Modular Visualization Environment and Parallel Processing

Václav Skala[1]
Department of Computer Science
University of West Bohemia, Box 314, 306 14 Plzeň, Czech Republic
skala@kiv.zcu.cz http://iason.zcu.cz/~skala

Abstract

The latest technology development has brought traditional visualization closer to users especially to users of the Intel IA32 (PC) platform. Generally the expression "visualization" means data processing in the way that a human being can imagine the physical or other phenomena represented by the given data sets. Although the visual understanding is nearly understood exclusively the term should be extended to more general sense. Visualization covers many fields of computer science, like numerical computation, graphics, parallel and distributed processing etc. On the other hand the application fields must be understood and the human perception must be understood and respected as well.

Several features of visualization in this platform are described including some new results obtained recently, expected development and open problems as well.

Keywords: algorithm complexity, computer graphics, visualization, parallel and distributed processing, visualization precession, volume data, triangular mesh reduction, stereoscopy.

1. Introduction

Data visualization is one of "hot fields" of computer science and its applications nowadays. During the last period standard visualization approaches have been developed for high-end computing systems and sometimes the supercomputing expression is used. Nevertheless during that period many conditions have been changed and computational power of today's Intel based computers is comparable with systems using RISC processors. The distribution of the visualization and computational load to graphics cards with graphics accelerators has changed many things in visualization. Also the performance-cost ratio is nearly of one magnitude better for Intel based systems.

Many algorithms presented in the last period have been developed for standard environment under the UNIX operating system, mostly based on

- SGI or SUN workstations with R10000 processors and "reasonable" size of memory,
- Intel IA 32 standard architecture, mostly using processors up to 233MHz and 256MB RAM.

This situation has been changed recently very significantly because of the huge production of Intel based platform and graphics cards. The cost of IA 32 systems is more or less the same as recently, but the computational performance and graphics acceleration have been increased significantly.

[1] This work was supported by the Ministry of Education of the Czech Republic - project MSM23500005

The standard configuration for the computer graphics and data visualization courses and research at the University of West Bohemia is PIII 550MHz (some of them with 2 processors) – P4 1,4 GHz, 512MB or 1GB RAM memory and 100Mb/s switched network. Graphics cards are of the TNT RIVA or Intergraph WildCat productions. The WildCat graphics card offers 2,300 GFLOPS with full OpenGL support. There is a limited access to 8 processors DELL PowerEdge computer and to UNISYS 32 processors shared memory computer.

Availability of multi-processors systems with shared memory systems based on IA 32 platform has changed the situation in this field, too. Many motherboards are already prepared for the 2-nd processor to be inserted. The availability of standard software tools and compilers with large repository of utilities available on the Internet have made also significant change in the use of the Intel platform.

There is a believe that this situation will be changed again as the new IA 64 architecture is to be available on the market soon and some limitations (like addressability of 4 GB etc.) and others barriers will just disappear.

