Implementation of Computational Methods in Urban Planning

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Abstract. In the context of rapid climate change, coupled with the accelerated growth of populations and urban expansion, there is an increasing need for urban environment revitalization and sustainable urbanization. This challenge presents an opportunity for the development of new computational methods that hold significant potential and offer a chance to enhance the urban planning process by innovating traditional approaches with the aid of cutting-edge technologies. In this doctoral dissertation, by integrating these challenges and potential solutions, a novel approach will be provided on how computer tools can improve the planning process and how generative workflows and process automation can be effectively applied. The flexibility and applicability of the proposed framework are analyzed, and a way for urban planners to identify synergy between design and ecological efficiency, which would otherwise be challenging to find using traditional methods, is elucidated. The results of this dissertation will offer a new method for advancing sustainability in urban planning and design.

1 Problem definition and background

Today, we face complex challenges in the planning of our living environments. In light of these challenges, the crucial role of computational tools, especially in the fields of urban planning, architecture, construction, and engineering, becomes increasingly evident. These tools have been evolving since the 1980s, leading to the development of a parametric and algorithmic approach, which has introduced a new dimension of interaction between architectural design and urban morphology, significantly influencing the shaping and regeneration of spatial environments.

From the very first experiments with the use of computational tools in architectural design processes, it became clear that these tools hold significant potential in urban design [1]. Computational tools have substantial practical value for planners, as they enable the application of generative workflows, automation, optimization (such as genetic algorithms), performance-driven urban design, as well as urban design simulations. They also facilitate plan evaluation and multi-objective optimization, which can expedite the planning process and yield better design outcomes through the use of generative parametric modeling [2].

The application of a parametric approach by architects requires a specific way of thinking, focused on establishing parameters rather than predetermined solutions. As emphasized by Kolarević, this approach involves specific rules, methods, and characteristics. Rejecting rigid solutions, the parametric approach views design as a dynamic process in which elements are constantly adapted and changed [3]. These tools enable architects and urban planners to optimize urban forms and spatial construction through parameter-driven perspectives, particularly in the context of cities as hybrid areas. In this regard, the subject of this research can be defined as the use of computational tools in bridging architectural and urban design.

From the study of scientific articles, it can be concluded that computational tools offer the most value in the initial design phases, where they enable the generation of various variations and performance analysis of these variations. It is crucial to note that well-designed and precisely planned processes are of utmost importance in these stages. Errors made in the early stages are often challenging or impossible to rectify later on. Therefore, when changes are implemented timely in the early design phases, their potential positive impact is the greatest, while the associated costs of these changes are minimal [4].

2 Methodology and preliminary results

In this work, morphological and topological models will be applied, encompassing information on input parameters, metrics, as well as the methods and software utilized in these investigations. The analytical reference point for evaluating urban performance can significantly depend on the research's objectives and scope. In this scientific article, two methodologies will be applied:

- Analysis and application of case studies as topological models, which benefit from the application of reliable conditions specific to real-life locations and can thus be used to assess results using available measurement data.

- Analysis of hypothetical models as topological models, which benefit from the potential to simplify specific location conditions and achieve greater control over the analysis. These studies will use standardized urban block settings for parametric analyses of urban performance.

Preliminary results of the study are reflected in the review and analysis of scientific articles, with a particular focus on the mentioned field. The examination of the selected literature includes the analysis of multiple scientific articles dealing with the use of case studies as a topological model, as well as the study of scientific works addressing hypothetical models. Additionally, that the research identied commonly used software and add-ons, as well as performance metrics employed in contemporary studies.

The aim of this analysis is to assess the applicability and efficiency of computational tools in urban design, as well as their potential for addressing challenges such as improving energy and environmental performance.

