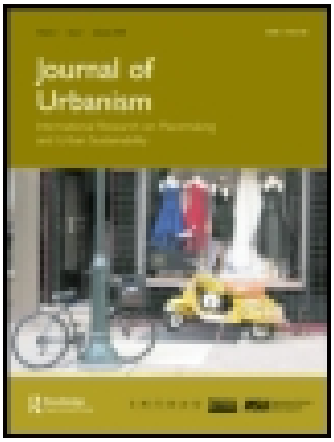

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Different approaches in the study of urban form

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RESEARCH PAPER

Different approaches in the study of urban form

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In recent years, the debate on urban morphology has been polarized by two different perspectives, the first developed within the International Seminar on Urban Form (ISUF), based on the Conzenian and the Muratorian traditions, and the second – space syntax – developed particularly in University College London. Both approaches are being further developed in a wide international context. The first and the second parts of this paper describe the origins, main characteristics, and contributions of these approaches, which are illustrated by the authors on-going research on Oporto urban form in Portugal. The last part presents some suggestions for bridging the gap between these approaches.

Keywords: urban morphology; Conzenian school; Muratorian school; space syntax; integrated approaches

Introduction

This paper is part of a research project on different approaches to the study of urban form, and is grounded on morphological work recently developed in our research centre, and inspired by the International Seminar on Urban Form (ISUF) perspective. Our main purpose is to contribute to a closer articulation between ISUF and space syntax approaches, addressing the challenge presented by some of their leading proponents. The first part of the paper describes the origins of the Conzenian and the Muratorian schools – two of the most influential schools within ISUF – and presents the main research directions of that body: the history of urban form, the agents of change, the relationships between urban morphology and planning, and urban micromorphology. This approach is illustrated by a study on the evolution of Oporto's (Portugal) urban form during the last two centuries. The second part of the paper presents the foundations of space syntax in University College London, as well as its main distinctive features – the focus on space, the representation of spatial relationships in the axial map, the syntactic measures, and the construction of a pattern language – its directions of research and the current themes of debate. This approach is also illustrated with the Oporto case study. The final section presents some suggestions for bridging the gap between these approaches at three distinct levels: theoretical, conceptual, and methodological.

ISUF and the Conzenian and Muratorian traditions

This first part focuses on urban morphology within the ISUF perspective. In spite of the presence of different morphological traditions in several European countries, we focus on

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the British historical–geographical school, based on the work of Conzen, and on the Italian typo-morphological approach, grounded on the legacy of Muratori. This is mainly due to the quality and dynamics of their recent research work, and to their importance within ISUF.

The origins of the Conzenian and the Muratorian schools

Our analysis of the evolution of the British Conzenian school is based on the work of Larkham (1997, 2006) and Whitehand (2001, 2007). In spite of the existence of an autochthonous British tradition – of which the works of Smailes (1955) and Carter (1970) are examples – Larkham and Whitehand identify the origins of the Conzenian school in German geography, particularly in the works of Schlütter (1899) and Geisler (1918). The link between the German and the British cultures was established by Conzen, a German geographer who migrated to the United Kingdom in 1933. Conzen sustained a morphological approach at a time when geographers were favouring functional approaches and statistical methods. Conzen's seminal study on Alnwick in Northumberland focuses on a number of key questions for urban morphology (Conzen 1960). How does the plan of an old-established town acquire its geographical complexity? What contribution can the development of a plan provide to the regional structure of a town? What concepts can be deduced from this kind of research to the theoretical body of town plan analysis?

The Conzenian tradition was developed by Whitehand, who extended this approach to the dynamics of building processes and to economic issues, particularly the relationships between the city, its habitants and the dynamics of the building industry. In 1974, Whitehand founded the Urban Morphology Research Group (UMRG) at the University of Birmingham. A number of key British urban morphologists, notably Hall, Kropf, Larkham, Lilley, Samuels and Slater, subsequently became members of this research group. Its focus on urban form is founded on urban areas based on the study of their history, the main agents, and the fundamental ideas involved in their design and transformation. The UMRG has two main focuses: the study of planning and management of medieval and pre-modern cities; and the analysis of the design processes of townscapes in the 19th and the 20th centuries.

The Italian school of urban morphology and building typology was founded by Muratori in the 1950s. Its central idea was the historic understanding as the key to recover the sense of continuity in architectural practice (Cataldi *et al.* 2002, Cataldi 2003). Muratori believed that the urban and architectural crisis was mainly due to the modernist assumption that an analysis of the city dividing it according to its main elements (isolating them from their context) would lead to a more effective planning practice. Muratori intended to build a critical theoretical framework to explain the process of creation and transformation of urban forms throughout the centuries.

After the death of Muratori, his work was further developed by Caniggia, an assistant in Rome (for example, Caniggia 1963, Caniggia and Maffei 1979, 1984). Caniggia was concerned with the simplification of Muratori's theory, highlighting its operative aspects and fostering its wider diffusion. Theory and practice formed a consistent process in the work of Caniggia, as they did in the work of Muratori.[1] This process was based on a typological analysis of the city, which was in clear opposition to a kind of prevailing architectural leadership.

Currently, the most important core of this Italian school is constituted by the Centro Internationale per lo Studio dei Processi Urbani e Territoriali (CISPUT), founded in 1981 in Florence. Its main goal is the promotion and development of typo-morphological research in the study of cities and their processes of transformation.

Directions of research

Having presented two of its most important schools, we move on to the identification of the main themes and characteristics being developed within the wide ISUF framework. In recent years, this framework has found, in its annual International Seminars and in its journal *Urban Morphology*, a platform for an exciting debate. A first characterization of the ISUF approach in a wider geographical context is provided by Darin (1998), Heineberg (2007), Hofmeister (2004), Kealy and Simms (2008), Oliveira and Pinho (2006), and Vilagrasa (1998) for Europe; by Conzen (2001), Costa (2006), and Gilliland and Gauthier (2006) for the Americas; and by Siskna (2006) for Oceania. Because of the restrictions of a journal publication, we chose to focus on four particular themes of the debate: (1) the history of urban form; (2) the agents responsible for townscape transformations; (3) the relationships between urban morphology and planning; and (4) urban micromorphology.[2]

A number of British contributions for the development of a general theory on urban form and for a greater utilization of deductive procedures are referred to by Larkham (2006). After two decades of modest progress in this direction, the creation of ISUF in the 1990s constituted a remarkable contribution for this process.

The bridging between the Conzenian and the Muratorian schools constitutes one of the most interesting steps for the establishment of a common framework to enable the international comparison of theories, methods and practices. This bridging process has found a number of difficulties. Different disciplinary backgrounds, architecture and geography separated these schools. While the first has been studying urban form for prescriptive purposes, with the aim of developing a theory of city design – how cities should be built – the second has been studying urban form for descriptive and exploratory purposes, with the aim of developing a theory of city building – how cities are built and why (Moudon 1997). Nevertheless, a number of similarities between Conzen's and, in particular, Caniggia's approach have been stimulating this process: (1) both were concerned with cities as historical phenomena; (2) both conceptualize this phenomena in a manner and to a degree that contrasts with the dominant descriptive approaches; (3) both recognized cycles in development and focused on periodicities on the creation and adaptation of physical forms; and finally (4) both privileged the predominant forms in the landscape, the huge number of ordinary buildings, rather than the small minority of buildings of architectural distinction (Whitehand 2002, 2003).

