COMPARISON OF 3D CONSTRUCTION VISUALIZATION METHODS TO PROVIDE VISUAL SUPPORT IN GIS ENVIRONMENT FOR THE CONSTRUCTION PROJECTS

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Abstract

The development of 3 dimensional (3D) display technologies led to the widespread 3D designs and applications in construction industry. The major developments that offer visual presentation for the construction projects are 4D CAD, BIM and nD modeling. In addition, 3D GIS applications that use visualization features of GIS are also available. Unlike CAD tools, GIS software provide spatial data about construction for project participants. According to the previous studies, converting 2D CAD drawings into 3D data layers that refer to each construction activity is an efficient method. It is possible to transfer and edit them in GIS through data interoperability. Besides, 3D modeling and editing tools such as 3D Studio Max and SketchUp enables the realistic design with their material library and texture features. These modeling software can transfer data directly into GIS. In this study, two available 3D building visualization methods to provide visual support in GIS environment for the construction projects were compared. AutoCAD, SketchUp and ArcGIS were utilized for modeling, data transfer, editing and 3D visualization. 3D data transfer processes between these software were also discussed and multipatch geometry type that is supported by ArcGIS was emphasized. A reinforced concrete construction in Eskisehir, Turkey was determined as the study area for the case study. In consequence of the study, it was discovered that while the feature class objects that were transferred from CAD to GIS have 2D geometry, multipatch objects are in 3D geometrically thereby more realistic. Irregular 3D objects cannot be defined in feature class but they can be created in SketchUp and transferred into GIS as multipatch. On the other hand, each layers corresponding to the construction activities should be drawn individually in SketchUp.

Keywords: 3D Visualization, GIS, CAD, SketchUp, Multipatch

INTRODUCTION

2D project drawings are utilized in phases of the construction projects on the purpose of the planning, design and network analysis. However these drawings do not have enough details about the construction applications in the site. Furthermore, manipulating and representing real world objects in 2D are no longer adequate (Rahman and Pilouk, 2008). Planners and engineers use 3D visualization in order to evaluate the efficiency of the construction project and develop various applications (Ford, 2004). GIS that has a significant role in the advanced technology can also be utilized for 3D visualization. Using GIS for construction projects is important because of its spatial perspective with geographic reference system which CAD tools do not have.

Cheng and Yang (2001) proposed to divide the project drawings into layers that are corresponding to each construction activity and transfer them into GIS environment. Bansal and Pal (2006) stated that one-piece project drawings are not appropriate to generate 3D view in GIS. Thus they also divided the project drawings into the data layers. Bansal and Pal (2007) calculated the quantity takeoff for a model construction using Avenue script language, integrated the calculations with 3D data layers and displayed in GIS environment. Zhong at al (2004) developed a dynamic 3D simulation system for an arch dam construction. Bansal and Pal (2009) utilized GIS for displaying direct sunlight gain of a model construction in 3D. Ekberg (2007) studied on multipatch data structure for displaying and analysis of complex 3D objects in GIS environment. Multipatch is a type of geometry composed of planar 3D rings and triangles, used in combination to model objects that occupy discrete areas or volumes in 3D space. This geometry type may represent geometric objects, like

spheres and cubes, or real-world objects, like buildings and trees (ESRI, 2006). Multipatch could be stored in geodatabase and used with standard tools of ArcGIS. It also has the same display feature with other geometry types. Although multipatch exists in ArcGIS as a data type but there is no possibility to create/edit multipatch features within ESRI products interactively (Bansal, 2008). This is possible only through programming with ArcObjects or through a standalone application such as SketchUp (Ford 2004).

Advanced 3D applications allow the designers for the emphasis on virtual reality and this expanded the usage area of 3D design software such as AutoCAD, 3D Studio max, SketchUp, Microstation, ArchiCAD etc. SketchUp which is utilized for creating 3D design enables virtual reality. Data transfer between SketchUp and ArcGIS is also possible.

In this study, two available 3D construction visualization methods that are used to provide visual support in GIS environment for the construction projects were compared. Method that was developed by Cheng and Yang (2001) and 3D multipatch methodology were discussed. A residential RC construction in Eskisehir, Turkey is determined as the study area for the case study. In conclusion of the case study, it was determined while multipatch objects are 3D, CAD objects that were transferred from CAD to GIS are 2D geometrically. Besides, CAD based inclined objects are not defined as 3D in GIS environment, but in SketchUp. However, each data layers corresponding to the construction activities have to be created one by one in SketchUp.

METHODOLOGY

GIS Based 3D Visualization

3D visualization methodology that was developed by Cheng and Yang (2001) and used also by Bansal and Pal (2006) includes converting project drawings that are in AutoCAD to data layers corresponding to each construction activity and transferring them to GIS. Data layers could be rendered in 3D by extrusion and base height functions in GIS software. Following parts provides detailed information about the steps of this methodology.

Converting drawings to data layers: Both architectural and technical drawings are utilized for 3D visualization. Interior and exterior details are created by using floor plans from the architectural drawings. Foundation phases and structural details of the construction are obtained from the basement and formwork plans in the technical drawings.

