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Space syntax and urban form: the case of late-medieval Padua

VINCENZO VALENTE

Università degli Studi di Padova, Dipartimento dei Beni Culturali, p.zza Capitaniato 7, Padova, *valente@unipd.it*

This paper summarizes a study of medieval Padova in which GIS is used as a basis for exploring the space syntax of the city's street networks and considers the usefulness of these methods in the study of medieval urban landscapes. Using indices derived from space syntax methods, such as *integration* and *choice*, it is possible to read urban space and understand more clearly the distribution of building typologies in the context of *integrated* streets.
Keywords: GIS, space syntax, urban topography, 14th-15th centuries, Padua

Questo articolo descrive uno studio di Padova medievale in cui il GIS è stato utilizzato come base per indagare la space syntax *della rete stradale urbana e considera l'utilità di questo mezzo nello studio dello spazio urbano medievale. Usando gli indici derivanti dai metodi della* space syntax*, è possibile leggere e interpretare più chiaramente lo spazio urbano e la distribuzione delle tipologie degli edifici nel contesto stradale.*
***Parole chiave**: GIS, space syntax, topografia urbana, XIV-XV secolo, Padova*

1. The ARMEP project: targets and GIS

The project *Padua Medieval Residential Architectures* (ARMEP: Architetture Residenziali Medievali di Padova) has used GIS to investigate Padua's medieval architectural heritage, including processing time-sequences of residential buildings between the 11th and the 15th century (Chavarría Arnau 2011a). The project consisted in two key elements: one is archaeological in nature and concerned the stratigraphic analysis of building frontages. This was carried out using photo-plans and through direct observations from ground level and aimed at a synthetic identification of the main construction phases of buildings in the

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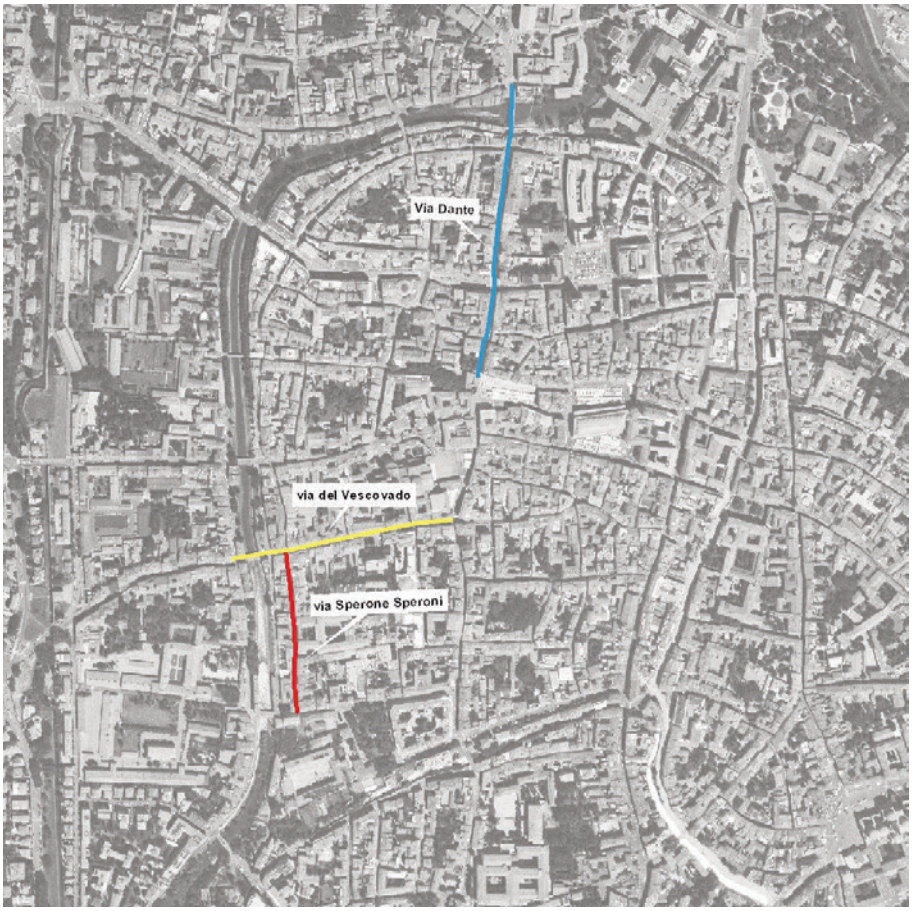

Fig. 1. Padua historic centre. The figure shows the linear development of via Dante, via Vescovado and via Sperone Speroni.

intra-mural area of medieval Padua. The second element was of bibliographic – and where possible also archival – research, and aimed at collecting written sources (both published and not), cadastral maps and historic maps, iconographic sources (frescos, paintings, drawings, sculptures, and so on), historical photographs, and data from past archaeological excavation in the city. All of these sources of data were integrated in a GIS-based data processing system (fig. 1; Valente 2011).

The mail result has been a systematic recording of all kind of evidence related to residential architectures of Padua dating between the end of the Early Middle Ages and the 15th century. In addition to this, research

