1.1. OVERVIEW OF THE THESIS

Over the past decades, in the shade of acceleration of science and technology, there has been an obvious cognitive shift in the theories of "architectural design"; one of the main issues of this shift is "how to think biologically". This has lead to a growing computer involvement with digital architectural design in a notion of observing nature and using its ways of coping in the design process. Evolution, natural selection and effectiveness could be phrases used in reference to architectural design approaches. It does not only challenge what we are designing but also how we design. The generative and creative potential of digital media is opening up new emergent dimensions in architecture where evolution of architecture takes place. (Menges, 2012)

"Evolutionary Architecture of Bio-Digital Design and Genetics: Towards Morphogenetic and Evolutionary Computational Design" is the title of this thesis which approaches the study of evolutionary architecture from a computational and biological digital perspective within the context of bio and genetic design principles. However, this thesis pays special attention to new computational, natural, cybernetic, algorithmic and ecological environmental architectural design. Furthermore, it aims to develop concepts like genetic, generative and emergence into the natural and digital world using genetic algorithms and digital evolutionary computational tools. Since the emergence of computational theories and methods in the past decades, extracted principles from natural systems have been influential in the design and computation domain. These biologically inspired means have impacted evolutionary architecture, by introducing computational form-generation techniques. Learning from natural models, one of the fundamental aspects of all biological systems is functional to integrity in terms of their performance as well as their interaction with the environment to approach a generative evolutionary morphogenetic computational design. (Bourdakis, 2013)

1.2. INTRODUCTION

As Lehman (2011) said: Space, structure, and form are three terms which reflect the traditional outward expressions of an architectural concept which has been developed in the mind of any architect. Consequently, this idea is taken further and goes through the design methodology of architecture. But essentially, the architecture conceptualization is much more sophisticated than the past concept. The architecture in depth is more than a surrounding envelope which merely exists in a state separated from its occupants and their objects and tools.

"There is a paradigm shift from the making of form, to the finding of form."

According to Kolarevic (2004), it is an important paradigmatic shift that needs to be taken into consideration; as such, evolutionary architecture is the best application to this concept. Evolutionary architecture investigates the fundamental form generating process in architecture, parallel to a wider scientific search for a theory of morphogenesis in the natural world. It proposes the model of nature as a generating force for architectural form. The profligate prototyping and awesome creative power of natural evolution are emulated by creating virtual architectural models which respond to changing environments through evolutionary morphogenetic computational design processes. Successful developments are encouraged and their evolvement helps keep the environment sustainable and aids designers to solve design problems and generate forms.

1.3. PROBLEM DEFINITION

1- New buildings are not friendly to the environment; they are only trying to cope with new technologies without paying attention to the effect of it and its relation with nature. (Schwinn, Krieg, Menges, Mihaylov, Reichert, 2012) where:
   - Designers don't put in consideration the effect of environment, site location and orientaion on their computational design form and its material.
   - Creating buildings which abandon the use of energy (electricity, AC units, etc...)

2- Biological studies and genetic researches aren't used in digital processes, material design and digital simulations in architecture. (Menges, Krieg, Reichert, 2013)

3- Designers are facing the challenge of finding the best computational solution within the context of many inputs, variables, restrictions and considerations; these directly affect their decisions and make the normal design process so difficult with many errors in the final solution, more over reaching the optimal design solution may lead to losing lots of time and effort.(Menges, 2012)

1.4. MAIN RESEARCH QUESTIONS

In this context, a number of questions are addressed in this research about the importance of evolutionary architectural design in contemporary digital designing process:

- What is the potential of such a digital design approach?
- Why evolutionary design is to be used?
- What are the important natural terminologies involved in evolutionary design?
- How ecological environments could be integral with digital technical innovation, new attitudes toward genetics, biomaterials, algorithms and science/design collaboration? Specifically, illustrating how it works "digitally grown" in the plant-generating software and genetic algorithms?
- How could evolutionary principles through genetics, bio-digital concepts and algorithms be applied in morphogenetic computational architecture?
- How could evolutionary design benefit from new digital design software, technology and involvement of nature?
- How could evolutionary morphogenetic computational process have evolved in genetic algorithms and programs as a designing tool to help in reaching the best solution for the design problems
- Hence, why do we choose meaningful, evolutionary architectural approach for design problems and generative design tools?

1.5. RESEARCH AIM AND OBJECTIVES

The aim of this thesis is finding how to link and apply biological, natural, algorithmic and genetic principles in evolutionary morphogenetic computational design. These principles are then abstracted in order to be used as specific design concepts and tools.

