

Systematic Approach for Developing As-built Schedule for Construction Project

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ABSTRACT

It is widely recognized that construction industry is information intensive and complex industry. However, present trend and proliferations towards multi-participant mega projects have heightened the need for an effective and efficient evaluation and monitoring by stakeholders. A persistent problem in construction has been in documenting changes, which occur in the field, and preparing the as-built schedule. Combining computer vision technology with 3D CAD to produce as-built drawing offers a potential solution. However a recent investigation indicated that there is a lack of systematic and automated evaluation and monitoring in construction projects. The aim of this research 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. 3D CAD is increasingly being used as a design tool for construction projects and digital images can be used to provide accurate information needed to document as-built construction schedule. The DCM provides a bridge for storing structural design information in an integrated construction relational database management system that can be shared by a range of computer applications. The DCM model is a 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. A pilot study of Car Parking for Larkin Mosque is conducted to check the validity of DCM. The application of DCM model in monitoring the progress enables project management teams to better track and controls the productivity and provides better mechanism for management of project.

Key words: Construction management, as-built schedule, autoCAD, digital photographs, construction sites

ABSTRAK

Industri pembinaan merupakan satu industri yang kompleks dan melibatkan banyak maklumat yang perlu diproses. Walau bagaimanapun, perkembangan terkini ke arah kepelbagaian projek mega telah

meningkatkan permintaan pemerhatian dan penilaian yang cekap serta efektif daripada mereka yang berkepentingan di dalam projek tersebut. Masalah yang berterusan dalam pembinaan adalah dalam mendokumentasikan perubahan-perubahan yang berlaku di tapak dan menyediakan jadual ketika-bina. Teknologi komputer dengan gabungan 3D CAD menawarkan satu penyelesaian yang berpotensi digunakan untuk menghasilkan lukisan ketika-bina. Walau bagaimanapun, penyelidikan yang dilakukan baru-baru ini menunjukkan terdapat kelemahan dari segi pengawasan dan penilaian yang sistematik serta berautomasi dalam projek pembinaan. Tujuan kajian ini dilakukan adalah untuk mengenal pasti teknik yang digunakan untuk pengawasan dan penilaian kemajuan fizikal dalam projek pembinaan dan seterusnya menentukan bagaimana penggunaan teknologi perkomputeran yang terkini boleh diaplikasikan dalam pengawasan kemajuan fizikal di tapak pembinaan. Kertas kerja ini menampilkan Model Pemantauan Pembinaan Digital yang merupakan satu sistem interaktif yang mengintegrasikan CAD dan aplikasi yang berkaitan dengan pembinaan untuk menyelesaikan masalah pengawasan dan membangunkan kaedah laporan kemajuan dalam peringkat pembinaan. 3D CAD digunakan secara meluas sebagai perisian reka bentuk untuk projek pembinaan di mana imej digital boleh digunakan untuk menyediakan data yang diperlukan secara tepat untuk dokumen jadual ketika-bina. Pelbagai usaha dan percubaan praktikal telah banyak dibangunkan oleh para penyelidik untuk mengautomasikan proses penghasilan jadual ketika-bina dengan mengaplikasikan teknik fotogrametri terkini kepada gambar. DCM juga memainkan peranan sebagai penghubung untuk menyimpan maklumat reka bentuk struktur dalam sistem pengurusan pengkalan data yang berkaitan dengan pembinaan berintegrasi yang boleh dikongsi dengan beberapa aplikasi komputer. Model DCM merupakan sebahagian daripada membangunkan sistem pengurusan kawasan tapak pembinaan yang mengambil status kerja pembinaan semasa dan memberi carta bar perkembangan semasa. Satu kajian rintis tempat letak kereta Masjid Larkin telah dilakukan bagi mengesahkan model DCM tersebut. Penggunaan model DCM bagi memantau perkembangan projek membolehkan kumpulan pengurusan projek untuk menentukan dan mengawal produktiviti serta menyediakan mekanisma yang lebih baik bagi pengurusan projek.

Kata kunci: Pengurusan pembinaan, jadual ketika-bina, autoCAD, foto digital, kawasan pembinaan

INTRODUCTION

It is widely recognized that construction is an information intensive and complex industry. Traditional computational techniques create problems in construction industry because of the sheer 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 as control of information to describe the required work, support decision-making and analyzing the physical progress (Syed & Froese 1998). This paper focuses on the issue of evaluation and monitoring of construction project and developing a systematic model from the point of view of Malaysian construction industry.

