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THESES OF THE DOCTORAL DISSERTATION (PHD):

DIGITAL RECONSTRUCTION OF THE URBAN MORPHOLOGY OF THE OLD CITY OF ALEPPO: BETWEEN THE MAMLUK AND THE POST-WAR CITY, THE CASE OF "AL-JALLŪM AND AL-ʿAQABA DISTRICTS.

-A PARAMETRIC STUDY-

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ABSTRACT

Aleppo, an urban settlement that dates to the Bronze Age, is also a renowned world heritage site. The Old City of Aleppo suffered extensive urban damage during the war that started in Syria in 2011. This dissertation presents a pioneer study for the implementation of digital technology in visualization and studying the history and development of two districts in the Old City of Aleppo, *al-Jallūm* and *al-ʿAqaba*.

This dissertation designs a process for a parametric time machine for Mamluk Aleppo. The historical reconstruction of the Mamluk Era (16th Century) is based on both cartographical and historical inputs. However, the study attempts to transcend the concept of a mere time machine. It links the past and the present by tracking the development of the studied area between the historical reconstruction of the Mamluk period and the post-war city. This is achieved through an extensive digital field survey using laser scanning and areal photogrammetry. The goal of this study is to compare both digital models and track the changes in the morphology of the city through the study of the changes in the heights of individual buildings and the general silhouette of the city, in addition to a comparison between the mass and void ratio between the two time periods.

i. INTRODUCTION

Over the past decade, technological advances allowed architects and archeologists to achieve higher levels of finesse and precision in virtual reconstruction. Reality-capturing workflows such as laser scanning and photogrammetry paved the way for technology as a tool for the reconstruction of historical sites, monuments, and artifacts, as well as an informant to the urban decisions within a historic fabric.

As a result, digital models have enabled historians and architects to pay a 3D virtual visit to our past. A concept often referred to in scholarly literature as the "urban time machine". It aims to create an accurate architectural visualization of monuments or cities in different ears and track their development during different historical periods. Those models are not only tools of simulations of a time long gone, but they hold the potential to influence the decision process of the modern city and offer deeper knowledge of the morphological evolution of historic centers.

The idea of urban time machines relied on topographical maps, cartographic data, and historical pictures and paintings for the reconstruction of historic cities in different historical periods. Historical accounts from each period then help to examine previous inputs. Such projects gained momentum in the 1990s, especially for capitals of vast empires, such as Rome or Athens. Most recently, the European "Time Machine Project"[1] has been gaining a lot of popularity; and many cities in Europe have created their own urban time machines.

The 21st Century encompassed a gigantic leap for the field of historical reconstruction, represented in the several applications of photogrammetry and terrestrial laser scanning. These technologies not only help fabricate the past but hold the potential to aid the preservation and reconstruction of heritage under risk of conflict, climate change, and natural disasters. For example, the digital analysis of a post-war city can offer different levels of information for the city, its history, development, story, while being a tool of relief and recovery. Today, while the cultural heritage in the Middle East is facing deliberate destruction by wars and extremism, the same technology can play an important role in documenting damages and reconstructing the morphological development of cities before, during, and post-conflict.

Aleppo, a world heritage site since 1986, enjoyed an advantageous location on ancient trade routes. This location contributed to the prosperity and wealth of the city. The oldest mention of Aleppo dates to the 25th Century BCE. Making Aleppo a stronghold for several rulers throughout history: from Hittites, Assyrians, Akkadians, Greeks, Romans, Umayyads, Ayyubids, Mamluks to the Ottomans.

Old Aleppo stands as a fortified city encircled by a wall reinforced with defensive towers, with a centered citadel surrounded with covered markets bedesten (*bazars*),

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[1] https://www.timemachine.eu/project-scouting-service/

residential quarters, *madrassas*[2], *khans*[3], and religious buildings that used to be ancient temples; in addition to churches, synagogues and mosques, the most important of which is the Great *Umayyad Mosque*. These mixed-use buildings suggest a religious and social diversity that supported the important role of Aleppo as a commercial city on trade routes. As a result, the city developed a complex and mixed urban fabric that was subject to several destruction attempts and reconstruction processes, most significantly during the 12th to the 16th Century because of the constant invasions at the hands of the Mongols and Tatars as well as political instability. The most recent destruction the city has witnessed was during the conflict in Syria (2012-2015. Many of the buildings within the old city have suffered different amounts of damage, varying from mild to severe to complete demolition. Therefore, Aleppo was inscribed on the List of World Heritage in Danger in 2013.

