AN INNOVATIVE APPROACH TO TEACHING MECHANISM USING AUGMENTED REALITY TECHNOLOGIES

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Abstract: This paper presents a markerless AR book for teaching in enjoyable way mechanisms in mechanical engineering courses. The main idea is to provide to the student real time information on mechanism structure and kinematics by mixing images from the real world with 3D virtual objects. Although the user may watch a physical experiment by means of a webcam, on the computer screen he will see real book pages and, superimposed, the relevant graphical annotations and 3D mechanism simulation. The software, hardware and the methodology, as well as the results are described in detail. Using this teaching concept, a variety of computational mechanism models can be studied, which reduces the need for classical experiments that involve expensive installations. The advantage of this system method is the usage of inexpensive equipment for intuitive learning the simulation of mechanisms.

Keywords: Augmented Reality, AR book, virtual 3D models, co-location

I. INTRODUCTION

An undergraduate mechanical engineering curriculum invariably includes a course about the Theory of Mechanisms and Machines through which students learn modelling and analysis of mechanisms. Teaching Theory of Mechanisms and Machines has traditionally relied on physical models. These physical models provide an intuitive representation of the mechanical structure, allowing students to explore aspects such as type and construction of joints, mobility etc. [1].

The classical method of teaching the Theory of Mechanisms and Machines course is a difficult task which requires the students' imagination or the usage of expensive mechanical installations. The teaching methods must evolve according to the new technologies that can help the students in the learning process.

Advances in Computer Aided Design (CAD) and Engineering (CAD/CAE) have allowed creation of virtual prototypes that represent mechanical systems at any scale and complexity. Recently, virtual prototyping based on CAD/CAE and Virtual Reality (VR) has been proposed as an improved interface for teaching systems dynamics to mechanical engineering undergraduate students [2], [3], [4]. Using haptic systems, the numerical results of simulations and tests can be converted into forces that the user can percept. This way the plots and graphs can be replaced with the actual experience of switching a virtual device reproducing the force feedback that would characterize the real counterpart with a high degree of fidelity [5]. The disadvantage of using VR technologies for teaching is the high complexity and the cost.

Augmented Reality (AR) is a relative new research direction that allows creation of an interactive virtual space embedded into the physical word. Unlike Virtual Reality (VR) systems, in which users are completely immersed in the virtual environment, AR users see the virtual objects and the real world coexisting in the same space (co-located) [6]. It is the goal of AR to supplement reality

rather than completely replace it as in conventional VR applications [7]. The AR technology provides useful information about the environment, enhancing perception of spatial information and interaction with the real world. AR technologies are now used in various application fields like medicine, manufacturing, military, education and entertainment etc. [7]. In high education are few teaching materials based on AR, almost all have been developed within engineering education field [8], [9].

This paper presents the development of markerless AR book for teaching in enjoyable way mechanisms in mechanical engineering courses. The main idea is to provide to the student real time information on mechanism structure and kinematics by mixing images from the real world with 3D virtual objects. Main objective of this work was to develop an innovative AR system to allow students learning Theory of Mechanisms and Machines in a fun way. The system is innovative because, as far as we know, there is no other AR system that has been developed for this purpose.

II. RESOURCES

In order to augment human's visual sense, a physical display device is used allowing combining real and virtual images and present them to the user. Many forms of video display can be used: Head Mounted Displays (HMD), portable displays (like Smart Phones), monitors and projectors. In this research, there were used a Trivisio stereo video see-through AR display (Fig. 1.a) and a Desktop AR system (Fig. 1.b). HMD is a common choice for AR because it is portable, and it is placed directly on the users' visual range. The main advantage of HMD AR is the improved user's immersive experience. But the use of a HMD is impractical for daily educational activities and has a high cost. The Desktop AR system is more appropriate for the educational activities, because uses low-cost, off the shelf components. The Desktop AR system is composed from a Webcam with 1280x1024 resolution mounted on a tripod and a notebook PC.

a.   b.

Figure 1. The Trivisio see-trough AR HMD (a) and the Desktop AR system (b)

III. METHODOLOGY AND RESULTS

The AR-based system is composed from the book with the theoretical contents of Mechanisms and Machines and files from the AR application which allows visualization of the co-located information contained in that book. In principle, the methodology for create the mechanism learning AR-based book could be formulated as to cover the following steps:

(1) Generating virtual 3D models of the mechanisms - using specialized Computer Aided Design software (for example CATIA (www.3ds.com)). Each component of the mechanism is modelled as a distinct CAD part, and then all of the parts are assembled in their position.

