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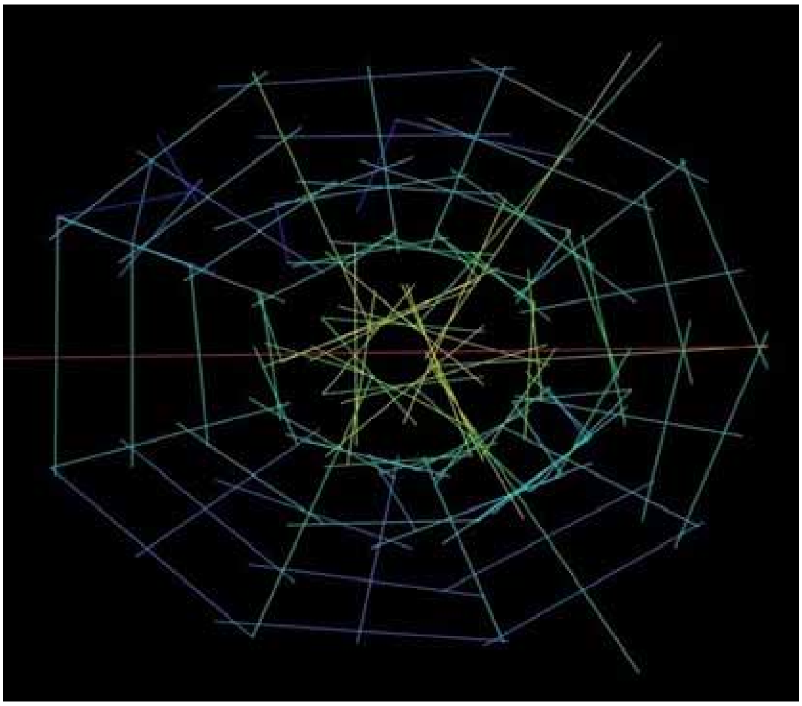

SEARCHING FOR ARIADNE'S THREAD

SOME REMARKS ON URBAN RESILIENCE AND ORIENTATION

ABSTRACT

This paper concerns the methods of analysis of the configuration of the urban grids. More in details, it will focus on the configurational approach to the analysis of urban settlements, briefly presenting the different methods and techniques it has inspired, sketching their features, highlighting their actual utility and their respective advantages and limits. Moreover, it will propose the use of some further configurational parameters, suitable for describing and reproducing interesting features of urban settlements; more in details, it will cast attention onto the richness and the variety of paths within a settlement, what makes it resilient, that is capable of sustaining changes and transformations without radically modifying its inner geography. Such parameters have been tested on the case studies of Pisa and Venice, which can easily be recognised as particularly relevant and significant, in that the results they provide are diametrically different. Those outputs will then be presented and discussed; the findings are suitable for suggesting resilience as a singular clue for urban orientation, so that the configurational techniques can be proposed as a tool for evaluating and predicting this spatial attitude, here finding an Ariadne's thread for urban wayfinding.

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1 INTRODUCTION

The configurational approach to the analysis of urban settlements is a wide stream of territorial studies deriving from its primal theorization by Bill Hillier, who founded it in the mid 80s with the denomination of space syntax (Hillier, Hanson 1984; Hillier 1996a). Since then, researchers all over the world have embraced this approach and have gone developing methods and techniques, experimenting them on a wide range of cases and issues. The configurational approach is based on the fundamental role it attributes the grid of their paths, appraised as the primary element in determining the patterns of human behaviour: mainly movement, which is oriented and leaded by the visual perception of the spatial layout, and through movement, also the location of activities, land value and so on. At the root of the configurational approach is the assumption that an urban grid contains, as a consequence of the spatial relations between its elements, a specific (either strong or weak) vocation for attracting movement flows; such a vocation is likely to drive movement-seeking activities towards the most crowded spaces as well as to address the movement-avoiding ones towards the most segregated and deserted. It is then movement, as addressed by the grid perception, the key element of most urban phenomena (Hillier 1996b); and, in that it does not depend on the located activities(on their presence, on their position, on their consistency), but uniquely on the grid configuration, such movement is called 'natural', that is intrinsically derived from its spatial layout. The consequence of such assumption in anything but unessential: the spatial layout (that is the way blocks and buildings are disposed and mutually arranged and lined along the streets), as decisive in the distribution of movement and in the location of activities, has to be assumed as the input variable of the system, while the activities (their position, their consistency) are to be expected as its very outcome. Such logic does hence take the space of an urban settlement in the foreground, making its material shape the fundamental element of the phenomena (both material and immaterial) that occur along its paths. A further conceptual element at the basis of the theory is the fundamental importance of the relations between the spatial elements of the grid, on which depends its configurational state: it is then the relations which drive the distribution of activities and land uses, through the distribution of movement flows, while geometry provides the arrangement of blocks and buildings with its mere morphologic appearance. Summing all up, the two columns of the configurational approach are hence the primary role of the grid configuration, on a one hand, and, in the other hand, the essential dependence of configuration on the spatial relations between the elements of the grid itself.

