

## AUGMENTED REALITY AS AN AID FOR THE USE OF MACHINE TOOLS

Jean-Rémy CHARDONNET<sup>1</sup>  
Guillaume FROMENTIN<sup>2</sup>  
José OUTEIRO<sup>3</sup>

---

### ABSTRACT:

*THIS ARTICLE PRESENTS A WORK IN PROGRESS OF USING AUGMENTED REALITY AS A WAY TO HELP HANDLING COMPUTER NUMERICAL CONTROL (CNC) MACHINE TOOLS. SEVERAL REASONS JUSTIFY THE USE OF AUGMENTED REALITY IN MACHINE TOOLS: (I) A HIGH COMPLEXITY OF USING SUCH MACHINES, ESPECIALLY FOR BEGINNERS; (II) LOW ERGONOMICS SINCE THE OPERATOR HAS TO MOVE CONTINUOUSLY BETWEEN THE MACHINE WINDOW AND A CONTROL SCREEN TO ENSURE SMOOTH OPERATIONS; (III) THE WINDOW IS OFTEN OBSTRUCTED BY THE LUBRICANT, THEREFORE THE OPERATOR MUST OFTEN RELY ONLY ON INFORMATION DISPLAYED BY THE CONTROL SCREEN; (IV) A NON-USER-FRIENDLY INTERFACE OF THE MACHINE; AND (V) A COMPLEX MAINTENANCE OPERATION.*

*IN THIS WORK, A PROTOTYPE OF A SYSTEM ALLOWING AN OPERATOR TO IMPROVE ITS WORKING CONDITIONS AND BETTER HANDLE CNC MACHINES USING AR DEVICES IS PROPOSED. THESE DEVICES ARE POSITIONED IN FRONT OF THE MACHINE, CONNECT TO IT AND DISPLAY REAL-TIME INFORMATION, SUCH AS THE OPERATING CONDITIONS AND A 3D REPRESENTATION OF THE CUTTING TOOL MOTION. A USER INTERFACE WAS ALSO DESIGNED TO MANAGE OPERATORS' PROFILES WITH CUSTOMIZED INFORMATION. THE SYSTEM WAS TESTED BY SEVERAL USERS WHO CONFIRMED ITS POTENTIALITIES TO ASSIST MACHINE OPERATORS IN THEIR WORK. OTHER POSSIBILITIES OF THIS SYSTEM ARE UNDER INVESTIGATION, SUCH AS A TRAINING TOOL FOR BEGINNERS AND A GUIDE FOR MACHINE MAINTENANCE.*

---

**KEY WORDS:** AUGMENTED REALITY, ERGONOMICS, MACHINING TOOL, INDUSTRY 4.0

### INTRODUCTION

Augmented reality (AR) has gained great interest over the last years, especially in industrial applications, due to cheaper devices and the large possibilities offered by this technology. Moreover, AR is one of the pillars of governmental programs in several countries such as “Industrie du Futur” in France, or “Industry 4.0” in Germany, to achieve high

---

<sup>1</sup> PhD, Associate Professor, Le2i, Arts et Métiers, CNRS, Univ. Bourgogne Franche-Comté, HeSam, Institut Image, Chalon-sur-Saône, France, jean-remy.chardonnet@ensam.eu.

<sup>2</sup> PhD, Full Professor, LABOMAP, Arts et Métiers, Univ. Bourgogne Franche-Comté, HeSam, Cluny, France.

<sup>3</sup> PhD, Associate Professor, LABOMAP, Arts et Métiers, Univ. Bourgogne Franche-Comté, HeSam, Cluny, France.

industrial productivity, thus accelerating the deployment of this technology in industrial applications.

In this regard, we present in this paper a work in progress of using this technology in the context of manufacturing with computer numerical control (CNC) machine tools. Issues are related to: (1) low ergonomics since the operator has to move continuously between the machine window and a control screen to ensure smooth operations; (2) the window is often obstructed by the lubricant, therefore the operator must often rely only on information displayed by the control screen; (3) a non-user-friendly interface of the machine, especially for beginners; and (4) a complex maintenance operation (figure 1).



