IMPLEMENTING VIRTUAL REALITY TO FOSTER CONSTRUCTION DEFECTS CHECKING AND REPORTING

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The scarce human workforce during the economic downturn and the COVID lockdown measures exposed the need for more reliance on in-person construction site visits. During the pandemic, the research team conducted a systematic review to investigate how virtual reality (VR) techniques can be applied to foster more effective construction defect checking and reporting. The findings indicate that VR technologies can be applied in marker-based inspection, which is crucial for developing the automatic defect recording and tracking system. Built on these findings, this paper reports a case study conducted in Melbourne, Australia, demonstrating how VR techniques can be applied to develop practical solutions for enhancing defect checking and reporting in an actual construction project. The solutions focused on reducing the time-consuming and inefficient manual tracking process. This study shows a step forward in assisting human judgment by resolving the in-person marker-based inspections and manual defect tracking encountered in traditional defect checking and reporting practices.

Keywords: Immersive technology, VR visualization, Marker-based inspection, Case study.

1 INTRODUCTION

Construction defect checking and reporting aim to ensure compliance with the pre-determined project standards and reduce non-compliance with building regulations (Lundkvist et al. 2014). Site visits are crucial in defect checking and reporting (Forcada et al. 2013). Contractors rely on site visits to inspect their work. They are responsible for instructing the respective sub-contractors to repair all the identified defects before handing the project over to the owner. The project manager (who represents the owner) and the registered building inspector (who represents the government) also rely on site visits to ensure the buildings are defect-free before occupancy.

Nevertheless, construction site visits and associated post-visit data management procedures are still labor-intensive (Lundkvist et al. 2014). Problems were then exposed during the COVID lockdown when on-site visits were cancelled or postponed. Different levels of restrictions and social distancing measures imposed by the governments resulted in a massive reduction in the number of workers and professionals allowed on site (Infrastructure Australia 2020). This delayed the defect inspection process as both contractors and inspectors from the government do not have sufficient time and workforce to manage the mounting cases (Denny-Smith et al. 2021).

In this aspect, the emerging virtual reality (VR) technology has shown great potential as an intuitive and visualization medium, allowing building inspection to be conducted in an immersive environment. However, the application of VR in defect checking and reporting is technically
challenging as it should deal with: I) real-time tracking, II) significant process change in data collection and record-keeping, and III) mindset change across the industry (Paolini et al. 2014). Comport et al. (2006) described real-time tracking as no easy task as this involves precise capturing of the users’ foot positioning and movement through a camera display unit. For data collection and record-keeping, Berg and Vance (2017) argued that despite the advancements in its software and hardware in recent years, there is still a lack of a systematic approach to recording and documenting site photographs. Mindset change across the industry is also crucial in fostering VR applications in building inspection. Gontier et al. (2021) conducted a systematic review and found that the construction industry perceived the adoption of VR technologies in projects as time-consuming and costly. Similar findings were reported by Davila Delgado et al. (2020), who criticized the construction industry for lacking expert knowledge and foresight to assess how VR technologies may enhance productivity and the quality of work.

With this background, the research team conducted a systematic review that aimed to answer two questions (RQs):

- **RQ1**: What parts of defect checking and reporting practice heavily rely on the human workforce?
- **RQ2**: What VR techniques are relevant to reducing the reliance on the human workforce for defect checking and reporting?

Research findings of this systematic review were reported by Nicholls and Wong (2022). Regarding RQ1, forty-five publications were read to capture content reporting or describe what parts of defects checking and reporting practice rely heavily on the human workforce. Those captured content were further analyzed, and three themes are found in these articles: [1] Physical site visits, [2] In-person marker-based inspections, and [3] Manual tracking and follow-up process. Regarding RQ2, twenty-seven publications were read to capture content describing which parts of defects checking and reporting practice rely heavily on the human workforce. Three themes are found in these articles: [1] VR marker-based inspection, [2] Automatic tracking and defect recording system, and [3] VR feature BIM defect management system.

However, the results reveal that researchers usually establish arguments through literature review, interviews or surveys to determine future research directions. None of the reviewed articles demonstrates how VR techniques can be applied to enable virtual defects checking and reporting. Built on the work reported in Nicholls and Wong (2022), the study reported in this paper aims to curb such research gap through a case study to demonstrate how relevant virtual reality techniques can be applied to enable immersive defects checking and reporting in projects.

