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Parametric analysis of urban form, from geometrical to topological

Luca Maricchiolo¹

¹Laboratoire d'Urbanisme « Lab'Urba », Université Paris-Est Créteil
14-20 Boulevard Newton, Cité Descartes, 77420 Champs-sur-Marne, France
e-mail: luca.maricchiolo@u-pec.fr

Keywords: urban form, urban design, morphometrics, parametric design, city information modelling
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Abstract.

This paper presents a methodology to read urban space and to display it through parametric representation. It is based on quantitative analysis of geometrical properties of different urban sequences, parameterized on a sample trajectory representing observer path. A labelled $t(x)$ parameter allows to evaluate such path, systemizing on its visual, spatial, and morphological variations, through some indicators:

- a. Dimensions $D(t)$: urban space large, measured orthogonally to the observer trajectory tangent at $t(x)$;*
- b. Focal distance $Fd(t)$: visual depth tangent to observer trajectory at $t(x)$;*
- c. Sequences variations: number of dimensions and focal distance deviations greater than respective average value, representing major changes in visual perception along the path, so that they produce the transition from one scene to another one in an urban sequence.*

Quantitative data depending on a unique parameter $t(x)$ lead to display graphical and statistical representation, as computing of average value, range, and standard deviation.

This methodology has been tested on few case studies in European cities: Rome, Palermo, Naples and Barcelona, comparing historical urban fabrics to XIX century planned ones, highlighting constants, differences and variations.

The parametrical analysis of sequences indicators allows to shift from geometrical information to a topological model, abstracting results from shape specificity. The configuration pattern linking metric and relational information is experimented as a design pattern. This puts urban analysis in the perspective of design practice, leading to the script of an input matrix for an informed parametric urban modelling.

Key Words: urban form, urban design, morphometrics, parametric design, city information modelling.

Introduction.

The research presented in this paper addresses the issues of data collection in urban morphology and their use into computational urban design. Particularly, it proposes a quantitative methodology to read urban space, with the aim of discussing links between urban morphology analysis and urban design.

Studies of urban morphology are traditionally aimed at understanding the generation of voids and masses – urban morphogenesis – relying on qualitative approaches to identify figures, elements and syntactic structures as well as their forming processes. The disciplinary evolution has proposed a great variety of approaches, mainly addressing two dimensions: the planimetric one, based on the building footprint and street network; the three-dimensional one, based on the articulation between spaces and buildings. Among these, different schools addressed specific mechanisms. Michael Conzen (Conzen, 1968), with the Anglo-Saxon one, identify three key elements and syntaxes: roads and their composition in road systems; plots and their aggregation in urban blocks; buildings and their arrangement in plots and blocks. Saverio Muratori (Muratori, 1960), Gianfranco Caniggia and Gian Luigi Maffei (Caniggia and Maffei, 1979) focused on local syntaxes, linking building typologies with the assembly rules along paths in the conformation of street and block shapes. The introduction of mathematical models, computer aided design tools for urban analysis (Martin et al, 1972), and graph theories in network analysis (Steadman, 1983), moves towards approaches based on measurable characters.

Within the framework of quantitative knowledge in the field, two main methods can be distinguished: configurational analysis and spatial analysis (Erin et al., 2017). Configurational analysis aims at quantifying the ability of street network to structure movements within the fabric, basing on the structural features of the network and of the relationships established with other elements in the urban space. The theoretical reference of Space Syntax (Hillier, 1996) addresses the network of public spaces modelling through graphs. Graphs can be built either as a system of axes intersected in nodes, or as a system of adjacent convex spaces (Fusco and Tirico, 2006). Configurational analysis introduced an innovation in the sense of a quantitative approach in urban morphology, based on the "network" component, leading to methods to address accessibility (Urban Network Analysis. Sevtsuk and Mekonnen, 2012), perspective continuity (Axial analysis. Figueiredo and Amorim, 2005) minimal paths (Angular analysis. Turner, 2000) and centrality analysis (Multiple Centrality Assessment. Porta et al., 2006)

