

TOMASZ DĘBIŃSKI, MARCIN HOJNY, DARIUSZ JĘDRZEJCZYK\*

## STEREOSCOPIC VISUALIZATION FOR MODEL OF DEFORMATION OF STEELS WITH MUSHY ZONE

### WIZUALIZACJA STEREOSKOPOWA MODELU ODKSZTAŁCANIA STALI W STANIE PÓLCIEKŁYM

#### Abstract

The paper deals with visualization of results for simulation of a deformation process of a sample with a mushy zone. The numerical model consists of three basic subsystems: the mechanical, thermal and density changes parts. These describe both solid and semisolid deformation states. Taking into consideration their specific distribution graphical visualization is very helpful for understanding the course of the process. Moreover, a three-dimensional presentation is applied in various fields, ranging from medical imaging systems to technological processes assistance to scientific visualizations and entertainment. The stereoscopic imaging technique is still being developed. It is based on the idea of showing each eye the same scene from a bit different perspective. As an effect the illusion of depth is created due to the way the two images are interpreted by the human brain. Stereoscopy is not a new concept, but in the past few years a significant increase in the interest in this method of visualization could be observed. It is caused by computer and audio-visual technology development. In the paper several techniques of creating stereoscopic images are presented together with their physical bases and devices providing such functionality. The use of projection equipment and possibilities of its application to visualization of semi-solid steel deformation is discussed. Apart from that a description of an implementation of OpenGL specification for stereoscopic presentation of computer simulation results is provided.

*Keywords: computer simulation, graphical user interface, stereoscopic visualization*

#### Streszczenie

W artykule przedstawiono użycie techniki stereoskopowej do wizualizacji wyników symulacji procesu nagrzewania i odkształcania stali ze strefą półciekłą. Model numeryczny składa się z trzech oddzielnych podsystemów: mechanicznego, termicznego i przewidyującego zmiany gęstości opisujących odkształcenie strefy stałej i półciekłej. Biorąc pod uwagę specyficzne rozmieszczenie tych stref, wizualizacja jest bardzo pomocna w zrozumieniu procesu. Obrazowanie trójwymiarowe jest szeroko stosowane, począwszy do medycznych systemów obrazowania, poprzez rozrywkę na wizualizacjach naukowych kończąc. Istnieje wiele technik tworzenia obrazów stereoskopowych, ale wszystkie prowadzą do przedstawienia obrazu z nieco innej perspektywy dla każdego oka. Efekt wywołania złudzenia głębi uzyskuje się dzięki interpretacji przez mózg odpowiednio przygotowanych obrazów. Stereoscopia nie jest techniką nową, jednak w okresie ostatnich kilku lat można zaobserwować kolejny wzrost zainteresowania tą techniką obrazowania dzięki rozwojowi technologii komputerowej i audiowizualnej. W artykule opisano kilka technik tworzenia obrazów stereoskopowych wraz z podstawami fizycznymi oraz przykładowymi urządzeniami umożliwiającymi prezentowanie scen stereoskopowych. Omówiono wykorzystywany sprzęt projekcyjny oraz możliwości zastosowania. Ostatecznie przedstawiono sposób implementacji z wykorzystaniem OpenGL oraz stereoskopową prezentację przykładowych wyników symulacji komputerowej.

*Słowa kluczowe: symulacja komputerowa, interfejs użytkownika, wizualizacja stereoskopowa*

\* Ph.D. Eng. Tomasz Dębiński, Ph.D. Eng. Marcin Hojny, Ph.D. Eng. Dariusz Jędrzejczyk, AGH University of Science and Technology.

## 1. Introduction

Despite a wide usage of computer graphics and a three-dimensional graphics presentation, the three-dimensional approach was used in a flat screen visualization.

In the recent years the techniques of generating and presenting computer graphics have seen an increasing interest in stereoscopic visualization technique.

The solution is not new but modern technology enables its wider use in various areas of life. The general rule in stereoscopic display is to visualize different images for both eyes.

On the market there are many available solutions [1]. Originally simple color filters and contemporary linear or circular polarizers are used.

