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Fuzzy logic in architectural site planning design

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Abstract

This paper presents a fuzzy logic application for architectural site planning design. A residential settlement layout is the result of a complex design process aiming to manage the most advantageous location for all houses with certain objectives and constraints. The introduced fuzzy layout planning model will help designers to reach the optimum solution by supporting their reasoning patterns and decision making mechanism. This paper gives the general frame of the proposed analysis model with operational steps through a case study. To reconfigure it as a generative model for producing site layouts is the goal of further research.

1. Introduction

Housing design is not a merely architectural/interior design problem, but also a land use problem. Decisions about building-land relation are not only limited to massing (shape and size of the building) within a square meter or orientation (direction of the building) for daylighting, but also strongly refer to the location of a building in the settlement. The place of a house on a layout means accessibility, neighboring, scenery and many others, which affects the overall design and architectural quality of that house. Therefore, site plan design is the crucial part of housing design. Architects aim to develop a proper site plan, which can provide equal benefits and availability for each housing unit as far as possible. According to Biddulph[1], a residential urban design opens up or reduces opportunities for inhabitants, like how density (units per hectare) can define residential schemes and influence

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lifestyles. Wells, Evans and Yang[2] detail how planning decisions affect people's physical health and psychological well-being. An efficient planning provides better settlements at both urban and housing scales, which is required for social, financial and environmental sustainability.

In site planning, some basic and objective design elements such as step free pedestrian walks and weatherproofing shelters are required for the quality of life. Besides, a layout design mostly depends on subjective indicators like privacy and easy access to services. In that sense, site planning is a constrained optimization problem for each and all housing units; where various types of parameters take a part from zoning regulations to user preferences. Architects or planners intuitively handle all layout components with maximizing/minimizing functions of variables to create a site plan. Since it is inherently a very hard task, they may skip the quality of each house while designing the whole; thereby lose control of the process and final result. However, like many Computer-Aided Architectural Design (CAAD) applications, site planning may also be structured as a multi-criteria decision-making (MCDM) process by using a suitable computational model, which is the objective of this paper.

The design process of site layout planning does not cover a wide architectural literature. Nevertheless, some soft computing methods have already attempted to cover similar topics of research: the analytical hierarchy process (AHP) with fuzzy evaluation to decide most suitable areas for rural buildings by using physical, environmental and economic criteria[3]; evolutionary algorithms for architectural floorplan layout design and optimization[4,5]; also artificial neural networks (ANN)[6], genetic algorithms (GA)[7] and multi-element search algorithm[8] in facility buildings layout planning of construction projects. Layout planning was studied at urban level by Ligmann-Zielinska[9] as developing a multiobjective spatial optimization model for sustainable land use patterns in city planning. There are also several new papers focusing on site design at a relatively smaller scale. El Ansary and Shalaby[10] used GA for optimum site layout of residential houses, providing maximum visual privacy and minimum solar radiation for each settlement. Aksoy et al.[11] also worked on settlement scale with Pareto based non-dominated genetic algorithm. They produced layout alternatives for apartment house complexes according to sustainable design parameters, regulations and local climate conditions as objective functions. Baydoğan and Şener[12] tried Artificial Bee Colony (ABC) algorithm to decide the location and mass of buildings within the constraints of "Standardized Building and Zoning Regulation" in Turkey. All those articles were developed to assist that chaotic process of planning layouts with the help of techniques tolerating imprecision and approximation.

This study aims to develop a design support model for site plans by using fuzzy mathematics to evaluate housing units' locational quality. Fuzzy logic is preferred as the most appropriate soft computing method which can replicate designers' way of thinking while maintaining a certain satisfaction level for each residential unit. With predefined parameters and if-then control rules, fuzzy model calculates the value of housing locations on a site plan, and lists them from the most advantageous to the least. The model, as an analysis tool, can be used to assess an existing built-up site plan, which is useful for new regulations and operational development. However, the main objective of further research is to use the model in the preliminary design stage; to generate layouts with satisfaction values for location of houses. Later, optimum site plans can be produced by keeping all houses above a defined lower limit value or by assigning a value distribution ratio to the settlement. From this perspective, the proposed model can be useful for students and practitioners of urban design, planning, architecture and landscape; or whoever is in the position of decision making for land usage.

The paper first gives the methodological approach and conceptual foundation of the model encompassing relevant issues on fuzzy logic in architectural design. After the structure of the model is described, it is applied to a medium density summer housing settlement in Famagusta, Cyprus. The results of the analysis are promising in terms of giving a rational and sensible evaluation, which mostly match up with reasoning in human decision making. In the conclusion part, the potentials of the model as a layout generator in the early stages of design are discussed.

2. Fuzzy Site Planning Model

In design, site layout planning problems are dynamic, multi-objective and uncertain in nature. For each single house on the plan, location is a utility function that is to be maximized according to designer's knowledge and experience. When layout design is computerized, fuzzy systems are the best to carry out that subjective decision-making process. Fuzzy logic and set theory was coined by Lotfi A. Zadeh in 1965 as an alternative for binary logic. This approach allows partial belonging; values in the interval [1 - 0] from the highest level of compatibility (1) to non-compatibility (0). Zadeh[13] mentions three basic concepts of human cognition, which are granulation,