In this process of continuous development and refinement of concepts, Larkham (2006) and Whitehand (2001) highlight the importance of five concepts originally defined by Conzen: the morphological region, the fringe belt, the morphological period, the burgage cycle, and the morphological frame.[3]

The first research direction on which we chose to focus corresponds to the historical reconstruction of the physical form of urban areas and it is supported by a diverse set of data sources, such as fieldwork in existing urban tissues, the analysis of old maps, the study of historical documents, and archaeological work. While in England and in Poland this line of research has mainly been developed by urban geographers; in other countries such as Germany this work has mainly been developed by historians (Whitehand 1992).

The main issues dealt with within this line of thought are, among others: the comparison between different medieval European cities (Slater 2005); the study of the *composite* town plan (Slater 1990, 2005); the reinterpretation of problematic historical issues, such as the possible existence of a particular urban structure that has subsequently disappeared; the analysis of medieval planning through plot dimensions and forms, and through the differences between ideal and real structures; the analysis of orthogonality in medieval planning

(Lilley 2001); and finally the refinement of specific, rigorous and transferable analytical techniques (Baker and Slater 1992). The combination of this historical trend with the use of geographic information systems (GIS) has been particularly interesting (for example, Lilley *et al.* 2005).

The second strand of current research is the analysis of the agents responsible for urban transformations. In this respect, a number of studies are identified according to their chronological scope, as follows: the main medieval agents, namely the Church (Slater 1987) and aristocratic families (Lilley 2001); the characteristics of landownership in the industrial period, during a process of conversion of agricultural land into urban use, and the production of suburban developments; and finally, the main agents acting throughout the rising period of industrial capitalism, with the subsequent changes in many small cities, in terms of urban layout, architecture and land uses. Focusing on later periods, other studies are also identified, such as: the main characteristics of the real estate sector, distinguishing direct and indirect agents and the different types of procedures (Larkham 1988); the importance of the family life cycle in the process of residential development, particularly in the decisions on conservation or transformation of original plots and buildings (Whitehand and Carr 2001); and finally, the tensions between the main actors in the process of suburban redevelopment (Larkham and Morton 2005).

In recent years, the relationships between morphological thought and urban planning practice have been playing a central role in research on urban form. Despite some difficulties when moving from description and explanation to prescription, urban morphology, as a specific field of knowledge on the urban structure and transformations, has an unquestionable legitimacy to contribute to more informed interventions in the city.

A number of recent studies have been focusing on the application of morphological concepts in planning practice, namely: the fringe belt (Kropf 2001, Whitehand and Morton 2003, 2004); the type, urban tissue and levels of resolution (Kropf 1996a, 1996b, 1997, 2001); the morphological region (Larkham and Morton 2006); and the design area (Hall and Doe 2000). For a selection of planning documents integrating these concepts, see Oliveira (2006).

The fourth research theme is urban micromorphology (for example, Moudon 2002, Whitehand 2001, Whitehand *et al.* 1999). This entails a detailed analysis of the spatial relationships between the physical changes occurring at the scale of the individual plot and of ordinary 20th-century houses. Whitehand (2001) and Whitehand *et al.* (1999) distinguish and characterize two different levels of change. Large-scale changes (subject to development control) are negatively correlated with the dwelling density at which the neighbourhood was originally developed. On the contrary, smaller-scale changes are positively correlated with these same dwelling densities. The fundamental reasons for these are the greater susceptibility of the areas of higher-dwelling density to the contagious diffusion of minor and cosmetic changes.

Oporto case study

This approach is illustrated[4] below with a research project carried out by the authors. Its main purpose is the comparative analysis of the evolution of the urban forms of Lisbon and Oporto during the last two centuries. (The definition of this time framework was due to the low rates of urban growth before the 1800s.) Notwithstanding, only the latter case will be considered in this paper.

Oporto has never been the object of this kind of cartographic study. In the 1990s a number of Portuguese researchers chose to analyse smaller cities but, at that time, they did

not have the required tools to approach a city at this scale (for a brief description on the study of urban form in Portugal, see Oliveira and Pinho 2006).

The authors' research was based on a set of fifteen maps of the city of Oporto produced after 1813 (the first representation of the city by George Balck). Cartographic redrawing in our GIS Laboratory started with the preparation of an updated and rigorous computer-made representation of the city. After some initial work, which included the erasing of all unnecessary layers of information, the 2003 map was ready to generate all the previous maps by successive subtractions of all the physical elements that were built in the period between the two consecutive maps. In practice, each new redrawn map was the framework for the redrawing of the previous one. In each step, it was also necessary to introduce all the detailed adjustments for a precise overlapping of each pair of maps. This effort to make all the successive town plans strictly compatible allowed for the construction of a model, permanently updatable and, due to the layered organization, able to support different kinds of analytical work. Obviously, such a complex process has to deal with maps of rather different levels of rigour. For instance, all the original maps prepared before 1892 were produced with no contour lines (a technique established in France at the beginning of the 19th century) which made the redrawing exercise far more difficult. Moreover, some plans included dashed representations of a number of projected urban forms that were never built, judging by the subsequent plans.[5]

In the end, and in order to emphasize the essential aspects of the urban form evolution, all the relevant information from the original cartography was removed. The analysis of the redrawn maps makes evident the essential elements of the urban form – urban spaces for circulation, urban spaces for permanence, ordinary buildings, and singular buildings.

The fifteen analysed plans (Oliveira and Pinho 2006) suggested the existence of three morphological periods in the last two centuries of Oporto's urban history: a *monarchic period* corresponding to the five earliest town plans (1813–1865), a *late monarchic and dictatorial period* relating to the maps comprised between 1892 and 1960, and a *democratic period* corresponding to the more recent four town plans (1978–2003) (Figure 1).

The *monarchic period* corresponds to the initial stages of urban expansion outside the medieval walls. The then emerging streets (such as the emblematic Rua do Almada) were planned and built, by the so-called Junta das Obras Públicas, on a territory structured by five (non-planned) roads leading to the different cities in the North of Portugal. The process of expansion to the West was reinforced by the construction of a number of singular buildings in strategic locations, acting as landmarks. In the new streets, regular plot systems were adopted, supporting the emergence of residential buildings with a rational design and framed by a number of standardized elements of construction. The spatial organization of Oporto was profoundly marked by the industrialization process and the associated housing construction for the working class, mainly in the form of the so-called *ilhas* (rows of houses built on narrow and long plots, of around 6 m frontage and 100 m of maximum depth).

