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Evolutionary optimization technique for site layout planning

A.M. El Ansary[a,*], M.F. Shalaby[b]

[a] Department of Civil and Environmental Engineering, Western University, London, Ontario, Canada N6A 5B9
[b] Geometric Modeling and Scientific Visualization Center, King Abdullah University of Science and Technology (KAUST), Saudi Arabia

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ABSTRACT

Solving the site layout planning problem is a challenging task. It requires an iterative approach to satisfy design requirements (e.g. energy efficiency, skyview, daylight, roads network, visual privacy, and clear access to favorite views). These design requirements vary from one project to another based on location and client preferences. In the Gulf region, the most important socio-cultural factor is the visual privacy in indoor space. Hence, most of the residential houses in this region are surrounded by high fences to provide privacy, which has a direct impact on other requirements (e.g. daylight and direction to a favorite view). This paper introduces a novel technique to optimally locate and orient residential buildings to satisfy a set of design requirements. The developed technique is based on genetic algorithm which explores the search space for possible solutions. This study considers two dimensional site planning problems. However, it can be extended to solve three dimensional cases. A case study is presented to demonstrate the efficiency of this technique in solving the site layout planning of simple residential dwellings.

1. Introduction

Site layout planning is complex and comprises a large variety of factors (e.g. sustainability, esthetics, and visual privacy). Planners face challenges to satisfy all these factors especially in the lack of an automated approach. The planning process mainly depends on planners' experience and common sense. The project manager or planner usually performs the task of preparing the site layout based on his/her own knowledge and expertise. Apparently, this could result in layouts that differ significantly from one person to another. To put this task into more perspective, researchers have introduced different approaches to systematically plan the layout of construction sites (e.g. Li & Love, 1998; Yeh, 1995). These approaches differ from one another in the level of detail they provide. Some of these approaches focused on arranging a set of predetermined facilities (e.g. warehouses, job offices, and various workshops) on a set of predetermined sites. Also a previous investigation conducted by Osman, Georgy, and Ibrahim (2003), presented integration between computer-aided design (CAD) platforms and optimization capabilities of genetic algorithms (GAs) to minimize the total transportation costs between facilities. Others (Tuhus & Krarti, 2010; Wang, Zmeureanu, & Rivard, 2005), presented multi-objective optimization models coupled with an energy simulation program to optimize building shape and building envelope features in green buildings. These models considered building envelope features in the optimization analysis including wall and roof constructions, insulation levels, and window types and areas. A multi-objective-optimization was also utilized in a previous study by Sariyildiz, Bittermann, and Ciftcioglu (2008) for the positioning of houses in a residential neighborhood. The main objective of this study was to place buildings in a favorable configuration constrained by two objectives, which are the performance of the garden in the south direction of each house and the visual privacy experienced for the south facade of a house. To the best of the authors' knowledge, the optimum building orientation and location, which affects the performance of a sustainable building, is not investigated. In addition, all these previous approaches did not provide a level of detailing to solve the problem of visual privacy between neighboring dwellings, which is considered as the utmost requirement in the Gulf region.

In Gulf Cooperation Council (GCC) countries, which include the Kingdom of Saudi Arabia, nearly 80% of household electricity is used for air conditioning purposes (Akbari, Morsy, & Al-Baharna, 1996). Moreover, it is unfortunate to note that electricity generation in Saudi Arabia is completely dependent on the unsustainable practice of burning fossil fuels, which causes major environmental impacts on air, climate, water and land as stated by Alnatheer (2006). Given recent energy concerns, there has been a considerable interest in recent years with regard to the concept of sustainable architecture. This places an emphasis upon natural energy sources and systems with the aim of achieving building comfort through interactions between the dynamic conditions of the building's environment. For example, the placement of a window in a sustainable building is of the greatest importance as it could provide effective natural light,

* Corresponding author. Tel.: +1 519 619 6733.
E-mail addresses: aelansar@alumni.uwo.ca, aymanelansary76@gmail.com (A.M. El Ansary).

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comfort cooling and ventilation. On the other hand, such placement plays a major rule in the visual privacy of neighboring dwellings.

Due to the improvement of economy in the Gulf region, several construction projects have been started. Many of these projects are directed toward another type of housing known as the compound. These compounds are varying in size from small clusters of dwellings to a population of a small town. The planning layout of these compounds needs to provide both sustainability and visual privacy as an important socio-cultural factor.

The main objective of the current study is to provide these factors by developing a numerical tool that is capable of selecting the set of design variables, which leads to the desired optimum site layout. This numerical tool integrates the object oriented features of MATLAB, and a genetic algorithm optimization technique built in-house. The outline of the remainder of this paper is as follows. In the next section, the problem is described in detail including an example showing how the authors got motivated to conduct the current research. This is followed by Section 3, where the optimization technique and the assumptions included in the analysis are discussed. Section 4 provides a detailed presentation and discussion of the results through a case study. Finally, in Section 5, the main conclusions drawn from the study are presented.

