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A systematic review of Augmented Reality content-related techniques for knowledge transfer in maintenance applications

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ABSTRACT

Augmented Reality (AR) has experienced an increasing trend in applied research in the last few years. This emerging trend is focused in content-related challenges: mainly creation (Authoring), adaptation (Context-Awareness) and improvement (Interaction-Analysis) of augmented content. Research in these techniques has enabled Academia to recognise Augmented Reality capability for knowledge transfer, either from AR systems to users or between users. But to the best of author's knowledge, there are no specific literature review in these areas, neither on their relations with AR knowledge transfer ability. Therefore, this paper aims to identify these relations through an analysis of state-of-the-art techniques in Authoring (A), Context-Awareness (CA) and Interaction-Analysis (IA) in the context of maintenance applications. In order to do so, a Systematic Literature Review (SLR) has been conducted on 74 application-relevant papers from 2012 to 2017. It comprised a thematic analysis to establish the relation between maintenance applications, research in A, CA and IA and AR knowledge transfer modes. Its results helped to classify AR maintenance-applications by technological readiness levels. They also revealed the potential of AR for users' knowledge capture, and future research required for full knowledge management capabilities. Furthermore, the SLR method proposed could be extended to correlate AR systems and applications by their knowledge management capabilities in any AR application context.

Contents

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1. Introduction

The Augmented Reality (AR) definition has evolved over the years alongside techniques and applications. Based on its extended capabilities, the authors propose to define AR as: *"a set of human-computer interaction techniques* [1] *that enriches user's real-world experience* [2,3] *by embedding contextualised information* [4] *into user's space in coexistence with real-world objects* [5]*"*. Moreover, Nonaka [6] defines knowledge as information in context. Knowledge transfer is also defined as *"the conveyance of knowledge from one place, person, system or ownership to another"* [7]. Therefore, if AR is able to transfer information and put it into context, then it should be able to transfer knowledge [1] to the users.

The idea of AR being a knowledge transfer technology is also confirmed by latest research in the area. Literature reviews in different application fields such as design and manufacturing [4], maintenance [8], surgery [9], or education [10] have identified research gaps regarding AR knowledge transfer abilities. Besides, these gaps were always related at least with one content-related technique: creation (Authoring), adaptation (Context-Awareness) or improvement (Interaction-Analysis) of augmented content. These methods are emerging AR research areas in their own:

- **Authoring (A):**the software techniques that aim to create augmented content and properly display it in the real world [11].
- **Context-Awareness (CA):**the software techniques that aim to use contextual information to characterise augmented content [12].
- **Interaction-Analysis (IA):** the software techniques that analyse the status of the interaction between user and augmented content to provide relevant feedback and/or improve the interaction [13,14].

To the best of authors' knowledge, no research has been found to review the state-of-the-art of these techniques. Moreover, there is no research focused on clarifying the relation between these techniques and AR knowledge transfer capabilities. Nevertheless, conduct that research can involve an immense amount of work if we consider reviewing these techniques from all AR applications. Therefore, it could be an intelligent strategy to narrow that research down to an application field where AR knowledge transfer capabilities can have a great impact.

Maintenance has a critical role improving organisations' competitiveness and contributing to their sustainable development [15,16]. The global-market size of high-value products maintenance-industries has been estimated in £490 billion by 2015 and £710 billion by 2025 [17]. High-value products are increasingly complex, technology intensive, expensive and critically reliable, requiring from continuous maintenance throughout their lifecycle [18]. This leads to two of the main challenges that drive maintenance research [15,18–20]:

1 Extend life of high-value products with optimum cost.
2 Improve efficiency and effectiveness of maintenance processes.

Due to high-value products' features, maintenance processes are knowledge intensive for maintainers [2,18,21,22]:

1 Number of equipment, subsystems and components implicates a large number of operations.
2 Complexity involves a large variety of different tasks from diagnosis to repair.
3 Long life causes varying levels of quality, standards and depth in documentation.

Therefore, the provision of the right information to the right user in the right quality and time is critical to increase efficiency of these maintenance processes [23,24]. As a visualisation technology, AR can provide support to maintainers with these knowledge-intensiveness challenges described above [25]. A, CA and IA techniques are identified as important AR areas to enhance maintenance efficiency and effectiveness [4,8]:

- **Authoring (A)** to provide proper maintenance processes visualisation and so enhance their efficiency.
- **Context-Awareness (CA)** to adapt visualisation to the maintainer and so enhance their effectiveness.
- **Interaction-Analysis (IA)** to capture maintainers feedback and analyse their performance in order to enhance visualisation and so improve its efficiency.

Therefore, A, CA and IA can help to enhance maintenance processes efficiency and effectiveness by providing an adaptive,