The *late monarchic and dictatorial period* corresponds to the northern and western urban expansions, supported by three avenues (a new type of urban form characteristic of this period, and sometimes complemented with another emergent type of physical element, the roundabout) – Boavista, Marechal Gomes da Costa and Antunes Guimarães, and by a East–West structural street, Constituição. The city growth was organized along these large axes, defining new directions, supporting new building facades, organizing the built-up areas of the surrounding urban fabric. The public transport system had a fundamental role in the spatial arrangement of the city in this period, enabling the emergence of larger distances between residence and work. By this time, the urban fabric of Oporto was marked by the construction of the first social housing blocks, built to eradicate all the *ilhas* from the

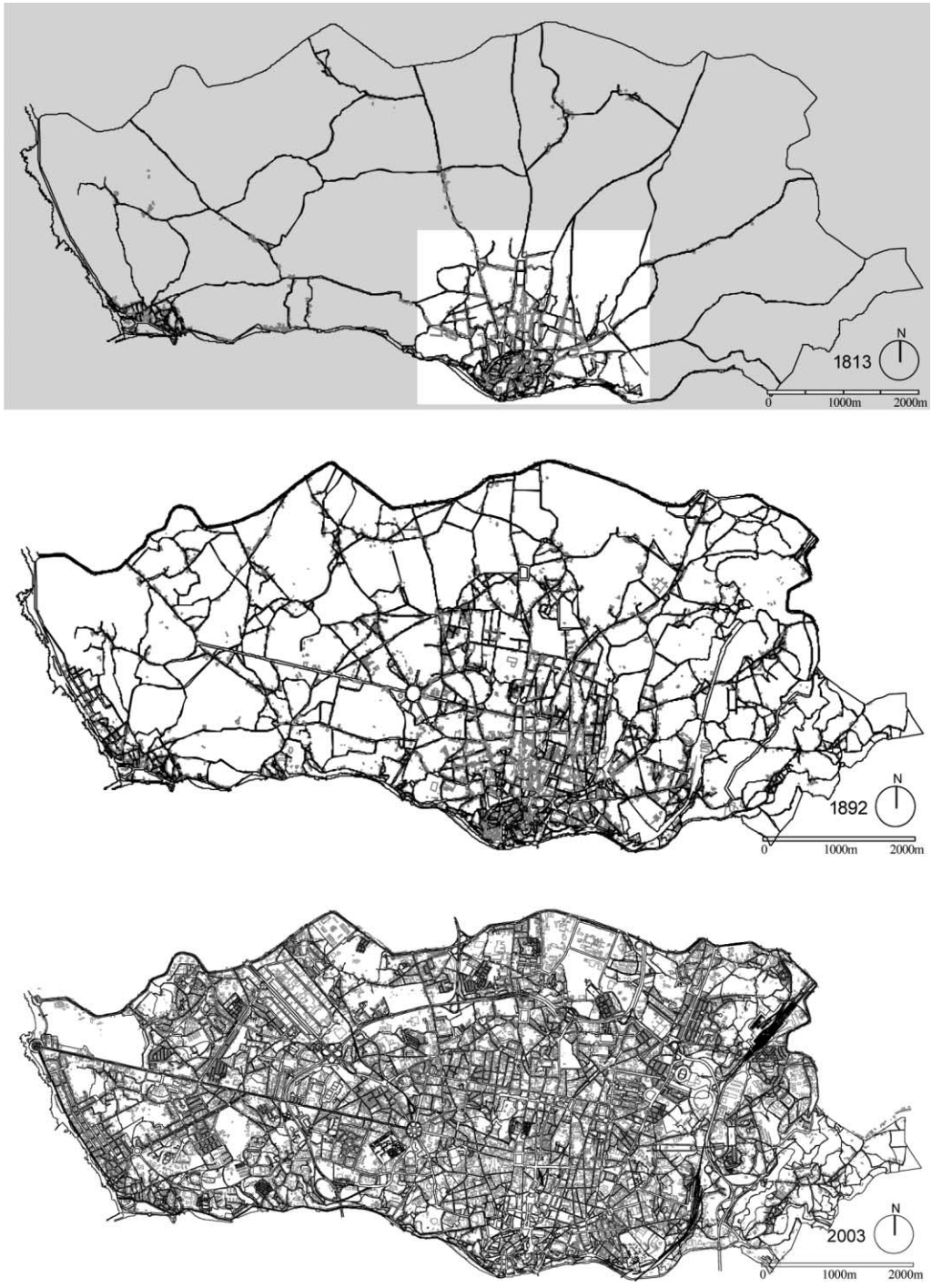

Figure 1. Oporto morphogenetic analysis: town plans of Oporto from 1813, 1892 and 2003, based on the original prints of *Planta Redonda* by George Balck, *Planta Topográfica da Cidade do Porto* by Telles Ferreira, and *Planta da Situação Existente* by STCMP (Serviços Técnicos da Câmara Municipal do Porto).

city. These housing interventions corresponded, in a first phase, to single-family two-storey buildings and, in a second phase, to a series of massive interventions – throughout the 1950s and 1960s – in large neighbourhoods composed of several multifamily buildings freely disposed on the ground.

The maps comprised between 1978 and 2003 correspond to a third morphological period which included a set of new urban forms. Heavy urban road infrastructures were constructed overlapping the traditional urban tissues of Oporto. These fast circulation roads represented a radical change in the structure and organization of the urban fabric. The large green park on the West side and the renewed (sea and river) waterfronts have substituted the traditional squares and gardens of the city as the main urban areas for permanence and are, at present, intensively used by the local and metropolitan population. The construction of the new campus on the West (Campo Alegre) and on the North (Asprela) of the city confirm the relocation of the university from the centre to the peripheral parishes. Finally, housing promotion by the private sector, particularly in the outskirts parishes, is intensified in this period.

A look at the fifteen-map sequence, particularly in the late monarchical and the dictatorial period, makes evident the importance of two axes in the overall urban layout, Boavista and Constituição, leading the city towards West and North.

The 1813 map already represented the Eastern part of the Boavista axis, named as a street and not as an avenue (Figure 3). This street linked a large square, República, with one of the five gateway roads to some of the most important nearby cities in the North of Portugal. In 1813, Boavista was 11 m width, 500 m long, and 80% of it had already been occupied with buildings. More than 150 years later, in 1978, the street was thirteen times longer, with the largest expansion between 1839 and 1892. The evolution of the percentage of building facade during the whole time period can be divided in two distinct parts: an initial decrease between 1813 and 1932, and a final increase between 1932 and 1978. Still, the building facade percentage in the latter was far from the initial percentage in 1813. The number of perpendicular streets had been growing throughout the years studied, more reduced in the 20th century than in the 1800s.

Construction of Rua da Constituição started in 1843. Nevertheless, the first map to include this street, and to represent the whole city, was the 1892 map. Despite its apparent unitary form, Constituição had been built in three moments: first its central part between a square, Marquês, and another gateway road, Antero de Quental; then a Western extension; and finally, an Eastern extension. The percentage of building facade along the street was not very high, particularly in the Eastern part. Here, a new orthogonal urban tissue emerged, limited to the North and to the South by local topography. Curiously, building construction in these peripheral parts was higher than in Constituição. The street length remained the same between 1892 and 1932, and increased between 1932 and 1978. The percentage of building facade has been growing regularly, from 20% by the end of the 19th century, to 58% by the end of the 1970s.

The use of cartographic redrawing in the study of Oporto highlighted the most important contribution of this method: a rigorous representation of the spatial characteristics of urban phenomena. Five main outputs are identified: the construction of a model of the evolution of urban form, continuously open to the addition of and articulation with other morphological and planning data and information; the overall and simultaneous visualization of the evolution of the urban form of a particular city throughout a long period of time; the rigorous identification and characterization of expansion areas (the overlapping of two consecutive maps, using different colours, allows for a direct perception of those areas that have gone through deeper urban transformations); the opportunity to analyse systematically

unexplored urban development processes; and finally, the possibility of typifying the different urban tissues taking advantage of a rigorous and versatile cartographic base (Pinho and Oliveira 2009).

