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A new AR authoring tool using depth maps for industrial procedures

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ABSTRACT

Several augmented reality systems have been proposed for different target fields such as medical, cultural heritage and military. However, most of the current AR authoring tools are actually programming interfaces that are exclusively suitable for programmers. In this paper, we propose an AR authoring tool which provides advanced visual effect, such as occlusion or media contents. This tool allows non-programming users to develop low-cost AR applications, specially oriented to on-site assembly and maintenance/repair tasks. A new 3D edition interface is proposed, using photos and Kinect depth information to improve 3D scenes composition. In order to validate our AR authoring tool, two evaluations have been performed, to test the authoring process and the task execution using AR. The evaluation results show that overlaying 3D instructions on the actual work pieces reduces the error rate for an assembly task by more than a 75%, particularly diminishing cumulative errors common in sequential procedures. Also, the results show how the new edition interface proposed, improves the 3D authoring process making possible create more accurate AR scenarios and 70% faster.

1. Introduction

Augmented reality (AR) systems have been widely used in numerous applications such as medical procedures [11], automotive and aerospace design [27], maintenance tasks [14], or cultural applications [34]. The term augmented reality (AR) defines computer graphic procedures or applications where the real-world view is superimposed by computer-generated objects in real-time [2].

One of the major problems in the development of an AR application is the creation of content, due to the lack of appropriate tools for developing 3D images with depth perception. There are popular software libraries like ARToolKit [17] and ARToolKitPlus [36] that use OpenGL, VRML or OpenSceneGraph [5] to represent the 3D models on the real images in real time. However, the use of these and others computer graphics libraries requires programming skills to generate AR applications, and every AR development should be constructed from the scratch.

In order to avoid these problems, AR authoring tools were proposed a decade ago [26,12,33,19]. The main advantage of AR authoring tools is that they do not rely on time and cost consuming recompilation steps, and therefore the changes and enhancements in the development of AR systems are fast and efficiently completed. Different authoring tools have been developed during last years. By order chronological order, we can cite some representative examples, like the work by MacIntyre et al. [21], that consists of a software plug-in built on top of Macromedia Adobe Director, and it allows to author AR content for this widely used multimedia development environment. Another examples are an extensible and general-purpose AR authoring platform based on XML descriptions, proposed by Ledermann and Schmalstieg [20], or STUDIERSTUBE Framework, another proposal for the prototyping of AR applications developed by Schmalstieg [28]. Even a well-known visual programming environment (ECT graphical programming tool) was modified to add support for AR input by Hampshire et al. [10]. Later, an extensible authoring tool that supports both scripting and a drag and drop interface and real time interpreted input was developed by Seichter et al. [31]. A recent work even classifies the existing AR tools depending on the use of high or low level libraries, and the programming knowledge required for using these tools [37].

Assembly, maintenance and even repair tasks are some of the direct application fields of AR tools, and a lot of proposals have been made in these industrial areas [22,38,9]. However, most of the proposed AR systems have been specifically developed for enhancing certain procedures in the domain of the problem. The development of augmented reality systems usually involves two key design issues: the decision of implementing a mobile or a non-mobile system [9,29], and the choice of selecting a

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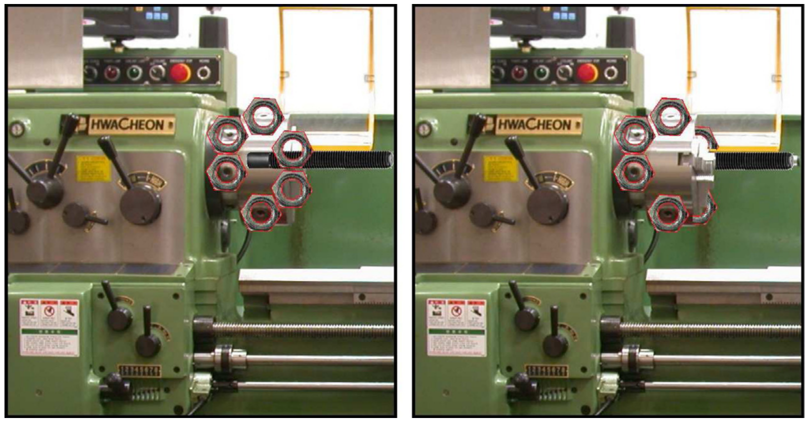

Fig. 1. An example of the occlusion problem in an AR system for industrial maintenance purposes.

helmet-mounted or a hand-held display systems as AR visualization device [38]. Although several AR systems have been proposed for industrial purposes, most of them superimpose the computer-generated objects on the real view of qualified workers. This forced superposition cause the occlusion problem, which occurs in AR systems when a computer-generated object closer to the viewer obscures the view of real elements further away along the line-of-sight [4]. If the occlusion problem is not properly addressed in the development of an AR system for industrial purposes, then the developed tool does not significantly facilitate workers their actual on-the-job tasks. This fact is especially evident in the development of AR systems for assembly or repair/maintenance purposes, because of the cluttered backgrounds and the frequent occlusions in these types of industrial environments [25].

