Medjunarodni naučno-stručni skup
XXV NAUKA I MOTORNA VOZILA 2015
SCIENCE AND MOTOR VEHICLES
International Automotive Conference
14 - 15 April 2015, Beograd, Serbia

NMV15AET05

ADVANCED VIZUALISATION TECHNOLOGIES AS A TOOL FOR IDENTIFICATION OF VEHICLE DETAILS AND ELEMENTS

Tashko Rizov PhD, Prof. Risto Tashevski, PhD

„Ss. Cyril and Methodius“ University in Skopje, Faculty of Mechanical Engineering, MKD

ABSTRACT

The advancement in technology provides engineers today with a new ability in the area of technical visualization – to create a three-dimensional (3D) manual. Compared to the existing methods for creating manuals in engineering, and the existing methods for horizontal and vertical knowledge transfer, this new methods based on 3D objects can contribute to shortening the needed time for training of engineers and also to lowering the number of errors due to human factor.

With the use of augmented reality in some of the engineering processes where the use of manuals is essential, these contributions are even more convincing.

This paper presents a solution, based on technical visualization, using augmented reality for identification of elements in the processes of vehicle inspection or maintenance. In addition, the paper presents an example of the use of this technology through a model of a customized application developed for the operators in order to get a visual 3D step-by-step guidance in the process of locating the appropriate data elements on the vehicle during the identification procedure. The solution provides user with ability to easily transfer knowledge, increase efficiency and improve safety of the personnel.

KEYWORDS: Augmented Reality, 3D Objects, Image Tracking, Vehicle Identification, Technical Visualization

1. INTRODUCTION – What is Augmented Reality (AR)?

Some people thinks that the next big thing in technology is Augmented Reality (AR), as shown in Fig. 1, which represents a variation of Virtual Environments (VE), or Virtual Reality (VR). This statement is getting its verification every day. The ability this technology is providing to users is unimaginable - its applications spread each day as more people are becoming aware of it, and as they start understand how it can augment their lives.

VE technologies completely immerse a user inside a synthetic environment. While immersed, the user cannot see the real world around him. In contrast, AR allows the user to see the real world, with virtual objects superimposed upon or composited with the real world. Therefore, AR supplements reality, rather than completely replacing it. Ideally, it would appear to the user that the virtual and real objects coexisted in the same space. A more comprehensive definition of AR would be as a system that has the following characteristics: (1) combines real and virtual world, (2) interactive in real time and (3) registered in 3D [1]. Augmented Reality enhances a user's perception of and interaction with the real world. The virtual objects display information that the users cannot directly detect with their own senses. The information conveyed by the virtual objects helps a user perform real-world tasks.

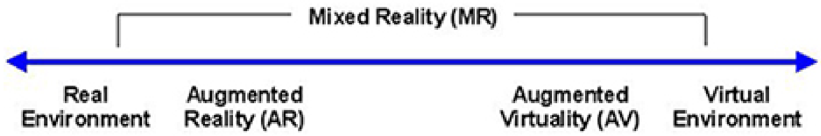

Figure 1. *Milgram's Reality -Virtuality continuum.*[1]

Augmented Reality might apply to all senses, not just sight. So far, researchers have focused on blending real and virtual images and graphics. However, AR could be extended to include sound, smell or tactile. At this paper the focus is only on sight as a human sense that needs to be augmented in order to achieve enhancement of the students' ability to visualize space and objects in it.

A basic design decision in building an AR system is how to accomplish the combining of real and virtual. Two basic choices are available: optical and video technologies. Each has particular advantages and disadvantages.

In the optical case, the virtual image is projected at some distance away from the user. This distance may be adjustable, although it can be fixed if the display is mounted to the user. Therefore, while the real objects are at varying distances from the user, the virtual objects are all projected to the same distance. If the virtual and real distances are not matched for the particular objects that the user is looking at, it may not be possible to clearly view both simultaneously.

A key measure of AR systems is how realistically they integrate augmentations with the real world. The software must derive real world coordinates, independent from the camera, from camera images. That process is called image registration. Image registration is one of the most basic problems currently limiting Augmented Reality applications. The objects in the real and virtual worlds must be properly aligned with respect to each other, or the illusion that the two worlds coexist will be compromised. More seriously, many applications demand accurate registration. Without accurate registration, Augmented Reality will not be accepted in many applications. Registration errors are difficult to adequately control because of the high accuracy requirements and the numerous sources of error. These sources of error can be divided into two types: static and dynamic. Static errors are the ones that cause registration errors even when the user's viewpoint and the objects in the environment remain completely still. Dynamic errors are the ones that have no effect until either the viewpoint or the objects begin moving [2].