Recently a technology widely used in projection screens (Wavelength Multiplex Imaging WMI, Dolby 3D Digital Cinema) is based on sending different color spectrum to each eye so that different images are combined into one. Such a composed screen can be seen by using appropriate glasses. Simultaneously a developed autostereoscopic display technology does not require use of special glasses in order to achieve the stereoscopic effect [1].

## 2. Stereo rendering techniques

Stereoscopic technology used active and passive projection. In case of active audience using snapshot LCD glasses synchronized with the alternating, images are displayed to the left and right eye [3].

At the time of display for the left eye the right eye shutter is closed and vice versa.

This solution requires a high refresh rate because of the flickering effect. In case of the passive one, polarized light is used and the flickering effect does not occur. Subscribers use glasses containing two opposite polarized filters. One for the left and one for the right eye. The light in each eye is properly polarized and can only pass through a correct filter.

This principle is used to send different images to the left and right eye. In this way, a depth perception can be created. Because the human eye is not sensitive to the polarization of light, changing the polarization does not affect image visibility.

In practice, the system uses linear and circular polarization. If the light is polarized in one of the mutually perpendicular directions it is referred to as the linear polarization. One disadvantage of this projection type is the loss of information necessary for stereoscopic projection in the case of the observer's head deflection.

This is due to incompatibility of polarization glasses and the projector. However this technology is popular due to its low costs in situations where the possibility of head tilting is limited.

In the case of circular polarization the viewer can bend its head and change the viewing angle relative to the displayed stereoscopic images. This is possible because the light is polarized in one direction. Figure 1 shows that even when the filter wheel is rotated the light passes through.

In the case where a stereoscopic image is obtained by using two flat images the parallax phenomenon is used. If the observed object is outside the plane of the projection image for the left eye it is on the left side and for the right eye it is to the right side. The distance between the left and right is called a positive image of a horizontal parallax. If the object is in

front of the plane the projection for the left eye image is displayed on the right side and the right-eye image to the left. This is known as a horizontal negative parallax. The creation of an image of two points on a flat screen is more complex to commonly used approaches [2, 5, 6].

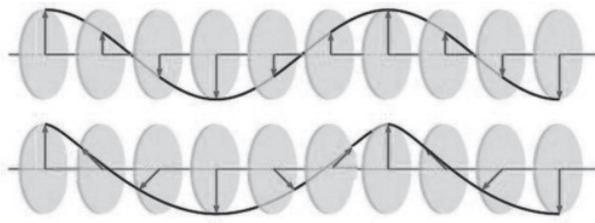


Fig. 1. Comparison between linear and circular filters

**Toe-in** – this approach is used because of the simplicity of the symmetrical projection and there are no special requirements to the used cameras. The cameras are not only shifted relatively to each other, but also rotated and fixed at a common point. That creates a vertical parallax, increasing with distance from the center of the image. This leads to a discomfort for the observer after a long time. Despite the disadvantages of this method it is still used because of an easier use of the cameras in parallel where it is necessary to trim and crop (Fig. 2) [6].

