PROPOSED HEALTH AND SAFETY IN STEEL CONSTRUCTION PROJECTS THROUGH BIM AND IMAGE RECOGNITION

Rula Sharqi, Ph.D. Candidate, rs220@hw.ac.uk
Ozan Koseoglu, Assistant Professor, o.koseoglu@hw.ac.uk
School of Built Environment, Heriot Watt University, Dubai Campus
Ammar Kaka, Professor a.p.kaka@hw.ac.uk
Vice-Principal of Heriot-Watt University, Executive Dean and Head of the Dubai Campus

ABSTRACT

Steel structures construction continues to be one of the most hazard prone jobs in the construction industry. Safety in construction is a result of a combination of several factors such as the implemented construction technology, worker's training standard, site working conditions, and the design of the project. Even with the strict application of international safety and hazard prevention codes and standards the fatalities in the steel construction site activity as a result of falls for an example is double that compared to other site works. This fact demonstrates the need to improve the safety procedures and implementations in steel construction sites. Based on these facts hazards identification and precautions are essential ingredients of any construction site safety management system.

The objective of this paper, which is a first stage of a Ph.D. project, is to review past research that is aimed at addressing some of the safety problems during construction, and identify how to apply novel technologies as Building Information Modeling (BIM) and Image recognition for automating safety on site. The contribution of this research project lies in introducing a new methodology by using photographic analysis which has been increasingly used to tackle different site related operations. The paper proposes a methodology based on BIM model incorporating the 3D image data available from an actual project, indexing all real images taken, searching and retrieving selected time images and comparing them with BIM model. This will help the safety managers to monitor progress and make decisions on the implementation of safety standards approved for the project. The integration of image recognition and BIM will enable the identification of risk assessment while assisting the production of the daily site safety report.

Keywords: Health and Safety, Building Information modeling (BIM), Image Recognition.

1. INTRODUCTION

Steel structures construction continues to be one of the most hazard prone jobs in the construction industry. Safety in construction is a result of a combination of several factors such as the implemented construction technology, worker's training standard, site working conditions, and the design of the project a fact that demonstrates the need to improve the safety procedures and implementations in steel construction sites.

Based on construction site visits, collecting information by questionnaire survey, meetings with contractors, and discussions with sites safety representatives, site safety challenges were highlighted, and solutions were proposed.

The research work presented in this paper sets to achieve this target by developing a system incorporating real time work progress imaging with the applicable site safety codes, standards, and requirements, and Selecting as a first step, an easily defined construction activity with a high risk profile e.g. scaffolding.

This process is accomplished by Modifying or adapting existing suitable and specialized computer software to perform the image recognition and comparison activities.

Hazards identification and precautions are essential ingredients of any construction site safety management system. The objective of this research project can be summarized as the introduction of a new methodology to the field of steel construction safety namely photographic analysis. This objective can be achieved by adapting a methodology based on building a Building Information Modeling (BIM) from an actual project, indexing all real images taken, searching and retrieving selected time images and comparing them with the rendered project design model.

This leads to expecting future site activities utilizing the project work program and identify associated site hazards and risks.

The process automatically outputs relevant safety reports and displays them via an advanced visualization tool.

Apart from the above aims and objectives, the following subjects shall be addressed also:

(a) Remote progress monitoring facilitating the comparison between the present state of construction with the original plan thus assisting in the decision making addressing variations in project's progress in a time and cost effective manner.
(b) Identifying the differences and variations between the design and the actual structure.
(c) Keeping track and evidence of the ''as-built'' (including temporary facilities and equipment).
(d) Remote productivity monitoring.
(e) Automated 3D image database local modeling for automated equipment control and safety.
(f) Resolving disputes (when utilized as evidence)..

2. SAFETY IN CONSTRUCTION

The construction industry involves many operations that can be risky, dangerous, and unhealthy. The number of injuries, accidents, and work related illnesses reported on construction sites exceed that of the manufacturing industry, thus contributing to additional costs and delays in projects. To ensure that a construction site is safe for operations, proper site management procedures have to be put in place, taking account of safety considerations. Elbeltagi and Hegazy (2002) presented an effort to provide a quantitative approach that will help in maintaining safe and productive construction sites. First, safety issues on construction sites are discussed and the factors that contribute to unsafe sites are outlined. Three aspects are then considered during site planning to improve safety: (1) Defining the necessary temporary facilities needed for safety reasons on construction sites; (2) Defining proper safety zones around the construction space; and (3) Considering safety in the process of determining the optimum placement of facilities within the site. These considerations will lead to a safe site and accordingly increase productivity. A case study is presented to demonstrate the benefits of the three safety measures proposed and future extensions are outlined.