Application of augmented reality for 3D model presentation can be used in all field of engineering where we use virtual three dimensional models in process of projecting. However, the most commonly AR is used in area of mechanical engineering, civil engineering, architecture and education in engineering [3].

One area that AR lends itself to is machine assembly (Fig. 2). Rather than working from manuals, virtual environments or fixed screens, which can be a relatively static way of working, AR can be transported around the factory via a tablet or smart phone [5]. The most important thing good AR software does for the industrial market is to connect optical or mechanical sensors, such as optical, laser scanning or measurement, and take this positioning data to allow a user to overlay digital CAD data into the live view. This allows you to visualize the CAD data on top of the real manufacturing environment [3].

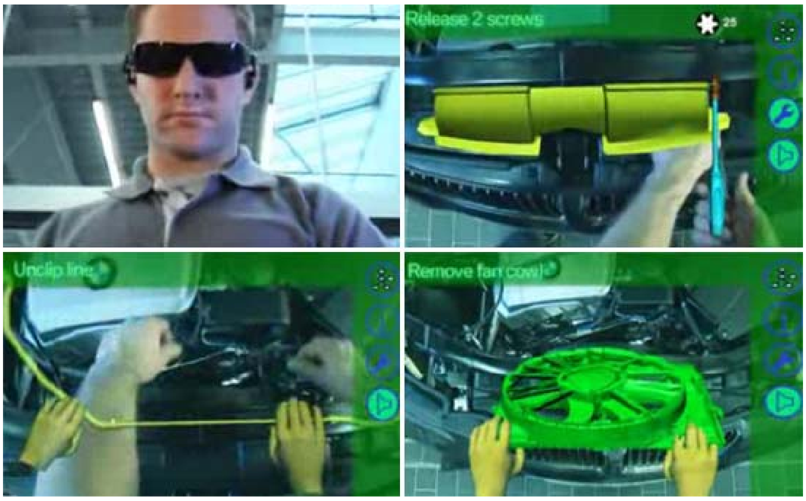

Figure 2.*BMW's Augmented Reality maintenance visual manual [5]*

Various methods for determining the position and orientation in the visual augmented systems have been developed long before the emergence of modern systems for augmented reality. In addition, techniques developed for determining the position and orientation used in AR systems are often different from those used in other fields of use, like air or maritime navigation. This is largely related to the characteristics of AR systems, the need for their mobility and severe restrictions in the cost [7].

Visual systems may be divided into two categories: with markers and without using markers. Visual systems using markers require advance preparation of the environment in which the user has to carefully place the markers prior to augmenting the reality. To enable the augmented reality system to use these markers to determine the position and orientation, it must be aware of the type (appearance) of the marker and its position. If using only one camera, then the initial parameters of the camera (as the pixel size and focal length) must be known [7]. Also, the size of the marker and its location has to be determined. Examples of such markers are shown in Figure 3.

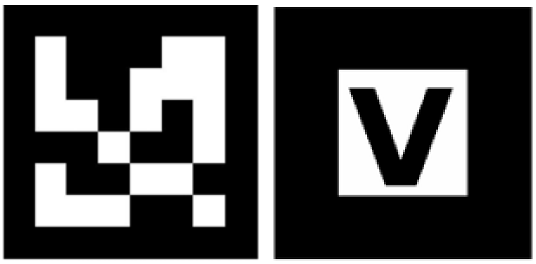

Figure 3.*Visual tracking markers forAugmented Reality* [6].

The types of markers may vary from those that may be identified by their appearance (as markers shown in the figure 3), to markers that will be identical but with their well-defined distribution in space. Also, illuminated markers with infrared light may be used. [4]

2. AR IN THE AREA OF MOTOR VEHICLES

The application of augmented reality in the field of motor vehicles is a research topic in every major car manufacturing company. Right after this technology was made available, the research departments of the automotive companies presented concept ideas based on the use of the augmented reality.

In general, the use of AR in the automotive industry can be grouped in three categories:

- Systems which provide safety improvements during driving the vehicles,
- Systems which provide entertainment and additional information for the driver and the passengers,
- Systems which provide facilitation for certain activities in the vehicle maintenance process [9].

