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What Really Occurs At The Construction Site?

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Abstract
The visual representation of a construction project using 2D & 3D CAD is traditionally associated with the design phase where the model of the final product is developed. In recent years visualization technologies have been applied to the construction phase as well. Advancements in IT and Communications on one hand, and the need for better, cheaper and faster construction projects on the other, are the driving forces that increase technology uptake by the construction industry. Although limitations and barriers still exist, if appropriately used, modern technology may prove to be a valuable tool to the construction manager.

Keywords
Construction Site, Monitoring, Information Flow, Visualization

1. Introduction

All parties involved in the construction industry acknowledge the need for changes that will improve quality, competitiveness and profitability and increase value to clients.
Alshawi and Ingirige, 2003, lay out seven factors, interrelated and interdependent, that influence the changing construction environment:
1. Globalization of the marketplace, leading to labor mobility and competitiveness between foreign and local firms.
2. Economical forces, affecting mainly client organizations and initial objectives of their projects
3. Increases in project complexities, resulting in an increased number of specialists involved and needed in the decision –making process.
4. Need for faster results with given resources, a factor placing severe time pressures on the project team.
5. Changes to project scope to expand benefits, a factor requiring rapid reaction and decision making.
6. New procurement practices, changing the way the project team members interrelate.
7. Changes in client sophistication, demanding higher quality on products and services at lower prices.

The construction industry is required to perform in this challenging and demanding environment by reconsidering the technology and project management practices applied and the people involved.
This paper describes some state of the art technologies applied during the design and construction phase of a project, placing emphasis on those providing "views" of the construction process or the construction site.

The benefits gained from the application of such technologies are straightforward:

- Clear communication of the construction schedule with all related parties
- Early recognition of problems leads to better decisions
- Visualization of progress improves resource allocation
- Real time remote monitoring saves time and money

The impediments to the utilization of such technology cannot be overlooked, though. IT and communication technologies may be advancing radically, but the construction industry seems to have a lower level of uptake. There is no doubt that the construction industry has embraced some IT advancements, but several barriers need to be overcome, in order to integrate them broadly. The cost to invest to IT technology is high and if the benefits of that investment are not clear, the reluctance is justified.

2. An overview of practices and technologies

The following sections present and discuss some current practices and technologies used to run construction projects.

2.1 4D Models

Construction planning is traditionally based on bar charts and the Critical Path Method (CPM). These provide explicit associations of the components of a project with the related activities required. Although project planners rely on the 2D drawings of a project to develop the CPM schedules, the aforementioned associations do not represent the spatial complexion of a project. This limitation may result in confusion, while trying to interpret the schedule.

4D CAD was introduced as the concept that combines a 3D CAD model with time (4^{th} dimension). By visualizing the construction process, project stakeholders are getting a better understanding of the schedule and thus communicate more effectively. Construction problems can then be identified prior to their occurrence, due to the 4D model capability of representing visually the construction process. Furthermore, a 4D model can assist the generation of site usage layouts, the estimation of construction materials and quantities and can be used for cost evaluation (Chau *et.al*, 2004).

It is during the last decade, that research efforts have been made towards the application of 4D models in construction projects and the construction community realized the benefits that can be gained in cost, productivity, resource allocation, safety and most importantly, decision making.

However, the improvements to the 4D models that need to be considered have been also realized: Data preparation to set up such a model is difficult, costly and time demanding. Another factor that cannot be neglected is that 4D models are not (yet) user-friendly.
Despite the fact that these limitations raise discussions and debates, 4D models remain a valuable tool in the construction management process.

2.2 nD Models

nD modeling evolved with the introduction of object – oriented computer-aided design (CAD).; the "objects" in these CAD systems can also store non-graphical data about the building in a logical structure (Aouad *et. al.*, 2006)
The concept of nD modeling has been widely accepted to aid the laborious and costly process of decision making in a construction project, due to the conflicting factors that need to be coordinated.

While 4D models added only the time parameter to the geometry models, nD models envisage adding n design parameters, enabling true what-if analysis to be performed. nD is regarded as integrated design, by accommodating various social, economic and legislative factors (Lee *et.al*., 2002)

2.3 Virtual Reality

Virtual Reality (VR) technology is a wide topic, covering a variety of techniques and devices (Savioja *et. al*., 2003). The goal of VR is to mimic the nature such that – at the best- users can't distinguish between reality and virtual reality. the obvious application area is architectural design. According to Savioja et. al., in a more general level, entire construction projects can gain major benefits from utilizing VR.

Worksepp and Olofsson, 2006, explored and documented the use of VR in a construction project as a complementary source of information to 3D CAD models and 2D CAD drawings in the construction of a large scale palletizing plant in northern Sweden. Additionally, they provided a review of the use of VR in construction projects: a large hotel and office building, a lecture hall and a high-rise apartment and commercial store building. Again, VR technology has been regarded as a valuable decision support tool not only for the design and construction phase but also for the conceptual design of the plant layout. The technology was used throughout the entire project, and the authors underline the significant reduction in coordination costs.

