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Pedestrian circulation simulation based on Ant Colony System in site analysis

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ABSTRACT

Site analysis is among the first steps in the architectural design process. Diverse ways of the aforementioned step can cause dramatic changes in solutions and final designs. Considering different parameters that impact current pedestrian circulation system design, the process of site analysis has become more complicated and additional critical items can interfere with this process. Therefore, it would be worthwhile to quantify the qualities in order to evaluate site analysis. As the nature of Ant Colony System algorithm is compatible with the nature of site analysis, it has been used to simulate pedestrian circulation inside a proposed site. Based on the simulated diagrams of people movement with the assumption that the building is constructed, the designer or planner would be able to place entrances and different occupancies in appropriate locations, find the noisy zones, and have a reasonable understanding of the pedestrian circulation in the proposed site.

1. Introduction

Site analysis is an essential part of architectural design. This leads the output of a design to be in congruence with outer and inner requirements. Site analysis reveals different potentials of sites, and therefore directs the design process in a more compatible approach with its environment. The aim of the whole process is to satisfy the design requirements to the highest possible degrees [1].

There are plenty of interrelated arguments in architectural design process. Recently emerged circumstances have made it more complicated. Increasing population, global effects of industrialism and crucial needs for sustainability can be mentioned as some of the issues that need further investigations. Therefore, since 1960s computer technologies with different problem solving methods have assisted architects in design process [2]. These methods facilitate design process in analyzing, space layout planning, thermal simulation, objective modeling and etc.

There have been different inspirations from natural mechanisms implemented in architecture. The mentioned ideas vary from simple concepts, like the idea of bridging by observing a fallen log [3] to different algorithms derived from nature [4–6]. On this paradigm, Ant Colony Optimization (ACO) algorithms introduces a probabilistic technique for solving computational problems which can be deduced as finding best routes through graphs [7,8]. The ACO metaheuristic algorithms were inspired by the foraging behavior of real ants and is characterized as a distributed, stochastic search method based on the indirect communication of a colony of ('artificial') ants [9,10]. This method has been implemented in some recent research on simulation of crowd movements in a research on human pedestrian movements, which focuses on the movements of pedestrian especially when the crowd is panicked [9]. A research has studied optimization of a site layout affected by the mutual interaction of facilities. The aims of this paper are minimizing travel distance, decreasing materials handling, and avoiding the obstruction of materials and plant movements. Lam et al. [11] revealed 20–60% reduction in the cost of materials handling by the adoption of an appropriate facility layout Lee [12] has worded on the reduction of the total walking distance of passengers to and from various facilities. The author has proposed an integrated model that estimates the total walking time of a passenger by simulation and searches for a near-optimal layout by ACO. Lee [12] indicates that the results showed that it would save passengers time and would improve the service efficiency of the station. An ACO algorithm has been proposed for defining the signal settings of each intersection of an urban network which would effect on costs and on user route choices. The artificial ants has two kinds of behavior in that research; first, that is based on the response to pheromones and second, the innovative one that is based on the pressure of an ant stream [13].

This research seeks to propose a method to simulate pedestrian circulation. Previous studies have applied different methods for

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simulating pedestrian travels and human behavior in route finding. These studies range from probabilistic methods to metaheuristic algorithms varying from travel distance analysis in health care facilities to transportation analysis [14–17]. This paper utilizes ACO algorithm to simulate pedestrian movement in a park as the case study.

2. Materials and methods

As part of the site analysis process, the pattern of circulations around the proposed location has an essential effect on topological arrangements. Indeed, it helps to choose proper locations for entrances, clarifies noisy and silent zones, and altogether gives a comprehensive understanding of movements around the special site.

Human movement in a site determines some of the most important characteristics of the space. For instance the entrances are the openings of a building that should have some special characteristics such as being easily found as its simplest essential parameter. This means the mentioned component should be implemented in a place that allows people to have the optical connection with the least obstacle. Beside visual concerns, ease of access is another criterion that illustrates the relation of crowded zones and entrances.

As an architect or a group of designers, that is supposed to design a building in the supposed site, one of the important sets of data that should be considered from the very first stages of design is the considerations of sound zones. The aforementioned parameter would be more imperative in some special cases or maybe more important in some special zones compared with others. As a considerable portion of the noise resources are generated by human, such as the noise of vehicles, scrutinizing people movement would considerably show the mentioned zones. It reveals the routes that are used more frequently. It also helps to have a realistic imagination of the densities of people in different zones.