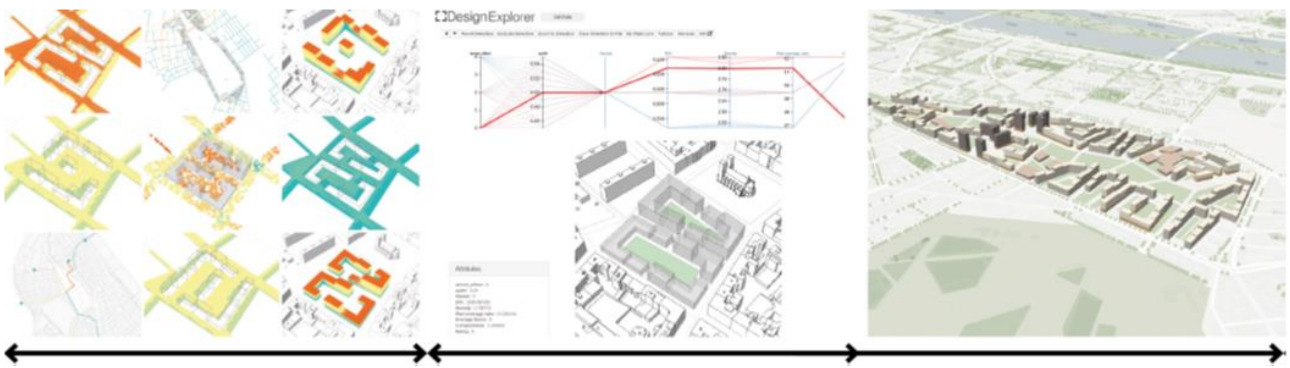

Fig. 1. Analysis and Simulation, Design Evaluation, and Visualization [5]

3 Futher work and Conclusions

This study is expected to emphasize the importance and effectiveness of computational tools in enhancing urban design, particularly in light of challenges posed by climate change and the need to improve energy efficiency while addressing environmental issues. The research aims to confirm the hypothesis that computational tools, specifically parametric design, through sophisticated multi-level optimization, analysis, and simulation, can significantly enhance energy and environmental efficiency in the context of urban areas and individual buildings.

Working with the parametric visual programming add-on Grasshopper offers numerous advantages in generating various scenarios. Flexible workflows and handling large amounts of data are just a few of these advantages. However, data import from different systems and interoperability between various applications and formats still pose a challenge that requires further research and improvement.

Parametric models enable real-time visualization and presentation of various scenarios and results. Nonetheless, it is important to note that the parametric approach is not a universal solution to all urbanism-related questions. The physical form and parameters addressed in this work may only be a part of the complex picture, with other factors such as cultural, social, and economic influences also needing consideration.

The parametric system can be an efficient, automated, and flexible tool for simulation, but it should be used as a decision support rather than a complete replacement for traditional planning methods. The parametric approach works best in the conceptual phase of urban design, providing parameter and data-based simulation and evaluation when it has the most impact on the urban environment's design.

In conclusion, the parametric approach, combined with open tools/add-ons, enables advancements in research and application in the field of urban design. These tools open possibilities for better understanding, optimization, and decision-making regarding the improvement of environmental performance and energy efficiency of structures. Another potential extension of this methodology could be the automation of the optimization process using the Grasshopper interface in conjunction with evolutionary algorithm add-ons, adding a generative aspect to the analytical approach.

References

[1] Zhang, Y., & Liu, C. (2021). Parametric Urbanism and Environment Optimization: Toward a Qualty Environmental Urban MOrphology. International Journal of Environmental Research and Public Health.

[2] Sun, Y., & Dogan, T. (2022). Generative Methods for Urban Design and Rapid Solution Space Exploration

[3] Kolarević, B. (2005). Architecture in the Digital Age: Design and Manufacturing.

[4] Dubljevic, S., Tepavcevic, B., Markoski, B., & Anđelkovic, A. S. (2023). Computational BIM tool for automated LEED certification process. Energy & Buildings .

[5] Fink, T., & Koenig, R. (2019). Integrated Parametric Urban Design in Grasshopper / Rhinoceros 3D .

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