The need has long existed for tools to streamline the job of systematic evaluation and monitoring for management of construction activities. Progress reporting involves the recording of construction achievements for detection of deviations from actual plan and forecasting

project performance (Nadir & Simaan 1995). A 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, McCullough (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 (Abd.Majid et al. 2004; Ciesielski 2000 & Cheng & Chen 2002). 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 (Hastak et al. 1996). The research studies have been carried out to manage and automate the process of developing the as-built schedule from digital images (Abeid et al. 2003; Memon et al. 2004a & Stumpf et al. 1995). This research focused on using computer vision and digital images processing as a means of producing as-built schedule of progress work. This paper describes the current status of an ongoing research project, which aims to develop an easy to use tool to monitor and control the construction progress at the construction stage.

LITERATURE REVIEW

Most construction project employ scheduling methods to monitor and control the progress of work and develop progress reports, which involves 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 construction schedule (dependent on cost, schedule, and quality reports and personnel performance reviews) (Sanvido & Paulson, 1992). 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, precedence network and line of balance (Conlin & Retik 1997). Bar charts or Gantt charts are powerful communication tool and extremely useful, visual and graphical medium in construction scheduling and used by project managers since the early 1900s (Melin & Whiteaker 1981). Network techniques have been available since the late 1950s (Fondahl 1980).

The as-built project information plays an important role in project planning and control. People responsible for schedule updates and adjustments need access to the as-built information to evaluate productivity and progress. Problems, conflicts, and interferences during construction must be identified so that delays and cost overruns can be avoided. The as-built schedule also provides feedback to designers/engineers to improve their design, construction engineers to improve productivity and contractors would like to keep this information for their future job bidding.

Conlin and Retik (1997) described the traditional approach for determining the amount of progress as to compare the contractor's planned schedule with calculated dates to an 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. The research reported here focuses on the issue related to developing the digitalized actual physical progress bar chart during the construction stage. As-built schedules are costly to prepare because of the amount of research necessary to determine the actual dates and considerable judgment is also required. 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 disadvantage observed that considerable time being expended in attempting to reconstruct the project's history, in the case

of general project historical information or site records or engineer's diaries may be missing or at best incomplete. 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 onsite construction performance is essential in order to enable management to take corrective measures in realtime (Navon & Goldschmidt 2003).

EXISTING PROJECT CONTROL SYSTEMS OF PROJECT MANAGEMENT

Effective control of information flow is a critical ingredient throughout the life cycle of construction projects. Examples include the control of information to describe the required work, support decision making, analyze progress, pass on to other participants, and record for future reference during claims, and support estimating on similar projects in the future (Tenah 1981, 1984, 1986). 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 shop 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 a 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 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 from 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 from 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.

DIGITALIZING CONSTRUCTION MONITORING (DCM)

DCM is prototype software which developed to measure the actual project progress and plot on-bar chart. DCM is under development at Construction Technology and Management Center (CTMC), Faculty of Civil Engineering, Universiti Teknologi Malaysia (UTM), Skudai, Johor, Malaysia. Mui et al. (2003) mentioned that Construction Industry Development Board (CIDB) has launched an e-construction Portal exchange which is to automate the process of life-cycle construction of projects and this study is the part of that approach. DCM will be tested within Malaysian Construction industry considering any building case study. Memon et al. (2005), Abd. Majid et al. (2004) Memon et al. (2004b) defined DCM as to develop the link between existing method of monitoring the physical progress of work activities and modern technology to emulate human brain.

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 to 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.

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 DCM is to systematize the project monitoring and evaluation system that improves productivity and improves the construction management methods for project progress reporting and project control.

STRUCTURE AND COMPONENTS OF DCM

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 functions 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 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 DCM, it was programmed with knowledge-based system programming method. Being a typical expert system, DCM consists of AutoCAD, Photo-grammetry techniques, Database management system and Knowledge base system. DCM simulation to formulate to user interface is as shown in Figure 1. DCM 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 Relational Data Base Management System (RDBMS) stores the two main 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. DCM is implemented using object oriented concepts and event driven programming.

The object-oriented concepts were utilized in the graphical user interface of constructing the DCM processes. Graphical interfaces were created in the Photo-grammetry and photomodeler environment and then exported into Visual Basic™ (event driven programming). Relational Data base was implemented using Microsoft Access™ engine to store project related information. The simulation concept of DCM model is currently being used to test and check the validity. The main goal of DCM 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.