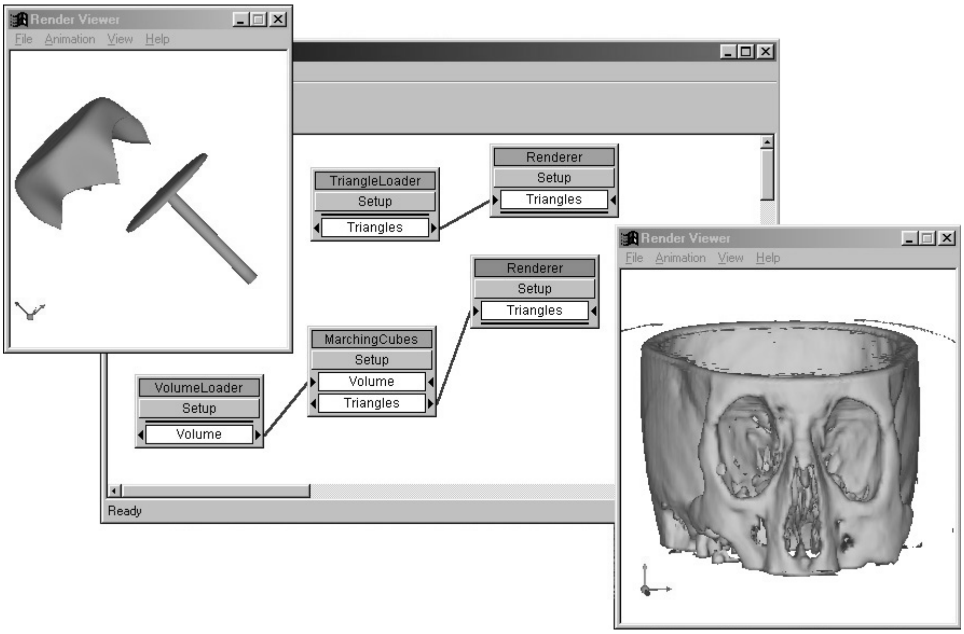


Figure 1: Example of the MVE use

2. Visualization environment

Recently the visualization programs were prepared according to the actual needs and also the algorithms were developed specifically for the application. Because of the high cost of labour and short period that is available between the problem formulation and experiments with data exploration the Modular Visualization Environments (**MVE**) have been developed, like IBM Data Explorer, AVS etc., and used nowadays. Those systems are commercially available, but they are expensive. All those MVE's are based on the data-flow approach when general modules are connected together in the way that the data are processed and transferred to another module, Fig.1 shows a simple example.

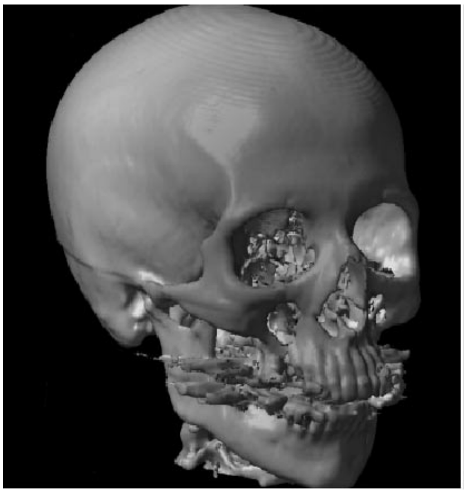
This approach enabled a significant speed-up of data exploration. Because of the huge data processing the very important feature of the MVE is the way how the data are transferred from one module to another one. The reasonable way is to transfer just the pointer do the data structure allocated in the shared memory, but it makes implementation more complicated and some MVE's just transfer the whole data volume between modules. It was also a reason why the MVE system has been developed at the University of West Bohemia. Details on the MVE system can be found at http://herakles.zcu.cz including the Users and Programmers Guides. The MVE system can be downloaded and used free for non-commercial purposes as well.

3. Volume data processing

There are many fields where the visualization can be used, but the volume data processing and visualization is probably one of the most challenging fields. The volume data are often acquired by scanning material of interest by using MRI (Magnetic Resonance Imaging), CT(Computer Tomography), PET(Positron Emission Tomography) and others scanning devices. The volume data representation is not restricted to medical data and it is used in technical applications etc., too

The "standard" volume data are organised as a cube of voxels with resolution of 128x128 up to 1024x1024 in one slice. Number of slices can differ significantly. Some attributes (scalar, vector etc.) are associated with each voxel, usually only scalar value is associated, nowadays. It can be seen that the memory requirements grow cubically with the resolution of the data. It means that we have to process data of 10MB to 10GB size.

There are some highly special graphics cards, like VolumePro [Rtvi00a], that enable to process the volume data and visualize them, but the size of volume data is limited to 512 x 512 x 256 voxels.



