Industry-Academia Collaboration to develop a BIM-based MEPF Coordination Educational Module

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Abstract

In joint industry-academia collaboration, the authors are developing a prototype educational module to teach students of construction management process-based best practices implementing Building Information Modeling (BIM) to facilitate Mechanical, Electrical, Plumbing and Fire Protection (MEPF) coordination. Based on a prominent construction company's pioneering experience, the prototype teaching module highlights lessons learned coordinating complex, real-world projects, and incorporates hands-on, interactive exercises. The authors document and discuss the development of the module, which strives to illustrate BIM in both theory and practice. The module includes process diagrams, war-stories, dynamic 3D models, and interactive exercises to critically evaluate BIM working processes. Using Adobe Captivate along with a variety of BIM tools, the authors incorporate a demonstration video to highlight the assembly, mapping and visual inspection of several BIM models as developed by a variety of professional project team members. An interactive homework assignment has students investigate hard and soft MEPF clash detetction and coordination issues. The assignment forces students to think critically to identify the source, eliminate redundancy and propose a solution for various clashes. Future work will seek to extend and evovle the MEPF cordination teaching module and to develop additional domain-specific teaching modules related to BIM.

Keywords

BIM, MEPF Coordination, Construction Education, Industry-Academia Collaboration, e-learning

1. INTRODUCTION

In today's construction, Mechanical, Electrical, Plumbing and Fire Protection (MEPF) systems account for a significant portion of project planning and costs. This is increasingly true on high tech and renovation projects, challenging project types facing contractors today. MEPF coordination requires design and installation of intricate routings of ductwork, piping and electrical raceways in and around building structure. Traditional MEPF coordination has relied on sequential overlay and comparison of 2D drawings to detect and eliminate spatial and functional interferences between MEPF systems. Today, however, Building Information Modeling (BIM) is gaining popularity among contractors and sub-trades by providing a powerful and reliable platform for analysis and visualization of MEPF systems. Mounting adoption by industry and research findings suggest that BIM can improve the MEPF coordination process in buildings (Korman et al., 2008).

At Colorado State University, faculty in the Construction Management Department are developing teaching modules to integrate BIM into core construction management curriculum

(Clevenger et al, 2010). This curriculum-wide effort leverages industry-academia collaboration to create teaching modules that demonstrate the power and underlying principles of BIM-enabled work processes in construction practice. This paper documents the lessons learned from the development of an individual teaching module focusing on BIM-enabled MEPF coordination. The primary objective for this teaching module is to facilitate better learning and understanding of core concepts of MEPF coordination. It does not teach the precise steps and functionalities required in professional implementation of BIM software.

To develop this module, the authors are using Adobe Captivate 5 (Adobe, 2010). Adobe Captivate is an advanced screen capture software capable of creating demonstrations and electronic learning presentations independently of the featured software. Captivate simulates the use of BIM software in an executable electronic learning (e-learning) environment viewable using Adobe Flash player. In this e-learning environment, students are able to click buttons and enter data to seemingly advance and select BIM functionalities, while not actually operating native BIM software. The basic content of this teaching module incorporates actual, professional building information models and highlights real-world project experience. The presentation and communication of this content is directed and edited by professional educators. The basic interface simulates direct interaction with BIM software for the students. The educational goal of the pilot module is to expose students to industry best practices, while increasing understanding of and aptitude for evolving construction processes. Industry-academia collaboration is critical to support this effort in construction management education. Industry has expertise in BIM implementation, while it is difficult for academia to maintain a high level of familiarity with the state-of-art software. At the same time, academia is expert at teaching core educational construction management concepts that industry in its daily pursuit of and focus on practical expediency may not be able to identify or effectively communicate.

