Computer Aided Design-Based Layout Model for Site Planning

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Abstract

This paper presents a computer-aided design (CAD)-based site layout model designed to account for the diverse nature of construction sites. In the proposed, model, the site layout problem is represented by a flexible object-based model. The model allows the configuration of physical objects and their encapsulated attributes to suit the unique demands of each project. This feature facilitates the transfer of experts' knowledge to a set of libraries imbedded in the developed model. The paper describes the structure of the proposed model and its four components: (i) user interface; (ii) database; (iii) project modules. The functionality of these three components and their interconnectivity are also discussed. The developed model is implemented in a computer system that operates in CAD environment and makes use of object-based design concepts.

1. Introduction

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Front-end planning of site layout before commencement of construction can have a significant impact on the efficiency of site operations and/or the cash flow associated with resource management [10]. A well-planned site can: (i) minimize travel time; (ii) decrease time and effort spent on material handling; (iii) increase productivity; and (iv) improve safety, and hence decrease construction cost and time. However, recent site-visits and interviews with superintendents and site managers, as well as the literature [4], reveal that site layout planning is often ignored in the planning phase of construction projects. This can be attributed to the fact that it is not commonly considered a defined task, and, consequently, is not allocated a proper budget. This discourages construction teams from devoting the time and resources required to perform this task efficiently. Site planning could be a challenging task that requires good knowledge of different aspects of the construction processes involved, as well as related procurement schedules. To prepare a layout for a site, the planner has to extract information from various sources in different formats such as drawings, spreadsheets, bar charts, and text documents. To date, no standard tool has gained wide, acceptance among. Construction personnel to aid in this task [12]. In practice, space allocation on construction sites is typically carried out on a first-come first-served basis, which could result in chaotic sites arid productivity losses.

Due to the complexity and large number of factors involved, computers were identified as an efficient tool to help site planners as early as the 1960s, particularly for layout of industrial plants [15]. Over the last few decades, several attempts have been made to formulate the process of site planning and implement it in automated systems CORELAP [9,11] was one of the first computer models developed for plant layout using operations research (OR) techniques Recently, artificial intelligence (AI) emerged as a viable tool to analyze site layouts and provide near optimum solutions to this problem (knowledge-based systems: [1,3,5,6]; neural networks and genetic algorithms: [7,8]). The main advantage of AI methods lies in their ability to deal with inexact, incomplete, and/or ill-structured problems. Other hybrid models have been developed to benefit from aspects of different techniques. Move-Schedule [16] is a dynamic space scheduling system that incorporates experts' knowledge in its optimization process Cheng and O'Connor [2] integrate a knowledge-based approach in a model developed using geographic information system (GIS). While these models address site layout with different assumptions, one or more of the

0-7695-3038-9/07 $25.00 © 2007 IEEE
DOI 10.1109/ICCIT.2007.64

following shortcomings can be detected in the system referred to above:

(1).They limit the optimization process to minimization of travel effort. Yet in practice, the efficiency of a layout is judged by a number of other features including safety and security, which are not a function of travel effort.

(2). They utilize fixed construction site elements, which generally results in limited number of temporary and permanent facilities that can be used to set up a project. Consequently, these systems are rigid and can only handle single-problem scenarios. Any change in logic or requirements calls for restructuring these systems, and, accordingly, rendering them impractical.

(3). They do not support user-system interaction and do not allow the utilization of the user's experience and knowledge. Despite the capabilities that computerized systems provide, site planners prefer to alter decisions made by a computer system based on their knowledge and experience.

2. Proposed Model

The proposed model could essentially be viewed as a space planning model that considers common industry practice and accounts for a set of constraints related to productivity, safety, and security. The construction site is modeled using a set of objects, along with their functionality and interrelationships.

