Augmented Reality CAD/CAM Training Application Version 2.0

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Abstract: - Analyzing the feedback obtained from our previous version of an augmented reality training application, we identified the weak points and found solutions to improve them. This paper presents a natural and intuitive way for manipulating and interacting with digital objects using technologies from video game consoles. Furthermore the newly developed AR application also provides other improvement such as an easily adaptable modular structure that requires minimum programing skills to obtain different AR training scenarios.

Key-Words: - Augmented Reality, 3D modelling, Training application, Bare-hand interaction

1 Introduction

Teaching CAD software can be difficult and it proves out to be almost impossible when students with a lack of spatial visualization skills and have to understand a technical drawing.

Because of this issue, we have developed an augmented reality aided 3D modelling application to verify the hypothesis that augmented reality (AR) can be used to improve students' spatial visualization skills. The application was based on two medium difficulty technical drawings, and it contained step by step instructions for 3D modelling in CAD software CATIA v5. These instructions consisted in a 3D model, superimposed wit AR over the technical drawing, for each step of the CAD modelling process [1]. This application was tested by 26 students, from the third year of study at the Faculty of Engineering, with positive results. To investigate the implications of this application, each student completed a survey.

Here are the students' answers on the most important questions:

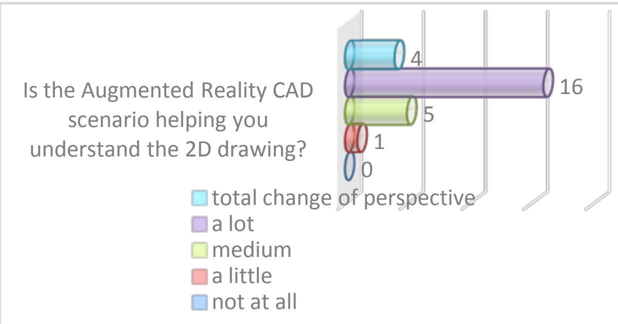

Fig. 1 Results for the question: "Is the Augmented Reality CAD training scenario helping you understand the 2D drawing?"

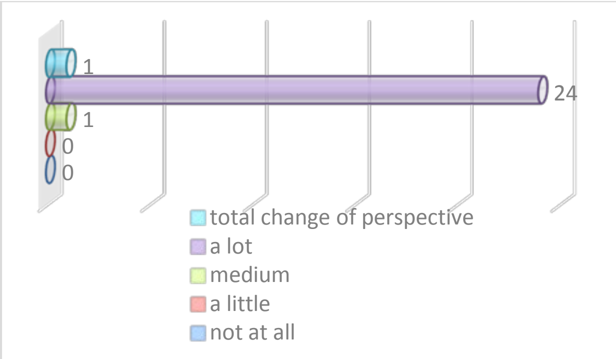

Fig. 2 Results for the question: "Is the Augmented Reality CAD scenario helping you understand the 3D modelling steps?"

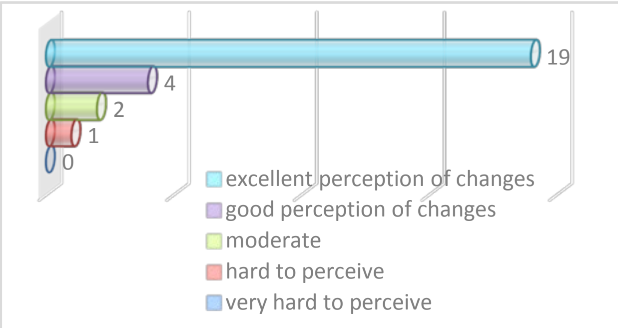

Fig. 3 Results for the question: "How do you perceive the differences, from one step to another, between the 3D models in the AR training scenarios?"

At the same time, another AR application consisting in instructions for machining processes was created. This application is meant to teach the students which is the right order of the CNC

machining steps and how to properly use the Catia V5 CAM- Prismatic module.
The results of this application were also encouraging, as it can be seen in the following chart.

