HARVESTING TECHNICAL NOTE

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Augmented Reality tools versus paper-based routine maintenance tasks

Summary

Augmented Reality (AR) promises to supplement human capabilities by enhancing how people interact with their work environment. AR can be used in machinery maintenance by providing real-time visual instructions and overlaying virtual information onto the physical machinery, helping technicians to easily identify components, understand their functions and perform repairs more efficiently. In this study, an Augmented Reality tool developed for forest harvesting machine maintenance was compared with conventional paper-based methods.

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Introduction

This work forms a part of the Human Factors component of the Primary Growth Partnership (PGP) programme, 'Te Mahi Ngahere i te Ao Hurihuri – Forestry Work in the Modern Age' (FGR, 2018). The aim is to develop methods and tools to measure and understand the work of machine operators and be able to monitor changes to their work with the introduction of new innovations from the PGP Programme. This knowledge will guide engineering design of new technology to improve the operator experience, productivity, and safety, thereby enhancing human-machine interactions (FGR, 2019). Scion's Human Factors group leads this work and engages specialist expertise when appropriate.

The promise of Augmented Reality (AR) is to supplement human capabilities by enhancing how people interact with their work environment. AR can be used in machinery maintenance by providing real-time visual instructions and overlaying virtual information onto the physical machinery, helping technicians to easily identify components, understand their functions and perform repairs efficiently. It can also help technicians to access remote expertise and collaborate with others for troubleshooting. Additionally, AR can assist in tracking maintenance activities and updating maintenance records, making it easier for organisations to keep track of equipment maintenance and perform predictive maintenance.AR tools have been shown to help maintenance staff acquire knowledge and skills more rapidly than conventional paper-based instructions (Obermair *et al.*, 2020; Palmarini *et al.*, 2018).

Feedback from Waratah NZ Ltd

The development of the AR in-field servicing tool is described in detail by Thompson et al. (2021). The AR in-field machine maintenance application was field tested with technicians at Waratah NZ Ltd and with Waratah harvester machine operators.

- Both technicians and machine operators spoke highly of the app. It is novel, it is intuitive, and it engages younger generation logging workers.
- New operators commented that it is a great way to learn harvester head specifics, and the app reduces the time it takes to learn.
- Waratah's service technician reiterated that today's operators do not refer back to paper manuals and if there is a digital version of the information, they'll use that. Even more so if it is interactive and intuitive.

Figure 1. Augmented Reality Waratah 622B Head

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- Contractors were happy that it has the ability to export daily checklists etc. once complete as this serves as a record for health and safety purposes. It can be hard to keep an accurate record of training, and this is a way to allow users to complete training on their own time, while still keeping a record of progress.
- *"…Personally, I really like the app, and I like how the information was presented. It can be difficult getting 'under' the machine at times and some minor User Interface (UI) tweaks to allow the user to manipulate (rotate/realign) the head could help with this…"*
- For future development, it was suggested that having some way to swap the virtual model to an "Real Life" (IRL) model would enhance service steps even further.
- For future testing, a way to gamify the experience could produce some quantitative data to assess the efficacy of the app.

Paper-based versus Digital Methods

Traditionally, in industrial settings workers are provided with instructions on paper for routine maintenance tasks and checks (Kolla *et al.*, 2021). As machinery evolves in complexity, paper-based procedures and manuals are becoming progressively more difficult to create and use effectively. Operators need more than simple text to understand the nuances of automation and complicated machinery. Training with paper-based methods is often time-consuming, prone to error or misinterpretation, resource intensive and potentially influenced by literacy levels. Moreover, the forest environment is exposed to the elements (rain, mud, wind) and thus is not conducive to paper methods.

Given the relative newness of functional AR technologies, there are few comparative studies between physical (paper) and virtual (AR) instructions. Comparison between variables such as system usability, number of errors, cognitive workload, physical workload, and Task Completion Time (TCT) will allow us to understand the advantages and pitfalls of each system.

The functionality of AR technology is dependent not only on task complexity, but also the device, user interface, and interaction mechanisms employed (video, overlay, audio etc.) Studies have shown workers using AR made fewer errors, and experienced lower workloads than when paper-based methods (Funk *et al*., 2015, 2016; Blattgerste *et al*., 2017; Zheng *et al*., 2015).

