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The operationalization of "A Pattern Language" by using network analysis tools

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Abstract

One of the most significant public space studies, "A Pattern Language", published in 1977, is until today's background for some contemporary investigations. The aim of this paper is to propose an operationalization of the patterns' network of the book into a network analysis tool. The methodology is based on a new classification of patterns, in addition to what is initially presented in the book: "context patterns" (evidencing pre-existing conditions and potentialities) and "design patterns" (considering possibilities limited by the stakeholder at that location). The digital operationalization can enhance the analytical and predictive character of the work.

Keywords: Pattern language; Network analysis tool; Christopher Alexander; Public spaces

INTRODUCTION

Despite the possible obsolescence, "A Pattern Language" is still an investigation topic because it was one of the most significant public space studies of its time (Gehl and Svarre, 2013). Currently, it is incorporated and adapted to new contemporary approaches. According to Park and Newman (2017), the relevant merit of the text is the connectivity between patterns, in which users can easily expand their design potential from these connections. This paper aims not to discuss how to update the concepts presented in the book, but to propose new alternatives for classification and manipulation. Therefore, the aim is to operationalize "A Pattern Language" through the network analysis methodology with a new classification, so that users can consider the local pre-existing, quickly adapt the patterns to their projects and find which patterns are most important in the formed network for the project.

The book "A Pattern Language" appeared in the middle of criticism about modernist architecture and urban planning, questioned in the 1960s and 1970s also by authors such as Jacobs (1691) and Whyte (1980). Pursuing to interpret users' desires and promote a dialogue between professionals and laypeople in participatory processes, the work sought to identify timeless characteristics of the space conformation, construction, and rescue the local scale between people. A Pattern Language is an attempt to reveal and demystify socio-spatial considerations through organized design patterns for easy consultation and, above all, to show the interconnection of these patterns in a system. According to Dawes and Ostwald (2017) in the book "The Timeless Way of Building", Christopher Alexander (1979) details what he calls "the city's unnamed quality". According to him, a "pure" and genuine quality marked by beauty and inherent occupation in traditional cities, which provide a cohesive design language that is an idea that grounds the pattern.

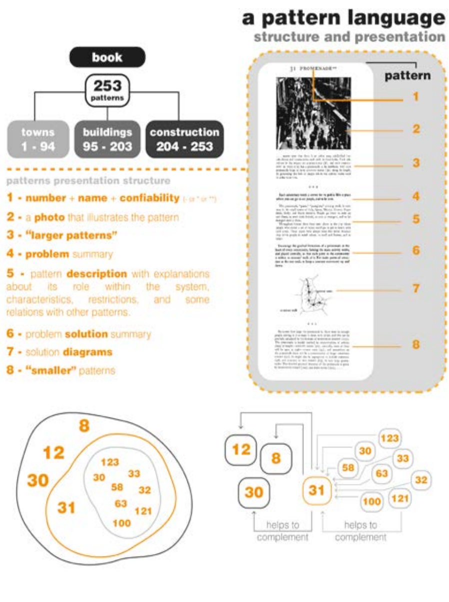

Figure 1: Structure and presentation, example with pattern 31

Due to the characteristics found in the book structuring, "A Pattern Language" can also be placed as ontology.

Ontologies study general properties of certain knowledge, organizing it in sets of classes, properties, and restrictions in order to show semantic solutions and improve interoperability between systems. Classes can be organized hierarchically by building taxonomies, properties are relations + internal attributes and restrictions have different qualities (Vaz, 2011).

The book presents a set of 253 patterns organized into three classes (Figure 01), towns (patterns 1 to 94), building (95 to 204), and construction (205 to 253). Patterns presentation follows a uniform order and organization. First, the pattern number, name, and asterisks are presented, indicating its reliability, that is, how the problem solution describes the deep and inevitable properties of a well-shaped environment. In sequence, in some patterns, a photo appears to illustrate how it works in a real situation.

The text is divided into parts; initially, the interconnected patterns that form the grounds for it to happen are presented, that is, the "larger patterns", with a broader scope. In sequence, there is a paragraph that best summarizes the problem. In the text box, the characteristics, restrictions, and relations with some patterns are detailed. Below, another highlighted paragraph describes the problem solution and some even have synthesis diagrams. In the end, the "smaller patterns" are presented, secondary patterns that complement the described pattern.

