Title:
Augmented Reality System Integrated with CMMS to Minimize Unscheduled Downtime

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Introduction:
The application of Augmented Reality in maintenance are many. For examples, AR system was shown to improve the performance, reduce the error and stress of the technician during maintenance task in comparison with traditional paper-based manual [2-3]. Other studies have shown that AR system can ease the knowledge transfer of maintenance procedure to the novice staff without incurring expensive and time-consuming training [1],[5],[6]. Although AR has been shown in many aspects as a productivity-enhancing technology, no application is specifically designed to minimize the unscheduled downtime due to unexpected breakdown which can greatly affect the business performance and competitive advantage of an industrial firm. For instance, long downtime can influence the capability of an industry to meet the production deadline while still ensuring the excellent quality of product at minimum production cost. This paper presents the development of AR on the Hololens integrated with Computer Maintenance Management Software (CMMS) to equip the operator to deal with the unexpected breakdown effectively and productively. The next sections of this paper describe the system architecture of AR-CMMS and technical implementation, the demonstration of the use case, and the general conclusion of the potential benefits for the industry.

Augmented Reality System Integrated with CMMS:
CMMS ties together equipment information, maintenance data and schedules, failure history, as well as parts inventory. The main use of a CMMS is to effectively plan preventive and predictive maintenance as to minimize the number of surprise breakdowns and work outages. However, the new form of connection between CMMS and AR allows the enhancement of contextual awareness against unexpected breakdown, and hence, provides right actions to deal with it through explicit visualization of asset information, manual from manufacturer, best-practice maintenance and diagnostic procedure, as well as the availability of the spare parts. Furthermore, the release of Hololens by Microsoft as a wearable device for AR display allows user to see an AR-enriched environment while still permitting them to perform maintenance task with both hands. In this way, the effective procedure of maintenance processes can be planned and displayed to the unskilled operator, guiding him to diagnose the problem and even to carry out the correct maintenance task more intuitively and safely.

The architecture of AR-CMMS system is presented in the Fig. 1. The developed system consists of CMMS, information controller, and the Hololens. Asset information such as equipment, failure, and maintenance data which are stored in CMMS database were linked in a relational database. Data query/write from AR system to database was managed by information controller through Graphical User Interface. The GUI utilizes AR module to retrieve asset information and control the display of the information through AR modalities.

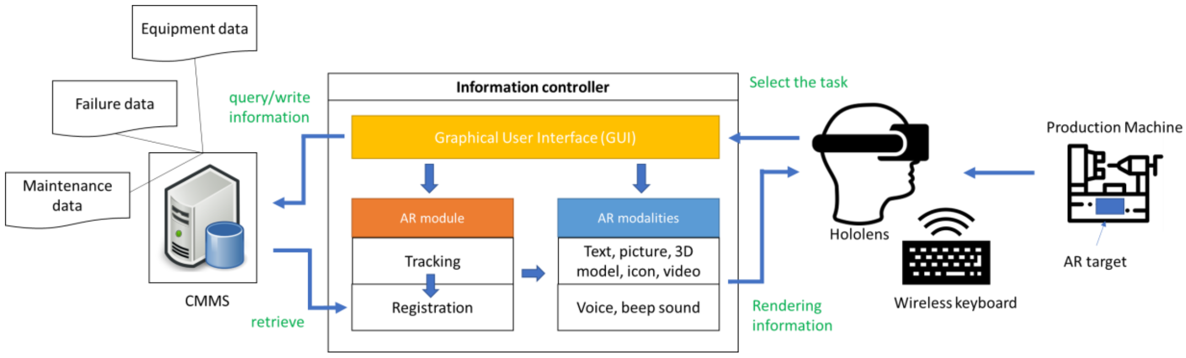

Fig. 1: The architecture of AR-CMMS system.

Vuforia 8.0.10 was used as AR engine that tracks the AR target (i.e., Image Target) in a real environment and associate it with the asset ID for the information retrieval. The AR target also serves as reference location in physical space where the asset information should be displayed relative to the user's view. Unity3d was used to develop information controller including the design of GUI and the display of the asset information in different AR modalities such as visual (test, picture, 3D model, icons, video) and/or audio (voice message, beep sound). The communication between CMMS database and AR application was established by means of a web service. The AR application in this work was developed based on Unity3d which has a built-in implementation class *UnityWebRequest* for composing HTTP requests and handling HTTP responses, allowing Unity based application to interact with the web server back-ends. A PHP based web service was created to facilitate the interaction between AR application and web server.