2 BACKGROUNDS

The conceptual basis of the configurational theory, which was sketched above, is founded on the hypothesis of the existence of the so-called 'natural movement', defined as the portion of movement that is determined by the grid configuration itself, and hence does not depend on the presence, the position and the consistency of the actually located activities. On such basis, an urban grid implicitly contains of the grid to host the activities according to their respective interest and attraction to movement (Hillier et al. 1993).
Several operational techniques have been developed, sharing the conceptual basis so far briefly sketched, and distinguishing each other for the different way they use to reduce the urban grid into a system. The original Hillier's theory proposes the axial analysis, which transforms the grid into the so-called axial map, a set of mutually intersected lines (the fewest and longest ones which, covering the whole grid, roughly correspond to the lines of sight) (Hillier, Hanson 1984). The axial analysis has to be carried on computing the spatial relation between a single line and all the other, so as to obtain a set of numeric values

corresponding to some parameters, called configurational indices. Among them, the most used are the connectivity value, the control value and the integration value.

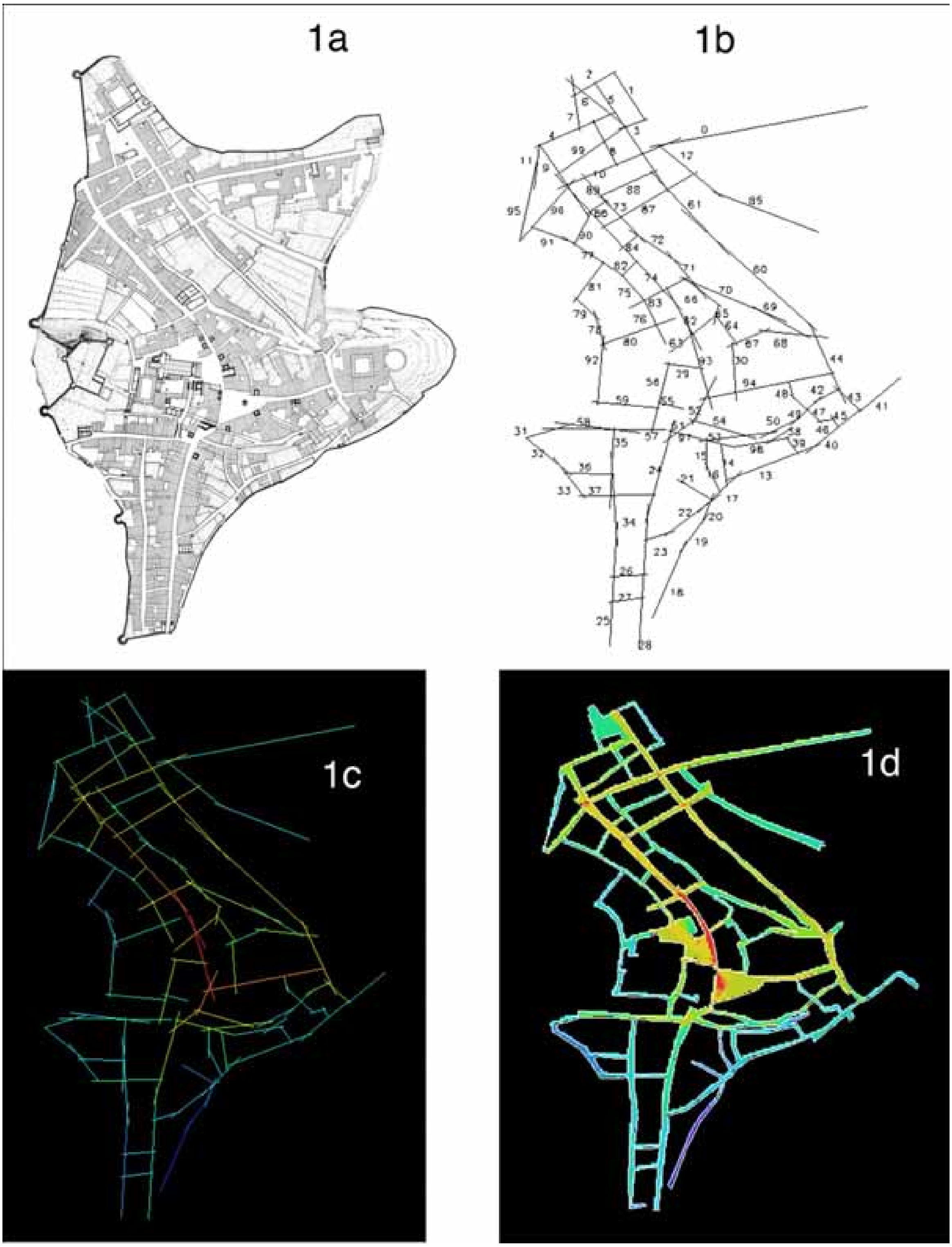


Fig. 1 The reduction of the historic core of San Gimignano (1a) into an axial map (1b). Distribution of axial integration (1c) and VGA integration (1d)

The connectivity value of an axial line is the number of lines which are directly connected, that is intersected; numerically, such value will obviously vary from 1 to n-1, being n the number of lines of the whole axial map. The control value the grade a single line actually controls the path to and from itself; numerically, its value is the sum of the inverse of the connectivity values of the intersected lines. The integration value is by far the most significant configurational parameter, and is defined as the mean depth of a line with respect to all the others, where the depth is the distance a couple of lines, topologically appraised as the number of interposed lines along the shortest path between them. In order to depurate this parameter from the effects of the size of the grid, so as to make possible comparing grids of different dimension, several normalization expressions have been so far introduced, so as to provide different numeric ranges.

The relevant importance of integration derives from some strong evidence of its capability of reproducing the distribution of natural movement; in doing so, it will also result as a reliable indicator of the distribution of the movement-seeking activities, and hence an evocative indicator of urban centrality (Hillier 2000).

