Proceedings of the IETEC'13 Conference, Ho Chi Minh City, Vietnam.

Development of an Augmented Reality–Aided CNC Training Scenario

Ioan BONDREA
"Lucian Blaga" University of Sibiu, Sibiu, Romania
ioan.bondrea@ulbsibiu.ro

Radu PETRUSE
"Lucian Blaga" University of Sibiu, Sibiu, Romania
radu.petruse@ulbsibiu.ro

Carmen SIMION
"Lucian Blaga" University of Sibiu, Sibiu, Romania
carmen.simion@ulbsibiu.ro

ABSTRACT

We present in this paper an overview of the concepts and potential industrial Augmented Reality applications. We describe two AR scenarios designed to facilitate the assembly and quality assurance processes. Not only does this scenario assure the quality control process but also it displays, to the user, the assembly steps and nonconformities. We present the results regarding how this scenario is successfully tested on a FESTO assembly line. Also in this paper we briefly describe an AR–aided cutting tools management system.

The main part of the paper consists in the development of an AR–aided CNC training scenario performed on a DMC 635V 3 axis milling machine.

Keywords: *Augmented Reality, Industrial AR, CNC AR training*

INTRODUCTION

In recent years, one of the quickest ascending technologies is Augmented Reality (AR). Augmented reality is a technology which permits its user to see, hear, feel or even smell to a greater degree than those not using it. AR creates an environment where digital content is superimposed over a real world.

Like most technologies that eventually reach the mass market, augmented reality had been developed for more than half a century when Morton Heilig patented the Sensorama simulator, an electronic image, sound, vibrations and smell simulator. In the industrial field, AR was first used experimentally by Thomas P. Caudell in 1990 to improve Boeing's electric wire assembly process. Since then AR has become more and more popular, mainly due to the latest technological advances in mobile computers.

A survey conducted in 2010 by the German Research Centre for Artificial Intelligence revealed a spectacular rise for AR publicity, from 56% to 85% compared to a similar survey in 2007. Moreover 77.8% of the participants (industrial representatives) could envision the use of AR in their companies.

Industry analyst Tomi Ahonen recently stated that AR might be the 8th mass market to evolve, following print, recordings, cinema, radio, TV, the Internet and mobile technologies. It is also forecast that AR audiences may pass 1 billion users by 2020 (Figure 1).

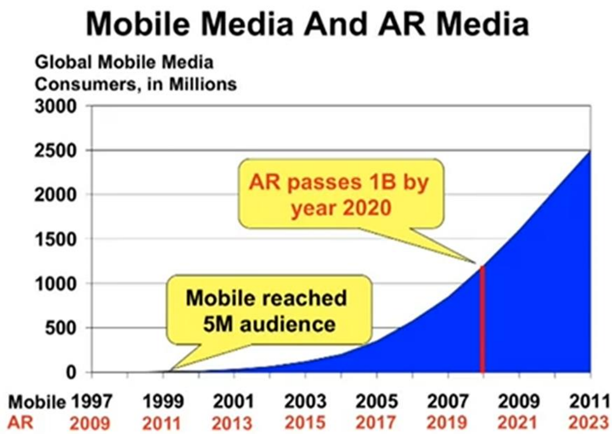

Figure 1: AR's audience evolution according to Tomi Ahonen
(Ahonen, 2013)

AR APPLICATION AREAS

Maturation of AR technologies, together with advances in hardware, influences AR applications in becoming more diverse. This statement is strengthened by Xiangyu Wang's 2012 study on augmented reality. This study was performed on 120 AR articles between 2005 and 2011 within the normative literature to provide a state of the art of AR implications and classification. As can be seen in Figure 2, this study disclosed an increase in AR interest and also a variation expansion of applications.

