Identification and Computation of Space Conflicts Using Geographic Information Systems

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Abstract

Various types of spaces for different purposes on various positions at various times are required to execute various construction activities on a construction site. Labors, equipment, materials, temporary facilities, and structure to be developed share the limited space available on a construction site. Planners use four-dimensional (4D) CAD modeling of the execution sequence to understand and generate the space requirements. The 4D CAD modeling simulates the construction process by linking execution schedule with a 3D model to visualize the construction sequence. 4D modeling is found helpful in the construction space planning. However, 4D CAD modeling lacks in considering the topography and surroundings when construction is in the hilly regions. In the present study, a geographic information system (GIS) has been utilized for the space planning. GIS facilitates the modeling of topography and existing surroundings. The components corresponding to different activities in the schedule and multiple types of spaces corresponding to various activities defined in the execution schedule have been generated in the *SketchUP*. A GIS-based procedure has been developed in *ArcGIS 10*, a GIS software, that enables identification and computation of the construction space conflicts before actual implementation of the schedule.

Keywords: Geographic Information System, Project Management, Workspace

Introduction

Deficiencies in the space planning results congested jobsite, loss of productivity, space conflicts, and schedule interference or delay [Guo (2002)]. Construction site engineers usually arrange daily activities on the jobsite according to the planned execution sequence. Existing literature suggests that like any other resource, construction activities also need execution space as a resource that need to be planned before the finalization of a schedule [Akinci et al. (2002a)]. It is impractical for a planner to visualize the dynamic multiple types of space requirements mentally because it changes with time/schedule like any other resource requirement in the construction industry. 4D CAD-based production models were used for the automated generation of spaces required by the construction activities to reduce time-space conflicts [Akinci et al. (2002b)].

Despite of many researches and applications of the 4D CAD technologies their use is not very common in the construction industry. After 4D CAD, there has been a major revolution of building information modeling (BIM) that also provides a mechanism to develop a conflict free construction schedule [Choi et al. (2014)]. BIM facilitates 3D modeling, scheduling, and linking them together to visualize the execution sequence that helps in the identification of space conflicts. However, construction space planning is not only related to the construction sequence visualization developed in CAD or BIM. For example, space planning for gravity dam construction where topography plays a major role cannot be done without geospatial capabilities (available in GIS) which are missing in both, BIM and 4D CAD-based systems [Zhong et al. (2004)].

Keeping the importance of geospatial capabilities in view, contractors or organizations create, store, and share 3D modeling along with its surroundings [Bansal and Pal (2008)]. 3D model, topography, surroundings, 4D scheduling, and geospatial analyses capabilities together in a single platform help in the space planning much better way [Bansal (2011)]. In addition, modeling of the spatial relationships through GIS-topology is of great use in the spatial computing perspective because GIS-based topology has been matured in the last decade. However, recent efforts to represent topology in BIM still need further investigation [Borrmann et al. (2009)].

The use of 4D models in the GIS is found helpful in the space planning. The visualization of execution sequence in 4D along with its neighborhood supports space planning of a construction planning in hilly regions. A 3D model acts as an input in the development of a 4D model. However, the 3D modeling capabilities available in the GIS have not been developed like BIM or CAD-based systems [Bansal and Pal (2008)]. A few commercially available GIS tools offer 3D formats. In this respect, researchers have the challenging role to mature 3D GIS. The researchers have to show the GIS users the possibilities and constraints of 3D GIS in order to obtain a serious breakthrough of the 3D GIS. Therefore, at present, an alternative to the 3D modeling has been explored. The present study discusses how space-planning procedure in the 4D GIS has been designed for conflicts identification and computation.

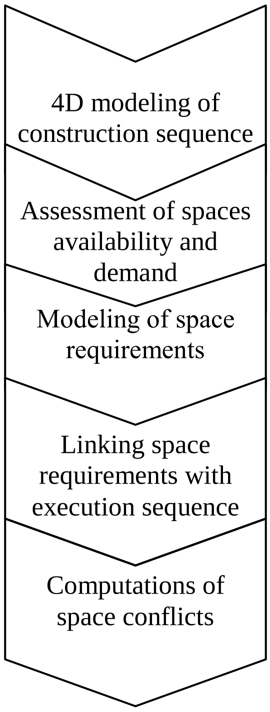

Figure 1: Process of space planning.

