Project Management Development – Practice and Perspectives
Sixth International Scientific Conference on Project Management in the Baltic Countries
April 27-28, 2017, Riga, University of Latvia
ISSN 2256-0513, e-ISSN 2501-0263

AUTHORING INDUSTRIAL AUGMENTED REALITY APPLICATIONS

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Abstract

With the rapidly advancing technologies in the time of the fourth industrial revolution, it becomes more and more important for companies that want to maintain a competitive edge, to develop, implement or to the least adopt innovative solutions that provide business and technical value to the company itself and to its customers. SMEs aiming to position themselves or maintain their market share face this challenge in an aggravated manner.

The aim of this paper is to discuss the added value of creating, authoring and implementing augmented reality applications for maintenance of machines in the context of manufacturing SMEs. The paper is structured in a way that combines a literature review of the different concepts relating to authoring and augmented reality within the context of the fourth industrial revolution and the business value created through the use of augmented reality applications. This is followed by an introduction and discussion of the project “InMachine” in which this work is embedded. Then a concept to simplify the authoring of maintenance augmented reality applications in manufacturing SMEs. This is done based on the authors’ experience, who are affiliated to one of the partners in this project. The paper concludes with reflections from the findings of the literature review and the progress of the project and a look into the future prospects of this field.

Key words: *Augmented Reality, Industrial Applications, Maintenance, SMEs, Project Management*
JEL code: O14, O31, O32, M15, L86

Introduction

While during the fourth industrial revolution, which is currently arriving at big enterprises and now making its way towards small and medium sized companies, the production environment itself with all involved machine and transportation mechanisms is getting “smart”, the way humans interact with it did not change much. On the other hand, Augmented Reality (AR) has grown out of the research labs into the mass market with first successful applications like Pokémon Go. The real-time overlay of digital information on the real world surrounding us, which is the key element of Augmented Reality, allows the creation of completely new ways to interact with the digital world. While many, even quite early, research prototypes could show the high potential AR featured digital maintenance manuals offer, they are still not really used in productive environments, as the creation of such AR maintenance applications is not yet paying off due to its high costs/effort.

This paper will present an approach to simplify the creation process of AR maintenance applications as used in the InMachine project allowing the economic authoring of such applications to tap into their big potential and simplify the interactions of humans with the next generation of industrial “smart” machines.

ISSN 2256-0513, e-ISSN 2501-0263

Introducing Industrial Augmented Reality

The term "Augmented Reality" originated in the 1960s upon the creation of the first 3D head-mounted display by Ivan Sutherland (Sutherland, 1968). However, it is first actual industrial AR was realized by Boeing in the beginning of the 1990s, when a head-mounted display was used "to superimpose a computer-generated diagram of the manufacturing process with a real-time world registration and the user's head position calculation" (Caudell & Mizell, 1992) (Nassir, 2004) (Tetland, 2016). There was however no consistent definition for the term and it was interchangeably used with the term "Virtual Reality". In 1994, Milgram et al's attempted to bring all related terminology into a single publication to draw the line between the different terms and their respective definitions. Milgram et al. oppose the view that reality and virtuality are "antitheses", but rather see them "as lying at opposite ends of a continuum" – the so-called "Reality-Virtuality (RV) continuum" (Milgram, et al., 1994) (*See Figure 1*).

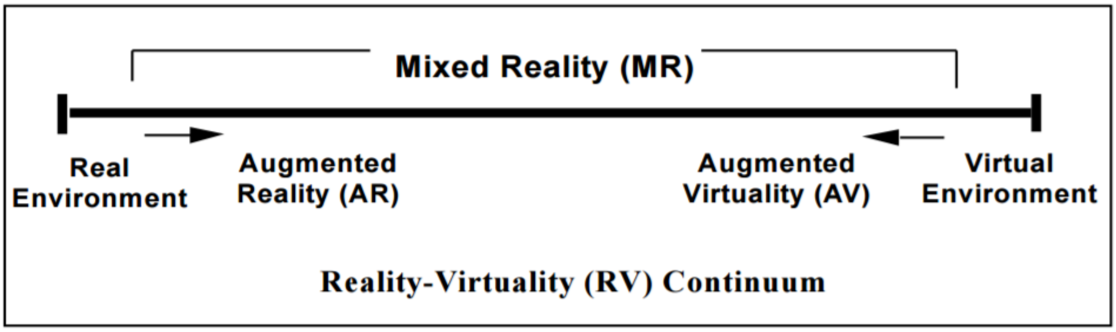

Figure 1: **Simplified representation of a RV Continuum** (Milgram, et al., 1994)

Within this framework, Milgram et al. define a Mixed Reality (MR) environment "as one in which real world and virtual world objects are presented together within a single display, that is, anywhere between the extrema of the RV continuum" (Milgram, et al., 1994) (Milgram & Kishino, 1994).

