Using See-Through Visualization in Construction Work: Potential and Challenges

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ABSTRACT

The construction sector is increasingly utilizing information in planning, operation and analytical work. However, the use of this information to support operators is still, to a large extent, an unexplored area. As a case study, we present one vehicle used at the construction site, the mobile crane. Even though modern mobile cranes have been equipped with multiple systems that are designed to assist operators to perform their tasks, operating a mobile crane remains a risky task due to the complexity of its operation. Previous studies have also shown that, even though operators are supported through instrumentation systems, operators only pay little attention to the displayed information since they have to concentrate on operating the mobile cranes. Using see-through visualization might improve this situation by presenting the information embedded with the work and near their line of sight. Therefore, operators can perform their tasks while maintaining good awareness of the machine and the surroundings.

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Figure 1: An example of mobile crane's cabin. Operation-supporting information is presented using monitors on the dashboard[2]

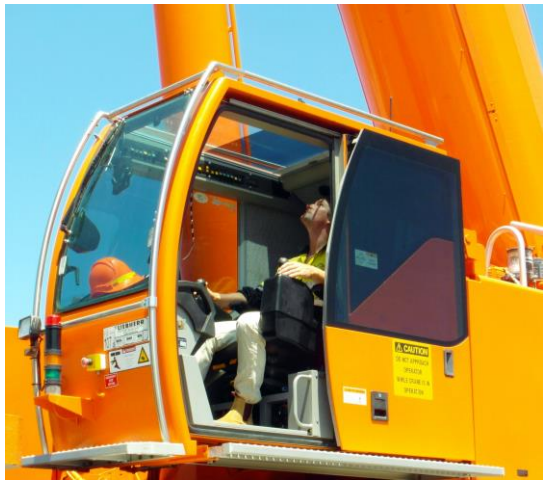

Figure 2: Mobile cranes' operators often looking above when lifting and moving objects[3]

[2] https://www.liebherr.com/

[3] https://waata.com.au/high-risk-work-licences/slewing-mobile-crane/

KEYWORDS

Mobile cranes; augmented reality; potential; challenges

INTRODUCTION

The construction sector is increasingly utilizing information in planning, operation and analytical work, such as:

- The topology of the area, obtained by manual measurement or drones.
- Electronic blueprints of the construction, or from earlier constructions, such as water pipelines or electricity wires in the ground.
- Sensors and production data from the machinery, for example, various tasks being completed or detailed positioning to support work according to the construction plans.
- Environmental data, such as temperatures and weather conditions that will affect the construction work.

To efficiently use various data mentioned above, it is of interest of both academia and industry, but it is so far mostly used for planning and managing tasks. In this paper, we present mobile cranes, one type of industrial vehicles that could benefit from a more immersive presentation. We will first describe the existing problems in mobile cranes, followed by some examples on how see-through visualization could enable mobile cranes' operators to maintain awareness when performing their tasks.

PROBLEMS IN MOBILE CRANES

Mobile cranes are one of typical machines that can be found in construction sites and they have a vital role in lifting and distributing materials both horizontally and vertically [7]. Mobile cranes are also versatile machines, since they can be utilized and mobilized around construction sites within short period of time [7,9]. Despite these benefits, mobile cranes are also considered as the most dangerous machines in construction sites, since they contribute to one-third of injuries and fatalities in the whole construction industry [4]. Crane-related accidents can cause tremendous losses in property and life of both workers and non-workers, such as pedestrians [4,6]. Moreover, mobile cranes are also responsible for 70% of all crane-related accidents [5].

Mobile cranes are complex machines and operating them requires full concentration [2,3,6,9]. When lifting materials, mobile cranes require wide workspace in three dimensions and operators must be careful in preventing the boom and the lifted object from hitting other objects, for example, existing structures, newly erected structures, other machines, and people. When lifting an object, the centre of balance of mobile cranes is constantly changing depending on many factors, such as both height and

Figure 3: The information about the weight and the height of the lifted object is presented directly on the windshield[4]

Figure 4: A warning on loss of balance. In this case, there is a loss of balance on the left side of the machine, thus the warning is presented on the left windshield[4]

[4] The original images were taken from Construction Simulator 2015, developed by weltenbauer. Software Entwicklung GmbH and published by astragon Entertainment.

weight of the lifted object, direction of the boom, uneven ground, wind, etc. The operation is also increasingly complex, since operators do not only have to interact with the machine to perform their tasks, but also with ground workers. Ground workers are involved in some operations, for example, giving signals, hooking the cable with the lifted object, and placing pads for mobile cranes' outriggers.

