Taikichiro Mori Memorial Research Grants 2021
Research Achievement Report

Project Title: Optimizing high-density urban morphology with the use of generative design algorithms

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Investigative Fieldwork Report

Investigating the Factors of Urban Change and Adaptation in Moroccan Cities

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The activities that we led during the academic year 2021-2022 were crucial in advancing the state of the research goals and resulted in developing new aspects of this multi-disciplinary research project that combines urban simulation and generative design. The research activities were threefold: first is the historic analysis of Arab/Islamic cities, which furthered with fieldwork to Morocco during August 2021 that also allowed us to get feedback on our simulation model. The second is generative urbanism and urban simulations, in which our simulation models went through a verification phase in which we tuned and analysed the results and also integrated the findings of the fieldwork to Morocco to be added in the next set of experiments. This allowed us to develop new simulation models based on the historic data that can be used for social housing projects in Morocco.

Research background:

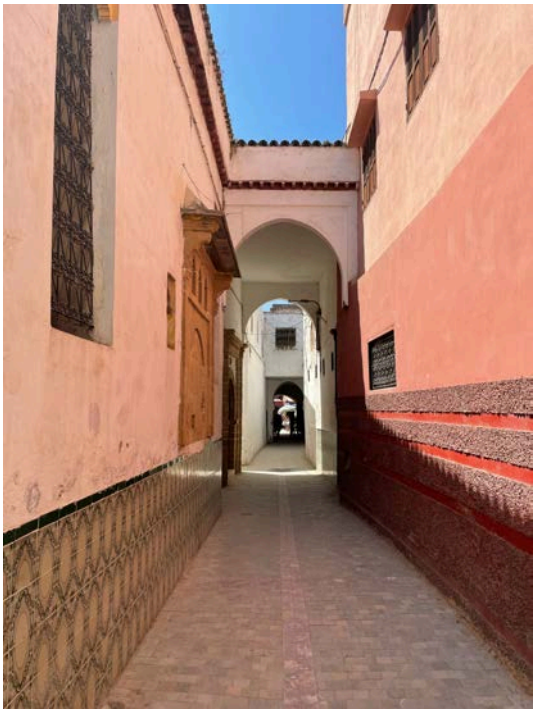
In this study, we review urban modelling as a discipline and discuss the relationship between urban form and generative urbanism theory. Later, we examine several factors that allow highly dense and low-rise urban settings, such as unplanned settlements (i.e. old towns, informal settlements, etc..) to be highly adaptive to social, spatial, and environmental change. Following this, we formulate guidelines to generate some of the characteristics of these urban forms. After discussing the use of simulations in the field of urban modelling, we introduce Generative Algorithms as a design strategy for our experiment. With this, the simulation seeks to explore the generation of abstract urban forms and their optimization. In this regard, this experiment makes use of 3D and parametric design tools (Rhinoceros 3D and Grasshopper) to define a generative urban simulation and optimization model. For this purpose, grid-based operations with base modules are used in conjunction with introverted urban blocks.

In this study, an urban simulation is used as a tool for generating high-density, low-rise morphologies that are based on generation rules and processes that interpret some of the characteristics of generative urbanism. While the urban space is a complex system that can be described through comprehensive models, this research discusses the use of generative design

and generate, evaluate, and rank a multitude of abstract urban morphologies that reinterpret key features of site-specific urban characteristics

Fieldwork to Morocco

This fieldwork to Morocco investigates the factors of change in the Moroccan urban landscape and the degrees of adaptability of different urban settings to these factors. The purpose of this study trip is to conduct an on-site qualitative investigation study for my doctoral research that investigates new models of adaptive urban development through the development and use of urban simulations tools for the Moroccan context. The use of more flexible and dynamic urban development design and policies adaptability and more diversification to benefit the practice of urban design; while preserving the social, cultural, and spatial characteristics peculiar to Moroccan urban settings.


The bare walls of the Medina of Salé, August 2021

In my doctoral research, it is anticipated that an algorithmic design model is a fitting contemporary solution that can simulate and offer a wide range of objective-based spatial solutions in such an urban context. This research aims to define how traditional ways of dwelling that were characterized by their spatial adaptability can be leveraged to be applied for urban design in contemporary ways of dwelling. This can be especially useful in the case of social housing and high-density planning, a feature that current practices of urbanism in the context of some Islamic emerging countries like Morocco is still so far lacking. Ultimately, the research aims to explore the possibilities of new models of urbanism that can evolve with growing human needs and allow for a malleable urban space.

As part of my current study about the defining factors of the urban form of Islamic cities, I conducted investigative fieldwork in the cities of Rabat and Salé in Morocco from August 13th to September 2nd, 2021. The purpose of this research activity was to collect first-hand information about the urban growth of urban tissues of old Islamic cities, and new towns of Morocco. In addition, I also conducted interviews with several professionals, scholars and researchers that specialize in the urban history of Morocco, urban planning, and social housing policies.