Some years after the beginning of space syntax, a different configurational technique, called visibility graph analysis, was proposed, reducing the urban grid into a mesh of vertices, homogeneously distributed along the paths and visually connected (Turner et al. 2001). Such technique share the same conceptual basis of axial analysis, in that it assume a primary role of the grid, reduces it into a system of mutually connected elements, and then provide each of them (each vertex) with a set of numerical values depending on the relation linking it with the others. On such basis, also the configurational indices of axial analysis can be transferred into VGA, and, among them, mainly the integration value. What really changes, on the operational point of view, is the arising of some advantages with respect to axial analysis, as well as the presence of some limits. Among the advantages, we ought to mention a strictly objective construction of the system, which automatically derives from the setting of the density of the mesh, selected in order to fill up the space of the grid and to provide a proper level of detail. Besides, the capability of VGA of taking into account the wide open spaces of the grid, that is the squares, highlighted by the two-dimensional view the method provides. On the other hand, VGA involves the increase of the computing power it actually requires, as well as some difficulties in managing the results, which are scattered in an extremely high number of elements (and hence data). In order to sum up the above sketched techniques, a small example is here presented, showing the urban grid of the historic centre of San Gimignano (fig. 1a), its axial map (fig. 1b), the distribution of axial integration (fig. 1c) and the distribution of VGA integration (fig. 1d). The distribution of integration value is here shown by a chromatic representation, where warm and cold colours respectively stand for integrated and segregated lines/vertices.

A further configurational technique that deserves some mention is the Mark Point Parameter Analysis – Ma.P.P.A. -, which was introduced in 2004 (Cutini et al. 2004) and reduces the grid into a set of singular points (so-called mark points), selected along the paths as particularly significant (middle points of squares, deviation points of road-centre lines, intersection points of road-centre lines, and so on). The main advantages Ma.P.P.A. can provide are an easy construction of the system by its importation from an existing territorial database, a useful possible exportation of the results into the same database and a more capillary and significant definition of the configurational state of the system.

Beside the ones above briefly sketched, many other configurational techniques that here cannot be presented have been introduced in these last few years; among them, it's useful to mention those which reduce the urban grid into the network of its road-centre lines (Crucitti et al. 2006; Porta et al. 2006; Turner 2005). In any case, whatever the system is, the method is applied computing the relations between its elements and determining the values correspondent to the configurational indices; among them, as we noticed above, the most significant one is the integration value, demonstrated and highlighted in several studies (Bortoli, Cutini 2001; Cutini 2001) as capable of reproducing the distribution of centrality (in terms of attractiveness towards activities). Such a capability makes configurational analysis (whatever technique is actually used) a reliable tool for enhancing the comprehension of the inner geography of urban settlements, and, even more, for supporting and orienting the town planning in managing the arrangement of paths and the distribution of centrality.