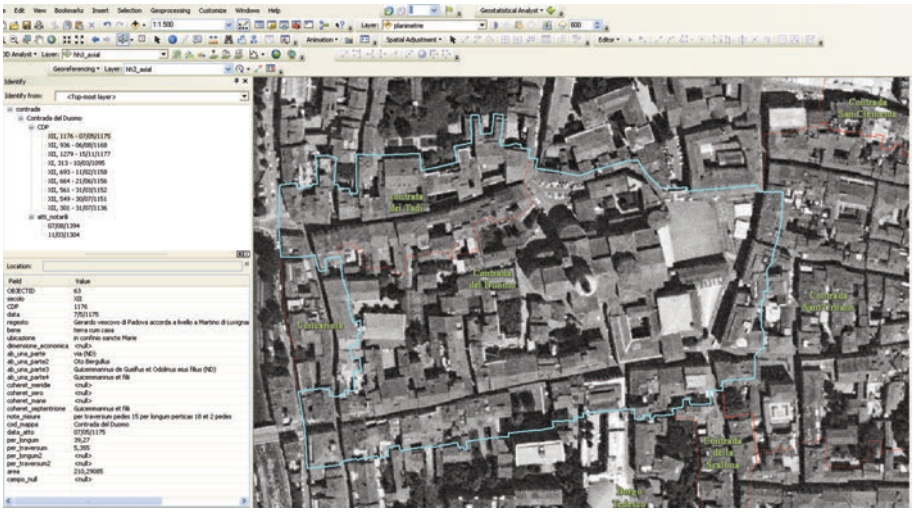

Fig. 2. Screenshot of the GIS, that shows the use of the polygonal layer "contrade". This layer is linked to historical sources, so is possible to visualise historical data (parcel measures, building typologies, owners, …) on maps.

also focused on plot patterns containing medieval buildings (Boaretto, Valente 2011)[1]. Analysis of these data was carried out in a GIS environment starting from historical sources and projecting archaeological data onto the area referred to in documentary material, comparing plot measurements and dimensions referred to in both (fig. 2). This approach reveals permanence in 12th and 13th century plot-structures in Padua. Closer inspection of the different building typologies yielded from this approach has shown that the detached house, referable as the *row-house* kind, developed into new building types over time, including the creation of the *paired-house* type up to the merging property parcels[2] (fig. 3). In the 14th century the transformation process becomes more remarkable with a specialization of the basic module, and introduces new architectonic and decorative elements that combine to form the type described as "palace".A new urban look seems to characterise Padua from the 14th century, partly different from the one it had during the medieval city-republic period.

[1] For the particular datasets used here, see Valente 2011, pp.153-178.

[2] The typology "row-house" is meant here in the "Caniggian" sense (Caniggia, Maffei 1979, pp. 81-95): it is a building with a 5-7 m wide street level front, featuring a ground floor and an upper level in the first versions. The "paired house" indicates the multiples of the row-house module with a street level front width of 10-12 or 22-24 meters (Maretto 1987, p. 85).

Fig. 3. "Cittadella Vigodarzere" palace. On the right side the photo of the palace, instead the image on the left side shows the overlapping of the Napoleonic cadastre, the linear layer "prospetti", the polygonal layer of the parcels. It appears clearly the merging of two parcels in a unique building (in green and orange).

2. The Space Syntax

The way the later building type evolves seems to be closely related to its relevant location inside the grid of the street network in the city. With the purpose of establishing the possible link existing between location and architecture, new techniques can be used to formulate theories suited to understanding how these urban spaces are organised. This kind of analysis can lead to a deeper understanding of medieval urban space and its changes through the later Middle Ages. The starting point for the application of 'space syntax' is the belief that the chief factor determining the layout of a urban space is the way it is used (Hillier, Hanson 1984). With space syntax, the suggestion is that human perception of urban space works through linear, visual perspectives in the urban landscape which determine the motion and movement of bodies inside the town (*natural movement*): urban space thus gets organised through the optimisation of bodily movement. This approach to urban morphology seems to overturn the standard pattern which defines the organisational processes of the town. The role played by nodes in the city seems to be depending on motion, whereas the production of a flow inside the town should be rather considered as an effect than the cause (Tosco 2009). As a matter of fact this analytical method applied to urban spaces is only an outward sign: the importance of nodes for the morphogenetic processes is not questioned,

but the key to understanding urban phenomena depends only on the movement across the urban space (Cutini 2002). Space syntax's advantage consists in focussing attention on the urban 'mesh' and uses of the urban street network; that is, the physical channels through which motion takes place. It also allows us to make use of spatial data derived from digital data, using GIS to quantify urban spaces for use in quantitative models.

Space syntax's fundamental assumption claims that urban complexity can be successfully investigated if we start from the study of the spatial systems that inter-connect an urban landscape. The starting point of an analysis based on space syntax principles consists of picturing the town's communications network, made up of roads, main streets, squares and pedestrian routes. Space syntax also is exclusively based on topological features, and its basis lies in people's motion in and through the city and visual perceptions of these urban spaces. A deep insight into the features of the space connections makes it possible to measure differences between the central and suburban parts of Padua, as well as routes used to enter and exit the city. Resulting output maps can then be used to reflect on the historical implications of space syntax approaches for understanding the medieval city, and comparing these with other research approaches used in urban morphology.

3. Some Space Syntax's measures

The space-syntax analysis starts by making an *axial map*[3]. From this axial lines are derived. These are visual sight-lines that correspond to the motion and movement of people through an urban landscape. The derivation process of the axial map is carried out in a GIS environment, along with specific software, DepthMap, that is designed and distributed by the Space Syntax group at University College London[4] (fig. 4). The latter was used here for deriving the axial lines. Each axial line is assigned a set of values and indexes.

The widest used and most interesting space syntax indexes are *connectivity, integration, control value* and *choice.* By *connectivity* we mean the number of segments which each arch intersects. The *control value* is the degree with which an axis controls access *from* and *to* the intersected axis: for instance, a road *i* with many side-lanes or cross-streets has got a high control degree, as it is necessary to go across the *i* axis to go both

[3] This kind of map is analogous to being a 'negative' of the urban landsape, obtained by subtracting the full area of the built-up area, minus indoor spaces.

[4] Visit the web site http://www.vr.ucl.ac.uk/depthmap/.