Fig. 1. Issues related to current use of CNC machine tools

Still few examples of implementation in machining exist in the literature. In past work, several technologies were used to help operators better monitor manufacturing processes. Olwal et al.<sup>4</sup> presented an autostereoscopic see-through AR system based on two external projectors projecting on a holographic optical element mounted on the machine's window. Though this system provides high ergonomics for the operator, it however requires a heavy, expensive and specific setup and it is just used as a visualization tool (no interaction can be performed). Other systems used markers to track the position of the tools<sup>5</sup>, providing a low cost solution, but they were mostly used as a validation tool for machining simulation purposes, and not in real machining conditions. Computer vision algorithms were also

<sup>4</sup> Olwal, Alex; Gustafssonb, Jonny; Lindforsb, Christoffer; *Spatial augmented reality on industrial CNC-machines* (paper presented at the SPIE 2008 Electronic Imaging, Vol. 6804 (The Engineering Reality of Virtual Reality 2008), San Jose, CA, January 27-31, 2008)

<sup>5</sup> Pai, Yun Suen; Yap, Hwa Jen; Dawal, Siti Zawiah Md; Ramesh S.; Phoon, Sin Ye; *Virtual Planning, Control, and Machining for a Modular-Based Automated Factory Operation in an Augmented Reality Environment*, Scientific Reports 6, 2016; Kiswanto, G.; Ariansyah, D.; *Development of Augmented Reality (AR) for machining simulation of 3-axis CNC milling*, (paper presented at the 2013 International Conference on Advanced Computer Science and Information Systems (ICACSIS), Bali, 2013, pp. 143-148); Zhang, J; Ong, S. K.; Nee, A. Y. C.; *Development of an AR system achieving in situ machining simulation on a 3-axis CNC machine*, Comp. Anim. Virtual Worlds, 21 (2010), pp. 103-115; Petrusse, R. E.; Brîndașu, P. D.; *Augmented Reality Applied in Machining Processes and Cutting Tools Management*, Applied Mechanics and Materials, 693 (2014), pp. 279-284

considered to recognize specific parts of the tools<sup>6</sup>, but the major issue is occlusion problems, which is a typical issue in computer vision. A huge piece of literature explored possibilities to manage occlusions (see for example in<sup>7</sup> for an implementation in machining processes). Again, this past work shows its effectiveness only in machining simulation and not in real machining conditions.

We propose to use cheap portable devices to perform AR as an aid for the use of CNC machine tools, namely tablet PCs, AR glasses, as these systems are widely spread among society. These devices can connect to any machine tool without any specific setup, thus bringing to operators ease of use of our system. A user interface was designed to manage operators' profiles with customized displayed information, such as operating conditions and a 3D representation of the cutting tool motion.

## DESCRIPTION OF THE SYSTEM

### General architecture

Our system is based on the use of a portable device capable of performing augmented reality, i.e., with an embedded camera, such as tablet PCs, AR glasses, etc. Our system's architecture is summarized in figure 2.

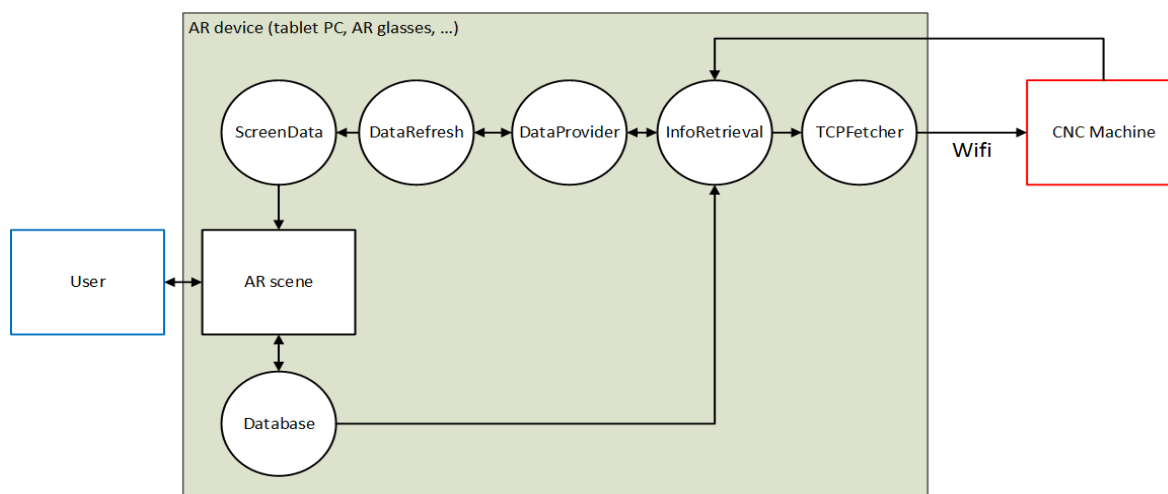


Fig. 2. General architecture of the system

The architecture is composed of different modules written in C# to communicate with the CNC machine and provide real-time information to users:

- TCPFetcher module is the connection module with the CNC machine. The device connects by Wifi through the TCP protocol.
- InfoRetrieval module asks the CNC machine information to be displayed to the user on the AR device. Information is requested every 200ms to avoid latencies in the system.
- DataProvider module gets and stocks the required information.
- DataRefresh module organizes the information to be displayed, depending on what the user wants to see.