This characteristic of the relation between "larger patterns" and "small patterns" can be represented by mathematical sets or by a matrix of connections (Figure 01), which also demonstrates a root of mathematical and topological thinking about space. The patterns form languages, creating coherence in a region, city, or buildings from patterns that, complemented and combined in different ways, generate infinite variations. Alexander, Ishikawa, and Silverstein (1977) make an analogy with a poem, which are words organized in order to generate meaning, new semantics. Using patterns does not guarantee good designs; the most crucial question is how they are used together, interconnected to form a language.

As well as it has been defended and discussed over the years, the book has also been widely criticized. One of the significant criticisms concerns the universalist character of the work, with the idea that all humanity shares an innate set of values, denying alternative ways of life, local influences, political, social, economic, and cultural aspects, that is, a "romanticized" world vision. The use of handmade construction models is incompatible with contemporary society demands (Dawes and Ostwald, 2017). According to Park and Newman (2017), in the book, it is not clear how to discard some patterns with coherence, in addition to the difficulty of finding which ones are the most important, as some even contain up to nine pages, which makes it difficult to manipulate the whole, so important to the idea of the network inserted by the authors.

This work is part of broader research focused on developing one logic for a digital design process applied to a real urban intervention situation. Expectedly, this paper provides a new possibility of using "A Pattern Language" in a more automated and personalized way, besides opening the possibility to incorporate new patterns and digital technologies more connected to contemporary problems and the large volume of data available to architects and city planners today.

METHODOLGY

Even in the face of criticisms already presented, there is a considerable number of current researches committed to understanding and operationalizing these patterns within a contemporary context and also inserting them in a digital environment. An example is the study by Jung and Kim (2016). It seeks to increase the possibilities of using A Pattern Language using a network analysis tool as a way to analyze and assist the application of the patterns with the book's original classification. Another study carried out by Park and Newman (2017) points to a lack of clarity in the most influential patterns. It aims to identify which ones are the most important when considering the book in full, thus indicating the nature of the proposed intervention when covering the three scales: towns, buildings, and construction. The methodology of this paper, as well as these previous studies, seeks both to insert the patterns in network analysis software, and to identify more important and connected patterns. The difference is the insertion of a new classification, patterns of "context" and "design", which focus on the pre-existence of the place where the project is located and the actors' possibilities, helping the network not to be disconnected from reality.

NETWORK ANALYSIS

The networks have a visual and intuitive quality capable of extracting some functional groups from a complex system. The analytical structure of networks is an essential part of the complex systems science and allows the representation of these systems interactions to apply various structural measures. Thus, once we transform the data into a graph representation, it is possible to apply numerous analytical methods. However, not all are meaningful and interpretable about the data or the questions asked (Zweig, 2016).

When the intention is analyzing systems using network analysis software, it is important to highlight some mathematical concepts embedded in these programs' operation logic, such as topology, theories of networks, systems, sets, or graphs. According to Araujo et al. (2015), topology derives from mathematics. It proposes to study topological spaces, and the topics that are closest to architecture are network topology and geometric. In this analysis, a graph can easily explain the network topology, with nodes and edges, in which the relationship between nodes is preserved even if we change their position and/or the length of the edges. In other words, it represents the interdependence in a system.

Mathematically, two non-empty sets form a graph (Figure 02), one with nodes and the other with edges. We can represent it in different ways: vertex diagrams, adjacency list, and set diagrams or adjacency matrix. Mathematically, edges or relations can be defined with even subsets of entities, $R \subseteq O \times O$, where $O \times O$ shows a set of all possible pairs (Zweig, 2016). In this way, network analysis software transforms graphs into an interactive diagram, facilitating visualization and manipulation. In this case, the network analysis does not collaborate only for visualization. The aim is to use the metrics that the software enables to understand the role that the nodes (patterns) play within the conformed network and which are the implicit narratives for the design.

common example is the Fruchterman-Reingold algorithm (Zweig, 2016). However, it is important to emphasize that the central position of nodes into a layout algorithm should not be confused with centrality metrics, as these algorithms only approximate neighboring nodes, but they are not analytical.