Application and Value-added of Industrial AR Technologies

Although AR technologies have been present in our world since the 1990s, their industrial use is relatively still at an early stage, concentrated in R&D and piloting phases. Some of the main contributors and implementers of these technologies include Boeing, Airbus, Bosch (Tetland, 2016).

According to Digi-Capital and AugmentedReality.Org, "augmented reality market is going to hit $120 billion by 2020" (Digi-Capital©, 2015) and Smart Glasses market will arrive at 50 -100 million shipments by 2018 (AugmentedReality.Org, 2015) (Viscopic, 2016). The major areas where the application of AR technologies brings significant improvement to the processes and their business value are:

- Training: The use of AR in industrial training facilitates skill transfer in several areas, including training for assembly and maintenances of machines. Through capturing and rendering technologies, the trainee can "interact with the real-world objects and simultaneously access the virtual information for guidance", thus reducing errors and time consumed to complete a task (Webel, et al., 2011). In a study conducted in Iowa State University to compare AR training with more traditional training methods, students were given instructions and the task to put together a mock airplane wing. The group that received instructions converted to an AR built as an overlay on the assembly "experienced a 90% reduction in the number of errors during the assembly" and 35% reduction in the time built to the wing, in comparison to the group using instructions on the desktop computer (Price, 2015).

- Operations & Error Prevention: It is easier to obtain data about the functioning of the machines, to track and monitor operations and detect errors through use of AR technologies, such as glasses, cameras and depth and motion sensors. Aside from the study above, research shows that "the accuracy of engineers can go up to 96% and they are able to work 30% faster" (Robinson, 2017) (Tetland, 2016).
- Maintenance: the combination of MR technologies and wearable devices enables technicians to implement preventative and corrective maintenance through real-time data, thus reducing production down-time and increasing the longevity of the machines. According to Columbia University, maintenance comes as a "natural" application for MR technologies; as maintenance tasks usually demand "maximum preservation of a user's focus on a specific area of interest" and "the need to synthesize additional information, such as delicate and complex sequences, obtuse component identification, and lengthy textual data" which is burdensome, time-consuming and costly (Henderson & Feiner, 2007).

As the work described here is part of a funded project, the following paragraph will give an introduction and overview of the project. This will provide the necessary context for the later described concepts.

InMachine Project

The InMachine project is a funded research project using local intelligence and networked planning in order to increase the efficiency of technical production machines in collaborative production networks of SMEs. The aim of the project is to mitigate such innovation risks in SMEs and to support them with high-tech services.

The development of finely tuned production and control requires that the machines act as autonomous planning instances. The smart machines will be connected with each other and with a central planning unit to form a collaborative production system. The machines will be able to evaluate its local sensor and operating data and to identify critical system conditions such as defects or required maintenance work. They will be able to solve the problem locally for example by moving the jobs or scheduling them to other production machines. This reassignment can be negotiated among the machines in the networked machine network with appropriate planning priorities. (University of Applied Sciences and Arts, 2016)

In addition to making the production process more efficient, machines also need to undergo constant repair and maintenance processes. Usually those procedures require specially trained workforce, since there are certain steps to be followed and other concerns to take into consideration. This makes those procedures comparatively expensive and time consuming, especially if the specialized worker is not available at the moment or doing another maintenance job.

ISSN 2256-0513, e-ISSN 2501-0263

A solution for this problem will be to guide a worker without any prior specialized training in the maintenance or repair process step by step presenting all necessary information and precautions that should be considered at the moment when they become relevant. This can be done by an Augmented Reality application that will guide any worker through the process of maintaining and repairing of small and medium complexity tasks. This solution offers a more practical and economic way to hold such tasks, and can be done more quickly and smoothly.

The workflow of the solution in Manufacturing SMEs will be as the following: The smart machines send signals to the AR mobile application notifying the need for maintenance or repair, and stating the required task to be done, for example, replace a certain part. These processes can be requested regularly or occasionally depending on the machine and the type of the process. This also allows the machine to take real-time sensor values into account, which might show an upcoming need for repair. Then, any worker can go to the machine and perform the task with the help of the AR application that will guide her/him through the whole process from start to end.

The maintenance and repair processes differs from one machine to another, which can be taken from the machine's technical description, user manuals, etc. These processes consist of many steps, and every step should be held differently and have different precautions that should be considered. Thus, we are dealing with varied types of machines, processes and steps. Which means that if an ad-hoc implementation solution is to be used, every process would have to be built from start to end from scratch, and the solution will be tailored just for a specific process with little possibility of reuse, in addition of not being time and cost efficient. Moreover, the employees creating the AR application need to have good technical programming skills, since they are going to build every process from start to finish, which will draw their attention from the contents and the process design to the underlying technology. (Geiger, et al., 2003)

Hence, there is a strong need for a rapid prototyping environment for rapid application development, to quickly design and test the AR application with the underlying processes for each machine.

