

City Interactions in Urban Planning: The Square Example from an Ontological Analysis Point of View

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Abstract. The evolution of cities and technologies for the city has generated the need and possibility of integrating data coming both from socio-technical and environmental systems, and individual and collective participation in the making of places - of the city in particular. The growth of the possibilities for managing and integrating knowledge has also led to managing, integrating and constantly monitoring the evolution of data and their respective impacts on the territory as in the vision push forward by Urban Digital Twins (UDT). In this paper, we delve into the possibility of managing knowledge and supporting decision making through ontological approaches, and consider the issue of which aspects an ontology should cover for effective disambiguation and interpretation sharing in urban scenarios where different agents and systems must interact. More specifically, we explore the square as a urban type with the goal of reassessing earlier formalization steps in view of the construction of a UDT. The study is a further step along an original research carried out by our group at the crossroads between formalization of complex knowledge and planning of urban complexity.

Keywords: City · Digital Twin · Ontological Analysis · Urban planning

1 Introduction

Planning the city and the territory turns out to be an increasingly complex and subtle activity. The amount of information we can collect, the variety of sources, and the different research methodologies have highly enriched the possibility of knowledge acquisition. Furthermore, today there is increased awareness of the limits of the rational-comprehensive planning approach which is now seen as rigid and divisive. It too often leads to choices that are blind of the existing connections in the present and future urban system. This awareness has pushed attention on how to intervene on territories and cities in a more appropriate, intuitive and empathic way, maintaining at the same

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time a technically sound and pragmatically oriented use of the resources. In research, the need for an approach broader than the pure handling of surfaces, destinations and values, has also gained ground. From these changes, other perspectives also emerged like the necessity of reading, interpreting, extending, and integrating the dynamism and plurality of needs and viewpoints (not only human), or the need for sustainability and for a more equal resource sharing. Awareness has made the planners' lens multifaceted and rich in visions, offering them the possibility of working with a new humility in the complex and haunted world of 'vast' choices - that is, those affecting large territories or portions of space, affecting large quantities and qualities of relationships, which have an impact on the present and the future. Recently, this awareness has allowed for broadening the scope of knowledge and data in width and in-depth making possible the reading and analysis of sedimented layers.

The new tools developed over the last twenty years, supported by scientific and technological advancement, have given rise to a season of fertile research from the Multi-Agent System to Space Syntax, CAD, and GIS, from E-Governance tools to those crowd-sourced (a.k.a. volunteered) based on individual contributions, etc. alongside more traditional 'walks', meetings in parishes, and street movements.

Among the new tools, artificial intelligence, which has exploded in its disruptive speed and all-pervasive potential, has given rise to tools that have integrated modelling approaches with data coming from sensors distributed over certain portions of the territory, leading to the conception of the Digital Twin for the city [1].

Although it remains difficult to give a definitive definition of city [2, 3], cities can be understood as the result of a specific political, economic and social organisation. Nonetheless, the semantics of the social roles of an urban artefact remains difficult to understand and challenging to represent [4].

As a conceptual artefact which provides a common disambiguated vocabulary for the experts and the practitioners, an ontology is particularly suitable for disambiguation and knowledge sharing between different agents (including humans, non-human animals, and artificial agents) and useful to overcome the subtleties of natural and technical languages and their specificities [5]. In this research line, we have based our analysis on the foundational ontology DOLCE (Descriptive Ontology for Linguistic and Cognitive Engineering), developed at the Laboratory of Applied Ontology in Trento, within the broader European project WonderWeb [6–11].

In this paper, we propose a twofold analysis that moves in the direction explored and suggested by Stufano Melone et al. [5] towards an ontology-based Urban Digital Twin. The indeed goal is the exploitation of a fourth component of smart cities (along which the material, the agentive and the knowledge components), which we call the relation component (see Sect. 2), linked to the identification of roles in the use of urban places [2, 4]. In this case, we analyse a urban square (see Sect. 3). In it, we look at the urban square as an urban type and a role-dependent element as discussed in the work of Calafiore et al. [4]. In doing this, we begin an ontological modelling of collective uses of an urban place. Concluding reflections and follow-up perspectives are drawn out in Sect. 4.