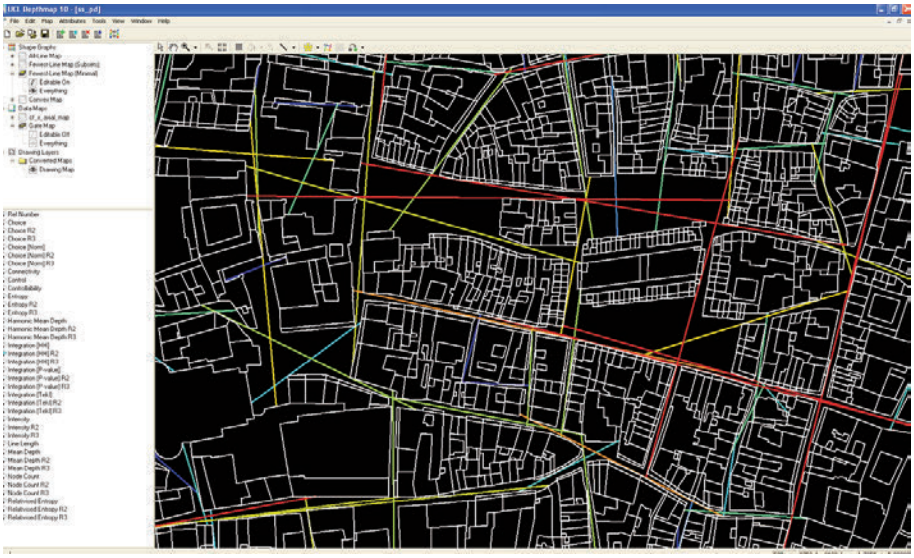

Fig. 4. Screenshot of the software DepthMap.

into and come from the lanes. The *choice* is the value identifying the importance of a path in the wider context of the urban system: a high *choice* value shows that the mentioned road is the most frequently used in all possible path conjunctions. And lastly *integration* which is the average distance of an axis with respect to all the other grid axes. It is probably the most important measure as it identifies either the central or suburban position of a line with respect to the grid. If we use the graph representation to get a diagram of the axial lines, the integration rate of an axis can be best defined: in order to get to a road featuring a high integration value, a movement is required with a low number of direction changes (fig. 5). In other words roads with a low degree of integration lie remote from the other roads, and a higher number of routes and consequently of direction changes is needed to reach them. Lanes – or minor streets – are typical examples of seclusion, whereas the principal streets and main roads are considered *integrated* as a rule. Further insight into the mathematical basis pertaining to the above-mentioned measures is to be found in the various publications available on space-syntax[5]. In this paper the focus is on making of axial map for medieval Padua based upon the GIS and spatial data derived through ARMEP, and an analysis of the city's space syntax.

[5] Batty 2004; Jiang, Claramunt 2004, pp. 295, 309; Jiang, Claramunt 2000, pp. 161-171; Turner 2005, pp. 425-444; Kostakos 2010, pp. 34-36.

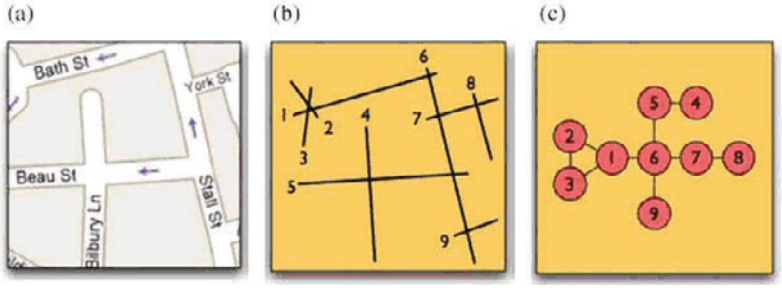

Fig. 5. a) Cartographic representation of streets; b) axial lines representation; c) diagram showing the links between axial lines (Kostakos 2011).

4. Application of space syntax to medieval Padua

To undertake a space syntax analysis of medieval Padua, a series of maps is required which is chronologically consistent with the spatial data to be compared. The perusal of historical maps (Gaudenzio 1958; Ghironi 1988), together with the investigation of the building sequences (from ARMEP) and the consultation of historic sources, has led to a hypothesis that the medieval town fossilised between the end of the 14th and the beginning of 15th century (Cessi 1985, pp. 3-33). This urban form remained largely unaltered until the end of the 19th century, at which time major cuts were made through the townscape and a series of demolitions changed some sections of the historic urban core.

Starting with Napoleon's cadastral records of 1811, Padua's streets and thoroughfares were digitised through a polygonal geometrical scheme. This GIS feature-layer was later processed using DepthMap for the purpose of creating axial lines and calculating *integration*, *control* and *choice* values. In this way the axial lines were imported into the GIS so integrating them with the ARMEP data base. From this has emerged how the flow of pedestrians' movement in Padua today identifies clearly both the central and the suburban areas of a built-up centre. In addition, experiments based on on-site checks of pedestrians' flow have pointed out how such movement flows along these axial lines, demonstrating the soundness of the method when applied for modern urban planning (Desyllas, Duxbury 2001). However, despite some essays written on the employment of space syntax in the historical field[6], it seems few if any studies have been carried out on motion patterns in past urban societies

[6] For the application of Space Syntax in a medieval town-centre see Craane 2007; Kubat 1999.

