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IMMERSIVE 3D VISUALISATION FOR CAD/CAM

WIZUALIZACJA 3D Z ZANURZENIEM W ZASTOSOWANIACH CAD/CAM

Abstract

The paper briefly introduces different approaches in Virtual Reality as applied to Machine Engineering and Virtual Machining. The description of examples of state-of-the-art in the field is followed by a presentation of a novel idea to utilise simple hardware equipment to provide immersive visualisation for regular desktop computers.

Keywords: *immersive virtual reality*, *position tracking*, *view adaptation*

Streszczenie

Artykuł zawiera krótkie wprowadzenie do zastosowań wirtualnej rzeczywistości w narzędziach Inżynierii Maszyn i Wirtualnej Obróbki. Po opisie przykładów najnowszych rozwiązań w tej dziedzinie przedstawiono nowy pomysł na uzyskanie pewnych efektów wirtualnej rzeczywistości z zanurzeniem z wykorzystaniem prostych narzędzi i zwykłych komputerów osobistych.

Słowa kluczowe: *wirtualna rzeczywistość z zanurzeniem*, *śledzenie pozycji*, *adaptacja widoku*

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1. Introduction

Modern mechanical engineering depends very strongly on computer tools. Many different types of applications are used in different steps in the design process. A progress of capabilities of hardware systems and software technologies in past years facilitated a significant time and cost efficiency improvement in manufacturing. This can be achieved partially thanks to advancement in CAD/CAM tools that simplified the design process. Sophisticated simulation software that allows for building virtual models of the items being designed and robust testing before physical manufacturing substantially decreased the production costs [1]. Research has also been devoted to real time simulations [2]. A thorough study of the field is far beyond the scope of the current contribution, yet such reviews are available [3].

1.1. Virtual Reality

Virtual Reality (VR) technologies are being applied in the field for many purposes. The term Virtual Reality itself may refer to different aspects of human-computer interactions. To present the problem input and output computer interfaces will be considered separately. Modern hardware technology provides an abundance of different types of interfaces for different purposes. Here only a "general purpose" interfaces, as opposed to "dedicated" solutions (designed for single particular application) will be considered.

VR input devices include different types of three degrees of freedom (3DoF) pointers (e.g. Logitech 3Dconnexion Technology, Kantek 3D RingMouse), six degrees of freedom (6DoF) controllers (Polhemus LATUS, Motion4U Xaelander), virtual gloves (e.g. CyberWorld P5 Glove, Cybergloves CyberGlove II), head tracking devices (e.g. NaturalPoint4 TrackIR) and many more. For design purposes haptic interfaces that additionally provide force feedback with 3D manipulation (e.g. Virtual Design Works [0]) are also available. Even game consoles are also becoming more advanced and provide capabilities for 6DoF control (Nintendo Wii, Sony PlayStation Eye) or ever full body motion tracking (Microsoft Kinect for Xbox 360).

Output interfaces range from advanced stereoscopic projectors of different types (e.g. DepthQ), to different types of transparent and non-transparent Head-mounted Displays (HMD, produced by Sony, Optimus, Canon, eMagin, and many more). Currently the 3D technology is also becoming available for home use. 3D televisions are already produced by many companies (LG, Panasonic, Samsung, Sony end more). The NVIDIA 3D Vision is supported by the latest Graphics Processing Units in the GeForce Series which brings stereoscopy to home computers.

Possibilities of application of Virtual Reality in CAD systems has often been explored, both generally [0] and in the context of Machine Engineering [0, 0]. Certain problems with such integration have been pointed out. A study by Stark et al. [0] suggests that current CAM systems require more precision than most VR interfaces can provide. It is also noted that many CAD systems require types of input (e.g alphanumerical) difficult to provide in immersive VR environment for full functionality. On the other hand it should also be noted that VR provides for new intuitive ways of interaction with the virtual model that resemble interactions with physical objects and is already widely used in industry [0].

