The ACPROM Model: An Expert System for Evaluating the Construction Progress

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Abstract
A persistent problem in construction is to documenting changes which occur in the field and preparing the as-built schedule. In current practice, deviations from planned performance can only be reported after significant time has elapsed. And manual monitoring on construction sites is costly and error prone. Availability of advanced portable computing, multimedia and wireless communication allows, even encourages fundamental changes in many jobsite processes. However a recent investigation indicated that there is a lack of systematic and automated evaluation and monitoring in construction projects. Consequently the aim of this study is to identify techniques, which are used in the construction industry for monitoring and evaluating the actual physical progress, and to establish how the current computer technology can be used for monitoring the construction physical progress on site. This research presents a prototype expert system, namely Automated Construction PROject Progress Monitoring (ACPROM) system, developed for integrating construction drawings, digital images of construction site progress and construction schedule. Using emerging technologies and information systems ACPROM model suggests new process or reengineer the traditional AEC field inspection process This system can automatically interpret the CAD drawing of a building and extract data of its structural components and develop the database and simultaneously extract the information from digital images and by simulating these two databases the percentage of progress will be calculated and actual physical progress bar chart will be developed automatically. ACPROM provides a bridge for storing structural design information in an integrated construction relational data-base management system that can be shared by a range of computer applications. ACPROM model is part of developing the Tele-Construction base site management system, which retrieves the status of construction work in progress and develop the actual progress bar-chart of work. The application of ACPROM model in monitoring the progress enables project management teams to better track and controls the productivity and quality of construction projects. The use of the ACPROM can help resident engineer, construction manager and site engineer in monitoring and evaluating project performance. This model will improve decision-making process and provides better mechanism for advanced project management.

Keywords
As-built schedule AutoCAD, Digital Photographs, Progress Reporting, and Project Monitoring.

1. Introduction
It is widely recognized that construction is an information intensive and complex industry. Traditional computational techniques have failed our industry because of the shear number of information interfaces and complex relationships. Effective and systematic monitoring and control of information flow is a critical ingredient through the life-cycle of construction projects, such a control of information to describe
the required work, support decision making and analyzing the physical progress. The main focus of this research is to study the issues related to project evaluation and monitoring and developing a systematic model considering the Malaysian construction industry’s viewpoint.

The need has long existed for tools to streamline the job of systematic evaluation and monitoring for management of construction activities. A recent survey of a large-scale project management information and control systems (monitoring over 1,500 public works projects) showed that the need for data entry at the project level was the major obstacle to the success of the systems as whole (Futcher, 2001). In fact, McCullouch (1997) reported that, on average, 30-50% of the time of field supervisory personnel is spent recording and analyzing site data. This paper addresses, a different class of computer application for construction management, namely for managing the monitoring and evaluating system for construction projects and improving progress reporting and control system by incorporating detail information from site photos and AutoCAD drawings.

Construction managers/general contractors need to keep track of design and construction changes and as-built information in order to control and monitor construction progress. The as-built project information represents how construction is actually performed. Accurate documentation of as-built project information in daily logs not only supports management task during construction, but also provides the baseline data in case of claims and disputes. Currently, construction engineers and superintendents rely mostly on written reports to document site conditions and project progress. Written reports have their limitations. Writing skills affect the quality and clarity of reports. As a result, many important details are left out in the writing process and can never be recovered.

A number of systems exist for representing project information and information is created in various formats throughout the life-cycle of a construction project, from design, through construction to facility operation and maintenance (O&M). The need to control construction project performance has been widely discussed. In practice little has been done to address this problem; most of the research efforts in the field of project control still focus on the development of cost control models. Practical attempts have been made to automate the process of producing as-built schedule by applying photogrammetry techniques to photographs. Recent research has focused on using computer vision and digital images processing as a means of producing of as-built schedule of progress of work. This paper describes the current status of an ongoing research project which aims to develop an easy to use tool or expert system to monitor and control the construction progress at the construction stage.

