Title:
Augmented and Virtual Reality in Education for Young Students with Special Needs: A CNC Milling Machine Application.

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Introduction:

Augmented Reality (AR) is one of the major technology trends right now and it is going to increase much more in the next future. The main characteristic about AR is the possibility to see and interact with virtual objects while being always able to see the surrounding real world thanks to a dedicated device. This technology allows a totally new way of interaction, communication, and productivity. The aim of this paper is the development of an AR application for the Charly4U CNC milling machine that helps students and unskilled people to work and interact with the machine safely. Two configurations were studied: an Android based version running on an android device and a second solution running in a laptop device (desktop version).

Augmented Reality in Education

The main idea behind this project is the use of different and innovative technologies, such as AR and VR, to improve the learning procedure, especially for engineering students. It is known that the best way to understand a procedure, a task or an activity is to get a hand-on experience. In this case a CNC milling machine is needed to directly work on it and to understand the steps that must be followed to avoid any kind of problems both against the operator or the machine. Even if a CNC machines are present in the university on in the laboratory the students usually are not able to work with them or more probably fear the possibility of causing damages. Based on that, a supervisor, a professor, or a technician is needed to teach the undergraduate all the needed steps to work on that specific machine. These are the two main limits of today learning procedure about this complex mechanical apparatus: the

need of the device be it a turning lathe, a milling machine or whatever, and on the other hand a skilled operator must be present during the entire process both to teach as to control the machining process.

Augmented Reality in CNC machines:

Once analysed the research activities done in the context of VR and AR focusing on the educational use of the technology a further step in the state-of-the-art analyses will be related to applications that are very close to ours. So basically, in this section will be presented virtual reality or augmented reality applications that have both educational and industrial intent. Some papers were selected but it is important to highlight that not many applications have been found on institutional web portal about these topics. Five different papers will be presented, starting from a training-learning blast-furnace plant application up to a more specific turning lathe one. Vieira et al. [4] proposed a virtual reality model for a green ironmaking industrial unit, that is basically a typical charcoal mini-blast furnace (CMBF).

Minoufekr et al [3] proposed a communication framework to simulate CNC machine production through augmented reality using the Microsoft HoloLens. The work-piece that should be created on the CNC machine is first design with a CAD software, then the 3D model is converted in working steps and tool path in CAM environment. The G-code that has just been created contains all the necessary information for the machine to process the work piece.

Chardonnet et al [2] in September 2017 proposed an augmented reality work to help handling computer numerical control (CNC) machine tools.

App technical specification:

The steps that have been considered in order to develop our application are basically three, the first one involves Inventor, the 3D models, and the animations; the second one requires the use of 3ds MAX as a conversion platform and finally the use of Unity3D was needed to create the application. The general idea about the app is that it must guide the users during their work on the CNC machine and therefore it must contain all the technical information that they need. This knowledge was divided in two main menu, one related to the three-axes configuration of the machine and the second one for the four-axes layout. In fact, the Chary4U machine has this possibility. It has a 3-axes layout where the spindle can move horizontally (x direction) and vertically (z direction) while the basement can slide (y direction). In addition to these three movements, in the four-axes configuration the machine, with the present of a second spindle, is able to rotate the work piece around its axis, thus obtain the fourth moving direction. The overall application is therefore split in two different parts, with or without the four-axis, but the technical information is essentially the same. The app provides to the users all the steps that must be followed to setup and work on the machine from the power on to the emergency stop.

Basically, after the first scene highlighting the name of the project and its developing partners a second environment will show up where some information and numbers about the Charly4U CNC machine are given. There is basically information regarding the technical data about the machine, like dimensions or axes strokes and, on the other side, some information about the manufacturing company is reported. In addition, under the company logo a web link to the firm website is present. This is used to give a brief presentation about the CNC in terms of characteristics, dimensions, and performances. After this introduction phase the core of the application began with the 'New Machine Setup' scene. In this context the user has four different buttons to choose from: 'Before Starting'; '3 Axes Layout'; '4 Axes Layout'; and 'Once Finished'. Once clicked the 'Before Starting' button the initial procedure to power on the machine and to link it to the computer-based software will be shown. Figure 1 shows the Charly4U CNC millind device.

Fig. 1: The Charly4U CNC Milling Machine (from Mecanumeric).