The dissertation is based on field digital survey to document two districts in the Old City of Aleppo using laser scanning and aerial photogrammetry to create a model of the war damages across the studied area. Furthermore, the study will apply an analog/digital approach to the Old City of Aleppo to create an urban time machine for the city in the 16th Century and use that historical replica to study the morphological changes by comparing the historical reconstruction with the digital model of the post-war city.

ii. **SCOPE**

1. **Time Frame**: The study focuses on the 16th Century and the 21st Century (2018) when the field survey took place.
2. **Boundary**: The study identifies the old city of Aleppo as an intra-muros city and does not discuss the expansion of the city beyond the historical walls.
3. **Choice of Case Study:** The "*al-Jallūm Quarter*" was chosen because of its proximity to "*Tall al-'Aqaba*", "*Tallat al-Sawda*" and "*al-Kallāsa*" which are considered by scholars to be (independently or collectively) as the earliest settlement' nuclei of Aleppo, in addition to the distinctness of the Hellenistic plan grid in the quarter, and the availability of previous 2D studies, upon which this study is based.

iii. **PROBLEM AND RESEARCH QUESTIONS**

Various historical studies and papers have been published about Aleppo, owing to its prestigious status. Travelers such as De Bruyn, orientalists such Michael Meinecke, and Jean Sauvaget, and artists such as Matrakçı Nasuh mentioned and represented the old city of Aleppo within their written of painted work. However, the drawings have remained flat or two dimensional, unable to fully express and describe the urban fabric and development of the morphology of the city through a comprehensive 3D model for the urban change and growth of Aleppo. Therefore, this

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[2] A type of inn once found in the Middle East and parts of North Africa and Central Asia that effectively functioned as a trading center and hostel (https://www.britannica.com/technology/khan-architecture)

[3] An institution of higher education in the Islamic sciences (https://www.britannica.com/topic/madrasah)

work seeks to answer an urban and architectural question with the help of 3D modeling and by relying on an accurate hybrid digital survey. But the main question of this study is: **How did the 3D urban fabric of Aleppo change between the late Mamluk period (16th Century) and the post-war city?**

Another layer of this study considers the tragic destruction of the city's fabric, which created a need to document the phase of destruction to preserve it for future studies, analysis, and restoration projects. Small projects have been initiated by international organizations in individual buildings such as *Beit Ajaq-Bash* at *Beit Ghazala*. Nonetheless, the bulk of the documentation carried out was by Unmanned Aerial Vehicle (UAVs)[4] that is not easily available for scientific quality evaluation. However, the "Aga Khan Trust for Culture" has carried out scientific 3D documentation[5] in multiple historical bazars as a part of the project for the rehabilitation of the commercial center of the Old City of Aleppo. This thesis will expand the limits to the two of the (mostly) residential quarters (*al-Jallūm* and *al-ʿAqaba*). But more importantly, it will explore **what is the optimum pipeline for implementing analog data with digital datasets?**

iv. OBJECTIVES

This dissertation investigates to what extent digital documentation methods can help in creating models of the past, especially when supplemented with analog spatial data and historical accounts, and how can these models be reflected and compared to the post-war city. It will focus on investigating the political, economic, social, and religious aspects that shaped the urban structure of the city and will use the historical data to guide the historical modeling process. It will visualize the old city of Aleppo between the 16th Century to the post-war condition of the city, as it was surveyed through laser scanning and drone imagery in 2018. Thus, the main objectives of the study can be summarized as follows:

1. Study the 3D spatial development of the city through 3D models based on thorough architectural reading of the historical sources backed with available cartographic data such as maps, surveys, orthophotos and analog photos.
2. Create a parametric modeling and visualization workflow capable of interpolating the historically documented urban and architectural changes and their extent and context. Which will enable the creating of 3D digital models of the historical urban fabric changes of the old city of Aleppo.
3. Design a digital pipeline to superimpose historical-topographical data and combine them with the digital data.
4. Investigate the city in the Mamluk period as a selected historical anchor point and evaluate the magnitude of the social, political, economic, and religious events representing turning points for the morphology of the city.

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[4] (The Aga Khan Trust for Culture, 2018, p. 5)
[5] ibid.