2.1. Examples of use of AR in the area of motor vehicles in the world

Car manufacturers like BMW, Toyota, Mercedes and General Motors in the last years have presented prototypes with which augmented reality is being utilized in motor vehicles. For example, the Japanese car manufacturer Toyota, through its Department for development Kansei, in cooperation with the Institute for interactive design in Copenhagen (CID), in 2011 presented a prototype called “Window to the World” which provides interactive entertainment for the passengers on the back seats (Fig. 4). This system enables the passengers to zoom in on parts of the surrounding and the passing objects during driving. In addition, the system provides an option to measure distances between points of interest or objects that are in the field of view or to simple doodle simple shapes and forms on the back window of the car [5][9][11].

Figure 4. *Toyota’s Window to the World [6]*

Another concept for utilization of augmented reality was presented by General Motors (GM) as the system for vision enhancing. This system consists of numerous sensors and cameras mounted inside and outside the vehicle which monitor the vehicle’s surrounding and the orientation of the driver’s head and direction of sight. After that, this data is used to project additional information to the windshield regarding the condition of the road, navigation assistance or warnings for different danger elements that might appear. Also, this system provides the ability to mark the edges of the road with virtual lines on the windshield of the vehicle in harsh weather conditions or other cases of limited visibility of the road [9][11].

2.2. Example of use of AR in the area of motor vehicle technical inspection

The following example shows the benefits and drawbacks of the use of a technical visualization solution based on augmented reality for certain activities in the vehicle identification and conformity assessment process conducted by technical services in Macedonia. The current National and European legislation strictly define the process of inspection and conformity assessment of motor vehicles. This process can be conducted only by accredited inspection body, approved and assigned by the respective national authorities to conduct such activities – so called Technical services for vehicles. The Technical services may provide variety of services for conformity assessment and approval of vehicles which in general are of great importance to the country and play major role in maintaining the safety of national and international traffic and protection of the environment.

The process of identification of vehicles is conducted in several steps, where one of the elements is to obtain the Vehicle Identification Number (VIN) and the engine number. The engine number is a unique mark placed by the manufacturer of the engine or by the manufacturer of the vehicle and it contains coded information regarding the year of manufacturing, the type of the engine, country of origin etc. By decoding the engine number through comparison to existing data bases all relevant properties of the engine can be determined.

The key issue in this activity is determination of the engine number position and accessing it. The issue is raised by the simple fact that there is enormous variety of the position of the engine number taking in consideration the ever-growing variety in engine manufacturers and models. According the European Automobile Manufacturing Association (ACEA), in 2013 in the World around 282 different manufacturers of cars only were noted, which results with huge variety on the location of the engine number. Even the same manufacturer for different engine types or for different model years uses different position [11].

When a technical service in Macedonia would like to establish a managed system for knowledge transfer regarding this element a serious challenge arises. This was the key motivation behind the idea for development a solution for technical visualization using augmented reality.

3. OCCLUSION - THE BIGEST CHALLENGE IN TECHNICAL VIZUALIZATION USING AUGMENTED REALITY

As explained above in AR the live video and real time computer graphics are merged and the results are displayed on a video monitor. Virtual objects that are to be included in the video signal are rendered on a black background. In this case, the video output of the graphics workstation is combined with the output of a video camera using luminance keying [7][9]. In the final video output, the live signal is displayed in the black regions of the computer generated signal. In this scenario, virtual objects always occlude the real ones in the final output. Displaying a non-black virtual object immediately hides the real object displayed in the same pixels in the video signal. Virtual objects occlude real ones by default. Today, varieties of methods are known and may be employed to produce the interactive occlusion of virtual objects by real ones [7].

Such method is model-based, where a geometric model of the real objects is registered to their real world counterparts. Assuming that the model accurately represents the real object, this registration produces the modeling transformation that places the geometric model in the correct position in camera coordinates to produce an image identical to the live video image of the real object.