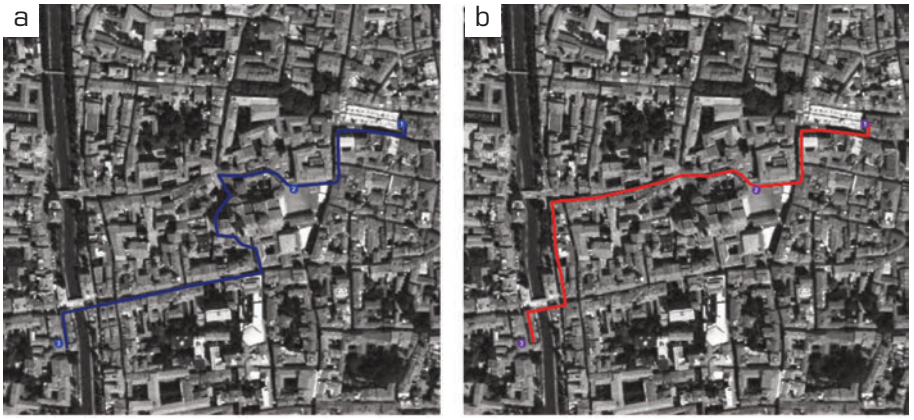

Fig. 6. Network analysis of the streets of the Napoleonic cadastre. Image A shows the path suggested by GIS analysis (based on procession stops) with integration value; B shows the path suggested by GIS analysis with distance value. In order to calibrate the values of the SS with the network, a spatial join (ArcGIS tool) was applied.

which might allow the principles of space syntax to be applied to the analysis of the medieval urban landscape.

A first attempt at applying space syntax to medieval Padua has been devoted to the simulation of the *natural movement* by means of historical information from the 14th century. For the city of Padua we can count on the evidence of Giovanni di Conversino who left a record of the route and the stops made during the processions of the *Bianchi* in 1399[7]. We can take, for instance, the path covered the first day the procession: starting from the church of San Clemente (fig. 6a, point 1), headed for the Cathedral (fig. 6a, point 2), and later, at the mouth of via dei Tadi, turned left passing by Palazzo Vescovile to go further along the today's via del Vescovado, going towards the church of Sant'Agostino (fig. 6a, point 3) for the first stop, a church placed outside the walls[8].

The analysis of the road network contained in the ARMEP GIS has pointed out that the path selected by the *Bianchi* is rather anomalous: the more obvious route would have been along via dei Tadi, going across the bridge

[7] Dressed in white the crowds of devotees visited a great number of Italian towns. They got to Padua in September 1399 (Marcianò 1980).

[8] *Ergo secunda feria, quae fuit tercio kalendas octobris, ecclesie ceu prefatus sum, Chatedralis quarta dignitatis duplici prerogativa antecedens platea excessit tenore descriptio. Secuta successio prima omnium episcoalis Ecclesia visitata qua omnisacies, accepta lege, migrantes dextrorsum Sancti Johannis ad portam iter habuere, supera toque ponte, ad levam deflexe, Sancti Agustini memoriam, fratum predicatorum sedem visitaverunt …* Cod. 288, Balliol College Oxford, ff. 137 v.a. – 165 v.a.

bearing the same name and heading for Sant'Agostino (fig. 6b). The peculiarity of the actual chosen route was also noticed by Ada Francesca Marcianò, the editor of Giovanni di Conversino's text. She was surprised by the fact that the *Bianchi* had not crossed the Tadi bridge[9]. She explains this choice through the necessity of the *Bianchi* to go along the road which could *easily receive the procession while going* (Marcianò 1980, pp. 63-65, in particular notes 3-4). As a matter of fact, had the *linearity* of the route been the prerequisite condition, then both via del Vescovado and via dei Tadi could also have met this condition, as they both show the same cross-section, the same length and the same orientation. The result of the calibration of the network contained in the GIS with the axial lines - in particular with the *integration* value – is the same road the procession went along. The selection of the route taken by the pilgrims in the procession shows their will to cross the town along a symbolic path based on a circular scheme: in fact each route starts from and ends up in the same point[10]. The space-syntax network analysis used here reveals how most of the urban routes selected during procession follow the motion (as defined by the spec-syntax software), instead of the distance and walking time criterion[11].

The analysis of *Bianchi*'s route has proved to be a sort of test which can provide a comparison basis for the ARMEP data bank entries in order to sketch out a logical scheme for the layout of 14th and 15th century architectures. The axial lines featuring the highest integration values are all located in the streets Dante, Santa Lucia, Roma, San Canziano and del Vescovado (fig. 7), thus revealing the highest peak of centrality in the squares area of the city, where markets were held, in an area between the north-south axes of via Dante and via Roma and the east-west axes of via del Vescovado and via Santa Lucia (fig. 8). Along these axes are situated prestigious residential architectures, such as the palaces Cittadella Vigodarzere, Savonarola, and Montorsi[12], the group of buildings known under the name of "*hospitia*" located in via Dante, a series of five buildings in via del Vescovado[13], and four palaces in via Santa Lucia (fig. 9).

9 According to a time-tested tradition of urban planning studies, the Tadi bridge was considered the direct link to the Bishop's Palace: Gasparotto 1959.

10 *And so it was planned that the route would get back and end in the same place where it had been started, so that it could have a circular scheme, which is the most perfect motion and is as eternal as the motions of the celestial spheres* - see cod. 288, Balliol College Oxford, f. 150. For other similar circular processional routes and their symbolism see Lilley 2009, 163-176.

11 Refer for instance to the processions occurred on the I, II, III, IV and V day: Marcianò 1980.

12 All these palaces belonged to Paduan aristocratic families. For more information about these architectures see Chavarría Arnau 2011.

13 These are the buildings located at number 74/80, 54/64, 81/85, 79 and 59/63. To have a visual reference of the mentioned architectures visit the web page http://www.fineo.lettere.unipd.it/armep webgisdefault.aspx.

