Integrating Building Information Modelling and Augmented Reality for Construction Projects in Oil and Gas Industry

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Abstract

Construction site is the place where the process of building or assembling infrastructure happens. As one of the most complicated type of projects, large scale construction projects involve large human multitasking activities across different geographical locations and a wide range of disciplines as well as high frequency exchange of information. The most commonly recognized way of executing a project includes preparing the construction drawings, planning out the contract, allocating the workload, scheduling, and administering the progress. This paper introduces many innovative techniques including Augmented Reality (AR), barcode reading and indoor way-finding technologies, and integrates them as alternative means of executing certain activities of construction project. Using a Liquefied Natural Gas (LNG) scenario, this paper presents: (i) a study of how AR can be effectively used to improve the way the information is accessed; (ii) sensing and tracking technology such as barcoding as a technological feasibility of locating a specific component of complex LNG plants based on computer-based information; and (iii) indoor way-finding technology integrated with AR, with which the construction worker can easily find out where the exact component is located in a warehouse or actual construction site.

Keywords: Augmented reality, barcode reading, indoor way-finding, liquefied natural gas

1. Introduction

In construction, 3D modelling is often seen as an unnecessary complication by practitioners (Arayici et al., 2011). Very often it suffices to develop a 2D design for single details or specific building locations, and the same principle is applied on many locations inside the building. At the same time, a more unrefined model is needed from the total building perspective. However, when the focus is on a detailed workpiece, then more detailed

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information context concerning the ambient components will be shown. Defined as the combination of real and virtual scenes, AR is able to combine the 3D object into the normal viewing perspective without losing any of the advantages of object movement and individual movement in real-world environments (Toro et al., 2007, Doil et al., 2003). Therefore, AR can be used to facilitate the monitoring and control of a construction project's progress, and to visualize a facility in the context of the real workspace to enable the 'as built' progress against 'as planned'.

Construction process requires a high level of automation and integration of information and physical resources (Čuš Babič, 2010). Yet, the effective locating of information developed in data repository during the actual construction process challenges the designers, planners, workers, and managers throughout the entire construction lifecycle. Typically, they interact with a project through various information mediums and models mainly based on 2D planer isometric drawings or elevations (Gao et al., 2006). Integrating the barcode reading technology with navigating software packages such as navisworks can ease the information location process and support various work tasks, i.e., error checking, component finding, property browsing and so on (Turner et al., 2003; Gressel and Ehrlich, 2002). This facilitates site work, requiring individuals to both, to manage information and transform physical resources to a constructed facility.

In order to allow accurate indoor overlays and enable you to create indoor assistance of way-finding, information or games, we prototyped an indoor way-finding system which applies the Latitude Longitude Altitude - Markers (LLA Markers) (Jörg, 2002). On mobile devices such as iPhone and Android, the LLA way-finding works seamlessly. If a valid marker is found, the location of the smartphone will be adjusted according to the encoded latitude and longitude coordinates of the marker while the GPS sensors of the smartphone are ignored. This fixed location will be shown by an AR arrow, which points to the correct and cost-effective path to the components that are needed.

2. Assisting technologies for on-site construction work

2.1 Augmented reality walk-through

Traditionally, design is realized through the production of 2D shop drawings from a 3D object model. The traditional method of having an index sheet and a mass of drawings in the site offices that are 'thumbed through' to look at a specific detail is a time-consuming and tedious process. This AR Walk-through functionality can facilitate design and constructability review process (Vainio, 2002). Specifically, this AR functionality can provide a full 3D interactive solid model of the design, giving the workers a visual understanding of specific details (Abowd, 1997).

As depicted in Figure 1, the camera can recognize a set of tracking markers and bring up the 3D models accordingly. If in the office, the table-top AR can overlay the 3D model right on the area where it is located in the paper drawing plan (see Figure 1). The results look like all the 2D plans are extruded to have 3D effects. Users can split the 3D model in cubes, for example, to have a closer look at each floor level, to examine each specialty trade, or to examine each selected cross section. If onsite, by picking up the marker and hold it vertically, users can even walk into and through the module named 14108, which is an actual LNG plant provided by Woodside Energy Ltd. and feel what it is like on real construction site (see Figure 2). Users can rotate, zoom, and show problems such as missed insulation and valves.

