BUILT FORM

A Pioneering LISP Framework for Diachronic Urban Analysis

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Abstract

This paper describes a pioneering methodological innovation bridging computational tools and traditional urban morphology by introducing a LISP-based scripting framework for morphological and typological analysis of historical city formation. Developed in 2020 as part of the author Elham K. Hassani's Ph.D. dissertation at Sapienza University of Rome and grounded in the Italian school of urban morphology—particularly the work of Caniggia and Muratori—it provides a replicable method to read and classify urban transformations over time. This was the first application of LISP programming to automate identifying and categorizing urban elements—plot structure, route alignment, and building typology—across multiple historical phases. The methodology integrates qualitative morphological principles with quantitative computational processes, enabling a deeper understanding of urban form evolution and building type variation within a diachronic framework. Using Kashan, a traditional Iranian city, as a case study, the method reconstructs historical phases of urban growth, revealing their spatial logic, typological patterns, and morphological shifts. This dual-level analysis moves the field beyond static visual mapping toward rule-based interpretive systems, contributing to current efforts to apply AI to resilient city-making. Its significance is shown by its integration into Sapienza's curriculum.

Introduction

Urban morphology investigates the formation and transformation of cities over time, scrutinizing the physical structure of the built environment and the socio-cultural processes that influence it (Moudon, 1997). The Italian school of urban morphology is one of the most important theoretical schools in this field. Its founders, Muratori and Caniggia & Maffei, came up with a typological method for understanding how urban form and building types have changed over time. Their approach regards the city as a living entity, interpretable through the analysis of plots, routes, and architectural typologies (Cataldi, Maffei, & Vaccaro, 2002).

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While these founding concepts still hold for the Italian school, its analytical practice has largely depended on qualitative interpretation and fixed cartographic representation (Carlotti, 2016). However, steady improvements in computational methods now make it possible to improve morphological analysis with algorithmic accuracy. Programming languages and automated spatial procedures can manage extensive historical and geographical datasets, providing a degree of reproducibility and precision that is unavailable using traditional manual methods (Karimi, 1998). Still, only a few studies have successfully combined the Italian school's typological tradition's depth of interpretation with the speed of computational analysis (Neglia, 2019).

Recent studies in computational modeling and resilience assessment similarly demonstrate the potential of algorithmic frameworks for structural analysis and urban-scale interpretation. Bakhshandeh, for example, presented a comprehensive review of monitoring techniques for the condition of bridges, showing how sensor networks, machine learning, and data-driven analysis can enhance the analysis of structural behavior (Bakhshandeh, 2024). Bakhshandeh and his colleagues also integrated probabilistic modeling into urban risk assessment, a step that closely aligns with Hassani's earlier, successful effort to translate complex morphological theories into programmable and replicable analytical systems (Bakhshandeh et al., 2025a; Bakhshandeh et al., 2025b).

The current study, conducted as part of Dr. Hassani's dissertation research at Sapienza University of Rome (Hassani, 2022a), is an early, pioneering example of incorporating a LISP-based scripting framework into the Italian school's analytical process. This framework automates the identification and categorization of fundamental urban components—plot structure, route alignments, and building types—across successive historical phases. The resulting method of analysis combines the qualitative principles of the Italian school of urban morphology with quantitative computational methods to provide a more accurate way to read and classify how the urban fabric changes over time, accomplished with far less time and effort than the qualitative methods it replaces.

The Italian school of urban morphology: origins and development

The Italian school of urban morphology, also known as the Muratorian school, arose from the teaching and theoretical work of Saverio Muratori (1910-1973), who aimed to reconnect architectural design with historical continuity. Muratori rejected the positivist and technocratic approaches to early twentieth-century urban planning, arguing that a systematic comprehension of historical urban processes was required for meaningful architectural practice.

Muratori's approach, referred to as "operative history," viewed cities as dynamic entities influenced by societal cultural factors. He proposed the fundamental analytical notions of type, fabric, and organism as instruments to analyze the evolution of urban form across time in his groundbreaking works, including *Studi per una operante storia urbana di Venezia* (1959) and Studi per una operante storia urbana di Roma (1963). To maintain continuity between the past and present, his work highlighted the necessity for architectural design to emerge from the logic of existing urban structures. His assistants, especially Gianfranco Caniggia, Paolo Maretto, Renato and Sergio Bollati, Sandro Giannini, and Guido Marinucci, developed Muratori's ideas after his death. Caniggia organized Muratori's principles into a thorough typological approach, highlighting the connection between specialized and fundamental structures as well as the gradual nature of urban transformation. His work with Gian Luigi Maffei produced important manuals that spread these theories around the world, including *Composizione architettonica e tipologia edilizia* (1979, 1984) (Caniggia, 1979; Caniggia & Maffei, 1984).