Due to the complexity in operating mobile cranes, operators' cognitive workload remains high [6]. Moreover, repetitive tasks and long working hours also make operators more vulnerable to fatigue and distraction, thus lowering their ability to mitigate upcoming hazards [2,3,6]. A study in 2012 found that 43% of crane-related accidents between 2004 and 2010 were caused by operators [4]. Modern mobile cranes are equipped with many information systems with the purpose to assist operators to perform their tasks. Despite this effort, operators still pay little information to the displayed information, since they are fully occupied with monitoring the environment and performing the operation [6,8].

THE POTENTIAL OF SEE-THROUGH VISUALIZATION IN MOBILE CRANES

The current way of presenting information in mobile cranes is using displays that have been installed on the dashboard (see Figure 1). This placement has drawback, as the presented information is outside of operators' line of sight [8]. As an example, when lifting and moving any object, operators usually spend most of the time looking above (see Figure 2), thus making the presented information unintentionally overlooked. This situation is undesirable, since operators are not fully aware of the information being presented and this might lead to hazardous incidents. Therefore, there is a need for a new way of presenting information in mobile cranes, which can improve operators' awareness.

Augmented reality, where virtual information is overlaid on the real world [1], has the potential to present the information in mobile cranes in a more embedded way with the operation. As an example, when the operator is lifting an object, the information about the weight and the height of the lifted object is presented next to the lifted object itself (see Figure 3), as well as the information regarding the drastic change of balance (see Figure 4). With more sources of information being incorporated, such as the worksite's performance information, operators could be assisted in planning, for example, by presenting the incoming material, the location with the highest need of material, and the upcoming need of materials. Moreover, higher level of incorporation of geo-data from cameras and external sensors could give operators better support in detailed positioning (see Figure 5). Operators could also get support to avoid other surrounding objects, such as electrical lines, to see what is behind structures in front of the machine, to get prognostics of the swinging lifted object due to the wind, ground workers nearby (see Figure 6), etc.

Figure 5: Showing the direction where the lifted object should be moved when the destination is outside the operator's field of view[5]

Figure 6: A warning when there is a ground worker near the machine or the lifted object[5]

[5] The original images were taken from Construction Simulator 2015, developed by weltenbauer. Software Entwicklung GmbH and published by astragon Entertainment.

CHALLENGES OF SEE-THROUGH VISUALIZATION IN MOBILE CRANES

The first challenge is related to presenting the information in the right location. As shown in Figure 3 – Figure 6, we can see that the information is presented dynamically on the windshield, where objects of interest are seen with respect to operators' point of view, instead of on fixed positions on the windshield. However, this kind of visualization is difficult to be done in practice, since it requires a robust tracking system to recognize objects of interest, and then present the information in the right location. We have not yet seen commercially available devices that are suitable to be used in this context.

The second challenge is related to the visibility of the presented information. Although taken from a simulation, Figure 3 shows a good example, where the information cannot be seen clearly due to the lack of contrast between the presented information and the background. Regardless of what colours are used to visualize the information, there are occasions where the presented information does not have enough contrast with respect to the background. Another problem is the difficulty to see the presented information due to the brightness, such as sunlight. As an example, although nowadays there are many transparent displays are available in the market, it is still difficult to see the information on transparent screens in bright environments.

The third challenge is related to information overload. As the information will be presented near operators' line of sight, there are possibilities where there is too much information than what operators could digest at once. Therefore, there is a need to present diverse information with caution, thus preventing from overloading operators with information. One way to do this is by embedding context awareness into the system, thus operators receive only specific task-related or situation-related information at one time. This will enable operators to perform their tasks, while maintaining good awareness of the machine and its surroundings.

CONCLUSION

As industrial vehicles get increasingly automated, there is a possibility where the role of operators will be more like in-situ planners, who rely on diverse information sources in order to analyse the current situation and actions ahead. We believe that just adding more information will not be a successful approach to support operators. For us, it is thus of interest to explore more immersive information approaches that could capture the information and present it in a way that improves operators' performance.

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