The next two figures describe the general procedure in industrial firm to approach the unexpected breakdown and how the proposed system could optimize the pipeline of maintenance procedure to boost the profitability and competitive advantage of an industrial firm.

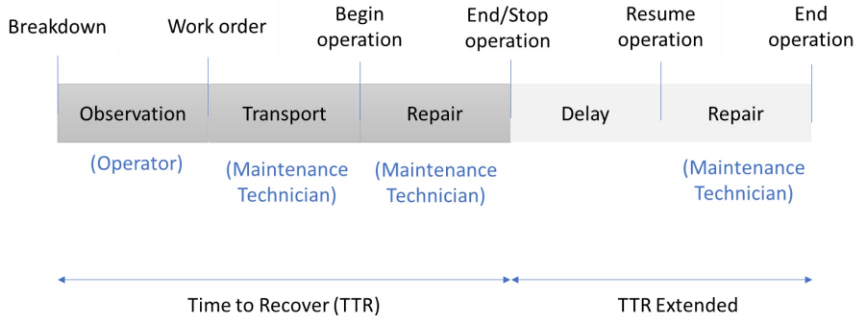

Fig. 2: General procedure to rectify unexpected breakdown using CMMS.

In the Fig. 2., when the unexpected breakdown is detected, the operator needs to check and report the high-level problem of what he observes (e.g. the effect of failure) through Work Order (WO) in CMMS. In this phase, the maintenance jobs that need to be attended by maintenance technicians will be appeared in the CMMS. The technicians will review the work request provided by the operator and examine the information to have some ideas of possible problems before arriving to the plant area where the machine breakdown occurred. When the technician arrives, he carries out the maintenance procedure and once the repair on the breakdown machine is completed, the work order is finalized and closed, which also indicates that maintenance work has been successful in putting back the machine to the normal operating condition. In the other case, if the maintenance cannot be concluded because of the missing resources (e.g. spare part) or lack of expertise, the maintenance operation will be postponed until it is feasible to be resumed. The time to recover (TTR) is the time that is required in maintenance operation to bring the equipment back into the normal operating condition.

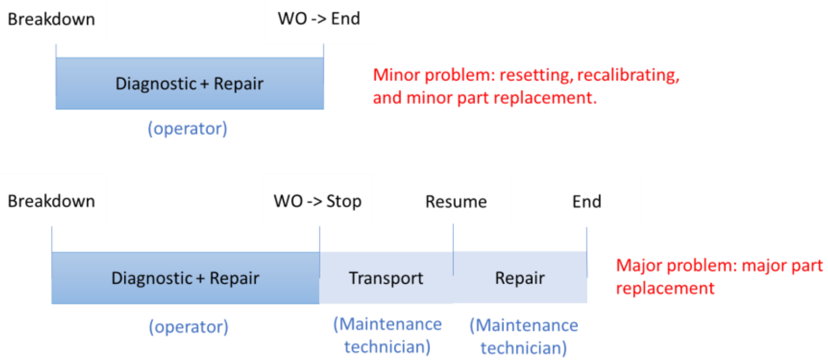

Fig. 3: The procedure to rectify unexpected breakdown using AR system integrated with CMMS.

On the contrary, Fig. 3. shows that the integration of AR and CMMS can in some cases help the untrained operator to perform diagnostic and corrective maintenance when the problem is minor, and thereby eliminating the unnecessary waiting time for the skilled worker to attend to the problematic equipment. In the case of the major problem, the system can guide the operator to perform diagnostic on the possible problem as to narrow down the cause of failure which eventually lead to a more accurate planning of maintenance action (e.g., maintenance priority, assignment of maintenance crew, required tools, and spare part ordering), and thus avoiding the non-productive maintenance operation and recommissioning. This is especially true when the machine to be maintained is complex, the variability of error and duration among different technicians is high, the maintenance task to be performed is rare, and the operation need to be done in a remote location [4].

Case Study:

Manufacturing firms could have a wide variety of production machines with different characteristics of failure history and maintenance instructions. Linking all this information together and visualize the relevant information in appropriate modality to the human operator can generate productive value in dealing with unexpected breakdown. In this study, the usability of the proposed system in maintenance was demonstrated on a 3D printer machine. Due to the advancement in the underlying technology, 3D printer can be complicated to troubleshoot when the malfunction occurs, as print issues can be caused by multiple sources of problem. In this study, two types of failures were considered: (1) failure that involves fixable component (easy task) and (2) failure that requires certain expertise to solve the problem (difficult task). In fact, 3D printer can have many print issues. However, for the sake of demonstration, two print problems (i.e., no element comes out of the nozzle and layer shift) were chosen to show the advantages of the proposed approach.