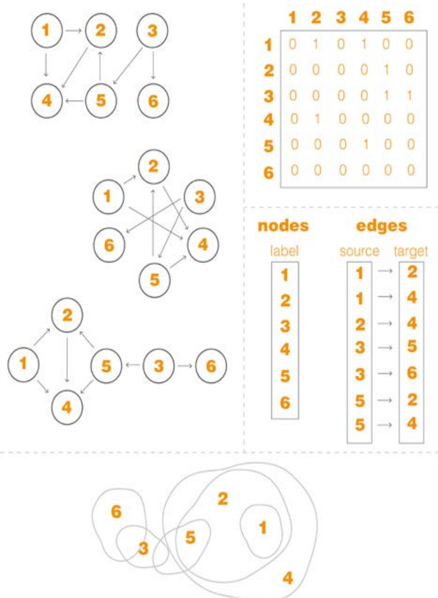

Figure 2: Different ways to show the same graph

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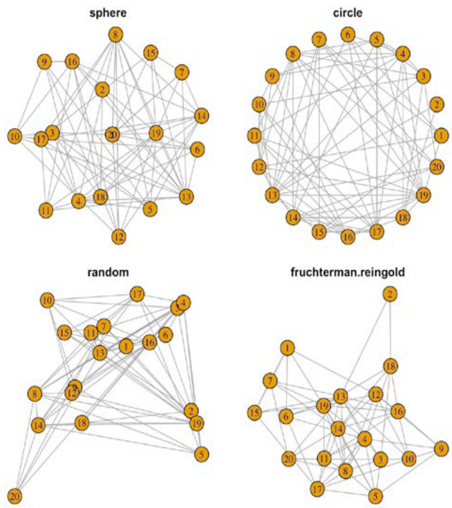

Figure 3: Network layout algorithms

Font: Network graph layouts with R and igraph

According to Zweig (2016), the difference between a graph and a complex network is that the first is an abstract representation between the entities, while the network combines a graph with additional information about the entities and their relations. In this paper, this additional information is incorporated by external context analysis, by introducing other layers of information from the real intervention space for analysis, not just design, into the network.

The first challenge of network analysis according to Zweig (2016) is to transform data into representation. When we change the relationship into a network representation, mathematical information must be passed on. Therefore, it is necessary to identify which kinds of data we will represent because they should be a distinct set of entities and relations between them. After defining the entities and relationships, it is necessary to incorporate decisions about the direction and intensity of the connections. The next step is data visualization. There are some layout algorithms (Figure 03) to help in this sense, many of them based on the strength of connection attraction, a very

The most important motivation in using network analytical methods are modeling and analyzing the probability of indirect effects between nodes as the direct effects could only be evaluated by basic statistics. The notions of distance are fundamental, as they are measured between pairs of nodes and result in a single number. But in some cases, the average distance (density) is not as impressive as the maximum distance (diameter of the network). The maximum distance (diameter) reveals how many edges are necessary to connect the two most distant nodes and the average distance (density) demonstrates the expected distance between two randomly chosen nodes (Zweig, 2016).

Beyond distance, other important measures are centrality ones, which measure the dominance of single nodes or the nodes that assume greater importance in the network. The most common centrality measures are degree centrality, betweenness centrality, and closeness centrality, but there are still other metrics such as eigenvector, current-flow, and others. The degree analysis considers the direction in which the connections are made and generates three types of ranking: degree, in-degree, and out-degree. The degree indicates the number of connections that a pattern (node) has with each other; it is the sum of the in-degree and out-degree values. The in-degree measures the number of incoming relations and the out-degree number of relations coming out of that node. Betweenness measures the number of turns a node acts as a bridge along the shortest path between two nodes; it relates fewer with connections, like degree measure, and more about flows. Closeness measures the average distance from one node to all others reachable, which are the closest nodes to the rest (Matas, 2017).