Since 2004, representatives of approximately a dozen national engineering and construction organizations (including ASCE) have collaborated on projects to promote DfCS and reduce barriers to its implementation.

Gambatese et al. (2005) presented a pilot study that was conducted to investigate the practice of addressing construction worker safety when designing a project and to determine the feasibility and practicality of such an intervention. Among the perceived impacts of implementation, project cost and schedule were mentioned most often along with limitations being placed on design creativity. The results of the pilot study indicate that designing for safety is a viable intervention in construction. They also described the key changes needed for implementation of the concept in practice which include: a change in designer mindset toward safety; establishment of a motivational force to promote designing for safety; increase designer knowledge of the concept; incorporate construction safety knowledge in the design phase; utilize designer's knowledge about design-for-safety modifications; make design for safety tools and guidelines available for use and reference; and mitigate designer's liability exposure.

The Recommendations for this accidence were:

- Hooks and other rigging fixtures should be selected and used properly to prevent loading beyond their structural capacity.
- In a towing or lifting operation, workers should be removed from the hazard area or guarded from the reach of the rigging in the event of failure.
- An excavation site must be inspected daily by a competent person to detect and correct hazards, particularly those related to expected loads on equipment.
- Employers are responsible for ensuring (a) compliance with all safety rules, (b) that equipment is maintained and used according to the manufacturer's instructions, and (c) that workers are properly trained to operate equipment safely.

Toole, Hervol and Hallowell (2006) summarized the practical and ethical reasons why designers should consider the design for construction safety (DfCS) concept, presents practical and specific ways that structural engineers and steel detailers can design for construction safety, and identifies barriers facing the DfCS initiative.

The construction industry must have a safety culture in order to reduce number of accidents, fatalities and injuries that involves workers and properties. Misnan and Mohammed (2007) discussed the conceptual framework of the development of safety culture in the construction industry, known as one of the dangerous industries but which can still provide a safe working environment thus offering a safe and promising career. Safety culture is an alternative for encouraging competition at any level.

Safe equipment operation is a major concern on construction sites since fatal on-site injuries are an industry-wide problem, Chi et al. (2008) presented a preliminary crash avoidance framework for heavy equipment control systems. The proposed framework has a potential for effecting active safety for equipment operation. The framework contains algorithms for spatial modelling, object tracking, and path planning. Beyond generating spatial models in fractions of seconds, these algorithms can successfully track objects in an environment and produce a collision-free 3D motion trajectory for equipment.

3. IMAGE PROCESSING AND RECOGNITION IN CONSTRUCTION

The capability to automatically identify shapes, objects and materials from the image Content through direct and indirect methodologies has enabled the development of several civil engineering related applications that assist in the design, construction and maintenance of construction projects, Brilakis and Soibelman (2005) presented material identification methodology, the method utilizes content based image retrieval concepts to match known material samples with material clusters within the image content. The results demonstrate the suitability of this methodology for construction site image retrieval purposes and reveal the capability of existing image processing technologies to accurately identify a wealth of materials from construction site images. The capability to automatically identify shapes, objects and materials from the image content through direct and indirect methodologies has enabled the development of several civil engineering related applications that assist in the design, construction and maintenance of construction projects. Examples include surface cracks detection, assessment of fire-damaged mortar, fatigue evaluation of asphalt mixes, aggregate shape measurements, velocimentry, vehicles detection, pore size distribution in geotextiles, damage detection and others. This capability is a product of the technological breakthroughs in the area of Image and Video Processing that has allowed for the development of a large number of digital imaging applications in all industries ranging from the well established medical diagnostic tools (magnetic resonance imaging, spectroscopy and nuclear medical imaging) to image searching mechanisms (image matching, content based image retrieval).

In large scale projects, the integration of thousands of construction site images stored in site photographs and logs is a significant part of the construction documentation. However, locating and identifying such data required for the important decision making processes is a very hard and time-consuming task. Therefore, automated methods for the integration of construction images become important for efficient construction information management. Brilakis (2005) explored processes for retrieval, classification, and integration of construction images in Architecture, Engineering, Construction and Facilities Management AEC/FM model based systems. Specifically, a combination of techniques from the areas of image and video processing, computer vision, information retrieval, statistics and content-based image and video retrieval have been deployed in order to develop a methodology for the retrieval of related construction site image data from components of a project model. This method has been tested on available construction site images from a variety of sources of past and current building construction and transportation projects and is able to automatically classify, store, integrate and retrieve image data files in inter-organizational systems so as to allow their usage in project management related tasks.