Fig. 4. shows a sample of data organization in a database that links machine data with failure history and its associated causes along with maintenance actions that have been performed. One specific machine (MachineID) can have a failure (FailureID) that consists of multiple sources of problem (CauseID). For each source, a specific maintenance guide (InstructionID) can be properly planned and designed from the manual book which is complemented by the know-how knowledge of the skilled technician. Fig. 5(b). shows that user can access the functionality of the system for the task that he wants to perform (e.g. diagnostic task) or create Work Order (WO) using wireless keyboard to input the data as shown in Fig. 5(a). The interaction of user with GUI is realized by hand gesture and voice recognition facilitated by Hololens.

ID	MACHINE NAME	VENDOR NAME	PURCHASE DATE
1	3D printer	Sharebot	11-05-2017
2	3D printer	Shining3D	12-01-2018
3	Laser Cutting	SainSmart	15-03-2016
4	CNC Milling	SoraLuce	19-09-2015
....	....	....	

CAUSE ID	CAUSE NAME
1	Broken filament
2	Nozzle too close to print head
3	Nozzle clogged
4	Current voltage setting
5	Loosen belt or grub screw
6	Problem on stepper motor
....	....

ID	MACHINE ID	FAILURE ID	CAUSE ID	DOWNTIME	INSTRUCTION ID	TOOLS	SPARE PART
1	1	1	1	20	....	....	....
2	1	1	2	5	....	....	....
3	1	1	3	50	....	....	....
....	....	....	....	....	....	....	....

ID	FAILURE_NAME	FREQUENCY
1	No filament comes out from the nozzle	15
2	Print not sticking to the bed	10
3	Layer shift	2
....	....	....

Fig. 4: The link of asset information in a relational database.

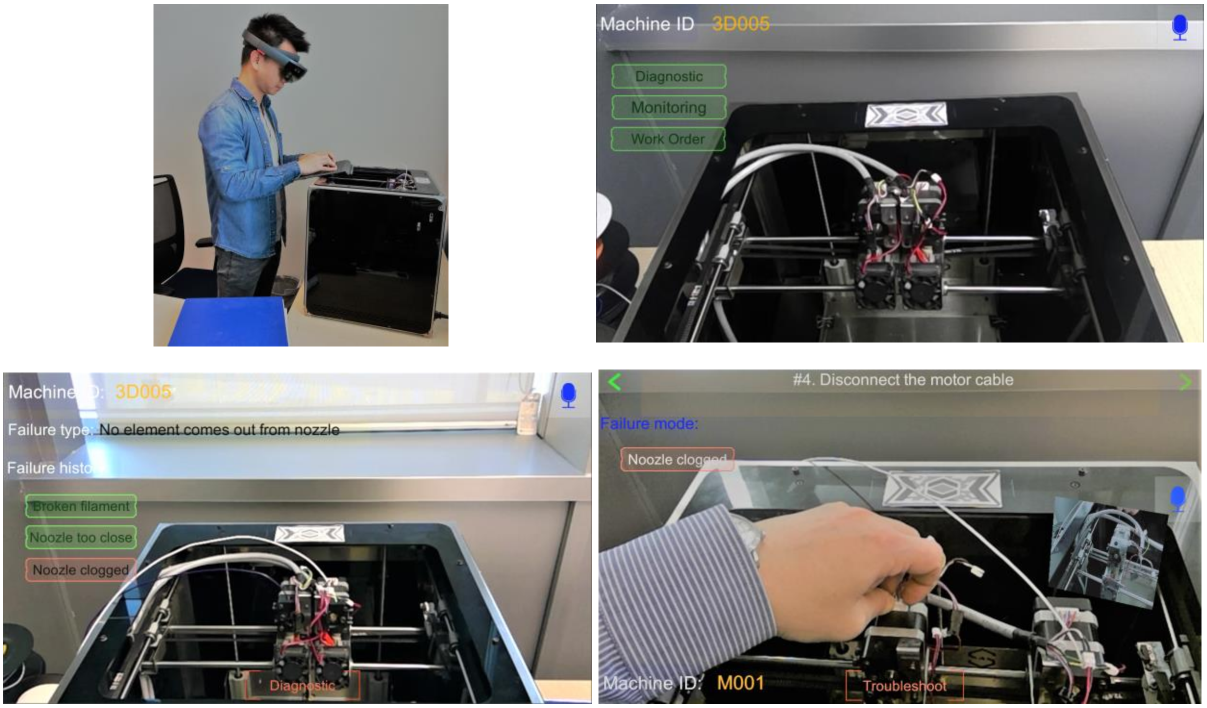

Fig. 5: AR system integrated with CMMS to deal with unexpected breakdown. The figures from left to right and top to bottom are: (a) a user wearing Hololens and using wireless keyboard, (b) functionality of the system, (c) diagnostic operation based on failure history, (d) AR system guided the operator through text instruction and video on how to troubleshoot the problem.