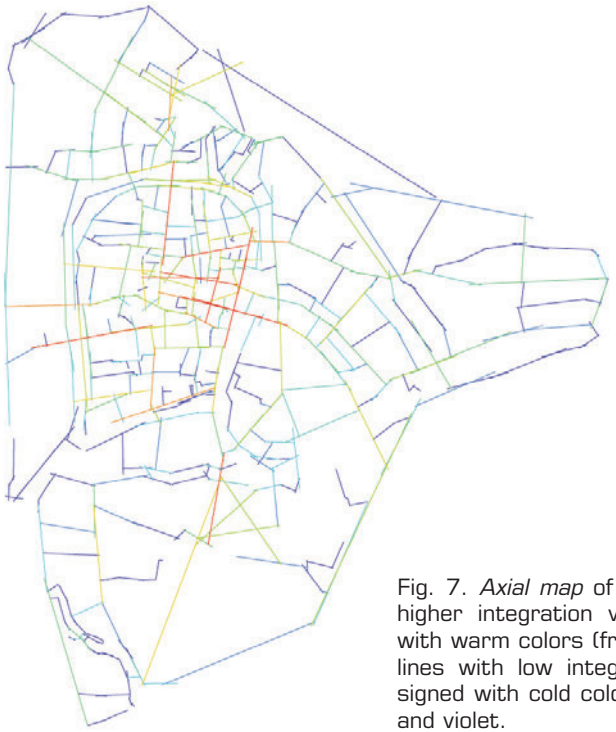

Fig. 7. *Axial map* of Padua. The lines with higher integration value are represented with warm colors (from yellow to red). The lines with low integration values are designed with cold colors from green to blue and violet.

Although some building construction phases can be dated back to the city-republic period (12th-13th centuries), major changes were seen in the following centuries. Among the significant elements to be detected in the building sequences dating after the 13th century, was the adoption of a trefoil arch made from Nanto stone. Its jambs also feature a variety of shapes, the most widespread of which is the moulded post with a capital of a "composite" kind, embellished with small palmettes[14]. These architectonic items are missing in the areas showing a low integration value from the space-syntax analysis. If we consider for instance the building typologies for via Sperone Speroni[15], only one *palazzo* is present[16], while the other buildings nearby are one-family dwellings or constructions made up by merging a number of single units. The 'seclusion' degree of via Sperone

[14] To go deeper into the topic of architectonic elements such as windows, capitals and embellishments see Chavarría Arnau, Russo, Schivo 2011.

[15] Via Speroni shows an integration index between 1.8 and 2.08. For your reference, consider that highly integrated axes are set in the range between 2.7 and 3.1.

[16] It is the building located at 32/38. See Boaretto, Valente 2011.

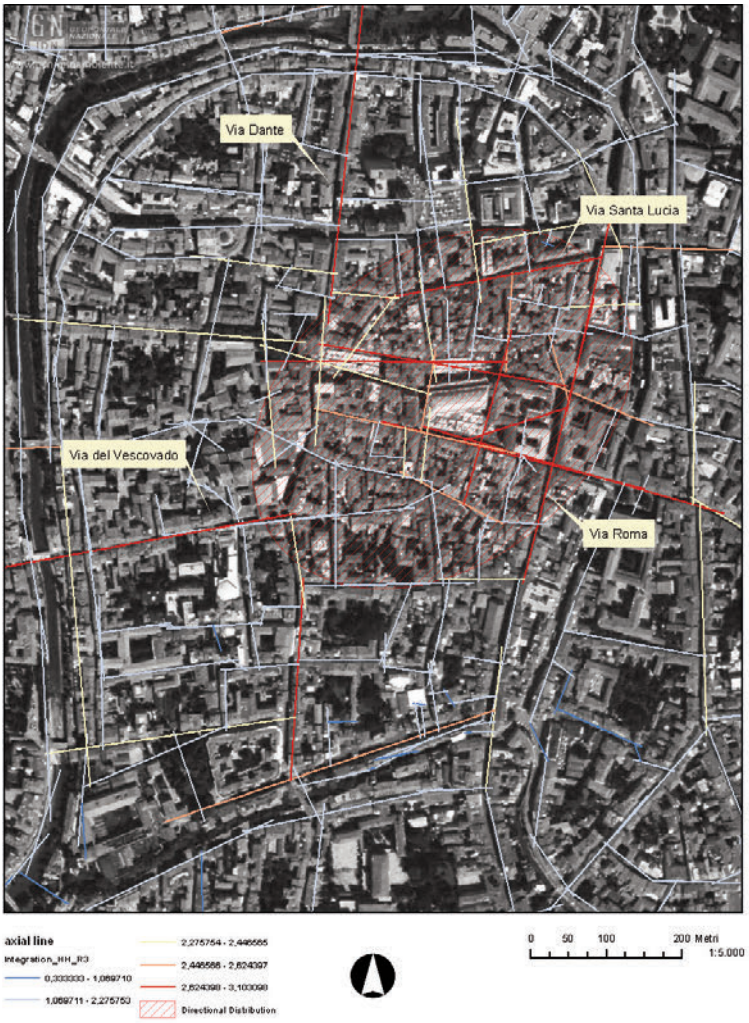

Fig. 8. *Axial lines* GIS import. The figure shows the names of the streets with a higher integration value.

Speroni, with respect to the grid of the urban routes, seems to be the reason why this basic type – the row house and the aggregated house – was kept unaltered, leaving out the new models which would introduce more decorated shapes of architectonic elements into the built bodies. Buildings along via Sperone Speroni in fact show plain items, such as rectangular windows and round arch windows featuring a palmette on the extrados (i.e. the building located in Via Sperone Speroni 80) , whereas some previous elements are kept unchanged, such as round arch arcades fea-