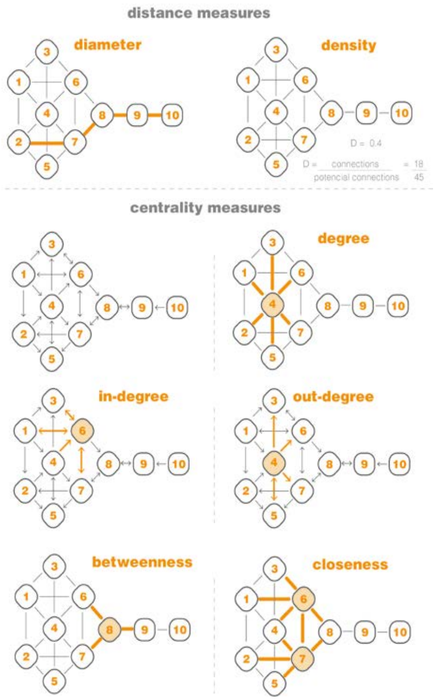

Figure 4: Some network measures
Font: Adapted from Gasevic (2014)

A NETWORK OF CONTEXT AND DESIGN PATTERNS

This operationalization follows some instructions from the beginning of the book "A Pattern Language". The authors indicate that users should choose an initial pattern that best describes the overall scope of the project in mind (Figure 05). In the sequence, we suggested a list of patterns based on this scope, but only those that describe something possible to achieve should be included. In this methodology, these are the "design patterns (DP)". They are those that can be designed by the actors, our stakeholders considering their possibilities, and the reality of the intervention selected place.

Following the instructions, Alexander, Ishikawa, and Silverstein (1977) still make it clear that the network is open to adjustments by the designer, who can insert new patterns and relations. With the broad information sharing and data available today, the insertion of new patterns has several open paths, which can incorporate from new realities within the scope of cities, buildings and construction techniques, as well as new digital tools. This "personalization" is one of the possible adaptations to mitigate the possible universalist and "romanticized" character attributed to the book.

After the final list of design patterns, the next step is to analyze them individually and identify the connections established in each of them, which "larger" and "smaller" patterns are connected. The "larger" patterns of each one represent the existing conditions that that pattern can complement, and in this methodology, they will be classified as "context patterns (pc)". The proposal is to filter these larger patterns, the "context patterns", eliminating those that can not apply to the local reality. An alternative is to use available open digital data to identify this context, for example. This idea makes sense because a pattern cannot complement a feature that does not exist at all.

The "smaller patterns" that have been added should be filtered by the same criteria as the design patterns, analyzing the actors' possibilities or stakeholders. The same pattern can be classified as context (CP) and design (DP) at the same time because some characteristics may already exist and still be improved through the project. Thus, it is possible to reach a network with local aspects and the reality of the actors' execution, such as budget, type of intervention, materials availability and so many other factors that condition a design.

We converted the connection matrix into two tables: one that contains the nodes and the other that contains all the connections already identified considering the direction of the relations, the "smaller patterns" that go in the direction of the "larger patterns", as they are the ones that enter the set of larger patterns to complement it. We inserted these two tables in the network analysis software and can be manipulated initially by layout algorithms and color assignment for better visualization. The fifth and final step is applying the metrics in the network analysis software (Figure 05), to find priority patterns and the out-degree was selected. The justification is that the degree is a relatively simple analytical measure; however, it is a crucial step towards understanding more complex networks because there is a tendency for relationships between nodes with the same degree value (Zweig, 2016). The out-degree indicates the number of connections that leave that node, that is, it points out which patterns most help to complement others, whether they are about what already exists in that place, or when they help to complement design possibilities. With this metric, we can visualize the most important patterns in the set logic established by Alexander, Ishikawa and Silverstein (1977), but considering the local context.