Overview of the Authoring System

As shown before the main goal is to simplify the development process to allow content experts to create the application instead of requiring technology experts. For this a web application is being developed which will enable the author to create a prototype for the AR application. For this the author describes the steps in the repair or maintenance procedure. Each such step is composed of the displayed elements, their animations and so on. The logical flow from step to step is specified by simply connecting those steps and adding conditions, when to go into which following step. Technically this is then mapped to state machines; every process has a state machine that will be extracted at run time from the instruction set of the process, which was entered to the application by the author. The state machine represents the steps (states) that the worker should follow in order to do a certain task, and the events that may occur and change the flow of the execution. These events might be user events, like a button click, or a received signal from the smart machine. As the overall workflow includes a number of different software tools, the complete authoring solution can be described briefly with the following steps:

- Content Creation

Content creation is an important activities in developing an AR application. For that purpose, Autodesk Maya or Blender computer graphics software can be used for 3D modelling

ISSN 2256-0513, e-ISSN 2501-0263

and animation. Blender offers the ability to create add-on's using Python language (Blender, n.a.). Hence, an addon can be created to allow direct export of the contents created in Blender to the web application server. Likewise, Maya also offers a scripting language (MEL) which can be used to create an extension for the same purpose. The export function will include exporting static and animated contents (Paelke, et al., 2004).

- Application Logic Creation (State Machine Creation)

The flow of scenes in the AR application is sequential, the application executes from start, going from one state to another till it reaches the end. However, some events might occur that may change the flow of execution. Moreover, every process has different steps, where each can be affected by different events that will change the flow of execution in a different manner. Thus, every process has its unique attributes and workflow. A state machine performs actions in response to external events. The action, to be performed, depends both on the received event and on the internal state of the machine (Calsavara, 2003).

The content author enters the process to be held as an instruction set, which will be interpreted and converted to a state machine as an SCXML (State Chart XML) file, then parsers will be used to access the data of the created state machine file. Hence, each process will be designed automatically depending on the provided state machine (Paelke, et al., 2004).

- Composition (Linking Content and Logic)

There are many elements in the state machine; each state represents an AR scene, which consists of graphical contents that illustrate the specific step to be held in the form of animated 3D objects and other helping multimedia information. Events can also be represented by animated objects to notify the user. Hence, it is important to link each element of the state machine with the suitable corresponding graphical content.

Application are represented by actors based on the theatre model by Laurel (1991), they are classified to the following categories: (Geiger, et al., 2003)

- Real actors: they are the real world objects, they are created for the purpose of testing as an input for the AR application. The designer cannot control their geometry and behavior.
- Virtual actors: they are the virtual objects added to the real world in the AR application. Their geometry and behavior is controlled by the designer, and they must be referenced to a real world object, and they should be laid out in a way that insures the user's understanding of what should be done.
- Meta actors: they are visual or any multimedia information that is supplemented to the real world, but does not have a real world reference.

- Runtime Execution (incl. Tracking)

At this stage, we have the contents, and the design plan for the AR application. The runtime environment, in the form of an app for Android Phones and Tablets uses then a tracking system like the ARToolKit SDK to execute the formerly created logic and show the content, practically creating a new application. (Paelke, et al., 2004)

ARToolKit is an open source tracking library to create Augmented Reality applications, in which virtual objects overlay real world objects. Tracking is important in AR applications, which means to determine and follow the position and orientation of an object with respect to the user's viewpoint in order to know from which viewpoint to show the virtual objects. ARToolKit offers tracking libraries that makes developing an Augmented Reality application easier. The tracking libraries depends on real time comparison between the camera's position and orientation and the trackable (usually as a marker on the real-world object) position and orientation (HIT Lab Washington, n.a.).

Conclusions

In this paper we discussed the added value of creating augmented reality applications for maintenance and repair tasks within manufacturing SMEs. For this we presented a literature review and over view of the different involved aspects from a technical viewpoint as well as from an economical one. After an introduction to the InMachine project which provides the current context for this work, we presented the concept for an Authoring Environment enabling content experts to create AR maintenance and repair manual, instead of requiring in depth technical knowledge. To abstract the technical details from the author a number of different approaches is being used. While relying on established tools for creating the content itself, a mapping of step in a manual to State Machines was used to allow easy authoring of the application logic and at the same time efficient execution during runtime.

The next steps will be to complete the implementation of all shown concepts and conduct intensive tests with content creators from the InMachine project. This way a number of AR repair and maintenance manuals will be created, allowing to fine-tune the features of the runtime system (e.g. interaction techniques or tracking methods) but also to improve the authoring environment and finally verify the targeted efficiency in the authoring process.

Acknowledgements

This research is funded by the German Federal Ministry of Education and Research (BMBF) within the programme KMU-innovativ: Förderprojekt InMachine (grant agreement number for FH Dortmund: FKZ: 01IS15055A-F).

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ISSN 2256-0513, e-ISSN 2501-0263

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