Space syntax

The origins in University College London

While the core of a *quantitative approach* to urban form analysis was, in the 1960s, in the Centre of Land Use and Built Form (LUBFS) in Cambridge directed by Leslie Martin and Lionel March, at the end of the 1970s it moved to the Unit for Architectural Studies in London directed by Bill Hillier. Space syntax research began in this period with the main purpose of understanding the influence of architectural design on the existing social problems in many housing estates that were being built in the UK.

Besides an interesting set of seminal papers published in the 1970s during the first years of this research programme (e.g. Hillier 1973, Hillier *et al.* 1976), two books must be highlighted: *The Social Logic of Space* (Hillier and Hanson 1984) and *Space is the Machine* (Hillier 1996b). In the first, a new theory is proposed that focuses on space as a dimension of social life. Hillier and Hanson (1984) build a conceptual model where the relationships between space and society are analysed, bearing in mind the social dimension of space patterns, and the spatial dimension of social patterns. The second book synthesizes the development of this theory throughout the 1980s and the beginning of the 1990s, highlighting its specific features, particularly the configurational and analytical dimensions. This theoretical development corresponded to wider research on the functional and spatial nature of city and buildings, to the production of software exploring the graphic dimension of space syntax's analytical tools, and to a large number of practical applications within architecture and urban design.

Throughout the last decade several contributions to space syntax method and theory can be traced. In terms of method – frequently corresponding to the development of new software – we should highlight the texts: of Turner (2004), Turner and Penn (1999) and Turner *et al.* (2001) on the process of *syntacticizing* the *visibility graph analysis* and on the proposal of the *Depthmap* software (its application to the Oporto case study is described below); of Dalton (2003) on angular analysis; and of Figueiredo and Amorim (2005) on continuity lines resulting from the aggregation of axial lines. In terms of theory, we should highlight the texts: of Peponis *et al.* (1997, 1998a, 1998b) on geometrical issues; of Batty (2004a, 2004b) on graphs; of Hillier (2002) on urban form; and of Hillier (1999) on the relationships between space, movement and land-use patterns.

A number of studies on the evolution of a city throughout a long time period, as in the Oporto case study, can be found in the space syntax literature. Perdikogianni (2002) compares the evolution of spatial and functional patterns of two Cretan 'organic' cities – Heraklion and Chania – since the 17th century (1666–1990), demonstrating how the morphology of their grids was a determinant for the development of two different historical cores. Dai (2004) analyses the evolution of the Chinese city of Suzhou throughout the last seven centuries (1229–2004), investigating the relationships between the changing functional pattern and its spatial structure in the urban transformation process. Gemil (2007) analyses the sequential development and the consequent urban patterns of Bucharest since 1852. Azimzadeh (2008) analyses the different periods of urban development of the Swedish city of Gothenburg between 1644 and 2004, focusing on the urban layers resulting from planned developments.

The main characteristics

The focus on space and the relationships between space and movement are two fundamental aspects of the space syntax approach. In its seminal texts, such as Hillier and Hanson (1984), this focus on space emphasized the boundaries between the emerging space syntax and other approaches. These authors believe that most of these approaches were discussing space in terms of its defining surfaces. Others were debating space on its own and not the relationships within buildings and urban areas, which was the purpose of space syntax. Hillier and Hanson (1984) defend a theory that a descriptive autonomy for space can be established, enabling the consideration of a wider morphological variety to reflect the different relationships between space and society. In synthesis, a new view of architecture and of the city is proposed, emphasizing those urban spaces where people move through and where social and economic activities are carried out. Spatial configuration is a key concept in this approach, meaning the relationships between two spaces within a system considering their relationships with all the other spaces in that same system (Hillier *et al.* 1987).[6]

Space syntax presents some innovations at the level of the relationships between urban space and movement, either pedestrian or vehicular. Contradicting the then current theories that pointed to the existence of flows to and from *attractor* land uses as the main explanation for these relationships, space syntax suggests that the configuration of the urban layout itself is the main generator of movement patterns. Hillier *et al.* (1993) designate the movement generated by the layout configuration as *natural movement*. They sustain that movement has a morphological dimension or, in other words, is a functional product of the intrinsic nature of the layout. As such, the question of movement and of space use in general cannot be separated from the question of urban form itself.

The way that spatial relationships within a building or an urban area are represented is another distinctive element of space syntax. This representation is translated into an axial map[7] which is constituted by the least set of axial lines that cover the whole system, in a way that any convex space is crossed by one of those lines (Hillier and Hanson 1984). The axial line corresponds to the longest line that can be drawn through an arbitrary point in the spatial configuration.[8] The axial map can be translated into a graph, which is a finite set of nodes, called vertices, connected by links, called edges. A number of topological measures can be extracted from that graph to quantify the characteristics on the spatial configuration.

The definition of topological measures intends to quantify the spatial pattern of relationships of a system. We focus on global (radius n) and local (radius 3) integration, connectivity, global and local intelligibility, and synergy. Global integration measures the relative depth of each axial line to all other lines of the system. Local integration measures the accessibility of each line up to three steps away. Connectivity measures the degree of intersection or one-step possibilities of each axial line. Global intelligibility expresses the degree of linear correlation between connectivity and global integration, and is defined as the degree to which what we can see and experience from the spaces that make up (or are connected in) the system and what we cannot see – the integration of each space into the system as a whole. Local intelligibility is calculated by the degree of linear correlation between connectivity and local integration. Synergy expresses the degree of linear correlation between local and global integration and somehow intends to reduce the influence of the system size.

Lines of research

While in the early days space syntax mainly focused on pedestrian movement patterns, today its main lines of research include land-use patterns, the global versus local dimensions,

spatial cognition, social cohesion and exclusion and, finally, crime and order. Due to its recent dominance in space syntax literature, the two latter issues are subsequently developed.

A set of recent papers shows how space syntax can be used in the study of the spatial dimension of segregation (Dalton 2007, Hillier and Vaughan 2007, Marcus 2007a, Vaughan 2007). Drawing on a study of a small American city, Dalton (2007) shows how an alternative perspective on integrated transport can lead to unusual, albeit effective, solutions to social and economic exclusion. Hillier and Vaughan (2007) propose an explanatory model for the ability of a city to accommodate social differences by organizing patterns of accessibility according to the degree of co-presence required by the activity contained in each space. Marcus (2007a) shows that when public space is designed to be segregated rather than part of an integrated network of streets, it can have profound effects on the ability of housing estate residents to form social ties. Taking London as a case study, Vaughan (2007) identifies a *line of poverty* with a strong spatial dimension, distinguishing between poor, spatially segregated streets and more prosperous, spatially integrated streets.

In his key study on space and crime, Hillier (2004) suggests the absence of a correlation between crime and density, and only a poor correlation between affluence and crime. Contrarily to these current assumptions, Hillier defends a very strong correlation between layout type and different types of crime. Each particular type of crime and the associated built environment characteristics has recently been studied by different authors – street robbery by Reis *et al.* (2007) and Sahbaz and Hillier (2007); residential burglary by López (2005), López and Nes (2007), Nes (2005), and Reis *et al.* (2007); thefts from cars by López and Nes (2007) and Nubani and Wineman (2005); and antisocial behaviour by Hanson and Zako (2007) and Heitor (2001). This set of studies uses the space syntax approach by itself or in combination with other methods. It goes from a micro- to a macro-scale of analysis, and it is able to provide evidence from different geographical contexts throughout the world.