Purpose of GIS in Construction Planning

A construction either big or small cannot remain in isolation but is closely related to all other facilities in its surroundings. Even as a single entity, it creates a vast amount of information by its existence in in its surroundings. A construction cannot be planned as a single entity; careful consideration has to be given to the immediate neighborhood. Usually, this is done manually based upon previous experience. Software tools like building information modeling (BIM) and CAD mainly consider the inside geometry of a construction project, while, GIS is more concerned with the space outside a building. Therefore, any new construction using BIM and CAD systems can be planned in isolation only. GIS helps in efficient decision making with its capability to handle both spatial and attributes information which is queried, analyzed, and displayed together in various graphical and non-graphical forms. Spatial data describe features' geometry whereas; attributes stored in tabular form describe characteristics of different features. The 3D models of a construction project should be prepared along with topography to consider the surroundings. Layouts of existing utility services like: electric lines, gas supply, water distribution systems, sewerage network, etc. which play a major role in locating new facilities, can easily be stored in GIS environment. Construction planning especially in hilly regions where topography plays a major role cannot be simulated without geospatial modeling and analysis capabilities which are available in GIS. The CAD and VR-based systems lack geospatial analytical capabilities such as evaluation of a location for flooding, drainage pattern, and route planning for vehicles carrying consignments from different access routes to construction site. Further, a planner also needs spatial information about the neighborhood of a facility to be developed to determine its dependence on project under consideration. Such dependence is not easily modeled in CAD and VR-based systems. The use of GIS allows a planner to view and analyze the effects of a new construction on existing facilities. GIS-based approach also helps in incorporating environmental aspects in the early phases of construction planning.

Process of Space Planning

In the space planning, to finalize a construction plan in terms of when, where, and how long a space is required on the jobsite, a link between workspace requirements and the execution schedule is found significant. 3D model along with its surroundings, a 4D sequence, and geospatial analysis capabilities into a single GIS platform helps in the space planning. The modeling of an area with spatial constraints using GIS-based topology contributes in the identification of space conflicts. Therefore, the main objective behind the present study was to explore the use of GIS in the space planning to identify spatial conflicts. The procedure for the identification of spatial conflicts was designed in which workspaces corresponding to various activities in the schedule were generated in the SketchUP. A link between workspaces and the 4D model of construction sequence was established in the ArcGIS 10. After the identification of space conflicts, their computation was done in ArcGIS 10 (Fig.1).

Identification of Space Conflicts

4D Modeling of Construction Sequence

Initially, the execution schedule of the project under construction was finalized. The modeling of building interior in 3D was done in the SketchUP. The terrain modeling around the building was done in ArcGIS 10 [Bansal (2014)]. The modeling of building interior depicts floor level detail whereas digital terrain model represents topographical condition of the jobsite. Linking of the project execution schedule with 3D components developed in the SketchUP [SketchUp (2010)] to make 4D construction sequence was done in ArcGIS 10 [Bansal and Pal (2008)]. The degree of detail in a 4D model depends upon the detail in the execution schedule. Hence, it is better to use full work breakdown structure. Detail in a schedule and division of a 3D model into small components have serious implication on the time required in the 4D modeling.

Assessment of Spaces Availability and Demand

Three categories of the available spaces were considered in the present study. These spaces includes: space provided by the jobsite on the ground, space provided by the temporary structures such as scaffolding or working platforms, and space provided by the structure to be constructed with time. The categories of the available spaces were characterized in terms of their sizes, locations, and time of availability. An activity requires working and path spaces for labors, equipment, and materials storage. Hence, various categories of space requirements for each activity were calculated. The spaces were positioned outward, inward, above, below, or around the reference component to be constructed. Site engineers describe each space requirement with respect to component to be constructed, component’s location, size, and shape. The present study does not focus on the volumes and types of different spaces required, for more details about this, readers are directed to the earlier studies [Akinci et al. (2002a; 2002b)].