3 THE RESEARCH

Most of the researches so far on configurational theory have gone variously discussing the different operational methods, or introducing and testing new techniques, or even criticizing the conceptual bases of the approach (Ratti 2004). Here, assuming a configurational point of view, and taking for granted the actual similarity of the existing configurational methods, we are at investigating around a specific feature of an urban settlement, that configurational analysis is suitable to highlight and, at a certain extent, also to measure. We are referring to the resilience of a settlement, intended as its richness in different paths mutually connecting each other all its parts, so as to offer a various choice of paths from any origin to any destination. At an individual scale, an observer perceives this feature with a wide choice of path towards any destination. Such feature is called 'resilience', in that, at a global scale, it expresses the grade an urban grid can sustain a (large or small) transformation without modifying its relational(and hence configurational) state. A small example is likely to favour a better understanding of the matter; let us consider two different urban grids, whose respective axial map is here sketched in figure 2a and 2b (on the left), and let us suppose (on the right) the interruption of a single line, in both cases located within the inner geometric centre of the system.

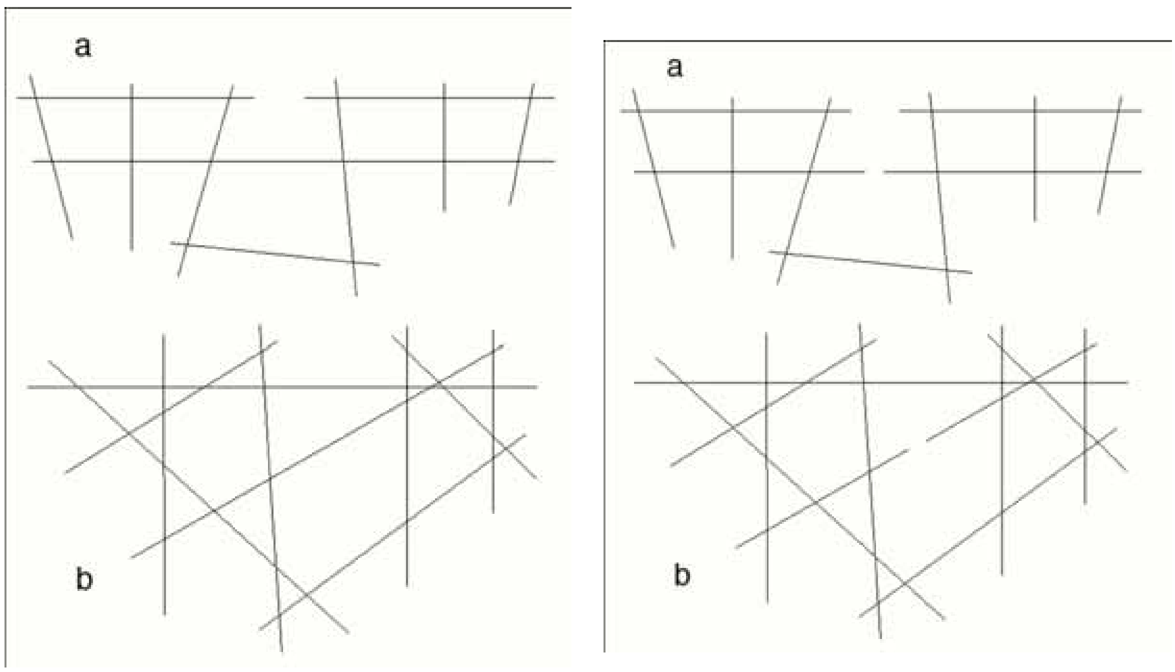
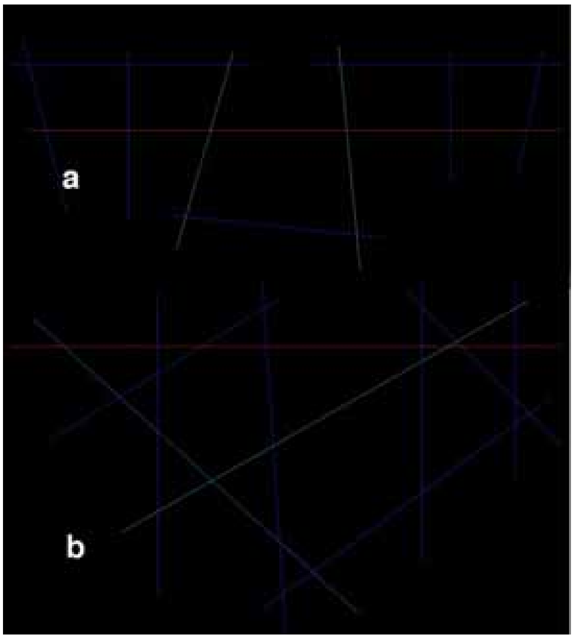