Method

Participants

Eighteen participants (average age 39.5 years, range 19-63) were recruited during the Fast & Forward Forestry Expo 2022 held in Rotorua (18-19 November 2022) to take part in the study. Consent was obtained, followed by a short demographic questionnaire to determine the participants' experience in forestry and with Waratah machine maintenance. Of the eighteen participants, only one had no forestry background. The remaining seventeen had an average of 12.2 years forestry experience, with twelve reporting they have worked with Waratah harvester/processor products (average time of 7.3 years).

Experimental Procedure

With assistance from staff of Waratah NZ Ltd., two similar maintenance-related part location tasks were selected. The criteria for selection included relevance to daily checks and routine maintenance likely to be performed on the Waratah 622B head, ability to locate parts in both instruction systems, and opportunity to measure speed and accuracy (Table 1.)

Two instruction systems were provided to each participant to complete the part location tasks: a conventional paper-based parts catalogue, and a tablet AR system. To compare the effectiveness of the two systems, task completion time was recorded, and anecdotal usability data was collected via a short six question survey. To control for learning effects, a within-subjects design was employed where each participant completed both tasks in randomised order.

Table 1. Instruction System Resource and Pathways

Task	Locate the grease points of the upper delimb unit	Locate the sensor locations of the top saw assembly
HTH622B III Parts Catalogue	Lubrication Fitting Part No. WA101356 Page 46 Reference No. 14	Proximity Sensor Part No. F351139, WA136319 Page 78 Reference No. 29, 30
Scion Waratah AR App (iPad)	Task Dropdown: Grease Points Grease Delimb Knife Pins & Cylinders	Task Dropdown: Functions Dropdown: Sensor Locations Show Sensor Locations

Results

A repeated measures ANOVA test was performed to determine if task completion time was different between paper-based (W = 0.906, p-value = 0.073) and Augmented Reality instruction systems (W =

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0.955, p-value = 0.524). There was a significant difference in the time to complete the task (Figure 2). Specifically, participants took less time to complete the task when using AR than when using paper (Estimate = 74.722, df = 17, t-value = 5.297631, p-value = 0.0001).

A second repeated measures analysis of variance (ANOVA) model was used to test for the combined effect of Mode (Paper, AR) and Task (Sensor, Grease) on time to complete the task. No significant effects were found between the interaction of task and mode, or when comparing the two tasks, indicating complexity was likely matched (Figure 3).

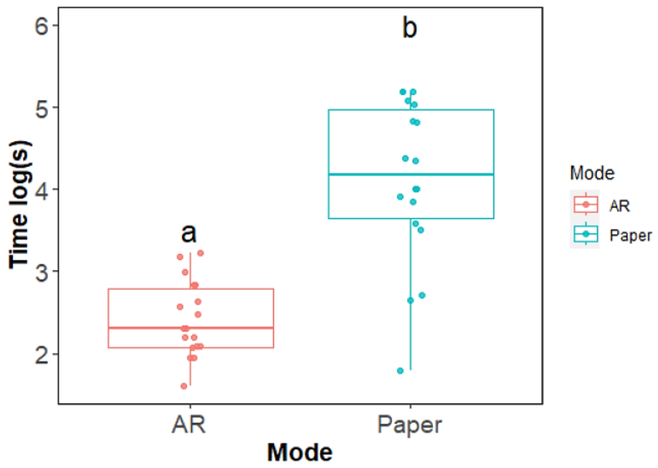

Figure 2. Task completion time comparison between paper-based and augmented reality systems.