The idea presented here is based on an observation that when it comes to output interfaces the only "generally available" products that give a full impression of immersion

are systems based on HMDs. Stereoscopy can deceive human depth perception, sometimes to a great extent. The rendered scene doesn't, however, adapt to user position relative to the screen. This means that as user moves relative to such a stereo vision image the presented scene seems to be moving as well. The goal is, then, to adapt the rendered image according to user's position.

2. Adaptive 3D visualisation

The original idea to overcome the problem of "static" rendering by tracking user position and adjusting the rendering options was presented by John Chung Lee in his Wii Head Tracking project (http://johnnylee.net/projects/wii/). Implementation of such an idea may be used together with stereoscopic screens to enhance the effect. The functions of that original implementation have been extended in the presented solution, which also overcomes certain problems. Details of the theoretical basis of the presented extensions can be found in [7]
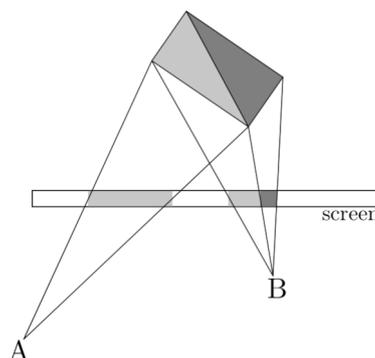
Fig. 1. The screen as a virtual window (top view). The image of the rectangle on the screen rendered when the user is in position A is different from the one rendered after moving to position B – the darker side becomes visible

Rys. 1. Ekran jako wirtualne okno (widok z góry). Obraz prostokąta na ekranie rysowany gdy użytkownik jest w pozycji A jest inny od tego rysowanego po przemieszczeniu do pozycji B – ciemniejszy bok zaczyna być widoczny

2.1. Adaptation

The purpose of view adaptation can be explained using analogy to physical picture and an empty frame. In case of a regular image what we see on its surface is still – it does not change depending on the position of the viewer relative to it. This is the case with all standard computer screens, even stereoscopic ones. An empty frame (or a window), however, allows for looking at the objects behind it from different perspectives. The idea is also shown in Figure 1. Such adaptation creates an impression that the virtual objects are a part of the real world behind the screen.

As is schematically shown in Figure 1 such adaptation allows for a more natural visualisation of virtual objects. It is possible to view them from different sides as if they

were standing just behind the screen, without having to rotate them. The current implementation allows even for rendering of objects that in the virtual world are located between the user and the screen.

It is not possible to see the back side of the object just by moving relative to the screen, exactly as it is not possible when looking at something through the window. To see the "back" of an object the "virtual window" has to be positioned differently in the virtual scene, which is also possible (unlike with the Wii Head Tracking).

It is worth noticing that the adaptation does not require any particular rendering pipeline. The current implementation is a modular library that simply calculates parameters that are needed to set up the rendering properly. This makes it usable with either OpenGL or DirectX, or any other rendering tool.

2.2. Positioning

The basis for adaptation is user tracking. In the current implementation two methods of visual tracking have been implemented. Both use regular web cameras and glowing markers.

The first method uses two cameras and a single light point as marker, that should be fixed relative to the user's eyes. The position is computed using images from the two cameras and analysing the difference in position of the light point in them. This approach proved to be stable and provides a very good illusion of immersion. The problem here is, however, that the process of setting up the cameras (aligning them) is relatively time-consuming. It is for larger visualisation purposes (projectors etc.)

The other method uses a single camera and a marker that allows for determining its radius from in a camera image (e.g. a glowing sphere). The relation between the physical dimensions of the marker and its image allows for the position of the marker to be computed. The advantages of this solution are the lower time overhead (only one camera is accessed per each rendered frame) and simple setup (e.g. laptop's built-in camera may be used).