Spatial analysis, based on Geographic Information Systems (GIS), concerns all the elements present in the urban fabric and focuses on the spatial relationships and configurations between them. It addresses categorization of elements and relations, as building types, neighbourhoods typologies, land use, mobility, density, building-plot relationship, referring to different models to analyse their arrangement in the urban form. Despite most of GIS based analyses rely on « point and click » method, whose reproducibility is affected by the sequence of operations, some computational tools have been recently implemented, in both Python and R, as well as plug-ins in GIS software, to systematize spatial analysis (Fleischmann, 2021). Morphological tessellation using Thiessen polygons on building footprints is a reproducible method to identify an analytical spatial unit for individual buildings surroundings (Fleischmann, 2020). Furthermore, tessellation using Thiessen polygons around a path identifies a new analytic urban unit, the proximity band around a street segment, that is particularly interesting as it adopts a perceptive point of view, different from traditional planimetric spatial analysis. (Araldi and Fusco, 2019)

The development of Geographic Data Sciences is still primarily linked to functional and mobility issues. The issues related to shape, geometry and proportions of space seem to be of less interest, although these represent a major success factor of an urban form. Analysis scale matters. GIS is oriented to territorial development and urban planning, while the scale of urban design is often underrepresented due to lack of detail and loss of three-dimensional approach and internal focus. Urban design measures address urban form at the highest scale of definition, and they request internal observation, as external data (e.g. satellite observation) can hardly be exploited, due to

lack of definition. Basic units are urban frontage, streets or squares, whose measurement can be used as a support to explain or govern a whole range of urban phenomena, as vitality, safety, accessibility. In this perspective, quantitative approach provides objective measures to be compared with urban performances (Lynch, 1981) to empower multidisciplinary analysis (Clifton et al. 2008) and modelling (e.g. City Information Modelling. Gil, 2020).

The analysis methodology hereby presented addresses a quantitative measurement of urban space adopting internal focalization, basing on pedestrian's point of view to question perceptive experience. If perception is subjective, however some physical features of space are objectively measurable, as dimensions, spacing, proportions (Ewing et al. 2006). The investigative categories adopted in the present research to collect countable data from several urban sequences in a comparative approach follows the theoretical approach proposed by Kevin Lynch (Lynch, 1961). This will be discussed to better understand the combinatorial criterion of few urban sequences in Mediterranean historic cities, whose common features can be explained by the limitation of combinatorial possibilities – as grammar and syntax limit to a finite number the possible combinations of letters in language (Hillier, 1996). Thus, analysis aims at recognizing recurring geometrical and topological features as to produce similar perceptive situations.

Methodology. A parametric approach for the pedestrian point of view.

This paper presents the indicators, the methodology and the collected data of the analysis of six urban sequences of historic cities in Mediterranean Europe, followed by the results discussion oriented towards design. The general objective is to develop a methodology to read urban space, to highlight recurring characters and to explore results potential in a design algorithm. This is based on consecutive steps, whose results are presented during the discussion:

- the parametric measurement of six sequences of public space in six historical fabrics;
- the evaluation of the results on the basis of some indicators aimed at identifying the sequences;
- the construction of a topological model based on the identified sequences;
- the testing of the topological model in a design algorithm.

Measurement adopts an internal focus and is returned in parametric representation along a sample path through urban fabric. The transition from Cartesian to parametric representation aims at abstracting analytic metric data from local shape specificities: the unique and reproducible independent variable is the walking time along an urban path, which is adopted as a fundamental parameter. Metric data are, thus, represented as function of t parameter on a sample trajectory. This allows getting away from geometric features, ensuring a stronger results comparability and absolute values fit for design algorithm. Dependent variables and indicators are based on the normative theory of Kevin Lynch (Lynch, 1962), which offers a reference benchmark.