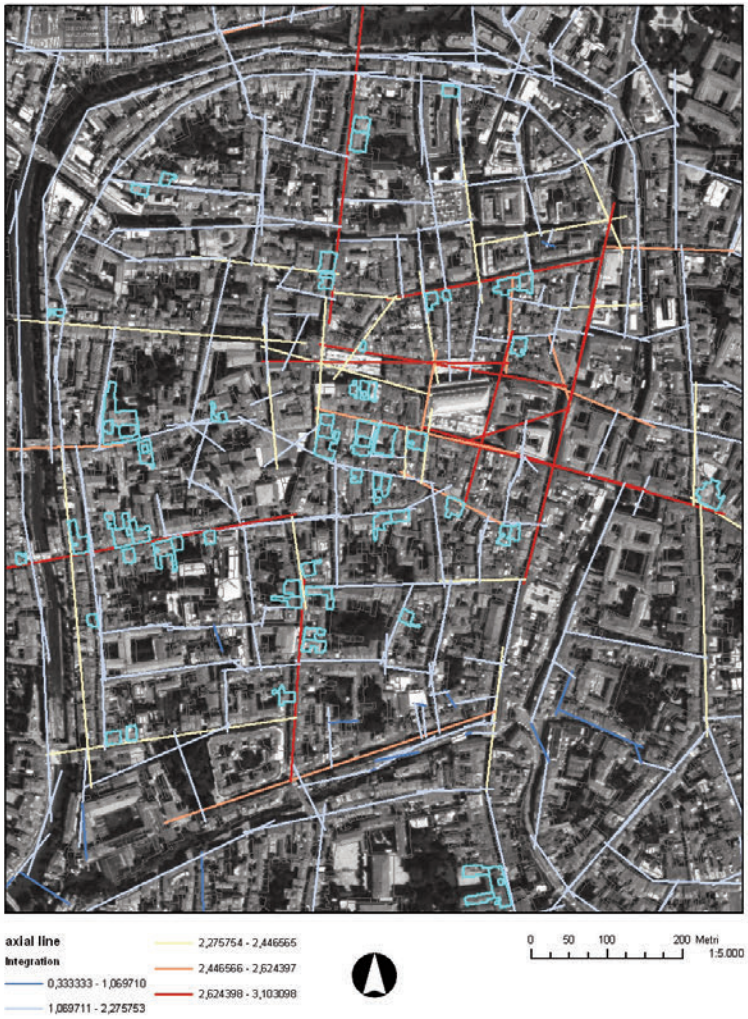

Fig. 9. A GIS query highlighted the building typology "palace".

turing a narrow opening, between 2.3 and 2.8 meters long, resting on low and massive pillars made from trachyte blocks (Maretto 1987, pp. 72-115). Similarly here the space syntax analyses reveal the seclusion feature of the urban fabric in the medieval quarter of Sant'Urbano, located directly to the south of the squares. The values here[17] range from 1.4 and 1.7. Except for the presence of Palazzo Buzzacarini[18] dating back to the

[17] The values are referred to the measure obtained through Depthmap on the radius 3 *integration*.

[18] The building is located in via San Martino and Soferino 65-81.

13th century, the remaining architectures do not show any relevant architectural elements. It is worth noting that historical sources pertaining to the quarter of Sant'Urbano reveal the presence of poor plain constructions, made entirely from wood, in the second half of the 14th century[19].

In Padua the 14th-century urban structure seems to redesign the nodes of the medieval town, for instance, with the construction of the Carrarese Reggia. As a matter of fact the Carrarese family picked an area featuring a high integration rate (between 2.7 and 2.8), located between the business core of the squares and the religious one in the area surrounding the Cathedral (Bortolami 2005, pp. 119-144), including the buildings located in the area of today's via dell'Accademia to the West, via San Nicolò to the North, piazza dei Signori to the East and via Arco Valaresso to the South. It does not seem to be an incidental choice: it rather complies with a spatial logic of occupying a central position inside the town. The necessity to link the palace with the Castle, thus granting a connection to the military pole, led to the construction of an elevated walkway, called "Traghetto", which could replace the interposed road route network hindering people from easily reaching it[20]. The Castle in fact stood to the South of via Sperone Speroni, whose suburban features have been described above. The syntactic analysis carried out here, through the axial lines, clearly shows how the Castle position has low integration and control rates, reflecting its seclusion in the mesh of Padua's urban routes (fig. 10). Notaries' deeds and property value assessments also reveal that properties around the Castle (fig. 11) were given a lower values between the 14th and 15th century. For instance, 60 liras were required for a beneficial agreement for three *cassi domorum* in the San Tommaso quarter (AdSP, Notarile 32, f. 40r, year 1378); 7 liras for a beneficial agreement for two houses located close to Sant'Anna nunnery, in today's via Sperone Speroni (AdSP, Notarile 32, f. 375v, year 1404); 7 liras were also the value for a beneficial agreement for a *cassi domorum* in the Brondolo quarter (AdSP, Notarile 32, f. 375v, year 1404); 12 liras were the rent value for a house in Borgo Tedesco (AdSP, Value assessment in the year 1432, town register - folder 383, par. 76r). The contracts of Sant'Urbano quarter show the same trend too: 8 liras were in fact needed for a beneficial agreement for a house partially made from wood and partially a masonry work (*partim de lignamerie et partim de muro*) with courtyard belonging to it (AdSP, Notarile 32, f. 50r, year 1378). Areas in Padua showing higher integration indexes feature a higher property as-

[19] *una domo de lignamerie positam in Androna Sancti Urbani …* AdSP, Notarile 32, f. 54v, year 1378.

[20] Built on the days of Ubertino da Carrara, it was demolished in 1777. Today some wall fragments can still be seen in via Accademia and via Frigimelica (see Baroni 1990, pp. 44-46; Verdi 2006, p. 95; Rusconi 1936).