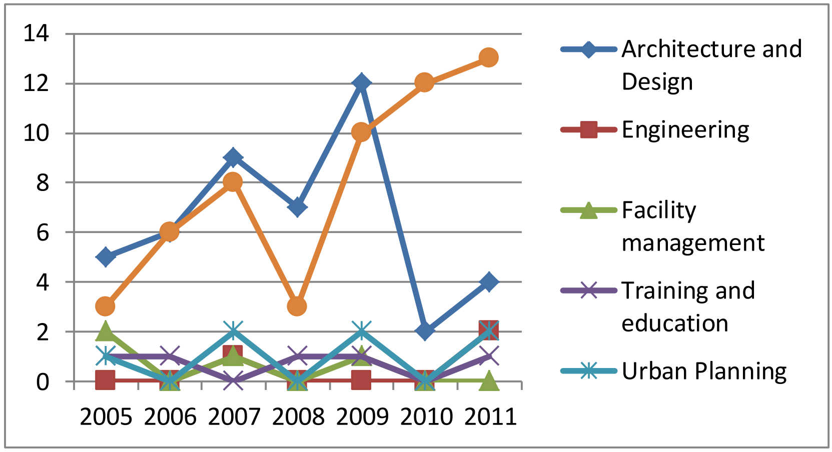

Figure 2: AR articles between 2005 and 2011 and their classification (Xiangyu Wang, 2013)

AR is currently applied in many domains such as: advertising, entertainment, education, medical purposes (image guided surgery), driving aids, military training, and it can also be used for industrial applications.

AR USED FOR INDUSTRIAL PURPOSES

Some of the most important scenarios in which AR technology can be applied, with great benefits, in the industrial field are:

- Training and worker support. Together with the development of augmented reality eyewear, which becomes more affordable day by day, AR worker support is one of the most tangible implementations. It can be used by untrained workers to realise complex maintenance or production development operations on which they would have required intensive training.
- Factory planning. AR can be used very efficiently to plan and simulate a factory layout, in real time and on the spot, from the positions of workplaces and machines to components manufacture and assembly logistics.
- Real-time production line monitoring. Using a tablet-PC or a smart phone the service technician can identify and receive real-time information regarding the current state of the production line, which includes, for example, the process configuration and machine parameters.
- Design review. With the aid of AR, production processes are improved because it delivers to the production engineer the chance to compare in real-time the 3D model with the manufacturing limits.

Our previous work consisted in demonstrating experimentally that AR can facilitate industrial development. For this purpose we have developed the following scenarios: AR applied in assembly design, AR used for quality assurance, AR used for cutting tools management and AR as an improvement for computer integrated manufacturing.

AR Applied in Assembly Design

Manual assembly is common in manufacturing processes where automation is not cost-effective, products are highly customised, or processes cannot be done by automatic machines. From this demand of manual assembly lines comes the need to educate workers for specific operations. At the present moment, there are very few industrial AR-based applications and there is little user feedback on AR utility. This is the main reason why we superimposed 3D models on a FESTO assembly line, to see how AR is perceived and how it can improve the assembly process.

We have also chosen an assembly task because it represents the majority of applications of AR in the industrial field, such as: equipment maintenance, worker training and plant layout planning. For each part of the assembled workpiece (Figure 3) we have assigned its corresponding virtual model, a *.wrl file as follows, created in CAD software. Because AR provides a step-by-step assembly model the worker can easily cope with the process (Bondrea, I., 2011).