Fig.2 Examples of axial maps (on the left). As they result after a perturbation (on the right)

Such interruption may be either the result of an urban transformation or the temporary effect of an episodic traffic break. In any case, such a variation will determine some effect on the relations mutually linking all the other lines, hence modifying the global configurational state of the system. In the first case, since this variation avoid most of the connection paths between the other lines of the first axial map, the transformation of the configurational state of the system, here represented in figure 3a and 3c by means of the distribution of the integration value, can be said dramatic: the integration core has clearly shifted from the geometric centre of the grid towards its external lines. On the contrary, the effect of a similar variation on the second grid (figure 3b and 3d) is anything but slight, hardly perceptible, so as to leave actually unchanged the position of the integration core. The second grid has therefore adsorbed the variation, which has, on the contrary, radically upset the first one.



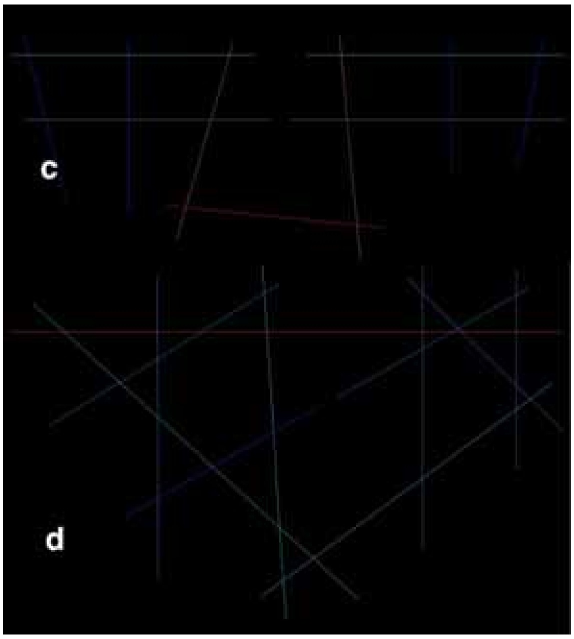


Fig. 3 The distribution of integration value in the maps of fig. 2

The comparison of the analysis of the grid configuration with respect to its previous consistency and to the modified one can therefore indicate the grade the urban system is capable to adsorb any transformation, that is its level of 'resilience': the more different the two configurational states do result, the less resilient can be said the system. Yet, we could ask whether a simple configurational analysis of an urban system, without supposing and introducing a transformation of its layout, can somehow reproduce such a singular capability, so that the grade of 'resilience' of the grid can be appraised and even measured. On such a purpose, two parameters are here proposed, briefly discussed and then, hereinafter, tested on some case studies.

The first one is the mean value of connectivity. If we reduce an urban grid into an axial map, the connectivity value of an axial line is defined (Hillier, Hanson 1984) as the number of lines that are directly connected to it, that is the number of intersected lines. As it can be easily understood, a line which is provided with a high value of connectivity will benefit of a large variety of paths connecting it to any other line of the system; more in concrete terms, a street user moving along the grid will have a wide possibility of choosing its path. On the contrary, a low connectivity value is expected to stand for the presence of obliged paths to and from the considered axial line.

Of course, connectivity is a local index, in that its value is computed taking into account only the lines that surround (and are actually connected to) the considered one. All the same, the mean value of connectivity, extended to all the lines, all over the grid, can be assumed as a global feature of the whole system, so as to reproduce the density and the variety of paths connecting each line to all the other lines of the axial map. Should a line (and then a path) be interrupted, a high mean value of connectivity would guarantee a dense presence of alternative paths. Therefore, such a parameter can properly reproduce the 'resilience' of the system, intended as its capability to resist and absorb a material transformation of the grid without significantly modifying its relational state (Rabino, 2012); or, in other words, its capability of adapt its movement patter to the different spatial layout. As shown in figure 4, the two extreme paradigms can respectively be recognized as represented by a tenial grid (where each line is chain connected only to the preceding line and to the successive one) and by a star-shaped grid (where each line is connected to all the others).

