Digital Technologies for Integrated Education in Construction Engineering

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Abstract: Enhancing the preparation of engineering students to deal with real construction projects requires the development of their abilities to handle several engineering concepts in an integrated fashion. This paper presents an integrated approach to delivering construction engineering education using new technologies capable of providing an environment to handle real construction situations with manageable pieces of knowledge available in flexible representations media. In this approach, a computer-based system will be developed to allow the housing of the knowledge of different concepts in formats that can be integrated and used for several purposes and construction engineering aspects. The formats contain representations including sections of digital videos related to construction methods and materials, schedules as well as design alternatives. These representations are organized in association with construction projects components to provide effective compilation and manipulation to support integrated analytical and decision-making processes. The proposed approach will provide the educator with an effective mechanism to deliver the construction knowledge by integrating several concepts in the course, which will help prepare engineers to solve real construction situations.

Introduction

Enhancing the preparation of engineering students to deal with real construction projects requires the development of their abilities to handle several engineering concepts in an integrated fashion. Integrated management processes are complex and crucial for solving most real construction situations[1]. Whether a construction project involves developing a schedule, a plan, or an estimate, selecting a construction method and material, or improving its productivity and quality, engineers must possess the skills to carry out integrated analytical and decision-making processes taking into consideration the effect that each of these functions has on the other[2, 3]. Teaching engineering students how to carry out these processes can be improved with ample exposure and effective delivery methods to enable them to grasp the inherent and intricate concepts, and perform relevant hands-on applications for an adequate preparation for their career.

A common and evident obstacle encountered in teaching construction engineering is the difficulty to bring the construction site to the classroom and to have access to real construction sites during the lecture schedules. A video about a complete project or part of it may clarify some aspects of

"Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition

the concepts. However, the manipulation of this knowledge to deal with specific construction situations and integrated analyses is almost impossible except if videos are digital so that they can be truncated into manageable and useful sections. Capturing visually construction activities and their products in manageable pieces of knowledge allows one to carry out several analyses to demonstrate real construction situations by integrating several concepts in the process. Students and educators can explore and analyze several construction methods and materials, design alternatives, estimates, and/or schedules by composing sets of cases from sections of digital videos available in predefined formats. These formats capture real construction activities and products and are associated with the project components for effective compilation and manipulation.

Digital technologies have been effectively used in management functions related to construction activities. Abeid and Arditi[4] developed a dynamic scheduling system that links digital movies of construction activities, a work schedule, and progress control of construction. They used a time-lapse technique in a way that months of construction performance can be viewed in minutes. In addition, they introduced a method to produce a digital movie, which allows thousands of pictures to be compiled and managed. In their study focusing on digital technologies, Abeid and Arditi[5] have also developed a database containing digital photography, which permits the viewer with play back at lower frame rates identify the tasks and their problems. Use of their database provides an effective mechanism for detecting and monitoring problems such as analyzing claims and investigating accidents.

The enhancement of management activities with digital videos is gaining success due to the enriching visual aspect provided to the user, and the array of possibilities of information manageability that can be performed in a digital environment[4, 5, 6]. Martini[6] reported that the benefits of technology-enabled teaching extend to the highly visual approach, which will allow visual critical analysis of phenomena and features visible in photographs. This is advantageous because of the special characteristics of digital images including the use of digital enhancement, annotation, and manipulation to convey concepts, clarify phenomena and provide image-based homework assignments.

This paper presents an integrated approach to delivering construction engineering education using new technologies capable of providing an environment to handle real construction situations with manageable pieces of knowledge available in flexible representations media. In this approach, a computer-based system will be developed to allow the housing of the knowledge of different concepts in formats that can be integrated and used for several purposes and construction engineering aspects. The formats contain representations including sections of digital videos related to construction methods and materials, schedules as well as design alternatives. These representations are organized in association with construction projects components to provide effective compilation and manipulation to support integrated analytical and decision-making processes. The proposed approach will provide the educator with an effective mechanism to deliver the construction knowledge by integrating several concepts in the course, which will help prepare engineers to solve real construction situations.

The extent to which the use of digital formats can enhance integration among engineering concepts is vast. For example, integration between Electrical Engineering and Construction Engineering may involve analyses relating electrical systems requirements to construction activities sequencing. Figure 1 depicts the envisaged possibilities for delivering integrated education among the different engineering disciplines, sub-disciplines, and within a single sub-discipline, which in this paper refers to construction engineering and also defines the scope of the present work to which integration will be limited, for demonstrating the proposed approach.