3.1 Image Processing in Progress Monitoring

One of the differences between industrial manufacturing or processing plants and construction sites is the temporary nature of the construction site, which has traditionally precluded installation of sophisticated production monitoring systems, Constr, Engrg and Mgmt (2005) tested the feasibility of this concept. The results indicate that the system is technically feasible, and offers the potential to deliver real-time, accurate project control information at very low cost. Monitoring of production progress, cost, and quality is performed almost exclusively manually, resulting in being expensive, approximate, and are commonly delivered with a time lag that does not allow for an effectively closed control loop. Automated monitoring of construction lifting equipment to provide useful feedback information for project management is a strong potential candidate; almost all components and materials must be transported by machines, and monitoring of machines is relatively straightforward. A system concept, employing a "black box" monitor and an electronic building information model, was developed.

Shih, Lai and Tsai (2006) developed a panorama image database management system (PIDMS) to manage construction-related records. A set of panorama cameras was used to record panorama images and videos for the inspection and management of working schedule, manpower, materials, or machinery. Users such as construction site managers, contractors, general users, designers, draftspersons, or system managers can log in through a browsing interface. The system is made according to functions, such as real-time monitoring, image labelling, working drawing browsing, video indexing, and construction recording. Three levels of application were developed. This research dealt with real-time panoramic monitoring of construction sites. The panorama images and videos were used as maps for an Internet communication platform composed of daily records, such as images, texts, and numeric data serving as a panorama- or image-based information system. The PIDMS increases the efficiency and effectiveness of supervision. Also, Brilakis and Soibelman, (2006) focused on construction site image data and presented a novel image retrieval model that interfaces with established construction data management structures. Their model is designed to retrieve images from related objects in project models or construction databases using location, date, and material information extracted from the image content with pattern recognition techniques.

Systems which aim to look at buildings have formed an active research area in computer vision over the years. Many of the tasks attempted range from basic detection of their presence, model based fitting to recover their position, 3D recovery of their form, and image based analysis of their properties, Lukins and Trucco (2006) presented a comprehensive background of existing building focused techniques in computer vision, but go on to show how these can be used to accommodate the need for looking at dynamically changing structures. The primary motivation for this is the desire within the construction industry for complete automation in tracking the progress and changes made in large-scale projects. They also illustrated the challenges posed by this task with a first prototype system, and conclude by offering up some further directions for research to which computer vision could be applied for the assessment of construction progress.

Assessment of progress in construction projects is a manual task that is often infrequent and error prone. Images of sites are extremely cluttered and rife with shadows, occlusions, equipment, and people – making them extremely hard to analyse. Lukins and Trucco (2008) presented a first prototype system capable of detecting changes on a building site observed by a fixed camera, and classifying such changes as either actual structural events, or as unrelated. They have exploited a prior building model to align camera and scene, thus identifying image regions where building components are expected to appear. This then enables us to home in on significant change events and verify the actual presence of a particular type of component. They placed their approach within an emerging paradigm for integration in the construction industry, and highlight the benefits of automated image based feedback.

Trinh, Kim, and Jo (2008) described an approach to recognize building surfaces. A building image is analyzed to extract the natural characters such as the surfaces and their areas, vanishing points, wall region and a list of SIFT feature vectors. These characters are organized as a hierarchical system of features to describe a model of building and then stored in a database. Given a new image, the characters are computed in the same form with in database. Then the new image is compared against the database to choose the best candidate. A cross ratio based algorithm, a novel approach, is used to verify the correct match.

4. BUILDING INFORMATION MODELING (BIM)

There is a great deal of confusion as to what “Building Information Modeling” means, with no universal agreed definition despite the numerous definitions being proposed. There is, however, some consensus on the themes that comprise the concept of BIM. BIM includes information database technology, 3D modeling concepts, and interoperable software used to design and simulate different scenarios and construction activity (Bratton 2009).

Although BIM just recently started gaining awareness and recognition, it has been around for a while. BIM originated from product modeling used in other industries such as automotive, aerospace, oil and gas.

In the mid-1990s building SMART (formerly known as IAI) built on this objective to create Industry Foundation Classes (IFC) which is a common language used for information sharing across disciplines and technical applications throughout the project life cycle. The recent increase in awareness is as a result governments’ efforts in supporting BIM approach by setting up National Standards example of this is the National Building Information Model Standard (NBIMS) (building SMART 2012; Underwood et al. 2010).