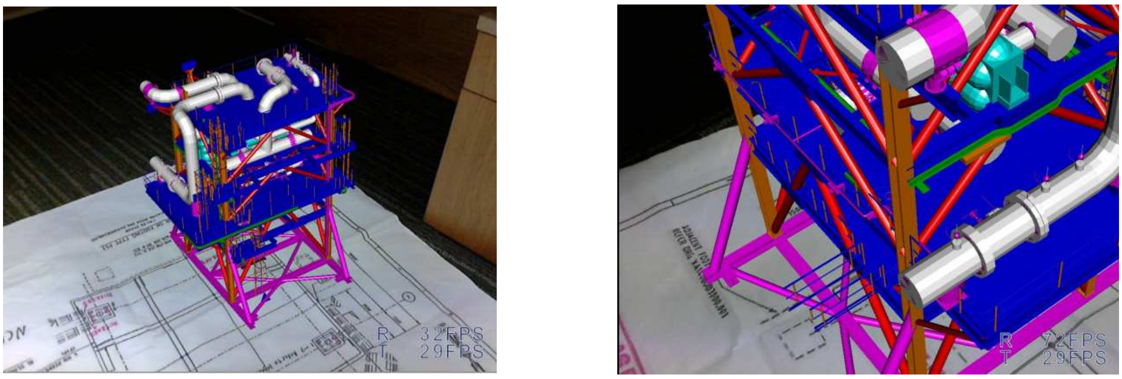


Figure 1. Table-top Augmented Reality for design and constructability reviews

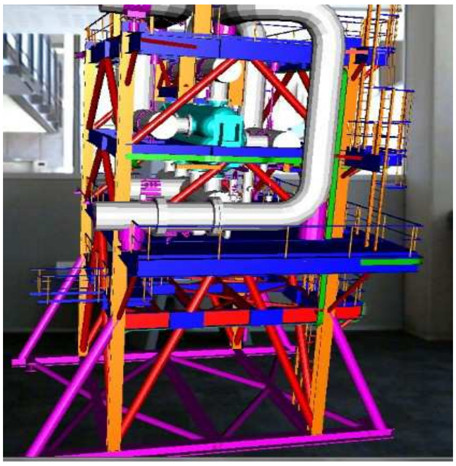


Figure 2. Augmented Reality visualization of 4D CAD models in the context of real environment

In this study, AR has been identified as a solution. This is where AR technology comes into the picture since from a cognitive psychology standpoint, it has the potential to merge the informational activity to the direct work activity to make information access more efficient and therefore completely change the way we think about and use instructions. As an emerging technology, AR can integrate the information context such as the assembly path and fixation forms of parts/components into the real workspace.

A summary of the AR for assembly is as follows:

1. We are now on the fabrication and assembly site
2. The pipe needs to be installed, but workers do not know what, where and how
3. Workers are trying to look for information in stacks of drawing, which takes time and there involved many simple mistakes.
4. Using AR-based animation, we can simulate the installation sequence visually in the real scale and right in the real context as well.

Construction workers can then see the location, angle, orientation, dimension, shape, geometry, materials, texture, assembly sequence, assembly path, assembly safety instructions and therefore streamline the assembly– knowing what to do.

Models are real-time loaded during the assembly task, so the workers are able to control the animation process by left-clicking (loading model and playing animation) or right-clicking the mouse (unloading model and reversing animation).

2.2 4D-based model locating triggered by Barcode

As shown in the Figure 2, the 3D model of an LNG plant is massive in file size and it has to be more user-friendly if the AR and Virtual Reality (VR) technologies are to be adopted and widely used in LNG. A tracking and automatic positioning prototype is developed, including the barcode of each component of the construction. Therefore, all of the specific components could be searched and located by their unique ID.

With an independent or integrated barcode reader in 4D CAD, the user can scan the barcode on a piece of pipe and the model of the pipe will be highlighted (see Figure 3 and 4). Alternatively, we type in any tag number or barcode of the associate component. Users can then view and modify the properties of the pipe in 4D CAD. Relevant manuals, specifications and certificates associated with this pipe could also be viewed.