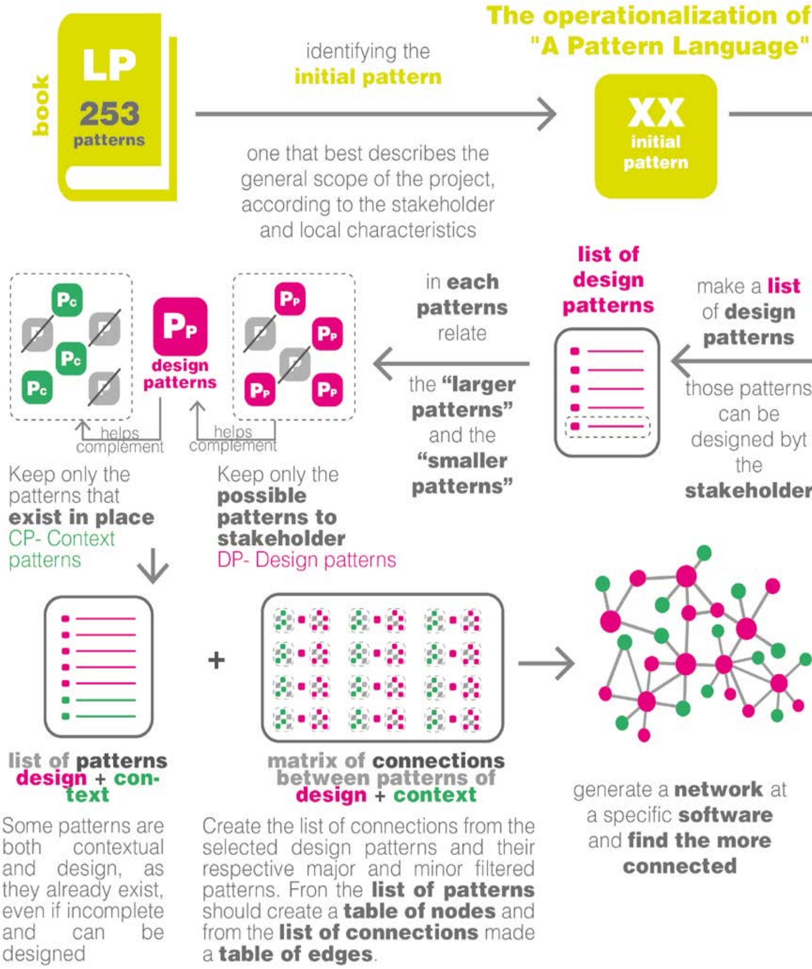

Figure 5: Operation steps
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RESULTS

In this paper, the software chosen for the analyzes was Gephi, as it is an open-source and offers different graphic possibilities for visualization and rendering. The real situation chosen was an urban intervention carried out in a district of Viçosa, a small town in the state of Minas Gerais, in Brazil.

The actors or stakeholders were Nó.lab, a research group from the Federal University of Viçosa that aimed to experiment with digital design processes through a broader research project, which had this urban intervention as a practical case.

Figure 6: Identifiable neighborhood

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District is located about 8 km from the city center, with approximately six thousand inhabitants. The access to the district is only by a highway and the origins of the urban occupation were the black population from the displacement of gold mining regions. In this context, we chose the pattern number 14 (IDENTIFIABLE NEIGHBORHOOD) as the initial one. Alexander, Ishikawa, and Silverstein (1977) state that people need to feel part of an identifiable spatial unit, a neighborhood, which can be evidenced by three characteristics: (1) small populations; (2) a small area, with a diameter of approximately 300m, and (3) not having the intersection of a large avenue. As a scope, we focused the intervention in an area of 300m, selected through georeferenced data and an analysis of segments based on space syntax theory.

After we selected the initial pattern and the intervention area, the next step was the selection of the list of design patterns. All of these patterns are consistent with the local context of the 300m diameter and with the possibilities of the research group as a stakeholder. We haven't inserted new patterns, but we adapted the 161- SUNNY SPACE pattern, as it does not match the city's weather reality and changed to 161 - SHADED SPACE.

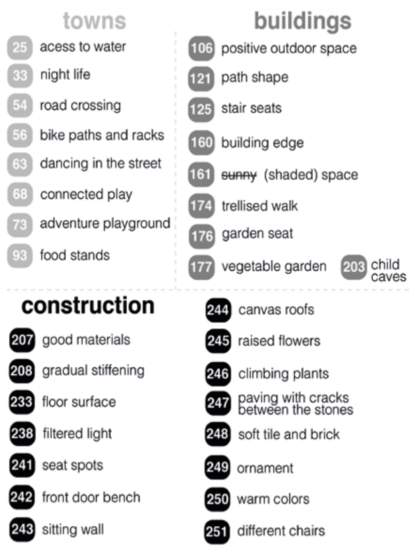

Figure 7: List of selected design patterns

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Starting from these 32 selected design patterns, we developed the connection matrix, as well as the application of filters for their respective context and design patterns, as indicated in step 3 of the methodology. The insertion of the network in the *Gephi* software was based on two tables, nodes - class for context and design patterns + edges - source and target - (Figure 02).