2 The Fourth Component in the Ontological Analysis of the City

Ontological analysis helps to model the social content of the built environment besides its planned characterization [12, 13]. It offers support to decision-making and to defining the patterns of use and living of an urban place, as an example the urban square: local knowledge expressed by emerging social patterns is crucial [4].

Previously we conducted ontological analyses, in order to elicit the structuring components of the city within this perspective [2]. A city is a complex and rich system, composed of heterogeneous parts that interact in different ways and for different reasons. We therefore identified and discussed three core components of the city. The three elicited components are: (i) city-place; (ii) city agent; and (iii) city-knowledge.

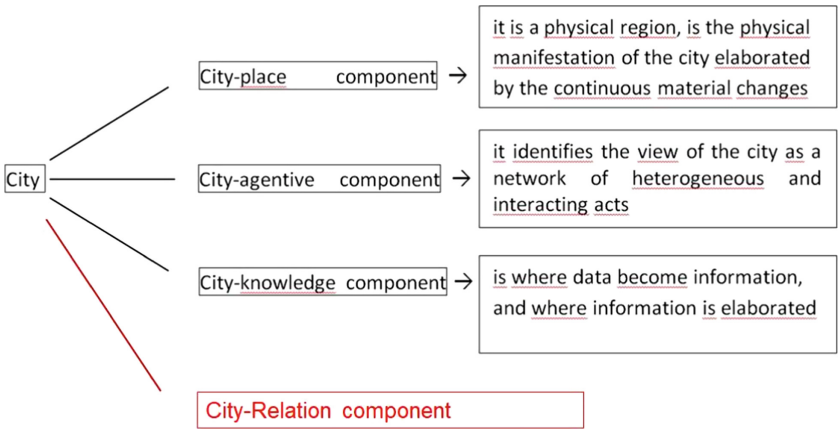

Fig. 1. City-components schema with a fourth layer component [3]

Certainly a city is not the mere juxtaposition of these disjoint components, due to its intrinsic systemic complexity. Rather, the city as a whole emerges from these interacting and intertwined components. The general vision is a city resulting from interactions between ontologically distinct components, where the nature of the interactions is as necessary as the qualification of the components themselves. In this framework, the level of development of the components of a city and the quality of mutual interactions can identify the type of that city. The main characteristic of these components is that they exist in the city as a whole, thus characterizing the ontological and conceptual structure of the city itself [2].

Interactions determine the relationships within and across the components in the complex system that the city is [14]. Therefore, the next step in the analysis is to make this interaction network of the city explicit. We suggest identifying it as the fourth component of city as a place (Fig. 1). The relationship component structurally shows up in both the natural and artificial spaces. In a Leibnizian sense, the relationship in the city is itself substance [15].

3 The Example of Square: The Market Square in Naples

The square is a representative element of the Western city, in its being an urban architectural type, and in its being a focal point of the life practices and habits of the inhabitants as well as a geometric space central to the historical layout of the towns themselves [16]. In villages with up to a few thousand inhabitants, the reference square is usually just one. It is identified by use, is central and barycentric in practices and space - despite the possible presence of a number of 'square-like' spaces in the residential/architectural fabric [17]. In fact, we often see oldest urban architectural fabrics with a constellation of small squares that innervate the distribution of urban 'voids'.

In larger cities the system of squares intrinsic to the urban fabric is multiplied and complexified. We will not go into detail here in the description of the various possible declinations, nor in the list of possible configurations and examples [e.g., 18]. We just want to highlight the constant and significant presence of the square element and many squares in the same urban fabric. Each of such squares in a larger city takes on its dimensions of use, semantic and role interpretations which depend on their location in the fabric itself and on the community that inhabits that part of the city [19].

In earlier studies we looked at the square to address the difficult integration and at the same time the importance of integrating literary sources for knowledge of the places on which planners and administrators are called to decide and act [5, 20, 21]. We also explored the square as an urban architectural type, concerning the elements of the city [22].



