

ИЗСЛЕДВАНЕ НА МЕТОДИ И СРЕДСТВА ЗА ПРОЕКТИРАНЕ И РЕАЛИЗАЦИЯ НА ДОСТЪПНА ПРЕНОСИМА СИСТЕМА ЗА ВИРТУАЛНА РЕАЛНОСТ ЗА РЕШАВАНЕ НА ИНЖЕНЕРНИ ЗАДАЧИ

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Резюме: Разгледани са методи и средства за изграждане на достъпна мобилна система за виртуална реалност, която лесно може да се интегрира в процеса на решаване на инженерни и научно-технически задачи. Системата е изградена на базата на мобилен компютър с графичен контролер с четири буфера и 3D телевизор с пасивни очила. Обсъдени са формати за представяне на стереоскопични изображения, начините за тяхното генериране, предаване, декодиране и визуализиране на 3D дисплей. Основни предимства на системата са съвместимост с графичния стандарт OpenGL и достъпна цена.

Ключови думи: мобилна система за виртуална реалност, стереоскопична визуализация, формати за стереоскопични изображения.

METHODS AND TOOLS FOR DESIGN AND IMPLEMENTATION OF AN AFFORDABLE MOBILE VIRTUAL REALITY SYSTEM FOR SOLVING ENGINEERING PROBLEMS

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Abstract: This article proposes a software and hardware solution for an affordable mobile virtual reality system which can easily be integrated in the process of solving engineering and scientific applications. An example realization of the proposed solution in which a mobile computer with quad-buffered graphics adapter is connected to a 3D TV display is described. Different stereo image formats, their generation, transition decoding and visualization on a 3D capable display are discussed. A use case is given, in which the sample configuration is used to review the results from different engineering analysis in stereo. The main advantages of the proposed system are the use of the OpenGL graphics standard and its affordable price.

Keywords: mobile virtual reality system, stereoscopic visualization, stereoscopic image format

1. Introduction

A typical virtual reality system is a large installation, which occupies usually separate rooms dedicated specifically for the purpose of immersive presentation of

examined models and consists of one or more display screens in combination with projectors, regularly two per screen, several networked computers and specialized input devices. Even though some virtual reality display systems are categorized as mobile, they are actually built up by placing screen, projectors, computers and mirrors in a big cabinet. Actually the term mobile is related to the fact that the cabinet has wheels which allow moving and rearranging the system appropriately in a big hall, but for transportation a dedicated van should be used. Another issue which limits the application of typical virtual reality systems in the overall workflow of solving engineering problems is the price. Until recently only big companies and laboratories could afford the purchase and maintenance of a virtual reality system. Recent technological developments in stereoscopic display technology and the increased market penetration of 3D capable displays and 3D TVs as well as the appearance of notebooks with characteristics typical for CAD workstations provide an inexpensive basis for building up an affordable stereoscopic mobile visualization system which could be used for presentation and exploration of research and engineering results outside a laboratory. Combining different components in a complete system with the aim to ensure compatibility for long period of time requires the implementations of standards. In this article we discuss various stereoscopic display formats supported by 3D TVs, consider how corresponding signals can be generated and present a concept for building up an affordable mobile virtual reality system, which can be integrated in the everyday engineering activities.

2. Related work

The main features, advantages and disadvantages of several affordable virtual reality software frameworks and products have been discussed in [1]. All systems considered are scalable and can run on different hardware configurations – in particular on both: computer clusters and desktop and personal computers, focusing on stereoscopic display systems like CAVE as well as individual devices as Head Mounted Displays (HMDs). For example the popular open source VRJuggler [8] framework supports various types of projection based displays and head-mounted displays. With the arrival of 120 Hz LCD displays, which can split the frequency to present different images to both eyes, introduction of 3D imaging technologies like NVidia 3D Vision [7] and iZ3D [6] and the boom of 3D Cinemas like IMAX the stereoscopic rendering has recently become very popular among common users, especially in computer gaming industry.