2.4 Project Management Over The Web

2.4.1 The World Wide Web

August 6, 1991 was marked the debut of the Web as a publicly available service on the internet, with the following message:

"*The WorldWideWeb (WWW) project aims to allow links to be made to any information anywhere.[…] The WWW project was stared to allow high energy physicists to share data, news and documentation. We are very interested in spreading the web to other areas, and having gateway servers for other data. Collaborators welcome!*" (Bernes-Lee and Fischetti, 1999)

Eight months before this date, Bernes-Lee had built all the tools necessary for a working web: the first Web browser, the first Web server (info.cern.ch) and the first Web pages that described the project itself.
Today, several construction projects have their own websites, for doing what exactly the WWW project was developed for: Sharing information.

The construction industry is one of the most information-dependent industries, among others, with its diversity of forms of information which include detailed drawings and photos, cost analysis sheets, budget reports, risk analysis charts, contract documents, and planning schedules (Deng *et. al.*, 2001). The need for timely information flow among the team members becomes more apparent in the case where construction projects are conducted overseas. Inadequate information is resulting to bad decisions. Bad decisions waste time and money, and those are key factors leading to project failures.

2.4.2. Web Cams

The physical distance between the construction site and the headquarters can be outdistanced with the use of the internet. File Transfer Protocols (FTP), e-mail, and live video-cam for construction site capture are some tools provided by commercial construction web platforms.
The latter is the most attractive feature and is becoming increasingly popular. The web cam is pointed at a particular location of interest, 24/7, allowing headquarters or corporate offices to observe the progress of the project at real time.
Web cams can also capture and archive a live image at a certain time frame producing time –lapse images. This capability to continually capture images in a timeline ranging from several minutes to once

per day/week or month, is resulting in a sequence of images that is actually an animation of the construction process.
Web cams have several other useful features like movement detectors, pan, tilt and zoom functionalities, night surveillance and wireless connectivity.

Some benefits from the use of web cams are:

- remote access to live images at any location
- central monitoring, reducing travel time and costs
- automation reduces the time and resources spend on monitoring the construction site
- Movement detection and alarm notification enhances security on site.

2.5 A Photogrammetry based Construction Site Monitoring System

Current research at the Department of Construction Engineering and Management in the National Technical University of Athens is aimed at the use of web cams for quantifying the progress made at the construction site. The methodology includes the application of photogrammetry on overlapping images taken remotely by web cams.

Photogrammetry is a 3-dimensional coordinate measuring technique that uses photographs as the fundamental medium for metrology and measurement. The principle used by photogrammetry is triangulation (the same principle our two eyes use to work together to gauge distance or otherwise, depth perception).

By taking photographs from at least two different locations, so-called “lines of sight” can be developed from each camera to points on the same object. These lines of sight are mathematically intersected to produce the 3-dimensional coordinates of the points of interest (Geodetic Systems Inc, 2007). Subsequently, the overlapping images provide a stereoscopic (3D) view of the location or the object (Figure 1).

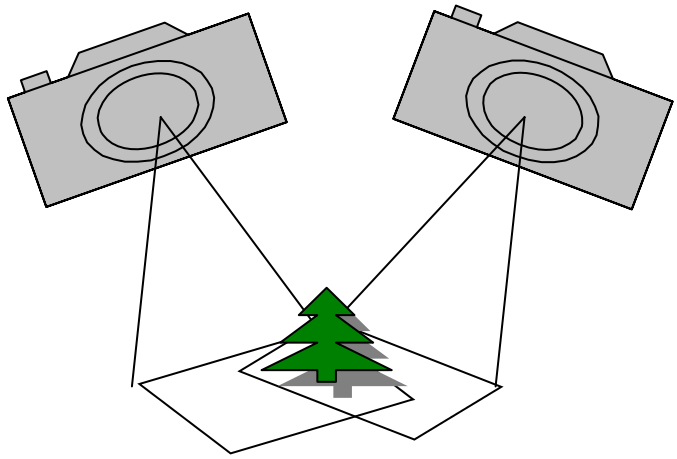

Figure 1: Overlapping images give a 3D view

The applications of photogrammetry are widely spread. In this research however it is used for object interpretation and object measurement providing knowledge of the actual progress made and information on the work accomplished.

Conventional methods like surveying are time intensive and require the allocation of staff at the construction site in order to monitor continuously the construction process. It is envisaged that this proposed method will provide automated monitoring with little human intervention.
Having acquired the measured quantities, the project manager can calculate the units of work completed. Furthermore, by coupling this information with the billing lists of the project, the system can be used to monitor cost performance to detect variances from plan. The system will operate on a GIS platform. These are database oriented and include many tools for handling large data volumes of different type.