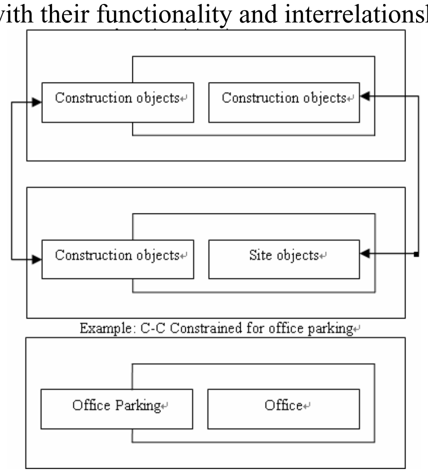

Figure 1. Structure of a constrained object

These objects are grouped in three categories: (1) site objects, which include existing elements on site such as buildings and service lines (e.g., phone, gas, and electricity) that affect the placement of other objects on site *Site objects* have a predetermined location and are generally unmovable; (2) construction objects, which include items that enter the site during the course of construction. The objective of site layout is to find the optimum or near-optimum locations for these objects. In fact, construction objects can be defined as movable items that occupy space on site. As such, construction objects address a range of items that are diverse in nature such as equipment, materials, temporary offices, parking, storage, and workspace areas; (3) constraint objects, which contain rules defined to represent the relationships among site objects and construction objects, which, when applied, satisfy the layout planning objectives. These locating rules, along with the relative weights assigned to them, constitute the knowledge base of the model. Constraints can exist between a construction object and a site object (C-S constraint), or between a pair of construction objects (C-C constraint) as illustrated in Fig 1 [14]. For example, a C-C constraint for office parking limits the distance between parking area and temporary offices on site. In the proposed model, the site layout problem is formulated as one of locating a set of construction objects while respecting the locations of site objects and satisfying the constraint objects. The structure of the model is based on the three categories of objects referred to above. These objects, through their attributes and methods, support the functional requirements envisaged for site layout and affect the way site layout problem is represented. The model presented here aims at assisting site planners and superintendents in performing their task efficiently. In doing so, the model provides users with the knowledge required to design an efficient site layout in an effort to avoid cost overruns, schedule delays, and unsafe working conditions.

2.1. Model architecture

The model consists of three main components: user interface, database and project module (Fig. 2) [13]. The user interface facilitates data entry and acquires problem-specific information and knowledge. The database integrates three libraries: site library, construction library, and constraint library. The project module assists users in initiating a new project by defining the requited objects. A detailed description of these three modules is provided in the following sections.

2.2. Proposed Model

The knowledge and expertise used to prepare a site layout are difficult to quantify. This represents a communication problem that has roots in knowledge acquisition and knowledge representation [2].The user interface of the proposed model is designed to interact with users at two different levels The first level provides the domain knowledge expert with tools to enrich the model's knowledge and its databases. This allows planners to apply their individual problem-solving strategies, and thus directly contribute to the enrichment of the knowledge base of the model. This feature eliminates the traditional need of a knowledge engineer for acquiring and structuring experts' knowledge, and hence decreases the risk of misinterpretation and incomplete acquisition of relevant knowledge. The extracted knowledge referred to above is represented in a set of rules and objects stored in the database of the model. Once the model is set up by the expert at this level, these rules and objects' data are saved into the database. These rules can later be used by a nonexpert at the second level, as long as the overall design conditions and requirements have not changed. In this case, the model provides ready-to-use data in its libraries and the user has to select the required objects, or use the default settings "as is". Hence, at the second level, the model can assist less experienced project team members by providing decision support for defining the requirements and problem setting for the layout of construction sites.