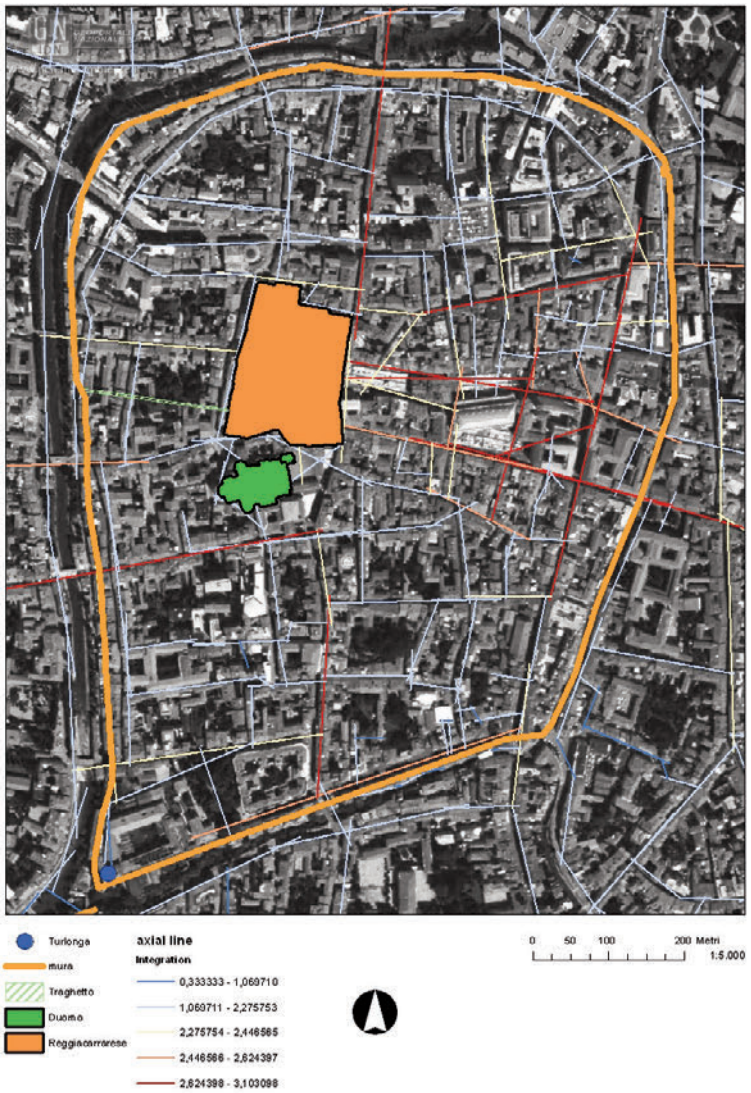

Fig. 10. *Layout* GIS with "Carrarese palace" and the cathedral. The *axial lines* clearly show the proximity of these two centres to the maximum integration values area. On the contrary the Castle (named *Turlonga*), is far from this area.

sessment value in contrast: 20 golden ducats were required for a beneficial agreement for a masonry house in Santa Lucia quarter and a couple of wooden houses in Sant'Andrea quarter (AdSP, Notarile 32, f. 251v, year 1395); 25 liras for a beneficial agreement for a land with a 32 Padua feet (11,42 meters) wide street level front located in Sant'Agnese quar-

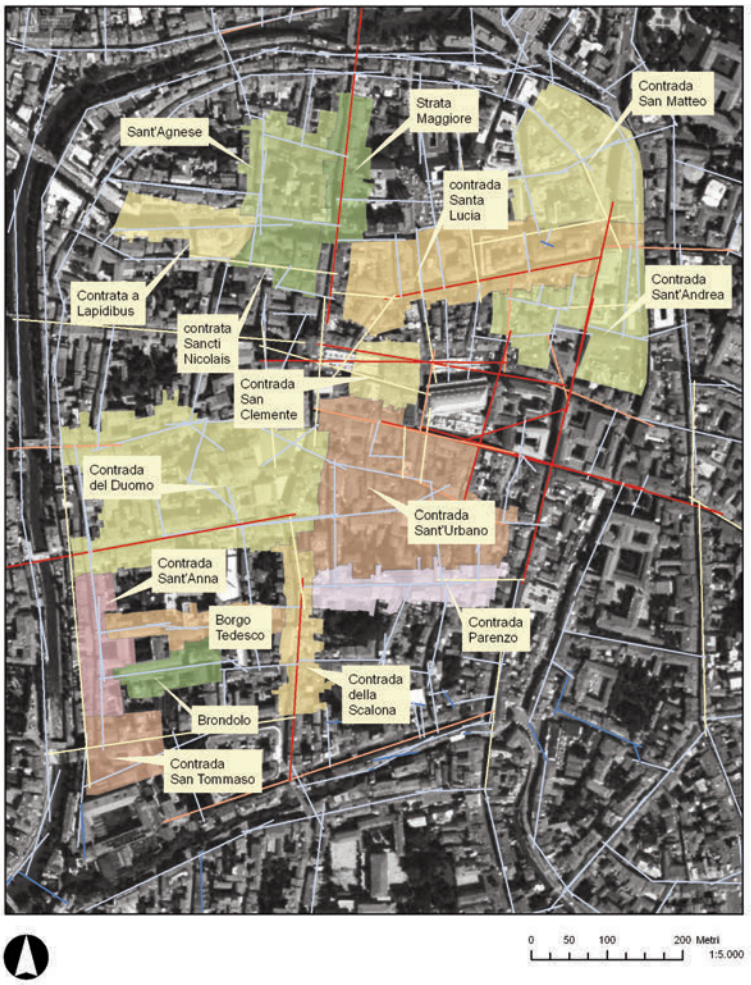

Fig. 11. Hypoteses of the limits of some "contrade", *overlaying integration* values of *axial lines*.

ter (AdSP, Notarile 32, f. 12r, year 1377); 50 liras was the rent for a house in the Santa Giuliana quarter (AdSP, Value assessment in the year 1432, town register - folder 383, par. 18); 50 liras were needed for the rent of another house located in the Strada Maggiore quarter (AdSP Value assessment in the year 1432, town register - folder 383, par. 29); 18 ducats for a house in the Scalona quarter (AdSP Value assessment in the year 1432, town register - folder 383, par. 76r).