Later, the school's geographical dispersion led to the emergence of institutions in Reggio Calabria, Genoa, Florence, and Rome, where academics carried on refining typological concepts in both historical and contemporary contexts. Organizations like the 1981-founded Centro

Internazionale per lo Studio dei Processi Urbani e Territoriali (CISPUT) were essential in maintaining Muratorian ideas and promoting multidisciplinary discussion. By the 1990s, the movement's impact had spread beyond Italy, helping to launch the journal Urban Morphology and the International Seminar on Urban Form (ISUF) (Cataldi et al., 2002).

Today, the Italian school is still fundamental to the study of urban morphology, providing a historically based framework that connects architecture, planning, and cultural geography. Its enduring contribution is to consider urban form as an evolving cultural product in which the built environment is transformed via both material and historical processes.

Principal case study: the historic city of Kashan, Iran

The Middle East's historic cities, especially those in Iran, offer an appropriate setting for integrating strategies to read the historical layers of the formation of the cities. A complex fabric of spatial logics and construction traditions may be seen in urban fabrics like Kashan, which show several layers of development from pre-Islamic settlements to Islamic and contemporary times (Gaube et al., 2018). Successive periods of Kashan's urban expansion are reconstructed and related to its spatial logic, typological patterns, and morphological alterations (Carlotti, 2020).

Figure 1. The Kashan Map was edited in 1995 by Shar o Khaneh Consulting Engineers based on a 1966 map. Evidence shows the traction of the anti-wall and the bazaar in the zone northeast of the city (Hassani, 2022a).

Though most evaluations are descriptive and rely on static mapping, prior research has recorded the city's compact layout, its complicated residential sections, and the prominent location of its bazaar. Because of its intricately interconnected urban fabric and the abundance of reliable historical records, Kashan was selected. There is an obvious need for techniques that preserve the theoretical complexity of typological analysis while encoding morphological principles into programmable frameworks (Hassani, 2023a).

In order to address that requirement, this study presents a scripting framework based on LISP that automates the identification and classification of important urban components, including building types, route alignments, and plot structures, across different historical periods. The study bridges the gap between qualitative and quantitative analysis by operationalizing the Italian school's principles in a computational setting. Thus, it supports the preservation of cultural heritage, the teaching of urban design, and the creation of resilient urban regeneration plans, demonstrating how classical morphological theory may influence computational tools of the twenty-first century.

Testing a diachronic and computationally assisted morphological technique is made possible by the city's progression from pre-Islamic settlements through medieval Islamic development and current transformations. Its mix of a central bazaar spine, complicated residential sections, and compact urban shape offers a typical scenario for analyzing how well the suggested framework may record intricate urban transitions (Hassani, 2024).

Research gap and objectives

Even if both modern computer analysis and traditional urban morphology have advanced dramatically in recent decades, there is still a clear disconnect between the quantitative rigor of algorithmic approaches and the qualitative typological ideas of the Italian school. Researchers have independently investigated computational techniques for modeling complex urban networks (Karimi, 2002 & 2012) and shown the significance of typological analysis for comprehending the diachronic development of urban form (Muratori, 1980; Caniggia & Maffei, 2001). However, only a small number of studies have been able to combine these strategies to create a strategy that is computationally replicable and theoretically viable. By implementing a LISP-based scripting system that incorporates the Italian typological tradition's interpretative guidelines into an automated analytical environment, this study fills that gap (Hassani, 2023a). Three primary goals are pursued by the research through a diachronic analysis of Kashan, a historic Iranian city with a densely layered urban fabric (Hassani, 2022b).

i. Demonstrating typological concepts in a computational framework without losing theoretical depth.
ii. Reconstructing historical phases of Kashan's urban growth using a repeatable and rule-based methodology.
iii. Providing a tool for urban design education and heritage management that improves the analytical power of morphological studies.

By defining this research gap and expressing these aims, the study lays the conceptual groundwork for the methodology outlined in the next section.

Methodological framework

This research uses a methodological framework that combines the interpretative principles of the Italian school of urban morphology with the computational capabilities of LISP scripting (Hassani, 2023b). The study's conceptual framework is based on the Italian school's emphasis on diachronic analysis and typological change. The study's goal is to demonstrate how classical morphological theory may be made reproducible and scalable for substantial historical datasets by converting these qualitative principles into programmable rules. The design employs a single, comprehensive case study technique, concentrating on the Iranian city of Kashan. This method enables a thorough, context-sensitive study while simultaneously evaluating the suggested computational framework's transferability to various urban environments.