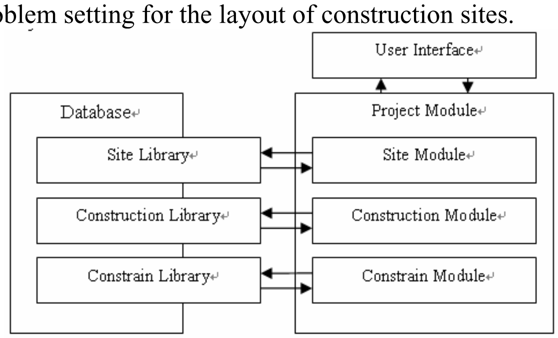

Figure 2. System architecture

2.3. Database

The database is designed to facilitate the storage and retrieval of objects. Libraries of defined objects in the three categories of "site", "construction"; and "constraint" are stored in the database. The libraries contain initial objects that can be selected to set up a site layout project. However, users can also add new objects in each of the respective libraries. This way, the libraries get populated as they are used. More importantly, this process addresses the needs and supports the planning strategies of each individual user. Upon the graphical creation of an object, the model prompts the user for the nongeometric input for that object. This information is then merged with the geometric data of the object, stored in the built-in database of a computer-aided design (CAD) system, to form a record in the object's relative library. There is a two-way link between the record and its corresponding physical object that appears on the graphical screen, which facilitates retrieval of the information linked to a physical object, or, conversely, finding of the physical object based on its record in the database.

2.4. Database

It is in the project module that a site layout problem is configured. In this module, objects from each of the model's three categories are "defined" in their respective submodules: site module, construction module, and constraint module The term "define" refers to selection from a library, modification of existing objects, or creation of new ones, An instance of each "defined" object is sent to the "project palette" representing the requirements for the project at hand. At this instance, the project is configured, and from this point on, the model deals with the objects in the project palette only.

3. Implementation

Computer implementation has been developed, as a proof of concept, based on the model described above. The system is coded using Visual Basic for Applications (VBA) 6.0 in AutoCAD® 2002 environment, and utilizes Microsoft Access® 2000 as the system's database VBA provides a seamless link between the system's user interface, AutoCAD, and the

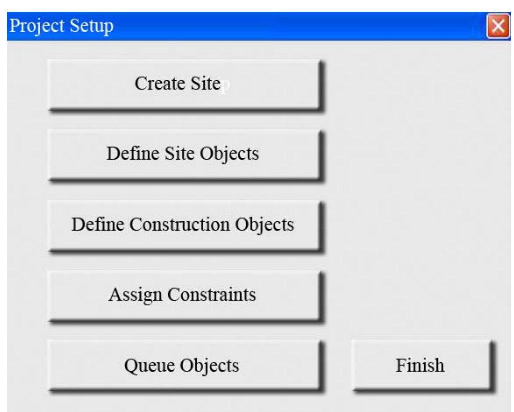

Figure 3. Steps of project setup

database. Since AutoCAD is a commonly used CAD tool for preparing project drawings, it will facilitate the reusability of previously generated drawings. The drawing capabilities of AutoCAD make it possible to generate various shapes with the desired precision when designing construction objects and site objects. Using a CAD tool also facilitates graphical data entry for objects.

Fig 3 shows a screen developed to assist in activating five sequential functions needed to start a new project. Creating site boundaries or the geometry of an object can be carried out using one of three options: (1) insert from file——this option is used when the geometry of the object is readily available in a file. It can be inserted into the project screen, where it will be recognized as an object by the model; (2) draw in AutoCAD——this option is used when the object is not readily available, and the user chooses" to create it using AutoCAD environment. Upon the selection of this option, the model passes the control to AutoCAD, prompting the user to draw the object. When the drawing is finished, the model captures the object and takes back the control; (3) aided drawing-this option is used when the object is not previously drawn in a file, and the user is not familiar with AutoCAD. The form designed to aid the user in creating the geometry of an object. The user, in this case, is required to input data relevant to the geometry of the object, which is either the coordinates of its key comers (vertices), or the length of its edges and the angles between them. It is important to note that the generated shapes are neither limited to rectangles nor to the rigid pattern itself.