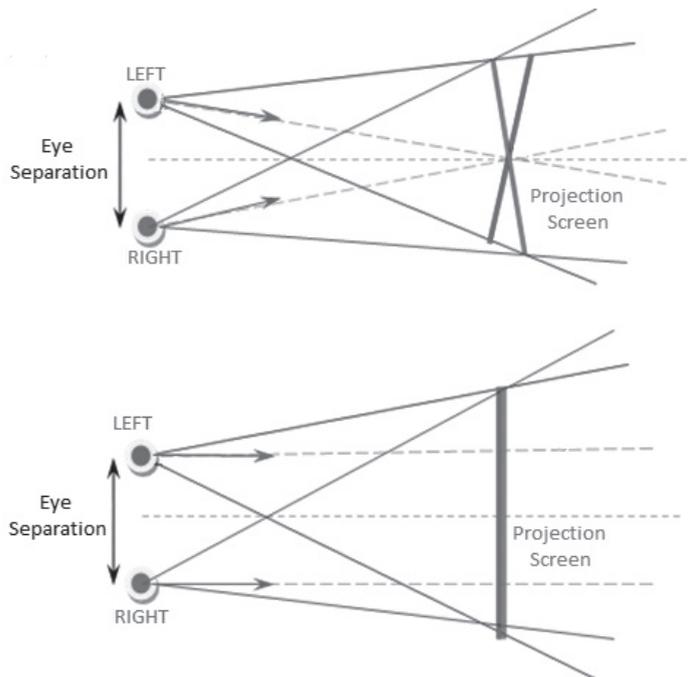


Fig. 2. Diagram of the toe-in and the off-axis (below) methods

**Off-axis** – this is a valid way to obtain stereo images which does not cause a vertical parallax. It is used not only for the horizontal movement but also the camera projection matrix is modified which gives an asymmetric projection result [6].

### 3. Stereoscopic viewing system

The construction of the software to the stereoscopic visualization of results was performed and tested using a system comprising two Gemini Barco IQ R500 LCD projectors. The system provides a modular design enabling the installation of mechanical floor or ceiling cracks first (Fig. 3).



Fig. 3. The modular design of the system based on Barco Gemini

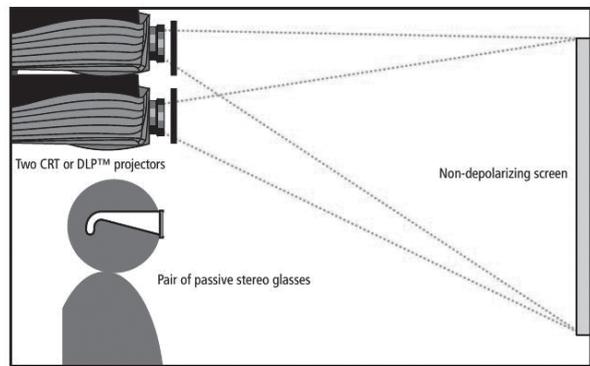


Fig. 4. Chart of the display system

It consists of two projectors with polarizing filters and a screen which does not depolarize light. A schematic of the applied solution was presented on Fig. 4.

### 4. Implementations

Implementations and tests of stereoscopic visualization were performed using OpenGL with nVidia Quad-buffed graphics card (Quadro FX 1500) [7]. Below the perspective projection and projection parameters evaluation are presented (Fig. 5) [8].

For correct setting of perspective parameters, calculation of new left, right, top, bottom parameters is needed.

$$\text{clip}_{\text{near}} = \text{dist} + \text{zero}_{\text{plane}} - \text{near} \quad (1)$$

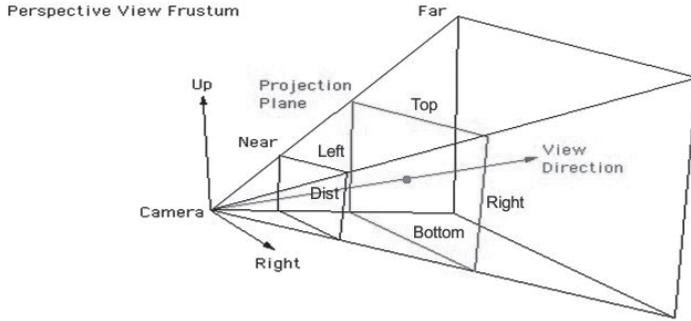


Fig. 5. The perspective projection diagram for one eye's subfield

$$\text{clip}_{\text{far}} = \text{dist} + \text{zero}_{\text{plane}} - \text{far} \quad (2)$$

$$\text{noverd} = \frac{\text{clip}_{\text{near}}}{\text{dist}} \quad (3)$$

$$\text{top}_w = \text{noverd} \cdot \frac{\text{top} - \text{bottom}}{2} \quad (4)$$

$$\text{bottom}_w = -\text{top}_w \quad (5)$$

$$\text{right}_w = \text{noverd} \cdot \left( \left( \frac{\text{right} - \text{left}}{2} \right) - \text{eye} \right) \quad (6)$$

$$\text{left}_w = \text{noverd} \cdot \left( - \left( \frac{\text{right} - \text{left}}{2} \right) - \text{eye} \right) \quad (7)$$

