35th INTERNATIONAL CONFERENCE ON PRODUCTION ENGINEERING

KRALJEVO - KOPAONIK

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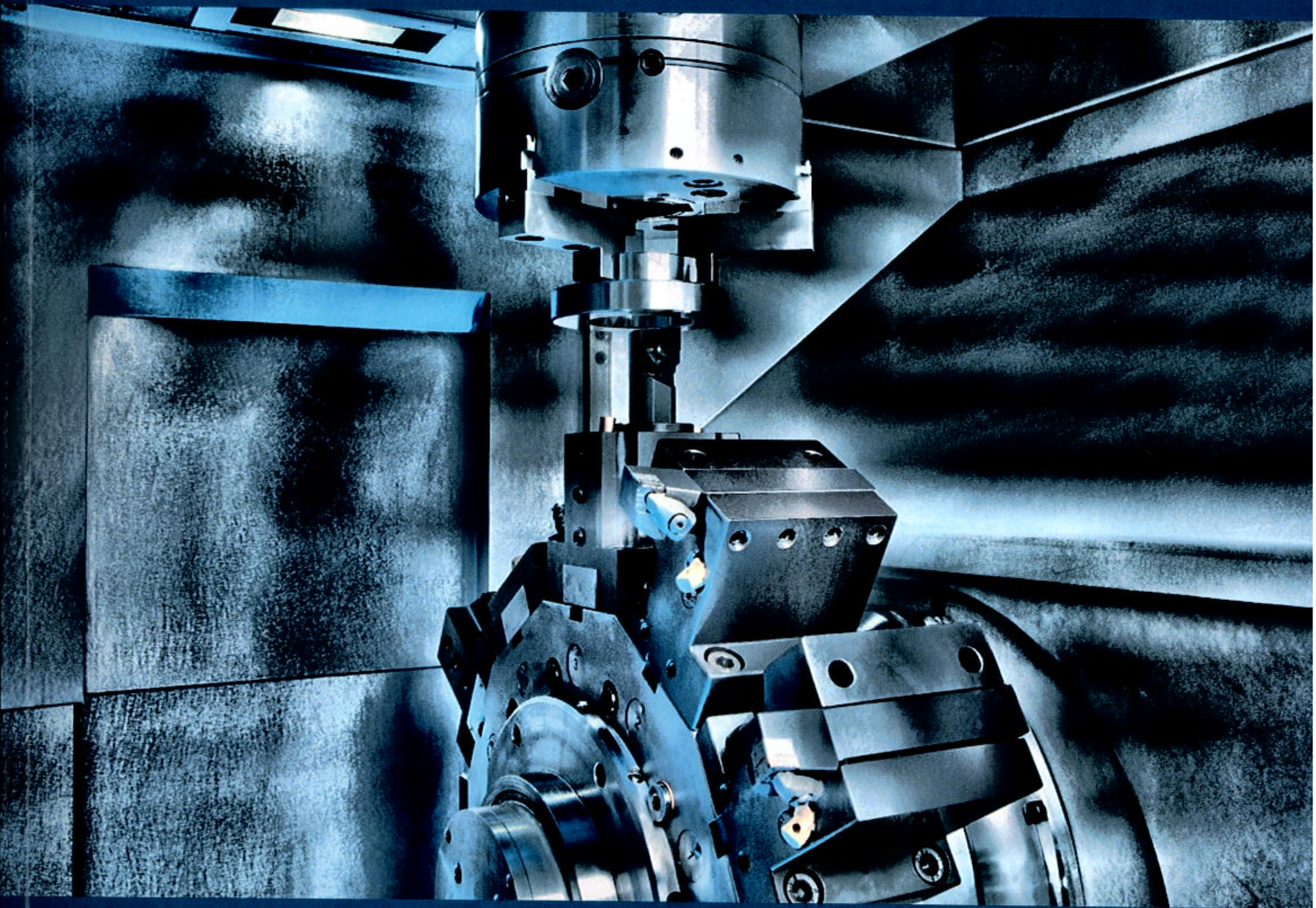

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AN INTERACTIVE AUGMENTED REALITY PLATFORM FOR CAD EDUCATION

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Abstract: *Current instruction methods of teaching CAD/CAM technologies rely heavily on traditional pedagogical techniques such as in-class and in-lab instruction and coursework. Augmented Reality (AR) technology to support learning activities becomes a trend in education and AR-based methods are proven to be effective teaching aids for engineering courses. This paper presents initial results of a project aimed to transform the current learning process of CAD/CAM by designing and implementing an interactive AR learning tool to help students to develop a comprehensive understanding of features, models, spaces and processes. A webcam or smart phone recognizes the AR marker information on the page of a CAD/CAM teaching book, generates real-time three-dimensional objects and superimposes them in the camera image. Generally, we present a platform that uses AR as a medium for teaching and representation of digital 3D geometry and a process to facilitate CAD/CAM education. This AR platform should enable a faster comprehension of complex spatial problems and 2D relationships, from which the students and engineers will benefit greatly during their learning processes.*