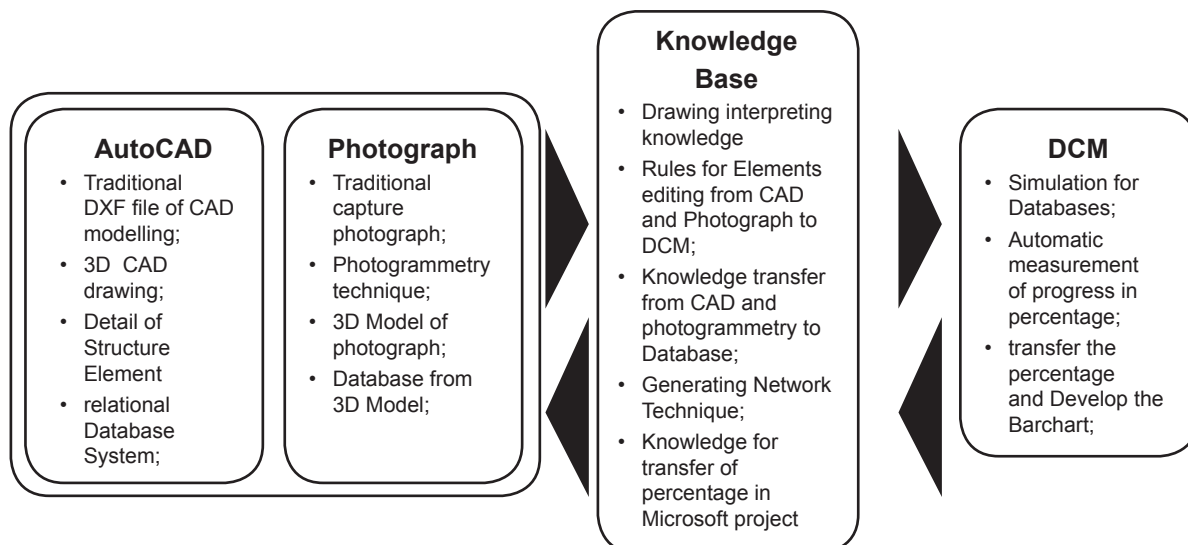


Figure 1. Components of Digitalizing Construction Monitoring

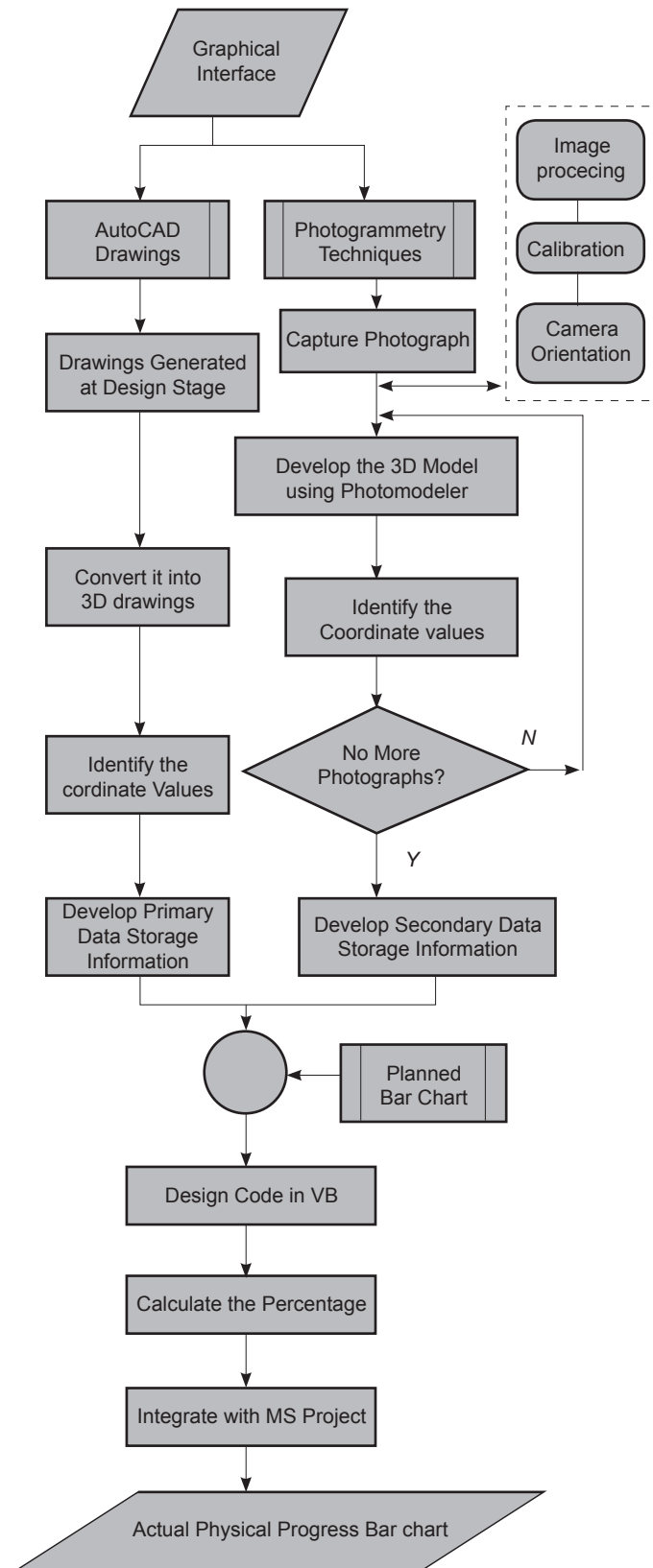


Figure 2. Process Flow of DCM

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 are 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 onsite to record the performance. Project drawings designed at the start of the project and expert system is used to develop the primary database and any change in drawings will be corrected in the primary database. Secondary database will be developed as construction work begin and the source of information from digital images. 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 Micro Soft Project to show the actual physical progress in bar chart. Comparising the actual coordinates with the planned coordinates will show the percentage of work completed in the actual physical progress report. Progress reporting mechanism in DCM includes comparing the co-ordinate's values of the activities, which is performed on-site with the coordinate values of original AutoCAD drawings.

UTILIZATION OF DCM MODEL

The DCM is operated through a user interface, to which access is via the set-up domain of the prototype. By installing the system, the user can access the various built-in functions; first he has to add the general information such as title of project, name of owner, consultant and contractor as shown in Figure 3 and then by clicking on submit icon it links to main page of the DCM and the user have to browse the required information in the interface.

Initially the DCM model was tested on the construction of Pile cap for Car Parking for Larkin Mosque, Larkin Johor. Figure 4 shows the development of 3D model from Digital photographs by marking the different points on photographs and computing the coordinate values for different points in Table format. The coordinate values obtained from 3D model, which was developed from 2D digital photographs