By engaging in this activity, I could reach a better understanding of the relation between the current and historical socio-cultural factors, the environmental setting, the demographic and how they reflect on the urban change and transformation of different urban settings and typologies in Morocco. By analysing the architectural survey findings and correlating them with the interviews to set up evaluation criteria that can assess the adaptability of urban settlements in the face of various constraints and other factors of change. I am currently analysing the findings for policy and design recommendations that can bring about a development model that learns from the adaptability and resilience of traditional towns and applies learned lessons to nowadays context.

I conducted a field survey to observe the medina urban typology more hands-on. To establish a more detailed Idea about building typologies in the Medinas, I surveyed the Medina of Salé city to familiarize myself with the field that was subject to the previous research works. This survey was conducted while also focusing on the factors of change, growth, and deterioration of these urban tissues. It was also a convenient opportunity to focus on the defining aspects of the medina typology and gather photographic material for further study. These data help to better understand patterns of transformation through long periods in the face of demographic and environmental change. Assessing the current state of these urban tissues from a socio-spatial perspective was also part of this fieldwork. This implies studying how the urban space is practised and socially produced through the application of a spatial analysis approach that considers factors of change and evolution of socio-spatial needs.

To investigate the factors of urban change, I also conducted semi-structured interviews with experts. I was able to gather data about the historical sites (traditional towns of Morocco), as well as 'new towns' (large scale development projects) to analyse the degrees of adaptability of these types of settlements in face of urban change. By conducting these interviews, I could better understand the social, administrative, and economic factors that define the organization, growth, and adaptation of contemporary developments compared to traditional ones.

This fieldwork was an important step in gathering documentation and primary data for refining and narrowing down the subject of my doctorate research. Indeed, discussing with various researchers that are knowledgeable about the topic of Islamic cities was highly beneficial and has allowed me to establish a stronger network that I could rely on in the future steps of my study. The research documentation and photographic material that I gathered, including references in the Arabic language as well as unpublished research thesis only available in Morocco are going to be the subject of further study in the weeks to come after my return to Japan.

Simulation experiments

The simulation model that results from this research initiated its conceptual framework based on observations of self-generated cities in north Africa -such as old towns or other forms of unplanned developments- in which complex urban forms allow for high-density habitat while still being optimized -through an incremental process- for conflicting environmental and morphological factors and constraints. With this premise, our research seeks to generate urban forms that can adapt in the face of conflicting design objectives and optimize a multitude of outcomes.

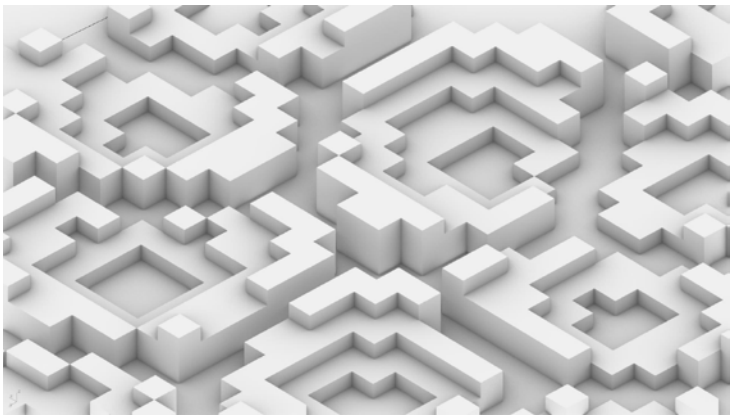


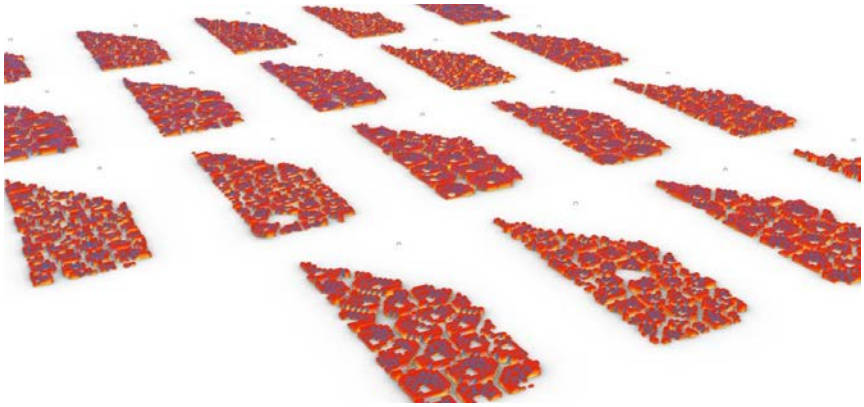
Figure 1: 3D generated urban form with the use of generative algorithms