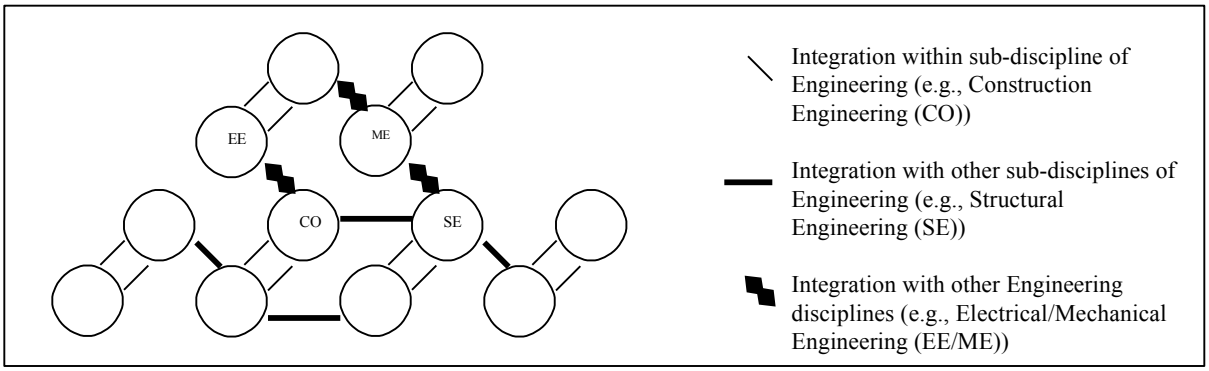

Figure 1. Extent Use of Digital Technologies in Integrated Processes

Digital Knowledge Organization

To organize the stored sections of digital videos, which will mainly be captured from construction sites, a representation model has been utilized in order to provide effective compilation and manipulation of digital knowledge. This model will allow the knowledge of different concepts to be structured in a computer-based system in formats that can be integrated and used for several purposes and construction engineering aspects. Construction products or assemblies of a construction project (e.g., column, footing, slab) form the core to which associations of digital videos are made. The associations include the intermediate products (outputs that have not yet become end products, e.g., mix) related to the assemblies, and the activities that shaped them. Figure 2 shows examples of how videos about construction products are associated to intermediate products, and some of their related construction activities.

In this organization scheme, the digital knowledge about products captures sections of videos of the product from different views. The knowledge about construction activities contains sections of videos, which reflect construction changes with time. The set of predefined videos are stored in formats, whereby the selection of these videos, to be used in a new project/analysis, is performed under the user's control. The time dimension, appearing in Figure 2, represents the chronological order of video sections of construction activities leading to the product. Each video section can be selected and played with sections of different projects to compose a series of activities and products suitable for the analysis at hand. For example, the user can view the sequence of the construction of a product while selecting different methods or materials and analyze their effect on the design, schedule, or estimate. This flexible technology-user interaction allows direct visual understanding and integration of several engineering concepts in the processes.

