EVOLUTIONARY ALGORITHMS IN ISLAMIC ARCHITECTURE

OSAMA ALRAWI
Dept. of Architecture, Future University in Egypt, Cairo, Egypt
Email address: pleximotif@yahoo.com

Abstract. The cosmological nature of Islamic architecture makes it a useful case study for the capability of the adaptation, assimilation and accommodation with the development of evolutionary algorithms and their applications in architectural design. Genetic algorithm derives its structure from the observation of nature. We shall review the concept of intelligent agents and their organization into complex adaptive systems as well as genetic-type algorithms for learning and evolution. Since algorithmic art consists of generation of images on the basis of algorithms, algorithms can be viewed as a notation, and notation is something that music has but visual artefacts in general miss. This paper aims to discover the role of evolutionary algorithms in historical Islamic architecture. Also, we shall try to investigate the way in which the future development could occur not only through the discovery of new facts or theories, but also through the rise and dissemination of new visions having different explanation of Islamic architecture that considers it as a result of serious application of formation through evolutionary genetic algorithms.

1. Evolutionary Algorithms

In nature, evolution is mostly determined by natural selection or different individuals competing for resources in the environment. Evolutionary algorithms are ubiquitous nowadays, having been successfully applied to numerous problems from different domains, including optimization, automatic programming, machine learning, operations research, bioinformatics, and social systems (BLADOWSKI).

Usually grouped under the term evolutionary computation or evolutionary algorithms, we find the domains of genetic algorithms, evolution strategies, evolutionary programming and genetic programming (Figure-1). They all share a common conceptual base of simulating the evolution of individual structures via processes of selection, mutation, and reproduction (AJITH ABRAHAM). A new branch of mathematics, "algorithmic complexity theory", had been developed by Charles Bennett of IBM and so the claim was, it could measure evolutionary complexity. It is with cosmic evolution, with such inanimate things such as crystals, solar systems and galaxies. Cosmic and natural evolutions are the growth in complexity (JENCKS).

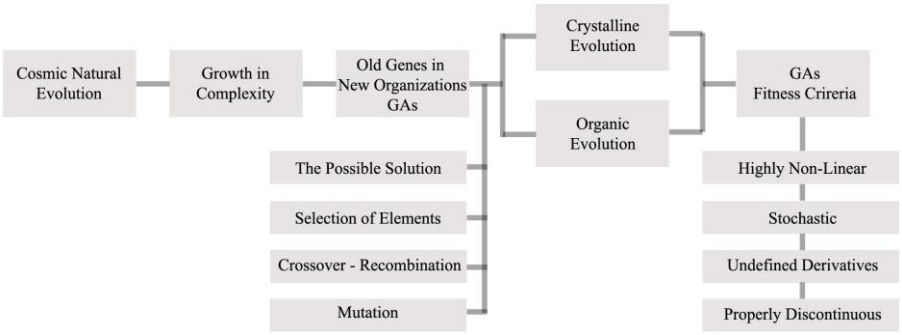

Figure 1. The main domain of Genetic Algorithms (*source: author*).

2. Islamic Architecture and the Emergence of Evolutionary Algorithms

Emergence is the creation of new organization that arises through the development of new relationships of control and constraint. The key to appraising increasing organization is to distinguish between "complicated" and "complex" systems. As a system becomes more complicated in order to solve local problems, there is no increase in flux or organization, but rather the adding of new parts that are the same with old parts. Increasing complexity, though, results in the elaboration of organization rather than the elaboration of just structure. In other words, complex systems are rich in organization, while complicated systems are rich in detail (Figure-2).