(2) Conversion of the 3D model mechanism data. The virtual model cannot be loaded in the AR software because there is not standard interoperability procedure. Therefore this step consists in extracting the entire geometric data of the CAD model and conversion of standard CAD file to an appropriate common exchange file format (for example 3ds, VRML, X3D etc.) that can be loaded by

general AR framework. The CAD system can export the CAD graphical models in other formats (for example Virtual Reality Modelling Language). Therefore, the VRML language is used for the representation of the 3D virtual mechanism. Using the conversion function directly from the CAD software will not maintain all the data of the original assembled model. Important features of the CAD model are not transmitted, such as topology of parts. Therefore, the geometrical parts of the mechanism are suitable to be used for visualization, but not for interaction. Consequently it is necessary to export each part individually by activation of the "hide" command in order to conceal other components different from one selected. The result is a VRML file, which contains each entity of the CAD models treated as an individual object.

(3) Development of the mechanism kinematics model. For the calculation of movements of virtual mechanism analytical methods presented during the course were used. We do not propose to discuss in this paper about inverse dynamic model of the mechanism. Information about this calculation can be found in [10]. The kinematics model was implemented as a subroutine using Javascript programming language and embedded in the VRML files by using a Script node.

(4) Registration of the co-located virtual mechanism model with the book contents. Software architecture was created for the visualization of the mechanism simulation in a co-located environment. The code written for the AR-based book system is based on a library called Instant Player (www.instantreality.org). The advantage of using this library is the possibility to integrate various VRML and X3d graphical formats of virtual objects and possibility to create External Authoring Interface (EAI). Registration of the co-located virtual mechanism model with the book contents was developed using the instant reality's vision Generic Poster Tracker module for tracking textured planar regions. The tracking methods used are randomized trees based key point classifier for pose initialization and a KLT tracker. In order to create an AR book based on this tracking technology, the user has to carry out the following steps: (i) acquire a reference image of the book content with the camera used for tracking by using image capturing software (for example the free software IrfanView www.irfanview.com) (Fig. 2.a), (ii) perform an offline classifier training phase using the function Generate Poster Tracker of Instant Vision module(Fig. 2.b), (iii) embed the tracker data from the generated *.pm file into the AR application and co-locate of the virtual mechanism model on the book page by modification of scale, 3D position, and orientation, relative to the camera transformation matrix(Fig. 2.c).
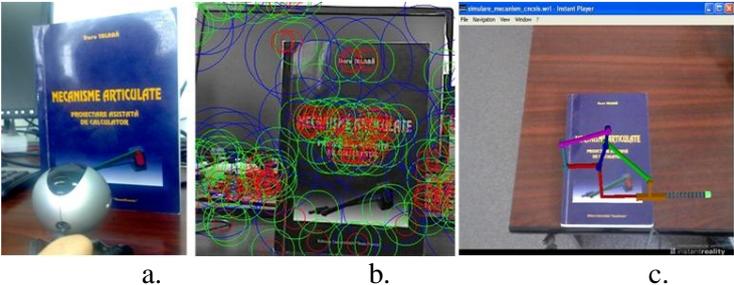

a.   b.   c.

Figure 2. Acquire a reference image (a), offline training phase (b) and co-location of virtual model (c)

(5) Simulation of the co-located virtual mechanism model. The user can interact with virtual mechanism by pressing the "S" keyboard key. When the key press event is detected by a dedicated Keyboard VRML node, the input data for the kinematics model are changed. An example of the simulation of slider-crank mechanism is presented in the Fig. 3.
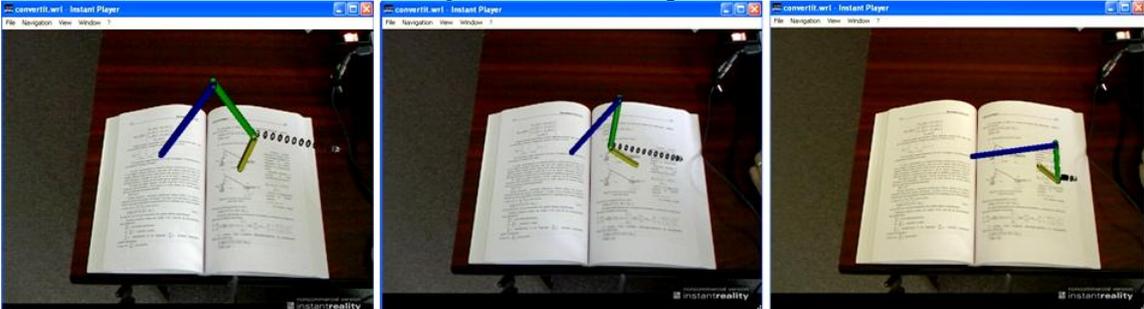

Figure 3. Visualization of slider-crank mechanism simulation using AR-based book system

IV. CONCLUSIONS

In this paper, it was presented the methodology and prototype software system of an AR-based book used for Theory of Mechanisms and Machines. This approach helps inexperienced users to learn mechanism simulation in an intuitive way. Using this system can be made without the need for expensive equipment, because only a video device and a computer are needed. However, out of these positive results the system has his limitations, since problems can come out when the intensity of the light it is weak, which make the identification of markers difficult and affects the level of tracking accuracy.

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