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Capturing Manufacturing Knowledge Using Augmented Reality Technologies

Ahmed SARHAN[a,1], Lancelot MARTIN[a], Mohammed EL SOURI[a] and James GAO[a]
[a] *School of Engineering, University of Greenwich*
Chatham Maritime, Kent, ME4 4TB, UK

Abstract. Manufacturing is a knowledge-intensive business in which companies are distinguished for their ability to deliver products and services using numerous forms of information and knowledge. Various information and communication technologies and systems have been created throughout the years to effectively manage information and knowledge in industry. However, capturing knowledge, particularly tacit knowledge, remains a challenge. Virtual Reality (VR) and Augmented Reality (AR) technologies for industrial tasks have been developed by the research and practitioner communities. For example, in manufacturing, VR/AR have been used to aid in different machining and assembly tasks. This paper presents a proposed an AR equipment 'Head Mounted Device (HMD)' under development, as a tool for capturing manufacturing expertise's knowledge. The technology intends to capture tacit knowledge using a 3D camera installed on the operator's HMD. The proposed approach also supplies the operator with information on production and ongoing processes.

Keywords. Knowledge Management, Augmented Reality, Head Mounted Devices, Digital and Smart Manufacturing.

1. Introduction

Skilled technicians are typically individuals who have already resolved a huge proportion of complex situations in the course of their professional career. The experience and knowledge obtained in these roles are beneficial both to the technicians and their companies. Organizational dynamics, as well as demographic changes, will result in the retirement of highly skilled and knowledgeable staff. Retired technicians will take this crucial specialist knowledge with them when they leave their employers. They are often unaware that they hold this specialised knowledge. It is therefore difficult to explain and hence challenging to transfer knowledge among employees. Therefore, human resource development plans must include procedures for research, documentation, and application of specialist knowledge within the organisation.

Explicit knowledge and implicit (or tacit) knowledge are the two main forms of knowledge [1]. Data, scientific equations, specifications, manuals, and standard operating procedures are examples of explicit knowledge that can be articulated in formal and systematic language which is relatively simple to analyse, save and transfer. Implicit or tacit knowledge, on the other hand, is very personal and difficult to codify. It is embedded in people's thoughts, influencing their values, attitudes, emotions,

[1] Corresponding Author. as9881i@gre.ac.uk

commitment, routines, processes, and actions. It is difficult to recognise, quantify, record, and store [1].

With the evolution of Virtual Reality (VR) and Augmented Reality (AR) technologies, it is now feasible to utilise VR/AR to collect, save and represent both explicit and tacit knowledge, with meaning and interpretation. AR provides potential for the seamless interaction of individuals, their environment, and digital data, together with cloud computing, additive manufacturing, blockchain, Internet of Things (IoT), collaborative robots, intelligent automation, and other emerging technologies. AR is one of these technologies that is entirely focused on increasing the interface between the physical community and the digital cyber-world. The aim of the reported work is to show the possibility of using AR as a tool for knowledge capturing and sharing.

2. Literature Review

Over the last two decades, AR has gained significant interests from researchers in the manufacturing technology field, owing to its ability to manage a wide range of challenges throughout the distinct phases of a product's lifecycle. Moreover, there is a noticeable pattern of leveraging advanced immersive AR apps to construct accommodating environments for understanding difficult working scenarios, acquiring risk-prevention knowledge, and enduring training. None of the previous solutions could be implemented without the required special tools including (a) HMDs, (b) portable handheld devices and (c) spatial devices [2]. Without the proper tools, none of the developed solutions could be achieved. For current industrial solutions, HMDs have proved suitability for industrial applications since users can move freely and use both hands to accomplish the required tasks. HMDs were utilised in a wide range of industrial sectors, including maintenance, assembly, quality control and training. In Jan et al. [2], user expectations towards the usability, usefulness and acceptance of smart glasses were evaluated during two use cases in the electronics manufacturing industry. Hao et al [2] examined the findings of the first survey on user expectations for new task assistance, as well as the next steps in the project's ergonomic evaluation. Moreover, a study conducted by Kim et al. [3] explored the effect of HMD on worker performance and the possibility of using HMD to enhance workplace health and safety.