Current debate

A number of fundamental themes in space syntax's current debate are focused on here: the axial map, the opposition between metric and topological measures, the incorporation of tridimensional elements, and the land-use patterns. The most recurrent theme in space syntax literature throughout the last few years has been the axial map. While some suggestions have contributed to the overall improvement of the axial map, others (for example, Batty and Rana 2004, Ratti 2004a, 2004b, 2005, Steadman 2004, among others) have not been incorporated by space syntax, for many different reasons.

A key issue in the criticism of the definition and generation of the axial map is the passage from handmade drawings to computer-aided drawings. Several authors have criticized this passage, allegedly because it did not bring a higher objectivity to the drawing and production of axial maps, and because it still allows different users to obtain different maps based on the same cartographic representation. Despite many different proposals, usually based on the complementarity with other methods and concepts – the isovists (Batty and Rana 2004),[9] the Digital Elevation Model (Ratti 2005), or the transport models (Steadman 2004), to name just a few – the key contributions to improvement of the axial map and to the acquisition of a greater rigour came from some leading proponents of space syntax, such as Carvalho and Penn (2004) and Turner *et al.* (2005). Carvalho and Penn (2004) sustain the idea of scale invariance in a range of line lengths composing a sample of different maps. Culminating a two-decade process to translate the definition of the axial map in mathematical terms, Turner *et al.* (2005) demonstrate an algorithm for the construction of an axial map of architectural space.[10]

Another criticism of the axial map is its *edge-effect* (Ratti 2004a, Eisenberg 2007). Drawing on the analysis of an ideal urban system in two distinct situations – self-contained and in communication with another system – Ratti (2004a) sustains that space syntax results are influenced by the size of the area of the city under consideration. Hillier and Penn (2004) use their analysis of Kings Cross in London, carried out at two different scales, to question the importance of the boundary choice. In addition, they present the concept of variable radius integration as an answer to this edge-effect issue.

Another theme of the debate is the opposition between metric and topological measures, particularly at a global scale. The assumption that space syntax's topological representation of the city ignores important metric information (supported by authors such as Ratti 2004a) has encouraged two different answers. At a global scale, corresponding to the so-called *foreground network*, space syntax proponents (Hillier 1999, Hillier *et al.* 2007) have been exclusively exploring topological measures. Nevertheless and somehow reflecting the dual form of the urban street networks, the same authors have been including topological measures weighted by metric length in their local analysis of urban space. This improves the perception of a *background network* of primarily residential space, responsible for the specificities of the different parts that constitute the urban patchwork (on the spatial definition of these urban areas, see Yang and Hillier 2007).

The incorporation of tridimensional information in space syntax's graphic representation is another theme of the debate (for example, Penn *et al.* 1998, Asami *et al.* 2003, Hillier and Penn 2004, Ratti 2004a, 2005, Wang *et al.* 2007). On the one hand, one of the major purposes of space syntax is to understand the influences of spatial configurations on social life. As such, its main proponents have been opposed to the introduction of other variables in the spatial model. On the other hand, space syntax critics believe that the absence of tridimensional information, namely building heights, weakens the research results, particularly at the level of movement patterns. Based on their study on five London areas, Penn *et al.* (1998) contend that pedestrian movement is influenced by building height, the level of the area, and by pavement width at the level of the individual road segment.[11] Nevertheless, the study shows that both variables have a minor influence when compared with configurational variables.

In general, despite some criticisms (Batty *et al.* 1998, Ratti 2004a), space syntax separates spatial and land-use analysis. Hillier and Penn (2004) contend that this separation has been particularly productive in studying the impact of configuration and movement on land uses (Hillier 1996b) and the generation of centres and subcentres (Hillier 1999), and in analysing the spatial dimension of a process by which spatial configurations first shape, and then are shaped by, land uses (Hillier 2002). The Walkability Index (Stonor *et al.* 2003) in some ways constitutes a more integrated approach. The index, developed for real situations where the combined effects of many variables on movement rates need to be understood, includes, among others, land uses, metric variables, local generators and attractors.

Oporto case study

Our analysis of the axial map of Oporto (drawn with *Depthmap* software) throughout its historical process of development comprises the following measures: global (radius *n*) and local (radius 3) integration, connectivity, global and local intelligibility, and synergy. Table 1 provides a synthesis of the metric and axial parameters of this historical process. Because of the space restrictions of a scientific paper, we chose to focus only on three of these maps: 1813, 1892, and 2005 (Figure 2).

Table 1. Oporto metric and axial parameters, 1813–2005.

Map	Number of lines	Line length	Global integration	Local integration	Connectivity	Global intelligibility	Local intelligibility	Synergy
1813	477	154,356	0.867	1.703	3.790	0.195	0.705	0.456
1824	486	155,378	0.875	1.710	3.814	0.209	0.710	0.466
1833	491	155,896	0.886	1.712	3.825	0.216	0.708	0.478
1839	503	164,521	0.917	1.737	3.869	0.253	0.691	0.539
1865	542	165,241	0.898	1.730	3.875	0.249	0.689	0.520
1892	2248	179,608	0.555	1.562	3.382	0.095	0.628	0.300
1903	2286	182,204	0.585	1.593	3.441	0.109	0.588	0.352
1932	2379	186,849	0.630	1.642	3.542	0.122	0.571	0.392
1937	2494	185,060	0.639	1.657	3.572	0.106	0.565	0.360
1948	2645	183,068	0.636	1.673	3.602	0.092	0.567	0.323
1960	2978	177,974	0.652	1.699	3.632	0.086	0.551	0.308
1978	3505	172,424	0.702	1.704	3.597	0.076	0.529	0.310
1992	3728	171,642	0.715	1.720	3.610	0.073	0.511	0.317
1997	4065	169,539	0.713	1.712	3.577	0.071	0.512	0.302
2005	4287	168,983	0.744	1.725	3.599	0.076	0.510	0.322

The Oporto axial system of 1813 is made of 477 lines with an average length of 155 m. It presents an average global integration of 0.867. The main integrator of the system is the Calçada dos Clérigos/Rua de Santo António (1.391), an East–West axis that separates two different types of urban tissues: the 'historical areas' on the South and the 'areas of continuous building frontages and largely complete plots' on the North (for a characterization of these tissues, see Oliveira 2006). Calçada dos Clérigos is linked to five lines presenting the other highest values for integration – longer lines in the North (1267 m and 767 m) and shorter lines in the South. Within the interstices of a main structure of quasi-radial lines (brighter lines), darker lines are found. The analysis of integration radius 3 shows that some of these darker areas, particularly on the West, and on the South along the Douro River, have a local focus (brighter lines). The average connectivity of the system is 3.790 and the most connected line is Rua do Almada (13), an emblematic street of a successful planning intervention carried out in the second half of the 18th century. As far as synergy is concerned, the local structure of the 1813 Oporto system has a value of 0.456, which is a reasonable correlation. Regarding intelligibility, the system holds two different performances: it has a value of 0.195 for global intelligibility, pointing to an unintelligible system, and a value of 0.705 for local intelligibility, implying an intelligible system at the local scale.