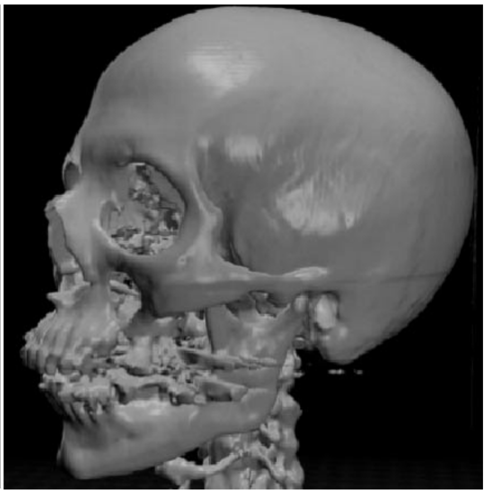


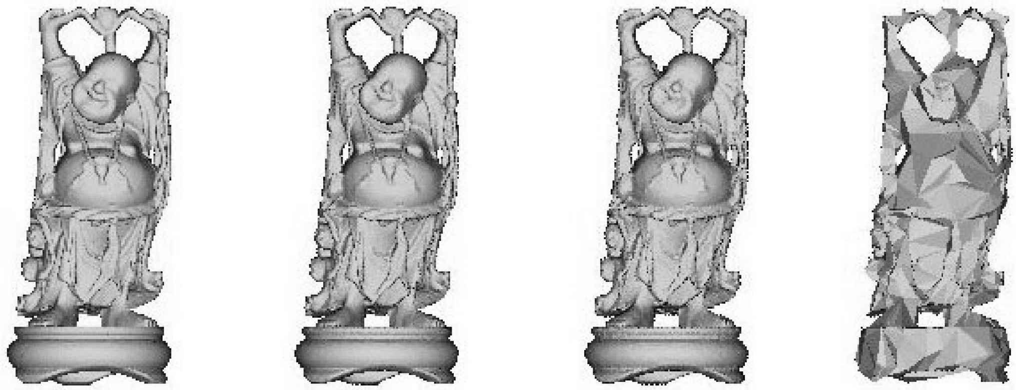
Figure 2a: Marching cube method Figure 2b: Direct visualization method

The very often way to display volume data is visualization of the iso-surface. Two approaches are used generally, i.e.:

- direct iso-surface visualization - the image must be recomputed and updated when the observer's position is changed; generally the ray-tracing method is used [Kroc00a], see fig.2b.
- iso-surface extraction using triangular mesh - the size of the triangular mesh is very high, usually about 10^5 - 10^6 triangles are extracted, but all geometric transformation with the triangular mesh including viewing are made in hardware of the graphics cards if the graphics card support the OpenGL API.

The favourite Marching Cubes (MC), or Marching Tetrahedra (MT) methods [Bart99a], [Krej00a], see fig.2a, are used in the vast majority.

The advantage of this approach is the possibility to reduce obtained triangular mesh without significant loss of details that enables much faster graphical processing [Fran00a]. Fig.3 presents some results from triangular mesh reduction. The considered data size can be processed by systems based on IA 32 platform if the acceptable processing time is in seconds for data sets with millions of triangles. If this response time is too high there seems to be a possibility to use parallel and distributed processing.



1 087 716 triangles | 105 588 triangles | 52 586 triangles | 13 100 triangles

Figure 3: The Happyb model at different resolutions (data courtesy of GaTech repository)

4. Parallel processing

Parallel and distributed processing seems to be very promising for computational and visualization purposes, indeed. There are several approaches to the parallel processing, but the processing using shared memory system seems to be the very native solution if such systems are available, especially if the use of threads is applicable, preferably without critical sections.

It is well known that the Amdahl's law gives the maximal acceleration a_{teor}

$$a_{teor} = \frac{1}{(1-p) + \frac{p}{N}}$$

where: N is a number of processors,
p is the ratio of the parallel code and whole sequential code

It can be seen that p can be expressed from the experimental results as

$$p = \frac{N * (1 - a_{teor})}{a_{teor} * (N-1)}$$

where: a_{teor} is the acceleration obtained from experiments.