The MEPF teaching module consists of three parts: 1) an annotated lecture describing industry best practice and distinguishing BIM-enabled coordination processes from traditional; 2) an e-learning demonstration where students observe the role and application of BIM in a simple real-world MEPF coordination project; 3) a homework exercise where students self-perform an e-learning exercise to replicate the implementation of BIM. The content of the teaching module focuses on presenting and reinforcing three core concepts in BIM-enabled MEPF coordination: the fundamental effectiveness of 3D visualization and automated clash detection, the presence of false clashes, and the role of clearance clashes. In this paper, the authors review and summarize the teaching module content under development as well as discuss lessons learned. We focus on the last two parts of the teaching module: the e-learning demonstration and the interactive homework assignment both created in Adobe Captivate. Part one, an annotated lecture introducing emerging BIM-enabled MEPF processes including real-world industry examples is not discussed because it is more standard, while still helpful to students and teachers not entirely familiar with BIM or BIM-enabled construction practices.

2. USING 3D CLASH DETECTION TO ENHANCE COMMUNICATION

The large majority of MEPF coordination performed on construction projects today, as in the past, relies on the comparison of 2D drawings either using juxtaposed drawings or overlays on light tables in what is sometimes called a Sequential Composite Overlay Process (SCOP) (Korman, Fischer and Tatum, 2003). For today's construction management students raised in a world populated with 3D models and animations, this method frequently appears antiquated and burdensome. In the classroom, as in the field, 2D drawings can be the cause of confusion and unsatisfactory communication and analysis. Professionals and academics agree that traditional coordination practice is inefficient and error-prone and is generally in need of process

improvement. Current research suggests that MEPF coordination using BIM requires less rework during installation then when BIM is not used (Khanzode, 2010).

Figure 1 highlights basic but far-reaching differences between 2D- and 3D-based MEPF coordination processes. In a screen shot of the narrated teaching module demonstration (Figure 1, left), students are reminded of the cumbersome process required to identifying clashes on a case-by-case basis requiring manual calculation of various heights to find potential misalignments. Next students are shown (Figure 1, right) the more streamlined and reliable process of automated clash detection using a 3D composite BIM where visualization capabilities are significantly enhanced and calculations can be automated.

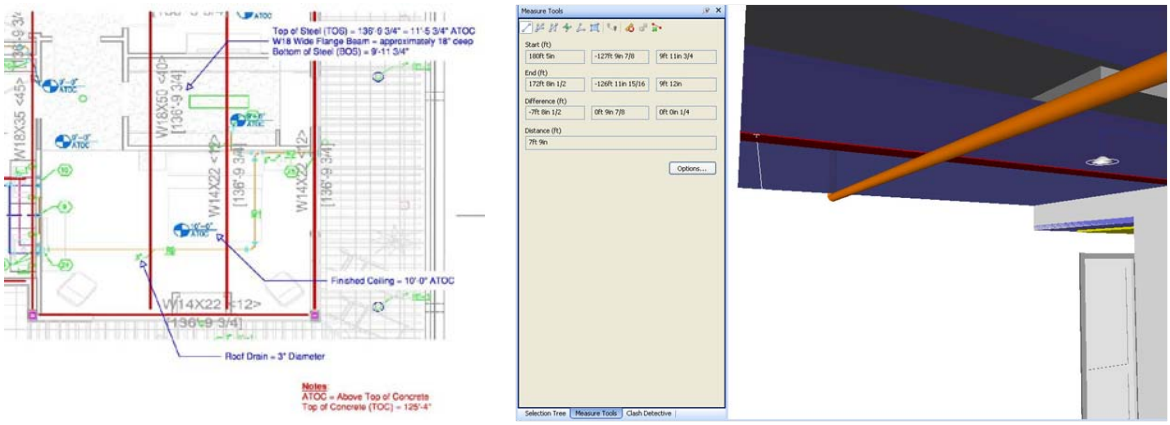

Figure 1: (Left) demonstrates the overlay of plumbing and steel drawings, and shows students the manual math required to identify misalignments; (Right) illustrates space and alignment issues identified using a composite 3D model. Students readily observe that it is easier to identify that the beam is too deep for the ceiling and that the storm line is routed below the ceiling using 3D visualization techniques