“BIM is an integrated process that produces a graphical representation of the physical and functional characteristics of a building using continuous information received at various stages of the building lifecycle.” From the definition, we can see the different aspects of BIM. First, BIM creates a platform for collaborative working through the Integrated Project Delivery (IPD) process. Unlike, the traditional project delivery method where the construction project is executed in a linear progression waiting for each discipline to complete their leg of the process, BIM treats the entire process as a holistic system by engaging key decision makers and capitalizing on each stakeholder’s unique experience and perspective. Based on the organizational structure focused on the relationships of each discipline engaged in the project lifecycle, BIM leverages those relationships from inception to decommissioning (BIM 2009; Bratton 2009). The figure below shows the integrated project delivery process created through the use of BIM.

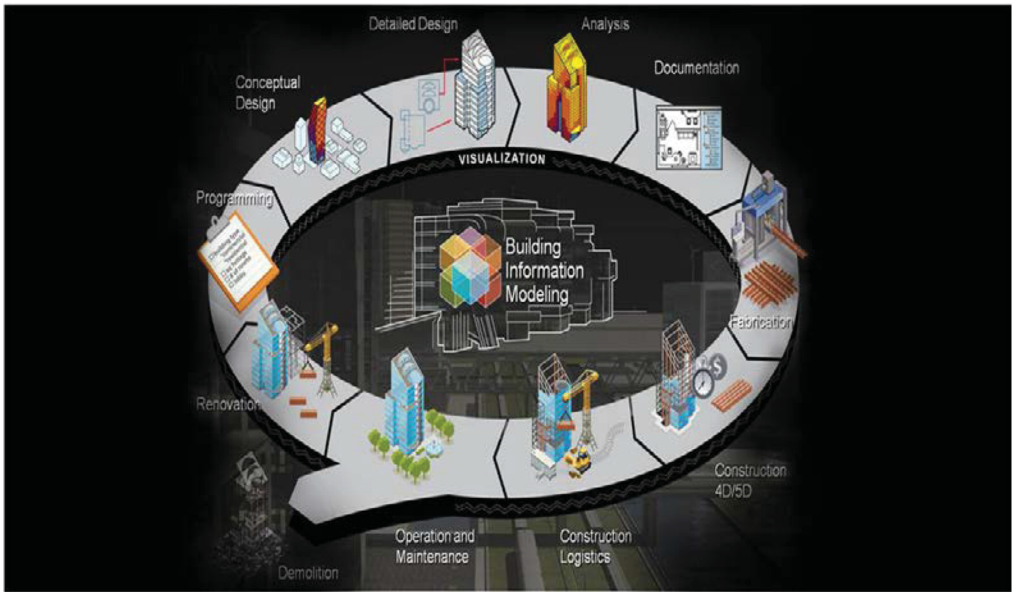


Figure 1: Integrated Project Delivery (adopted from Autodesk Inc, 2012)