2. Problem description

In most large residential compounds that are newly constructed in Saudi Arabia, the main goal is to place the clusters of dwellings in a defined area of land in such way that provides maximum visual privacy for each settlement. In addition, due to the desert climate in this region, it is desired to locate most of the windows in the North direction to avoid intense solar radiations.

The current investigation is motivated by the idea of providing a technique to facilitate the planners' decision-making process for site layout planning problems. In such type of problems, comparisons between alternatives should be conducted to provide a reliable assessment result. As such, in order to direct the current research to what practitioners need, a feedback from experts is needed.

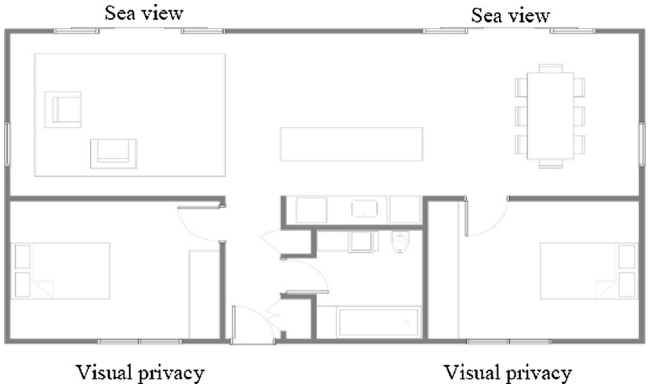

Fig. 1. Sketch plan of a typical residential house.

2.1. Motivation of the study

A number of experienced planners with different years of planning experience have been selected to develop a site layout planning of a typical residential house as shown in Fig. 1. They have been asked to provide a site layout of four typical units in a specific piece of land to achieve minimum visibility to bedrooms from surrounding settlements and maximum sea view for house facade. The area of the specified land was chosen such that the planners should face difficulties to achieve design requirements. Fig. 2(a) shows the best practical layout chosen from all layouts proposed by the experienced planners. It appears clearly from this layout that both visual privacy of bedrooms and direction of facade toward sea view are achieved. By applying the proposed numerical tool to the

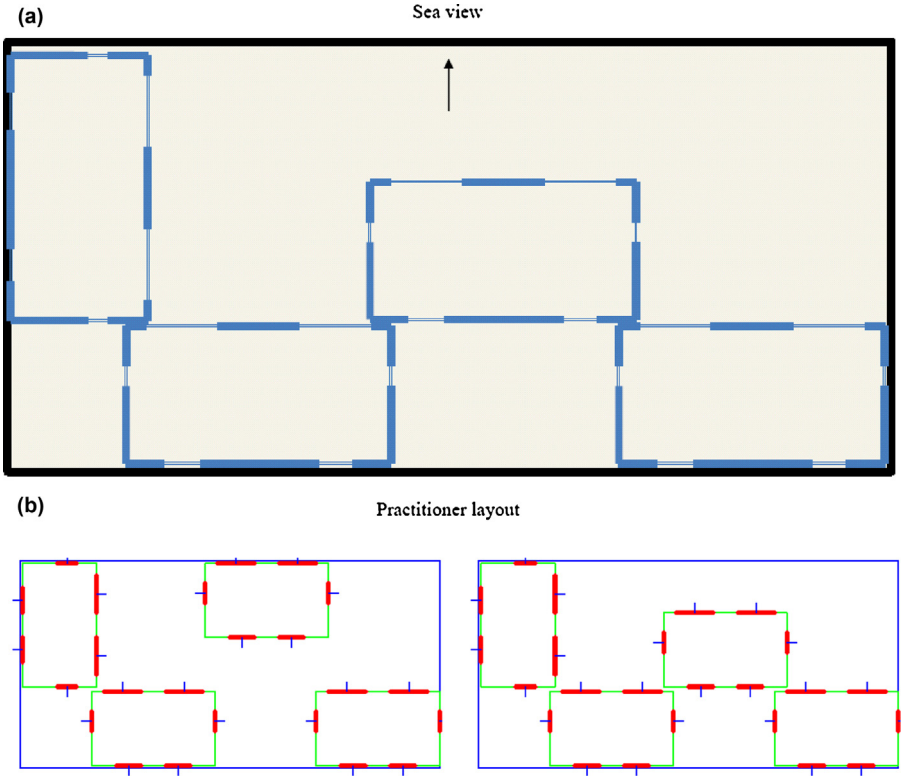

Fig. 2. (a) Layout proposed by practitioners. (b) Optimum solution with distance constraint (left), optimum solution without distance constraint (right).