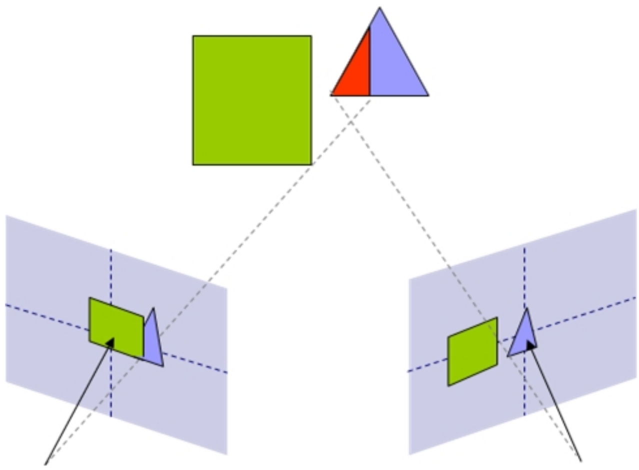

Figure 5. *Occlusion of objects depending of the line of sight [9].*

A different approach is the depth-based method. This method utilizes a depth map of the world to produce occlusions. The depth map may be transformed into a polygonal surface. The polygonal model represents the combined surfaces of the real world objects seen from the video camera. The depth map information can also be utilized by writing the camera derived depth values directly into the Z buffer of the graphics hardware. If at the beginning of each rendering cycle the hardware Z buffer is initialized with the real world depth values, occlusion of the virtual objects is performed automatically. When the virtual object is rendered, pixels that are further away from the camera than the Z values in the depth map are not drawn. By setting the background color black, the real objects present in the original video are displayed in these unmodified pixels [7][10].

4. TECHNICAL VIZUALIZATION IN THE PROCESS OF VEHICLE IDENTIFICATION USING AUGMENTED REALITY

As explained above, the concept idea presented in this paper is to use augmented reality and develop a solution for technical visualization that will provide automotive inspectors with a step-by-step visual guide for determining and accessing the engine number on the specific vehicle. In order to do this, a system was designed for use of augmented reality on the basis of the existing software tools available on the market. The design of the system includes use of hardware like video camera and personal computer, than software applications for processing and combining the video signals, detection and tracking of markers, data base management and providing user interface to present the results on a computer screen.

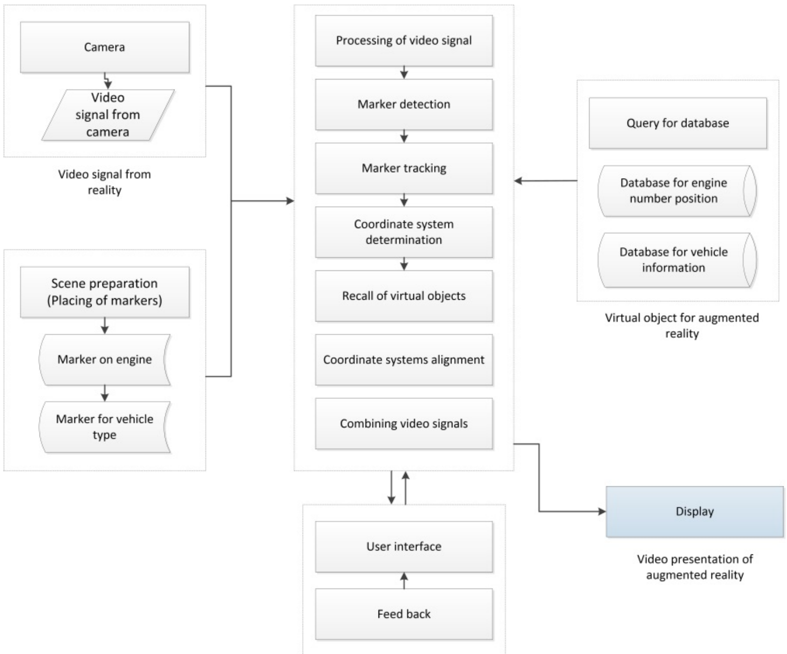

Figure 6. *Flow diagram of the concept idea for technical visualization [9].*

Based on the flow diagram presented in Figure 6, a multi-relational data base was created mapping the data elements of the virtual 3D models of the engines with the general information about the vehicles. Information regarding the location of the engine number and ways to access it are extracted from the data base *Autodata Technical Database CDA-3* (Fig. 7). Based on that, a 3D model of the engine with a virtual object as a corresponding marking that determines the location of the engine number were created. These models are than added to the multi-relational database.

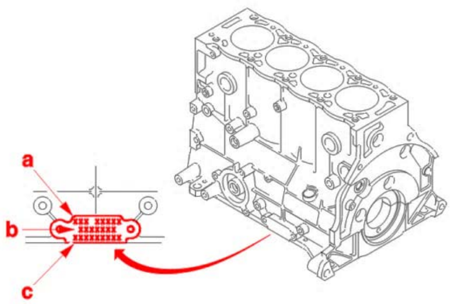

Figure 7.*Information on the location of the engine number provided in the Autodata database [9].*

As most suitable software tools for completing this concept as designed, the BuildAR application from HITLabNZ and ARToolKitPlus were selected. BuildAR enables processing and combination of video signals, detection and tracking of markers, user interface and presentation of the results to a computer screen. For detection and tracking of the markers the software application uses the algorithm ARToolKitPlus [6].