5. Compare the 3D Mamluk time-machine to the 3D model of the post-war city to determine the key morphological changes to the urban fabric of the city.

v. IMPORTANCE AND CONTRIBUTION

The dissertation at its core bridges history, architecture, and technology. The importance and novelty of the study lies in combining historic and cartographic sources, digital documentation techniques. It also combines parametric design for visualizing, studying, and comparing the city in two different periods.

It provides the first post-war digital survey conducted in Aleppo on an urban scale. It relies on a scientific approach through utilizing laser scanning combined with aerial photogrammetry in the documentation, analysis, and reconstruction of a section of the urban fabric in Aleppo. The digital survey covers an area of 1 km^2 that is considered one of the oldest neighborhoods in Aleppo.

It contributes to the study of history from an urban and architectural point of view by creating an urban time machine of the city and investigating the three-dimensional changes of the city that were not sufficiently covered in the previous scientific studies; all is expressed in a parametric environment.

vi. METHODOLOGY

The dissertation adopts a bidirectional strategy, merging both bottom-up and top-down approaches. - In the top-down approach, the 3D models obtained from the survey are utilized as the foundation for visualizing the development of the urban fabric. A bottom-up approach is employed to construct a parametric model. By drawing on theoretical city studies and previous research, this model serves as a time machine for the 16th Century city. Mixing the two approaches generates a more realistic depiction. It produces a two-directional channel transmitting from the past to the present and vice versa. During this process, the study employs multiple methodologies in investigating the urban changes that affected the city. The methods used for extracting the parameters for the parametric model are, naturally, different from the ones used to conduct and process the post-war field survey:

a. DESCRIPTIVE AND COMPARATIVE METHODS

By merging historical, archaeological, and spatial sources, this method creates guiding metadata and an analog base, which are indispensable to provide the parameters for the digital models of the fabric's development. This technique is also employed to contrast and track the morphological alterations to ascertain the pivotal influence of the social, political, religious, and economic factors in the city's evolution.

b. QUANTITATIVE METHODS

Using the latest laser scanning and aerial photogrammetry methods, an accurate survey of the post-war condition of the studied area can be performed. Varying

the acquisition resolution based on the level of detail to produce an efficient representation that offers satisfactory detail at reduced file sizes.

c. CONTENT ANALYSIS METHODS

This method pertains to the second objective of the research, which seeks to create 3D parametric model for the late Mamluk period. It involves the following steps:

- Collect the most important topographic resources of the city. Use AutoCAD to trace them with a unified scale. Geo-reference and superimpose the maps on the postwar survey using GIS. The workflow will facilitate the identification of the urban changes, then using them as a base map for the 3D reconstruction.
- Analyze the spatial data from the fieldwork in Aleppo and compare them with the built 3D models, spatial and interpolated textual data. This permits the assessment and quantification of the impact of various factors, including the economy, politics, war, and natural calamities, on the historical urban fabric of Aleppo.

vii. WORKFLOW

The work was divided into three stages:

- Data Acquisition: The field survey using photogrammetry and laser scanning techniques to create the base model of the parametric modeling process.
- Data Processing and Parameterization: Creating a parametric model of the city in the Mamluk period by combining field survey data and historical research.
- Data Analysis: Comparative study between the post-war survey and the parametric model of the Mamluk city to track the urban changes.

The **parametrization** of the data uses the following workflow:

The process includes recognizing and extracting urban and architectural patterns associated with each historical period. Then translating it to digital parameters. This is achieved by examining the historic and cartography data as the following:
- Examine the city as a complex.
- Examine the surviving city quarters.
- Examine the quarters in terms of individual buildings.
- Develop a computational pipeline to model important buildings according to their accurate floor plans and height.
- Develop a computational pipeline to model the generic fabric according to their plan but with randomized heights.

