Exploitation of Mobile Devices in Tracking Construction Projects using BIM

By

Mohamed Magdeldin Mahmoud Adel Zaher

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
In
STRUCTURAL ENGINEERING

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Exploitation of Mobile Devices in Tracking Construction Projects using BIM

Key Words:

Building Information Modeling; Augmented Reality; Construction Projects Tracking; Image Processing; Hand-Held mobile devices; Image Analysis; Facility Management.

Summary:

Augmented Reality (AR) is used to explore a new era of integrating the Building Information Modeling during project's life cycle phases with the real world to enhance the interaction, considering different aspects of construction projects. This research proposes newly developed android applications that allow visualization, monitoring, construction planning, and facility management validated through case studies during the project life cycle. Augmented Reality is utilized during construction using an application named "BIM-Phase" through implementing a 4D model enhanced with an augmented video to show the 5D model powered with different cost parameters. Whilst, Facility Management takes place through another application named "BIM-FM" that is used to illustrate different types of assets information to avoid premature asset failure, and manage the required level of service. The third application is named "BIM-Inspect" that is used for inspection using Augmented Reality as a 3D model enriched the real-world environment showing the different systems such as firefighting, HVAC, plumbing networks. Finally, "BIM-Track" application is cloud-based which is able to export the progress into an Excel spreadsheet from the mobile application to a remote computer to update the project's 5D model. "BIM-Track" android application is capable to be accessed to any uploaded project's 3D model as well. Case studies are presented to illustrate the uses of the proposed applications.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE

2D Two Dimensional
3D Three Dimensional
4D Four Dimensional
5D Five Dimensional
ACWP Actual Cost of Work Performed
AEC Architectural, Engineering and Construction
AR Augmented Reality
BAS Building Automation System
BCWP Budgeted Cost of Work Performed
BCWS Budgeted Cost of Work Scheduled
BIM Building Information Model (or Modeling)
CAD Computer Aided Design
CMMS Computerized Maintenance Management System
CNC Computer Numerical Control
CPI Cost Performance Index
EV Earned Value
FM Facility Management
GIS Geographic Information System
GPS Global Positioning System
MAR Mobile Augmented Reality
MEP Mechanical, Electrical and Plumbing
PaaS Platform as a Service
PV Planned Value
RFI Request For Information
SaaS Software as a Service
SPI Schedule Performance Index
VR Virtual Reality

ABSTRACT

Augmented Reality (AR) is used to explore a new era of integrating the Building Information Modelling (BIM) during project's life cycle phases with the real world to enhance the interaction, considering different aspects of construction projects including Architecture, Engineering, Construction, and Facility Management (AEC/FM). This research presents a new methodology for exploitation mobile devices using BIM to monitor construction projects during its life-cycle. This is done through proposing new developed android applications that allow visualization, monitoring, construction planning, and facility management. These applications are "BIM-Phase", "BIM-FM", "BIM-Inspect", and "BIM-Track". Augmented Reality is utilized during construction using an application, named "BIM-Phase", through implementing a 4D model integrated with an augmented video to show the 5D model powered with different cost parameters such as the earned value and planned value to help in decision making, minimizing time of delivering information. Whilst, Facility Management takes place through another application, named "BIM-FM", that is used to illustrate different information about assets to avoid premature asset failure, and manage the required level of service. The third application, named "BIM-Inspect", is used for inspection using Augmented Reality as a 3D model to enrich the real-world environment showing the different systems such as firefighting, HVAC, plumbing networks. Finally, "BIM-Track" application is cloud-based application which aids in speeding up the production of construction progress reports and improves data accuracy. The application allows collaboration, visualization, and data sharing through the internet to export the results into an Excel spreadsheet from the mobile application to a remote computer. In addition, the acquired data can be used to update project's 5D model. The project performance indices can be shown through 5D model to compare planned against actual progress. Case studies are presented to illustrate the uses of the proposed four applications throughout project life cycle.

