

## **AC 2010-640: MULTI-DIMENSIONAL CONSTRUCTION VISUALIZATIONS WITH EXAMPLES: SUGGESTED TOPICS FOR GRADUATE COURSE**

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# **Multi-dimensional Construction Visualizations with Examples: Suggested Topics for Graduate Course**

## **Abstract**

Construction industry in today's world is becoming enormously complex as project sizes are increasing and project duration are decreasing. At the same time designers are conceptualizing ever-complex designs, which no longer can easily be comprehended by 2D drawings. Classroom use of Information Technology (IT) for teaching science, engineering and technology has increased dramatically in recent years and has proved to be very effective in various situations. Using multidimensional (n-D) visualizations, animations, virtual reality and walkthrough of various structures in virtual environment students receive the understanding that is absent from the traditional "chalk-board" approach. The purpose of this paper is to demonstrate with examples various design and construction visualization techniques including image visualization, virtual reality, design animation, walk-through, time-space relationship visualization in 4D (3D+Schedule), time-space-cost relationship visualization in 5D (3D+Schedule+Cost), and Time-Space-Activity Conflict Detection using 4D Visualization in Multi-Storied Construction Project. The techniques demonstrated through virtual models can potentially be valuable course contents for graduate course for construction education and research.

## **Introduction and Background**

Today's information technology (IT) has proven an untapped resource for architectural/construction engineering and technology classrooms. As the modern-day student becomes more personified with an obsession for the interactivity of computer games, it has become vital that the classroom offer an engaging method of teaching and learning. Although the classical architectural/construction engineering classroom is highly dependent on the instructor, developing students' critical thinking skills become a challenging task for even the most inspired educators. Nonetheless, these skills are a continual necessity for students' plan to venture into the architectural/construction engineering professions.

Haque<sup>1</sup> is of the view that traditional lecture format teaching methods sometimes fall short of conveying the complex analysis and design principles that need to be mastered in structural design. However when the theories are exemplified in a virtual environment with multimedia, animation, interaction, and manipulated image visualization techniques in a virtual reality environment, students' conceptual understanding are enhanced.

Visualization has always been an important aspect in the construction industry and construction education has always laid stress on that aspect. Design professionals and educators used drawing as a practical tool for seeing, thinking and understanding their ideas, and for communicating them to others. In education, drawing was often woven tightly into curriculum and it was expected to play a major role in developing students' visual abilities.<sup>2</sup>

Fritsch and Kada<sup>3</sup> are of the view that the increased interest in the consumer market has led to the remarkable progress in game-engine industry. These powerful software packages are

efficiently run through rendering pipelines, special data-structures and speed-up techniques which in turn assist in visualizing texture mapped 3D objects, scenes and 3D worlds in real-time. Shiratuddin and Thabet<sup>4</sup> have described methods for developing realistic and low-cost three dimensional visualization applications using game engine software. Game engines possess the ability to produce virtual environments in a real-time and realistic manner. With the capability of walking through the visualization, games engines have the capability to allow the user to navigate as if in the real world. Low-cost production, networking support, entry level hardware requirements, collision detection and support for high frame rates per second are some of the major advantages offered by the 3D game engines.

Bar charts and network diagrams are typical means to represent and communicate construction schedules. Individuals having different background and being unfamiliar with these techniques find it difficult to evaluate and communicate the schedules.<sup>5</sup> Visual 4D planning and scheduling technique that combines 3D Computer Aided Design (CAD) models with construction activities (time) provides proven benefits over the traditional tools.<sup>6</sup> In 4D models, project participants can effectively visualize and analyze problems regarding sequential, spatial, and temporal aspects of construction schedules. Therefore, more robust schedules can be generated and hence reduce reworks and improve productivity.

It is essential to use alternative modes of instruction to create an 'almost real' environment, which enables students to better understand the construction concepts. In today's computer age, it is crucial to use all venues of information technology as effective tools of teaching.

## **Research Methodology**

This paper demonstrates with examples various design and construction visualization techniques including image visualization, virtual reality, design animation, walk-through, time-space relationship visualization in 4D (3D+Schedule), time-space-cost relationship visualization in 5D (3D+Schedule+Cost), and Time-Space-Activity Conflict Detection using 4D Visualization in Multi-Storied Construction Project. In this paper, the author compiled his recent research activities in virtual construction visualization and animations that can be valuable course contents for graduate construction education and research. The author also believes that these materials can be valuable topics for senior capstone design courses for undergraduates in construction engineering and management.