Target Population:

It was decided to test the application with the ASPOC Onlus Lab students. ASPOC stands for Associazione per lo Sviluppo del Potenziale Cognitivo and it's a foundation that help teenagers with disabilities and problems in cognitive development (Down Syndrome, Autism, intellectual disability, etc). ASPOC was founded by the parents of these teenagers and its main purpose is the development of meaningful learning contexts to improve the adult's approach with the disable teenagers and to enhance the effort from all those who are closely related contacts [1]. In this context,the Virtual Reality and Augmented Reality Laboratory of Politecnico di Milano, Lecco Campus provides weekly lessons to the ASPOC teenager students that shows how technology could improve cognitive and motion skills in disable persons: CAD/CAM technology, 3D printing, augmented reality, virtual reality, are only some of the interesting technologies that are used in this scenario. Therefore, it was decided to test our AR application also with all the ASPOC team. Basically, the aim of this activity is different compare to engineering students' one, but for sure, also this experience can give very interesting result both for the application development as well as on the teenagers. Many of these children have problems related to hand gestures and therefore an Android application based of gesture touch input hat work with hands motion capture are very interesting examples on how technology can be used in this sense. Also in this case a usability test was used, to understand how they fells about using the application.

Considering now the ASPOC team, 13 students were tested. Basically, in this case to have a better learning outcome for the students it was decided to test the application first with the help of a projector guiding them to understand all the important aspects about the process and then, individually, the students had the possibility to play with the tablet version as well as with the windows desktop version. For a subjective point of view this activity was very interesting for all the scholars tested since they were really happy and interested in the applications. All the students were excited about the possibility to see and interact with a virtual entity that clearly is not a common activity.

User Interface Validation:

It was decided to use the System Usability Scale (SUS) invented by John Brooke in 1986. Before going further in the SUS characteristics is crucial to have a look of what is usability. It is impossible to define the usability of a system or a tool without defining the context in which it is used and the corresponding

Fig. 2: First interaction with the application thanks to a projector and then the ASPOC student can practice alone with the mobile device.

users. Generally speaking, it is possible to define different classes of usability measure: effectiveness, that is the ability to complete tasks using the defined system and the corresponding output quality; efficiency, that is the amount of resources used in the tasks activity; and satisfaction, that is a users' subjective reaction in using the system.

Before having a quick look at the tests results it is important to highlight the some of the students that have tested the application do not have problems related to the input gestures, indeed some of them were able to interact with the virtual model much quicker and better compared to the engineering students or the technical staff. After trying both the two applications all the students have completed the 10 questions. Converting the five-emoticons scale in numbers, it is possible to say that the average response score is above 4, that clearly shows a very good feedback about the two versions of the application. It is interesting to highlight question number nine that was asking about the ability to use the desktop device by themselves, basically, in this case the average answer was 3, clearly because the interaction method is much more complex compare to the tablet one. Everyone selects the highest mark thus showing their happiness about the activities done. This was the most important aspect.

Conclusions:

It has been proved that augmented reality can be used in different sectors, from educational to industrial one, allowing the user to interact with the environment in a completely new way. The proposed work is mainly focused on educational field, proposing an AR application that helps nonskilled people on working with a CNC milling machine. This was mainly done for students of ASPOC college at Politecnico di Milano, Lecco campus, where the Charly4U CNC machine is present. All the students have the possibility to use this machine to realise academic or non-academic projects, the problems comes where most of them are not able to work on that device or they fear the possibility of causing damages. In this context this application was developed, to help students on working on the machine in safety. The results obtained from the SUS tests are great, showing a good usability of the two configurations of the application.

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Table 1: SUS questionnaire results for Android based application. Mean values ranges from 0 to 4 and negatively worded items have been normalized. The system obtain 85.2 / 10

	Statement	Likert Scale (1:5)	Normal Mean (0:4)	Std. Dev.
1	I think that I would like to use this app frequently	4.45	3.45	0.93
2	I found the app unnecessarily complex	2.00	3.00	1.73
3	I thought the app was easy to use	4.73	3.73	0.65
4	I think that I would need the support of a technical person to be able to use this app	2.00	3.00	1.34
5	found the various functions in this app were well integrated	4.64	3.64	0.50
6	I thought there was too much inconsistency in this app	1.45	3.55	0.69
7	I would imagine that most people would learn to use this app very quickly	4.64	3.64	0.50
8	I found the system very cumbersome to use	1.91	3.09	1.45
9	I felt very confident using the app	4.73	3.73	0.47
10	I needed to learn a lot of things before I could get going with this app	1.73	3.27	1.10
	Total (Sum*2.5)		**85.20**	**17.8**

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