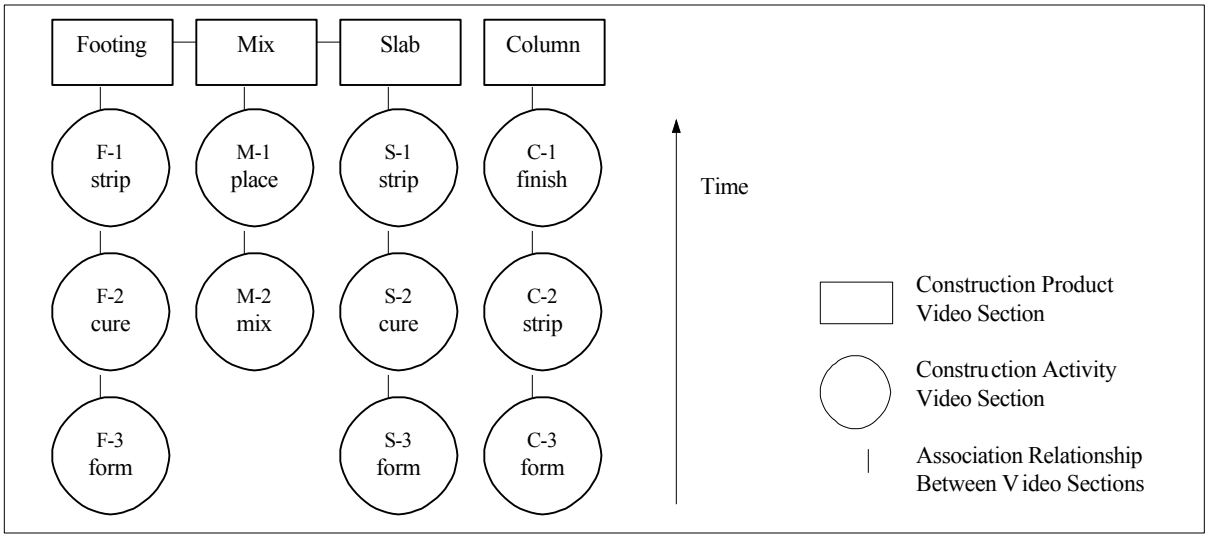

Figure 2. Example Digital Knowledge Organization

The representation model of products and corresponding activities permits these videos to be viewed in manageable flexible formats for an integrated education in construction engineering as well as with other engineering disciplines. Keeping the description at the end product level (e.g., slab) hides the predecessor states that this product has undergone (e.g., mix) and whose activities are necessary for the analyses. To allow access to the knowledge of predecessor states, the end product is associated to the process that has transformed its last state, and to the previous processes and their respective products. The simplest case to describe involves the association of one process to one product (i.e., its output). However, in some cases, the product remains unchanged while its location or other physical characteristics have been altered. To allow a representation of a product, which is an output of several processes, the process is employed to complement the product representation by defining the transformations of this product whose characteristics have changed (due to a process) while it has remained the same product. Figure 3 illustrates how these associations provide a means to define the videos for products. It shows, for example, how the mix may have two video sections for the products including the mixing output and the placing output.

Processes	Products	Digital Videos for Products
Process A1 (e.g., mixing) Process A2 (e.g., placing) Process B1 (e.g., stripping) Process B2 (e.g., finishing)	Product A (e.g., mix) Product B (e.g., column)	Video Section A-A1 (e.g., mixing output) Video Section A-A2 (e.g., placing output) Video section B-B1 (e.g., stripping output) Video section B-B2 (e.g., finishing output)

Figure 3. Product/Process Association for Organizing Digital Videos

Possibilities for Technology Use

Several integration paths exist in the area of construction engineering to which the approach can be applied, and include the selection of adequate methods and materials for a given product

and/or required completion time. Other lines of integration may involve the variation of the schedule time for a given estimate by changing the methods, or the selection of different products or design alternatives to suit an established schedule or estimate. Additionally, the use of the approach can also be extended to illustrations of how to measure construction elements for estimating, or to describe an activity for identifying the resources used. For example, calculating the take-off quantities for sheet piling will benefit from the visual representation of how the piles are driven and cut off, as well as how the area they occupy is calculated. Other activity-based functions can also be clarified with a play of the activities that led to the products. The sequence of activities and site layout can also be analyzed/designed taking into consideration site congestion, sequence of work, etc.. Playing simultaneously multiple activities at different site locations can also enhance spatial visualization, which is useful for determining interferences, coordination of crews and equipment. Deciding which methods to use and their effect on the completion time can enhance schedule design. Problem analysis can also be performed with the compiled formats including excavation related problems, constructability issues, unforeseen site problems, etc.. In addition, change orders can be examined and their consequences determined for preventing cost/time overruns. Students can also access the compiled knowledge in the computer-based system to complete assignments and enhance their understanding of construction processes including the design of site layout, planning and schedule design, estimating, etc.. Consequently, construction engineering education will be delivered with more effective tools and methods relying on visual, real video-based digital representations, which allow the manipulation of flexible knowledge to support integrated analytical and decision-making processes.

Example Formats

To demonstrate the approach, real construction components were captured in digital formats and were downloaded in the computer for compilation and further manipulation. Figure 4 extracts a still photo of the video section capturing the product as a concrete column. Figures 5 and 6 depict still photos of the videos of the construction activities associated with the column including forming and steel erection, respectively. In these figures a round concrete column is the product, which has been formed with a metal cast and its structural steel assembly has been erected. They represent samples of how sections of videos will be compiled and from which the user can select sets of products and/or activities to compose a useful representation of the analysis at hand.

By selecting a set of activities and composing a sequence to form a product (e.g., column), a visual understanding of the construction activities, the resources used, and the location on the site, etc. will clarify the process in a project/analysis under study. Further, the product can be seen from different perspectives. Alternative construction methods can be substituted to accelerate the pace of the project and can be viewed with the sections of digital videos. Several alternatives can be composed to examine the effect on the schedule, cost as well as product design. The benefits are drawn from an enhanced flexibility in manipulating (i.e., selecting from several compiled choices, viewing, composing, decomposing, etc.) the knowledge to evaluate the methods using real visual sections of videos to effectively convey the process. In addition, the integration is performed with the application of several concepts in the case under study, including resources used to, equipment interference, schedule design, and effect on cost, etc..

