, and then their neighbours, and so on, until one has traversed the entire graph and reached all nodes.

```
Begin
  s(root) = 0; i = 0;
  C = root
  V = V(G) - {root}
While C≠0 do
  Begin
    i = i + 1
    for each w ∈ N(C) do
      Begin
        D = D ∪ {w}
        remove w from V and all adjacency lists
        s(root) = s(root) + i
      end
    C = D
  end
end
```

Once the computation is done, all computed results are stored in an attribute table. In terms of the value of the morphological parameters introduced, a new map theme is created and it is coloured using a spectral legend with red representing the largest value and blue representing the smallest value; other colours represent intermediate values. In addition, the software has links to other colour legends often used in GIS.

With regard to the analysis functions, different shapes of selection tool are implemented by the adaptation of ArcView's *SelectRect*. The difference is that they return different geometric shapes, such as irregular polygon, circle, line and polyline, instead of rectangles.

This set of functions is important for spatial data analysis and it has been implemented within Axwoman. For instance, in exploring a local–global relationship (intelligibility), a local area should be selected instead of a global one. Therefore Axwoman has various advantages over the existing Mac-based stand-alone Axman[2].

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[2] Refer to homepage
http://www.bartlett.ucl.ac.uk/spacesyntax/software/software.html

CASE STUDIES

Urban level

To illustrate the functions of Axwoman, we introduce here two experimental studies, one at the urban and one at the building level. The first case study is the analysis of the small town of Gassin (hereafter referred to as G-Town) in southern France, which was initially used as an exemplar for space syntax by Hillier & Hanson [1984]. This example illustrates the essence of space syntax analysis in that the axial lines defined for the town are based on first defining the least number of 'fattest' convex spaces that span all the spaces between the buildings of the town. The various morphological parameters – connectivity, control and integration – have been computed using the software and these are presented in Figure 7 by colouring streets according to the spectral colour legend. In G-Town, the two best 'connected' streets pass through from west to east, and in effect these are likely to be the main streets. However, from the viewpoint of how each street (or space) 'controls' its neighbours, the right-hand one of the two best 'connected' streets tends to be weaker than the left-hand one. In terms of global integration, which measures the extent to which any street is linked to every other, the right street keeps its highest value but not the left one. As for many empirical studies, local integration based on a three-step distance was computed and it is clear from Figure 8 that there is a strong relationship between connectivity and global integration. The influence of morphological structure on human activities can

be analysed using appropriate observation data for these activities.

Building level

The second case study is a floor plan taken from a building complex currently functioning as an educational institution (Figure 9a). In the figure, each room or corridor is represented as a polygon and the door connections between rooms are represented by a short line segment. It should be noted that we did not use so-called convex polygons as we believe that each room is small enough to be viewed and perceived from a single vantage point, despite it being non-convex. According to space syntax analysis, each room or corridor space has a range of morphological property values such as connectivity, control
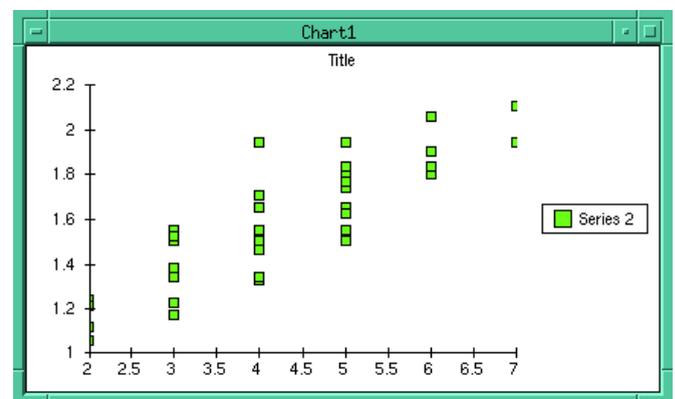