Key words: *Augmented Reality, Android & Desktop Platforms, CAD/CAM, Education.*

1. INTRODUCTION

Augmented reality (AR) technology is widely used to exploit computer algorithms to draw the virtual objects in a real space, fusing the virtual 3D objects or animations in real-life scenes (Figure 1). The rapid development of AR applications has contributed to its wide applications in advertising, engineering, medicine and etc. With augmented reality, CAD instructors can bring to real environment, virtual 3D elements or animations [1]. Commercial CAD/CAM software offers an overwhelming variety of complex features, models and processes in multimodular product development [2].

This article introduces the applications of AR technology in practical CAD/CAM education, and will discuss the significance of AR based learning. The core of this interactive system consists of video image processing techniques and interactive 3D model visualization.

1.1. Augmented Reality

Augmented Reality in general is the concept of enhancing the real world with additional virtual information. One of the most commonly used definitions of Augmented Reality was given by Ron Azuma [3]. Independent of specific technologies, an Augmented Reality system has to meet the following requirements:

1. Combine real and virtual worlds,
2. Augmentations are interactive in real time,
3. Augmentations are registered in 3D to the real world.

In recent years smart phones and tablets became an increasingly popular device for Augmented Reality. These combine all needed components (camera, display and processing power) for video based Augmented Reality in a small form factor.

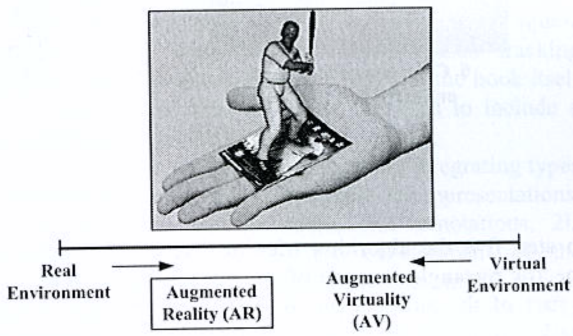

Fig. 1. Simplified representation of the Reality-Virtuality Continuum

For this reason and the fact that smart phones and tablets became widespread devices we choose to build our system as a video based Augmented Reality system for Android devices.

2. SYSTEM ARCHITECTURE

To fulfill the requirements for an augmented reality system, the foundation is to estimate the position and orientation of the camera in respect to the world or vice versa. The combination of a position and an orientation is called a pose. To do this we employ a technique called marker tracking.

2.1. Marker tracker

Marker tracking makes use of the camera image to find optical square markers and estimate their pose relative to the camera. A square marker consists of a black square with a white border. Within the square the ID of the marker is encoded. Different techniques can be used to encode the ID like template matching or the encoding as a binary number as in our case. The marker tracking pipeline is illustrated in Figure 2.
In the first step the image from the camera is converted to a gray scale image to speed up the image processing in all further steps.
Since the square markers are only black and white we can threshold the gray image in the second step to generate a binary image. This will remove noise and most of the environment from the image, which again allows a much faster processing for the next step.
The third step consists of using the binary find of all contours that are left in the binary image. Of these contours only contours with exactly four corners are selected as potential square markers for the following steps.
Using the corner positions of the rectangles from the previous step and the gray image the forth step consists of refining the corner positions of the rectangles to sub-pixel accuracy. This is realized by sampling the edges along each side of the rectangle and using this data to fit a line along each side. By calculating the intersection points of these lines the algorithm obtains the sub-pixel accurate position of the corners.