<sup>6</sup> Ma, Z. Y.; Yang, G. Y.; Su, X. W.; *Research on Technologies of Augmented Reality for CNC Machining Process Simulation*, Key Engineering Materials 579-580 (2014), pp. 276-282

<sup>7</sup> Gheorghe, C.; Rizzotti, D.; Tièche, F.; Carrino, F.; Abou Khaled, O.; Mugellini, E.; *Occlusion Management in Augmented Reality Systems for Machine-Tools*, (paper presented at the International Conference on Virtual, Augmented and Mixed Reality (VAMR 2015), Los Angeles, CA, LNCS 9179, pp. 438–446)

- ScreenData module displays the data in AR scene, i.e., the information are rendered to the user.
- A database has been created to store user profiles and machines. This allows users to configure the system to display only information they want to see in a convenient and fast way.

Information to be displayed can be operating conditions, cutting speeds, tool position, cutting tool motion, potential collisions, forces, etc.

The AR scene is composed of a graphic user interface to navigate through menus and select profiles (figure 3), and the display of desired information on the real environment filmed by the embedded camera of the device. We used Unity3D to build the AR scene and the final application. The application is then installed in the device.

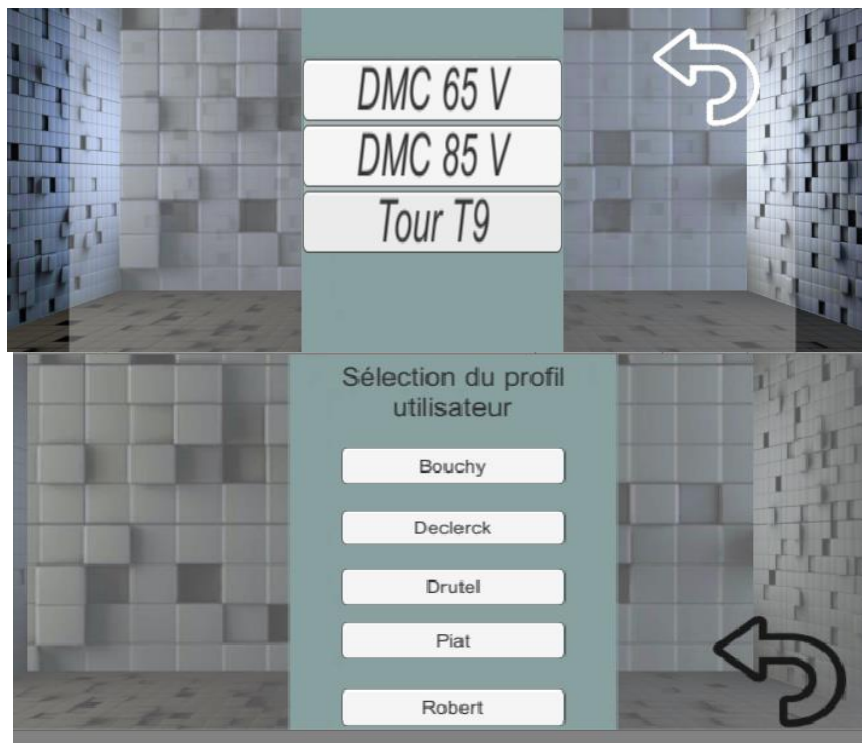


Fig. 3. User interface. Top: the user chooses the machine he wants to use. Bottom: the user selects his profile

### User manipulation

Here we considered just one use case where our system is used as an aid while operating the machine tool, i.e., while machining. Information that can be displayed for the moment is the cutting tool position and motion speed, and a 3D representation of the cutting tool motion (namely a 3D arrow).

The user first selects the machine tool he wants to use in the database then his profile. Note that he can also create a new profile in the database with customized parameters for the visualization of information. Then he places the AR device in front of the machine window. When starting a machining process, the user can see through the device the machine window with information from the machine tool (figure 4). To display the 3D representation of the cutting tool motion at the right position (the position of the arrow must match the one of the cutting tool), AR markers have to be placed on the machine tool to detect the position of the AR device with regard to the one of the cutting tool. Recognition is done using Vuforia SDK.