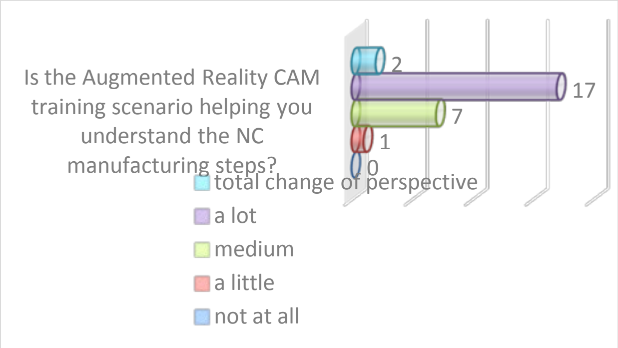

Fig. 4 Results for the question: “Is the Augmented Reality CAM training scenario helping you understand the NC manufacturing steps?”

Although we can consider the training application a success, from the feedback received and our observations during the test, we have identified some weak points. One of the most important disadvantages of our application was the way the user has to interact with the digital objects. On the main training application, all the interactions were keyboard based. The user had to press the [right] key to advance to the next step of the training scenario, with the [back] key it will go back a step, [1], [2] & [3] keys selects the desired instructions, [R] key will restart the scenario, [S] key stops the application, [P] pauses and freezes the superimposed 3D content and [Esc] exits full screen mode. Because of this way of interaction the only practical way to use the application was with a PC or a notebook, and even so the results for the question: “How do you find the interaction with the digital information?” tended to be mediocre.

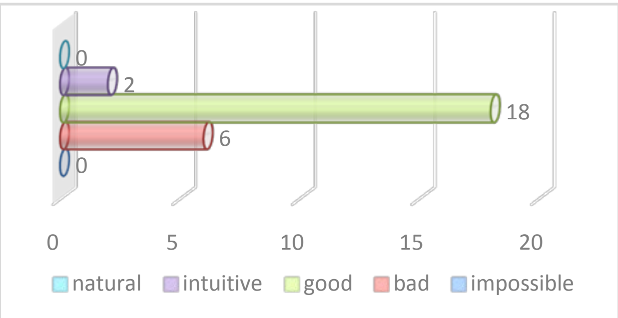

Fig. 5 Results for user interaction with digital objects

Another drawback that we have identified is that only one user can use this application simultaneously.

2 Version 2.0 AR application development

Because it doesn’t require any extra hardware resources we tried to solve the second issue and to develop the application so that it can be used by multiple users simultaneously. In order to obtain this we have added three markers that are tracked at the same time. One for the application instructions and the other two for each user.
However, this multi user option proved out to be very difficult to operate because both users had to interact with the digital content from the same keyboard. Also, the camera must be able to provide a wide enough angle, to avoid interferences between the two users, when they started to move the papers with the technical drawings and the AR markers.

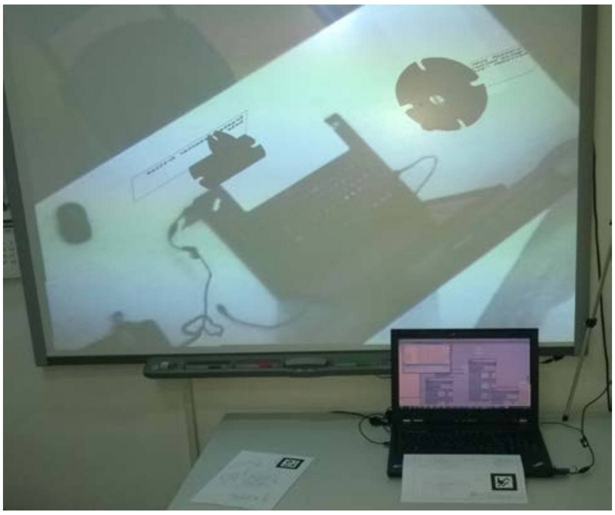

Fig. 6 AR training application modified for multi user use

The second issue that we have to solve involves the interaction between the user and the virtual environment.

In order to provide the most natural and intuitive user interaction we chose to use the Microsoft Kinect sensor.

This type of motion detection sensor was chosen because it enables users to interact with virtual objects only through body gestures.