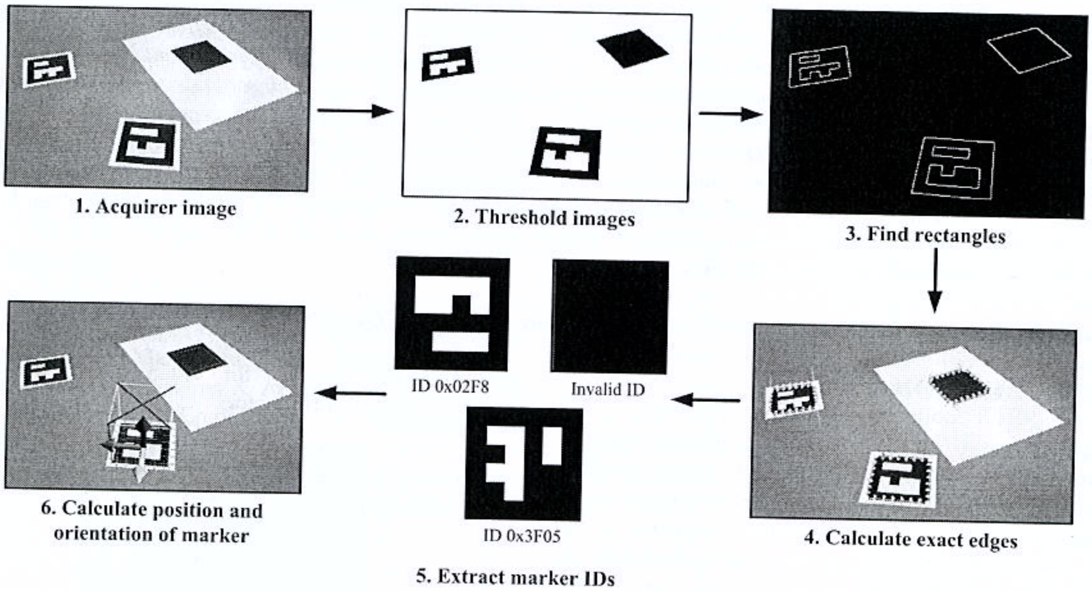

Fig. 2. Marker tracker pipeline

In step five the algorithm tries to determine whether a specific rectangle is a part of an optical square marker or a part of the environment by extracting the ID of the marker from the gray image. If a valid ID was detected then that rectangle is further processed. The ID of the square marker has the requirement to be rotation invariant. This property is needed to determine the order of the corner points, which in turn is needed to estimate the orientation of the square marker. Once a rectangle with a valid ID has been identified, the 2D corner positions from step 4 and the predefined size of the square marker are used to estimate its pose. Now we have all we need to fulfill the three requirements for an augmented reality system. By using the camera image as the background (real world) in our display and using the pose of the marker we now can superimpose the camera image with and virtual object (virtual world) as seen in figure 2. When the marker or camera is moved the augmentation stays on the marker (registered in 3D). The marker tracking pipeline is computationally inexpensive, so we can keep all interactions with the virtual objects in real time.

2.2. MagicBook

The concept of an Augmented Reality MagicBook was firstly introduced in 1997 [4]. The basic principle is that a real book is enhanced using Augmented Reality. Virtual objects are superimposed on the different pages of the book in the Augmented Reality mode. If the user is interested in a specific scene, he or she can fly into the scene by switching to the Virtual Reality mode and inspect it from the inside. This concept also included multi-scale collaboration, which enables multiple users to experience the same virtual environment. For our system we omitted the Virtual Reality mode as it is impractical for our application. We still have support for collaboration, as several users can see the same virtual model on the book page.

2.3. System description

Our system is composed of a tracking framework to provide the necessary tracking data and a game engine for rendering the virtual models and interaction with the augmentations.

As the tracking framework we are using UbiTrack1. UbiTrack is an open source, general purpose tracking framework for Augmented Reality developed by the „Group of Augmented Reality" group of the Technical University of Munich, published under the LGPL license. The greatest advantage of the UbiTrack Framework is the use of so called "Spatial Relationship Patterns" [5]. This leads to a component based design, which allows the easy replacement of specific hardware drivers and tracking methods, as well as a less error prone way to develop and setup more complex Augmented Reality systems. UbiTrack has been successfully ported to Microsoft Windows, Linux, Mac OS and Android.

Using a game engine for the visualization and interaction has the advantage that all the necessary groundwork for generating user interfaces, displaying 3D models, as well as an interaction pipeline for the virtual world are already build in. We can make use of high level functions like real time shadows, particle systems or physics simulations without the need to implement them. For the game engine we are using Unity3D2 for the ease of use and its platform independency. This allows us to deploy our application to all desktop systems and Android devices without any need to change the source code of the application.

3. APPLICATION

Our application basically works like the video based augmented reality system as seen in Figure 3. Each page of the tutorial book has an embedded unique square marker associated with the CAD model.