Fig. 4. AR system in operation (on the left: using a tablet PC; on the right: using AR glasses with a zoom on displayed information)

### FIRST USER TESTS

We made a pre-user test with 5 participants, all of them use machine tools regularly (several times per week) but none of them are familiar with AR systems. We asked them through interviews to evaluate the usability of the system (“did you find the system easy to use?”), in terms of software and hardware manipulation (“did you find the user interface easy to handle?”), ergonomics (“how did you feel with the devices?”) and utility (“do you find the system useful?”, “would you use it every time?”). They were able to give also free comments. To answer the questions, a 10-point Likert scale was provided. We proposed two different devices: a tablet PC, needing however to hold it all the time, and EPSON Moverio BT-200 AR glasses, allowing participants to keep their hands free for other tasks. Both devices ran Android OS. No indication on how to use the system was provided to participants, to check its ease of use. The machining process to be executed was basic milling between two positions without any work piece. The process was performed on a DMC 85V machine tool. Participants had to launch the AR application, select the right machine tool, ask for specific parameters to be displayed, such as the tool position and cutting speeds, and supervise the machining process over the AR system without looking at the machine-embedded control screen (figure 5). Interviews were done at the end of the machining process.



Fig. 5. A participant evaluating the application

From participants' answers, all of them were very interested in the system. They found it easy and practical to use. In terms of ergonomics, no significant difference was found between the tablet PC and AR glasses. Indeed, the tablet PC needs to be held all the time as mentioned above, depriving users of using their hands for other tasks, while AR glasses were considered a bit heavy on participants' head. Participants also pointed out that currently they probably would not use it every time since they are used to move continuously between the machine window and the control screen, and not yet with AR devices. Nevertheless, they told us it would be useful for learning purposes, e.g., for operators new to CNC machine tools, by getting views of the different parts of machine tools while discovering the tool, or by providing a tutorial on how to use the machine user interface for instance.

As free comments, participants reported to look forward to seeing further functionalities of the system.

### **CONCLUSION**

We presented a preliminary work on the utility of an AR system to provide aid for the use of complex machine tools. We used cheap and common devices capable of AR, and we aimed at being as generic as possible, not to be device nor machine dependent. First tests showed strong potentialities of our system.

Future work include the development of other use cases such as a training tool for beginners, a guide for machine maintenance, and deeper investigation will be done on ergonomics and interaction possibilities with the machine.



## REFERENCES

1. **Olwal, Alex; Gustafssonb, Jonny; Lindforsb, Christoffer;** *Spatial augmented reality on industrial CNC-machines* (paper presented at the SPIE 2008 Electronic Imaging, Vol. 6804 (The Engineering Reality of Virtual Reality 2008), San Jose, CA, January 27-31, 2008);
2. **Pai, Yun Suen; Yap, Hwa Jen; Dawal, Siti Zawiah Md; Ramesh S.; Phoon, Sin Ye;** *Virtual Planning, Control, and Machining for a Modular-Based Automated Factory Operation in an Augmented Reality Environment*, Scientific Reports 6, 2016;
3. **Kiswanto, G.; Ariansyah, D.;** *Development of Augmented Reality (AR) for machining simulation of 3-axis CNC milling*, (paper presented at the 2013 International Conference on Advanced Computer Science and Information Systems (ICACSIS), Bali, 2013, pp. 143-148);
4. **Zhang, J; Ong, S. K.; Nee, A. Y. C.;** *Development of an AR system achieving in situ machining simulation on a 3-axis CNC machine*, Comp. Anim. Virtual Worlds, 21 (2010), pp. 103–115;
5. **Petruse, R. E.; Brîndaşu, P. D.;** *Augmented Reality Applied in Machining Processes and Cutting Tools Management*, Applied Mechanics and Materials, 693 (2014), pp. 279-284;
6. **Ma, Z. Y.; Yang, G. Y.; Su, X. W.;** *Research on Technologies of Augmented Reality for CNC Machining Process Simulation*, Key Engineering Materials 579-580 (2014), pp. 276-282;
7. **Gheorghe, C.; Rizzotti, D.; Tièche, F.; Carrino, F.; Abou Khaled, O.; Mugellini, E.;** *Occlusion Management in Augmented Reality Systems for Machine-Tools*, (paper presented at the International Conference on Virtual, Augmented and Mixed Reality (VAMR 2015), Los Angeles, CA, LNCS 9179, pp. 438–446);