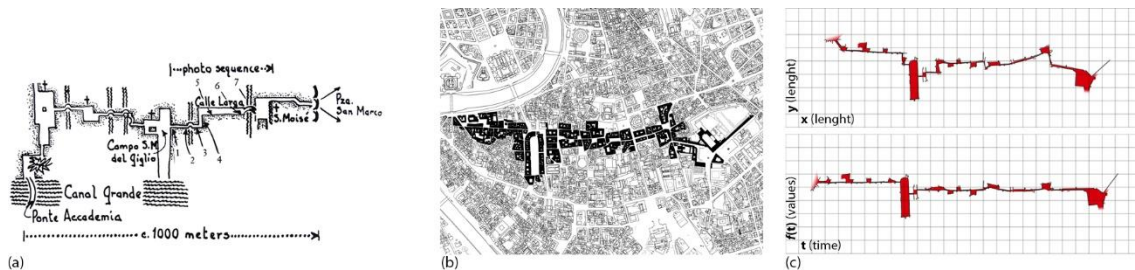


Figure 1. From cartesian to parametric representation. (a) Kevin Lynch, urban sequences in Venice (Lynch, 1962); (b) sample path in Rome case study; (c) the sample path in cartesian representation (above) and unfolded along the parametrized trajectory (below)

The analysis is carried on in a CAD environment (Rhinceros3D) through a visual programming tool (Grasshopper), based on building footprint from GIS information. On the basis of qualitative results, identification of local topologies and sequences configuration on a graph shapes a design pattern.

Measurement. Quantitative analysis of urban sequences.

On local indicators framework.

Several approaches to urban studies based on human perception suggest the transition to a representation of urban space from an external focus (plan) to an internal focus, based on inner perception or cognitive spaces. Perceptive role of space in shaping historical memory and assuming adequate performances has widely been raised in literature (from Sitte, 1889, to Jacobs, 1961) but it is Kevin Lynch, in *Site Planning* (Lynch, 1962), who operates an analytical, dimensional and normative description of the space of the city, which he will subsequently relate to a performance and multidimensional approach (Lynch, 1981).

In *Site Planning*, Lynch focuses on sensorial function of space, often ignored in site arrangement plans in favour of functional or technical needs. As argued by Lynch, urban space is, the most if not all, experienced through a sequence of views, driven by site directions and rhythms, whose element parallax movement can affect global perception. Thus, proportioning and articulation are not necessarily conceived in absolute terms, but relating to the perception and the movement of people in space. Basing on sequences structure, inner focalisation and parallax, Lynch addresses a few tentative quantities that can be assigned to the size and the proportion of external spaces:

(a) Space dimensions. Basing on human view capacity, urban space can be dimensioned moving from its perception. Humans can detect a man about 1,2 km away, recognize him at 25 m, see his face as a clear portrait at 15 m, feel him to be in direct relation to us, whether pleasant or intrusive, from 1 to 3 m. Consequently, about 15 m large space appear intimate, until 25 m it is human scaled; smaller, it appears too small and oppressive; for instance, most of the successful enclosed squares of the past not exceeded 130 m in the smaller dimension.

(b) Parallax. Urban perception is shaped by the limits to the angle of clear vision and to the rapidity of scanning. Thus, focal distance from the observer to the object affects urban perception: an element whose height equals distance is seen in detail but not as a whole; while distance is two times height, it would be seen clearly and entirely; from three times and more, visual field becomes predominant on the element, till this disappear to be part of the scene.

(c) Proportions. Most comfortable spaces are height a third of large; below, space ceases to be enclosed; over, it seems a pit.

(d) Sequences. Made of both spaces and paths, they should be measured by successive balances at each point of view. Evaluation results from cumulative effect, as a lack of formal balance at a moment can be less important than a qualitative connected chain of spaces. Sequences size on congenial physical characteristics: continuity and closure of form; differentiation, dominance or contrast of a figure on a ground; symmetry, order, repetition or simplicity of forms. Movement is as much important: the road suggests direction, eyes follow it as a thread that ties the whole together.

(e) Rhythmical continuity. Sequences should be linked harmoniously to create consistent variations alternating open to close, simple to intricate, brilliant to subdued. "The space should be considered as a total pattern – not seen flatwise from the air, but as a progression through which one moves" (Lynch, 1962, p. 81)

Although empirically thought, "these statements seem to derive from the optical characteristics of the human eye, and from the size of the objects which are generally of greatest interest to it, i.e., other human being" (Lynch, 1962, p. 60).

Urban sequence specimens.

The analysis methodology was tested on different urban fabrics. The demonstrative purpose of the methodology is independent of local quality of urban specimens, aiming at highlighting some tools to link spatial quantitative analysis to design.