VR, 3-D animation and walkthrough: Haque<sup>7</sup> has developed 3D models of steel, concrete and wood framed structures, and placed them in a virtual world using AutoCAD, 3ds MAX, VRML, Macromedia Director, Flash, and others. The principal objective of these virtual construction sites was to help architectural/ construction engineering or management students and non-technical personnel on construction sites to better visualize the sequence of operations, and design details of structures. The 3D model of a wooden framed residential house<sup>7</sup> (Figure 1) showing the foundation, framing as well as the finishing was animated to create a systematic sequence of the entire construction processes.

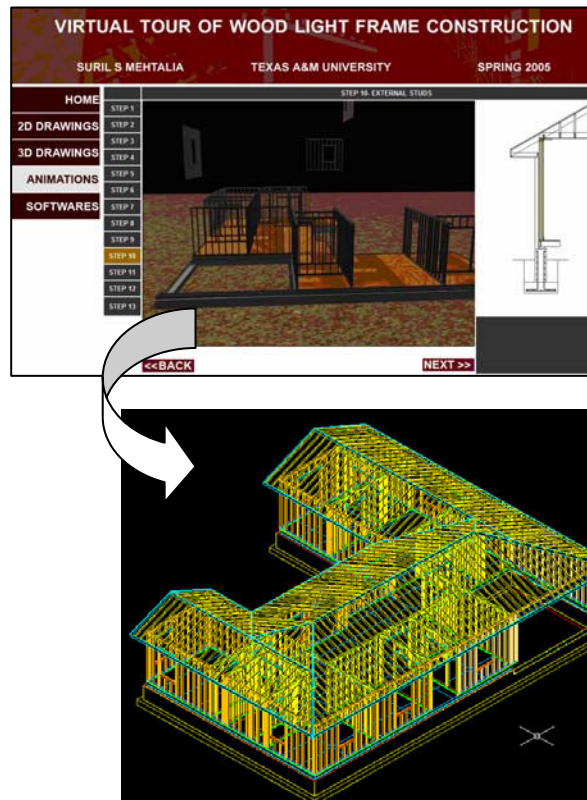


Figure 1: Systematic Construction Animation –  
Wooden Frame Structure

The image visualization and animations are powerful tools for teaching design courses. If a student has a difficulty with an analysis and design problem, the animations of the structural response to loads and the 3-D animated free-body diagrams explicitly show the foundations of the design mechanics by showing the connectivity between cause and effect. To teach steel joint analysis/design considering various failure mechanisms, animated 3D virtual models can be used very effectively. Figure 2 shows an animation using 3ds Max and VRML model for visualizing the joint-bolts failure in tension.<sup>8</sup>

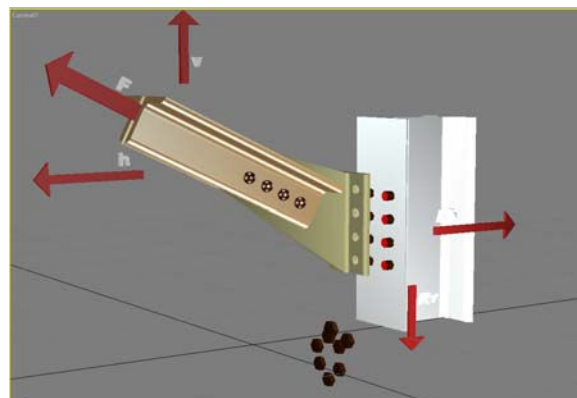


Figure 2: 3D animation of bolt tension failure

4D/5D/n-D Construction Visualization: Construction models integrated with the schedule, cost and other construction resource management information can be used to improve the design and planning process, which can lead to a more efficient construction process. Haque<sup>9</sup> illustrated an n-D model of virtual construction sites that can be used for educational purposes, for students in school and construction workers on site. The model showed the construction sequence of various construction activities including cost and other resource management information with time. The framework for the n-D model is shown in Figure 3.

The linking of construction schedule activity from MS Project and the relevant CAD component was done using the CAD components' unique handle IDs. Once the schedule activities were imported to the n-D environment, they could be readily linked to schedule activity by using an automatic linking feature of P4D application. Similarly the cost components were linked with relevant CAD components for creating 5D construction animations. Figure 4 shows typical 4D Construction Sequence visualization with necessary VRML details.<sup>10</sup>