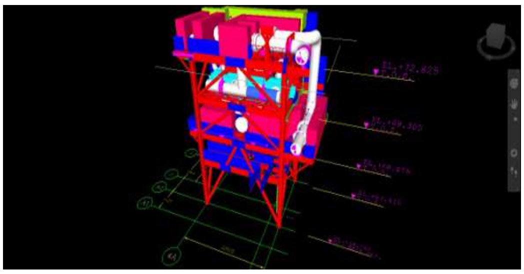


Figure 3. Highlighted item in 4D CAD

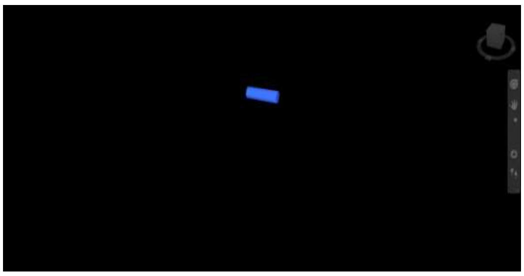


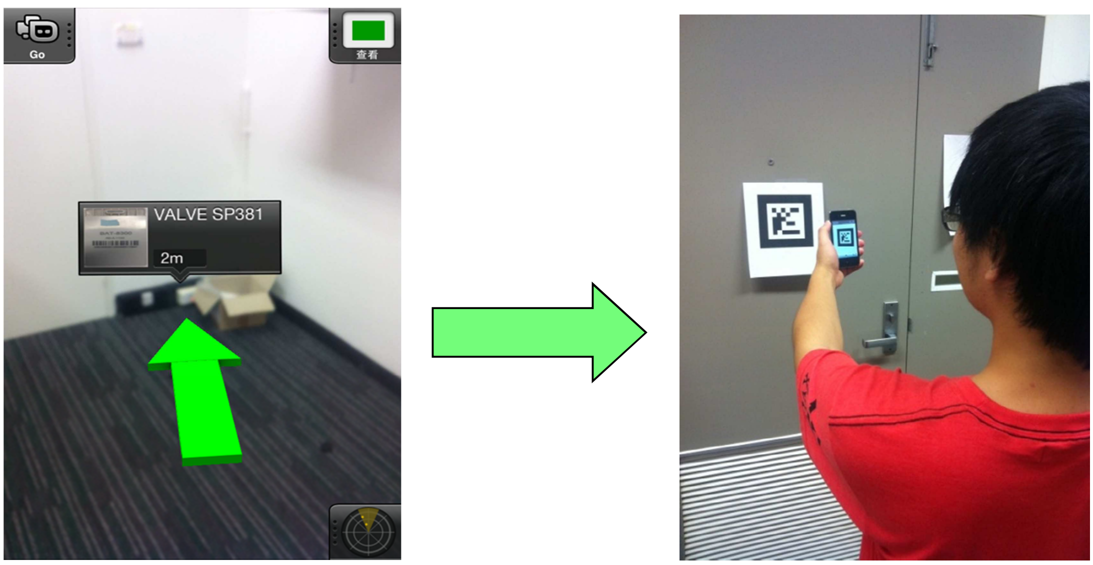
Figure 4. Component locating in 4D CAD

2.3 AR-based Way-finding

A geographic coordinate system enables every location on Earth to be specified by a set of numbers. A common method of coordinates is latitude, longitude and altitude (LLA). Latitude and longitude are the two numbers representing horizontal position and altitude represents the vertical position. The latitude (abbreviation: Lat., φ, or phi) of a point on the surface of Earth is the angle between the equatorial plane and a line that passes through that point. It is normal to the surface of a reference ellipsoid which approximates the shape of the Earth. Latitude is used together with longitude to specify the precise location of features on the surface of the Earth. Latitude and longitude together with some specification of height constitute a geographic coordinate system as defined in the specification of the ISO 19111:2007 standard. The difficulty is the amount of time needed to get accurate latitude and longitude positions of a particular location. The easiest way is using Google Maps to overlay indoor blue print and retrieving locations from there. The implemented application scenario can be described through the following example:

1. A box containing a valve with an Radio Frequency Identification (RFID) tag on has arrived at warehouse, however, the material coordinator does not know where it is because the warehouse has thousands of similar-looking boxes
2. The material coordinator is now looking for the valve on the 1st floor in the warehouse
3. He inputs a valve number into the iPad interface
4. He then scans the reference marker at the entrance of the warehouse (see Figure 5a)
5. There is a green arrow (see Figure 5b) showing on the iPad screen with valve ID and the estimate distance from where the entrance is to the arriving box
6. He follows the arrow indicator and walk towards the box

As the valve has an attached RFID, the RFID readers in the warehouse can pick up its accurate location in a real time manner and within a short period of intervals of updating. As the location of the box is changed, the directional indicator from where he is standing to the new destination of the box will be updated as well. Because the RFID readers can write back into tag its current location, way finding becomes much easier than before.



(a) (b)

Figure 5. Augmented Reality-based way-finding: (a) scan a quick reference marker to know where he is; (b) a virtual arrow indicator shows where and how far to go

On iPhone and Android devices, the LLA Marker detection works seamlessly. If a valid marker is found, the location of the smartphone will be adjusted according to the encoded latitude and longitude coordinates of the marker while the GPS sensors of the smartphone are ignored. This fixed location will stay until a different marker is found or the developer returns a different trackingXML on an event. Accuracy with LLA Markers is approx. 20cm (40cm in Altitude).

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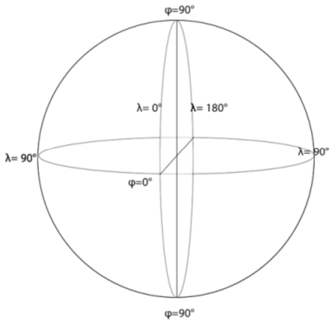
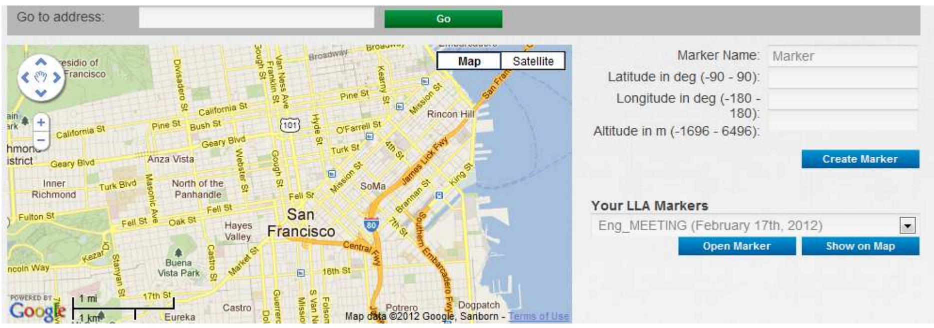
Users can use the interface as shown in Figure 6b to either click on the map or type in latitude/longitude/altitude to create an LLA Marker. You are able to resize the marker according to your needs. In general a size of about 2-4 inches (5cm - 10cm) is good for most use cases. It should be noted that the Altitude value is currently not being considered.



(a)



(b)

Figure 6. (a) Geographic coordinate system of longitude and latitude; (b) Interface of longitude, latitude, and altitude converter

3. Conclusions and future work

This paper presents three innovative technologies in facilitating the execution of construction project. The combination of these is based on the processing of digital information context, which provides a more intelligent alternative against the conventional means of handling a construction project. Contractors still tend to stay within their comfort zone, where they unreflectively adopt tried and tested technologies rather than evaluating and adopting new technological solutions such as AR.

Our future work aims to address a serious issue regarding the development and uptake of AR tools relating to the social phenomenon associated with this, as technologies are inseparable from the cultural and social settings. Therefore, the development process of designing AR tools should be cognizant of this relationship by working with (and through) designers' cognitive and behavioral drivers and constraints by explicitly 'building-in' and embracing the knowledge creation, application, storage and retrieval cycles. Contractors should therefore be actively encouraged to embrace the AR technologies' 'intentions' and 'capabilities', or they could find themselves entrenched in their 'comfort zone' of familiarity.

Another issue is the lack of standardization of information and communication technology (ICT) tools. The issue is that workers use different ICT tools and maybe different datasets. There needs a unified approach, just like onsite BIM has becoming a standard approach of the upstream data integration before construction starts, which is envisaged to be our next endeavor.

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