Data sources and preparation

To rebuild Kashan's historical evolution, a wide range of resources was gathered. Among these were historical maps covering the city's development throughout several time periods, from pre-Islamic times to the Safavid and Qajar dynasties; current field surveys that recorded existing street networks, building footprints, and typological features; and historical materials like cadastral records and old photographs.

Encoding morphological principles

Formalizing the main typological concepts of the Italian school into computational rules was the next step. Algorithmic conditions were used to convey concepts like the recognition of permanent urban features, the idea of successive building types, and the differentiation between basic and specialist structures. For example, criteria were created to categorize route alignments based on their persistence or change over time, and to identify plot structures based on parcel boundaries.

Development of the LISP scripting framework

To automate these principles, an original programming environment based on LISP was created.

Because of its adaptability in working with geographical data and its established connection to design and architecture software environments, LISP was chosen. The scripts could import georeferenced datasets; perform morphological classification; and create layered representations of urban components for each historical epoch. Each script was modular, allowing for incremental development as new insights were acquired during the research.

Automated classification and validation

To maintain the interpretive richness of traditional morphology, these outputs were cross-checked against historical narratives and field observations. Where discrepancies emerged, the rules were adjusted and the scripts rerun, ensuring an iterative process that combined computational precision with qualitative understanding. After the criteria were encoded, the scripts automatically discovered and classified urban components on the digitized historical maps. The outputs included a timeline of plot structure modifications; transformations in route alignments; and persistence and variety in building types.

A LISP-based computational framework for morphological and typological analysis

The LISP-based framework enables the encoding of morphological transformation rules and the simulation of diachronic urban change. While this study focuses on diachronic urban analysis through computational modeling in LISP, it has methodological affinities to the fields of engineering and simulation. For example, similar computational reasoning can be observed in structural engineering research, where numerical models are developed to simulate the dynamic behavior of complex systems under external loads (Bakhshandeh & Mahboubi Niazmandi, 2023). Although applied at a different scale, both approaches share a common logic of translating physical or spatial phenomena into parametric and rule-based computational frameworks.

Following the Italian school of urban morphology, the study views the city as a palimpsest of structural logics visible in the built form. To operationalize this theory in a modern, repeatable manner, the study combines manual morphological reading with computer automation, producing a unique LISP scripting framework for urban form analysis. Three phases comprise the method's development.

Phase 1: data acquisition and field investigation

In the first phase, a wide range of qualitative and quantitative data was gathered. Documentary surveys and literature reviews were combined with fieldwork and GIS-based mapping to create an accurate database for morphological reading. Historical maps, cadastral documents, and aerial pictures from 1955 to 2000 were studied with modern cartography to track the progression of urban development. Approximately forty schools in Kashan were investigated during field research in 2018 and 2019, undergoing in-depth analysis at both urban and architectural levels. Interviews with school principals, neighborhood residents, and municipal officials shed light on the social component of urban development and schools' potential role as community anchors in urban regeneration strategies (Hassani, 2020).

Phase 2: diachronic morphological reading and computational analysis

In the second step, data analysis, the study used a diachronic reading approach based on the morphological tradition of the Italian school. The investigation began by meticulously eliminating modern layers to rebuild the city's previous morphological forms, revealing how spatial elements like streets, plots, and building types changed and interacted throughout time.

The study used accurate superimposition of digital and historical maps to trace Kashan's morphological history during significant historical eras, from pre-Islamic to Islamic, Buyid, Safavid, Qajar, and Pahlavi. A key innovation of the study was its use of the LISP programming language in the AutoCAD environment to apply a computational method to morphological analyses. This was the first time that LISP was used in urban morphological research, automating procedures that had previously involved a great deal of manual interpretation.

Two primary analytical stages of the computational approach were created to improve accuracy and speed up the reading of morphological layers.