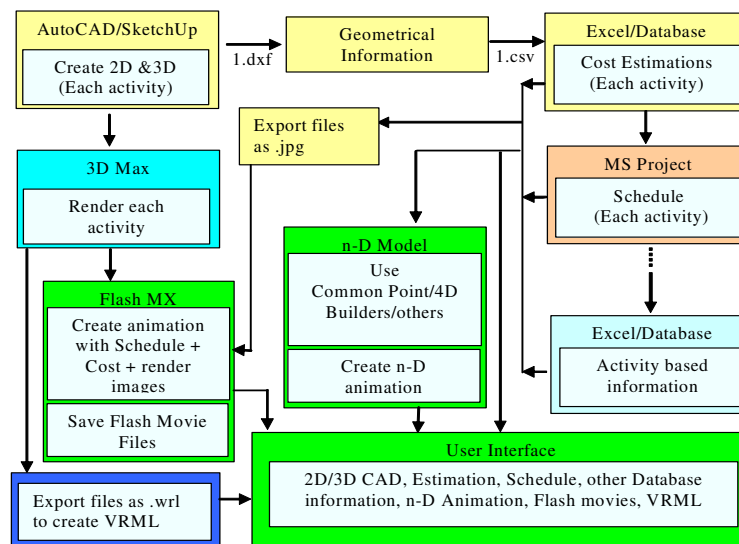


Figure 3: n-D Visualization Model – Flow Diagram

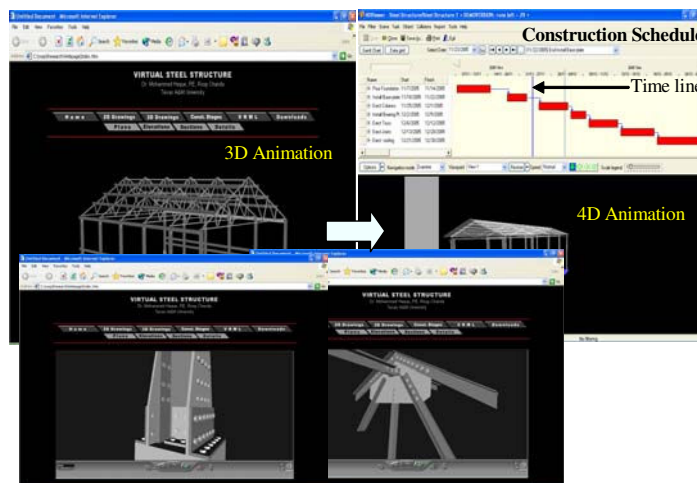


Figure 4: 4D Construction Animation with VRML

Methodology as discussed above can be used to integrate different types of data and information, such as resources, craft-split analysis, craft requirement, lost-time accidents, cost of rework, weather report, delays and reasons etc. to prepare n-D models. The primary purpose of the research done by Haque and Mishra<sup>11</sup> was to develop a framework (Figure 5) to facilitate development of time-effective 5D models with use of software prevalent in the industry, mainly:

- AutoCAD 2007
- Google SketchUp PRO – Version 6
- dxftocsv.exe (non-proprietary application)
- Project 4D (P4D) from Common Point Inc.
- MS Project 2003 or higher
- MS Excel 2000 or higher

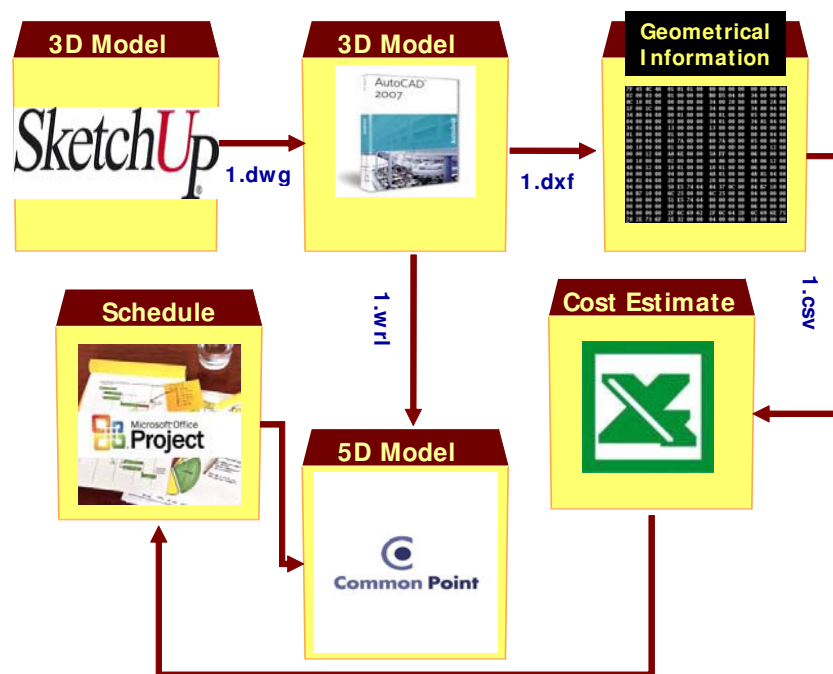


Figure 5: 5D Visualization Model – Flow Diagram

Time-Space-Activity Conflict Detection using 4D Visualization: Construction space management and scheduling of sequenced activities are important aspects for the timely completion of a project within estimated budget. Haque and Rahman<sup>12</sup> conducted a research to explore the effective use of 4D visualization in order to detect time-space-activity conflict in pre-construction and during construction. A 3D model of a multistoried building was developed, and each construction activity was linked to schedule and construction space requirements. Various color codes were used for activity and space requirement. The activities and space requirement colors were changed once the task activities were completed. During 4D simulation, these color codes help to detect if there is any conflict between activities and construction space requirements. The model produced logical evidence that a 4D model could be effectively used in