According to these premises, this thesis adopts the mission of investigating the evolutionary methodologies in the architectural design process, lighting the shade of fundamental form generating processes in architecture. However, architecture is considered a form of artificial life (bio & genetic), proposing a genetic representation in a form of DNA-like code-script. Then, it can be subject to development and evolutionary processes in response to the user and the environment.

The objectives of evolutionary architecture are to achieve in the built environment the symbiotic behavior and metabolic balance found in the natural environment. Consequently, it operates like an organism in a direct analogy of morphogenetic and evolutionary computational design with the underlying process of nature. (Frazer, 1995)

Hence, we can say the important objectives of the thesis are:

1- Exploring the potential of algorithms, bio digital and genetic-digital characters in getting a natural friendly design
2- Exploring the possibility of implementing and correlating selected biological, natural, genetic and algorithmic principles with morphogenetic evolutionary computational design to solve the challenge of having multi variable inputs and considerations in a design project.
3- Analyzing and evaluating a case study representing such a possibility and achieving the best design solution.

1.6. RESEARCH METHODOLOGY

This work is an analytical research utilizing an exploratory case study to achieve previously mentioned aims, it attempts to:

- Explore challenges that have often already been resolved in a natural and biological setting using computational genetic algorithms through incorporating concepts and techniques, such as growth or adaptation that have parallels in nature.

- Analyze the link between Science – Evolutionary Morphogenetic (bio & genetic architecture) – Digital technology. Resulting in a set of selected principles that could be applied in computational design.

- Apply optimization, adaptation, and many biological principles to design potential through using evolution of Bio-digital and genetic concepts using computational design methods, thus, leveraging our methods, talents and ideas to yield more generative built forms.

- Experiment with genetics and algorithms motor software, evolutionary processes, emergent systems, algorithms, parametric, scripting, etc. These last digital technologies have given us new production possibilities which are in turn leading to non-standard architectural formulations that resemble genetic principles (variation-mutation-hybridization). Further, software used in these experiments is Rhino, Rhino Script, Grasshopper and Rhino.

1.7. STRUCTURE OF THE THESIS

The research thesis includes three main parts consisting of five chapters, in addition to the introduction of research and the final conclusion as following:

Chapter 1: Introduction

In this preface, the research presents an overview of the thesis, introductory to the research, the core of the research problems and question, the aims and objectives, and the research methodology.

Section 1: Exploratory Study

Chapter 2: Nature Design and Digital Technology

This chapter demonstrates the evolution of the nature theory in architecture. Explaining the process of evolution and motives of this approach, it moves into exploring the sources of nature inspiration. Then, it shows the role of digital technology digital thinking and digital architectural approaches.

Section2: The Analytical Study

Chapter 3: Evolutionary Architectural Approach

This chapter undertakes the mission of exploring in details the essence of evolutionary architectural approach which is the main digital approach of this thesis.

Chapter 4: Generative Genetics and Parametric Evolutionary Design

This chapter presents the generative genetics in details and some biological concepts.

Section 3: The Applicable Study

Chapter 5: Morphogenetic and Evolutionary Computational Design

This is the start for the applicable study chapters, which presents the definition of morphogenetic evolutionary computation and their applications in architecture within some biological design principles

Chapter 6: Rhinoceros: A Design Tool for Generative Bio-digital and Genetic Evolutionary Design

An introduction to the used program and its plugins then a case study of Morphogenetic and Evolutionary Computational Design (Bio-digital and Genetics) using Rhino Script program with its plugins (Grasshopper – Galapagos – GECO) is introduced.

Chapter 7: Conclusion

In brief, the research presents the final concluded facts from the study

1.8. KEY WORDS

Evolutionary Architecture – Algorithms – Genetic Architecture – Bio Digital Architecture – Computational Design – Morphogenetic Design –Morphogenetic and Evolutionary Computational Design