Our historical review of the evolution of the urban structure of Oporto focuses on the 1892 map, which was, as referred to above, the first map to represent the entire municipal territory. The process of urban expansion – as well as the integration core – seems to be oriented to the West and to the North. While the number and the length of axial lines has increased (particularly the former), all the other syntactic measures under analysis have decreased. Decreases in global integration (from 0.898 to 0.555) and intelligibility (from 0.249 to 0.085) are particularly significant. Rua da Constituição, on the North of the historical kernel, is the main integrator of the system (0.878). The Eastern area of Campanhã emerges as the most segregated part of the city including the deepest lines of the system with integration below 0.300. The Avenida da Boavista, the longest axis of the Oporto

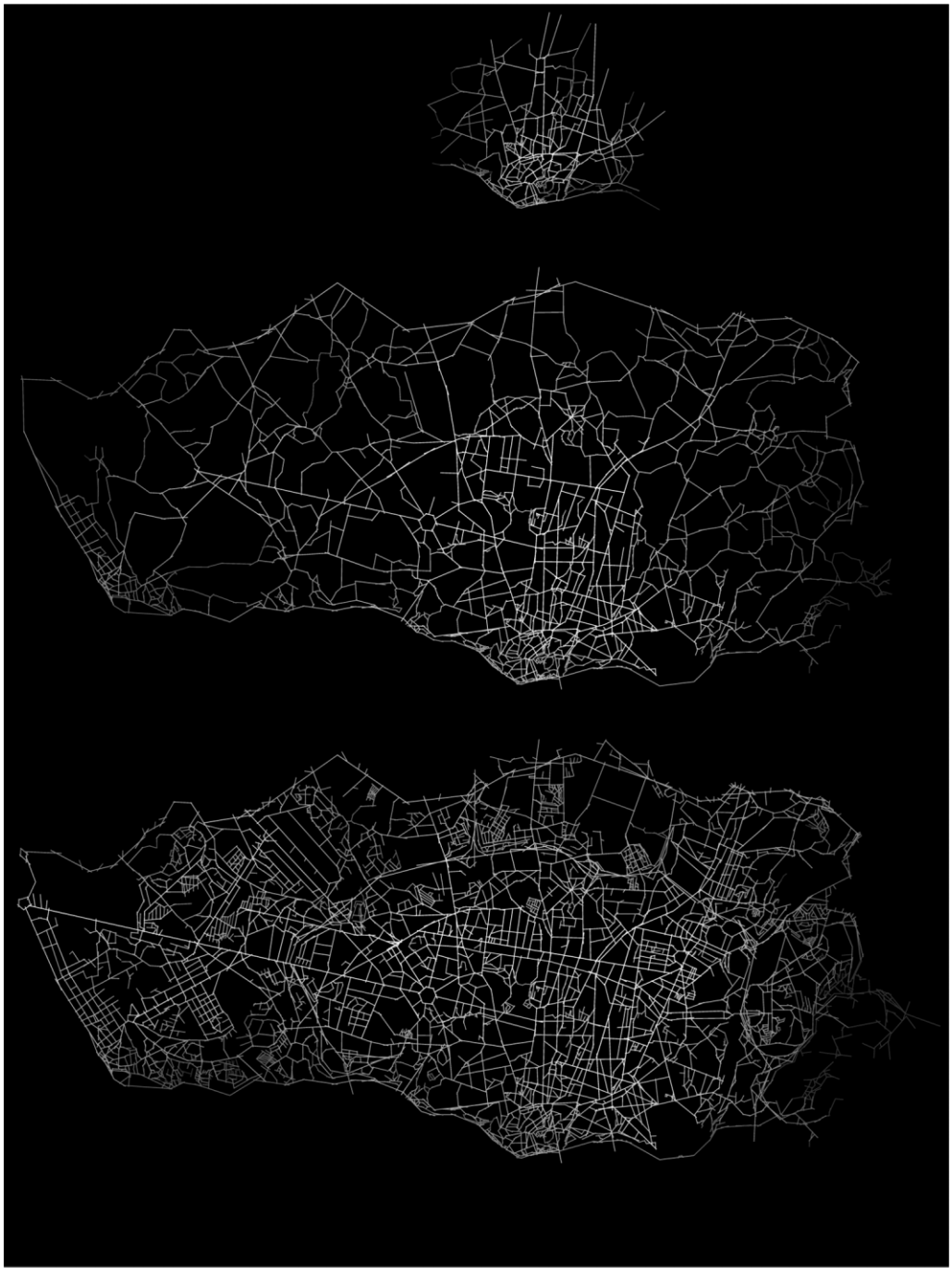

Figure 2. Oporto axial analysis (1813, 1892, 2005): the axial map of Oporto, for global integration, throughout its historical process of development: from the historical town of 1813 (with an average global integration of 0.867) to 2005 (with an average global integration of 0.744).