Upon creating site boundaries, site objects are defined using the interactive screen. The screen mainly consisted of two tables; the table on the left provides a gallery of site objects that exist in the site library along with their properties. The user can select site objects from the library and add them to the table on the right, which represents the project palette. Once an object is added to the project palette, an instance of its graphical representation is printed on the AutoCAD screen. To create new site objects that is not readily available from the site library, the user is first prompted to generate the geometry of that object using one of the aforementioned methods. The user is then required to input the nongeometrical properties of that object. The geometric properties of each physical object are stored in the built-in databases of AutoCAD. These properties are coupled with the object's nongeometric properties stored in the model's database. A dynamic link from each physical object to the project palette is established so that the data incorporated with that object can be accessed and modified from within AutoCAD. In addition to the three previously described methods for creating an object, the user can also make use of the "edit" command, which facilitates the reuse of object(s) that need(s) minor changes to suit the current project, and avoids recreating similar objects. Defining construction objects is similar to that of site objects. The main difference between construction objects and site objects is that the value of the location property of construction objects is null at the beginning of the project. This property gets set as construction objects are located on site.

Subsequently, the user can assign constraints to construction objects, making use of the interactive screen shown in Fig. 4, In this case, the user can select from a list of default constraints attached to each construction object and assign weights to signify the relative importance of these constraints. The model provides a list of topographical relations among objects such as 'close to', 'far from', 'west of', 'north of', and 'visible from'. The list of constraining objects consists of all site and construction objects defined for the project at hand. A proximity weight can be assigned to each constraint object by the user to

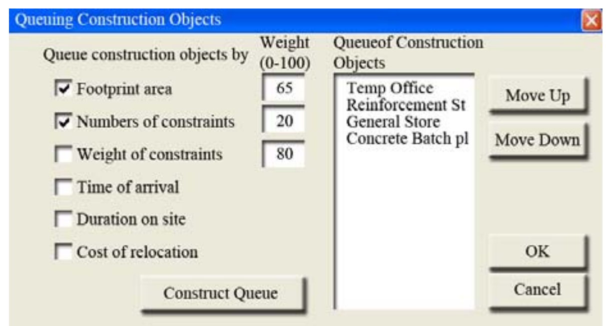

Figure 5. Queuing construction objects

express its importance over other constraints. This allows users to implement locating constraints other than minimum distance. For example, to apply a security constraint when locating a stack of electrical equipment and material, one can assign constraints such as 'visible from' and 'close to' guardhouse. Alternatively, they can be locked 'inside' a trailer or a warehouse. Upon completing the process related to creation of site (site objects, construction objects, and constraint objects), construction objects are queued based on the user-selected criteria and its assigned weights, making use of the interactive screens shown in Fig. 5.

4. Conclusion

This paper presented a CAD-based model for site layout planning along with its general architecture. The basic components of the system and the interconnectivity among them were described. A computer implementation of the proposed model was introduced. The model has a number of interesting features: (1) it provides a flexible support of a wide range of objects for site-planner. This permits the setup of different construction projects by selecting objects of three libraries; (2) the system has a built-in feedback to support the development of new objects and/or update existing ones. This allows for the gradual expansion and enrichment of the system's database and the supporting libraries; (3) site space analysis is done geometrically. This feature facilitates easy visualization of site planning process and provides a range of ranked near-best solutions to encourage user participation in the layout process; (4) the system allows site planners to decide on search criteria based on their knowledge and expertise. It also allows for experimenting with different rules and comparing the final layout results. Most importantly, unlike the previously developed models, it can readily accommodate further changes in the setting of a project and account for other locating constraints including safety.

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이 백서는 다양한 건설 현장 특성을 고려하여 설계된 CAD (Computer-Aided Design) 기반 현장 레이아웃 모델을 제시합니다. 제안 된 모델에서 사이트 레이아웃 문제는 유연한 객체 기반 모델로 표현됩니다. 이 모델을 사용하면 물리적 개체와 캡슐화 된 속성을 각 프로젝트의 고유 한 요구에 맞게 구성 할 수 있습니다. 이 기능을 통해 전문가의 지식을 개발 된 모델에 포함 된 라이브러리 세트로 쉽게 전송할 수 있습니다. 이 논문은 제안 된 모델의 구조와 네 가지 구성 요소를 설명합니다. (i) 사용자 인터페이스; (ii) 데이터베이스; (iii) 프로젝트 모듈. 이 세 가지 기능은 구성 요소이며 상호 연결성에 대해서도 설명합니다. 개발 된 모델은 CAD 환경에서 작동하고 객체 기반 설계 개념을 사용하는 컴퓨터 시스템에서 구현됩니다. 1.