3. Conclusions

The evaluation of the presented idea is relatively subjective, as it is an improvement of visual presentation. Nevertheless certain measurements were possible. The quantity that gives an indication of the performance of the current implementation is the time overhead. Accessing hardware (grabbing camera images) within the testing system (Linux) gave 0.02 s of delay per each camera frame. It should be noted that this value is doubled for current state positioning done using two cameras. The altogether frame rate for the single camera tracking was around 29 fps and 14 fps for the two camera positioning. This was achieved using a relatively simple 3D scene shown in Figure 2. The scene mimics the one used by John Lee in the presentation of his project, which gives a good impression of the functionality. The test setup used OpenGL for 3D rendering, but, as mentioned before, the adaptation code was entirely independent of any particular rendering pipeline.

The subjective impression of using both described types of positioning with the simple scene proved to be very good. The processing delay was unnoticeable. It allowed even for relatively quick motion without positioning problems. The results were comparable with those presented in the available video material for Wii Head Tracking.
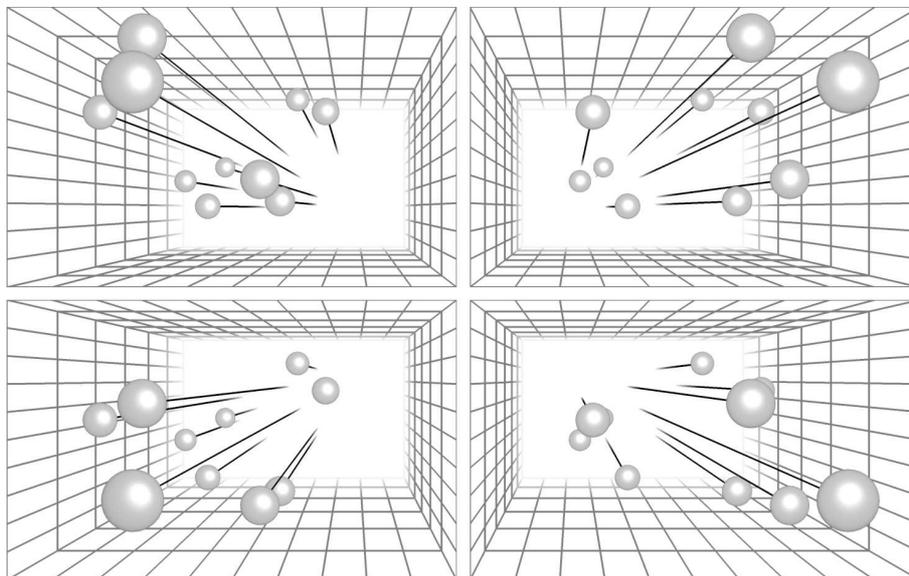
Fig. 2. Example screenshots of a simple scene with adaptation,
for different positions of the user
Rys. 2. Przykładowe zrzuty ekranu prostej sceny z zastosowaniem adaptacji,
wykonane przy różnych pozycjach obserwatora

3.1. Futher work

In its current shape the project offers two directions of improvement. One is the altogether performance optimisation and development of positioning methods. The existing positioning can be enhanced by a transition from visible light spectrum to infrared (IR). This would require only minor modifications of standard webcams and creation of appropriate infrared markers (based on IR LEDs). Also use of Commercial, off-the-shelf (COTS) products for positioning (e.g. NaturalPoint4 TrackIR) can help to improve performance thanks to use of dedicated hardware. Adding new positioning modules or camera access interfaces is facilitated by the modular architecture of the software.

The other possibility of further development is application of the solution to existing visualisation tools. Thanks to the lack of any particular external dependencies and platform independence of the core functions the idea seems to be applicable in almost every visualisation tool with only slight modifications in the original code. Among all possible applications CAD/CAM systems seem to have the potential to benefit greatly from the presented enhancement. The limitation of single user makes it impossible to use in collaborative environment. Nevertheless in all the cases where single designer works on a desktop computer the interaction with the virtual objects may improve greatly.

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