The idea behind technologies like NVidia 3D Vision and iZ3D is the application of a separate software component provided as extension to the graphics driver that generates automatically stereo pairs for the image rendered by the GPU. This driver also encodes the generated stereo pairs in a format suitable for the particular 3D display. The NVidia 3D Vision technology supports stereoscopic visualization by using only active shutter glasses synchronized with a limited set of 3D 120 Hz capable displays. The synchronization is performed either by an infra red emitter or by using radio frequency signals. Currently there are already even mobile computers support-

ing the NVidia 3D Vision stereoscopic display approach. The disadvantage of this software solution is that it has been focused on applications using the graphics standard Direct3D for the rendering process – mainly entertainment applications, i.e. games. None of the above mentioned drivers currently supports stereoscopic rendering of images generated by the graphics standard OpenGL. iZ3D are planning on including such functionality in some future version. NVidia 3D Vision supports OpenGL stereoscopic display visualization but only on quad-buffer graphics adapters and with the explicit limitation that the application itself needs to generate the corresponding stereo pairs. As scientific and engineering applications usually rely entirely on OpenGL for the rendering, none of the above mentioned technologies is suitable for stereoscopic visualization of scientific and engineering problems results.

In this article we propose a solution for creating an affordable mobile virtual reality stereoscopic rendering system based on the graphics standard OpenGL, which consists of a mobile computer with quad-buffered graphics adapter connected to a 3D TV display with passive glasses.

3. Stereoscopic Image Formats

Although there are mobile computers with 120 Hz displays compatible with NVidia 3D Vision technology and mobile computers with quad-buffered graphics adapters, there are no mobile configurations featuring both 120 Hz display and quad-buffered graphics adapters, which means that it is not possible to render in stereo an OpenGL application on a mobile computer (besides anaglyph stereo presentation).

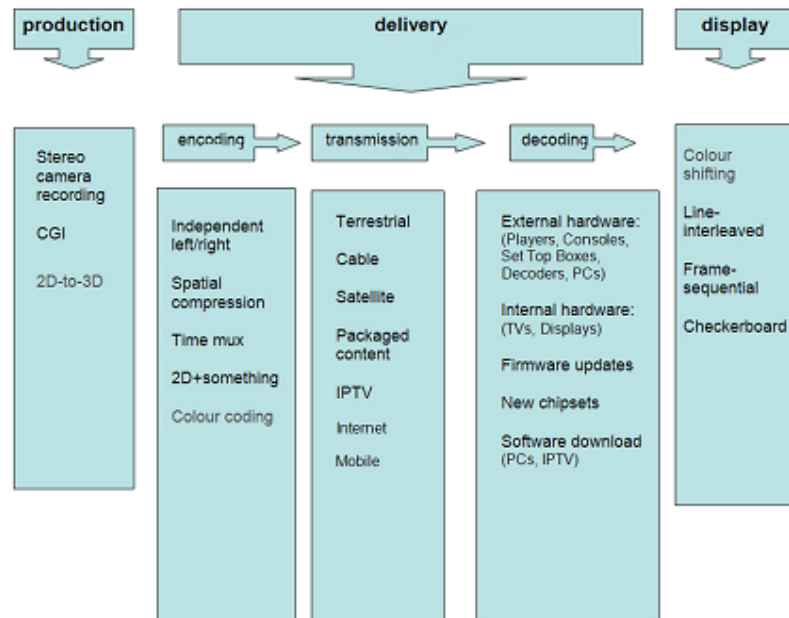


Figure 1. The 3D Content Lifecycle [2]

Consequently in order to produce stereoscopic visualization from an OpenGL application a separate 3D capable display has to be connected to a mobile computer

with quad-buffer graphics adapter and the stereo signal has to be transmitted to the 3D display in an appropriate format.

The general process of stereo signal generation, transmission and displaying, named the 3D Content Lifecycle, is introduced and described in detail in [2] and is presented on Fig. 1. The processing path we will focus in this article is: Computer Generate Imagery (CGI) → Spatial compression / Time multiplex → TVs → Frame-sequential.

In order for a 3D TV to be able to display a computer generated stereo pair the image that is created as output by the graphics controller needs to be in an appropriate format that the 3D TV can recognize. The formats commonly supported by 3D capable displays include the frame-compatible and the time-multiplexed formats, which are relatively easy to implement. As the encoding types are described in detail in [2] we will give here only a short description of the two encoding types related to this article:

- **Spatial compression** – obtained by combining the left and right images in a single frame. The disadvantage of this method is losing half of either the horizontal or the vertical resolution. There are two main subsets to this type of encoding:
 - Top-bottom – the vertical resolution is divided in two, one of the images is placed in the top half of the frame, the other – in the bottom (Fig 2).