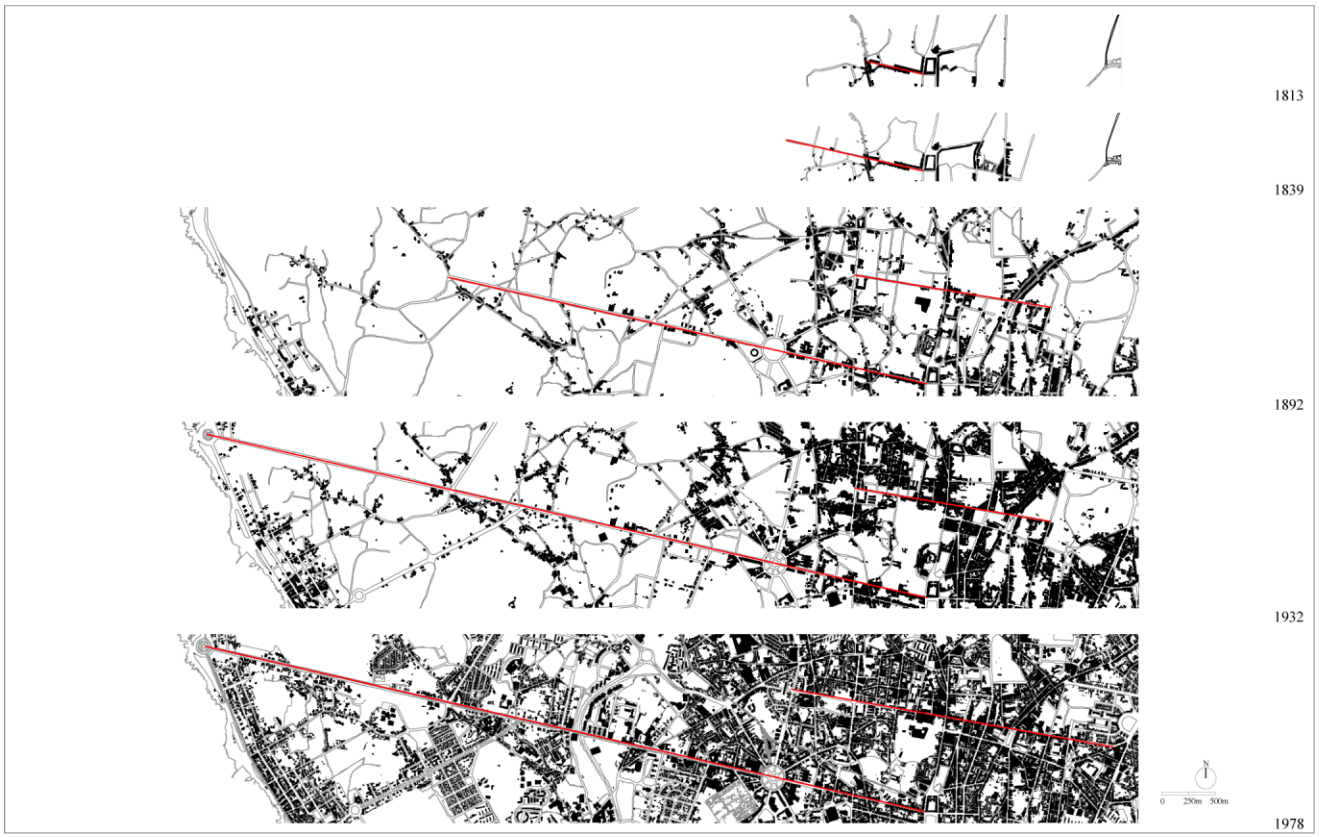

Figure 3. East–west axis of Boavista and Constituição: part of the town plans of Oporto from 1813, 1839, 1892, 1932 and 1978, based on the original prints of *Planta Redonda* by George Balck, of *Planta Topográfica da Cidade* do Porto by J. C. Lima, of *Planta Topográfica da Cidade do Porto* by T. Ferreira, of *Planta Topográfica da Cidade do Porto* by STCMP, and of *Levantamento Aerofotogramétrico* by DGPU. Source: Pinho and Oliveira (2009).

system, located on the North-west of the integration core, has the highest local integration (3.455). Far from the city centre and facing the Atlantic Ocean, Foz emerges as a dark area in terms of global integration, but as a bright (the main lines) area in terms of local integration. The Avenida da Boavista is the most connected line of the system (22), a situation that will remain until the end of the period under analysis.

The Oporto axial map of 2005 is constituted by 4287 axial lines (14.7% below the average European city; Hillier 2002). It has always been increasing since 1813, when 477 lines composed the axial map. The evolution of the average length of an axial line throughout the period under analysis can be divided in two different parts: an increase from 154.3 in 1813 to 186.8 in 1932, and a subsequent decrease until 168.9 m in 2005. Global integration in the 2005 map is 0.744 (18.9% below the average European city). It has suffered several variations throughout the period under analysis, the most impressive in 1892 when it decreased from 0.898 to 0.555 due to the consideration, for the first time, of the entire municipal territory. Connectivity in the 2005 map is 3.599 (21.9% below the average European city). Similar to global integration, connectivity suffered several variations between 1813 and 2005, although with a more reduced expression than the former. Local integration in the 2005 map is 1.725 (23.5% below the average European city). The evolution of local integration has fewer variations than the former measures – increasing from 1.703 in 1813 to 1.737 in 1839, decreasing to 1.562 in 1892, and increasing to 1.725 in the end of the period. All the second-level measures suffered several fluctuations throughout the period under analysis. The 2005 Oporto system presents a very poor correlation between global integration and connectivity (0.076), a poor correlation between global and local integration (0.322), and a reasonable correlation between local integration and connectivity (0.510). Finally, it should be mentioned that for all these measures Oporto seems closer to UK cities rather than to other European cities (Hillier 2002).

Bridging the divide

This final section presents some proposals for bridging the existing gap between the ISUF and space syntax approaches, at three different levels – methodological, conceptual and theoretical (for a synthesis of the two perspectives, see Table 2). The first proposal focuses on the development of the articulation between space syntax methods and GIS-based methods. This has been explored, in different research contexts, by authors such as Hanson and Zako (2007), Marcus (2006, 2007b), and Sahbaz and Hillier (2007). In this section, it is once again illustrated with the Oporto case study.

The results from the application of space syntax methods in the analysis of Oporto have, on the one hand, reinforced the main conclusions of our previous study under the ISUF framework, and, on the other hand, made evident some aspects that have not emerged in the morphogenetic analysis.

One key issue in our previous analysis was the definition of three morphological periods comprised between 1813 and 2005. Tables 3 and 4 make evident the link between morphological periods and integration measures. The maps included in the first morphological period have a global integration between 0.8 and 1.0 (showing that this syntactic measure is distinctive of each morphological period), and a local integration comprised between 1.70 and 1.75. The maps included in the second morphological period hold a global integration comprised between 0.5 and 0.7, and a local integration comprised between 1.55 and 1.70. Finally, the maps included in the third morphological period have a global integration comprised between 0.7 and 0.8, and a local integration comprised between 1.70 and 1.75. Despite some similarities between the definition of the morphological periods and the

Table 2. ISUF and space syntax.

	ISUF (Conzenian, Muratorian, etc.)	Space syntax
Theory (distinctive features, lines of research)		A theory of space as an aspect of social life A configurational theory of architecture and urbanism
	Tripartite division of townscape – town plan, building fabric, land use The conceptualization of historical development	The focus on space The relationships between space and movement The representation of spatial relationships in the axial map The syntactic measures – global integration, local integration, connectivity, etc. The construction of a pattern language
	The historical reconstruction of the physical form of urban areas The agents responsible for urban transformations The relationships between urban morphology and planning Urban micromorphology – building typology	Pedestrian movement patterns Social cohesion and exclusion Crime and order Spatial cognition Land use patterns Local versus global
Concepts	Morphological region – urban tissue – levels of resolution – design area Fringe belt Morphological period – typological process Burgage cycle Morphological frame Type	Spatial configuration Axial map Axial line Syntactic measures (global integration, local integration, connectivity, etc.) Foreground and background networks – definition of urban areas
Methods, tools and software	Morphogenetic method Town plan analysis Cartographic redrawing Metrological analysis	Axial analysis Visibility graph analysis Segment analysis Angular analysis New software: Depthmap, Confeego, Segmen, WebMapAtHome, etc.

Table 3. Global integration and morphological periods.

Global Integration	Maps	Morphological Periods
0.5–0.6	1892, 1903	Second
0.6–0.7	1932, 1937, 1948, 1960	
0.7–0.8	1978, 1992, 1997, 2005	Third
0.8–0.9	1813, 1824, 1833, 1865	First
0.9–1.0	1839	

values for connectivity, it was not possible to establish such a direct link as in the case of integration.

Another important feature of our previous study was the identification of the most important axis of the overall city structure. Table 5 presents all the axial measures referred to before and now applied to each of the axial lines and it includes an additional measure, the so-called control.[12] Syntactic analysis made evident the importance of the following axis: Rua do Almada (the longest axial line between 1813 and 1833 with the highest connectivity between 1813 and 1865, the highest control between 1813 and 1833, and the highest local integration between 1813 and 1865); Rua da Boavista (the longest line in 1839 and 1865); Avenida da Boavista (the longest line between 1892 and 2005 with the highest connectivity and control between 1892 and 2005 and the highest local integration between 1892 and 1960); and Rua da Constituição (the line with the highest global integration in 1892, 1903 and between 1937 and 2005, and with the highest local integration between 1978 and 2005). Besides these streets, axial analysis has also highlighted the importance of other axes that have been somehow devalued in our previous analysis, Calçada dos Clérigos/Rua de Santo António, Rua de Santa Catarina, and Rua Fernandes Tomás.

Recognizing the importance of the relationships between urban morphology and planning, the concepts relating to the *definition of planning areas* – a key issue in the current debate – should also be further explored. Within ISUF, this issue has been approached through the formulation and refinement of the concepts of morphological region, urban tissue, levels of resolution, and design area as well as by their application to a number of urban plans in France and in England. Space syntax has also been trying to define *urban area* in terms of space alone, and to understand how different *urban areas* aggregate to form a spatial whole, this is being mainly explored by the analysis of the *contextual spatial structure*. We believe that both approaches will benefit from an open and constructive dialogue. This should be able to establish a richer concept of planning area, attractive to, and easily manageable by, planning practitioners.