2. Traditional approach for developing as-built schedule

Most construction projects employ scheduling methods to monitor and control the progress of work and develop progress reports, which involve the recording of construction achievements for detection of deviations from actual plan and for forecasting project performance. The primary control system used by project managers to obviate or mitigate time-based claims in construction industry is using construction schedule. There are a variety of ways in which a construction schedule can be presented. The more common types of construction schedule are Gantt chart, activity on the arrow diagram, precedence network and line of balance. Bar charts or Gantt charts are a powerful communication tool and an extremely useful, visual and graphical medium in construction scheduling and used by project managers since the early 1900s. Network techniques have been available since the late 1950s.

Conlin and Retik (1997) described the traditional approach for determining the amount of progress by comparing the contractor’s planned schedule with as-built schedule that has substituted actual completion dates for all the activities. This method, however, has many disadvantages. A persistent problem in construction has been to develop the as-built physical progress schedule of construction scene. The as-
built project information represents how construction is actually performed. This research focuses on the issue related to develop the digitalized actual physical progress bar-chart during the construction stage.

As-built schedules are costly to prepare because it requires the actual dates and considerable judgment. Since detailed records are not always available and even if they are, work on the site does not necessarily match the planned schedule of a network. Creating an accurate as-built schedule from daily site records, engineer’s diaries and other documentation is extremely difficult. This is particularly the case if the sequencing or relationships of the work have changed from the as-planned schedule. Re-establishing the actual sequence from project record is very difficult. Another, extremely important disadvantage is that site records, engineer’s diaries, and general historical project information may be missing or at best incomplete. This results in considerable time being expended in attempting to reconstruct the project’s history from the above-mentioned documents. If this is the case then a great deal of judgment must be used to extrapolate key dates and actual progress. This state of affairs leads to the conclusion that automating control of on-site construction performance is essential in order to enable management to take corrective measures in real-time (Navon and Goldschmidt 2003).

3. Existing project control systems in construction industry

A great deal of work has been carried out in the area of monitoring and controlling the construction of a project. This section provides a brief overview of several studies reported in the literature relating to digitalizing the construction monitoring for construction project. A number of commercial software packages that relate to this topic are also listed. The sources outlined here provide the basis of the analysis of project monitoring and the system development presented in the following sections.

Lock (1993) mentioned that the purpose of computer based information system for engineers is to integrate the collection, processing and transmission of information so that engineering professionals can gain more systematic insight into the operations and functions they are managing. Syed and Froese (1998) quoted that the primary function of the computerized information system is to improve the efficiency of the project manager in retrieving project information from existing records. Russell (1993) described a computerized approach for collecting the site information, which builds on the traditional superintendent’s daily site report

With advancement in computer technologies, particularly in database management system (DBMS), it is cost effective to develop a computerized database for even small projects and organizations. A database can be seen as an attempt to overcome some of the limitations imposed by conventional filing systems, such as uncontrolled redundancy, inconsistency, difficult data sharing, and modification inflexibility. Mazerolle and Alkass (1993) proposed a DBMS in a project control process to store information on each delay when it occurs. Hiroshi and Nobuoh (1993) described a filing system of construction pictures and its integration with a database. Bowler (1994) pointed out the importance of Relational Database management programs (RDBMS) in the project management. Hamilton (1993) stated that, using a relational database improves record management process such as tracking the progress and location of sharp drawings, within a firm, listing present and past projects, maintaining correspondence, calculations, telephone records, and memoranda.

Virtual Construction (VIRCON) system was developed by Dawood et al, (2002), to support decision making system for construction planning. The VIRCON database is composed of a core database of building components which are in turn, integrated with a CAD package (AutoCAD 2000), a Project Management Package (MS Project), and Graphical user Interfaces. MULTROL, a multimedia project control and documentation system, was developed by Liu et al, (1994). The retrieval of project information is assisted by a graphical user interface and user-definable queries to support various needs of construction management. This system allows the storage and retrieval of project information in the
format of text, image, video and sound. A prototype system, CAD Construction Information Management System (CADCIMS) was developed by Stumpf et al., (1995), using Microsoft ACCESS™, and relational database management system in the Microsoft Windows environment. The interfaces had been developed among the Schedule Generator, the CADD system, and the database.