## 2 THE RESEARCH METHOD – CASE STUDY DEVELOPMENT

This case study is built on the work of the research team that was reported in Nicholls and Wong (2022), It was found that VR techniques may apply in marker-based inspection (Theme 1 of RQ2) and [2] automation of defect recording and tracking system (Theme 2 of RQ2). Inspired by these suggestions, this case study develops practical VR-based solutions for an actual construction project in Melbourne, Australia. Noted that the results from the systematic review also indicate VR as a critical feature of the BIM defect management system (Theme 3 of RQ2), this case study did not address this theme as constrained by the availability of project data related to BIM. Based on the thematic analysis results, practical VR-based solutions are developed and applied in an actual construction project in Melbourne, Australia. Brief information on this construction project is presented in Table 1.
Table 1. Project details of the case study.

<table>
<thead>
<tr>
<th>Project Information</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Nature</td>
<td>Residential apartment building</td>
</tr>
<tr>
<td>Project Scope</td>
<td>Five stories with two levels of basement</td>
</tr>
<tr>
<td>Project Sum</td>
<td>AUD $40,000,000</td>
</tr>
<tr>
<td>Project Duration</td>
<td>2 Year and 3 months</td>
</tr>
<tr>
<td>Procurement method</td>
<td>Novated Design and Build</td>
</tr>
</tbody>
</table>

The first step of this case study is to investigate the relevant defect checking and reporting practices of the targeted construction project. This project adopted the Australian Standard (AS) 2124-1992 form of the construction contract. The relevant defect responsibilities are articulated in Clause 37 of AS2124: "As soon as possible after the date of Practical Completion, the contractor shall rectify any defects or omissions in the work under the contract existing at Practical Completion" (Standards Association of Australia 1992).

Detailed defect-checking and reporting procedures are built on "The Guide to Standards and Tolerances", published by the Victoria Building Authority (VBA) (VBA 2015). Major types of defects for checking and reporting include:

- Type A – Damages,
- Type B – Distortion/Warping/Twisting,
- Type C – Water penetration damp related,
- Type D – Material deterioration (rusting, rotting, corrosion, decay),
- Type E – Operational, Type F – Installations (including omissions).

This case study demonstrates how VR techniques can be applied to reduce the human workforce's reliance on defect checking and reporting. The scope of this case study does not cover all types of defects. As a pilot study, it covers defects that are the ‘most commonly found from the construction projects in Victoria, Australia’ identified by the VBA in its quarterly Proactive Inspection Program Activity Reports. In 2021, the most prevalent categories where defects were observed in the construction projects in Victoria were ‘wet areas and external weatherproofing in the balconies’ and ‘compartment and separation’ (VBA 2021).

3 DEVELOPING PRACTICAL VR-BASED SOLUTIONS THROUGH CASE STUDY

Two examples are presented to demonstrate the development of practical VR-based solutions for defect checking and reporting.

3.1 Example 1: Defect in the ‘Wet Areas and External Weatherproofing in the Balconies’

Concrete spalling was identified from a column on the balcony. According to Section 9.10 of the VBA Guide to Standards and Tolerances, “Cracks in moldings and/or other architectural features, including joints between those features and adjacent surfaces, are considered defective if they exist at handover or exceed 2 mm in width within the first 24 months and can be seen from a normal viewing position" (VBA 2015).

If we followed the conventional defects checking approach, this defect item was supposed to be identified by the building inspector during the site visit. A painter's tape would then be stuck on the defect spot. The contractor would then follow up and contact the respective sub-contractor to repair the defects in the following days. The building inspector and the contractor's representative (project coordinator) should visit the construction site in person together. Records were often made in the text and/or attached with 2D photographs.
In this case study, a new approach was adopted. The building inspector conducted the site visit via video conferencing with the contractor. Before the site visit, he sent the contractor representative a list of checkpoints (marked in the contract drawings). During the video conferencing meeting, the contractor representative was asked to capture 360-degree panoramic images from every checkpoint. An appropriate image capturing device should be provided to the contractor to generate a high-resolution VR-based environment using 360-degree panoramic images. In this case study, the contractor was provided with the RICOH THETA V 360-degree camera to capture the 360-degree panoramic images on site. The selection of the RICOH THETA V 360-degree camera was based on its compact size of 45 wide x 130 x long, 22 deep, allowing convenient travelling to and around construction sites. Besides, RICOH THETA V 360-degree camera includes a free-to-download mobile app that enables instant upload and download of the captured VR images. Users can easily download the VR pictures captured from the camera with the mobile app, and watch those pictures anytime and anywhere by placing their mobile phone onto a VR goggle.