1.9. THESIS STRUCTURE

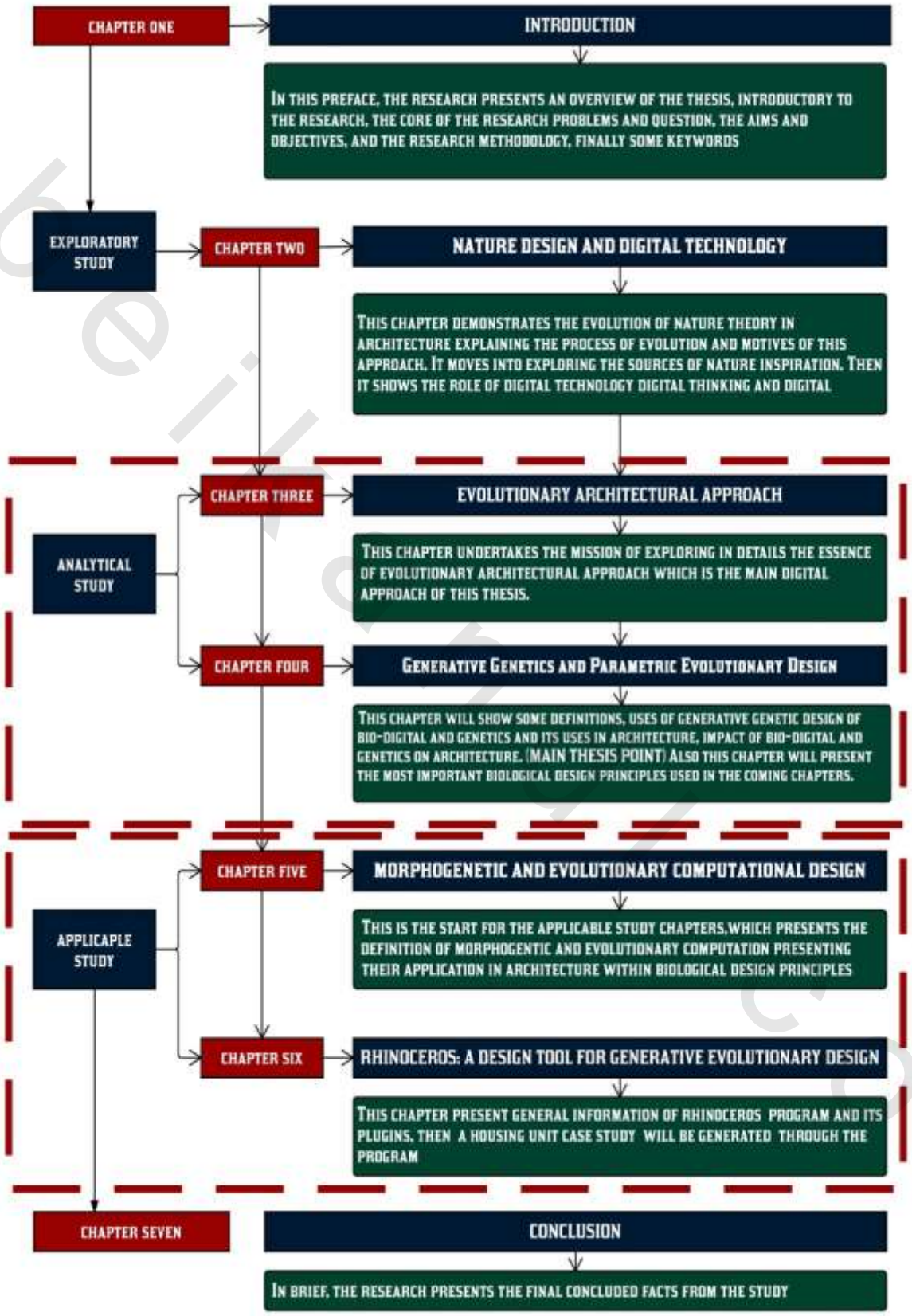

Figure (1- 1): Structure of the thesis
Source: Researcher 2014

CHAPTER 2.
NATURE DESIGN AND DIGITAL TECHNOLOGY

This chapter demonstrates the evolution of nature theory in architecture explaining the process of evolution and motives of this approach. It moves into exploring the sources of nature inspiration. Then it shows the role of digital technology digital thinking and digital architectural approaches.

Keywords:

NATURE, NATURE PRINCIPLES, SELF-ASSEMBLY, SELF-ORGANIZATION, ADAPTATION, EMERGENCE, ECOSYSTEM, GLOBLIZATION, CYBERNETICS, DIGITAL DESIGN, DIGITAL ARCHITECTURE, TOPOLOGICAL MODELLING, ISOMORPHIC SURFACES, METPHORIC ARCHITECTURE, PARAMETRIC DESIGN, EVOLUTIONARY DESIGN, GENERATIVE GENETICS

CHAPTER TWO

NATURE DESIGN AND DIGITAL TECHNOLOGY

CHAPTER STRUCTURE: EXPLORATORY SECTION