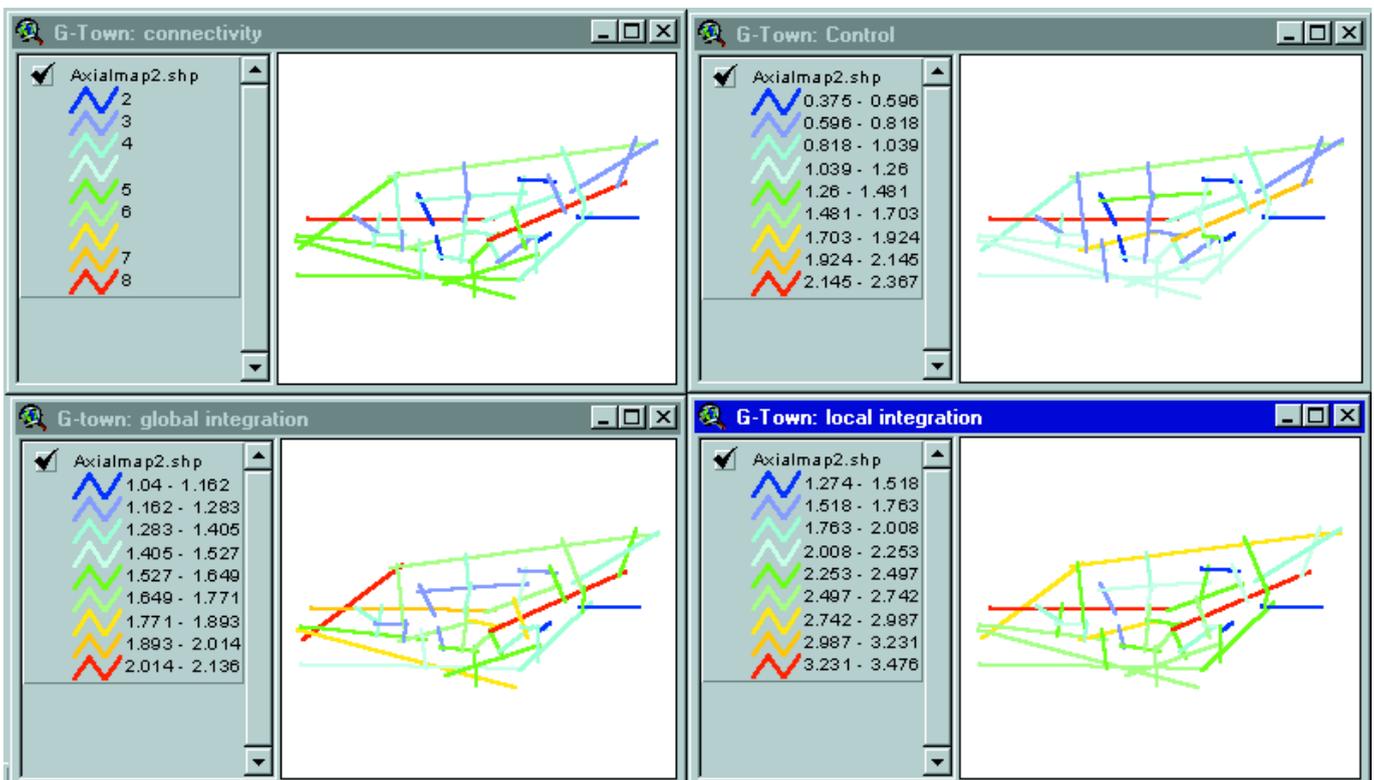**FIGURE 8** Scatter plot between connectivity and local integration

FIGURE 7 Spatial patterns with connectivity, control, global integration, and local integration

and integration. Of particular interest is the global integration represented by the colour scale shown in Figure 9b. The long corridor, coloured brown, is well integrated and tends to attract more movement of people, while rooms coloured light blue are well-segregated spaces. According to the real functions of rooms, we could group all spaces into two categories, those above the long corridor and those below the corridor. Those spaces above the corridor are used for teacher's offices and those below the corridor are classrooms for students, so interaction between teachers and students mainly occurs in the long corridor. On the other hand, the two clusters above the corridor have a common room for teachers to meet. Not surprisingly, teachers' offices are the most segregated of spaces, which is functionally appropriate. The same case study can be used to analyse the impact of morphological structure on how humans find their way around complex buildings.