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건설을 시작하기 전에 현장 레이아웃의 프런트 엔드 계획은 현장 운영의 효율성 및 / 또는 자원 관리와 관련된 현금 흐름에 상당한 영향을 미칠 수 있습니다 [10]. 잘 계획된 사이트는 다음을 수행 할 수 있습니다. (i) 여행 시간 최소화; (ii) 자재 취급에 소요되는 시간과 노력을 줄입니다. (iii) 생산성 증가; 그리고 (iv) 안전성을 향상시키고, 따라서 건설 비용 및 시간을 감소시킨다. 그러나 최근의 현장 방문 및 교육장 및 현장 관리자와의 인터뷰 및 문헌 [4]에 따르면 건설 계획 단계에서 현장 레이아웃 계획이 무시되는 경우가 많습니다. 이는 일반적으로 정의 된 작업으로 간주되지 않으므로 적절한 예산이 할당되지 않았기 때문일 수 있습니다. 따라서 건설 팀은이 작업을 효율적으로 수행하는 데 필요한 시간과 리소스를 낭비하지 않습니다. 현장 계획은 관련된 조달 일정뿐만 아니라 관련된 시공 프로세스의 다양한 측면에 대한 충분한 지식이 필요한 어려운 작업이 될 수 있습니다. 사이트의 레이아웃을 준비하려면 플래너는 그림, 스프레드 시트, 막대 차트 및 텍스트 문서와 같은 다양한 형식의 다양한 소스에서 정보를 추출해야합니다. 현재까지 표준 도구는 널리 보급되지 않았습니다. 이 작업을 도와주는 건설 담당자 [12]. 실제로, 건설 현장의 공간 할당은 일반적으로 선착순으로 수행되므로 혼란스러운 현장에서 생산성 손실이 발생할 수 있습니다.

복잡성과 관련된 많은 요소로 인해 컴퓨터는 특히 산업 플랜트의 레이아웃을 위해 1960 년대 초에 사이트 플래너를 돕는 효율적인 도구로 확인되었습니다 [15]. 지난 수십 년 동안 현장 계획 프로세스를 공식화하고 자동화 시스템에 구현하려는 몇 가지 시도가있었습니다. CORELAP [9,11]은 운영 연구 (OR) 기술을 사용하여 플랜트 레이아웃을 위해 개발 된 최초의 컴퓨터 모델 중 하나입니다. 인공 지능 (AI)은 사이트 레이아웃을 거의 분석하고이 문제에 대한 최적의 솔루션을 제공하는 실용적인 도구로 등장했습니다 (지식 기반 시스템 : [1,3,5,6]; 신경망 및 유전자 알고리즘 : [7,8]) . AI 방법의 주요 장점은 정확하지 않거나 불완전하거나 구조화되지 않은 문제를 처리 할 수 있다는 것입니다. 다른 기술의 측면에서 이익을 얻기 위해 다른 하이브리드 모델이 개발되었습니다. Move-Schedule [16]은 최적화 프로세스에 전문가의 지식을 통합 한 동적 공간 스케줄링 시스템으로 Cheng과 O'Connor [2]는 지리 정보 시스템 (GIS)을 사용하여 개발 된 모델에 지식 기반 접근 방식을 통합합니다. 이러한 모델은 다른 가정으로 사이트 레이아웃을 처리하지만 위에서 언급 한 시스템에서 다음과 같은 단점 중 하나 이상이 감지 될 수 있습니다.

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