Stage 1 - the first LISP phase: alignment detection (macro scale)

Step 1: Make the decimal layers (0 to 10, 10 to 20, etc.)

```
(setq i -1)
(setq li nil)
(repeat 18
(setq i (1+ i))
(setq an1 (* i 10))
(setq an2 (* (1+ i) 10))
(setq t1 (itoa an1))
(cond ((< an1 10) (setq t1 (strcat "0" t1))))
(cond ((< an1 100) (setq t1 (strcat "0" t1))))
(setq t2 (itoa an2))
(cond ((< an2 10) (setq t2 (strcat "0" t2))))
(cond ((< an2 100) (setq t2 (strcat "0" t2))))
(setq la (strcat "Angle -- " t1 " - " t2))
(make-layer la an2)
(setq li (append li (list (list an1 an2)))))
```

This stage centered on determining the residual alignments and directional logic of the city's structural framework, namely street orientations and urban expansion axes. The LISP script was created to analyze each line of the digitized urban fabric and automatically categorize it based on its angular orientation, which is separated into 10-degree intervals spanning from 0° to 180°. Each range was allocated its own color code, resulting in a chromatic map that graphically reflected the orientation patterns of Kashan's street network over history. This procedure made it possible to find morphological alignments that had persisted through several changes—traces of previous structural logics embedded in more recent urban layers. The study might determine the creation of new urban centers, the reconfiguration of spatial hierarchies, and the continuity or division of historical routes by employing this color-coded rotational approach. In addition to speeding up the reading process, this automated detection added an objective visual layer to the morphological process, which was previously merely interpretive.

Step 2: the layers of the lines should be changed to correspond to the target layers

```
(setq ss (ssget '((0 . "line"))))
(setq n (sslength ss))
(setq k -1)
(repeat n
(setq k (1+ k))
(setq s (ssname ss k))
(setq en (entget s))
(setq po1 (cdr (assoc 10 en)))
(setq po2 (cdr (assoc 11 en)))
(setq ang (angle po1 po2))
(cond ((> ang pi) (setq ang (- ang pi))))
(cond ((equal ang pi 0.001) (setq ang 0.0)))
(setq ang (* ang (/ 180.0 pi)))
(foreach a li
```

```
(setq an1 (car a))
(setq an2 (cadr a))
(cond
((<= an1 ang an2)
(setq t1 (itoa an1))
(cond ((< an1 10) (setq t1 (strcat "0" t1))))
(cond ((< an1 100) (setq t1 (strcat "0" t1))))
(setq t2 (itoa an2))
(cond ((< an2 10) (setq t2 (strcat "0" t2))))
(cond ((< an2 100) (setq t2 (strcat "0" t2))))
(setq la (strcat "Angle -- " t1 " - " t2)))))
(setq en (subst (cons 8 la) (assoc 8 en) en))
(entmod en))
```

Figure 2. Reading the alignments of the morphological layers of Kashan’s urban fabric, set at every 10 degrees from 0 to 180, using the LISP program (Hassani, 2022a)