An analysis of the *choice* values as revealed by the application of syntactic analysis on Padua in the Middle Ages, arouses further interest. This

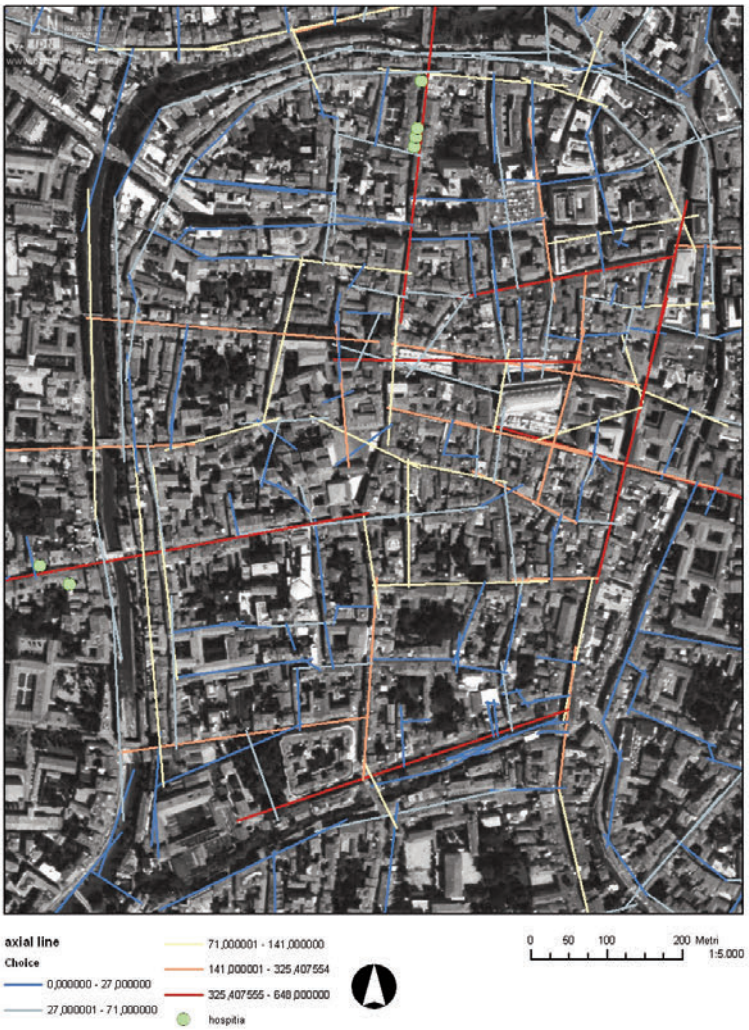

Fig. 12. *Layout* GIS with *hospitia*.

measure allows us to identify which roads were mostly used[21], Such *choice* is therefore a further way of measuring centrality, and we can simulate it by identifying the axes featuring higher degrees of flow and motion (Hillier, Vaughan 2007, p. 19). It is believed that paduan hospitia were built in the area next to the town gates (Galliazzo 1971, p. 55), but as the space syn-

[21] The *choice* reveals the number of times axis *i* is used when calculating the shortest paths between all pairs of axes in a system

tax reveals here the reason for this location is not to be found in a generic proximity to the town's access points, rather what is important is their closeness to the gates attracting the strongest flows of people (fig. 12)[22]. Thus space syntax demonstrates that the place where *hospitia* were located met the functional requirements these structures were meant to provide: they needed to be easily accessible, as foreign people and merchants staying in *hospitia* were not familiar with the road system grid of Padua.

5. Concluding thoughts

The aim of this paper was to offer an analysis of the urban fabric of medieval Padua through the use of space syntax methods, using GIS data derived from the ARMEP project. Such theory provides interesting opportunities as it differentiates clearly central areas from suburban ones by means of maps, introducing into the morphological analysis quantitative information which is useful for studying urban dynamics both temporally and spatially.

The location of certain building types, featuring a high specialisation level proves to be closely linked to *integration* values. Similarly the perusal of notary's deeds and property value assessments pertaining to real estates reveals that business values for properties were also determined by the *integration/segregation* rates of the intra-mural area. The collected spatial data lead to a conclusion that from the 14th century, the city was getting more organised from a topographic point of view: it was dividing into distinct living areas, where the most important buildings were concentrated along those access lines showing a higher *integration* rate, whereas humbler houses were located in *segregated* areas. Space syntax helps us to identify these patterns. In fact, a street that today seems central, such as Sant'Urbano, reveals conversely a high level of *segregation*. Similarly Contrada Parenzo seems peripheral like the near to Borgo Tedesco (street *segregated*), instead reveals a good level of integration, justifying also higher value of houses within the notaries's deeds (AdSP, Notarile 32, f. 258v, year 1395). The syntactic analysis also reveals something of an underlying urban planning scheme, or spatial logic, in the decision-making of Paduans: *hospitia* were not located by chance on the axes featuring a higher *choice* rate. For the same reason markets were not placed amidst areas featuring the highest degree of integration.

[22] The San Daniele and San Giovanni from Gerusalemme *hospitia* are indeed located in today's via Euganea, the natural prosecution of via del Vescovado.

When syntactic analysis is applied on the elements of the 14th and 15th century townscape it proves to be a useful tool. However, it is not suitable though for assessing the space syntax for the earlier period. For example, the secluded position of the Castle hardly fits into the image of the 12th century town, because, as sources witness, it was a strong 'attractor'. The street system in Padua before the 14th century may thus have had a different configuration and for this reason it is fundamental to assess the input data of the syntactic analysis most carefully if we want to grasp urban phenomena with due accuracy for other historical periods.

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Abbreviations
AdSP: Archivio di Stato di Padova.

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