SPACE SYNTAX POTENTIAL FOR URBAN SCIENCE

An important application of space syntax concerns the analysis of pedestrian movement within an urban system. A considerable number of studies on this have been carried out over the past two decades. The basic conclusion is that local integration can be used to study people's movements within an urban system. Accordingly, urban planners and designers can foresee movement flows before the actual development of real urban systems by analysing the morphological structure of the design plan using space syntax techniques.

For public building complexes, overall human behaviours can be influenced by a re-arrangement of space layouts. One fascinating example is the Tate Gallery experiment. Tate Gallery is a renowned gallery of modern art at Millbank, London. The experiment involved the use of space syntax for syntactical analysis and to collect data in
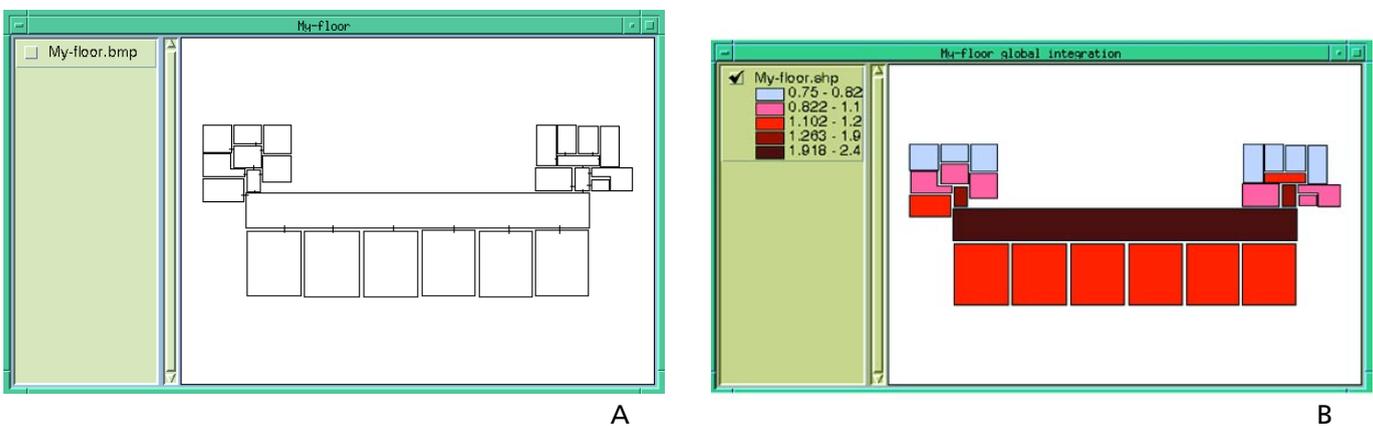