- *Outcome*:

The main outcome of this experiment is to propose a generative urban model that can explore conceptual solutions for high-density and low-rise urban forms that can be employed in social housing contexts. The use of an MOEA and Pareto front methodology has already shown the potential for solving problems related to social housing constraints, for the design of "social and cultural orientated urban tissues", and the exploration of urban block variations. The simulation model will be considering a few evaluation factors, some of which will guarantee a degree of environmental comfort and street accessibility for the same target density. This model conceives a tool that can show a multitude of different potential spatial outcomes to be considered by designers and/or stakeholders. This simulation aims to demonstrate, that the medina form has a certain ability for adaptability to environmental and morphological factors through an evolutionary process done through computational design. This is to be validated by consideration of both the exploration (diversification of results) and exploitation (optimization of results) of the urban form, which shows a global trend of diversification of solutions. As a result, the optimization of a large number of urban morphologies is achieved while also allowing for the volitivity of users and designers by way of compromised choices available with the Pareto methodology.

-Findings and Analysis

Due to the heuristic nature of the optimization algorithm, it does not conclude with a definite,



single optimized solution. Instead, it generates a multitude of optimized solutions for conflicting goals. Choosing the right solutions can be challenging for designers and users alike, which is why it is mandatory to use analytical tools, such as Wallacei X Analytics that help better navigate the results and make more informed choices. With a considerably huge search space of up to 4.6*e5 for the MOEA to explore optimized phenotypes, it is necessary to statistically analyze the results. The visual inspection of the solutions (Figure 2) might give an idea about the global trends of the algorithm but does not help to better understand the results.

Figure 2. Visualization of meshes of the final generation Pareto frontline rendered on a grid.

The inspection of the fitness values data and standard deviation curves of the Pareto front for the results of the experiment (Figure 2) shows that the genetic solver has shown a trend for optimizing the urban form while keeping enough diversification. While analyzing the data, there is a clear trend for further optimizing the mean value of the evaluation scores for all three objectives while also further spreading out the standard deviation curve. Narrowing the standard deviation graphs through the generations, also seen through the standard value trendline going higher up proves the system's ability to maintain a diversified solution that can prevent any premature convergence of the solver. However, due to the stochastic nature of the generative algorithm, the mean value trendline is constantly fluctuating, showing that the algorithm is still favouring the exploration of the objective space rather than its exploitation. As an outcome, we can assert that by utilizing this simulation model, it is possible to use this methodology of generative design to formulate certain types of urban settings based on characteristics of medina-type cities.

-Next steps:

Going forward, we aim to transition from the use of MOEAs which are heuristic optimization algorithms we used so far in our study to model and generate urban form, to agent-

based simulation (ABM) that are more adequate to formulate bottom-upping models that are predictive. Now, we are testing 3D printing to make prototypes and better physically grasp the generated morphologies. With the integration of mixed reality technology, we aim to make an interactive platform using the aforementioned printed prototypes that can make a digital-twin model for design prototyping and model evaluation and analysis, thus allowing for an assisted and better-informed iterative design process.

Discussion and prospects

This study has shown that combining generative design with morphological characteristics of medina-type cities in an optimization simulation can offer a diversity of outcomes, adaptability to constraints, and flexibility in generative rules. While this study aims to take some of the qualities of medina type urban tissues and explore their application for generative algorithms, it also concerns itself with the implications of such an approach. There are clear limitations to the way North African cities were designed in the modern age when considering contextual identity and the need to balance between modernization, rapid growth, and strong demand for housing. Indeed, there are benefits to adopting an Arab-Islamic city form regarding walkability, human scale, and the identity of the urban space. The use of an optimization methodology for urban design ought to offer a spatial solution that could take decades if not centuries of trial and error in the urban environment to reach. It aims to inspire the discussion about new ways to think and design today's North African cities. The authors are hopeful that the rise in the use of algorithmic design and the growing interest in designing cities at a human scale will contribute to more contextualized contemporary urban design.

Achievements

As a result of our project, the research progress was presented at Academic conferences:

- "Exploring the Morphology of the Moroccan Islamic Cities: Urban Forming Simulations for Adaptive Developments" World CAAD PhD. Workshop 2021, Sigradi 2021. December 2021.
- "Generative Urbanism and Urban Simulations" Annual Academic Conference, Architecture Informatics Society of Japan. February 2022.

Also, we have submitted an original research paper to academic journals for peer review to the "International Journal of Islamic Architecture". The paper is now in the second round of peer review, and it discusses the generative and social processes of urban and architectural space in Morocco in the context of its urban policies.