Knowledge creation and transmission are critical sources of companies' long-term competitive advantage. Many industrial organisations managed to capture and transfer explicit knowledge in the form of books, manuals, videos or databases. Nevertheless, organisations risk of losing valuable information and best practice when skilled experts retire because of intangibility and challenging transformation of tacit knowledge into explicit knowledge. Explicit knowledge has received a lot of study interest in knowledge engineering so far. However, research attention to tacit knowledge is insufficient. This is mostly due to the difficulty of acquiring, managing, and reusing tacit knowledge when compared to explicit knowledge [4]. In the current literature, there are primarily two approaches to dealing with tacit knowledge: Tacit Knowledge Sharing (TKS) and Tacit Knowledge Quantisation (TKQ) [2]. The primary distinction between these two techniques is that TKS seeks to transfer knowledge effectively between individuals, whereas TKQ seeks to turn knowledge gathered from specialists into a formal structure.

Personal insights, emotions, and hunches are examples of tacit knowledge. Nonetheless, it is essential to identify that tacit and explicit knowledge are mutually beneficial, and that both are necessary components of knowledge development, because explicit information without tacit understanding loses relevance. Furthermore, the knowledge transformation process involves the interplay of tacit and explicit knowledge rather than either tacit or explicit knowledge alone.

The majority of existing solutions for collecting tacit knowledge in industry rely on one-on-one interviews or group discussions. Recent research by Kimura et al. [5] investigated the importance and application of expert knowledge in the domain of injection mould production and offered a technique for collecting knowledge based on verbal discussions with engineers and reviews of technical papers. According to the findings of a case study, lead times were reduced by up to 55% as compared to the traditional procedure [5]. Efthymiou et al. [6] provided a structure for defining, storing, and extracting prior knowledge about production line layouts. Their research sought to help the early design stage of a system by applying a semantics method for knowledge representation and retention, as well as similarity measurement and inference approaches for knowledge extraction, using a case study from the steel construction and forging sector [6]. Previous research did not make use of the most recent technological advances in the industrial sector. Previous solutions were mostly based on imparting knowledge in person through training materials, in-person instruction and/or using knowledge stored in information systems.

3. Tacit Knowledge Management using HMD

The goal of knowledge management is to match the correct knowledge to the right individual at the right moment. This may not appear to be a challenging task, but it necessitates a strong relationship to business strategy, an awareness of where and how knowledge resides, the development of procedures that cross functional departments employ, and ensuring that activities are recognised and promoted by organisation members. A well-defined knowledge management approach, as well as the appropriate tools, are needed to achieve this goal.

3.1. Traditional tacit knowledge management process

There were no commonly used frameworks for tacit knowledge management in the literature. However, there were common processes that must be followed in order to manage knowledge. Figure 1 shows a typical framework for collecting tacit knowledge adopted from previous research [7] .Tacit knowledge capturing refers to the method of extracting tacit knowledge from experts' minds. Although it is challenging, certain established approaches for dealing with this challenge exist, such as community of practise (Cops), observation, storytelling, analogies, expert interviews, card sorting, and repertory grid [4]. Knowledge creation is described as the process of making individual knowledge accessible, amplifying it in social situations, and selecting links to add to the organization's current knowledge [8]. Because knowledge development costs the company a lot of time and money, the knowledge creation process is a significant activity that requires a lot of attention. It is necessary to review and revise knowledge captured in order to cope with external stimuli, address current organisational challenges, and assess the relevance and danger of knowledge in current situations [7]. Review and revision of knowledge is particularly crucial since a huge portion of knowledge may easily be forgotten or neglected if not utilised.

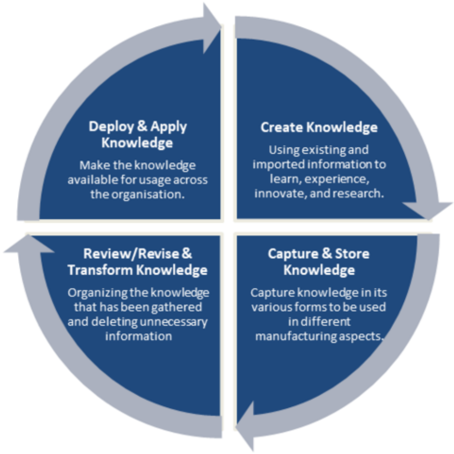

Figure 1. Knowledge Management Processes.

The process of distributing and exchanging knowledge throughout organisational levels using multiple interconnected processes, people, and technology is known as knowledge distribution. The visibility of knowledge distribution brings up new opportunities for organisational management. It may aid with day-to-day tasks as well as planning the organization's future development [6].