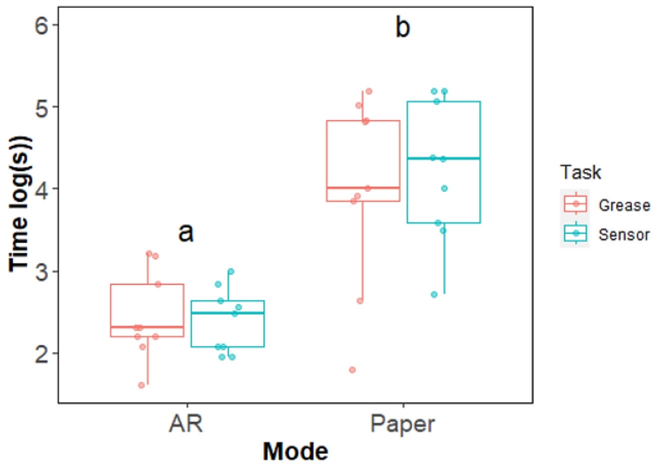

Figure 3. The effect of Mode (Paper, AR) and Task (Sensor, Grease) on time to complete the task.

The following figures show the independent effect of age, forestry experience and Waratah experience over the time to complete the task (Figures 4, 5, and 6). The lines represent the regression lines that adjust the best fit to the values of each mode.

As can be seen in Figure 4, there is a minor increase in task completion time as age increases. This trend is marginally less pronounced when using the AR instruction system. The data is wider spread in the paper-based mode, indicating greater variation.

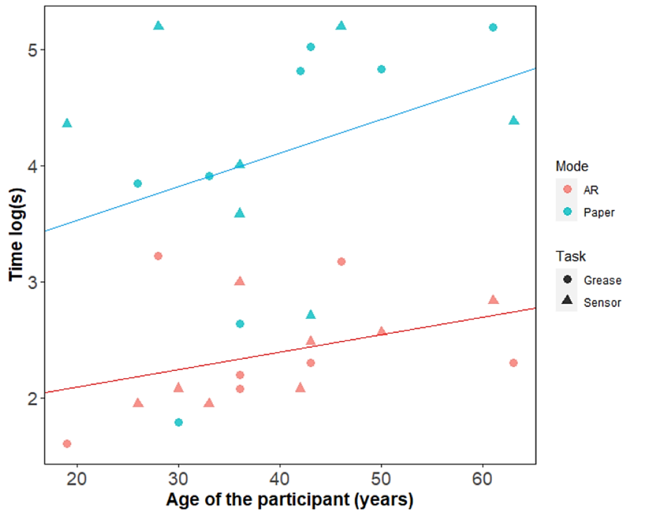

Figure 4. Relationship between age and time to complete the tasks.

Interestingly, the relatively flat red line in Figure 5 demonstrates that the AR system is not affected by the amount of forestry experience an individual had. In contrast, the paper system showed a trend where the more forestry experience a participant had, the longer it took to complete the task. This may have been an effect of aged eyesight, needing reading glasses which they did not have on them at the time of testing. Again, we saw a large amount of systemic variation for the paper-based system.

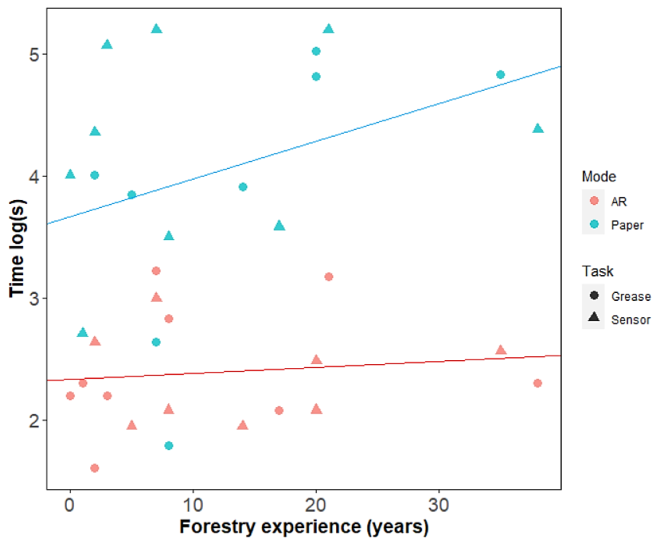

Figure 5. Relationship between forestry experience and time to complete the tasks.

Waratah experience was correlated with decreasing trend in task completion time for both systems.