A

B

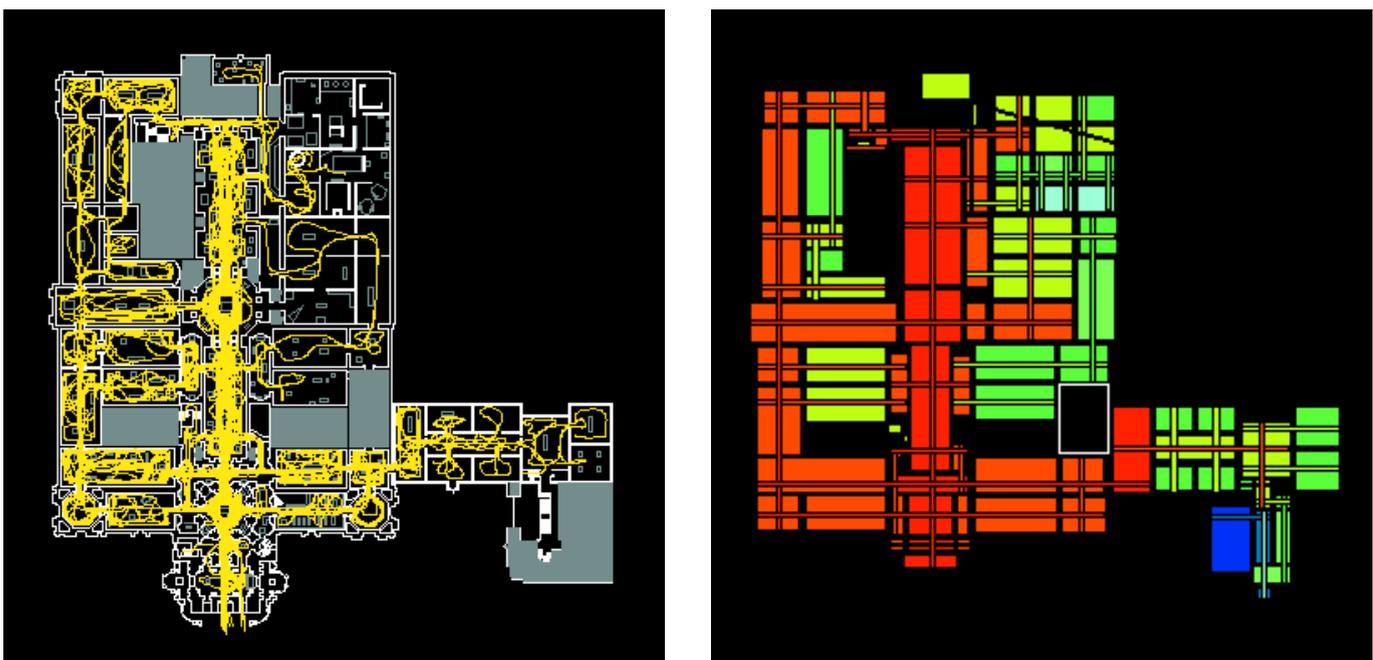**FIGURE 9** Floor plan (a) and global integration of each space (b)

FIGURE 10 People's routes observed (left) and space syntax analysis result (right), where red represents the highest local integration value and blue represents the lowest value [Space syntax, 1999]

order to analyse people's movement behaviours in the gallery. Through space syntax analysis and empirical observation it was demonstrated that there is a significant correlation between movement rates of people and local integration. Figure 10 (left) shows routes of people observed during the first ten minutes of their visit to the gallery, and (right) the result of space syntax analysis of the local integration of each space.

One of the main analysis parameters is the integration, which is one way to calculate accessibility of an urban pattern. A lot of space syntax studies have shown good correlation between integration and movement, and especially pedestrian movement. This method does perhaps not predict traffic flow more precisely than the gravitation models usually applied, but it is done with greater ease. This finding has an interesting scientific implication. It is the street pattern that generates movement, which in turn attracts the shops. Thus, shops are not the main generator of movement. This fact also means that it is possible to predict land value and land use through street pattern analysis. [Desyllas, 1997; Klarqvist, 1999]

A general idea in urban planning is that burglary of houses can be prevented by withdrawing them from spaces that have a higher frequency of use, ie, syntactically speaking, to locate them in more segregated spaces. Housing designers of today tend to apply the 'cul-de-sac complex' model. According to recent studies this approach is not based on reality. Shu [1999], in particular, has shown that people are safer in more integrated spaces, ie, in urban space with a better visual field and movement potentials. Several other types of crime seem to be affected in the same way, for instance rape and robbery, with the exception that the segregated spaces are located near highly integrated ones. Unprovoked violence seems, on the other hand, to occur in the most integrated spaces. Location of crime can thus be explained partly by space syntax theory, and accordingly the theory can be used as a component for actions related to the prevention of crime in urban planning and building design.

In complex buildings and cities, way-finding must sometimes be supported to a great extent by signs, numbers, colours, and maps. The labyrinth seems to be the model applied in the design, either as an aesthetic endeavour or as a consequence of unskilful design when handling a complex design brief. We all have had the experience that when entering a museum or a city for the first time it is possible to find our way to important spaces without any instruction or information in addition to what is given through the spatial configuration. When it is not possible we become frustrated and may even get lost. There are indications that the syntactic properties of lay-

outs determine the ways in which buildings and cities are explored [Peponis et al, 1990]. By adjusting the syntactic properties of plan layouts, it may be possible to modulate visitor 'itineraries'. Layouts can be described by both deterministic and probabilistic models.