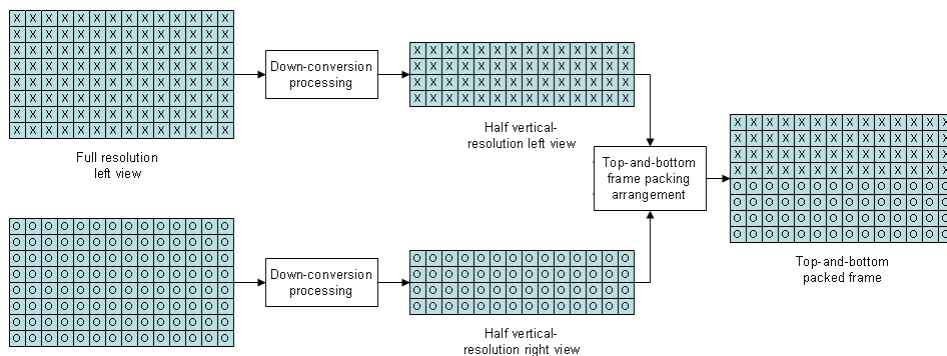


Figure 2. Top-bottom frame packing [4]

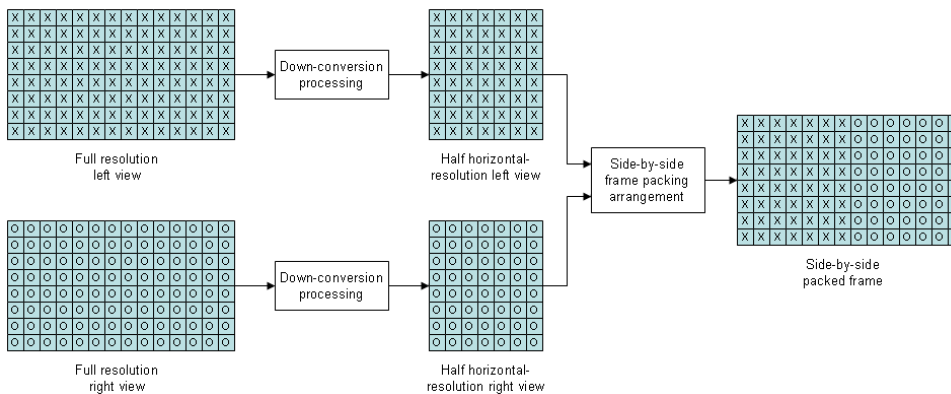


Figure 3. Side-by-side frame packing [4]

- Side-by-side – the horizontal resolution is divided in two, the images of the stereo pair placed next to each other (Fig 3).

- **Time multiplex** – left and right images of the stereo pair are transmitted one after the other. There is no loss in image resolution but requires doubling the frame rate and respectively – the bandwidth.

Two approaches can be used to produce stereoscopic image in a format supported by the 3D display.

1. Adjust the 3D graphics driver to output in a format, recognized by the 3D display.

When using a quad-buffered graphics adapter sometimes it is possible to find compatible devices which allow the 3D driver of the graphics adapter to be configured to output signals in the needed stereo format of the display. The driver takes the generated left and right images of the stereo pair, encodes them in the specified format and conveys them to the display output(s). The selected output format has to correspond to the decoder that the 3D display is going to use to decipher its input. A format has to be chosen that is supported both by the 3D display driver as well as the 3D display itself.

2. Perform the appropriate stereo encoding in the application.

As the formats that a 3D display can decipher are well known there is a possible workaround for generating the needed signal for a stereoscopic image if the first approach fails. The workaround forces the application itself to simulate the stereo encoding. This would mean that, for example in the case when a frame-sequential signal is needed, the application could render the image for the left eye and send it to the output, after that it should render the image for the right eye and send it again generating in this way the time-multiplex signal expected by the 3D display. If the output should be spatial-multiplex (top-bottom or side-by-side) the application could render the images of the stereo pair in buffers, after which it should perform the horizontal/vertical resolution reduction (by removing respectively alternating rows/columns from the image) and join the resulting images in a single frame, which is then sent to the video output.

4. Development of Mobile Virtual Reality System

The affordable mobile virtual reality system was designed and built up in the Virtual Reality Laboratory (VR Lab) at the Technical University of Sofia. The hardware of the constructed system consists of a mobile computer and a 3D TV display. The mobile computer is a Lenovo ThinkPad W520, equipped with an NVidia Quadro 1000M graphics adapter offering one VGA output and one Display Port output. The 3D TV is LG 42LW4500 with passive polarization and HDMI input. The difference between the mobile computer output (DP) and the 3D TV input (HDMI) required a Display Port to HDMI adapter. The virtual reality system can be extended including additional output and input devices like 3D audio system and haptic force-feedback device to enhance the presentation of modeled object properties and to increase the level to which the user can perceive and interact with the system.