Four sequences in the historical urban fabrics of Rome, Naples, Palermo and Barcelona, have been compared with two paradigmatic XIX century urban plans: the first extension of Rome as the post-unification capital, Rione Prati, consisting of regular orthogonal grid of approximately 100 x 70 meters, and Barcelona *eixample* planned by Ildefons Cerdà, based on 110 meters squared blocks. For each, the analysis focuses on an arbitrary path along a quasi-linear trajectory, traced avoiding main axes to simulate a random walk experiencing the urban sequences. This, to grasp diffused urban features rather than extraordinary ones, as they appear to a greater number of observers.

(i) Rome, Centro Storico. The analysed path goes through the *zona urbanistica* Centro Storico, crossing the medieval and the Renaissance fabrics, and avoiding main straight axes resulting of later planification. It begins in Rione Ponte, crosses Parione, Sant'Eustachio and Pigna districts, touching nodal points such as Piazza Navona, Piazza della Rotonda, to reach Trevi district and end in Piazza del Quirinale.

(ii) Palermo, Albergheria and Kalsa. The analysed path runs through the two *mandamenti* on the south side of the Cassaro, presently via Vittorio Emanuele. It moves from Piazza della Vittoria in front of Normanni Palace toward the sea in north-east direction, crossing Ballarò marketplace, Piazza Bologni, Piazza Bellini, and reaching the waterfront through via Alloro.

(iii) Barcelona, Barrio Gotico. The path crosses medieval district parallel to the coastline, from the *eixample* on south-west to the *eixample* on north-east. It starts in Raval neighbourhood at Sant Antoni marketplace proceeding along Carrer de Sant Antoni Abat and Carrer del Carme, to cross La Rambla and enter Barrio Gotico in Carrer de la Portaferriça until the cathedral. It runs through plan Cerdà's demolitions in Plaça Nova and Avenida de Francesc Cambò, facing Santa Catarina market to finally reach the example on the north-east side of Bairro Gotico in Placeta del Comerç.

(iv) Naples, Centro Storico. The path crosses the still visible Roman structure of the historical fabric. Moving from piazza Carità along via Toledo, it reaches the *castrum* at piazza del Gesù Nuovo and runs along the *decumano inferiore* (via San Biagio dei Librai), crosses the *cardus* of via Duomo, and it ends in Piazza Garibaldi, a vast XIX century square that became bigger after modern central station relocation.

(v) Rome, Prati. On the orthogonal XIX century grid, the analysed path is one of the axes, namely Via Cola di Rienzo from Piazza Risorgimento to Piazza della Libertà.

(vi) Barcelona, Eixample. The analysis concerns a sample path within Cerda's fabric, particularly Carrer del Conseil de Cent, from Carrer del Comte d'Urgell to Carrer de Bailèn.

Analysis parameter and variables

Sequences features are measured and represented as a function of an independent parameter, walking time $t(x)$ along the path, ranging from $t(0)$ at the start and $t(1)$ at the end, equal to about 20 minutes walking on an approximate length of 2km (+/-100m) at 5km/h. Analysis variables depending on t are :

(a) Dimensions $D(t)$. The scale of space is mostly represented by large, measured orthogonally to the path, from a built front to the other on opposite sides. Intersections with transversal streets are assumed as gates, as they don't interrupt perceptive continuity of the fronts, while shaping convex urban voids. Parametric representation of $D(t)$ shows the variation of urban space dimensions, highlighting discontinuities and rates of change. Lack of dependence from urban form geometry allows comparison.

(b) Focal distance $Fd(t)$. Urban form diversity is expressed by measuring the variation of axial viewpoints, on a direction tangent to the path. The more frequent are the viewpoints changes, and the shorter are their focal length, so space experience and perception are richest. Focal distance measures, hence, length from the observer to the first urban front or other perspective obstacle on an axial direction, namely tangent to the path at $t(x)$. Parametric restitution shows space depth:

lower values express a tight succession of scenes, so a strong articulation of the path, while higher values express long perspectives and more linear paths.