8

The 3D parametric model of Aleppo provides valuable insights as to how the historical visualization of the city compares to the current post-conflict situation.

viii. CHAPTERS OVERVIEW

CHAPTER I

The first section of the chapter investigated the city through historical periods relevant to the study and tracked its development on four main axes: politically, socially, economically, and religiously, during the foundation, Hellenistic, Islamic rule until the decline of the Ottoman Empire. A special attention was given to the religious, social, and political changes to the atmosphere of Aleppo after the arrival of the Turks. It also explored the reported earthquakes that affected the city and the extent of the damage caused by each natural disaster. The second section focused on the precedent studies about Aleppo and similar projects of 3D reconstruction of historic cities. The following chapters will rely on most of the methodology of the Urban Time Maps and the work of Gaube, Wirth and Sauvaget, in addition to the historical accounts.
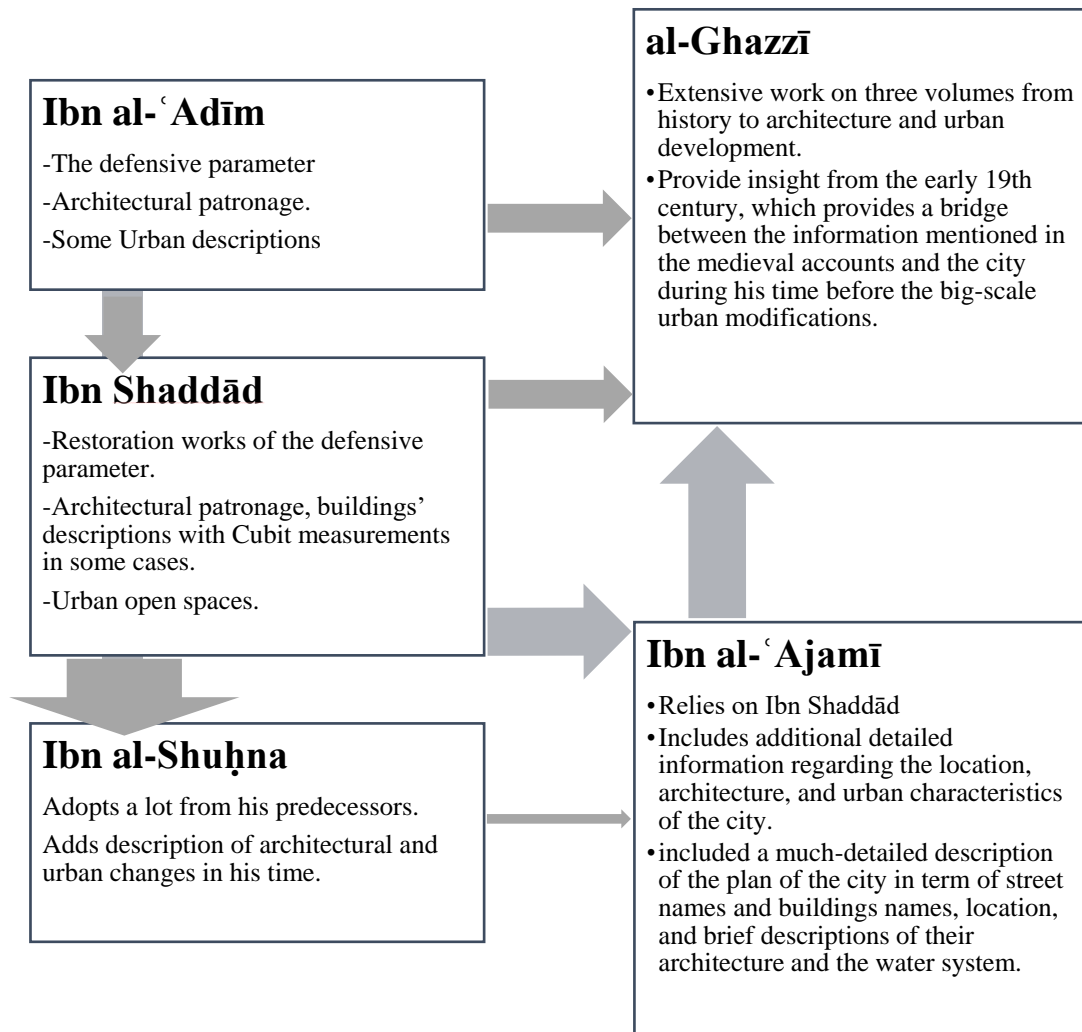
CHAPTER II

The second chapter discussed the urban development of the city through the available topographical, cartographic, and painted sources. During that overview, we conclude that until the second half of the Ottoman period, the city preserved its initial urban features. All the new buildings that were accommodated by the successive rulers had been added to the puzzle without altering the core of its fabric. Throughout history, different development principles were applied to create an organically grown organism against a planned artificial built environment. The most transformative period regarding the fabric of the intra-mural city is represented by the Ayyubid and Mamluk periods. The late Ottoman period introduced urban planning systems, with the decline of the importance of fortification and the new requirements for wide roads to accommodate vehicular traffic. Despite the political change, invasion, economic instability, and natural disasters, the intra-mural city did not undergo a drastic urban intervention until the major master urban projects implemented in the 1990s, albeit the studied area remains the least affected by both Gutton's and Banshoyas' master plans.