Wang (2001) presented an expert system ESSCAD (Expert System Integrating Construction Schedule with CAD drawing) developed for integrating construction scheduling with CAD drawings. As it was integrated with a CAD drafting system AutoCAD and scheduling software MS-project, it retains the advanced functions of CAD drafting and network analysis. Abeid et al., (2003) described the development and implementation of an automated real-time monitoring system for construction project programmed in a Delphi Environment. This system links time lapse digital movies of construction activities, critical path method (CPM) and progress control techniques. Abeid (2000) developed PHOTO-NET techniques, a system that integrates time-lapse photography with a dynamic scheduling and progress control tool. Streilein (1996) formulated DIPAD software, which combines digital Photogrammetric methods with the capabilities of a CAD system. The overruling principle of DIPAD is, that the human operator assigns responsibility for the image understanding part (high level grouping), and the computer for the actual measurement and the data handling.

The basic task of many Photogrammetric systems is to derive object space coordinates from 2D images. Analog, semi analytical and analytical techniques have been employed for a long period of time in Photogrammetry to extract ground coordinates of objects from hardcopy images. In recent years, digital techniques are implemented in Photogrammetric applications. Pappa et al., (2002) implemented the photogrammetry techniques for Gossamer Spacecraft Structures and he described that the science of calculating 3D object coordinates form images is a flexible and robust approach for measuring the static and dynamic characteristics of future ultra-light-weight inflatable space structures. He selected Close-range Photogrammetry, a flexible and robust technology with demonstrated potential for measuring Gossamer-type structure. Greco (2001) described Photogrammetry is one of techniques for obtaining reliable measurements from photographs and other type of images. DeChant (2000) mentioned that by using close-range Photogrammetry instead of taking traditional contact measurements, the photos were converted into AutoCAD models using Photomodeler pro version software.

From the related research it has been cited that many studies have been conducted to develop the integration model for a project and the ideas for developing automated real-time monitoring systems are rapidly growing with the advancement in the information technology. From the literature it has been cited that very few have given concern to develop the actual physical progress bar-chart by capturing the information form photograph. The close range photogrammetry is used for converting photographs to 3D Model with the help of Photomodeler pro version software, which is requirement for accurate photogrammetry.

4. Objective and scope

The objective of this research is to demonstrate that computer vision can be integrated with 3D CAD to produce construction as-built schedule. Computer vision defined by Raynar and Smith (1994) was that; take 2D images or photos as input and produces descriptive information as output. The actual construction is represented by the digital image of the construction scene. The CAD model represents the original design drawings of a project. By simulating the digital image with a perspective view of the CAD model, differences from the CAD model represent the as-built schedule. The scope of the research is to develop a vision or integrating system for processing images of the construction scene and for making the comparison to the CAD drawings.
Digitalizing the Construction Monitoring is the recent demand of the Malaysian Construction Industry and for the third world countries. The major object of developing this model is to develop the link between existing methods of evaluating and monitoring the physical progress of construction scene with modern technology by developing an Artificial Intelligence to emulate the human brain. The basic object of developing the ACPROM is to systematize the project monitoring and evaluation system that improves productivity, reduce the claims, and control the delays or improve the construction management methods in progress reporting and project control.

5. Structure and components of ACPROM

With the continued development of easy-to-use computer software and improved graphical presentation media, many of the practical problems associated with formal scheduling mechanics have been overcome. Some of the function involved in project management, especially those concerned with project monitoring and evaluation (developing the actual physical progress bar chart) were virtually impossible to execute with any great speed before computers were used (Levine 1989). The rapid growth in the availability and power of micro-computers, coupled with their continuously decreasing cost, has made it possible for construction managers to effectively and efficiently analyze the massive amounts of data necessary to monitor and control the progress of the many interrelated tasks that go together to make a construction project. The object model linked the 3D graphical and non-graphical representation of the project to the CAD drawing base systems.