Transfer the data layers to GIS environment: Transfer the data layers to GIS is related to data interoperability between CAD and GIS. Files in AutoCAD could be transferred in ArcGIS by Import from CAD function. Dissolve is utilized to merge the objects and feature to polygon to create polygons during the editing in ArcGIS environment. Base height and extrusion are used to convert the data layers from 2D to 3D.

Merging the objects: Dissolve function that is under the Geoprocessing tools are utilized to merge the identical objects in ArcGIS. Objects that are created to define each structural member in architectural or technical drawing could be merged in one by this function.

Creating polygons from lines: CAD based drawings include line data type. These lines could be converted to polygons using feature to polygon function.

Creating 3D view: In order to create 3D view of the construction, base height and extrusion functions of ArcScene are utilized.

Multipatch 3D Visualization

It is not possible to define inclined objects in GIS based 3D visualization methodology. Thus, multipatch data structure that enables displaying 3D data layers in GIS environment could be utilized. This methodology used by Ekberg (2007) and its efficiency was proven. In proposed methodology, 3D component are created in SketchUp. SketchUp can read .dwg/dxf files directly. Geometrically 3D components are created on 2D CAD drawings and saved as different .skp files. Then they are transferred to GIS environment as multipatch using Conversion tools of ArcGIS.

CASE STUDY

Study Area

A residential RC construction in Eskisehir, Turkey was determined as the study area. The construction has 242 square meter land area and five stories. Architectural and technical drawings of the construction were utilized as the visual data for the case study.

AutoCAD-ArcGIS Data Interoperability

Data transfer between AutoCAD and ArcGIS could be enabled by functions of Data Interoperability toolbox. dwg/dxf files were imported with .gdb (geodatabase) extension using Quick Import tool. Data layers were converted to feature class data structure. Base height and extrusion values were assigned each layers and 3D view were obtained. Fig.1 and Fig.2 represents 2D and 3D data layers respectively.

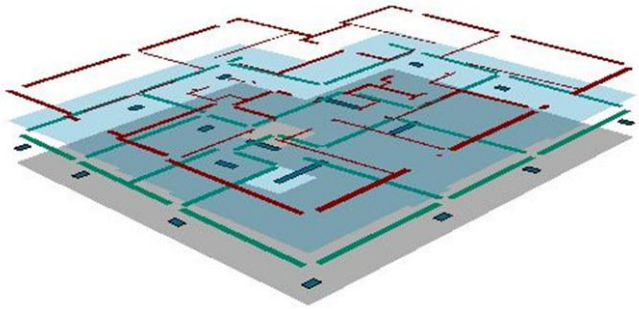

Fig. 1. 2D data layers that were transferred from AutoCAD to ArcGIS

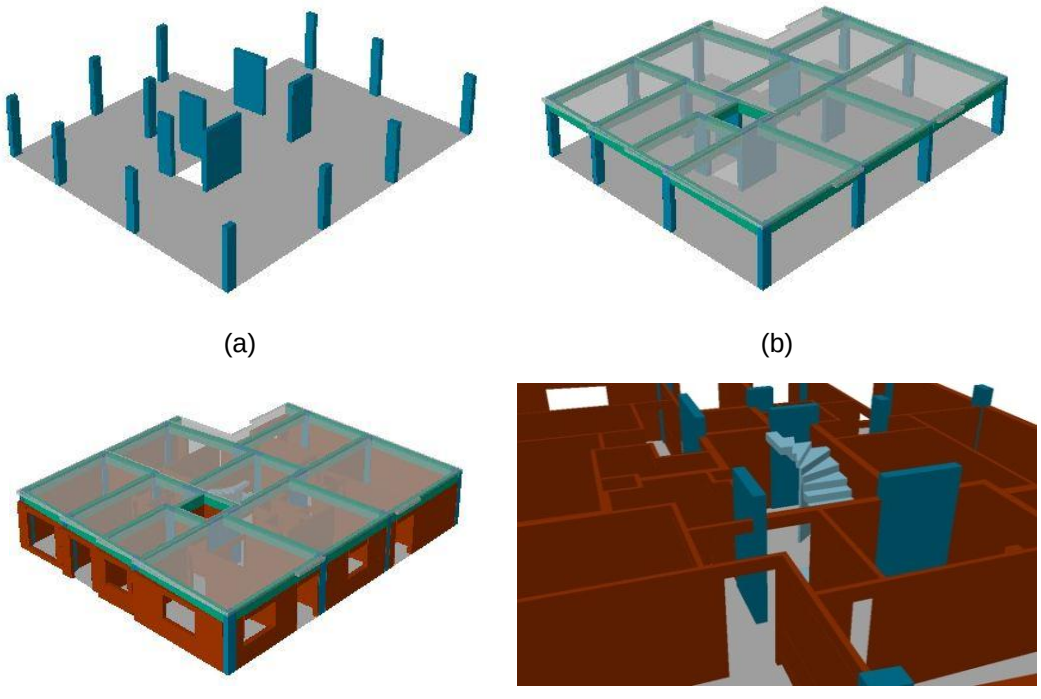

Fig. 2. 3D view of data layers in ArcScene, (a) Columns, (b) Columns, beams and slabs, (c) General floor view, (d) Interior details.