As displayed in Fig. 1, a VR image was captured at the checkpoint. The image shows the significant damage on the column corners with the chunks of concrete missing. This significant defect needs to be repaired by laying specific aggregate concrete and involving skilled labor. The instant upload of the VR image for checking speeds up the inspector’s decision-making process. Instead of sticking painter's tape on the defect spot, the inspector added a tag on the VR image, stating precisely the method of defect repairing (Fig. 2 refers). The tagged VR picture was then allocated with an appropriate reference number for easy retrieval by both the building inspector and the contractor representative.

Fig. 1. External balcony column defect – raw VR picture.

Fig. 2. External balcony column defect – VR goggle view with tags.
The new approach removed the blind spots that usually appear in 2-D pictures. This also reduced the possibility of losing information due to the loss of painter’s tape on site. Moreover, this supported the contractor in conveying more precise messages to the respective sub-contractor in fixing the defect.

3.2 Example 2: Defect in the ‘Compartment and Separation’

Scratches and blemishes were identified from the rendered wall. According to Section 9.4 of the VBA Guide to Standards and Tolerances, “Cracking and other blemishes in rendered or hard plastered surfaces on a masonry substrate…” and “Obvious spot rust marks, due to the composition of the material and other blemishes are considered defective if they are visible from a normal viewing position” (VBA 2015).

In line with the approach reported in Example 1, the defect was spotted by the building inspector during the online site visit. The building inspector found the scratches and blemishes through the VR images captured by the contractor representative. He then tagged the instruction to repair in the VR images for the contractor to follow up. Due to the sheer number of blemishes appearing on a wall, the painter or plasterer would have to re-do their work to the majority of the wall. The prompt decision made by the inspector alerted the contractor to check the workmanship of the respective sub-contractor, ensuring that similar defects would be fixed before the next inspection.

4 IMPLICATIONS OF FINDINGS

This case study demonstrates how VR techniques enable immersive defect checking and reporting. The two examples further articulate the development of practical VR-based solutions for a real construction project. Traditional defect checking and reporting practices require a physical site visit with the presence of both the building inspector and the contractor representative. It requires a contractor or inspector to stick the painter’s tapes on the identified defect spots, followed by capturing 2-D pictures for every defective item for following up action. It also requires the sub-contractor to understand the meaning of every painter’s tapes and separate photos taken by the contractor and inspector, which can pile up and become overwhelming for them and result in defects not being rectified.

This case study demonstrates the use of VR techniques in enhancing defect checking and reporting practices. It enables inspectors to conduct building inspection work remotely. It enables the contractor to record in real-time with the VR pictures captured at the checkpoints predetermined by the building inspectors. The new approach allows VR pictures to be uploaded and downloaded instantly. The quality of the inspections improved substantially. This is a direct result of the flawless 360 images captured that remove all blind spots that 2D pictures usually show.

Each picture will have tags attached with details about the nature of the defects and how they should be fixed. This is where the compliances from The Guide to Standards and Tolerances can be highlighted in each VR picture. Providing instructions in the tags will likely result in fewer disputes as it articulates why a defect is provided. The captured content could also be sorted and recorded in a more systemic format where photos were based on trades and not just site location.

5 CONCLUSIONS

Construction defect checking and reporting have been criticized as a lengthy and costly process. This is partly caused by the heavy reliance on manual checking and reporting defects; stakeholders rely on-site visits to identify defects. The findings of this study provide confidence for the industry
leaders that VR techniques can be applied to enhance the identification and reporting of construction defects.

How VR techniques can be applied in marker-based inspection and enable more effective defect recording and tracking was reported through a case study of a real construction project in Melbourne, Australia. The VR-based solutions presented in this case study reduce the reliance on manual tracking, which is a time-consuming and inefficient process of defecting that confuses contractors, inspectors and sub-contractors with unclear descriptions of where the defect is located as well as what trade is responsible for its rectification. This case study can be seen as a pilot study, but it is still considered a breakthrough as it precisely demonstrates how VR techniques can be utilized in defect checking and reporting.

References