Chapter 1: Introduction

1.1 General

Nowadays, Mobile hand-held devices are being used massively in different applications. Portability and accessibility granted the mobile hand-held devices such as smartphones and computer tablets a great advantage that attempt recent studies to automate the process of construction site monitoring. Developing a BIM model for a project contributes to projects' success, since it provides coordinated and consistent views and representation of the 3D model including reliable data . As a result, BIM is important in the project life cycle starting from conceptual design process till operating projects. Tracking construction projects during its whole lifecycle is a continuous process, so it is recommended to be automated instead of using traditional methods that require massive efforts. Image Processing can be one of the afforded techniques for tracking projects. In addition, Building Information Modeling has various applications that can be utilized through the whole project lifecycle using different mobile devices applications. Architecture, Engineering, Construction, and Facility Management (AEC/FM) industry is frequently searching for effective techniques to increase efficiency and productivity. Augmented Reality can be classified as one of the most effective mobile hand-held devices technologies that can be implemented successfully in AEC/FM industry. Mobile Augmented Reality has the potential to access the required information using mobile hand held devices (i.e. mobile, and computer tablets), and optical head-mounted display (i.e. google glass). There are several aspects for improvement in productivity of onsite operations. Kim et al. [1] listed that any onsite information management system should have the following characteristics: 1) enable project monitoring capabilities, 2) provide easy access to relevant information so that onsite resources could be managed more effectively , and 3) share information and facilitate interactions among project participant in real-time of project execution.

1.2 Problem Statement

Progress tracking mostly depends on supervisors daily or weekly reports, which involve intensive manual data collection and entail frequent transcription or data entry errors. Field engineers and/or superintendents use 2D/3D as-planned drawings, project specifications and construction details to review the progress achieved by that date then study these reports. After that, they study the construction schedule to identify the work planned to be done by that date. This requires a significant amount of manual work that may affect the quality of progress estimations [2]. Moreover, Engineers rely on the 2D drawings or 3D drawings (i.e. on 2D screens) during project's lifecycle which makes a gap between the real and digital environment. Recent researchers exert efforts on mixing virtual information with real environment to decrease this gap. Golparvar Fard [3] illustrated that most of Architectural, Engineering, and Construction meetings are spent on explaining and describing the rationale behind the decision making process and infrequently on value adding task as evaluating and predicting the effects of a decision on the project. Moreover, low effectiveness rates on these decision-making tasks are reported. The process of understanding projects' drawings, documents, specifications, etc. takes place during the project's life cycle that could result in defects in design and

rework in the construction industry. Moreover, weight, portability, cost, and size of hardware have a direct influence of their usage during the project's life cycle. The project life cycle passes through a series of sequential or overlapping phases [4]. Each phase generally focuses on a subset of project activities and project management processes. Wang et al. [5] indicated that BIM provides relatively static and pre-defined data and information.

1.3 Research Objectives

The objective of this research is to decrease the gap between the real and digital environment, and to automate construction project tracking processes to facilitate data collection, entail frequent transcription, and avoid data entry errors using mobile hand-held devices throughout all construction and facility operation phases. As such, this research focuses on exploitation of smart phones on the different stages of construction projects with other technologies throughout their life cycle for better experience. To achieve the main objective, the following sub-objectives are carried out:

- Automate the process of tracking ongoing construction projects using cloud based service to process site images.
- Monitor/Update construction projects' progress using mobile hand-held devices.
- Facilitate knowledge accessibility embedded in BIM models at construction sites.
- Enrich the use of 5D model through Augmented Reality applications in construction by visualizing the cost parameters during the execution of the project showing the execution stages.
- Decrease the gap between the real and digital environment in construction industry throughout projects' lifecycle using Augmented Reality (AR).
- Propose a Facility Management tool that assists decision makers through presenting information using the Augmented Reality.