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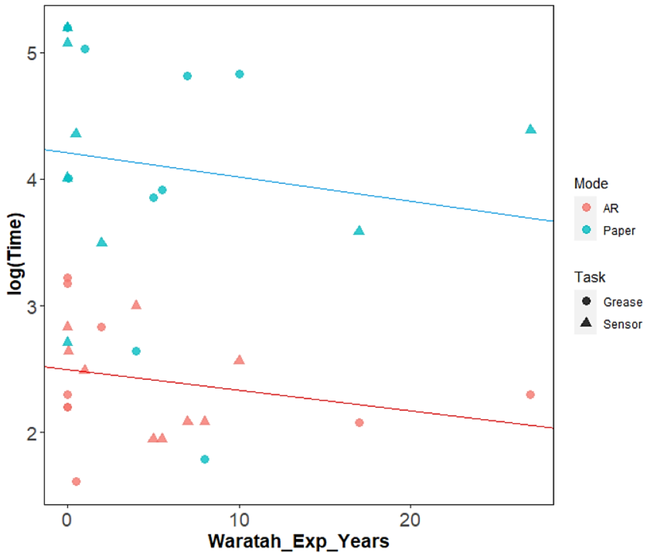

Figure 6. Relationship between waratah experience and time to complete the task.

The anecdotal survey results provided us insight into the experience, accuracy, and practicality of the two systems. Of the eighteen participants, sixteen indicated they preferred the AR system. Some of the reasons why included: "*less reading, more pictures*"; "*easy to use*"; "*picture paints 1,000 words*"; "*easier to visualise*". More participants found the AR system easier to use than the paper system, as can be seen in Figure 7. Furthermore, the participants felt that they would use the AR system, especially in training scenarios or with operators.

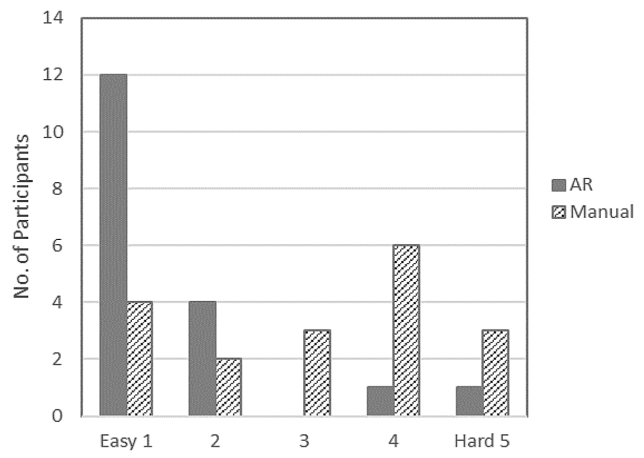

Figure 7. Participant ratings for ease of use for both systems.

Conclusions

AR provides several advantages over traditional paper-based systems for maintenance tasks. The industry participants of this study reported that the real-time visual instructions eliminated the need for manual interpretations, leading to improved maintenance accuracy and overall efficiency.

Other possible benefits and useful applications of AR in machinery maintenance include enhanced collaboration with the ability for multiple technicians to access and share information; real-time data from sensors that allows technicians to quickly diagnose and address issues; reduced downtime leading to increased productivity and lower cost; training opportunities as machine complexity increases; spare parts management reducing the need for physical inventory checks and improving the speed of parts ordering and delivery; and, the ability to access up-to-date information and perform tasks from anywhere without the need for physical documentation.

AR is proving to be a valuable tool, capable of evolving into a solution to the pressing challenge of industry-wide skills shortages. An issue forestry currently faces is an aging workforce that is rapidly nearing retirement – taking with them valuable experience and practical knowledge. A less understood aspect of the problem is the increasing introduction of new digital technologies into operations, such as automation and robotics. A trend that effectively changes the competency requirements to allow for optimal performance in dynamic, high risk production systems. Younger employees could be considered digital natives, potentially setting a favourable scene for AR technologies to attract a more diverse workforce and hasten skill acquisition. Concurrently, AR promises to help upskill our current, qualified workers with interactive and immersive training experiences, building their understanding of complex, ever-evolving machinery and processes.

This study is part of a long-term programme, with much more to be done in collaboration and partnership with sector stakeholders, researchers and innovators, and technology developers and manufacturers. Such collaboration is a key element of the PGP programme and one sure to guide the effective use and adoption of new technology across the New Zealand Forest industry.

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