(c) Sequences $S(t)$. The passage from a spatial sequence to the successive is identified by discontinuities in space dimensions and focal depths variations, or by the rate of change of such variables. A variation equal to or greater than, positive or negative, identifies the passage from one sequence to the next; in the same way, a variation (always positive) of the focal depth equal to the previous one identifies a sequence passage. The sequences are therefore described by both sudden variations of expansion or compression (e.g.: the way in or the way out of a square), and sudden variations of visual depth (e.g.: a turn along a path).

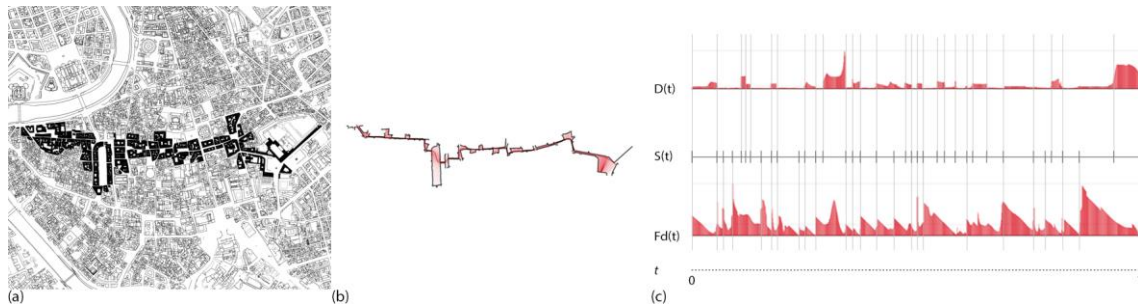


Figure 2. Analysis of a sample path in Rome, Centro Storico (a), along a parametric trajectory (b): (c) dimensions, sequences, and focal distances in parametric representation on basis $t(0,1)$

Results: scale, diversity, articulation, and rhythms

Metric data collected are visualized through both graphical and statistical representation. Graphics in figure 3 present $t(x)$ on the abscissa and $f(t)$ values on the ordinate, displaying variations of the indicators for dimensions, focal depth and sequences. Statistical representation in figure 4 addresses frequency and distribution of the collected values.

Graphical comparison between cases study directly shows compressions, dilations, and focal progressions differences, as to explain how urban sequences and their ratio change in relation of urban space shape.

Some considerations can be drawn on four main topics:

1. Dimensions and scale. As expected, average dimensions are lower for historical fabrics rather than planned ones. In all Rome, Palermo, Barcelona, and Naples historical centres average values are around 10 m large, fitting with human scale and recognizability of boundaries. Furthermore, dimensions don't exceed 200 m, keeping space scale not to far from Lynch's reference for enclosed squares.
2. Diversity. The gaps between minimum, maximum and average values express the variation rate; therefore, the standard deviation of data qualifies space in its capacity to provide compression and release produced when the observer passes from a narrow to a broader space.
3. Articulation. Focal distances express axial variations along the path, as turns, curves, visual obstacles. Intensity of gaps shows less linearity in space, whose articulation provides a higher number of perspectives per path unity. In historical fabrics (i, ii, iii, iv) visual depth varies from about 3 to 950m, associated with the long straight of Naples *decumano inferiore*. In planned fabric (v, vi) infinite length refers to focal depth exceeding sample limits, not finding any visual obstacle within the path.
4. Rhythms. The number of sequences per length unity reveals sequence ratio, that is the frequency of variations along the path, thus urban space rhythm



Figure 3. Graphical representation of the comparative analysis: (i) Rome, Centro Storico, (ii) Palermo, (iii) Barcelona, Barrio gotico, (iv) Naples, (v) Rome, Prati, (vi) Barcelona, Eixample

The following tables display key values of the collected data and their statistical comparison.