1.4 Research Limitations

The scope of this research is exploitation of smart phones on the different stages of construction projects with other technologies throughout their life cycle for better experience. However, it is has the following limitations:

- It does not provide advanced image analysis such as provided by Red Green Blue Depth Cameras (RGB-D) as Kinect devices.
- Captured images shall be captured from the same location.
- Image analysis in the research is guaranteed for big elements such as slabs, columns.
- Optical Head Mounted Displays (OHMD) such as Oculus, Google glass were not utilized to maximize the yield of Virtual Reality and Augmented Reality.

1.5 Research Methodology

This research depends on developing mobile applications that allow end-users to use the proposed application during the project cycle time to enhance the usage of new technologies. These technologies includes Mobile Augmented Reality (MAR), image

processing, updating time schedule using cloud based service. This could be achieved through the following:

- Studying recent literature related to Building Information Modeling, Augmented Reality, and Image processing.
- Developing a mobile application to monitor construction projects progress remotely using image processing tool.
- Using a cloud based service to update the time schedule easily on site without relying on manual data that may lead to inaccurate data entry and massive rework.
- Using the 5D model through the proposed applications to identify the project status with the respect to time and cost.
- Using the Augmented Reality to render 3D objects using a mobile application.
- Presenting assets data and information directly on the mobile hand-held devices screen without the need to search for the items' historical data through Augmented Reality application.

The proposed applications are demonstrated via actual construction projects as follow:

1. Etisalat Misr headquarter at Smart Village, Giza, Egypt.
2. Faculty of Engineering, Cairo University.

Figure 1.1 depicts the proposed methodologies of this research.

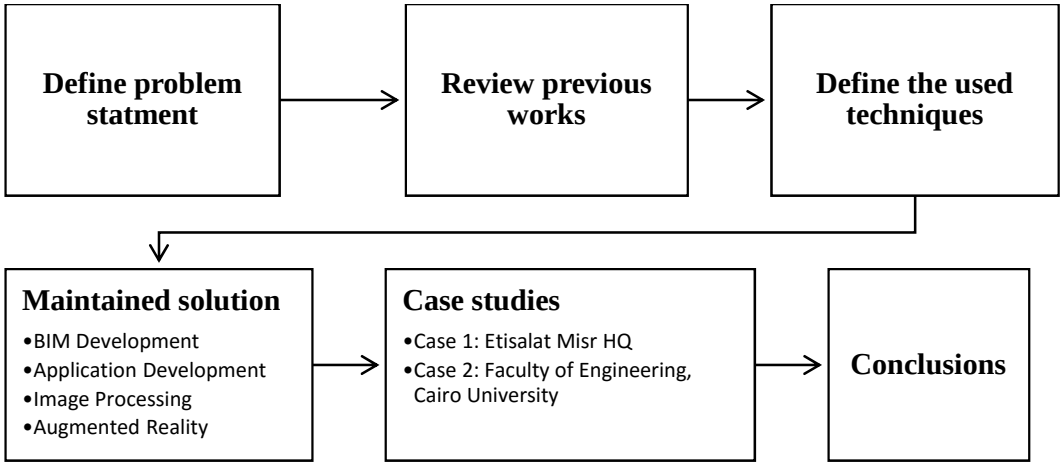

Figure 1.1: Research methodology

1.6 Thesis Organization

The research is designed in six chapters. Following this introductory chapter, the thesis structure consists of the following chapters:

Chapter Two: This chapter presents a review for Building Information Modelling's definitions, benefits , and usage in the construction industry. It also provides literature review regarding data acquisition tools in construction projects such as 3D scanners, Radio Frequency Identification (RFID), and image processing. Moreover, it includes literature review for Augmented Reality technology and its applications in the construction industry.

Chapter Three: This chapter proposes the framework for the considered applications. The implementation is conducted in the presence of supportive applications. Finally, an overview of the applications' interface are presented.

Chapter Four: This chapter illustrates the usage of the considered applications over the projects' lifecycle. This research uses some technologies such as image analysis, Augmented Reality, and cloud computing based services. This chapter illustrates the used technologies in the proposed applications.

Chapter Five: This chapter provides the data flow for the developed system. A case study is included to present each application.

Chapter Six: This chapter states the contribution drawn from the thesis and the recommendations for future works.