The Kinect sensor is made up of an RGB camera, a depth sensor, an IR emitter, and a microphone array, which consists of several microphones for sound and voice recognition. The Kinect drivers and SDK, which are either from Microsoft or from third-party companies, can track and analyze advanced gestures and skeletons of multiple users making it possible to control applications with hands free user inputs. [2]

Kinect for Windows SDK enables the user to develop applications using C++, C# or Visual Basic programing languages [3].

A toolkit for the Kinect which perfectly suits all our needs to control the augmented reality has already been developed by Evan A. Suma from University of Southern California. The "Flexible Action and Articulated Skeleton Toolkit" (FAAST) facilitate integration of full-body control with our AR application [4]. We are using the FAAST to emulate keyboard inputs using body gestures.

In order to test the functionality of this application we have to emulate a minimum of 4 keyboard inputs, two inputs for each user. The keyboard inputs will enable the users to advance to the next step of the training application or to go back to the previous step.

The application was developed to be used by 2 users simultaneously from a maximum of 4. This constraint was applied to simplify the body gestures needed. To be as intuitive as possible only hand gestures were chosen. User 1 will use the right hand to control the virtual objects and user 2 will use the left hand. User 1 has to swipe with the right hand from left to right to go forward and from right to left to go back one step in the AR scenario. The same is applied to the second user, the only difference being that it uses the left hand. The hand gestures emulate "UP", "Down", "Left", "Right", keyboard keys.

Also a 2 seconds timeout was added after each recognized gesture to avoid the generating of involuntary commands if the user makes extra moves (fig. 7).

Because the users' gestures are only hand based, the FAAST is set to track only the upper part of the body thereby permitting a sitting position. Based on empirical studies the optimal hand gesture velocity in order to be considered natural was set to 5 m/s.

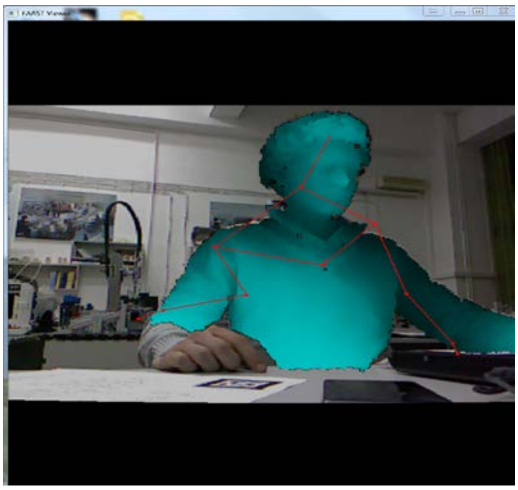

Fig.7 FAAST body gestures tracking using Kinect sensor

Because the application uses a database with many training scenarios, so that they won't be all activated at once, the models that are superimposed over the markers have to be activated first from the keyboard (fig. 8). This is a preventive measure to lower the computer hardware requirements.