This algorithm is robust and fast enough in the process of identification of fiducial markers with a consisting performance in various conditions. With this combination of software tools, the user is enabled to use more than one maker, to add virtual 3D models, 2D models, video, picture, sound or text [8].

In the concept presented in this paper, two markers are used. The first one has the task to define the location of the 3D model of the engine, and the second one to define the location of the general information about the vehicle (manufacturer, commercial mark, year of production, engine type, engine capacity, engine power, number of doors, number of seats, approved tire size). In that way, the inspector of the vehicle has the ability to check the information and compare it to the vehicle that is being inspected. This will provide additional control and eliminate mistakes in the inspection process [9][11].

In order to provide a step-by-step visual guide for the inspector, on the basis of the 3D model of the engine, together with the virtual elements that determine the location of the engine number an animation is created (Fig. 8). This animation is later presented to the inspector’s computer screen augmenting his real view of the vehicle’s engine.

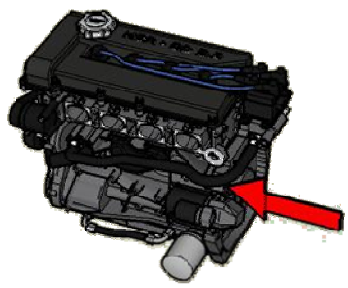

Figure 8. *3D virtual model of the engine with marking of the location of the engine number.*

Prior to activating the application for technical visualization it is necessary to prepare the scene. The vehicle must be positioned on to a defined location that location has to be in the field of view of the camera, the lighting should not result in flashes or reflections from parts of the engine or front of the vehicle obstructing the video signal from the camera. Finally, the corresponding markers should be placed on the top of the engine [9].

Figure 9. *Vehicle for inspection with prepared scene for technical visualization using augmented reality.*

Afterwards, the algorithm of ARToolKitPlus detects the markers in the video signal from the camera and is tracking their position and orientation continuously (Fig. 9). Based on the data gathered through image recognition of the marker, the system connects to the corresponding virtual model in the database, loading the corresponding animation to the computer screen of the inspector. The two video signals are processed and matched accordingly, resulting in an augmented reality step-by-step guide. The same is done for the second marker, where instead of an animation, text as virtual object is presented.

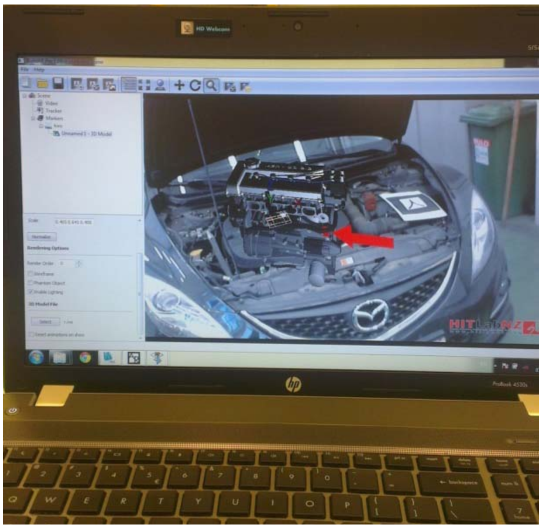

Figure 10. *Technical visualization using AR – visual guide for determining engine number position.*

In that way, a clear visual guide for the inspector is presented on the screen out of which the position of the engine number and the necessary steps to reach it are clearly explained. The visual guide is presented in AR (Fig. 10), where directly on the vehicle image virtual instruction is presented in a form of a 3D model of the engine.

5. CONCLUSION

Augmented reality appears to take over the lead in engineering visualization in the future. The principles of its functioning and application in the domain of designand presentation of 3D models are at a higher level than traditional. The further development and improvement of the technology is expected to contribute to the better quality and functionality of AR application.

The augmentation achieved with this concept, presents a successful application of augmented reality because the user is convinced that the real and virtual objects coexist. In addition, this application is a successful example because it contributes to simpler execution of activities related to inspection of vehicles in the process of approval.

The main shortcoming of AR in engineering is still the lack of capacity for photo realistic presentation of complex 3D models, because of hardware limitations and complexity of calculations performed so that it could work. One additional shortcoming is the need of 3D modeling of the virtual objects. In order for the suggested concept idea to become fully operational, a comprehensive data base of 3D models of engines is necessary. The dynamics of the development of this technology is evident. It is only matter of time when these shortcomings are going to be overcome.

The research presented in this paper clearly indicate the serious capacity of the suggested application of AR in the efforts to support the process of knowledge transfer in engineering activities in the area of motor vehicles.

The presented example opens new horizons for further development of the technology and its application.

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