Through hands-on demonstration, the teaching module exhibits how 3D coordination enables reviewers to more readily identify conflicts. Students are quickly impressed that, rather than overlaying 2D drawings and performing detailed math to identify potential issues, using a 3D viewer, reviewers (students) can orbit, inspect, take measurements, and visually and quantitatively analyze an issue within the reviewing software. In the case of this real-world project example, it proves significantly easier to identify beam-ceiling misalignment as well as note that the storm-line is mistakenly routed below the ceiling using a 3D rather than 2D platform to perform review. The narrative of the teaching module highlights core construction principles within the BIM process demonstration. For example, the narrative notes that it is typical construction practice to have the storm-line run below the steel. The inclusion of such domain-specific information is a primary distinctions between the teaching modules and traditional “software tutorials” which teach software functionality but do not necessarily include domain specific educational content.

In addition to educational content related to physical construction, the demonstration video serves to highlight lessons pertinent to virtual construction processes. The demonstration video illustrates issues of software interoperability and the complex sequence of operations involved when virtually coordinating separate building models. In MEPF coordination this is particularly relevant since separate models are created by numerous project team members in various disciplines and are commonly imported, opened or appended to existing models. Currently, professional application of BIM faces numerous issues surrounding interoperability (Eastman et al., 2008). Using the Captivate platform to simulate BIM functionalities and by stepping the students through several examples of importing and integrating separate models, the demonstration video and homework exercises demonstrate the challenges of model inte-

gration while insuring integration and compatibility issues do not halt faculty or student progress. Pre-recorded model integration is shown to the students in a step-by-step and interactive sequence giving the impression of implementing the software, while in reality software usage is pres-screened and simulated to insure successful execution. This somewhat opaque distinction is important since it greatly reduces the potential for frustrating and software capability issues which can easily happen and significantly impede novice implementation of BIM-enabled MEPF coordination.

3. USING FALSE CLASHES TO TEACH PROCESS

A second core lesson in the demonstration video is to illuminate a prominent by-product of the virtual construction process as it relates to MEPF coordination: false clashes. Automated clash checkers routinely detect numerous virtual false clashes that are the result of practical model simplifications. A false clash, or irrelevant clash, is a clash detected in virtual construction that is irrelevant to the physical construction process and requires no change in actual design or construction (Gijezen et al., 2010). Such a clash is typically a function of modeling assumptions and techniques. For example, floor penetrations frequently do not include the full detail of physical construction: pipes within pipe sleeves within voids in slabs, but are typically modeled as two or more co-located solids to save time and unnecessary virtual detail. Such modeling techniques make false clashes commonplace in automated clash checkers. Nevertheless, automated clash checkers are powerful analysis tools and are quickly beginning to play a critical role in leading professional construction management practice.