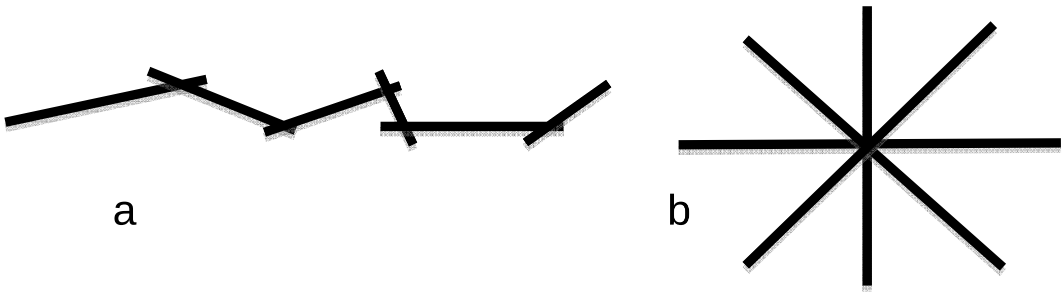


Fig. 4 A tenial axial map (a) and a star-shaped one (b)

The first one is the less resilient system one could guess, since every path (from any origin to any destination) is actually strictly obliged, and any local transformation of the grid will therefore determine the radical change of its global consistency; its mean connectivity value is 2(n-1)/n, rapidly approaching 2 as the number of the lines of the axial map grows. A particularly evocative system of this kind is the labyrinth, which essentially is a perfectly tenial and disorienting grid, in that each turn direction differs from the preceding one (Cutini, Rabino 2012). The star-shaped grid, on the contrary, is the most resilient system, in that the paths between the elements, and hence the configurational state of the grid, won't be modified by any transformation; numerically, in this case the mean connectivity value is n-1, indefinitely growing with dimension of the grid. Summing all up, the connectivity mean value is expected to vary from 2 to n, reproducing such value the resilience of the system.

As an easy demonstrative example, if we consider the above sketched axial maps, the system which is represented in figure 2a is actually provided with a connectivity mean value of 2.9, while the axial map of figure 2b has a connectivity mean value of 5.2.

A second configurational parameter suitable for representing this feature derives from the actual strength of the correspondence of the global integration value versus the local one. On such regard, it's worth specifying that two different integration values can be drawn out of the analysis of an axial map: a global integration value, which results extending the compute all over the grid, and a local integration value, with radius k, which is determined taking into account only the lines that lie within a (topologic) circle with radius k around the considered one; in most cases, the local integration value is selected with radius k=3. A narrow correlation of global and local integration stands for a strong correspondence of the whole urban system with its local sub-systems: each of them does in fact reproduce, at a smaller scale, the geography of the whole settlement, whose main integrators are also strong local integrators. A local perturbation of the grid (again, either an urban transformation or a transitory street interruption) will hence be adsorbed by the whole mechanism of the grid, and its configurational pattern is likely not to carry dramatic changes. The determination coefficient R^2, obviously varying from 0 to 1, is hence proposed as a further indicator of the resilience of the urban system.

Hereinafter, these two parameters are going to be applied and tested in two case studies, in order to verify their capability of reproducing the resilience of the urban grids.

4 CASE STUDIES

As our case studies, we have selected two urban settlements, rather similar for what concerns their dimension (both planimetric and demographic), but clearly different from a structural and morphologic point of view. Pisa and Venice, in fact, present a radically different spatial layout. The Tuscan city derives from the radial development of an ancient (originally Roman, then, and above all, medieval) inner core, and the grid of its paths, highly dense in the centre, gets looser and looser as one proceeds towards its edge areas, which have grown in the last decade sprawling into the surroundings. The urban structure of Venice is the well known result of the dense urbanization of several small islands, connected each other by means of bridges; due to the lacking of space, its actual extension has not grown in the last centuries.

The urban grids of Pisa and Venice have been reduced into systems, by means of the construction of their respective axial map. In the case of Venice, two different axial maps have been constructed, respectively taking into account and disregarding – side by side with the ordinary street paths, also the so-called 'traghetti': these are the crossing paths of the channels by gondola, and their position is so steadily defined as to let them be appraised as actual urban paths.