The software for stereoscopic visualization of the mobile virtual reality system is divided in two components: the module for stereoscopic OpenGL visualization, which is part of the engineering application and the 3D display driver of the NVidia graphics adapter. The general flowchart is presented on Fig. 4.



Figure 4. Stereo image generation, encoding, transmission and display

The engineering application developed at the VR-Lab opens and displays in stereo the geometry of a CAD model together with corresponding results from some engineering analysis, i.e. finite elements analysis, through the stereoscopic OpenGL module. The application renders separate images for the stereo pair in the left and right buffers of the quad-buffered graphics adapter. The process for a single frame is described in detail on Fig. 5. First the image for the left eye is rendered to the back left buffer of the quad-buffered graphics adapter, then the image for the right eye is rendered to the right back buffer. When the images for both views are ready the application swaps the front and back buffers and the result is transferred to the NVidia display driver which encodes the stereo pair in the selected format - in this case it is configured to output the stereo images in Generic active stereo format (corresponding to the time-multiplex format). The output is then transmitted to the input of the 3D TV which is setup to receive 3D frame-sequential signal.

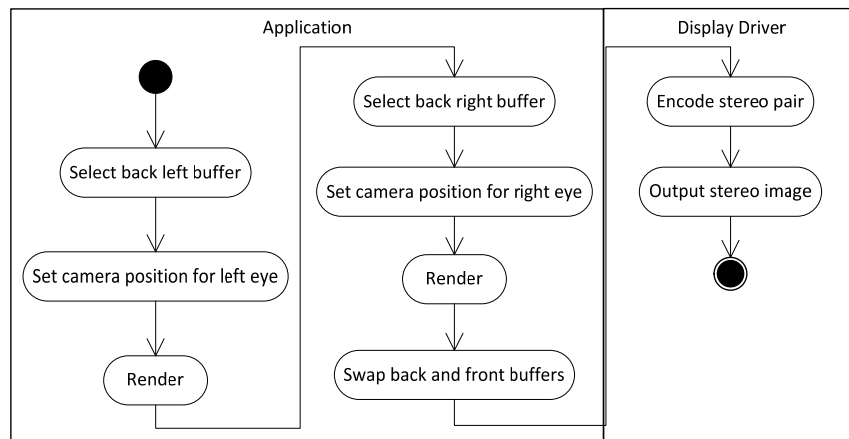


Figure 5. Generation of a stereo pair frame.

5. Stereoscopic Rendering of Engineering Tasks Results

The use of virtual reality for engineering tasks is currently limited to visual validation of design results, ergonomic and assembly tests, displaying of simulation outcomes in stereo. We have developed an approach to support engineers in understanding the results from different engineering analysis, i.e. finite elements analysis.

The basic concept of how to incorporate stereoscopic rendering in the general workflow of solving engineering tasks is presented on Fig. 6. First a CAD model has to be imported in the application. Then the results from the engineering analysis are associated with the model. The model together with its results is rendered in stereo to the left and right buffers of a quad-buffered graphics adapter and encoded as described in the previous sections. The encoded image is transmitted to a 3D capable display which decodes the signal and displays the image in stereo.

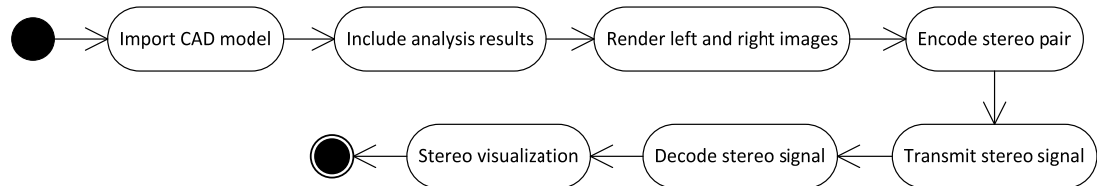


Figure 6. Stereoscopic rendering workflow of engineering tasks

Fig. 7 shows a practical example with finite element analysis of a boiler. The boiler has been analyzed for stress, temperature and displacement distribution. The CAD model of the boiler together with the results from the analysis is loaded in our application which runs on the mobile computer. As the mobile computer has a quad-buffered graphics adapted with a 3D display driver which supports the necessary configuration setup to be connected to a 3D TV display in a compatible stereo mode, the model and results are rendered in stereo straightforward from the mobile computer on the 3D TV. The stereo visualization allows for better perception and review of the model and results analysis. The described mobile stereo visualization system allows for undemanding transportation and use of the system at various locations leading to easier presentation of results outside a laboratory when necessary.