If the parallel processing is used the ratio p of parallel and sequential parts of the program should be analysed from experiments made in order to understand the behaviour of the program.

Fig.4 shows the behaviour of the triangular mesh decimation, see [Fran00b] for details, where 97% of the code has been done in parallel. It presents a stability of the approach taken for large triangular meshes, about 10^6 of triangles, and high stability according to the number of processors used as the ratio p actually slightly grows with the number of processors used.

The maximal theoretical speed-up for the infinite number of processors a_∞ is given as:

$$a_\infty = \frac{1}{0.03} = 33.33...$$

It means that the parallel processing has some limits that cannot be overcome. In reality a lower speed-up must be expected due to other reasons, see [Panc96a].

Another possibility is the distributed processing that is very often discussed. Unfortunately due to the very large amount of data that are processed our experience proved that the data transfer is significantly longer on the switched 100 Mb/s Ethernet than the processing on a computer with a single processor. Of course, there are some applications, where a small amount of data is processed and problem can be split to independent parts. In this kind of applications the distributed processing is applicable more or less without problems.

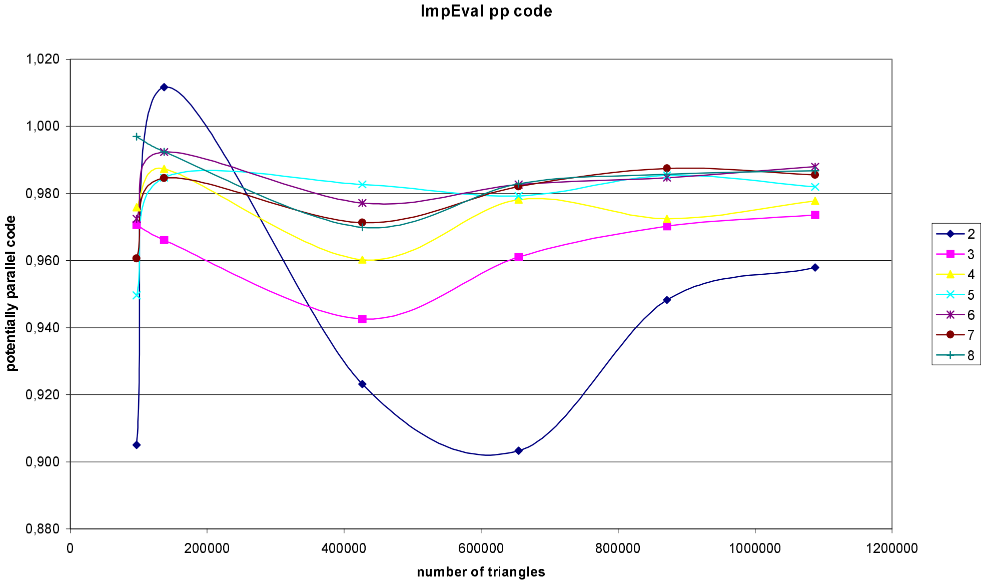


Figure 4: Behavior of *p* according to the number of processors used and triangular size mesh

5. Spatial perception

Generally the expression "visualization" means data processing in the way that a human being can imagine the physical or other phenomena represented by the given data sets. Visualization is nearly exclusively understood as the visual understanding, but this should be extended also to imagination in general, e.g. visualization for blind people etc. Also "visualization" is mostly connected to the visualization using a screen in some sense. There are very expensive devices for visualization, like VR Caves, VR Raves or VR working rooms, see fig.5 and fig.6 [Fake00a] that enables to interact with the VR environment.