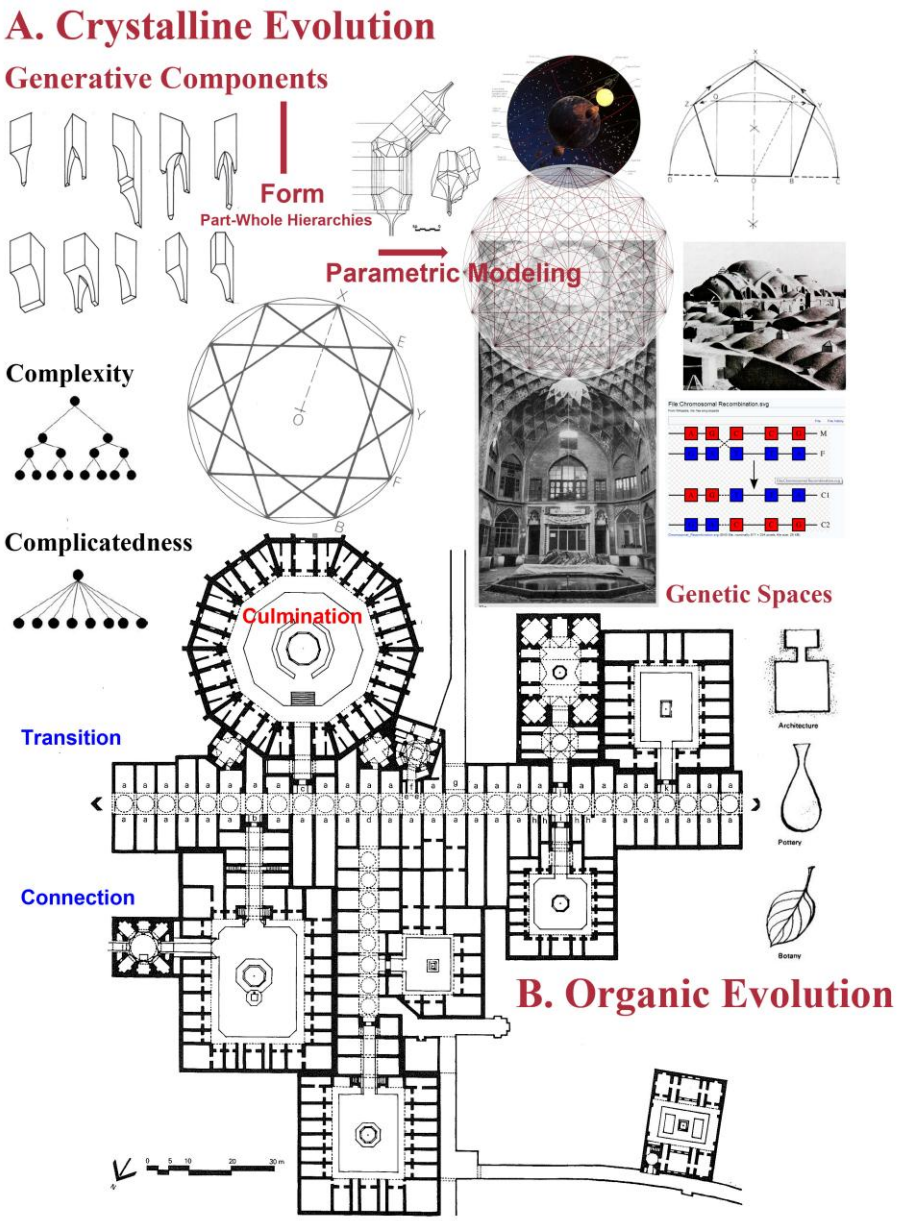

Figure 2. Evolution and Emergence in Islamic Architecture (*source: author*).

Complexity is created, in part, by nature using old genes in new organizational ways. Because of physical laws such as gravity, and the tendency for them to make all matter self-organize, the universe displays ever-increasing organization. On earth such self-organization precedes organic evolution by billions of years, and it operates according to different laws than natural selection. This could be called *crystallized evolution*: the tendency of all material systems, given the input of continuous free energy, to develop towards more crystalized or defined states. *Organic evolution*, like the crystalline variety, also has a general direction towards greater complexity and it is not only propelled by the same self-organizing forces but also by natural selection (Figure-2). Thus the two types of evolution, crystalline and natural,

combine to produce more highly organized systems and individuals. This is the main plot of the universe story, but it is a progressive drama that encounters many setbacks (JENCKS).

In Islamic architecture and urbanism space is also structured. In structured space, man knows where he is; direction is meaningful to him. Reinforcing this universal order are the corporeal creations of the macrocosm and the microcosm which exhibit with its strong emphasis on the family unit, provide an important sociological reinforcement for the centripetal organization of space and space usage (ARDALAN).

