Examination of Robotic Aerospace Engines Maintenance Supported by Augmented Reality through Cloud Manufacturing

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Abstract

This Paper aims to develop a demonstration using a mobile device to apply augmented reality to allow remote maintenance activities. This research was focused primarily on the aerospace industry studies as there was a research gap as there are few relevant researches in the manufacturing field and accepted industry needs. The targets were achieved by developing and designing controls in the engineering steps to create the optimum conditions for augmented reality. The design process pursued in four stages: first, research the current practice of using augmented reality remotely in manufacturing maintenance; second, classify maintenance remote assisting problems and weakness in augmented reality; third, design and develop software and hardware, depending on the case study for a prototype solution to remote maintenance enhanced by the augmented reality that can be demonstrated and tested; finally, validate the developed software and demonstration using industrial experts and authentic reports. The results of this project were an open source software updated IDEA 2.0 and a hardware robot, dubbed McRobot, which was automated to conduct the inspection process and support the augmented reality requirement. Three type of evaluations were done at the end, and all of them recorded positive feedback, validating this project for future development.

Keywords: Augmented Reality, Virtual Reality, Mixed Reality, Cloud, NDT, Remote Maintenance, Robot Maintenance, Wearable Maintenance Gadgets.

1. Introduction

Maintenance is a costly process that requires time, money and effort. Maintenance duration is one of the main factors that must constantly be reduced as much as possible, as it has dire implications in terms of effort and money. This is particularly true in the aerospace field, where even one minute can have a significant cost implication. Major manufacturing and management teams in academic and industrial institutions have provided solutions to the maintenance quandary. In one such example, Toyota TM developed concepts and strategies to reduce maintenance as much as possible in terms of cost and time (Biehl et al. 2004). These days, technological gadgets have entered the arena and use cutting-edge technology to provide solutions to maintenance issues. While there are many technologies being developed for manufacturing activities, several come particularly recommended for future work and development (Akan et al. 2011; Fuhrmann & Encarnac n.d.; Neumann & Majoros 1998). One of the current developing technologies that is of increasing interest is augmented reality (AR). The focus on AR from some of the biggest industries and firms is growing, as these players are coming to realise the valuable benefits of the technology. Also, the use of new technologies in information systems and advanced networks such as Cloud Manufacturing has allowed the manufacturing industry to apply new and complex manufacturing systems. Cloud Manufacturing is one of the emerging technologies that helps to exceed the limitation that been faced in AR process. AR can be described as the coexistence of virtual content with the real world through the, compositing and supplementing of a particular area in the real world using powerful technology tools (Azuma et al. 2001). To understand AR, one must also be familiar with VR (virtual reality) and mixed-reality. Numerous definitions are available for VR, but they are all similar in meaning. A simple definition might be the simulation of virtual objects in a virtual environment through the use of a wearable gadget like glasses or gloves. (Steuer 1992). Mixed reality (or hybrid reality, as it was formerly known) can be defined as virtual objects that can be enhanced in a real environment or vice versa (Pan et al. 2006; Zauner et al. 2003).Virtual reality (VR) is a part of augmented reality, and combining the two produces mixed reality. In Figure 1, the cross-section of the reality egg demonstrates the relationship between AR and VR: the egg shell represents mixed reality; the egg white signifies augmented reality; and the yolk is virtual reality.

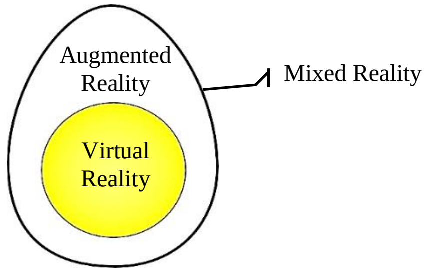

Fig. 1. Reality Egg representing the relation between augmented, virtual and mixed reality.

2. Methodology

The method for this project can be broken down into three stages. The first was a build-up stage, wherein collected data, gathered information and explored the technology as a research term. This phase also comprised a literature review and industrial requirements. By finishing the first phase and moving to the second stage, reserved for design and development, the whole project plan became clearer and was able to identify the gaps that needed to be filled. Finally, the last loop methodology stage included the process required to build up the design that was developed in stage two. It was beneficial to discover that moving backward from stage three (process) to stage two (design and development) could happened easily if updates are needed in the design or development algorithms. Moreover, the same goes for stage two (design and development) and stage one (research), if one needs to add new knowledge or correct some misunderstanding.

2.1. *First Stage: Research*

A literature review had been undertaken that included the basics of augmented reality, the reinforcement of AR, remote maintenance in manufacturing fields (with comparisons), the applications of AR , the benefits of using AR with remote support, and the scientific gaps that AR needs to fill. Also, one of the objectives of this project was to understand the real technology used in industries and to evaluate its. Nuclear AMRC (Advanced Manufacturing Research Centre) in Sheffield was visited to review the latest projects that industrial companies are developing as this science centre is one of the biggest in the UK for developing technologies (Stuart Harrison 2015).