Fig. 1 shows an example of the occlusion problem. Concretely, it shows a custom AR system that has been used for the on-site repair process of a CNC (computer numerical control) lathe located in a machine-parts factory. The pictures included in this figure show the step when the sliding headstock is taken off by releasing a fixing stud and six protective nut caps. The left picture in this figure shows how non-occluded 3D computer-generated stud and nut caps (intentionally modeled using eye-catching black and red colors) are visualized over the headstock of the CNC lathe, showing a misleading final location of the elements. On the contrary, the right picture of the same figure shows how this augmented stud and the two nut caps have been correctly occluded by the real objects in the foreground of the scene, indicating the proper location of their positions within the back side of the CNC lathe.

In this paper, we propose an easy-to-use AR authoring tool oriented to the development of AR applications for the execution of industrial sequential procedures. The main contribution of this tool is that it allows non-programming users to develop low-cost AR applications, including occlusion capabilities, in a timely manner (by means of the use of a Kinect sensor [15,16,39]). A new edition interface, using real world photos as templates while 3D modeling, is introduced. These templates, denoted as scenarios, are easily created using a wizard from 2 different sources: a common photo (2D scenario) or an image captured using a Microsoft Kinect device (3D scenario).

The rest of the paper is organized as follows: Section 2 describes in detail the proposed AR authoring tool. Next, Section 3 shows different application examples of the proposed tool, and Section 4 shows the performance evaluation of AR instructions in an assembly task using the proposed tool. Finally, Section 5 shows some concluding remarks and the future work to be done.

2. An overview of SUGAR

SUGAR (which stands for **S**ystem for the development of **U**nexpensive and **G**raphical **A**ugmented **R**eality application) is an open-source software platform designed to enable a rapid prototyping of low-cost AR systems. Our framework is oriented to develop complex AR software applications based on procedural simulations, which are modeled following an easy-to-use AR authoring editor. This AR editor generates an exchange file, describing the AR procedure, which can be loaded into different AR devices not requiring high computational power.

Fig. 2 shows the workflow for the development of AR applications using SUGAR. The SUGAR editor allows users with non-programming skills the creation of augmented reality procedures based on steps. The main challenge when creating an augmented reality application is to achieve a correct overlap (registration) between the real-virtual world and the virtual information that is added on the real world. For tracking purposes, two kinds of planar markers (ARToolKitPlus or Vuforia) can be generated with a simple calibration step. The first markers consisting on square black and white fiducial ARToolKitPlus markers that the users must print and paste on the real object within the industrial environments. The second markers, based on Vuforia natural markers, are able to track planar surfaces of the real object and, thus, no additional items must be placed within the actual environment.

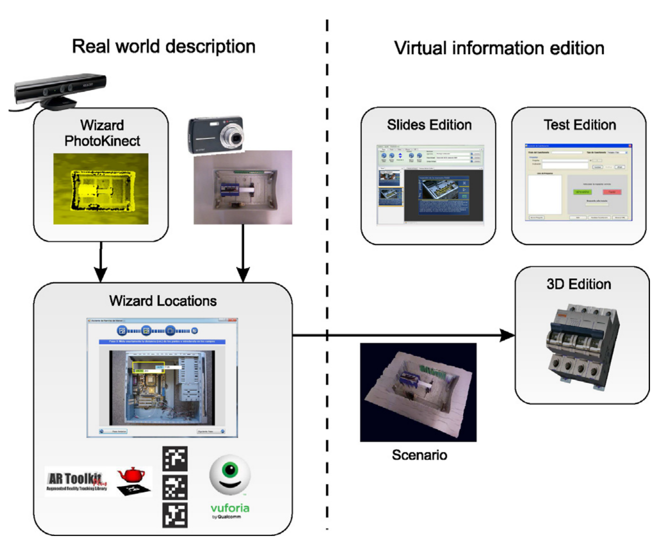

Fig. 2. Proposed workflow for the development of AR applications using SUGAR.