Design lives within two fundamental stages, the creative and the evolutionary. The *first* is that of producing the idea: this approach is built activating a logical jump between the existing and possible worlds that represent our wishes and thoughts. The *second* is the evolutionary stage, that of the development of the idea. This approach runs inside paths of refinement and increases in complexity of the projects. It involves the management of the project to reach the desired quality (RANDLY L). The architecture of traditional cultures demonstrates that it was the social constrains that conditioned the traditional urban form, backed up by shared values and correlated social conventions (BIANCA).

Most optimization problems are made up of three basic components (Figure-3). The *first* is the objective function which we want to minimize or maximize, the *second* component is the designation of a set of design variables that affect the value of the objective function, and the *third* component is the determination of a set of constraints that allow the design variables to have certain values (ELEFTHERIA). In this regard we could refer to Genetic algorithms (GAs) that forms randomized search and optimization techniques guided by the principles of evolution and natural genetics, having a large amount of implicit parallelism. Even though there is no formal definition of GAs, all of them consist of four elements.

The first is the population of chromosomes which represent the possible solutions of the problem. *The second* is the Selection of element and it refers to the part of the population that will evolve to the next generation. Selection is performed based on a fitness function that determines how "good" a solution is. The selection process is applied to each generation produced. *The Third:* Crossover (also called recombination), refers to the combination or exchange of characteristics between two members of the elite group defined by selection, by which offspring is produced. *The forth*, *Mutation,* in any case, before re-applying selection to the new population, mutation takes place. Mutation is a random event, occurring with a user-defined probability to only some of the new offspring. It is used to maintain genetic diversity by altering only a little piece of the new offspring (Figure-3).