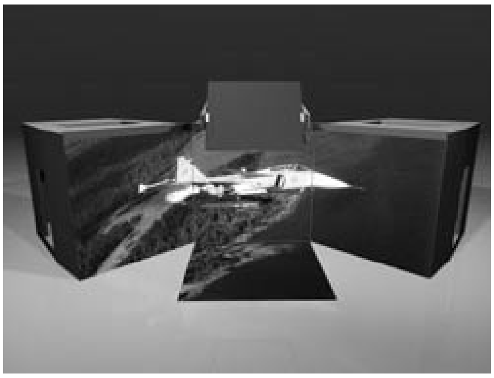


Figure 5: VR Rave

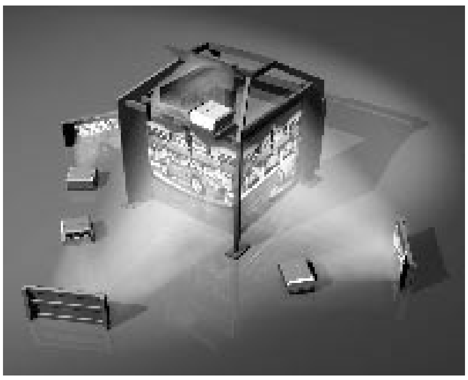


Figure 6: VR working room

Courtesy of Fakespace Comp

On the other hand "cheap" graphics PC cards do offer also LCD stereo-glasses, nowadays. It means that the visualization, even for small applications, moves towards to the visualization in the three-dimensional space.

Several devices for spatial perception have been developed and are used. A vast majority of them are based on stereoscopic projection mostly using light polarisation in some sense and different images are produced for each eye. They can be classified as:

- "passive" glasses with different orientation of polarised light produced by the source of the light,
- "active" glasses - each eye is blind for every second frame and this is synchronised with displaying images for the left and right eyes,
- anaglyph glasses - image has only red and blue colours and each eye has a colour filter (not used often nowadays).

Those approaches have several disadvantages, e.g.

- they are restricted only to "light active" devices that "produce" light,
- there is no possibility to make a printed version that can be viewed and understood without glasses nor stereo-viewed using glasses.

There are new approaches in development of new devices or in experimental use that can be seen nowadays. They are based on new principles, like Holographics autostereoscopic displays [Tray99a].

On the other hand there are simple devices available, like the ChromaDepth 3D glasses [Chro99a]. They are made of a high precision micro-optics lens, which create a stereo pair from a single image. The principle of is that the red colour is "bend" more than the blue colour if passing through a lens or an optical prism. The lenses accomplish this by shifting the image colours in different directions for each eye. The concept is straight-forward: encode depth into an image by means of colour, then decode the colour by means of optics, producing a true, stereoscopic, three dimensional image. Since colour is used to represent depth information, the depth-encoded image is a single pseudo-coloured image [Bail98a].

Of course, it is not possible to create true colour stereo images as the colour is used for depth coding. Nevertheless this approach has several advantages:

- no expensive devices are needed and images can be printed by colour printer preserving stereo perception if glasses are used,
- images can be viewed without glasses but the stereo perception is lost of course,
- OpenGL can be used to create images.

Fig.2a and 2b present pictures with the stereo perception with Chroma glasses.

All those new principles give a new dimension to the field of visualization, as the data exploration is becoming more affordable for smaller institutions as well as to the individual users.