Moreover, the most informative maps of the city were identified and aligned in the same datum of the results of the survey conducted during this study. This clearly revealed the changes to the urban fabric in terms of the division of urban blocks and the degradation of green spaces and courtyards. This analysis will play a pivotal role in the parametrization workflow to be designed within the scope of the study. In this workflow, the information of different levels such as urban and architectural surveys and different types such as historical text, images and paintings could be combined together as the metadata of the 3D visualization of Aleppo as the parametric layers of the digital model.

CHAPTER III

This chapter discussed the most informative and descriptive records about the urban planning of the city of Aleppo, using both medieval and modern sources, as well as famous architectural typologies popular in the city during different historical periods. The figure below summarizes the discussed information with particular focus on the knowledge transfer through the historical account, both Medieval and Modern.

Ibn al-ʿAdīm

-The defensive parameter
-Architectural patronage.
-Some Urban descriptions

al-Ghazzī

• Extensive work on three volumes from history to architecture and urban development.
• Provide insight from the early 19th century, which provides a bridge between the information mentioned in the medieval accounts and the city during his time before the big-scale urban modifications.

Ibn Shaddād

-Restoration works of the defensive parameter.
-Architectural patronage, buildings' descriptions with Cubit measurements in some cases.
-Urban open spaces.

Ibn al-ʿAjamī

• Relies on Ibn Shaddād
• Includes additional detailed information regarding the location, architecture, and urban characteristics of the city.
• included a much-detailed description of the plan of the city in term of street names and buildings names, location, and brief descriptions of their architecture and the water system.

Ibn al-Shuḥna

Adopts a lot from his predecessors.
Adds description of architectural and urban changes in his time.

The process of knowledge transfer through the historical accounts (The arrows represent how much the authors took from their predecessors) by Orabi, 2023.

CHAPTER IV

The first section of the chapter discusses the digital field survey using laser scanning and photogrammetry of two districts of the old city of Aleppo. It explores the following processing and post-processing workflows. While the second section addresses the parametric modeling of the historic fabric based on identified parameters of the urban fabric in Aleppo. The final section combines both datasets. It compares the two models to compute the spatial changes of the studied area and extract the parameters that guided the urban development of the city.

The final chapter summarizes the results of the dissertation focusing on the 3D study, asserting that the case study of al-Jalūm and al-ʿAqaba sets a proof of concept for the use of 3D-models in the analysis of the evolution of historic centers as well and the evaluation of the state of conservation of the city and the risks and threats that faces the historical fabric especially during and/or after the conflict.

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9-Orabi, R. (n.d.). Digitizing Urban Heritage: Examining the Ancient City of Aleppo.

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BIO OF THE AUTHOR

Rahaf Orabi obtained a degree in architecture from Damascus University in (2012); and subsequently, commenced employment at the Directorate General of Antiquities and Museums (DGAM), Syria. During the time there, Rahaf focused on 3D documentation of endangered archaeological sites. As a member of "Project Anqa", she took part in the digital documentation of monuments in Damascus and participated in the documentation of Palmyra after its liberation from ISIS.

Rahaf holds a master's degree in architectural design/Digital Architecture from Damascus University (2016) and a master's degree in digital Cultural Heritage from the Cyprus Institute (2021). She started the PhD program at Pázmány Peter Catholic University under "Stipendium Hungaricum Scholarship" in 2017. For her dissertation, she initiated an urban-scale laser-scanning project in the Old City of Aleppo.

Rahaf is a research technical specialist at The Cyprus Institute's "Andreas Pittas Art Characterization Lab (APAC)" since 2022, where she is taking part in projects for European Consortiums aiming for the documentation and digital analysis of fossils, artifacts, archaeological sites, and architectural heritage in Spain, Greece, Italy, Egypt, and Cyprus.

Mrs. Orabi has authored several peer-reviewed articles for prominent scientific journals and conferences that specialize in Digital Cultural Heritage. Furthermore, she is co-editing a book that explores the recovery of Aleppo.