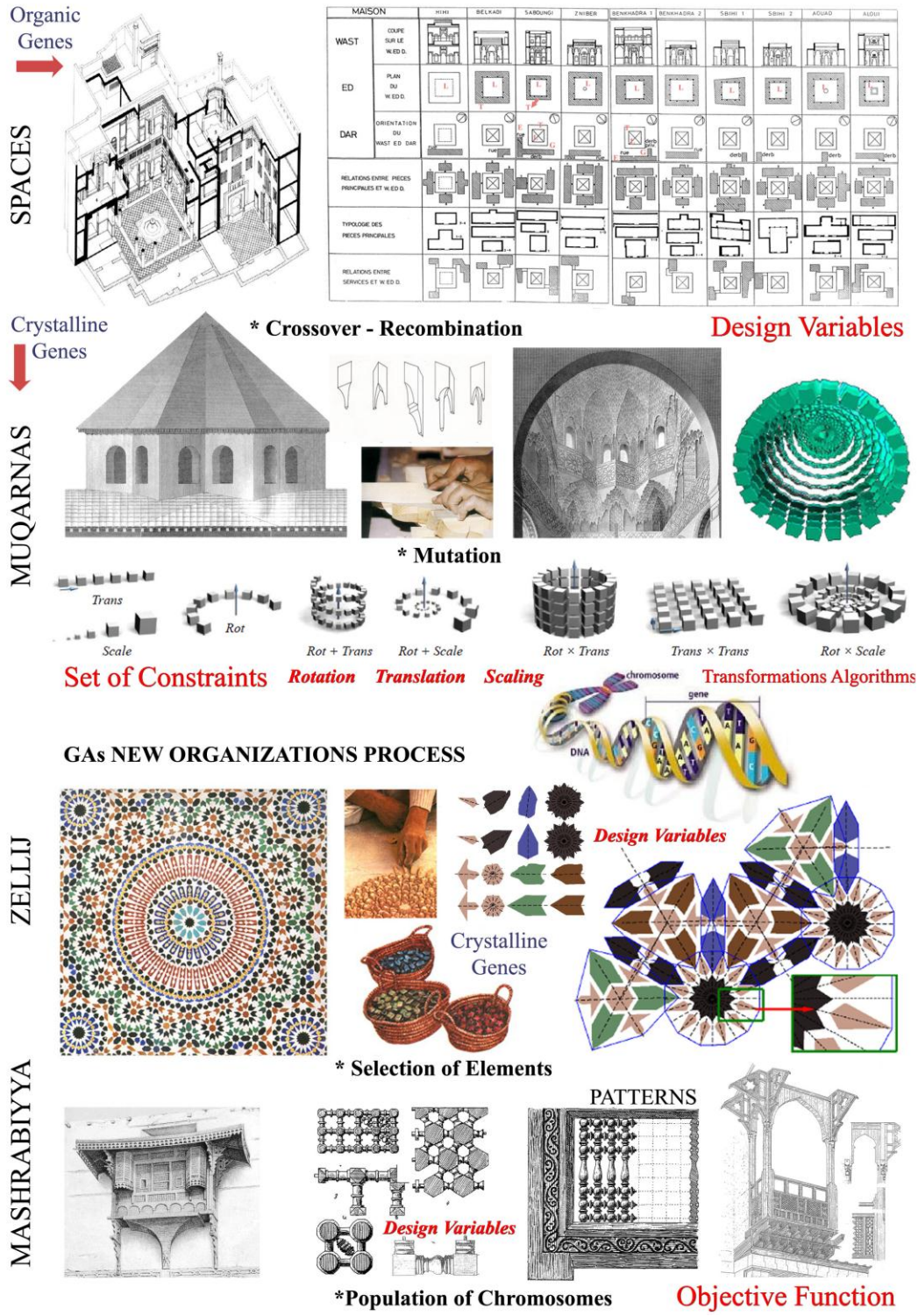

Figure 3. Elements of Genetic Algorithms in Islamic Architecture (*source: author*).

3. The Genetic Algorithms Fitness Criteria

Genetic algorithms provide a useful commencing framework since they already have a formal representation of various constructs and the combination and mutation operators (GERO). In architecture, form elements are architectural vocabularies that are simply some small, usually carefully chosen subset of the structures handled by some basic design system. Traditionally, architectural elements are walls, doors, columns, floors, rooms, windows, arches, ornaments, etc. Columns, beams and wall panels are elements of construction, and rooms are elements of composition. Architectural buildings are composed of those elements.

Repetition of the same types of those elements in a group of objects characterizes a style. For example, ribbed vaults repeatedly appear in most Islamic architecture especially in Iran and Uzbekistan. Variables of abstract shape patterns can be instantiated into shapes or patterns. In analogical reasoning, shape pattern schemas learned from one domain can be instantiated or applied in different domains. There are many possible generation methods, including instantiation, analogical reasoning, shape grammar and genetic algorithm (Figure-4).

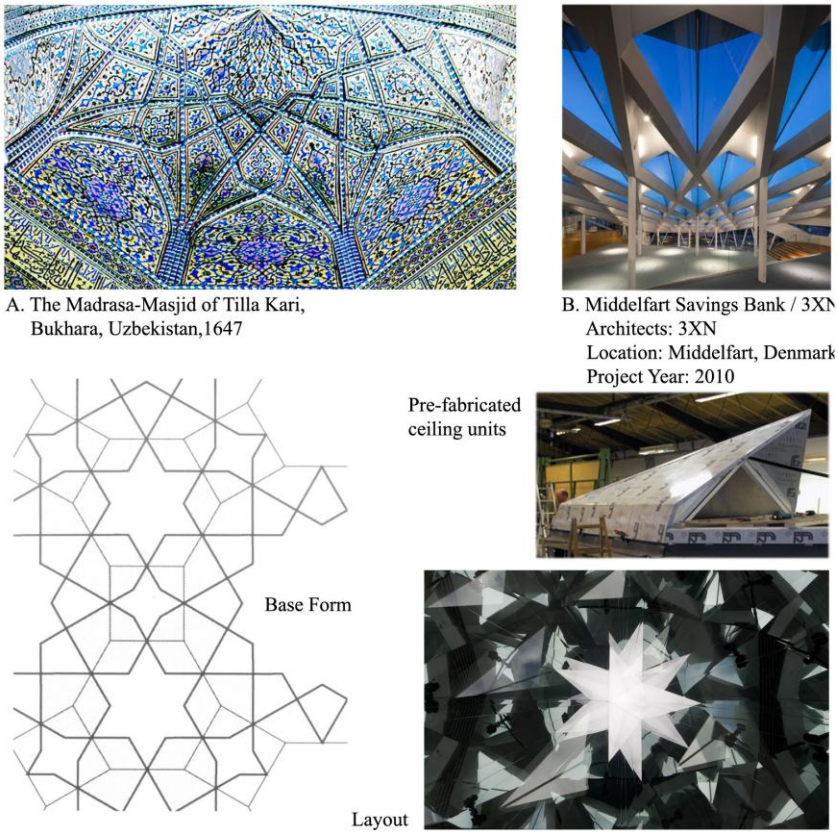

Figure 4. Objective functions of Genetic Algorithms and their fitness criteria (*source: author*).