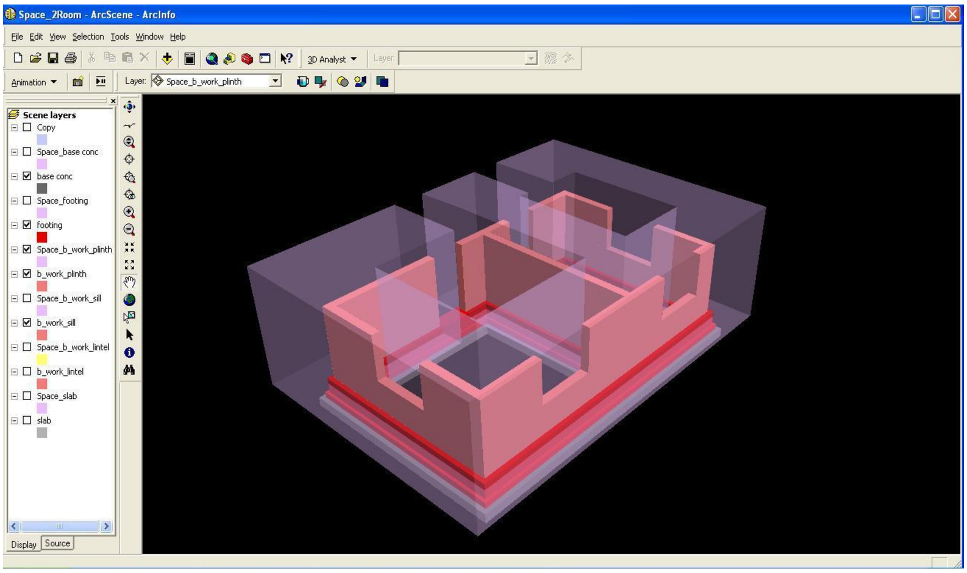

Figure 2: Work space requirement of the brick wall in the construction of a small

Modeling of Space Requirements

The position, size, shape, schedule, and reference component corresponding to each space decide its characteristics on the jobsite. SketchUP was used to model the spaces corresponding to each activities' space requirement estimated in the earlier step. Any shape of a space can be modeled in the SketchUP. The modeled spaces from the SketchUP were exported to ArcGIS 10 in the Multipatch format [ArcGIS (2014)], The Multipatch format supported in the ArcGIS 10 is used to represent spaces or components in 3D.

Linking Space Requirements with Execution Sequence

Project specific space requirements on a jobsite changes with time, therefore, the developed space requirements were linked with the execution sequence to generate dynamic space requirements. This link finds the start and finish times of each space corresponding to an activity defined in the execution schedule. 4D model of the execution sequence integrated with space requirements shows work space demand of various activities along with 3D components to be constructed along with its surrounding (Fig. 2). To finalize a plan, 4D model of the execution sequence integrated with space requirements was found helpful because the overlaps among various spaces were identified visually.

Computations of the space conflicts

The overlaps/conflicts between two spaces were identified visually with the help of integrated 4D model of the space requirements and execution sequence. The volume of an overlap/conflict between two spaces was computed in the ArcGIS 10 (Fig. 3). A closed space in the multipatch format is required for the analysis in ArcGIS 10 for finding an overlap; this is checked with *Is Closed 3D tool*. The *Enclose Multipatch tool* is used to eliminate gaps in multipatch features used to represent space requirements [ArcGIS (2014)]. Spaces in the SketchUP may be produce in extremely complex geometries. If one input is given, the *Intersection of features* in that multipatch dataset are computed, whereas if two were given, the *Intersection of features* from both datasets are determined and intersections found in only one input get ignored.