Taking into account characteristics and functions of ACPROM, it was programmed with knowledge-based system programming method. Being a typical expert system, ACPROM consists of AutoCAD, Photogrammetry techniques, Database management system, Knowledge base system, ACPROM simulation to formulate to user interface as shown in Figure 1. ACPROM processes the data as shown in Figure 2 from which it can be seen that the link between the digital images, CAD drawings and Planned Bar-chart is established and event-oriented programming (Visual Basic 6.0) is used to integrate the information from images and drawings to calculate the progress of the work and then integrate that percentage of progress with Microsoft Project, to show the actual physical progress in the bar-chart format. The RBDMS stores the mainly two kinds of data i.e. primary from AutoCAD drawing and secondary from Photomodeler using the Artificial Intelligence. Most of the data in the RDBMS are organized in rows and columns, which is widely used for effective representation of knowledge of expert system. The basic theory behind developing the model is to extend the traditional approach to represent the dynamic and simultaneous construction operations by incorporating interrelationships between hierarchical processes of evaluating. The objective of developing a Digitalized Construction Monitoring (ACPROM) model is to systematize the construction monitoring and evaluation of a project. ACPROM is implemented using object oriented concepts and event driven programming. The object-oriented concepts were utilized in the graphical user interface of constructing the ACPROM processes. Graphical interfaces were created in the Photogrammetry and photomodeler environment and then exported into Visual Basic ™ (event driven programming). Relational Data base was implemented using Micro Soft Access ™ engine to store project related information. The simulation concept of ACPROM model is currently being used to test and check the validity. The main goal of ACPROM model is to propose an interface process model between the 2D digital photo and detail design drawings and update the physical progress chart by integrating the information.
6. Progress reporting mechanisms in digitalizing the construction monitoring

Traditionally information about physical project progress is reported based on engineer’s diaries, daily site records, and other documentation is extremely difficult. The mechanism for developing the project’s actual physical progress based on digital system which compares the plan schedule of work with actual achievement on site to forecast the performance. Project drawings designed at the start of the project and expert system is used to develop the database and is reluctant, as any change order will be corrected in the database. Secondary database will be developed as construction work constructed and the source of information will be using photos. Visual basic will be used to build interfaces between the database developed from AutoCAD and Photos by using Photomodeler. By simulating both databases, it will calculate the percentage of progress considering the updating date and will transfer this information to Microsoft Project to show the actual physical progress in bar chart. If on comparison the actual coordinates with the planned coordinates then the actual physical progress report will show the percentage of work completed. Progress reporting mechanism in ACPROM includes comparing the co-ordinate’s values of the activities which is performed on site with the coordinate values of original AutoCAD drawings.
7. Conclusions

This paper described a computer model for automatic generation of as-built project schedule. The model utilizes the photogrammetry techniques and Computer aided design (CAD) capabilities for field data acquisition and is integrated within a knowledge-based expert system environment. The main focus of this study is to design a methodology for monitoring and evaluating the construction project and
developing a systematic model considering Malaysian construction industry’s view point. The objective of this research is to demonstrate that 3D CAD could be integrated with computer vision to produce as-built schedule. The development of ACPROM demonstrate the possibility of combining the pictures and CAD drawings, allowing the superintendents to systematize the monitoring and evaluation of site condition/progress more precisely. ACPROM demonstrates the benefits and potentials of applying knowledge base system to construction project control and documentation.

The application of ACPROM model in daily monitoring the progress enables project management teams to better track and control the quality of construction projects. It’s the author’s belief that by implementing the latest technologies in the field of construction, specially, during the execution phase could minimize the potential problems and encourages lesson-learned and innovation.

8. References


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