The Application Program Interface (API) of Hololens was used to program the gaze cursor based on user's gaze, the gesture recognition such as air tap alone for click action, air tap and hold to perform "click and drag" action, voice commands such as "Next" and "Back" to go to the next or previous instruction. By looking directly to AR target, the camera on Hololens can detect the ID of the machine and the system can retrieve the information of the asset from a webserver of CMMS database. When the unexpected breakdown occurs, the operator can report through the voice command or type the failure name that he observes, and possible causes will be displayed to the operator.

In this way, the system can guide the untrained operator with AR instruction to perform a step by step diagnostic to examine the root cause of failure or even perform corrective maintenance on the minor problem. The possible causes will be marked in green if the operator finds no issue with the suspected cause as shown in Fig. 5(c). When the actual problem is detected and fixed by the operator through the guidance of AR-CMMS system (Fig. 5 (d)), the operator needs to create and close the WO to update the maintenance history of the machine. In this way, the failure of the machine can be handled immediately by the unskilled operator in the shop floor with the aid of AR system. If the traditional approach is adopted, the corrective maintenance is subject to delay as it relies heavily on the expertise of the technician which causes the failed equipment to be inactive for a longer time and consequently leads to production loss. Furthermore, in a rare case but requires high expertise to fix the problem such as the malfunction of the stepper motor that causes layer shift, the proposed system can assist operator to rule out the unlikely sources of failure through diagnostic task, and thereby providing a more specific information about the actual failure (i.e. identified problem is on the stepper motor). This can help the technician to plan a more accurate and productive maintenance planning (e.g. order a spare part) to restore the machine to its normal operating condition. Moreover, the system can record every maintenance activity performed by either operator or technician. This enables the assessment of maintenance procedures with the associated equipment for quality control, performance evaluation, and cost analysis in attempt to derive the best practices for maintenance actions. The AR assisted maintenance system can be upgraded based on the company's best practices and distributed to other branches of the manufacturing industries that run the production with the same type of machine.

Conclusion:

The main purpose of the AR-CMMS integration is to establish a more effective approach to deal with the unexpected breakdown. Through the provision of asset information in AR, this approach could assist an untrained operator to immediately diagnose or even fix minor problem as to minimize the duration of the unscheduled downtime. Furthermore, the early inspection of the dysfunctional asset could help to devise a more accurate planning of maintenance operation, and thereby avoiding the non-productive maintenance operation and recommissioning. The reduction of time to recovery will improve the availability of the equipment and hence, increase the profitability and competitive advantage of an industrial firm.

References:

[1] De Crescenzio, F.; Fantini, M.; Persiani, F.; Di Stefano, L.; Azzari, P.; Salti, S.: Augmented reality for aircraft maintenance training and operations support, IEEE Computer Graphics and Applications, 31(1), 2011, 96–101. https://doi.org/10.1109/MCG.2011.4

[2] Fiorentino, M.; Uva, A. E.; Gattullo, M.; Debernardis, S.; Monno, G.: Augmented reality on large screen for interactive maintenance instructions, Computers in Industry, 65(2), 2014, 270–278.

[3] Henderson, S.; Feiner, S.: Exploring the benefits of augmented reality documentation for maintenance and repair, IEEE Transactions on Visualization and Computer Graphics, 17(10), 2011, 1355-1368. http://dx.doi.org/10.1109/TVCG.2010.245

[4] Palmarini, R., Erkoyuncu, J.A. and Roy, R., 2017: An innovative process to select Augmented Reality (AR) technology for maintenance, Procedia CIRP, 59, 23-28. http://doi.org/10.1016/j.procir.2016.10.001

[5] Sanna, A.; Manuri, F.; Lamberti, F.; Member, S.; Paravati, G.; Pezzolla, P.: Using handheld devices to support Augmented Reality-based maintenance and assembly tasks, IEEE International Conference on Consumer Electronics (ICCE), 2015, 178–179. https://doi.org/10.1109/ICCE.2015.7066370

[6] Wójcicki, T.: Supporting the diagnostics and the maintenance of technical devices with augmented reality, Diagnostyka, 15(1), 2014, 43-47.