A scematical representation of the system under development can be seen in Figure 2.

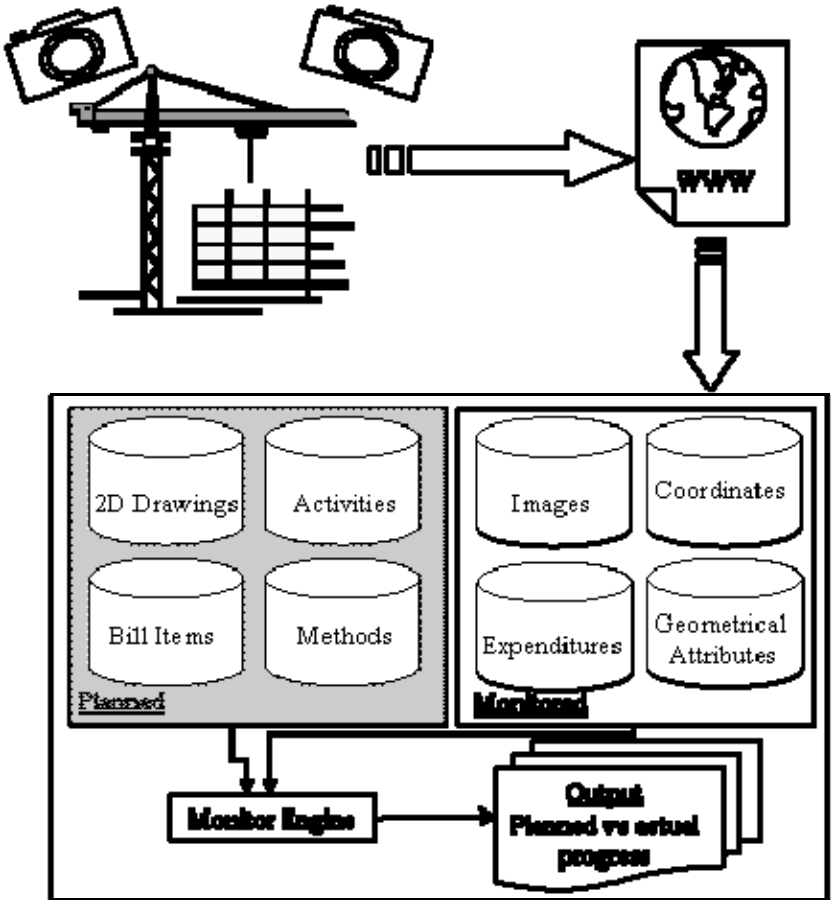

Figure 2: Representation of a web based construction site monitoring system.

The system stores all the relevant information from the planning phase, describing the product and the process (i.e CAD drawings, activities, methods, schedules, bill items). It also stores the monitored data taken by the web cam via the internet and the photogrammetry extracted information (i.e raw images, 3D views, geometrical attributes, coordinates). Expenditures (for labor, materials, fuel, etc), monitored by the accounting system of the project is also a component of the database. The spatial and logical association of the as planned vs. the actual monitored, generates the output. Coupled with specific information of time (schedules) and cost (bill items/ expenditures) the system can function as a control tool in real-time.

Additionally, GIS provides browser-based access to the data allowing output dissemination over the web to interested parties. Finally, due to its capability of coupling, generating and storing different types of information, the output can be used to create 4D, nD or VR models.

3. Discussion and Conclusions

Visualization technologies applied at the design and construction phase coupled with modern telecommunication technologies may allow effective monitoring of the project. A number of parameters related to time, cost, quality, use of resources and physical progress currently monitored manually can be automated. This, in turn, may revolutionalise project monitoring and control and may lead to better run projects (i.e. cheaper, faster and of better quality).

Information is regarded as a resource, valuable to the people involved in a project. Data transfer without interruption and delay can be crucial for the success or the failure of any project. Decision making is heavily depended on timely, accurate and well communicated information.
Decisions cannot rely on subjective judgment. The project manager needs to know what really occurs at the construction site. Illustrative information can overcome the barrier of subjectivity.

The latest advancements in IT and Communication provide the means to gather information and make it available to the different parties involved in a project. The construction industry may have embraced some advancements, but has not broadly integrated them. This could be due to a relative ignorance of the potential of IT, and reluctance to invest to IT technology. Additionally, IT Technologies are advancing radically while the construction industry is still looking for finding higher levels of uptake. Additionally, IT can prove to be very expensive. The costs for the hardware and software, the training and operational costs cannot be overlooked. If IT solutions are to be implemented effectively and return the investment, an organization has to spend time (and money) to understand its actual needs. Commercial solutions are readily available, but tailoring them to the individual is the key requirement. At the end, it is all about rates of return on investment.

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