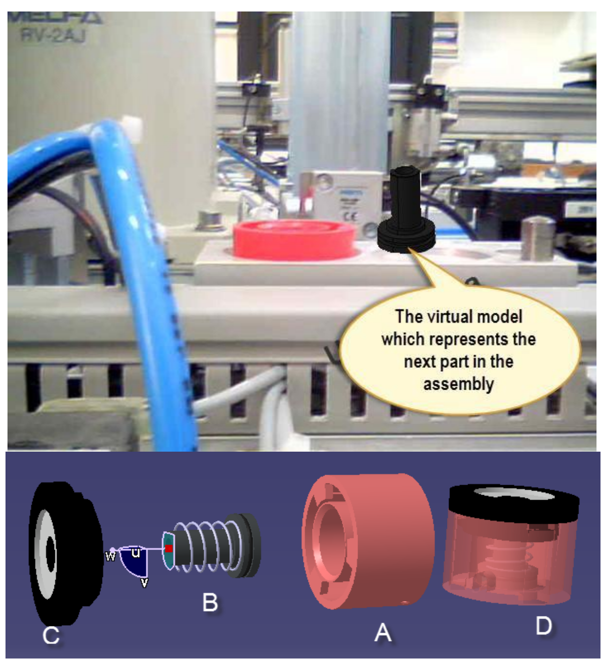

Figure 3: Assembly workpiece and 3D models

AR Used for Quality Assurance

The crucial factor for the successful use of AR is correct and accurate referencing to the real and virtual world. Because of the evolving markerless tracking methods that use image data from real environments, augmented reality can provide a fast and cost-efficient method for quality assurance operations. Using high-resolution image-capturing devices, the tracking system extracts characteristic features from the real environment such as points and edges (landmarks). These landmarks are compared to a digital model of the real environment which in our chase represents a conformable product in the quality assurance process. By checking the discrepancy between the landmarks and the digital model it is imposed a quality assurance operation.

The first QA analysis depends on the colour of the cylinder. Red- a message will appear suggesting that the part is accepted and it displays the piston (Figure 3 B), which is the next part that has to be added. If the cylinder is chromed a message will inform the worker that the part has an issue but is accepted, and if the cylinder is black an augmented message is displayed telling that the part is defective.

Using AR, information about the process result is superimposed over the live captured images, highlighting the actions that must be taken. For example, the user can be informed whenever the product is accepted or not and if it can be repaired or scrapped.

This application of AR can be very reliable if it is used in an unchanging environment with high-precision camera calibration almost excluding the possibility of PPM leaving toward the customer (Bondrea, I., 2012).

AR Applied in Cutting Tools Management

The very first step during an AR tool management implementation is to establish a database of cutting tools and to ensure communication between the computers and the personnel dealing with the tools. The cutting tools information stored in the database serves as the virtual content that is superimposed. The cutting tool data type can vary from plain text to complex CAD models depending on the user needs. Communication and access to certain tool data can be based on a QR code (Quick Response Code) unique for every cutting tool (Figure 4). But this solution is time consuming, and if the QR code is damaged it can be faulty.

Figure 4: QR code applied on a milling tool

Another solution for establishing communication between the cutting tool and the stored data is provided by the latest advances in AR technology – markerless tracking. This is based on recognising tools' distinctive characteristics such as edges, colours or serial numbers as landmarks. These landmarks are compared with real environment digital images obtained in real time by a capturing device (Figure 5).

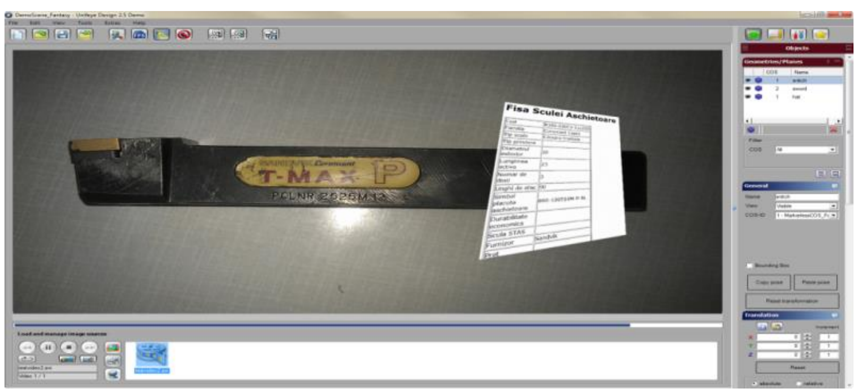

Figure 5: Markerless tools tracking using AR

This augmented reality application can be run on multiple platforms using different operating systems. This means it is a very practical solution and at the same time implementing it is cheap because the system requirements are low (Petruse, 2012).