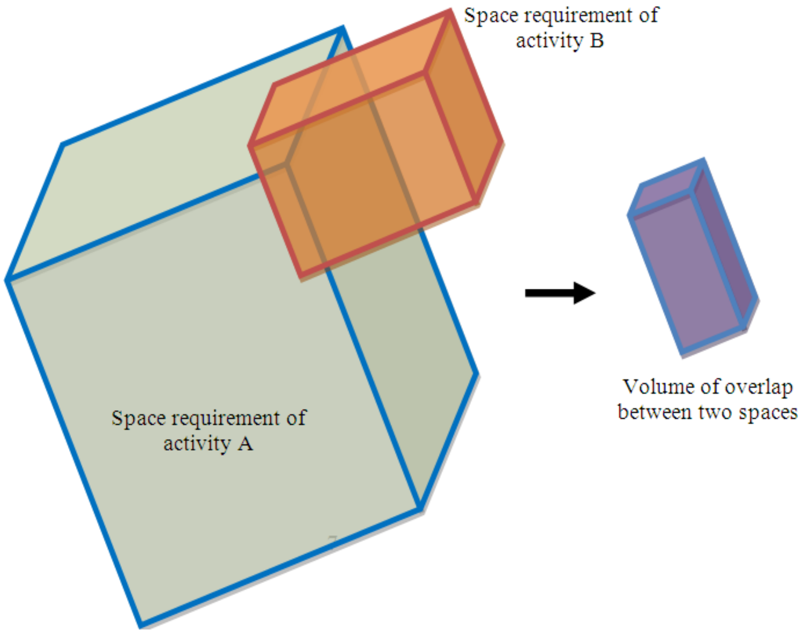

Figure 3: The volume of an overlap/conflict between two input spaces computed in the ArcGIS 10

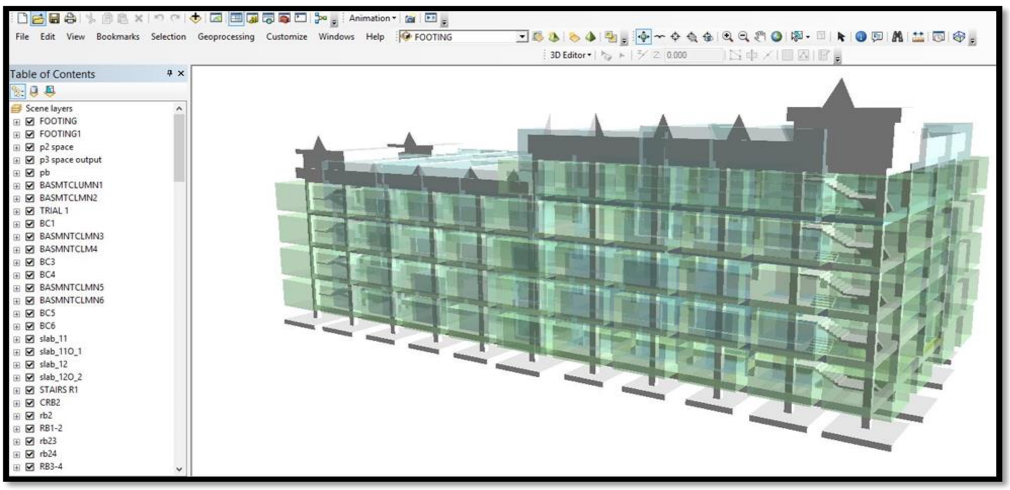

Figure 4: The case study building consists of two portions, left and right, left portion is of four floors and right is of five floors.

Case Study

The National Institute of Technology (NIT) Hamirpur, India is the premier technical institute of the region located in hilly terrain, covering an area of about 200 acres. The demand of buildings in the institute campus has been growing due to the increased academic and non-academic activities. The construction planning of a building is hilly region is highly influenced by site topography. Hence, construction of the building located in the hilly region of NIT campus was taken as the case study. The modeling of facilities/utilities around the case study building included institutional buildings, administrative block, health center, library, auditorium, and lecture hall complex. Other existing buildings modeled were food courts, water tanks, and stores. The existing public utility networks included were layouts of water distribution system consisting of main supply line and sub-mains, sewer network, road network, and overhead electric lines. Electric poles, telephone poles, and lamp posts were also modeled on their respective locations. The attributes corresponding to all existing facilities/utilities were kept in the relational database. For more detail about the modeling of surrounding readers are directed to the earlier study by [Bansal (2014)].