a construction site to detect time-space conflicts.<sup>12</sup> After preparing the 3D model, a volume of space requirement to complete a specific task was developed in Revit Structure. Each volume was identified by different color codes (Figure 6) in NavisWorks. During simulation one can see if there is any conflict between activity with time and spaces requirements or not. If the required areas for two adjacent activities overlapped each other, there will be no conflict when they are scheduled in different time zone. But if the parallel activities occurred in same time zone, there will be conflict.

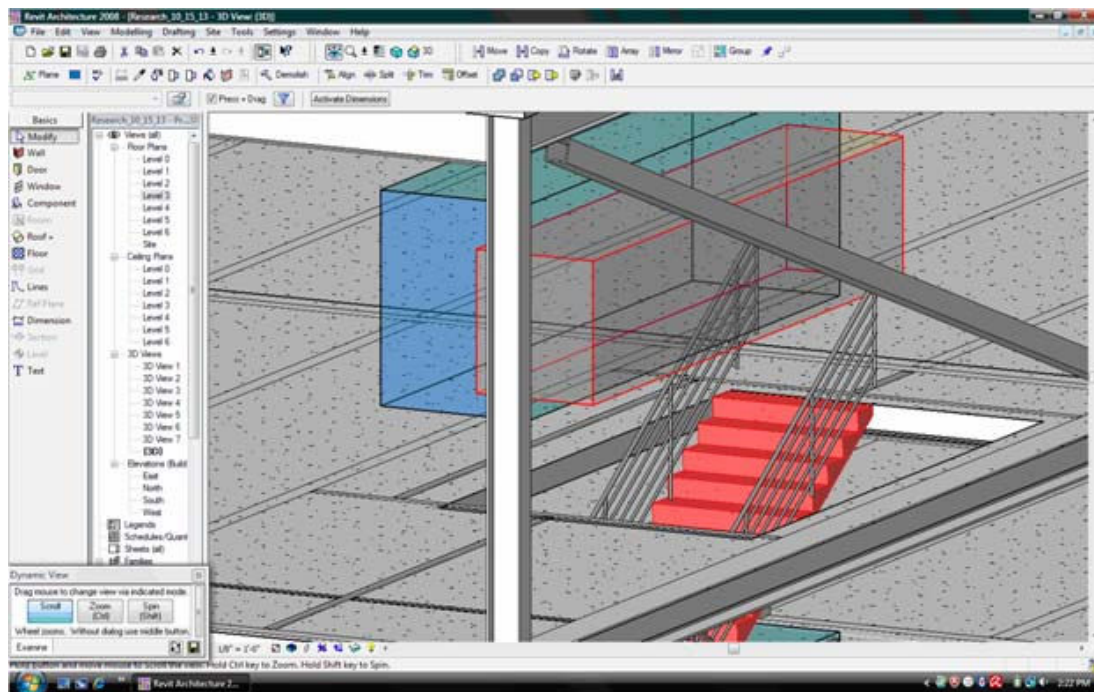


Figure 6: Color coded space requirement for each task

## Summary

In this paper, the author compiled his recent research activities in virtual construction visualization and animations that can be valuable course contents for graduate course, and topics for senior capstone design courses for undergraduates in construction engineering and management. The paper demonstrates with examples various design and construction visualization techniques including image visualization, virtual reality, 3D design animation and walk-through, first-person shooter (FPS) game engine simulated walk-through, time-space relationship visualization in 4D (3D+Schedule), time-space-cost relationship visualization in 5D (3D+Schedule+Cost), n-D (3D + Schedule + Cost + others parameters) and Time-Space-Activity Conflict Detection using 4D Visualization in Multi-Storied Construction Project. The main purpose for each of these models was to create virtual environment to simulate real life situations - especially in the field of architectural/construction engineering and technology. The virtual construction sites will help construction engineering or management students and non-technical personnel on construction sites to better visualize the sequence of operations, and design details



of structures, and will make them better equipped to design, manage, estimate and schedule more effectively. The courses will prepare construction engineering and management students to use advanced information technology to analyze, design and construction according to industry standards by selecting design projects with industry participation.

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