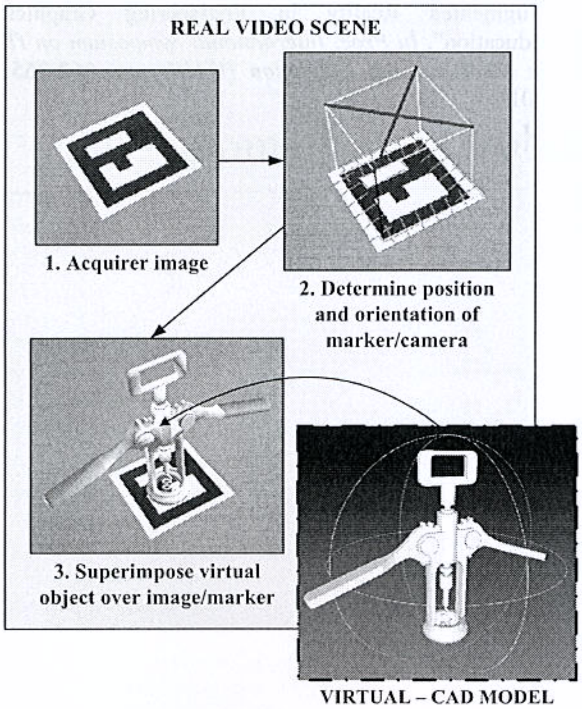

Fig. 3. Video based Augmented Reality

[1] www.ubitrack.org

[2]http://www.unity3d.com

Employing desktop version of developed AR platform or a Smartphone equipped with a camera, students are able to go through the exercises themselves. Focusing the camera on the markers retrieve the virtual 3D objects from database and the information and graphics are then overlaid onto the screen (Figure 4).

By recognizing the ID of the square-sized marker, the application determines which CAD model to display. The interaction with the CAD model is handled by single touch rotation gestures on the touch-screen of the device or by mouse inputs in case of the desktop application (Figure 4). The 3D model database is created using educational PLM system CATIA3.

Students can turn the pages of a tutorial, look at the problem inside the book, and finish their exercise much the way they are reading and drawing on a paper sheet [6]. The virtual models superimposed upon the real page will serve as the tip for imagining the relationship between the 3D geometry and their 2D projection.

4. CONCLUSIONS AND FUTURE WORK

The augmented reality technology can be used as a new tool to support of the teaching activities and to enhance the traditional learning experience. It emphasizes the perception of students and offers information that is not perceived directly by the use of their own senses. Besides understanding the relationship between 3D objects and their 2D representations, projections, AR Magic CAD Book aims at comprehending geometric relationships of reference lines, sides, planes, angles, developing their ability to make sense of visual information, and motivating logical thinking and cultivating logical skills.

In the future we plan to replace the standard square marker tracker with a texture/image based tracking system. This will allow using the pages of the book itself to be the marker, thus removing the need to include a specific marker on the page.

Such models can be further enhanced by integrating types of information other than just simple 3D representations. These types can include audio, text annotations, 2D images, and diagrams. As the development of the UbiTrack framework continues, we can make use of future ports of UbiTrack framework to other operating systems, e.g. Apple iOS and Windows Phone to support these devices.

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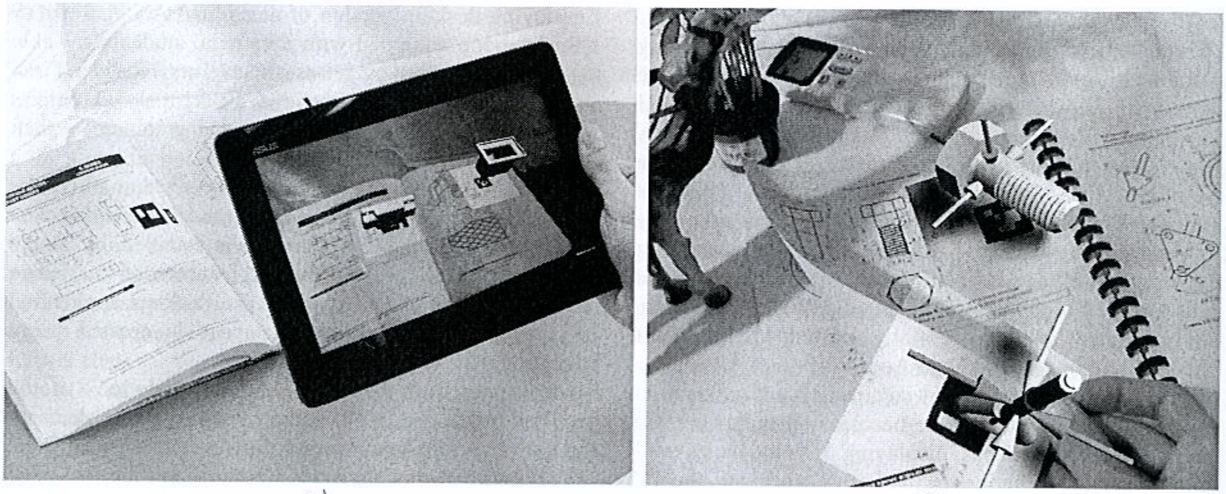
[3] www.3ds.com



a) b)

Fig. 4. CAD MagicBook Application – a) Android version and b) Desktop platform

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