AR–Aided CNC Training Scenario

Because there is a lack of results obtained from practical AR application and usage by untrained or new users, we have decided to create a simple CNC training scenario that can be tested by new users. During the development of this scenario we have to keep in mind that the targeted subjects have very little or no knowledge about how to operate a CNC machine.

The purpose of this scenario is to find out how AR is perceived by new users and in what manner it can be considered an improvement or a drawback compared to more traditional teaching methods like written instruction or computer assisted instructions. Completion time, number of mistakes (if any) and the degree of gained knowledge are the analysis criteria.

Our plan is to test the scenario, in a controlled environment, supervised by a professor, with final year students from the Faculty of Engineering. If the results are beneficial, as expected, we plan to apply the same scenario in a company, on untrained workers, in order to find out how different factors (age, environment, motivation, etc.) influence the subjects' results.

Technical Details

In order to be able to implement and use an AR–aided training scenario we had to solve the following technical elements:

A. Image source: 5Mpx Android Smartphone connected to the computer on which the AR software is running. The real-time image data transmission is done through Wi-Fi using the EpocCam software installed on both the computer and the Smartphone. Using EpocCam software, the Smartphone is recognised as a local usb–connected video camera.
B. Digital 3D models: The 3D models that are superimposed over the video image were created in CATIA V6 computer aided design software and exported as *.wrl files.
C. Tracking method: Even though the AR software (Metaio Engineer) is capable of markerless tracking, being in a controlled environment, for this scenario we have used a QR code as a marker tracking method. By using this tracking method the supervising professor has to change the augmented 3D model manually. Even though this is not the optimum approach, it is, however, the simplest to control and put into practice.
D. AR visualisation device: The user is able to visualise the overlaid virtual content through a tablet connected remotely to the computer on which the AR software is running.

Even though it has not been put in practice, because of the currently conceptual state, we will briefly describe the workflow for the first lesson of the AR–aided CNC training scenario – Measuring the Workpiece Coordinate System (Figure 6).