<i>indicator</i>	<i>u</i>	(i) Rome Centro Storico	(ii) Palermo	(iii) Barcelona Bairro Gotico	(iv) Naples	(v) Rome Prati	(vi) Barcelona Eixample
path length	m	2042.0	1789.0	1972	2068	1127	1887
D(max)	m	175.0	186.5	146.0	163.6	116.5	60.5
D(average)	m	10.4	8.2	9.5	14.4	24.8	20.0
D(min)	m	2.6	1.9	4.2	4.2	22.3	16.8
Fd(max)	m	235.5	300.5	302.5	955.9	Inf	Inf
Fd(average)	m	50.6	59.5	99.4	242.6	n.d.	n.d.
Fd(min)	m	2.9	8.6	3.0	6.5	Inf	Inf
S	val	37	37	33	19	4	1
S(ratio)	val	1.8	2	1.7	0.9	0.3	0.05

Table 1. Key values of parametric analysis, per indicator, per case study

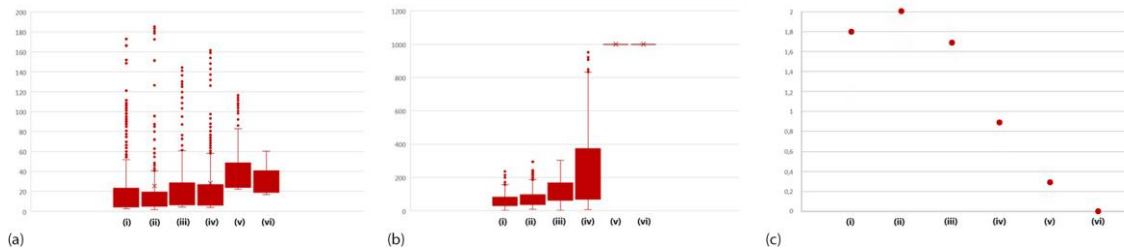


Figure 4. Data visualisation per type for every case study: (a) dimensions; (b) focal distances; (c) sequences per 100m

Dimensions and focal distances provide a measurement of urban space scale, diversification, articulation and rhythms: Analytic quantitative data allow a comparison and an objective evaluation of the case studies, on the basis of related indicators. Obviously, such evaluation is restricted to the analysed path, not giving any information about the identified fabric as a whole. Moreover, it is arbitrary, due to its dependency from the chosen path and the travel direction. However, for demonstrative purpose, it shows a methodology fit to be reproduced in every possible path within a neighbourhood, to offer more significant statistical data about the whole urban fabric.

Evaluation data are not suitable for developing a design algorithm, due to strict compliance with the specific case-study: values strictly depend on shape, while a broad generalisation of the relational principle, fit for design, requires stronger abstraction. Hence, the elaboration of a topological model addresses the script of configurational rules to feed a morphogenetic algorithm.

Discussion. The topology of urban sequences.

General topology of open spaces consists of a continuous surface space with as many holes as built elements (both isolated buildings and blocks). All squares and streets are a connected bi-dimensional surface, as any point can be reached by travelling on this surface. It is bi-dimensional and orientable, as it is easily recognizable an above and a below and there are not ambiguities between the two faces, although few overlaps are possible. It is bordered by all urban space internal boundaries, like urban frontages and enclosures, and by a hypothetical external city limit. Hence, as a general topology, urban space is a surface topologically equivalent to a disk with n perforations and an external boundary, which are independent of geometry (Brelford et al. 2015). Furthermore, accessible urban space is isomorphic to its access network, which can be described by graphs identifying nodes and connections (Agryzkov, 2017). Access network graph provides a configurational scheme, whose nodes are access points as well as intersections or aggregation spaces. Such urban representation is highly reproducible and generalizable, providing information about integration, connectivity and depth, as relational features, independent from element own

qualities (Brelsford et al., 2015). As a development of network analysis, several criteria can identify nodes and connections, to make graphs more consistent to the real or to the perceived urban form: these could be based, for instance, on isovists, street names, or axial analysis including only the fewest and longest lines (Hillier, 1996). Such normalizations of graphs aim at linking continuous paths that are not, actually, a system of segments, to better clarify relations between the parts of access network (D’Autilia, 2015).

Despite their effectiveness about cities configuration understanding, graphs representations do not provide any information about real quality of nodes and connections. Furthermore, they lead to some inconsistencies and ambiguities, for instance in the representation of a square with a fountain, that could be seen as a node in itself, or as network of small segments with as any intersections as the streets going to the square (D’Autilia, 2015). Another weakness concerns the base support, focusing just on relations and removing metric or geometric features data. This leads to some ambiguities in integration computation, including loss of urban scale and over-reliance on connections axiality (Ratti, 2004).