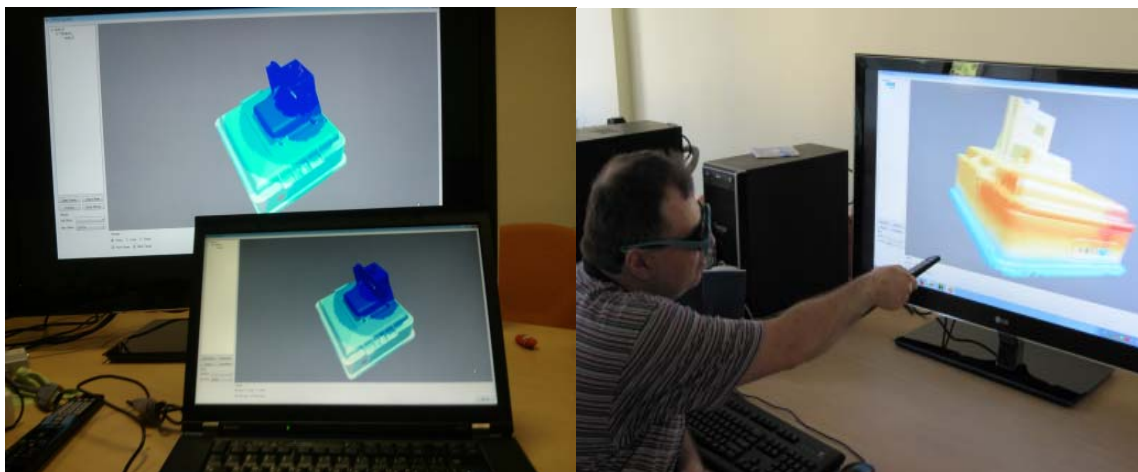


Figure 7. An application rendering stereo from a mobile computer on a 3D TV

5. Conclusion

The article proposes an affordable mobile virtual reality system relying on a powerful mobile computer and an additional 3D capable display with passive glasses.

The solution can be used by engineering and scientific applications rendering the graphics with OpenGL to produce stereo output. It provides advantage against popular NVidia 3D Vision technology to support the process of solving engineering tasks. For the experiment a 3D TV is used, but the workflow is the same for any 3D capable display which supports at least one of the stereo formats described above. The approach avoids the purchase of additional hardware and software components concerning the generation, transmission and presentation of the stereo signal. The main benefit of the mobile virtual reality system is its compatibility with the graphics standard OpenGL at very affordable price point.

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REFERENCES

- [1] Maleshkov S., D. Chotrov. **Affordable Virtual Reality System Architecture for Representation of Implicit Object Properties**. International Journal of Computer Science Issues. vol. 9, Issue 4, July 2012.
- [2] Roberta Piroddi, *Stereoscopic 3D Technologies*, Snell Ltd. April 2010
- [3] Karsten Müller, Philipp Merkle, Gerhard Tech, Thomas Wiegand, *3D video formats and coding methods*, Image Processing (ICIP), 2010 17th IEEE International Conference, 2010, pp. 2389 – 2392
- [4] Joint Technical Committee (JTC) Broadcast of the European Broadcasting Union (EBU), Comité Européen de Normalisation ELEctrotechnique (CENELEC) and the European Telecommunications Standards Institute (ETSI), *Digital Video Broadcasting (DVB) Technical Specification*, DVB Document A154, February 2011
- [5] NVidia 3D Vision, <http://www.nvidia.com/object/3d-vision-main.html>
- [6] iZ3D, <http://www.iz3d.com/>
- [7] NVidia 3D TV Play, <http://www.nvidia.com/object/3dtv-play-overview.html>
- [8] A. Bierbaum, C. Just, P. Hartling, K. Meinert, and A. Baker, *VR Juggler: A Virtual Platform for Virtual Reality Application Development*, VR-01, IEEE, 2001, pp. 89-96

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