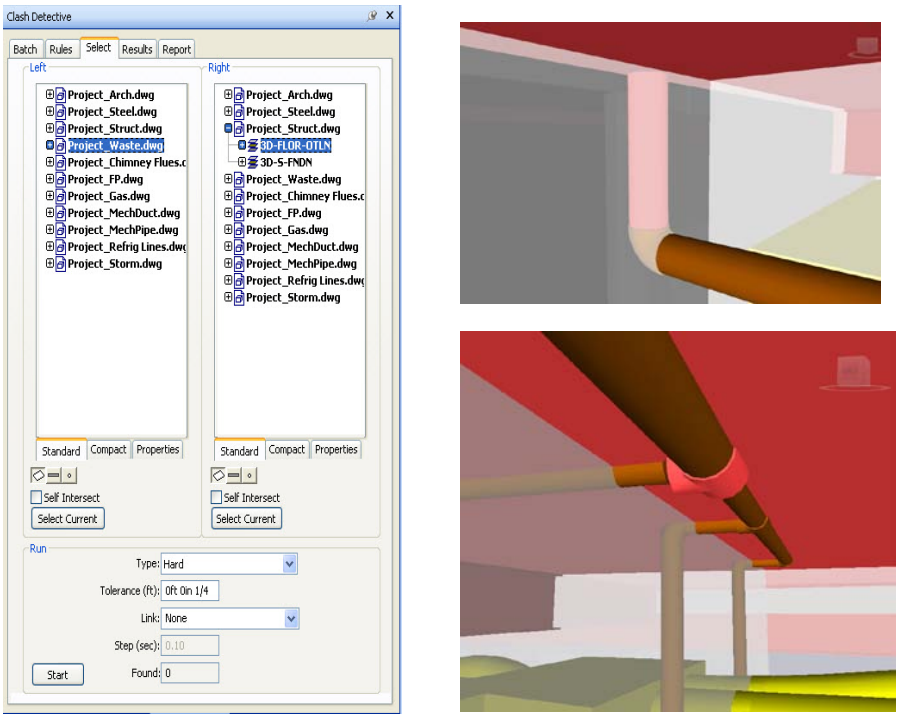

Figure 2: (Left) shows the selection tree from the Clash Detective tool in Navisworks Manage. (Top right) shows a false clash: a waste riser penetrating the floor slab. In reality, the waster riser will penetrate the floor slab. The wall is shown as transparent for ease in viewing. (Bottom right) shows a true clash in which the waste lines are mistakenly routed into the slab due to their excessively high placement in the model. This represents a design error and should be corrected.

In Figure 2, a hard clash test is run for a model to detect clashes between the waste system and the floor slabs. This test produces a number of legitimate or relevant clashes which will

require changes to the design. Examples include instances where the waste system routing is either too high or too low resulting in conflicts with floor slabs as designed. In addition, the hard clash test also produces clashes for all instances where a waste riser correctly penetrates the floor slab. These are false or irrelevant clashes. In the demonstration video and homework assignment, the examples and models are pre-screened to eliminate many false clashes since they can quickly become overly redundant and difficult to manage for the novice user. However, several particularly instructive instances of different types of false clashes are intentional left in the model for the purposes of the demonstration and homework to teach students basic principles relevant to virtual and physical construction.

Using the false clash demonstrated in Figure 2, a slab penetration, the demonstration video discusses two basic concepts: level of detail in virtual design and construction, and construction sequencing in physical construction. Using today's software, a modeler without significant experience, understanding or effort can create a visually convincing representation of design. In virtual design and construction, as with any drawing or representation of design, it is critical to understand the level of detail being modeled. With building systems related to MEPF, the level of detail is particularly nuanced (GSA, 2009). Professional BIM modelers frequently have their own proprietary standards outlining level of detail at different stages of building delivery. An important lesson presented to the students in the teaching module is that design evolves in specificity and that representations of design whether in 2D or 3D must correspond to the appropriate design phase. Without this correspondence, models may misrepresent more than they represent.

The teaching module also uses false clashes to provide teaching examples that highlight the importance of construction sequencing. While nothing may be as memorable as the first time a construction worker is required to "retrofit" an overlooked penetration into brand new construction in real-time, such first-hand lessons-learned are expensive and time consuming in the field. Educators and employers far prefer such lessons be taught in the classroom and avoided in the field. False clashes in BIM models which reveal and highlight legitimate floor penetrations, serve as a less agonizing reminder of the importance of proper construction sequencing. Students are asked to determine whether clashes are relevant or irrelevant in the homework assignment, forcing to think critically about basic construction materials and methods, and teaching them about expected construction sequencing.

4. USING CLEARANCE CLASHES TO DEMONSTRATE ACCESS ISSUES

The teaching module provides another opportunity to enhance student critical thinking in its presentation, application, and analysis of clearance clashes. Clearance clashes, or soft clashes, embody instances where insufficient space exists to properly support access, insulation or safety etc. (Eastman et al., 2008). A powerful advance over the process of overlaying 2D drawings that may or may not call out clearance requirements, using BIM it is possible to assign clearances to objects and to analyze penetration of these clearances. Visualizations of these clearances can be turned on and off to help students understand the spatial issues involved. In the teaching module, the issue of maintenance access for specific mechanical equipment are discussed. Figure 3 shows an example where access clearance for a piece of Heating, Ventilation, and Air-Conditioning (HVAC) equipment is modeled and planned, resulting in construction with proper accommodations for maintenance.