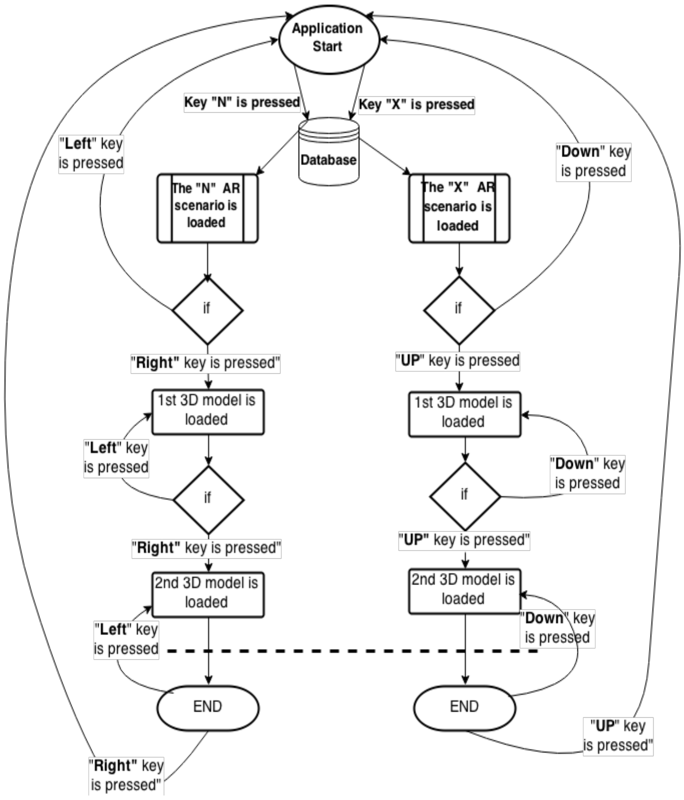

Fig. 8 AR aplication workflow

2.1 The use of a modular structure

The application's workflow is constructed as a modular structure that can be easily adapted to different AR scenarios.

We have created different modules depending on how many steps the AR scenario has to have. The smallest module contains 6 AR instructional steps and it is currently used to provide 3D modelling instructions for a simple part in Catia software. Currently the largest module contains 30 instructional AR steps, used for assembly instructions.

Each individual module has its own AR marker, in order to be able to superimpose the right virtual content.

Depending on the required AR scenario these modules can be easily combined to provide a complex AR application. Because the programing language is XML based, it is very easy to combine different modules using an XML editor tool.

In order to be able to easily replace the 3D models that are superimposed in an AR module they are code named as follows: “M6p1” M6= module 6 which based on a legend it tells the number of steps, p1= 1st 3D model from that scenario. The only differences between the modules are the number of steps and the 3D models’ codes.

For example, if it is needed an AR training application that consist in:

- 3D modelling instruction for one part with 15 AR steps,
- CAM instructions for CNC machining of a part with 20 AR steps,
- Assembly instructions for a product with 30 AR steps,

The following modules will be used:

- module 15 (M15) with 15 different 3D models, one for each step (p1 to 15)
- module 20 (M20) with 20 different 3D models
- module 30 (M30) with 30 different 3D models

All three modules are combined in an XML editor and the output is the required AR training application.

The maximum amount of modules that can be combined depends only on the hardware characteristics of the computer from which the application is running.

The resources for each module (3D models) are stored in the designated location inside the database codenamed accordingly. For example, module 15 has resources codenamed M15p1 to M15p15 which are superimposed over the AR marker no. 15.

2.2 Benefits

The AR instructions are much easier to understand that classic instructions. Also the AR application provides a massive improvement for students which lack the spatial visualisation skills. When questioned about how useful are AR instructions compared to printed instructions the majority of students replied “much more useful” (fig. 9)

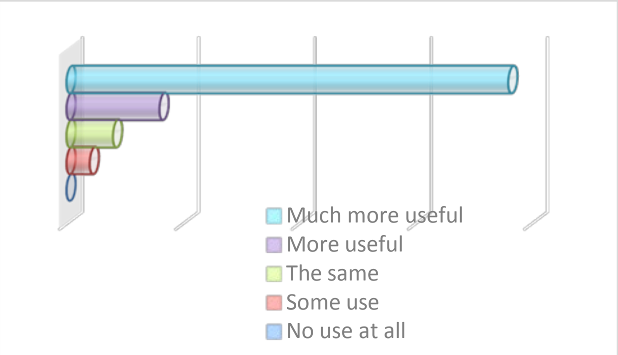

Fig. 9 Answers on how useful AR instructions are

An unsuspected benefit came by providing a familiar technology (the Kinect comes from video game consoles) to be used in a completely different way than the students were used to. This lead to a rise of interest in learning.

The rise of interest has been observed not only in students that were using the AR training application but also in their colleagues which only heard about the application.

Another benefit is that the problem solving times were considerably improved when students used AR instructions

3 Conclusion

The Augmented Reality CAD/CAM Training Application Version 2.0 proved to be a total success among students, providing great benefits. With this application we also proved that AR has the potential to replace current training tools such as printed instructions.

We believe that with minimum modifications, this application can and will be used to provide training services in other fields than CAD/CAM.

Future developments of this application involves shifting to the industrial field. This application can easily provide maintenance or assembly instructions in an industrial environment.

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