stored in the secondary database. Once the user added all the required information in the user interface about the planned bar chart, stage/level of structural element, 3D AutoCAD drawings for developing automatically primary database and 3D coordinates values from the digital photographs for developing secondary database, then clicking on the start process icon, it will start calculating the actual physical progress percentage by simulating the information from drawings and photographs. Figure 5 shows the result interface of construction of pile cap 1 named as Beam1 in this process and then by clicking on View icon it will link automatically to Micro Soft Project's Gantt chart view, which shows the comparison of planned progress with actual physical progress.

DISCUSSIONS

The DCM model streamlines the job of construction monitoring and progress reporting. From management point of view this system assists the contracting parties (Client, Consultant, and Contractor) to easily develop the progress report. More importantly, the use of DCM enables the project manager to easily calculate the percentage of progress without any trial and error method or by guessing. This system also helps the executive of the public works to easily know the accurate physical project progress from his office.

The smooth functioning of DCM relies heavily on the digital photographs and the database system developed from photographs and AutoCAD drawings. As such, DCM users need to be equipped with Photomodeler software, AutoCAD 2000 and Microsoft project to develop the reliable database and output result. Despite the costs involved for initial purchasing, the output result will be more useful and liable forever.

FUTURE DEVELOPMENT

The aim of DCM is to reduce the time needed for monitoring and evaluating the progress. At its initial stage DCM was tested on small super structure concrete members such as beams and columns. It is suggested to test the DCM for the construction of single story house and modified according to hindrances occurred during the construction. Special thanks goes to Ir. Dr. Mahmood Tahir for his cooperation in obtaining the required data.