2.2. *Second Stage: Design and Development*

The project's core goal was a successful design and development phase. This stage summaries the ideas need to build in term of the core of the requirements and objectives by studying the process, data flow and tools available. One can break down the design process into two separate areas: software and hardware. The software was designed by using the software engineering tools like storyboard, sequence diagram and IDF0 for data flowing, while computer engineering tools like mock-up and prototype designs were used for the hardware. Not neglecting the application programs that need to edited with specific details as an example of the programming language or the framework simulating the scripts.

2.3. *Third Stage: Process*

This phase consists of five parts related to each other consecutively. They are hardware development, software development, experiments, analysis and validation.

3. Results

3.1. *IDEA 2.0*

An open source software run on Matlab was updated with new functionality to enhance the outcomes from the data presentation algorithms with AR technology. This software was developed originally by Multipolar Infrared Vision –Vision Infrarouge Multipolaire: MiViM, Laval University, Canada then it was updated at Cranfield University under the title of IDEA (Infrared Degradation Enhancement and Analysis).

3.2. *Recognition Effectiveness*

At first, to augment any multimedia type with regard to the samples that are in the project, there was the need to for recognise the location and calculate the size of the enhancement objects. The locations were learned using OpenCV libraries, as it is open source and customisable to detect the damages to the composites materials. Then calculated the size to enhance in the top of the material needed to coincide the real world and acted as a real object. Finally, tracked the points detected and sizes calculated to provide the dynamic affecting the composite surface.

3.3. *Image Enhancement*

After developing the ability to recognise the size and location of the damage, the capability to enhance infrared images became easier and more practical. The only method that was new was calculating the size of the enhanced image related to the distance from the sample surface. The infrared images were generated from the same software (IDEA) after analysing the raw files that were taken from a previous project done at Cranfield University.

3.4. *3D Enhancement*

The same technique of using image enhancement was used in 3D enhancement. These images were generated from IDEA software by analysing the infrared images analysed the RAW files together. The same method was used to calculate the size based on the distance moving on the sample surface.

4. Validation

The three types of evaluations were used for validation. The results support the idea of remote maintenance using augmented reality in manufacturing as the experts and specialists have industrials backgrounds.

4.1. *Ultrasound, Infrared and Augmented Realty Comparison Results*

One of the methods to evaluate the results of this this project was to compare the result of the previous project done on the same samples to calculate the damage size on the 30J damage shiny sample. The results were calculated with different tools; ultrasound (c-scan), an infrared (25 HZ) camera and an RGB camera (represent the AR). The results would not be the same, as each tool has a different accuracy, but the range result could provide positive conclusion about the validation level for the result and offer more ideas to build upon for future development and recommendations.

4.2. *Experts and Specialists Feedback*

Some experts and specialists were interviewed to corroborate the project's outcomes. Their feedback was separated into three parts according to IDEA output results and their recommendations for the termination.
The experts' positions are as follows:

- Lecturer in Digital Signal and Image Processing at Cranfield University.
- Research Fellow at EPSRC Centre in Through-Life Engineering Services at Cranfield University.
- Research Fellow in School of Aerospace, Transport and Manufacturing at Cranfield University.
- Lecturer in Service Simulation and Visualisation at Cranfield University.
- Software Development Engineer in School of Aerospace, Transport and Manufacturing at Cranfield University.

4.3. *Authentic Similar Projects Contrast*

As is known to the authors, there have been few papers published about robotics in manufacturing. Most of these papers, published and developed at the end of twentieth century, concern the early birth of ideas in this field. The most famous papers focus, on specific tasks or deliver an idea that the authors hope will be developed in a future work. They all tacitly agree on the benefits of robotic systems in many facets such as income, costs, time, quality and management (Karasic & Asada 2011; Chirn & McFarlane 2000; Luk et al. 2005; Mesa-barrameda et al. 2014).

5. Conclusions

All the requirements and qualifications needed to make a remote assistant for manufacturing using augmented reality were realised. An Open-source hardware and software were developed and available for any engineer to customise those in such way to fit the industry area. Remote assistance improved the quality of augmented reality supporting. Although there are some limitations with regard to big data and graphic process rendering these shortcomings could be addressed using a private cloud. The key advantage of this Cloud is the ability to control the Cloud infrastructure without third party intervention. The case study using augmented reality in maintenance demonstrated a more rapid process in manufacturing workflow. The designed case study in the aerospace maintenance field pointed many further benefits than initially estimated.

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