Topology, as a non-metric science, could be very effective in the study of relations, especially at a global scale. However, at a local scale such representation suffers from a lack of information about spatial qualities; moreover, it is hard to dissociate pedestrian and human-scaled perceptions from metric information, as walkability relies more on distances and spatial comfort rather than on connections depth (Ratti, 2004).

Urban sequences, as defined in *Site planning* (Lynch, 1962), consist of a linear configuration (or chain) of urban voids, which quantitative description requires both metric and non-metric relational data. Abstraction from geometric information allows to focus on relational properties and to highlight configuration. Nevertheless, within this research, some metric-derived data are supposed to be kept, as the position and the scale of each sequence.

The hypothesis hereby explored consists of introduce few nodes features within a topological representation of the analysed urban sequences. The topology of urban sequences is restricted to the analysed path, not including general city topology. This is made of a chain of cognitive spaces, topologically identified by surface, boundaries (e.g. urban frontages) and gates (Stojanovski, 2013). Identifying as gates the connections between each convex void space, it allows to define a local topology of public spaces as a bi-dimensional continuous surface bordered by both enclosures and gates. In an enclosed square, delimited by compact urban fronts, access streets do not break unity of perceptive – or cognitive – enclosure. This is consistent with the perception of urban sequences as a chain of different, unitary, spaces, interconnected one to each other, although the whole path is actually just one topological surface.

Local topologies lead to identify a range of urban objects enriching the basic urban form ontology made of streets, buildings, and blocks (Kropf, 2014). This concerns elementary syntactic units whose internal and external relational properties are recurrent in urban forms, as to be defined as building blocks for an informed and generalizable city modelling. Perceptive and relational features, defining basic spaces as frontages, streets, squares, are at the basis of urban performances and could be very useful if integrated in base grammar for urban models (Stojanovski, 2018). Finally, representation of urban sequences as a chain of local topologies, interconnected by gates, fulfils internal focalization of urban space.

Urban sequences configuration consists of two syntactic principles:

- a. The chain itself, as a configurational path referring to gates and interconnections
- b. Local topologies, referring to cognitive spaces and represented as nodes

The parametric analysis is used as a criterion to qualify both principles: the parameterization of the path identifies the position (and the depth) of every space on the chain; the quantitative data define scale of each space.

This leads to define three syntactic units, basing on the spread of analytic values highlighted by parametric analysis, represented through an informed dual graph of urban sequences (in which nodes refer to each convex space and connections refer to gates):

- a. Expanded units (e.g. squares), consisting of spaces whose dimensions exceed the average values of the whole sequence, represented as nodes;
- b. Compressed units (e.g. streets), consisting of spaces whose dimensions are less than average values, represented as nodes as well;
- c. Gates, referring to links between units, equivalent to discontinuities of both dimensions and focal distances indicators.

The identification of these three syntactic elements is essentially based on local spatial qualities, with the aim of including in city modelling qualitative features, as shape, human-scale, perceptive experience, through quantitative analysis and reproducible methods.

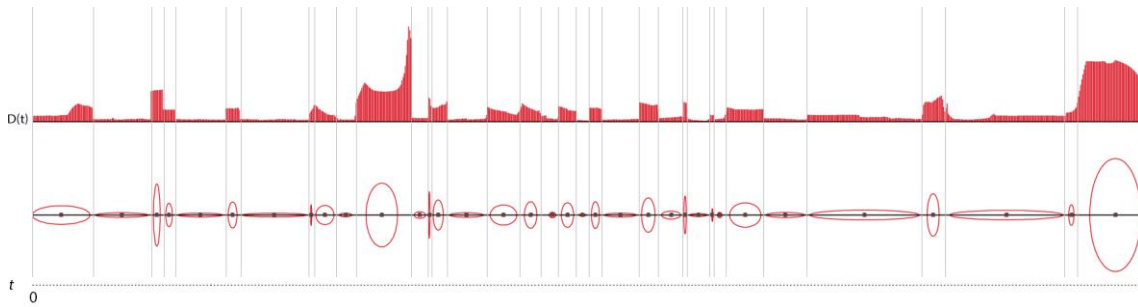


Figure 5. Urban sequence (i) represented as a chain of local topologies with proportional data based on dimensions $D(t)$.