Genetic Algorithms are best used when the objective function is: *First*, highly nonlinear; a nonlinear system is one whose output is not directly proportional to its input. *Second*, stochastic; a stochastic process is one whose behaviour is non-deterministic; it can be thought of as a sequence of random variables. Any system or process that can be analysed using probability theory is stochastic. *Third*, has undefined derivatives; the derivative of a function represents an infinitesimal change in the function with respect to one of its variables. Loosely speaking, a derivative can be thought of as how much one quantity is changing in response to

changes in some other quantity, and *finally*, properly discontinuous, as subgroups contains a number of a component that also contains a discrete subgroup of basic elements, after an appropriate choice of a base form.

4. Time Fixed vs. Timeless Architecture

The universe has a tendency to be interesting, and grow ever more so with time. Quality, superior organization and increasing sensitivity are built into the direction of the universe (Figure-5). There is the internal, spiral staircase of development towards more complexity. Today there is unusual mixture of science and visual languages, or design codes based on the myriad patterns of organization that the fundamental laws generate. The computer is particularly adept at revealing these patterns of nature, the fractals, strange attractors, complex morphological shapes of folding, and close packing.

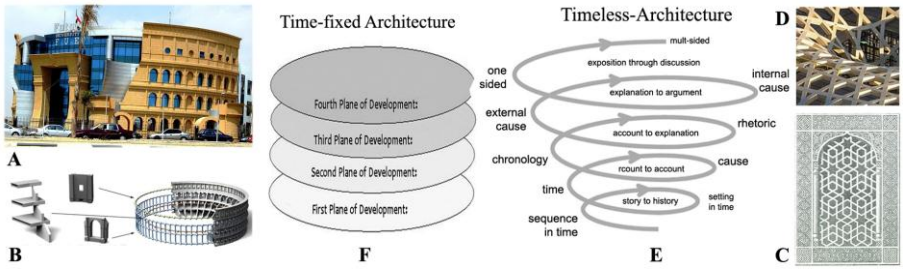

Figure 5. Growth and development in nature and architecture. A-Future University in Egypt, B- Roman Coliseum, Geometric Patter of a window in Qalawun Masjid in Egypt, D- Timber construction for the Yeoju Golf Club by Shigeru Ban: CAD/CAM by design to production. Reference: Geodesic Pattern, H. Pottmann. E- The growing spiral of development (Timeless-Architecture). F- The constant-static layers of development (Time-fixed Architecture) - (*source: author*).

This leads to architectural language that stems from structural or ornamental parameters and curved morphologies, complex elements that are often best explored through digitization. Qualities emerge from relationships between elements, or relationships between these relationships. Form relationships are a kind of syntax or compositional patterns that can be analysed and expressed formally. Genetic algorithms can use learned shapes and shape patterns as genotypes or phenotypes. Using genetic algorithms, many shape *patterns* can be produced (MYUNG).

Islamic Art and architecture, constrained, or maybe underpinned by the aniconic approach, concentrates on *geometric pattern* and draws attention away from the representational world to one pure form and meaning. To trace this in creation the direction is not backward but inwards (CRITCHLOW).

The fact that Islamic art was seen as purely decorative would bewilder the Muslim who can argue that the source of these "patterns" was indeed natural in that they explore the natural and cosmic order, and are also reflections of the timeless truth of unity. The principle of Unity brought into being an aniconic art in which the spiritual world was reflected in the sensible world not through iconic forms but through calligraphy, arabesque, geometry and rhythm. Islamic artists appropriated key elements from the classical tradition, and then elaborated upon them to invent a new form of decoration that stressed the importance of

unity, logic, and order. Essential to this unique style were the contributions made by Islamic mathematicians, astronomers, and other scientists, whose ideas and technical advances are indirectly reflected in the artistic tradition.

