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Innovative Framework for Immersive Metrology

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Abstract

The combination of augmented reality and metrology could lead to immersive metrology which has the potential to radically change how part inspection is undertaken, and by doing so enhance the value adding capability of being able to dynamically inspect a part in situ without handling it. This paper presents a case for immersive metrology within the context of part inspection. A framework is proposed to enable integration of the critical elements of augmented reality for dimensional inspection of different case study parts.

Keywords: Metrology; Augmented Reality; Human Computer Interaction; Verification and Validation; Measurment-assisted assembly

1. Introduction

Metrology is integral to every manufacturing operation. This can be in the form of traditional hard gauges for repetitive measurement of specified features, through to scanning methods that can capture multiple points on a given part surface. These methods gather information about the product either to qualify the conformance of the product to specifications or, in the case of reverse engineering applications to gain new knowledge. Typically, in manufacturing scenarios, metrology is undertaken within a quality department or, alternatively, within process, using in situ methods such as on machine inspection utilizing touch trigger probes, photogrammetry or non-contact high-fidelity scanning.

In parallel to developments in metrology, augmented reality has reached a maturity that enables it to be used within a manufacturing context. This new emerging technology enables the user to experience a richer and more immersive experience when digitally interacting with their environment.

Within an engineering context augmented reality is being used to help engineers design more efficiently using a combination of interaction and immersion within dedicated computer aided design environment. New technologies such as the Microsoft HoloLens [1] and the Meta 2 [2] are being used to help designers realize new ways to design and collaborate.

In a metrology context, Augmented Reality (AR) methods could enable a more streamlined and efficient way to gauge part measurement, inspection, assembly and constraint data. Whilst this has to some extent been carried out in industry [3,8,18,19] the combination of augmented reality and metrology could lead to Immersive Metrology (IM), which has the potential to radically change how part inspection is undertaken, and by doing so enhance the value adding capability of being able to dynamically inspect a part in situ without handling it.

The aim of this paper is to document and describe an IM research framework, with a defined experimental methodology.

In order to achieve this aim the following objectives have been defined:

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- To have a thorough understanding of the use of AR in manufacturing, particularly as a tool for verification and validation.
- To define the metrology information requirements at the time of assembly.
- To evaluate various AR technologies for displaying the required information and rank the technologies based on these findings.
- To develop a theoretical framework for increasing the metrology information availability at the time of assembly and inspection of a product.
- To create an experimental prototype that demonstrates the suitability of AR for verification and validation. In which IM can be tested, and put under varying circumstances to assess its performance.
- To discuss the results and identify limitations observed during the test case.

This paper is composed of a literature review that provides a brief background on AR in assembly which then identifies gaps and potential areas where this technology could be applied. It then introduces the research framework for IM followed by an explanation of the experimental approach that will be used to test the IM interface. Finally conclusions and future work are presented.

2. **Literature Review**

Augmented Reality is being used more and more in the engineering world as a tool to help engineers, and operators with training, design, manufacture, assembly and in some cases verification and validation of components [3]. This section will explain what AR is, how it works, current implementations in manufacturing and assembly, and finally how this technology has been used to help in the area of measurement and verification.

AR can be described as a human computer interaction system that blends the natural view that the user has of reality with digital information that can be of use at that point in time and place for the user. This digital information can be anything from videos, images, and text. What gets displayed will depend on the environment and current situation the user is in. This digital content if properly designed has the capability of enhancing or "augmenting" the reality that the user is experiencing. It is important to mention that contrary to Virtual Reality (VR) where the real world is blocked and what the user sees is a virtual scene, AR is achieved without the user losing sight of the real world. Hence why AR can be used for context-specific tasks, and has the potential to help in training, design, assembly verification and validation of components [4].

An AR system has four key components [3]:

- Video camera
- Tracking module
- Graphic Processing Unit (GPU)
- Display

The video camera captures the real world environment that the user is currently observing. Then the tracking module calculates in real time the actual position and orientation of the camera. Some consider this to be the most important component of an AR system [3] since without knowing the location of the camera or where the user is, the AR system does not know where to place the digital content. After the tracking module has successfully obtained the location and detected the markers, the GPU with this information now knows what it needs to display and where it needs to display it. Hence, it creates the digital information and passes it to the display in order for the user to see it. There are different type of AR displays. These are hand-held displays (smartphones, and tablets), monitors, projectors, and Head Mounted Displays (HMD). The display to be used depends on each application. The factors that determine this decision will be things such as available budget, access to technology, environment, task at hand, and if the user needs to have both hands free at all times. Figure 1 below shows an example of a hand held AR application.

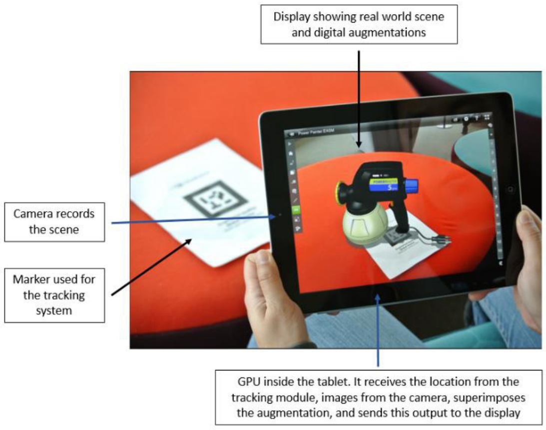

Fig.1. Representation of a hand held AR example setup. [5]

2.1. *Augmented Reality in assembly*

AR since its inception in the 1950's has been used for several types of applications such as in the entertainment industry, marketing campaigns, and finally to the industrial sector to try and help engineers and operators in training, design, and assembly guidance in an digital environment [20, 21]. According to Wang et al. [6] due to AR's ability to improve the interaction between computer systems and users by permitting them to move freely in an augmented environment and allow the users to interact with the objects naturally; AR technology has positioned itself as one of the most promising technologies to be able to assist in assembly processes.

In 2003, Tang et al. [7] did a comparative study between three different types of guided assembly methods. The first one was a paper based manual instruction set, the second was a Computer Assisted Instruction (CAI) method using a monitor as a display, and the third one used an AR HMD to overlay the assembly instructions over the workspace. The results showed