Conclusion. Towards urban modelling and design

Urban morphology and urban design are theoretically linked, as morphology focuses on how and why urban elements are composed. Design takes advantage of morphology categories, both in terms of theoretical approaches (normative theories rooted in the results of morphology studies), and of operational tools (methods to analyse local contexts as basis for design). Nevertheless, a mainly qualitative approach in urban morphology makes it difficult to have a highly generalizable systematisation of results and a direct application in design guidelines. Quantitative analysis in the field of urban morphology can fill this gap, providing precise and intelligible results to be used in the project. Parametric urbanism can offer a great support, relying on algorithms and rules on the basis of local parameters: “the challenge will be the capacity of quantitative urban morphology to serve as input and/or reference framework to parametric urbanism, in order to avoid the divergence between morphological studies and design proposals” (Erin et al. 2017).

With this regard, the development of a configurationally pattern, following quantitative analysis of an existing urban form, aims at exploring in parametric design a few principles recognized to be successful, namely human scale and articulation of public spaces sequences. This approach, whose experimentation is restricted to few indicators on sample case studies, leads to the definition of a simple algorithm to shape urban voids along a matrix path. Geometry of the path and the boundaries are independent variables, defined *a priori* in the parametric algorithm, while distances and dimensions of spatial units depend on path parameterisation. Hence, the algorithm defines occurrence and scale of space units, as to produce homeomorphic sequences reproducing similar space progressions.

This pattern outlines a way to link design with analysis, operating within evidence-based knowledge to feed a parametric algorithm. The definition of ontological categories from quantitative morphology can improve object-based urban modelling, offering a support for multidimensional data (Duarte et al., 2012); on the other hand, it suggests further research development to increase spatial and performance-based data usability in city information modelling.

Systematic analysis of urban space and sequences, thus, addresses multidimensional analysis by providing a data-driven semantic framework for city modelling, aiming at enhancing spatial and perceptive features in the whole process of analysing, designing and managing cities.

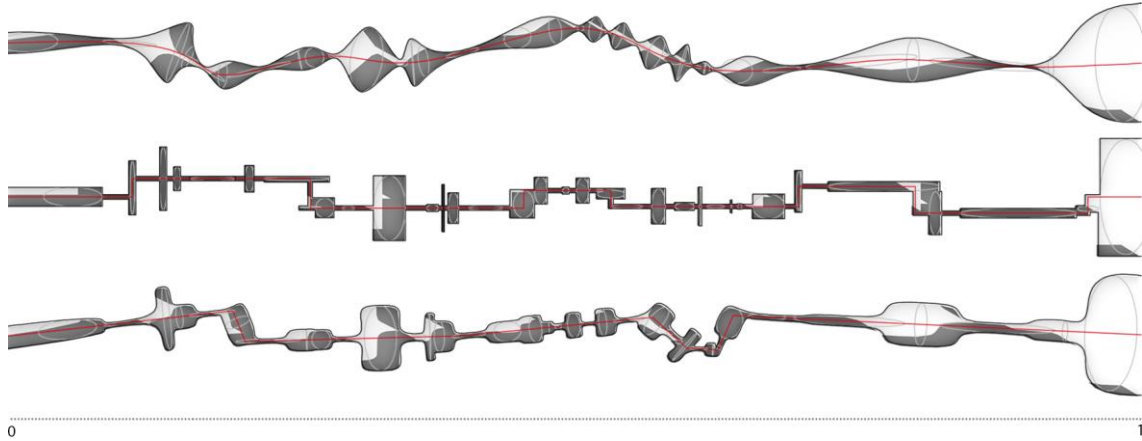


Figure 6. Urban sequences design through a parametric algorithm based on urban sequence (i) configuration, adopting three different sample paths with the related geometric languages.

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Illustrations and tables

- Figure 1. From cartesian to parametric representation: (a) Urban sequences in Venice (Lynch, 1962); (b) sample path in Rome case study (Author, 2022); (c) the sample path in cartesian representation (above) and unfolded along the parametrized trajectory (below) (Author, 2022);
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