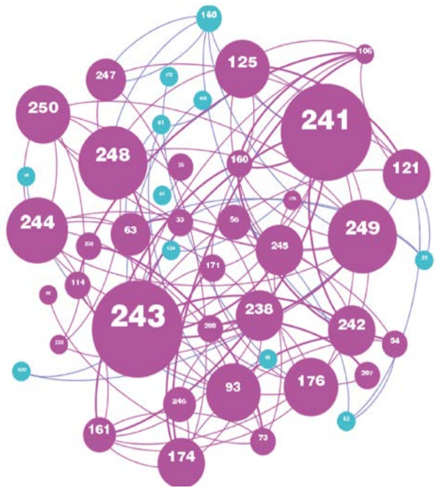

Figure 8: Network with "out-degree measure" apllied
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After generating the basic and unitary metrics of distance - diameter and density – we applied the metric of out-degree centrality (Figure 08) together with the context and design classes highlighted by different colors. The design patterns with the highest out-degree, that is, those that help to complement the preexistence of this 300m "identifiable neighborhood" were (241) SEAT SPOTS and (243) SITTING WALL. They were evidenced with the representation of the node in a larger size. In the sequence, some patterns with a high ranking of out-degree: (248) SOFT TILE AND BRICKS, (249) ORNAMENT, (244) CANVAS ROOFS, (176) GARDEN SEAT, (250) WARM COLORS, (242) FRONT DOOR BENCH, (238) FILTERED LIGHT and (174) TRELLISED WALK.

DISCUSSIONS

The patterns with the best ranking showed by the network analysis are related to the "sitting in public space" behavior, which can indicate two pieces of evidence. The first one is that the patterns network also showed the nature of the projects extracted from the book and that they are not based on a simple element, such as a bench, but on all the relations that may arise. No coincidence, Gehl, and Svarre (2013) defend "walking, standing and sitting" as the basic activities of the public space. Another evidence is that the patterns with the greatest raking are almost all on the same scale of intervention, which means they are consistent with what the neighborhood offers at that place and the possibilities that the actors and stakeholders have to intervene there. They are patterns that connect and do not function as isolated elements; for example, they can be benches associated with ornaments and edges of buildings or even gardens with a trellised walk and filtered light. What further reinforces Zweig's argument (2016) as a trend, the importance of the relationship between us with the same value degree in more complex networks.

This operationalization has a lot to do with the idea of emergence and clarification of the design process. The visual and graphical understanding of the network makes the relations established through the selected patterns easily identified, clearly indicating the character of the intervention or design. The primary purpose of using network analysis is to enable visualization and manipulation graphically, a difficult task to be performed using only the book. Understanding and manipulating networks digitally are the big keys to understanding systemic reasoning and the complexity implicit in them.

As Zweig (2016) shows, one of the main challenges is transforming data into representation and this is one of the discussions that this study opens: the potential to use the patterns connection logic of "A Pattern Language" and the new classification - "context "and" design " - to insert new standards that contemplate contemporary discussions of architecture and urbanism. If we didn't remove the context patterns from the network, the ranking of design patterns would probably be slightly different and the network less connected to the local reality. The local reality is also important, but the current reality of the world, new materials, digital tools, new forms of interaction, and so many other factors did not exist when the book was written and published. This is, therefore, one of the points of integration and progress for this research.

FINAL CONSIDERATIONS

Some of the next steps to advance the discussions on this operationalization are the addition of the concept of connection intensity, which we didn't explore, and the use of more advanced network analysis metrics. The operationalization proposed in digital support for the relations of the book "A Pattern Language" converge to the discussions of digital culture in architecture and urbanism as they mathematically explicit the patterns relations, expanding their capacity for analysis and understanding. Digital culture, as a set of social interaction practices mediated by digital technologies, benefits from the theme of this paper by facilitating the translation of the book's instructions into a logical-digital system that allows greater depth in the public space discussion. Transformative design, as a facilitator of the transition between analogue and digital, is also present in these discussions and updates of publications with analog input, but contributes to the theme of public space because it highlights the possibility of an expanded recombination and operation of Alexander patterns. The mediation between technology and society is also another point to be considered, as the graphical visualization of the patterns relations makes it possible to reproduce the method and increase the interpretability of the results.

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