As a result of the configurational analysis of the axial maps mentioned above, in figure 5, 6 and 7 the distribution of integration value in the different urban grids is shown by a chromatic representation, where warm and cold colours respectively stand for integrated and segregated lines. The map of figure 5 represents the axial map of Pisa, while figure 6 and 7 represent Venice, respectively without and with the presence of the 'traghetti'.

The same grids of Pisa and Venice have then been analyzed with reference to the local configurational indices, in order to obtain the distribution of radius 3 integration value, which is respectively represented in figures 8, 9 and 10.

5 RESULTS

The results of the analysis of the considered urban grids can be here briefly summarized: first with reference to some general indication concerning the inner geography of the settlements of Pisa and Venice; then, and above all, with reference to the feature that was named 'resilience', as it can be drawn out of the outputs of the analysis.

The integration core of Pisa (fig. 5) clearly results located along the central crux formed by the axis southbound-northbound and the orthogonal direction of the 'lungarni', the streets running along the river Arno. Such crux is centred on the Ponte di Mezzo, the bridge that can hence be recognized as the very centre of Pisa.

Fig. 5 The distribution of global integration value in the lines of the axial map of Pisa

Fig. 6 The distribution of global integration value in the lines of the axial map of Venice (without 'traghetti')

Fig. 7 The distribution of global integration value in the lines of the axial map of Venice (with 'traghetti')

Fig. 8 The distribution of local (radius3) integration value in the lines of the axial map of Pisa

Fig. 9 The distribution of local (radius3) integration value in the lines of the axial map of Venice (without 'traghetti')

Fig. 10 The distribution of local (radius3) integration value in the lines of the axial map of Venice (with 'traghetti')

A strong gradient can also be noticed as we proceed from the centre toward the edge areas, which are characterized by low values of global integration. The distribution of radius 3 integration (figure 10), on the contrary, shows a poorer gradient, with several strong integrators located in the edge areas of the settlement; all the same, it is possible to observe some correspondence between the distribution of global and local integration, with the strong global integrator that are also characterized by high values of local integration, and, vice versa, strong local integrator that are not relevantly segregated in a global scale. Such configurational finding does actually correspond to the distribution of the levels of centrality in the urban areas of Pisa: the settlement, in fact, is characterized by an outstanding inner core, where most of the prominent activities (in particular, shops and offices) are located, and by an external ring, mainly addressed to residential uses. Yet, a singular aspect appears worth mentioning: the north-western urban area, which is provided (fig. 5) by poor values of global integration, nonetheless is crowded with activities, due to the presence of some relevant monopolistic activities that work as attractors; in particular, here we refer to the monumental area of Piazza dei Miracoli, to the regional hospital of Santa Chiara, to the university of Pisa. Such presence determines some discordance between the configurational state of the grid, as it emerges from the distribution of integration value, and its functional pattern, as it appears from the density of activities in that specific part of the settlement. This local discordance ought to be highlighted in order to point out that the presence of monopolistic activities, as located without taking into account the distribution of attractiveness, are likely to modify the functional pattern that would result from the configurational state of the grid.

The analysis of the grid of Venice (either with the 'traghetti' or without them) provides results that more than slightly differ from those sketched above. First, we can observe a far poorer gradient centre-periphery of integration, both global and local: the integration core appears spreading all over the grid, even if the configurational centre results as corresponding to the Ponte di Rialto, which stands as the very heart of the settlement; what clearly confirms any intuitive expectation, since the Ponte di Rialto is by far the most crowded space of the grid of Venice, crossroads of most of its internal paths. Second, we may also notice a wide discordance between the global integration pattern and the local integration one: in few cases, in fact the main local integrators are also strong global integrator; while, on the contrary, several lines with high levels of global integration results provided with low values of radius 3 integration. Such feature, so clearly different from the pattern of Pisa, seems to suggest that the urban settlement of Venice may be used a suitable case study for testing the parameters we have above presented to reproduce the 'resilience' of the grid. On such a purpose, let us compare the mean values C_M of connectivity in the cases of Pisa and Venice, here represented in the table that follows:

	PISA	VENICE (w/o "traghetti")	VENICE (with "traghetti")
Mean Connectivity	6.638	2.707	2.707

Table 1 Mean values of connectivity in the axial maps of Pisa and Venice

It is easy to notice a sharp difference in the mean values of connectivity between Pisa and Venice, so as to confirm the first impression concerning the different 'resilience' of such centres. In other words, and more in concrete, it appears as though the inner structure of the grid of Venice is somehow labyrinthine, as composed of a large number of tenial sequence of lines. On a one hand, such feature seems to correspond to the intuitive experience of every street user, commonly being disoriented (and frequently getting lost) while walking within the *calli* of Venice; what actually seldom happens in Pisa, where wayfinding is generally much easier. On the other hand, the same feature is likely to make Venice's grid much less resilient, in that each slight and local change is likely to cause some significant transformation of the global pattern of urban relations.