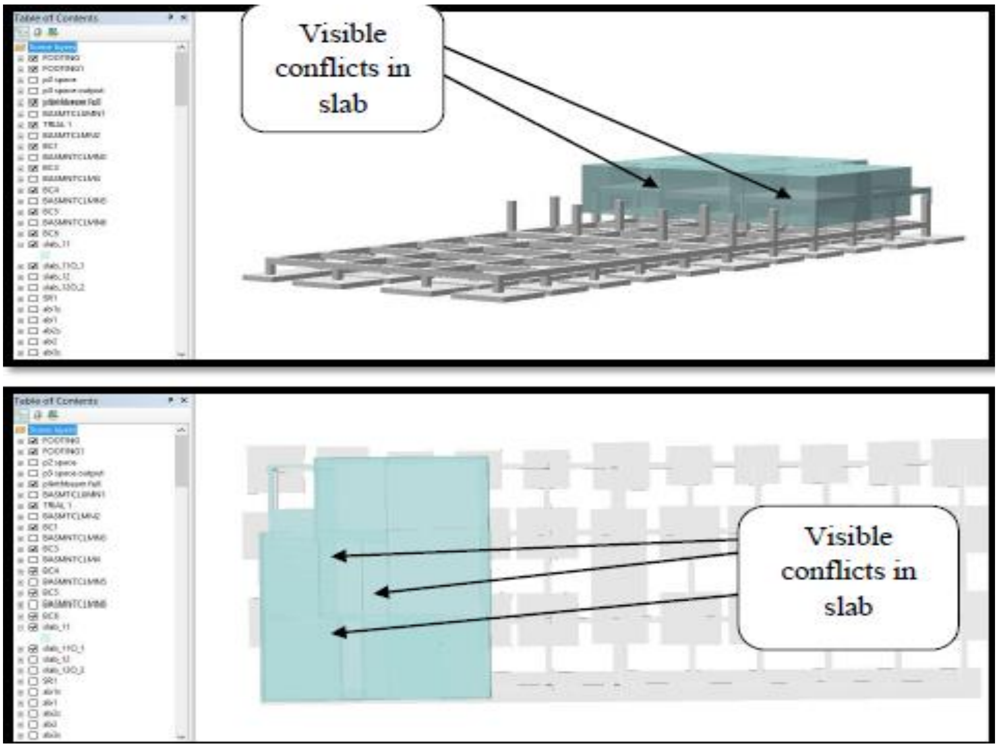

Figure 5: Identified space conflicts in the case study building through modeling in *ArcGIS.*

The case study building consists of two portions, left and right. The left portion is of four floors and right is of five floors as shown in figure 4. The construction plan of each portion was broadly divided into five parts. The construction of sub-structure was included in the first part of plan. It involved activities like: preparation of land, excavation, construction of foundation, and backfilling of foundation trenches. The second part of plan involved construction of reinforced cement concrete frame. The exterior walls, interior partition walls, and flooring were included in the third part of plan. The plastering, fixing of door and window frames, and fixing of panels were included in the fourth part of plan. The electrical fitting, plumbing, and finishing works were included in the fifth part of plan. The identified space conflicts in the case study building through modeling in ArcGIS have been shown in figure 5.

Conclusions

Without considering the space requirements, execution schedule cannot be finalized. Displaying spaces required along with the corresponding components in the 4D helps in the detection of time-space conflicts and accordingly modification of the execution schedule to resolve conflicts before construction. In the space planning, if the execution schedule leads to space conflicts, it is changed until it becomes conflict free. This facilitates in the rapid generation of a conflict free schedule. Various graphical operations on spatial and non-graphical operations in GIS improve and speed up construction planning and space planning.

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