

Health and Safety Visualization in Steel Construction Projects through Image Processing

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ABSTRACT

Steel structures construction continues to be one of the most hazard jobs in the construction industry. Even with the strict application of international safety codes the fatalities in the steel construction activity, is more than any other site works. This fact demonstrates the need to improve the health and safety in steel construction sites. The objective of this paper, which is part of a Ph.D. thesis, is to identify how to apply novel technologies to enhance the workers safety awareness on site. The paper proposes a methodology based on BIM model incorporating the 2D image data available from an actual project, and the approved project plan. Enhancing all real images, and comparing them with BIM model to expect the following site activities and their associated hazards, the hazards then will be presented to the site worker in an advanced visualization tool, in order to control and minimized the risk.

INTRODUCTION

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).

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, 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).

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 et al. (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 et al. (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.

HEALTH AND SAFETY IN CONSTRUCTION

Health and Safety is often regarded as paperwork simply carried out to keep in line with legalities. But, the reality is that accidents, often fatal, occur in the workplace. Construction is a high risk industry and accounts for 22% of fatal injuries to employees and 10% of reported major injuries. This is very significant, especially that the construction industry accounts for 5% of the work force only.

The main causes of construction **worker fatalities** are:

- Falls
- Being struck by a falling or moving objects
- Collapsing
- Being hit by a moving vehicle
- Electricity

The most common causes of **major injuries** are:

- Falls
- Slips, trips, and falls on the level
- Being struck by moving/falling object
- Handling

In 2011/12, 28% of all fatal injuries to workers were in construction and it accounts for the greatest number of fatal injuries of all industries. 51% of these fatal injuries were caused by falls. The major injuries to employees caused by falls account for 29% of the total major injuries recorded, while 25% of these major injuries are due to slips and trips.

Health and Safety in construction sites is not about the protection of workers, it is also important to ensure that members of the public are not put at risk.

Statistics further prove that enforcing Health and Safety regulations reduces the number of major injuries. There has been a reduction in the rate of reported major injuries since 2004/05 and the number of reported injuries has significantly fallen over the last five years confirming that strict Health and safety policies and procedures helps reducing accidents.

All work exposes people to hazards such as: loads which have to be manually handled; dangerous machinery; toxic substances; electricity; working with display screen equipment or even psychological hazards such as stress.

The reason there are not even more accidents caused by work is because Health and Safety systems of prevention are in place which have been built up over generations. However most accidents happen because they have not been prevented and despite all the precautions that are taken, there are still a considerable number of workplace injuries every year.

Health and Safety Principles. Attention to health and safety is not just about being socially responsible but should be regarded as a key business objective.

Working out what modern health and safety law means for a business can be cumbersome as there are a lot of regulations and supporting guidance, however the underlying principles are quite straightforward concentrating on ensuring the absence of risk to safety and health of the work force and the public.

These principles can be summed up under the following headings:

i) Health and Safety Management System:

A system including policies, people designations, and clear procedures has to be in place set out in a written health and safety policy statement to manage health and safety. The system should demonstrate how to plan,

organize, control, monitor, and review preventative measures, and appoint a competent person(s) to help comply with related legal obligations.

ii) Hazards identification and risk assessment:

The first step is to identify and record the main hazards which are the activities that could cause harm. The associated risks (the probability that significant harm will occur) have to be assessed and recorded also. Risk assessment is the key to working out what needs to be done. It helps prove to employees that the main activities that may cause harm were identified and the required preventive risk control measures were taken. The risk control measures should be adequate, implemented, maintained, and that they continue to be applicable. Employees have to be informed, trained, and supervised regarding these measures. For the most part the law sets out certain health and safety goals to be achieved and indicates appropriate 'benchmarks' to help work out whether the controls are up to 'reasonably practicable' standards. There is an underlying requirement to reduce or eliminate hazards at source, or isolate people from them (for example, by guarding machinery) before using other forms of control. Asking the following questions helps to identify where an organization is regarding its health and safety policies and how these policies can be improved. The health and safety policy statement should be the basis of any action plan: Is there an effective health and safety management system in place to tackle problems in a planned way?

- Are there clear policies and objectives for health and safety?
- Are the key people designated to achieve these policies and objectives identified and organized?
- What training do they need?
- Has a competent person to help comply with these duties been appointed?
- Have the main hazards been identified and the risks involved assessed?
- Were the right control measures to tackle these main risks selected?
- Are they adequate or there is more to be done?
- Are they actually being applied in practice?
- Is progress being monitored by inspecting the workplace regularly or investigating accidents and 'near misses' to learn from previous mistakes?
- Is a date to review the actual health and safety performance against plans being set?

iii) Working Together

Providing a safe and healthy work environment is a team effort and employees and their safety representatives should be consulted. Proper health and safety co-ordination needs to get going with other business contacts such as clients, customers, suppliers or contractors. Ownership and commitment to safety should be built throughout the workforce.

Above all and besides protecting people and the environment, action on health and safety can also make a major contribution to business success. Not only will it help stop accidents and work related ill health among the staff, but it will reduce accident losses, improve profit and loss statement and help the organization become more efficient. An organization should not wait for things to go wrong and then go for the 'quick fix' But rather build health and safety in from the start.

VISUALIZATION IN STEEL CONSTRUCTION PROJECTS

Hazards in construction are a result of a combination of several factors worker's training is one of the most important factors. This fact demonstrates the need to improve the safety training procedures in steel construction sites, and that can be done through different channels such as:

- Using advanced visualization tools to enhance the worker awareness of the hazards associated with the daily activity
- Develop a system incorporating real time work progress imaging with the applicable site safety codes, standards, and requirements.
- Select, as a first step, an easily defined construction activity with a high risk profile e.g. steel erection.

HAZARDS IDENTIFICATION

Hazards identification and precautions are essential ingredients of any construction site safety management system. The risk and hazards can be minimized through:

- 1- Introducing a new methodology to the field of steel construction safety based on photographic analysis and visualization.
- 2- The proposed methodology is based on building a three dimensional model 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.
- 3- Expect future site activities utilizing the project work program and identify associated site hazards and risks.
- 4- Output relevant safety reports automatically.
- 5- Detection of safety hazards and identifying the controls to minimized the risks, and then display them via advanced visualization tool.

SYSTEM DEVELOPMENTS

The system developments may also assist in:

- 1- Remote progress monitoring which provides information on the present state of construction that can then be compared with the original plan. This comparison assists decision making addressing variations in project's progress. The current methods for acquiring and updating project's progress information using digital cameras suffer from high computational processing cost, and time requirements.
- 2- Identifying the differences and variations between the design and the actual structure.
- 3- Keeping track and evidence of the "as-built" (including temporary facilities and equipment).
- 4- (d) Remote productivity monitoring.
- 5- (e) Automated 3D image database local modeling for automated equipment control and safety.
- 6- (f) Resolving disputes (when utilized as evidence).

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