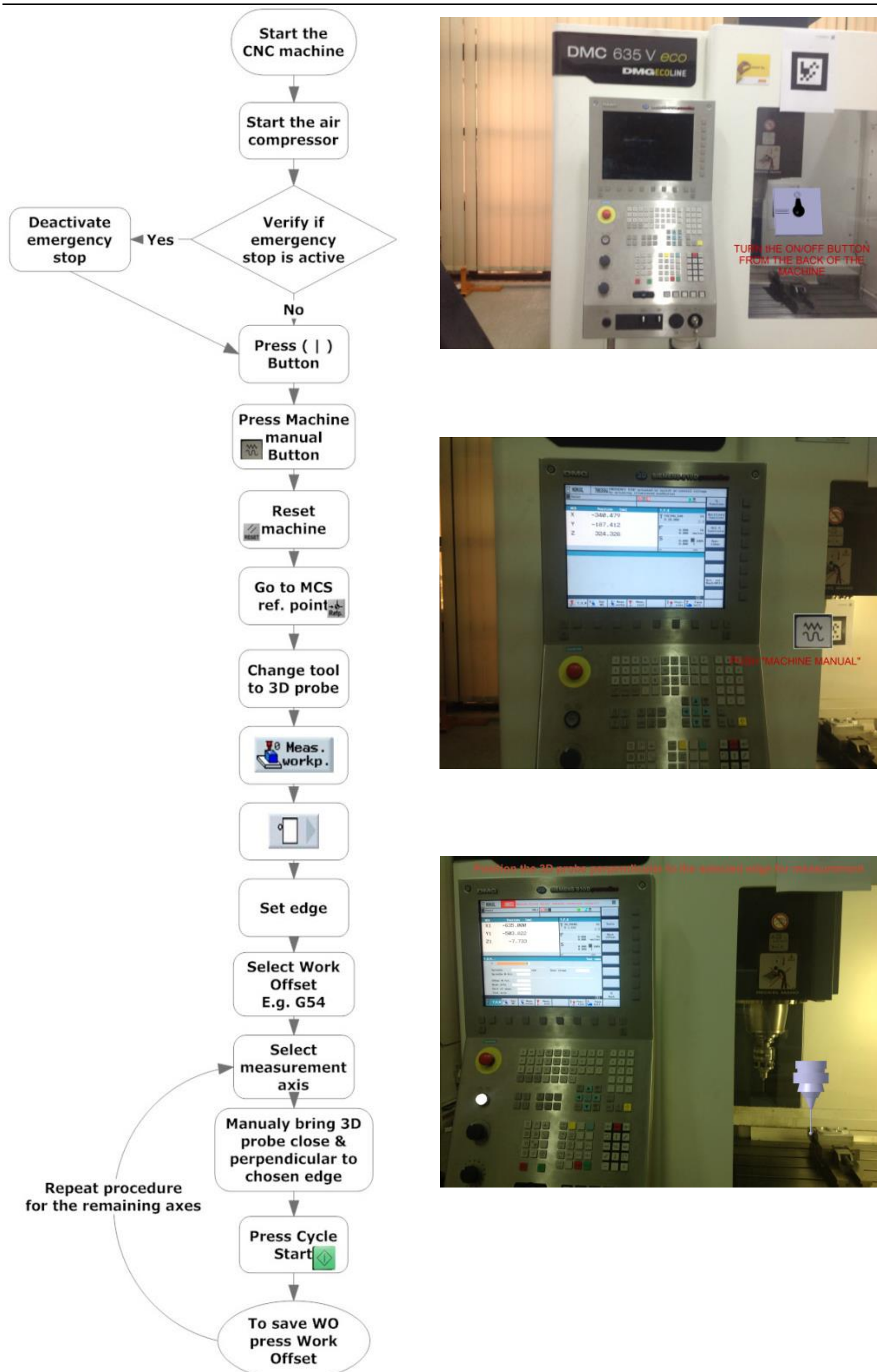

Figure 6: CNC AR training lesson's no. 1 workflow

CONCLUSION

AR can have vast industrial applications and, based on the experience we have gained when applying AR, we can confirm that this technology facilitates industrial development, even though it is still in a conceptual stage. Using AR, production times and costs can be lowered and at the same time with an improved quality. From our application we have determined that augmented reality can be implemented in both assembly and QA activities providing great benefits and lower costs in any scenario where the process offers distinctive recognisable landmarks.

Moreover, if further developed, AR has the potential to replace current tools management systems, providing a lower cost.

Further work is necessary to validate the AR–aided CNC training scenario.

REFERENCES

Ahonen, T. (2013). Augmented reality - the 8th mass medium. MongKok: TEDx.

Bondrea I., P. R. (2011). Augmented Reality Applied in Assembly Design. 10th *International MTeM Conference* (pp. 41-44). Cluj-Napoca: Technical University of Cluj-Napoca.

Bondrea, I., R. E. (2012). Augmented reality - An improvement for computer integrated manufacturing. *International Conference on Manufacturing Engineering and Technology for Manufacturing Growth*. San Diego.

Chih-Ming Chen, Y.-N. T. (2012). Interactive augmented reality system for enhancing library instruction in elementary schools. *Computers & Education*, 638-352.

Hung-Lin Ch, S.-C. K. (2013). Research trends and opportunities of augmented reality applications in architecture, engineering, and construction. Automation in Construction.

Petruse, R., B. D. (2012). Augmented reality applied in cutting tools management. ACTA Universitatis Cibiniensis.

Xiangyu Wang, M. J.-C. (2013). Augmented Reality in built environment: Classification and implications for future research. Automation in Construction.