OpenGL function that sets perspective is `glFrustum (...)` [10], the parameters of the view matrix are shown by equation (8).

$$\begin{bmatrix} \frac{2Z_n}{R-L} & 0 & \frac{R+L}{R-L} & 0 \\ 0 & \frac{2Z_n}{T-B} & \frac{T+B}{T-B} & 0 \\ 0 & 0 & -\left( \frac{Z_f + Z_n}{Z_f - Z_n} \right) & -\left( \frac{2Z_f Z_n}{Z_f - Z_n} \right) \\ 0 & 0 & -1 & 0 \end{bmatrix} \quad (8)$$

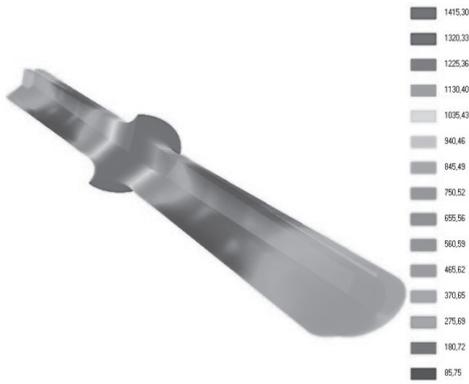


Fig. 6. Temperature (stereo)

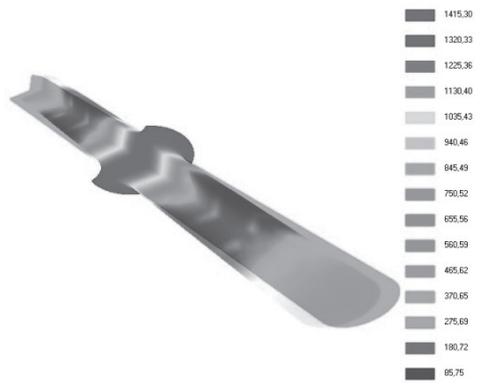


Fig. 7. Temperature (anaglyph)



Fig. 8. Radial velocity (stereo)

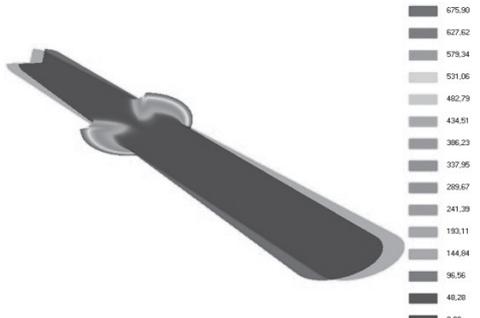


Fig. 9. Radial velocity (anaglyph)

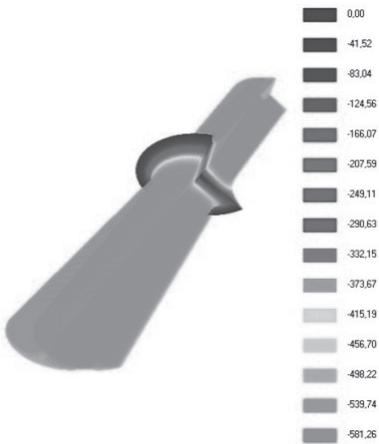


Fig. 10. Axial velocity (stereo)

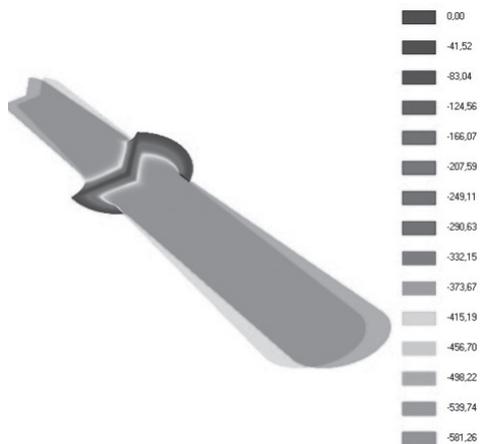


Fig. 11. Axial velocity (anaglyph)