3.2. Using AR for knowledge management

As described in Section 3.1, knowledge management is a time-consuming and labour-intensive activity due to its many distinct stages. As a result, several researchers attempted to suggest various solutions, frameworks, and tools to capture and manage knowledge. The previously developed solutions and frameworks did not have significant impact on either the length or the cost of the process. Therefore, more attention was shifted toward the use of more innovative tools. Automatically authored videos show its potential as a tool for knowledge capture and transfer. By using statistical design and experimental analysis, Giorgio et al. [9]demonstrated that expert help can reduce the assembly time of an unskilled operator. The study showed that automatically authored videos can convey knowledge but have the reverse impact on assembly time. In their study, Thilakumara et al. [10] compared live versus video demonstrations in conveying knowledge. The findings favoured the videos. There are various limits to using video as a tool for collecting and transferring knowledge, including camera positioning, significant on-site noise, and the contextual nature of some activities. As a result, HMD was proposed in the present work as a tool for knowledge management. HMDs were developed to encourage people to interact more deeply with their environment. The evolution of the HMDs enables the development of applications that need considerable computational capabilities. Nowadays, HMDs are integrated with various sensors that assist and guide the operator while working. The built-in camera captures video of the workplace and uses smart learning to comprehend what is going on in real time. Through the right interface, HMDs can be used to capture knowledge using voice commands, gesture tracking, and 3D depth cameras. The sensors will aid the operator in documenting and capturing his/her knowledge for later use. The collected knowledge could then be accessible via HMDs or a personal computer. The HMDs allowed the operator to evaluate the collected knowledge in the AR while maintaining visual connection with close collaborators in real time. Furthermore, with the proper interface, visualising and managing the acquired knowledge would be more accessible without prior knowledge of complex database programming. Different training materials could be created from the stored information and knowledge, increasing the usefulness of the collected knowledge. Knowledge management is characterised by a repeating flow of actions/steps/tasks that does not have a clear beginning or finish. Figure 2 depicts how a knowledge transfer process interacts with itself repeatedly during a cycle.

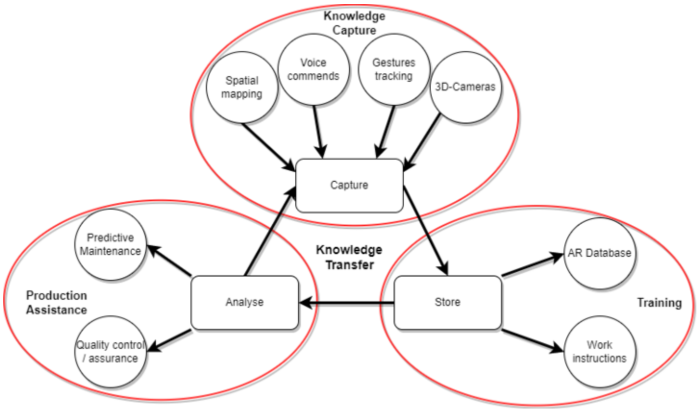

Figure 2. Knowledge transfer between capture, storage, and analysis

Owing to the huge development of HMDs, it is now feasible to employ various sensors/tools to govern interaction with the augmented projections. For the proposed solution, 3D-Cameras mounted on the HMD will be utilised to record the operator's knowledge via gesture tracking and spatial mapping. The voice commends will be used as an additional tool for recording comments and other explanations for the operator's understanding. Following the capture of the operator's knowledge, it might be retrieved later through HMD or a computer. The knowledge gathered would be utilised to create work instructions and training materials. Moreover, the knowledge captured could be analysed for Quality Control/Assurance and predictive maintenance purposes.

According to Refaiy et al [11], maintenance team performance is influenced by the sharing of tacit information, which improves the effectiveness of the measures supplied. The proposed interface will be initially used for maintenance tacit knowledge capturing in manufacturing companies. However, the interface will be scalable and could be applied in various departments. The proposed solution would not only capture tacit knowledge, but it will also support the operator with his tasks. HMDs will supply real-time feedback and guiding instructions to the operators during the execution of tasks/procedures to reduce the risk of incidents and to aid training. Furthermore, it will supply operators a personal digital knowledgeable assistant with whom they can interact to obtain the pre-captured knowledge.

4. Conclusions

Extensive personal contact and regular engagements are regularly required to transfer knowledge especially tacit knowledge. Through training or mentorship sessions, employees can achieve knowledge and experience by learning from more highly experienced co-workers. Technologies that support workers to capture and transmit knowledge are essential for effectively processing knowledge especially tacit knowledge. The use of HMDs to manage knowledge demonstrates a strong potential for expert knowledge transfer inside the company, which is independent of people and hence sustainable. Using a HMD can speed up the process of knowledge analysis by utilising Augmented Reality capabilities as an enabling tool. Furthermore, this could accelerate the process of content generation in order to respond quickly to the company's needs. The next stage is to design an AR interface that meets industrial requirements. This interface will be used to enable the experienced operator to capture his/her expertise so that it can be passed on to less experienced operators.

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