Figure 4. Column

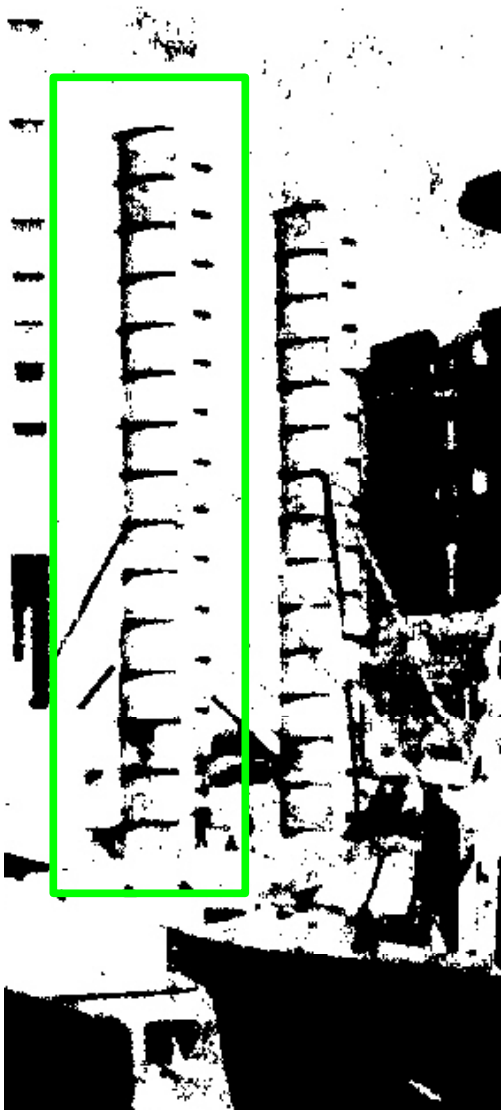

Figure 5. Form

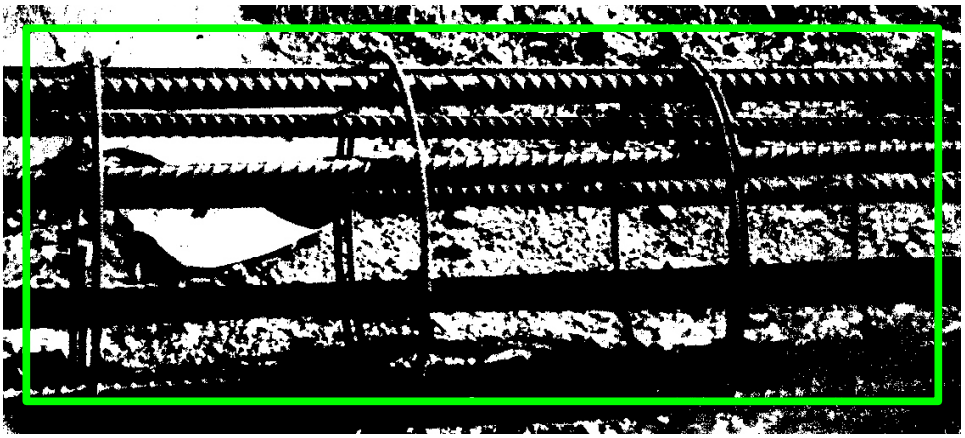

Figure 6. Steel Assembly

Conclusions

This paper has described an approach to deliver an integrated education to engineering students using digital technologies, which provide an environment capable of capturing knowledge in flexible formats. This knowledge can be organized and compiled in a computer-based system in association with construction projects components representations to provide effective manipulation in order to carry out integrated analyses and decision-making processes. The approach consists of using compiled predefined representations including sections of digital videos capturing real construction site activities and products for the composition of new sets of situations useful to several management processes and engineering concepts under a current/new study. This approach will provide the educator with an effective mechanism to deliver the construction knowledge by integrating several concepts in the course, which will help prepare engineers to solve real construction situations. Use of the digital formats of the round concrete column in preliminary integrated analyses during class teaching activities has shown that the approach is effective and flexible, and the results meet the objectives of the system. The approach will allow (1) integrated teaching with other educators, (2) enhanced students understanding and visualization of the concepts involved, and (3) collaborative access with and/or among students to complete assignments and problem-solve. A powerful multimedia database management system will be built, in Windows using the C++ programming language, for compiling and manipulating the digital formats stored in .JPG files. Further development will involve additional compilation of digital representations, and the preparation of case studies to fully implement the approach for utilization in the current program.

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