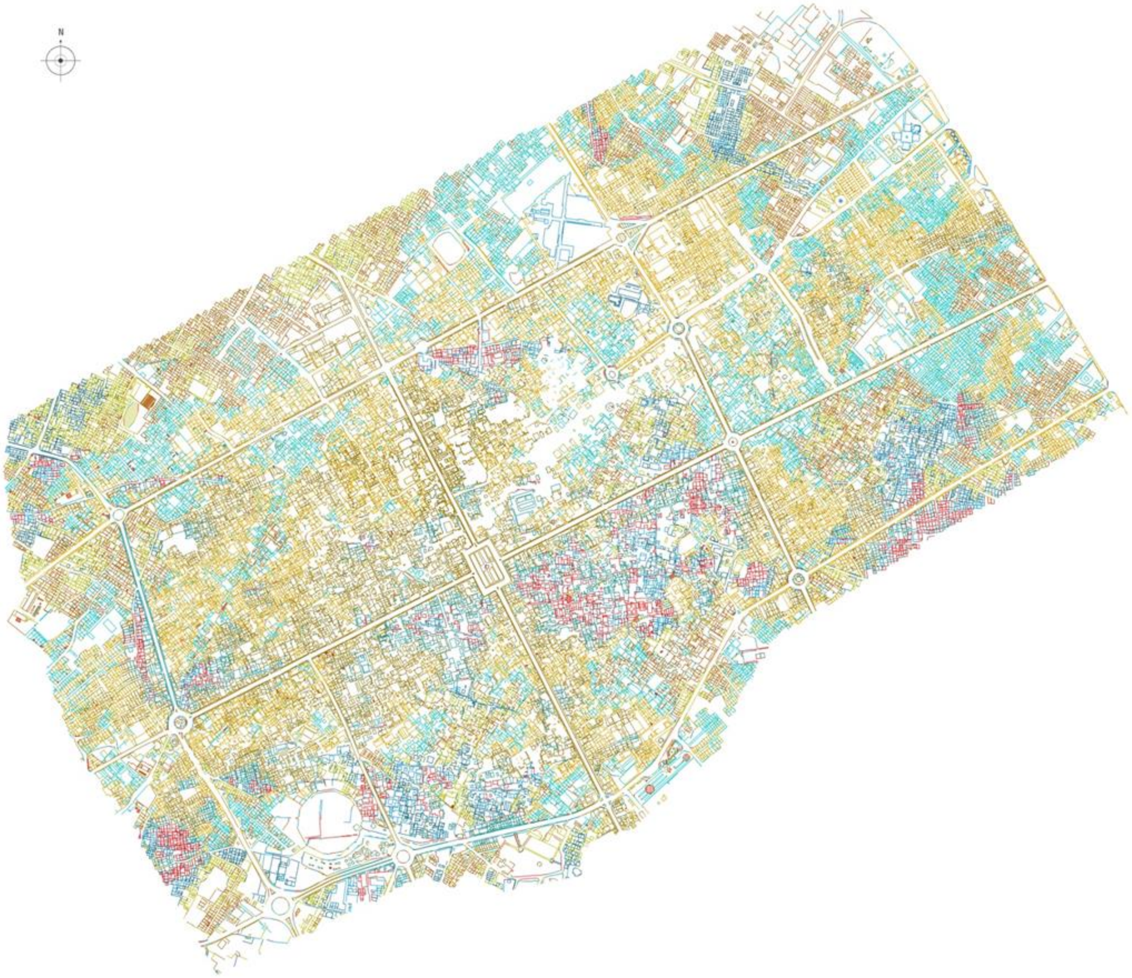

Figure 3. Reading the alignments of the morphological layers of Kashan's urban fabric using the LISP program produces this final result (Hassani, 2022a)

Stage 2 - the second LISP phase: plot regularity and pattern recognition (micro scale)

The micro-scale—the geometry and arrangement of urban plots—was the focus of the second phase of the computational methodology. In order to evaluate geometric proportions, the LISP method was created to examine each plot as a polyline form and compute characteristics like area, perimeter, and bounding rectangles. The script determined a "rotation ratio," which is the connection between the size of the bounding rectangle and the actual area of the plot, by rotating each plot through a series of angles (usually 100 rotations over 360 degrees). This ratio functioned as a quantifiable indicator of morphological regularity; the more irregular and bigger the plot, the greater the ratio.

A gradient color scheme, which ranges from pastel colors (high regularity) to dark tones (high irregularity), was added to each plot to illustrate this study (Figure 4). This resulted in an interpretive map that presented both visual and quantitative data at the same time, showing how the regularity and size of the building types changed over time. The algorithmic procedure successfully converted the qualitative concept of "urban irregularity and size" into quantifiable information, offering an original computational perspective for assessing the historical fabric of the city's spatial coherence.

Here is a summary of the formulas of the written program:

```
(setq ss (ssget '((0 . "*polyline"))))
(setq n (sslength ss))
(setq k -1)
(repeat n
(setq k (1+ k))
(setq s (ssname ss k))
(setq en (entget s))
(setq la (cdr (assoc 8 en)))
(setq pli (plinevertex s))
(setq bbox (acet-ent-geomextents s))
(setq p1 (car bbox))
(setq p2 (cadr bbox))
(setq cen (mid p1 p2))
(command "area" "object" s)
(setq le (getvar "perimeter"))
(setq ar (getvar "area"))
(setq li1 nil)
(setq totang 360.0)
(setq i -1)
(repeat 100
(setq i (1+ i))
(command "rotate" s "" cen (/ totang 100))
(setq bbox (acet-ent-geomextents s))
(setq p1 (car bbox))
(setq p2 (cadr bbox))
(setq dx (- (car p2) (car p1)))
(setq dy (- (cadr p2) (cadr p1)))
(setq zarib (/ (* dx dy) ar))
(setq li (append li (list zarib))))
(setq li (vl-sort li (function (lambda (e1 e2) (< e1 e2)))))
(setq zarib (car li))
(command "hatch" "solid" s "")
(command "chprop" "last" "" "color" "truecolor" color ""))
```

Together, these visuals form a morphological narrative. The alignment maps reveal how the street logic evolves, while the plot regularity and size maps reveal micro-scale coherence or disruption. The interpretive strength lies in combining both scales, associating macro-structural alignments with micro typological stability or transformation.

Phase 3: synthesis and urban regeneration guidelines

The findings from the typological and morphological studies were combined in the third phase of the study to create design and planning guidelines for the revitalization of Kashan's historic neighborhoods. This synthesis shows how computational scripting can improve the Italian School's morphological methods' interpretative rigor and make them more applicable to current urban issues, including social sustainability, historical preservation, and resilient city-making.