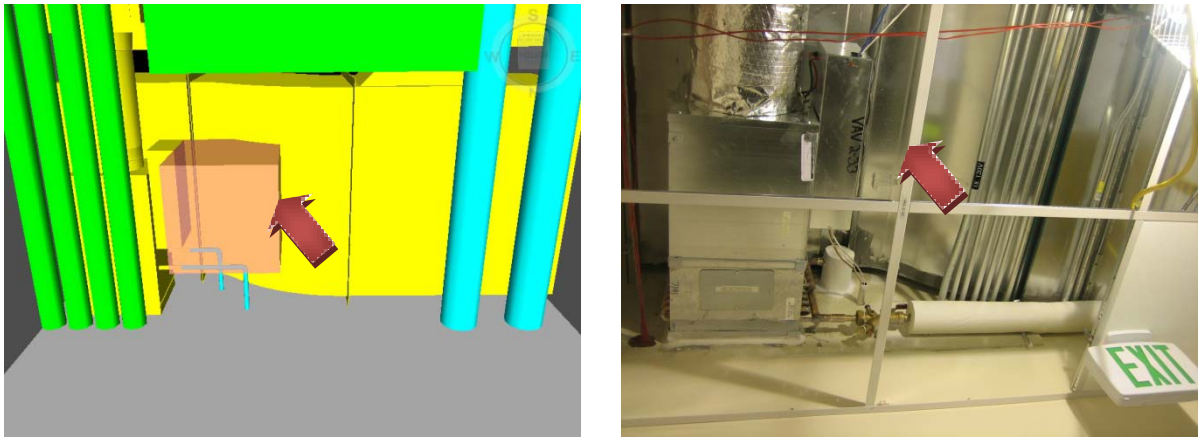

Figure 3: (Left) highlights the access area (transparent orange box) modeled in a composite MEPF model to ensure proper access is provided to the VAV coils. (Right) is a photograph showing the impact on physical construction where a large duct above the VAV is offset upward to allow for said access.

The teaching module discusses another example of clearance clashes: modeling pipe insulation. The module demonstrates that clearance clashes can be tested in the model to reveal instances where insufficient space exists to accommodate future pipe insulation. Students trying to determine the cause of a "clearance clash" involving such soft clearances will need to establish that the insulation has yet to be modeled, and will require space around the pipes in the future. Such exercises highlight material requirements, as well as reinforce concepts involving the level of detail modeled, construction sequencing, and system performance for construction management students in the classroom before they are exposed to them in the field.

5. CONCLUSION

MEPF coordination is a complex process in today's construction practice. Through industry-academia collaboration, the authors are developing a teaching module to simulate and explore the process of BIM-enabled coordination. The module leverages capabilities inherent to BIM, such as 3D visualization, and hard and clearance clash detection to teach and highlight basic virtual and physical design and construction concepts to construction management students in an interactive e-learning environment. The concepts included are intended to promote understanding of spatial relationships, sequencing, access requirements, level of detail, and materiality. The e-learning environment provides an affordable and adaptable laboratory compared to the more costly alternative of field experience. This educational experience can be particularly beneficial preparing students for complex, real-world MEPF coordination projects. By having industry participate directly in the development of the MEPF teaching module, the developers of the educational material attempt to ensure that the content and examples are pertinent and significant to industry practice while the presentation and explanations are well communicated, encourage critical thinking by the students, and focus on teaching core concepts rather than software implementation techniques.

On-going research will further develop the teaching module and pilot its application in various construction management educational settings. Future research will document and analyze the impact of using the teaching module to teach MEPF coordination to construction management students, as well as further analyze the impact of using BIM as an educational tool in construction management education in general.

6. ACKNOWLEDGEMENTS

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