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Mixed Reality in Learning Factories

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Abstract

Supported by rapid technological development, mixed reality (MR) applications are increasingly deployed in industrial practice. In manufacturing, MR can be utilized for information visualization, remote collaboration, human-machine-interfaces, design tools and education and training. This development makes new demands on learning factories in two major fields: One is the empowerment of users to work with MR in industrial applications. The second field is the utilization of the potential of MR for teaching and learning in learning factories. A great potential lies in the new possibilities of connecting digital content with the physical world. To analyze the potential applications of MR in learning factories in a structured way, an overview of potential MR applications based on the reality-virtuality continuum is presented with an analysis of case studies of applications in a learning factory including a mixed-reality-hackathon.

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Keywords: Mixed Reality, Augmented Reality, Learning Factories; Hackathon

1. Introduction

Mixed reality (MR) applications surround us in everyday life. This is most obvious in video games and entertainment, but MR is also present at live events, in retail, education, healthcare and engineering to highlight just a small selection [1]. In industrial practice, MR is increasingly utilized for information visualization, remote collaboration, human-machine-interfaces, design tools as well as education and training [2]. With MR, digital content can be connected with the physical world and both can be made available to the user at the same time. For example, in car

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manufacturing interactive see-through MR head mounted devices (HMD) can be used enabling designers to change the outer appearance of a car by augmented drawings making the design process more collaborative and effective [3]. MR is also frequently implemented to increase customer engagement in retail and marketing [4]. At the same time, MR is recognized as a powerful tool for teaching and learning [5] and for its ability to improve the efficiency of tasks by adopting to the user's experience level. An example concept for an augmented reality environment, which adapts to the data availability and the user's skill level, can be found for instance in the context of maintenance [7]. Furthermore, MR can enable long-distance learning [6]. The goal of this paper is to analyze the potential areas of applications of MR in learning factories in a structured way by providing a general, not hardware specific overview of potentially beneficial fields of application and use cases in teaching and learning environments on production engineering.

2. Mixed Reality in learning factories

2.1. Mixed Reality and the reality-virtuality-continuum

In a mixed reality environment or application, real and virtual objects are combined and "mixed" to create a user experience incorporating both the real and the virtual world. Real objects are characterized by having an actual objective existence. Contrary, virtual objects exist in essence or effect, but not formally or material [8]. With the continuous rise of MR application the terms "augmented reality" (AR) and "mixed reality" (MR) as well as "virtual reality" (VR) are sometimes used interchangeably today. As AR is a part of MR, it is important to define these terms. A comprehensive framework is given through the reality-virtuality-continuum shown in Fig. 1 based on *Milgram and Kishino* [8]. At both ends of the two dimensional continuum, fully real environments (reality) and fully virtual environments (virtuality) are located. In between, reality and virtuality are combined in MR environments with an increasing share of virtual elements from left to right. If an application within the reality-virtuality-continuum has a higher share of real elements, it can be classified as "augmented reality". Contrary, it can be referred to as "augmented virtuality". For an application to be classified as MR application, requirements originally designed for AR by *Azuma* in 1997 are adopted in this paper [9]. Although being more than 20 years old, the defined characteristics of AR are still valid and are also true for MR. Thus, three characteristics have to be fulfilled by an application to classify as an MR application. Firstly, real and virtual content has to be combined in an MR application or environment. Secondly, MR is required to be interactive in real time. Thirdly, MR needs to be registered in three dimensions. To make MR applications and environments visible and accessible for the user, hardware devices are required. In MR, these devices also enable the interaction of real and virtual objects. This is necessary for viewing virtual objects, as these cannot be viewed directly. Virtual objects have to be simulated to create a viewable representation utilizing a display device whereas real objects can be observed either directly or sampled and transferred into a digital model and resynthesized through a display device [10]. Different technological implementation concepts and actual hardware devices can be located on the reality-virtuality-continuum [10]. Tangible interfaces use physical objects to create virtual models. In Spatial AR, virtual objects are projected into the user's real environment. Holographic spatial AR allows a higher share of virtual objects and higher user immersion. Connected to the virtual environment, semi-immersive VR involves a significant emphasis of virtual objects over real objects and in immersive VR, the user is experiencing an almost total virtual environment. It is not within the scope of this paper to provide a survey of current MR hardware. Comprehensive surveys of MR technologies and applications can be found in different application contexts (e.g. [9]–[12]).

The selection of suitable concepts as well as actual hardware and software environments is one of the main challenges for productive implementation of MR applications. There are several approaches for selecting MR technology that are usually focused on one area of application. *Palmarini et al.* for example developed a process to select augmented reality technology for maintenance tasks [13]. A great potential of MR in the context of manufacturing lies in

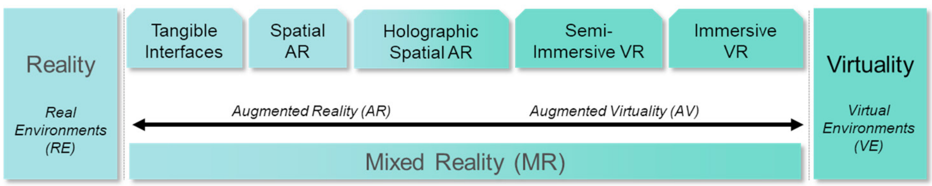

Fig. 1. Reality-virtuality-continuum based on [7] with allocation of implementation concepts.