Results of the analyses

Reconstruction of historical phases

Applying LISP scripts to the geo-referenced historical maps revealed five main stages of Kashan's expansion from its earliest pre-Islamic settlement to the present. Distinct developments in street networks, plot configurations, and building types were characteristics of each era.

- Early settlement: A compact settlement pattern centered on defensive buildings and natural water sources was visible in the earliest identifiable phase.
- Medieval Islamic expansion: As long-distance trade and religious institutions grew, a more complicated street hierarchy and a bazaar spine developed.
- Safavid consolidation: Building typologies varied, with imposing religious complexes supporting the central bazaar axis.

- Qajar adaptations: While preserving the core city's typological logic, residential areas grew outward.
- Modern interventions: New street alignments created by 20-century infrastructure partially destroyed the ancient fabric while preserving important typological features.

Plot structure dynamics

Plot configuration changes were identified by the scripting framework during these stages, showing a slow transition from large, regular parcels to a more complex subdivision pattern. The constancy of the basic spatial logics outlined in the Italian typological tradition was demonstrated by the persistence of some major plot borders despite these transformations.

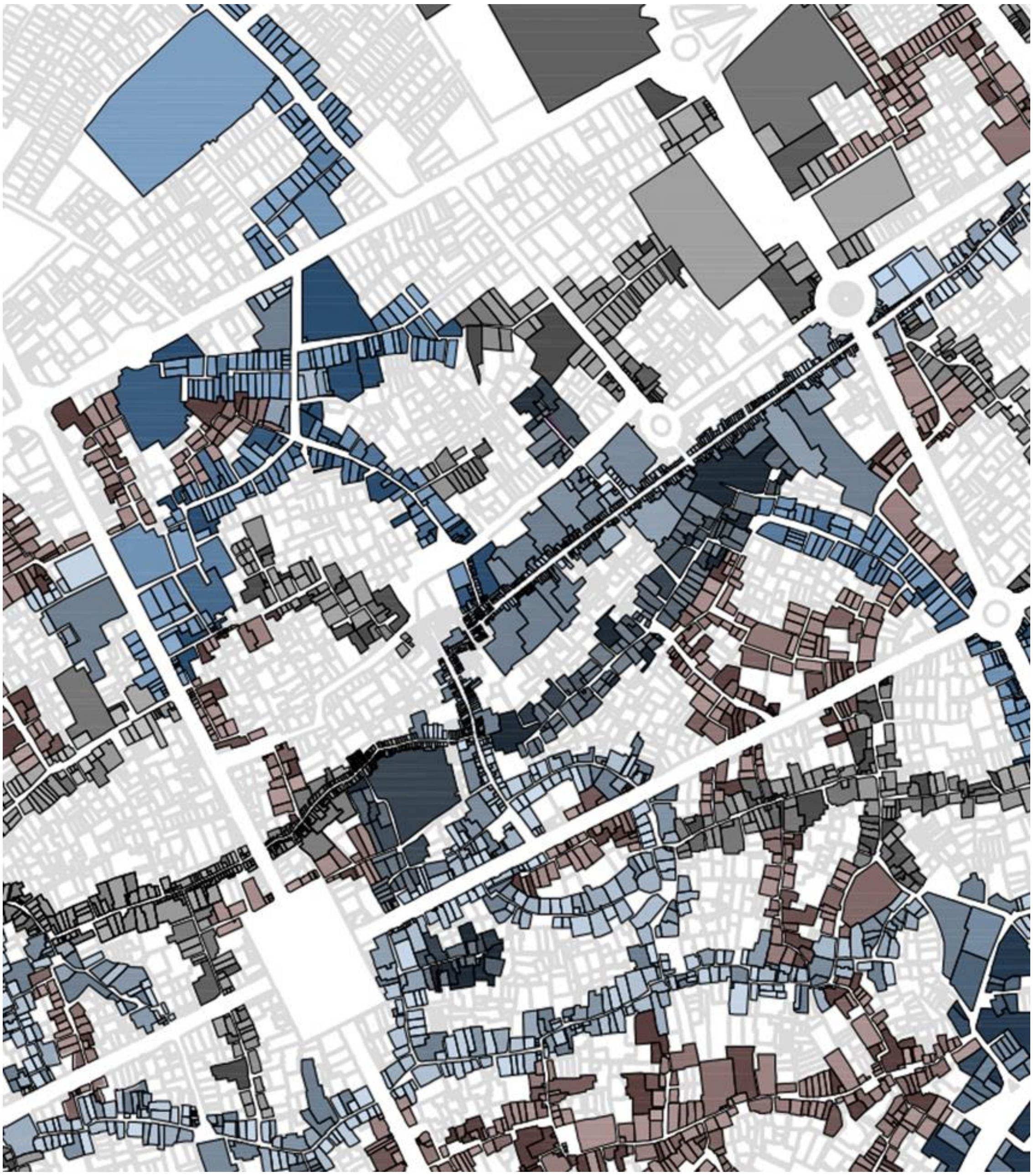

Figure 4. Analyzing plots in the urban fabric in terms of regularity and size, using the LISP program (Hassani, 2022a)

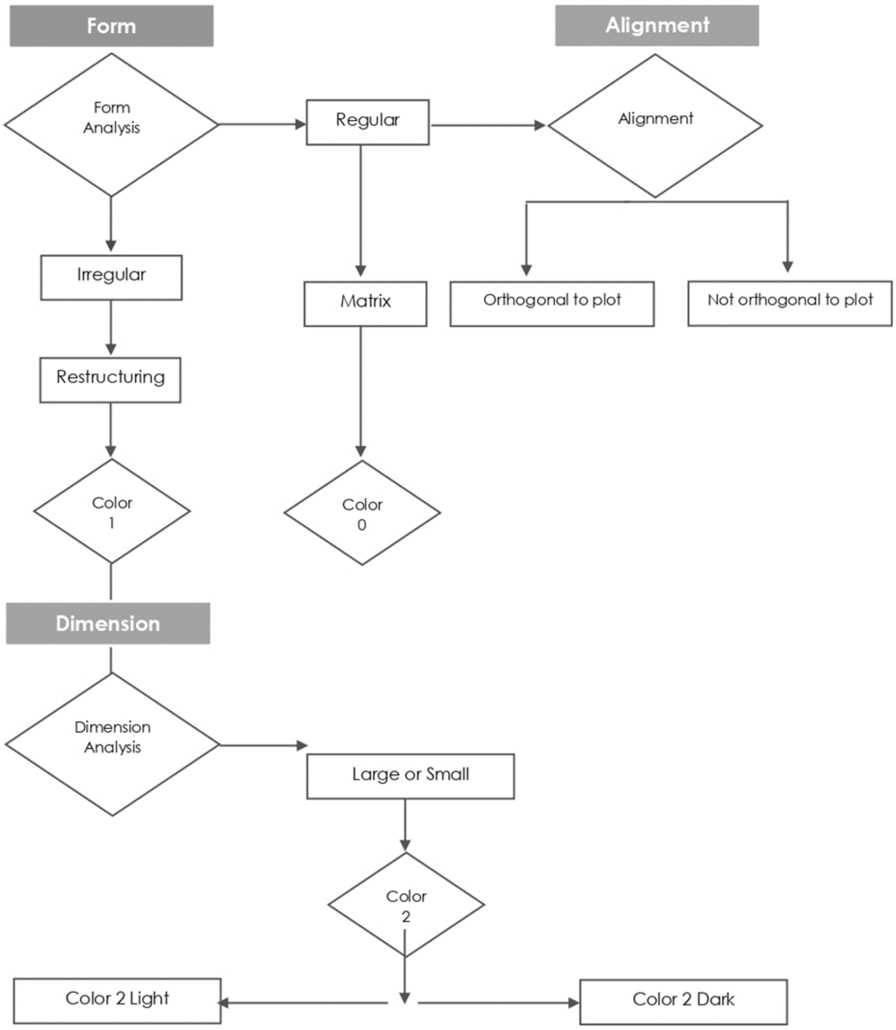

Figure 5. The algorithm of plot pattern analysis was utilized by the LISP Program in the second phase (Hassani, 2022a)

Route alignment and network persistence

Several important axes, especially those connected to the bazaar and important mosques, stayed constant across centuries, according to an analysis of route alignments. This continuity is consistent with theoretical ideas of permanent features in urban morphology and supports previous interpretations of Kashan's urban resilience.

Building typology evolution

Both persistence and transformation in building types were identified using the LISP-based categorization. While specialized buildings like caravanserais and religious complexes developed to adapt to varying socioeconomic situations, basic residential shapes demonstrated long-term stability. These results support the significance of the basic-specialized type difference made by the Italian school in describing the morphological development of Kashan.