Intelligibility has a cognitive meaning in urban planning and design. In recent space syntax research, Kim [1999] investigated how residents perceive their neighbourhoods and their city. Subjects (local residents in respective areas) were chosen from two localities in the northwest of London. They were required to sketch a more global area in terms of their understanding. Surprisingly, the results indicated that people living in intelligible areas have a more developed sense of global integration. Thus, from a cognitive point of view, intelligibility is the property of space that in some senses affects human perception of a part–whole relationship. Accordingly, most urban spaces should be designed as intelligibly as possible in order to facilitate people's navigation and exploration. By contrast, secret building complexes or areas should be designed as unintelligibly as possible.

A vast range of research was presented in 1997 and in 1999 during the first two Space Syntax symposia ever held [Hillier, 1997; Holanda, 1999]. This research showed interesting relations between urban and building space configurations, on the one hand, and social aspects on the other. Although the space syntax method is not just a scientific tool for explaining the relation between form and function, it may provide the foundations for understanding how to design an urban area or a building, as well as providing a means for testing design conjectures. The Space Syntax Laboratory in London has been involved in several professional projects supporting design processes. We expect that urban planners will find the space syntax method of great value when it is integrated into GIS and CAD they already use.

CONCLUSION

Successful development of GIS still implies the integration of new analysis and modelling methods for environmental and urban planning. In the past, space syntax has made an important experimental contribution to the analysis of urban structures. However, the dissemination of space syntax principles requires awareness of its modelling principles and capabilities within the GIS community, which is nowadays largely involved in urban studies.

The research described in this paper introduces the principles and modelling concepts of space syntax, and some of the main spatial parameters that support computational modelling and analysis of a spatial configuration for urban planning and design. Current results and advantages of the space syntax have been analysed with

respect to its potential for analysis of the morphogenesis of spatial patterns and their social implications. The space syntax method provides an efficient experimental approach to the understanding of spatial configuration. The space syntax implementation realised within Axwoman is currently oriented to the analysis of the dual graph based on axial line and convex polygon representations. We intend to extend Axwoman to achieve integration of isovist representations and the exploration of new cognitive and computational models that reconcile GIS and space syntax modelling concepts.

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RESUME

Dans le passé plusieurs méthodes d'analyse spatiale ont été développées pour une meilleure compréhension et une modélisation des phénomènes du monde réel. Cependant il y a encore un besoin pour l'exploration de nouvelles techniques analytiques pour la modélisation d'espaces urbains. Une syntaxe spatiale modèle les configurations spatiales d'espaces urbains en utilisant une représentation de graphes de connectivité. Une telle représentation de l'espace identifie des formes qui peuvent être utilisées pour étudier des structures urbaines et des comportements humains. Cet article propose des évaluations méthodologiques et pratiques du potentiel de l'approche de la syntaxe spatiale dans un SIG. Nous présentons les principes essentiels qui forment la base de la syntaxe spatiale, en plus de perspectives méthodologiques pour une intégration plus étroite avec un SIG, ce qui devrait s'avérer utile dans beaucoup d'applications de SIG, telles que la planification urbaine.

RESUMEN

En el pasado, muchos métodos de análisis espacial han sido desarrollados para mejorar la comprensión y el modelamiento de fenómenos del mundo real. Sin embargo, hace todavía falta explorar nuevas técnicas analíticas para modelizar los espacios urbanos. La sintaxis espacial modeliza las configuraciones espaciales de las áreas urbanas mediante una representación gráfica de la conectividad. Una tal configuración del espacio identifica patrones, que pueden usarse para estudiar estructuras urbanas y comportamientos humanos. Este artículo propone evaluaciones metodológicas y prácticas del potencial, que ofrece el enfoque de la sintaxis espacial en SIG. Se presentan los principios básicos de la sintaxis espacial, junto con las perspectivas metodológicas para obtener una mejor integración con los SIG, lo que debería ser de utilidad en muchas aplicaciones de SIG tales como la planificación y el diseno urbanos.