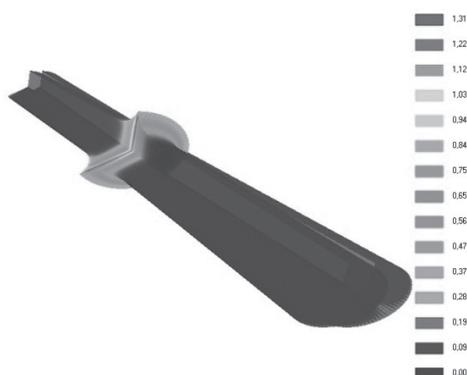


Fig. 12. Intensity of strain (stereo)

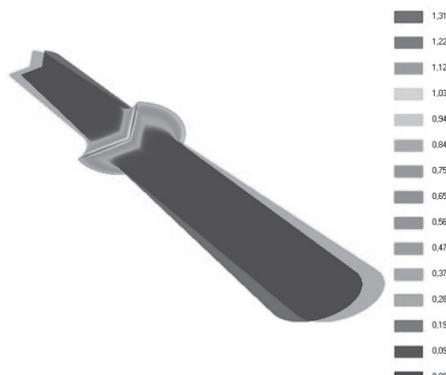


Fig. 13. Intensity of strain (anaglyph)

Where the *right-left* ( $R, L$ ) and the *top-bottom* ( $T, B$ ) variables are the coordinates of the clipping rectangle (projection screen) – the coordinate range, in the plane of zero parallax setting, which will be displayed on the screen. The ratio between (*right-left*) and (*top-bottom*) should equal the aspect ratio of the display. The *near* ( $Z_n$ ) and *far* ( $Z_f$ ) parameters are the z-coordinates values of the clipping planes with *zero plane* parameters as zero plane of zero parallax setting. The next most important parameter is *dist* – the distance from the center of projection to the plane of zero parallax with the *eye* value representing half of the eye separation. The eye obtains a positive value for the right eye subfield and a negative one for the left eye subfield. The projection is in the direction of the negative z-axis.

The discussed algorithms were used in visualization of the calculations results for the heating and deformation process with the semi-zone. Because the process is difficult and complex, both technically and numerically, thus presenting the visualization technique will facilitate the interpretation of the results of calculations. The examples of results on the following pictures from 6 to 13 in both techniques (quad buffer, anaglyph) were presented.

#### 4. Conclusions

In this article the problem of stereoscopic projection is presented with the most frequently used techniques and their advantages and disadvantages. The implementation techniques, modifications in OpenGL projection matrix are also presented. The stereoscopic visualization hardware and its applicability is tested. The best way for stereoscopic visualization is to use a dedicated hardware with a quad buffer, as the anaglyph presentation can cause incorrect display of colors.

Finally, the application for visualization of simulation for the deformation process of a sample in a semi-liquid state was presented. This type of presentation allows a better reception for the observers by making it easy to interpret results.

*The project has been supported by the Polish National Science Centre, Decision number: DEC-2011/03/D/ST8/04041.*

## References

- [1] <http://www.barco.com> (online: 15.12.2014).
- [2] *3D Revolution Productions*, <http://www.the3drevolution.com/3dscreen.html> (online: 15.12.2014).
- [3] Grasberger H.: *Introduction to stereo rendering*, Institute of Computer Graphics Vienna University of Technology, Vienna 2008.
- [4] Holliman S., Dodgson N., Favalora G., Pockett L., *Three-Dimensional Displays: A Review and Applications Analysis*, Ieee Transactions on Broadcasting, Vol. 57, No. 2, June 2011.
- [5] *OpenGL*, <http://www.songho.ca/opengl> (online: 15.12.2014).
- [6] *Information related to stereographics*, <http://paulbourke.net/stereographics> (online: 15.12.2014).
- [7] NVidia documentation manual, [www.nvidia.com](http://www.nvidia.com) (online: 15.12.2014).
- [8] Hawkins K., Astie D., OpenGL. ProgramowanieGier, Helion, 2003.
- [9] *Rendering 3D Anaglyph in OpenGL*, <http://www.animesh.me/2011/05/rendering-3d-anaglyph-in-opengl.html> (online: 15.12.2014).
- [10] *OpenGL*, <http://www.opengl.org> (online: 15.12.2014).