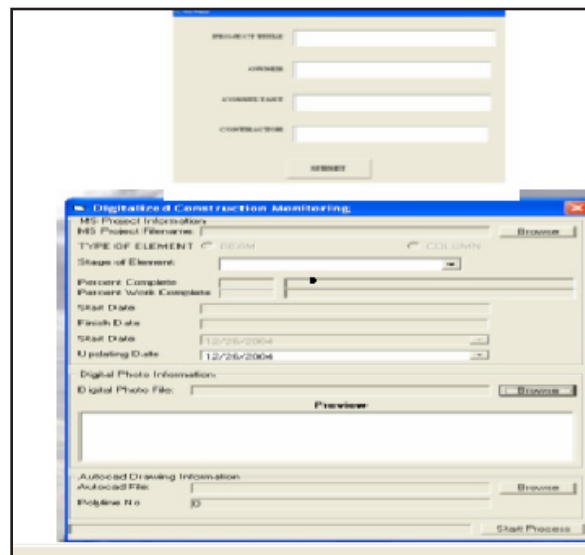


Figure 3. Sample Screen of User Interface of DCM

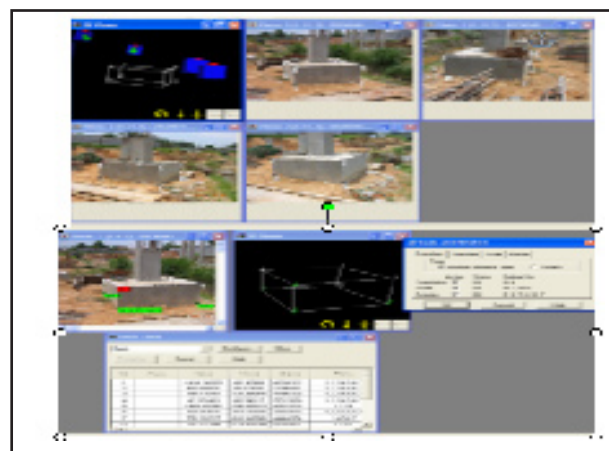


Figure 4. Sample Screen of Marking on Reference Points and 3D view with Camera Icon of the Construction of Pile Cap Showing the Coordinate Values and Orientation and Camera Parameters

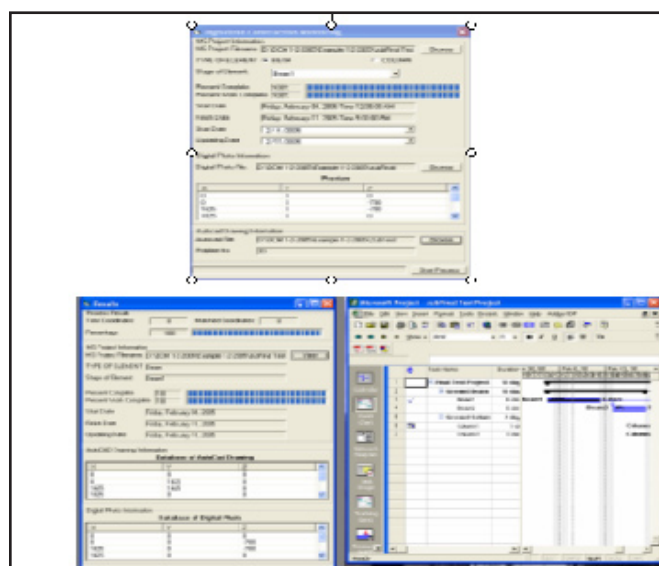


Figure 5. Sample Screen Result Interface of DCM for the Construction of Car Parking at Lark Mosque, Larkin Johor Bahru, Malaysia

CONCLUSIONS

This article 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 develop a systematic model considering Malaysian construction industry's viewpoint. However, this research is at initial stages but soon after completing prototype software, DCM can be implemented and tested under different construction industries through out the world. The objective of this research is to demonstrate that 3D CAD could be integrated with computer vision to produce as-built schedule. The DCM model is developed by using the Relational Database Management System (RDBMS) and demonstrates the possibility of integrating the digital photographs and CAD drawings, thus allowing the super-intendents to systematize the monitoring and evaluation of site condition/ progress more precisely. DCM demonstrates the

benefits and potentials of applying knowledge base system to construction project control and documentation.

The research described herewith attempts to overcome the limitations of the previous studies in the area of progress monitoring and developing the as-built schedule. The application of DCM model in daily progress monitoring enables project management teams to better track and control the quality of construction projects. By implementing the latest technologies in the field of construction, especially during the execution phase, could minimize the potential problems and encourage lesson-learned and innovation.

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