ACO algorithms help to simulate pedestrian circulation and are efficient ways for route finding. It simulates pedestrian circulation based on dimensions, predefined attractive points, and some statistic data. This paper seeks to simulate pedestrian circulation with the help of ACO algorithms and utilizing Matlab R2012a software. Different steps of the process are described below:

1. Identifying the number of entrances and the proportion of people who have entered through each entrance to the total number of entered people through all entries.
2. Proposing a graph from feasible routes in the park.
3. Assigning the attractiveness to each node based on statistics and expert decisions.
4. Calculating the possibility of all routes for each entry.
5. Selecting the direction for entrance based on previous step.
   a. Running the model for each entry.
   b. Multiplying the greatest possibilities of each entry to the related number of entered people.

Honarmandan Park, located in Tehran, Iran, is chosen as the case study of this research (Fig. 1). This selection was due to the grid of the pedestrians, buildings, and green spaces around the construction site, which create a big challenge for the site analysis. Furthermore, this park has historical background and has been used for different artistic exhibitions such as national biannual sculpture exhibition. Therefore, there are different nodes with different degrees of attractiveness that should be considered in site analysis. Due to the function of different constructions inside the park (Fig. 2) and the development guide, it has been supposed to design a library at the selected zone, which is showed with character 'D' in Fig. 3.

2.1. Entrances

As illustrated in Fig. 2, the park has 6 different entrances. Inquiries show that each of these entrances have their own potential and play different role in attracting people to come through. Of course this depends on diverse parameters like the direction of one way road around the site, the building functions outside the park, and many other factors. Table 1 shows the number of people who has entered the park through each one of them. This data shows the average number of entered to the park based on the

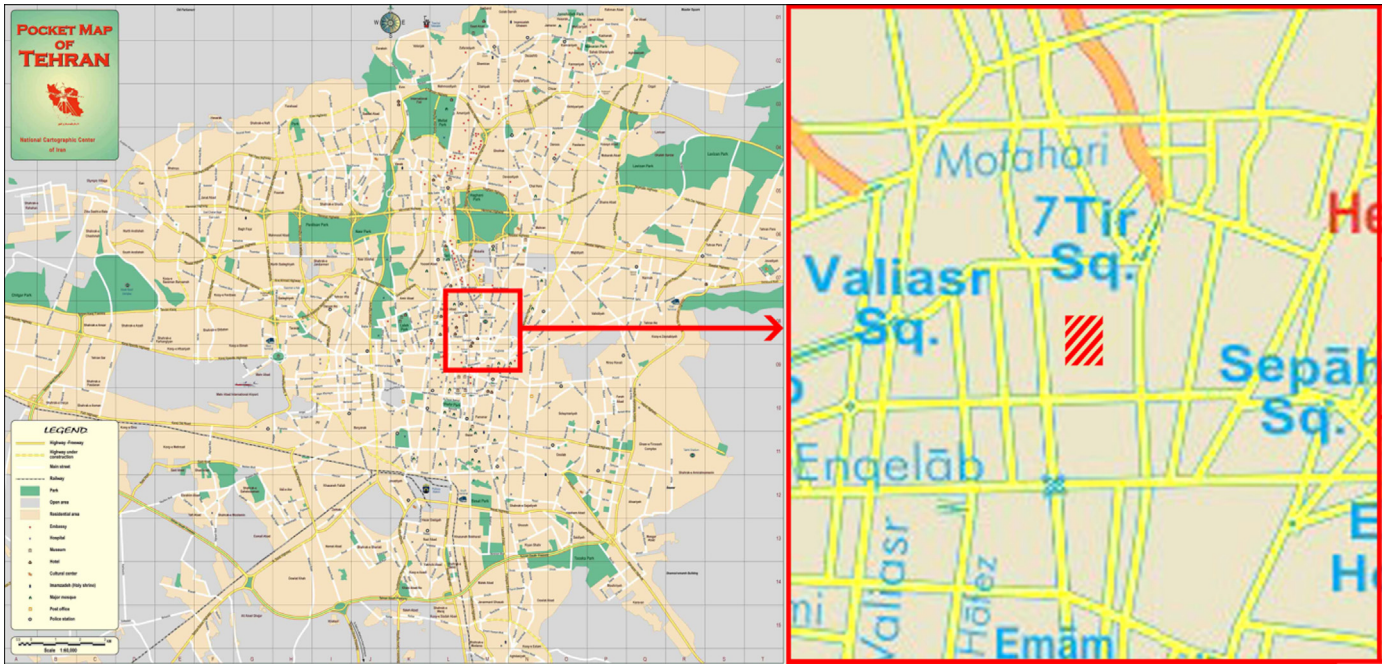

Fig. 1. Left: Map of Tehran (Iran) [18]; Right: Location of the site [19]. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)