Fig. 2. An image of the Market Square in Naples [4]

Calafiore et al. (2017) aimed to formalize the dimension of the use of space, managing the reflection according to the identification of the concept of role to 'tell' and 'diversify' the uses of a space. That analysis aimed to be inclusive, consistent and coherent in managing the knowledge deriving from the different uses and roles that the square in question assumes and encounters cyclically, for example over a week, or is determined by management decisions - such as parking regulations in the square. In particular, the mentioned work analysed the Market Square of Naples (Fig. 2), a case of coexistence of formal and informal social practices manifested by different 'groups' during a certain time frame. The ontological analysis carried out in Calafiore et al. [4], which includes a formal proposal, shows the square as a point of convergence and tension between the "designed" city and the "lived" one, which has always had a primary interest in urban planning. Those formal clarifications form a basis for the construction of an ontology of the urban square as an element in an Urban Digital Twin [1]. Local knowledge of urban places is central and is often shared in specific communities but is generally the most difficult knowledge to be collected [23].

Figure 3 reports an ongoing formalized representation of the used language and conceptual framework, based on DOLCE ontology model [24].

$$UrbAct(x) \rightarrow PD(x) \wedge \exists y(PC(y,x) \wedge UrbArt(y)); \quad (1)$$

$$Rec(spr,y,t) \rightarrow SPr(spr) \wedge SoC(y) \wedge Time(t); \quad (2)$$

$$SoC(y) \rightarrow ASO(y); \quad (3)$$

$$SPr(spr) \rightarrow \exists x,t,y\,(CF(x,spr,t) \wedge Act(x) \wedge SoC(y) \wedge Rec(sty,y,t)); \quad (4)$$

$$Act(x) \wedge Spr(y) \wedge CF(x,y,t) \wedge PC(z,x) \wedge DF(y,w) \wedge SoP(w) \rightarrow CF(z,w,t) \quad (5)$$

Fig. 3. An excerpt of logic formalizations identifying urban actions and social practises (from [4])

It lists an initial formalization of the conceptual framework of the square and its roles, formal and informal, intended and unintended. We put down it here as a canvas to be integrated in a wider research path about the managing of knowledge for planning activities.

4 Conclusions and Follow-Up

In conclusion, the city can be seen as a complex reality of multiple dimensions: open, dynamic and varied. The city system is characterized by emerging properties [25] that integrate into the city entity giving rise to streams of differentiated and multiple behaviors offered by the peculiarity of the agents who live there, by the consolidated customs, by the knowledge expressed, by the relationships activated and interactions acted out.

Ontological analysis allows us to clarify and manage part of the complexity of references, constraints, and functional objectives and identify relationships and interactions [26]. The present study has presented possible paths of representation of the complex knowledge of a city system. This modeling attempt arises from the recent line of research

developed around the so-called Urban Digital Twins. With the aim of identifying ways of representing knowledge within a digital urban model, we tried to explore partial modeling, in particular through the example of the urban square. The modeling perspective of the urban square cited here is rather original and based on our previous ontologically based research paths, concerning the organization of the components of a city [2, 27]. This study was therefore developed with a deliberately exploratory orientation.

In this contribution, we concentrated on two points, namely:

i) the identification of a fourth component to integrate the ontological model of the city and
ii) the need to construct an ontological model of the square following the formalization conducted by Calafiore et al. [4]. This has been carried out from the point of view of our previous reflections about the square as a crucial node from the architectural and social practices, and put under the vision of a Urban Digital Twin for the city.

In doing this, we try to lay the foundations for an ontologically based modelling of the square and, subsequently, of the city in an extensive and generalized form. The final goal is to manage and represent knowledge for decision support in planning.

From a general point of view it can be said that the research presents positive and promising perspectives. In fact, within the components of a city, the square appears as a representative element with intrinsic complexity, able to justify the approach used. The resulting suggestions were quite interesting despite the limited scope, just by virtue of these generalizable complexity perspectives. Of course, the limits of this study arise from the same partialisation, with respect to a context with such multiple and multidimensional complexities – i.e., the city itself. Modeling any element of the city, even a complex one, is not comparable to modeling a city as such, and the limits are clearly numerous – physical, spatial, temporal, perceptual, cognitive, emotional and so on. Towards a perspective of formalization of knowledge data, for the purposes of digital representation and management, these limits are evidently stringent and of unavoidable importance.

Just from the perspective of formalizing the collected databases, however, the ontological approach can provide integrability and interoperability features useful for achieving the objectives of interest [28]. Therefore, the next work within this line of research will be developed just in the ontological formalization perspective, starting by dealing with such challenges.

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