If the first point appears to deal with intuition and with 'common' experience, which can hardly be objectively demonstrated, on the contrary the issue concerning the resilience of Pisa and Venice can be discussed on the basis of the above proposed configurational parameters.

We have hence seen how different are in the selected cases of Pisa and Venice the two proposed parameters, that is the mean value of connectivity and the R^2 coefficient of the correlation global integration versus local one: in the case of Pisa we find an R^2 value of 0.641, which can be regarded as very high, and even impressive if compared to the values of 0.053 and 0.046 of the grids of Venice.

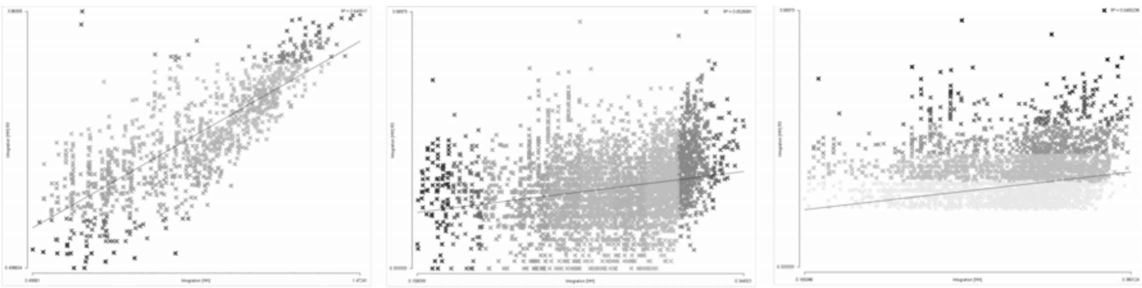


Fig.11 The correlation between global integration and radius 3 integration in the grids of Pisa (left), Venice without 'traghetti (centre) and Venice with 'traghetti" (right)

Fig. 12 The distribution of global integration value in the transformed axial map of Pisa

In order to verify that such differences actually stand for some relevant difference in the respective resilience of the grids, we then introduce in both cases a local perturbation of the grid, that is the insertion of a bridge. Either in Pisa and in Venice, in fact, the settlements are strongly characterized by the presence of the bridges: at present four bridges cross the river Arno in Pisa and three bridges cross the Canal Grande in Venice. In the following figures 12 and 13 the distribution of global integration in their transformed grids is shown, so as to clearly highlight the differences with the respective distribution of figures 8, 9 and 10.
Comparing such results, it is easy to notice how similar (nearly unchanged) are the distributions of integration in Pisa, and, on the contrary, how different are the same distributions in Venice. Here, the introduction of a further bridge has determined a dramatic change in the distribution of global integration and therefore in the location of the integration core.

Fig. 13 The distribution of global integration value in the transformed axial map of Venice (without 'traghetti')

6 CONCLUSIONS

Some inferences can be easily drawn out of the findings sketched so far. First, a correspondence of the trend of global integration value with the distribution of the levels of centrality does exist, so that in both cases the integration core roughly coincides with the most crowded (with shops, offices, strolling people, etc.) streets of the settlement; the distribution of integration value in the grid of Pisa shows a far stronger gradient centre-periphery than in Venice, where, on the contrary, well integrated lines appears scattered all over the grid. In the case of Pisa the distribution of global integration and local one are somehow similar, so that we can observe a narrow correlation between them; on the contrary, in the case of Venice an evident discordance between them is attested by a poor correlation coefficient. Also the mean connectivity value is much higher in Pisa than in Venice. Such differences seems to prove the efficiency of these proposed parameters to reproduce the level of resilience, what is confirmed by the relevance of changes in the configurational pattern that a local grid transformation actually determines: slight changes in the case of

Pisa, radical changes in Venice. At the same time, those findings appears to confirm the typical labyrinth-like structure of Venice and the consequent difficult wayfinding: what actually results from the intuitive experience of every street user, but can also be objectively stated (predicted, and even measured) by means of the configurational analysis of its grid.

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