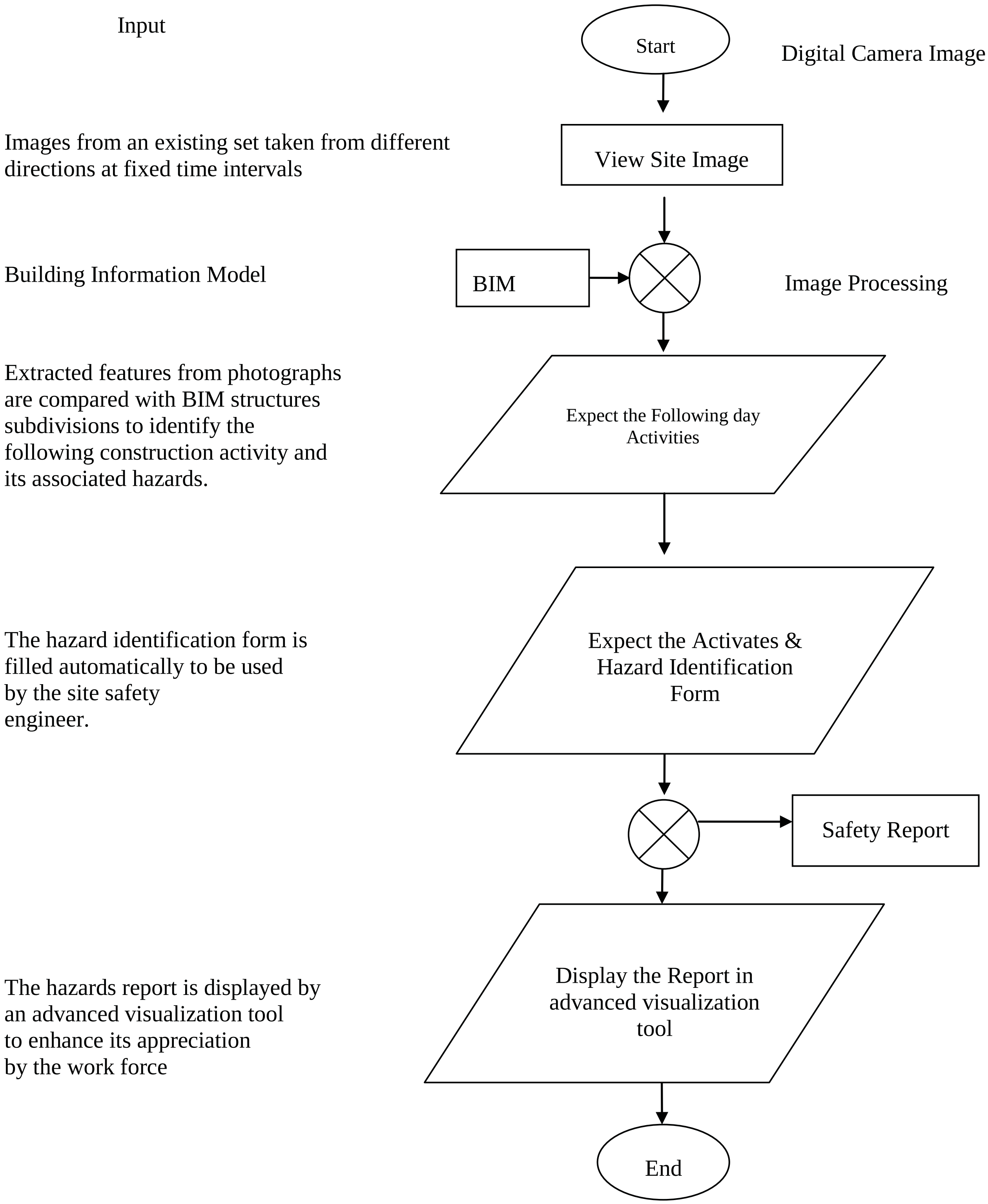
Secondly, IPD creates a streamline transition between these stages as a result minimizing information loss and delivering extensive information to clients beyond what they are accustomed to. Today in the construction industry, many project delays and errors are caused by inconsistent, ambiguous and incomplete information associated with the traditional 2D CAD drawings. Unlike, the CAD drawings which only include geometric information, BIM is a rich information model consisting of potential multiple data sources, elements that are shared across all stakeholders. Project information is stored in an integrated database that maintains a repository of the project information and allows applications to import and export files from the database for viewing, checking, updating and modifying the information throughout the project lifecycle. Changes made to information within the model are instantly propagated to all other views throughout the project which solves the problem of ambiguous and inconsistent information by defining a fluid flow of information usage thereby improving the quality, efficiency and sustainability of buildings delivered to clients. Other benefits of BIM include clash detection, improved estimates (such as project cost, time, quantity take off), efficient construction planning and logistics (4D), early detection of construction problem before occurrence and improved asset and facilities management (Singh et al. 2010, Autodesk 2011)z

The project depends on an existing set of site photographs. These photographs were taken by three fixed cameras in east, west, and south directions respectively. The frame rate was one photo per minute from day one of start of work on site till the structure of the site was completed. The imagining process did not continue for the finishing works.

The project also depends on a BIM. The first step in this project is to subdivide the steel structure works of the BIM into stages defining each work stage relative to its time of execution. The site photographs will then be subjected to a process of preparation distinguishing the area of interest and extracting the steel structure. The extracted features are to be compared with the subdivided stages of the BIM to establish existing phase of the project’s progress.

5. PROPOSED FRAME WORK

The following Flow Chart expressing the Project’s framework steps:



6. CONCLUSION

The contribution of this research project lies in introducing a new methodology to the field of steel construction safety by using photographic analysis which has been increasingly used to tackle different site related operations. The proposed method is based on building a four dimensional BIM incorporating the three dimensional image data available from an actual project, indexing all real images taken, searching and retrieving selected time images and comparing them with the rendered project design model. This will help a safety supervisor to monitor progress in terms of safety and hence make decisions on the implementation of safety codes, manuals, and standards approved for the project.

7. FUTURE WORK

Due to the importance of understanding the risks and hazards outlined by the site safety engineer, this project can be used to display the information in an advanced visualization tool in order to enhance the workers appreciation and thus reduces accidents probabilities.

The daily safety report can also be obtained automatically at the end of each working day.

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