AutoCAD-SketchUp-ArcGIS Data Interoperability

Project drawings of the model construction were transferred into SketchUp environment and drawn by means of corresponding to each activity. Visual components were saved as different .skp files. The reason of transferring the layers into GIS as different files is that drawings in a single piece are cumbersome for 3D construction visualization. Visual layers were imported as multipatch through Conversion tools of 3D Analyst. These layers were saved in a geodatabase and displayed on the user interface of ArcGIS. 3D model of the construction that was transferred into GIS environment can be seen from Fig.3

RESULTS AND DISCUSSION

Results

In feature class 3D visualization, visual data layers were created through CAD-GIS data interoperability. CAD based project drawings are geometrically 2D. ArcScene functions were utilized to create 3D view from these 2D data. However, this methodology is not sufficient to define irregular 3D objects such as roof. Thus, feature class 3D visualization does not include roof work of the model construction. In multipatch 3D visualization, .dwg files were imported to SketchUp and created in 3D. Then they were transferred into GIS as multipatch. As it is possible to define 3D inclined objects in SketchUp, multipatch 3D visualization included also the roof works. Visual data layers in each methodology were compared in visual reality aspect and it was discovered that multipatch 3D visualization has higher resolution because of being geometrically 3D thereby multipatch data layers are more realistic than the feature class data layers. Whilst visual data layers could be imported into ArcGIS directly and converted into feature class in the first visualization methodology, users have to create each component one by one in the second visualization technique. ArcGIS has geoprocessing tools to edit components. SketchUp does not have such a tool but it has toolboxes that are quite user friendly.

Discussion

Cheng and Yang (2001) was developed a GIS based 3D visualization methodology considering converting the project drawings to data layers corresponding to the construction activities and also a cost estimation algorithm. Bansal and Pal (2006), took these methodology and algorithm a step further and proposed to utilize ArcGIS editing tools instead of AutoCAD. However, it is not possible to define irregular 3D objects in that methodology. 3D multipatch data structure could remove this problem.

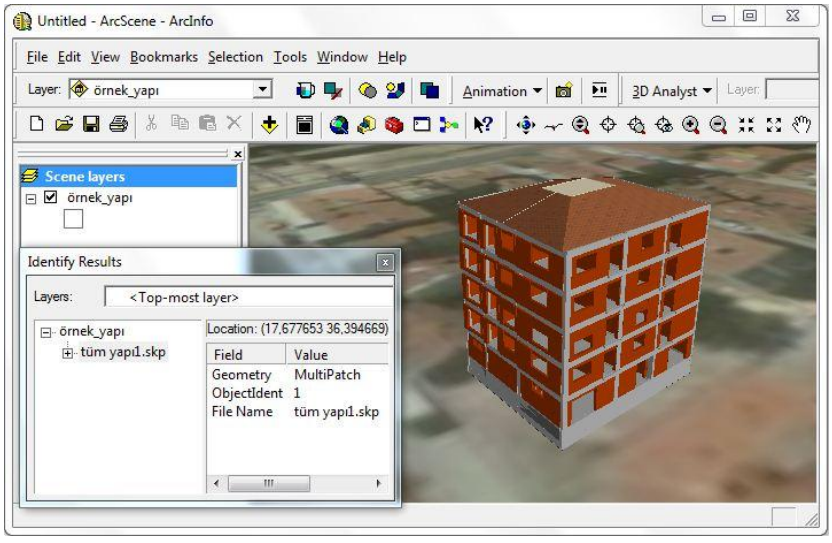

Fig. 3. Multipatch 3D construction model in GIS environment

CONCLUSION AND SUGGESTIONS

In this study, two available 3D construction visualization methods to provide visual support in GIS environment for the construction projects were compared. The case study of the methods was conducted for a residential construction in Eskisehir, Turkey. 3D visual layers were created in both ArcGIS and SketchUp environments utilizing the architectural and technical project drawings and displayed in GIS. GIS was utilized because of its spatial coordinator system which provides project participants to understand construction activities and their probable delays. ArcGIS which is mostly used and regarded as the most advanced GIS software on the market was preferred. Through CAD-GIS data interoperability, there's no need to draw the layers again. However, project drawings are created one by one in SketchUp. Despite that negative aspect, multipatch data are more realistic thanks to their true 3D geometry. Thus, inclined objects could be defined as multipatch. As a conclusion, it was determined that both methodologies have useful and adverse features.

In construction industry, 2D project drawings are utilized frequently. But lack of application details in the project drawings is one of the major problems of the construction projects for the project managers. Through integration between construction activities and 3D visual layers, it will be possible to track the project progressions and determine the probable delays. Furthermore, it is proposed to develop new methods for 3D construction visualization in GIS environment. Available methods that used for 3D visualization in GIS are not so efficient because of their requirement of time consuming drawing and editing processes. Thus the use of programming languages to create 3D layers from 2D project drawings is proposed for the further researches. 3D visualization through encode will reduce the total editing time and enable to save time.

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