One of the key features of the ISUF approach is the recognition of the tripartite division of the townscape into land use, building fabric and town plan, the latter comprising streets,

Table 4. Local integration and morphological periods.

Local Integration	Maps	Morphological Periods
1.55–1.60	1892, 1903	Second
1.60–1.65	1932	
1.65–1.70	1937, 1948, 1960	
1.70–1.75	1813, 1824, 1833, 1839, 1865	First
	1978, 1992, 1997, 2005	Third

Table 5. Oporto fundamental axes, 1813–2005.

Map	Number of lines	Line length (maximum)	Integration (maximum)	Connectivity (maximum)	Control (maximum)	Local integration (maximum)
1813	477	1267.080 ALM	1.391 CLE	13 ALM	3.418 ALM	2.957 ALM
1824	486	1267.080 ALM	1.402 CLE	13 ALM	3.418 ALM	2.954 ALM
1833	491	1267.080 ALM	1.410 CLE	13 ALM	3.368 ALM	2.963 ALM
1839	503	1369.070 BOA	1.471 CLE	13 ALM	3.287 FER	3.011 ALM
1865	542	1369.070 BOA	1.455 CLE	13 ALM + FER	3.621 FER	3.006 ALM
1892	2248	2830.930 aBOA	0.878 CON	22 aBOA	6.750 aBOA	3.455 aBOA
1903	2286	5021.930 aBOA	0.919 CON	30 aBOA	9.333 aBOA	3.785 aBOA
1932	2379	4961.380 aBOA	0.979 SAN	32 aBOA	11.060 aBOA	3.861 aBOA
1937	2494	4961.380 aBOA	1.018 CON	32 aBOA	10.893 aBOA	3.839 aBOA
1948	2645	4961.380 aBOA	1.018 CON	32 aBOA	10.824 aBOA	3.846 aBOA
1960	2978	4961.380 aBOA	1.033 CON	37 aBOA	13.779 aBOA	3.924 aBOA
1978	3505	4961.380 aBOA	1.194 CON	39 aBOA	13.834 aBOA	4.117 CON
1992	3728	4961.380 aBOA	1.210 CON	44 aBOA	16.163 aBOA	4.208 CON
1997	4065	4961.380 aBOA	1.193 CON	45 aBOA	16.780 aBOA	4.227 CON
2005	4287	4961.380 aBOA	1.259 CON	46 aBOA	16.847 aBOA	4.221 CON

Note: ALM, Rua do Almada; BOA, Rua da Boavista; aBOA, Avenida da Boavista; CLE, Calçada dos Clérigos, Rua de Santo António; CON, Rua da Constituição; SAN, Rua de Santa Catarina; FER, Rua Fernandes Tomás.

plots and buildings (Conzen 1960). Much of ISUF's theoretical development rests on this recognition, which is gaining more importance over the years. Our third suggestion corresponds to a similar valuation of the *urban plot* within the space syntax theoretical framework. This is not a novel idea. Indeed, it is already being explored by authors such as Marcus (2006, 2007b). This Swedish author proposes an analytical theory of urban form that highlights the importance of three fundamental themes: accessibility (analysed within space syntax), density (dominant in geographic analysis of urban space), and diversity. The importance of the *urban plot* in this theory – as a *legally defined space*, and as the representation of the presence, location, and influence of an actor in the urban space – is reflected on its correlation with diversity indices, such as the presence of different age groups or the coexistence of different types of businesses.

The successful process of bringing together the Conzenian and Muratorian schools within ISUF may be a stimulus to the creation of a working framework for the construction of bridges between this perspective and the space syntax approach. It should be highlighted that besides linguistic differences, there was a clear disciplinary distinction between the research centres of Birmingham and Florence, the first including mainly geographers, and the second architects.

Currently, ISUF and space syntax are the most important approaches to the study of urban form. We would like to highlight not the supremacy of one over the other but, instead, the defence of a reflexive utilization of these different theories, concepts, and methods, framed, in practice, by each particular context and study objectives.

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Notes

1. Other Italian architects in the 1960s sustained critical reviews of modernity. Rossi's theoretical and methodological proposals were particularly relevant and quite different from the Muratorian school (Marzot 2002, Menghini 2002). While the former was concerned with the construction of the city, Rossi focused on city composition, based on the search for ideal and absolute forms.
2. Nevertheless, other themes could be identified, namely: the morphological elements (such as streets, plots, buildings, etc.), the existing and emergent morphological techniques, the sources for morphological research, the study of the trends and fluctuations in the process of urban development, the analysis of specific parts of the city (city centres, residential areas, etc.), and the relationships between urban morphology and architecture.
3. The morphological regions defined by Conzen (1960) correspond to areas of distinctive urban form in terms of plan type, building type and land use, becoming as such distinguishable from the surrounding areas. The author defines the fringe belt as a zone originating from the temporary stationary (or very slowly advancing) fringe of a town and composed of a characteristic mixture of land-use units initially seeking peripheral location. When residential urban growth restarts, this area becomes surrounded, but assumes a number of characteristics that are different form the previous and subsequent urban tissues. The morphological period corresponds to the influence exerted by a time period on the urban forms of a particular territory. Conzen defines burgage cycle as the progressive filling-in with buildings of the backland of burgages terminating in the clearing of buildings and a period of urban fallow before the initiation of a redevelopment cycle. Conzen defines the morphological frame as the set of urban form pre-existences that stand for and that condition, at least in an initial stage, the process of urban development.
4. For a detailed analysis of this research project, see a set of three papers recently published (Oliveira and Pinho 2006, 2008, Pinho and Oliveira 2009). The first presents an overview of research in Portuguese urban morphology and the identification and characterization of the different periods of urban development in Lisbon and Oporto. The second analyses the most influential planning policies on these cities since the second half of the 19th century to present times. The third critically assesses the methodological framework that supported this research project.
5. The other main difficulties we found in practice were the lack of adequate representations in older maps of the peripheral areas of these cities, long time periods between two consecutive maps, the need to handle original maps with rather different levels of rigour, and the fact that this is a very complex and time-consuming exercise.
6. Spatial configuration is thus a more complex concept than spatial relationship that considers only two spaces.
7. In recent years, a number of papers have developed the theme of axial maps. Carvalho and Penn (2004) explore the fractal properties of the axial maps. Figueiredo and Amorim (2005, 2007) explore the possibilities of extending axial lines discounting angular changes that occur under a certain limit. Turner *et al.* (2005) propose an algorithm for the construction of the axial map. Based on his new method, Angular Segment Analysis, Turner (2007) suggests a closer articulation between axial and road-centre line representations, which are more common to GIS.
8. In practice, the axial map is a representation of the street network made just of lines. One of these lines is chosen as the starting point. This line will be intersected by a number (n) of other lines, which are labelled Depth 1. Each of these n lines will then be intersected by m lines, which are labelled Depth 2, and so on. In other terms, each line on the map is numbered according to how many changes of direction separate it from the starting line.
9. For further development, see Batty (2001).
10. This algorithm is associated with Peponis *et al.*'s (1998a) method for the construction of axial maps.
11. At the level of vehicular movement, net road width is the most important variable.
12. Control expresses the proportional quantity of accesses to an axial line in relation to the adjacent lines.

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