5. Conclusion

Deep analysis for this architectural heritage, proved the use of tools and techniques of evolutionary genetic algorithms regardless using this terminology in the history of this type of architecture. The reason for that is the cosmological nature of this architecture which was ideologically oriented toward the laws of nature which God had created in his universe. The laws of nature turn out to be universal (apply everywhere in the universe), absolute (do not depend on anything else), eternal (do not change with time), omnipotent (all-powerful), and creative (cosmogenetic). Primitive analogies are found at several levels between cosmic and human processes. The universe grows in complexity and its offspring grow in culture, as they experience and try to understand it. At different levels of reality, the universe is becoming the measure of all things and is wrapped in our daily life. Cosmo genesis is the metaphorical web that penetrates every area of life and matter, tying them together in a partly finished architecture.

Changes in Islamic Architecture and its future development need to use the tools and techniques of evolutionary algorithms as means to the rediscovery of God's revelations. Islamic Architecture within this context contains the means to enable man to see the forms of nature once again as a source of inspiration and multiplicity as so many reflections of the Unity which is both the origin and end of the order of multiplicity. Due to evolutionary algorithmic system that was proved to be resident in the core formation of Islamic Art Architecture and Urbanism, it is of great importance for future research to capture the patterns of these algorithms and treat them as a starting point to preserve the identity and character of modern Islamic cities.

In historical Islamic cities, form results from the delimitation of structured space. Numbers are the units of this spatial definition, and geometry expresses the “personality" of these numbers. Through the use of numbers and geometry, as mathematical expressions, the creation of shapes recalls the Archetypes.

References

AGOSTON E. EIBEN, ROBERT HINTERDING, and ZBIGNIEW MICHALEWICS, 2011, Parameter Control in Evolutionary Algorithms.

AJITH ABRAHAM, NADIA NEDJAH, and LUIZA de MACEDO MOURELLE, 2010, Evolutionary Computation: from Genetic Algorithms to Genetic Programming, Department of System Engineering and Computation, Engineering Faculty, State University of Rio de Janeiro.

ARDALAN, N. & BAKHITAR, L. 1973. The Sense of Unity- The sufi tradition in Persian architecture, Chicago, USA.

BIANCA, STEFANO, 2000, Urban Form in the Arab World past and present, Thames and Hudson, UK.

BLADOWSKI, JAKUB, Algorithmic architecture, Gdańsk University of Technology, e-mail: jakub_bladowski@o2.pl. http://nas.isep.pw.edu.pl/kok/journal/index.php/archive-issue/volume-2-year-2011-issue-1-january-march/file/20-algorithmic-architecture

CRITCHLOW, K, 1976. Islamic Patterns: an analytic and cosmological approach. New York: Thames and Hudson.

ELEFTHERIA FASOULAKI, 2012, Genetic Algorithms in Architecture: a Necessity or a Trend, Department of Architecture, Massachusetts Institute of Technology.

Francisco Albert Gil1, José María Gomis1 and Manuel Pérez, 2009, Reconstruction Techniques for Image Analysis of Ancient Islamic Mosaics, The International Journal of Virtual Reality, 8(3): 5-12.

GERO, JOHN S., 2006. Key Centre of Design Computing, Department of Architectural and Design Science, University of Sydney, NSW, Australia.

JENCKS, C, 2007.Critical Modernism: where is post-modernism going? Great Britain. Wiley Academy.

JOHN S. GERO, 2006, Key Centre of Design Computing, Department of Architectural and Design Science University of Sydney NSW, Australia.

MYUNG YEOL CHA, 2009, Style Learning: Inductive Generalisation of Architectural Shape Patterns, Department of Architecture Paichai University, Taijon Seogu Domadong 439-6, South Korea.

RANDLY L. HAUPT, SUE ELEN HAUPT, 2004, Practical Genetic Algorithms 2nd ed., Wiley, NJ, USA.

UJJWAL MAULIK, SANGHAMITRA BANDYOPADHYAY, 1999, Genetic algorithm-based clustering technique Department of Computer Science, Government Engineering College, Kalyani, Nadia, India.