Validation of the computational approach

The automated results were cross-checked against field surveys and historical documents to ensure the computational method's correctness and repeatability. The continual process of modifying the scripts guaranteed that the final findings were theoretically coherent and empirically sound.

Discussion of the findings

Integrating typological theory and computational practice

The findings show that the interpretative guidelines of the Italian school of urban morphology may be effectively encoded using a scripting framework based on LISP. The technique adds a degree of repeatability to typological research that has been mostly lacking from traditional morphological investigations by automating the detection of consistent route alignments, plot borders, and building types. This reinforces requests in the area for approaches that connect quantitative modeling with qualitative theory.

Implications for heritage conservation

The example of Kashan shows how the management of ancient urban environments might benefit from the use of computational technologies. The approach offers a foundation for identifying regions of high morphological significance that require particular conservation consideration by exposing whatever aspects of the city's structure have survived for generations. These findings may influence measures meant to preserve the city's cultural identity and shape municipal planning regulations.

Contributions to urban design education

As a pedagogical result of this new strategy, the technique has been implemented in Sapienza University's architecture for urban regeneration and urban design studios, as well as during the author’s visiting appointments at universities in Sweden (Lund, Malmö) and Uzbekistan (Tashkent University of Architecture and Civil Engineering) (Hassani et al., 2024).

Contributing to AI-supported urban regeneration

This scripting framework was an important, early example of incorporating artificial intelligence into morphological analysis. As computational models advance, merging typological theory and machine learning will enable real-time evaluations of urban change and support strategies for resilient urban regeneration. This is consistent to make urban morphology actionable in city-making, as espoused by pioneers like Giancarlo De Carlo and Jaime Lerner.

Limitations and future work

Although the case study illustrates the approach's feasibility, more investigation is required to evaluate the framework in other geographical and cultural contexts. To improve the model's predictive capability, future research may include other data sources, such as socioeconomic indicators or climate-related constraints.

Conclusion

The concepts of the Italian school of urban morphology may be operationalized within a computational scripting framework, as this study has shown. The research demonstrates that traditional morphological theory may be made both replicable and scalable by encoding typological concepts—such as the transformation of specialized forms and the persistence of fundamental building types—into a LISP-based environment.

The particular case of Kashan, with its intricately layered urban history, demonstrated that the technique can recreate consecutive stages of expansion and show the structural logic of route alignments, plot boundaries, and architectural typologies. As a result, it gives essential knowledge for historic preservation, allowing planners and policymakers to identify morphologically significant aspects.

The approach offers educational value in addition to cultural significance. Students may interact with computational methods and the interpretative depth of typological theory at the same time. The analytical component of urban design education is enhanced by this dual focus, which also equips aspiring professionals to operate at the nexus of theory and practice.

More importantly, the scripting framework provides a foundation for morphological analysis's use of AI. Long-standing goals in the field to make urban morphology actionable in the practice of city-making may be realized as computational models develop and typological theory and machine learning are combined to support resilient urban regeneration strategies and allow real-time assessments of urban change. Note that while Bill Hillier’s Space Syntax also uses computational analysis, its focus is diagnostic, considering aspects of urban regeneration such as walkability and the relative complexity of underlying urban patterns (Froy, 2025).

The evolution of AI and parallel developments in computational data analytics have brought us to the point when the application of AI to resilient urban regeneration as a practice is feasible.

Four aspects of urban regeneration are particularly ripe for application:

i. Understanding context: AI can serve as a 'community memory' for a city's evolution, making histories and visual documentation accessible to all participants in layperson's terms and exportable to planning processes for analyzing changes in form, pattern, density, and resilience.
ii. Incorporating urban data: AI with computational analytics can rapidly integrate and analyze GIS data, making implications widely available while testing how reliably AI can interpret findings for broader community access.
iii. Supporting intervention: AI can visualize urban interventions, generate and evaluate options against different criteria, and support area plans through consensus-building on rezoning and design guidelines. As a 'co-intelligence,' AI transforms planning into an ongoing, interactive dialogue (Mollick, 2024).
iv. Supporting local engagement: AI can track and summarize community group discourse about their districts and potential interventions, serving as a collective memory for typically voluntary and ephemeral groups.

As this suggests, we are on the cusp of realizing the ambitions of pioneers like De Carlo and Lerner to transform how we make our cities, realizing urban morphology’s intent to address the social as well as the physical factors that shape cities’ growth over time. The Kashan study’s use of LISP to speed its analyses was an important, early step in that direction, showing one aspect of AI’s revolutionary capabilities (Hassani et al., 2025).

Disclosure statement

The author reports there are no competing interests to declare.

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