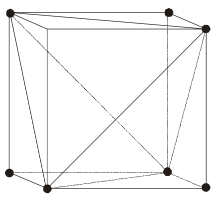


Figure 7.a: 5/6 tetrahedra scheme

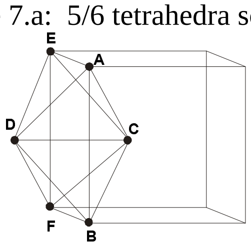


Figure 7.b: 12 tetrahedra scheme

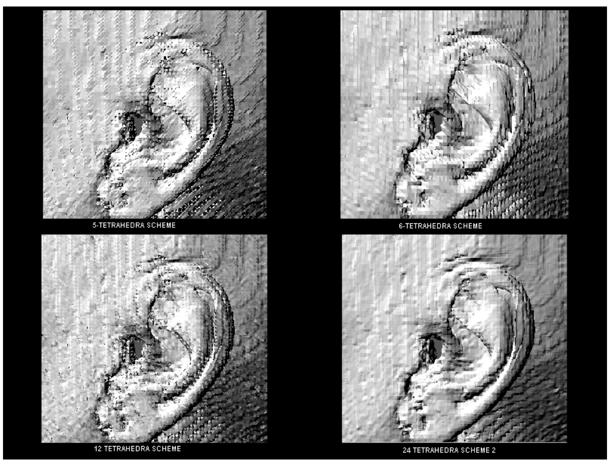


Figure 8: Examples if different tessellation are used

6. Visualization precision

The precision of visualization is not usually mentioned if some algorithms are presented, although it is extremely important as in some cases it might cause wrong and dangerous interpretation of the obtained results. There are two main aspects: precision of visualized phenomena and perception interpretation. Iso-surface extraction methods, like MT using 5, 6, 12 and 24, resp. 48 or other tessellation schemes are used very often. Fig.8 shows obtained results for the MT method if 5, 6, 12 and 24 tetrahedra tessellation is used.

There was believe that if a tessellation with more tetrahedra is used the better results are obtained. Of course if a tessellation with more tetrahedra is used the longer computation is required and also more memory is needed as more triangles are obtained. Some experiments have been made recently to find out more, see [Skal00b] for details.

The obtained results were quite surprising. The experiments proved that if tessellation with more tetrahedra is used the "better" image is obtained, but the surface of the final triangular mesh and the volume of the covered by this mesh have greater error [Skal00a].

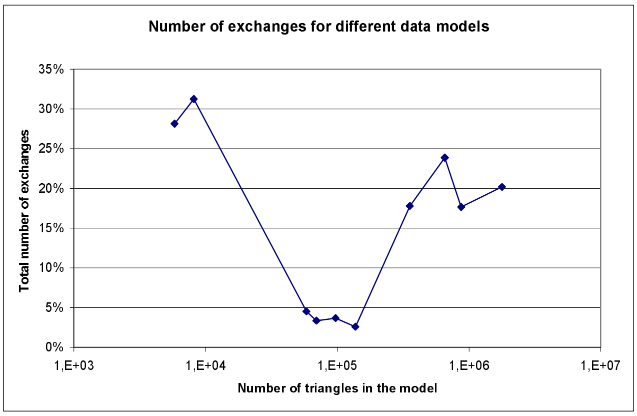


Figure 9: Edges exchanges of the triangular mesh

Triangular mesh is very often used for surface representation. Generally there are some edges that are important (compulsory) and edges that can be swapped as they just split a four-sided polygon to two triangles. The triangular mesh can be optimised in order to get a smaller surface of the triangular mesh as much as possible. Fig.9 shows the number of exchanges for different data sets. From experiments made can be seen that about 20% of exchanges can be expected for large data sets. This optimisation has an influence to the final model. Fig.10 shows the original model, fig.11 presents the result after the mesh optimisation.

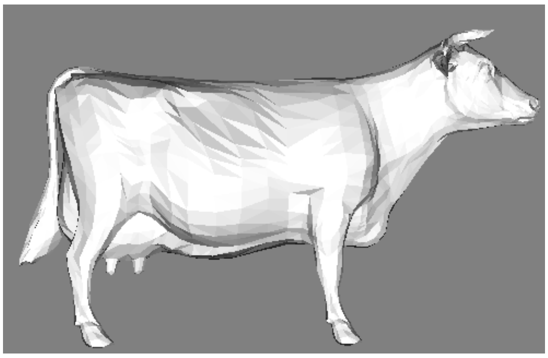


Figure 10: Before the mesh optimisation

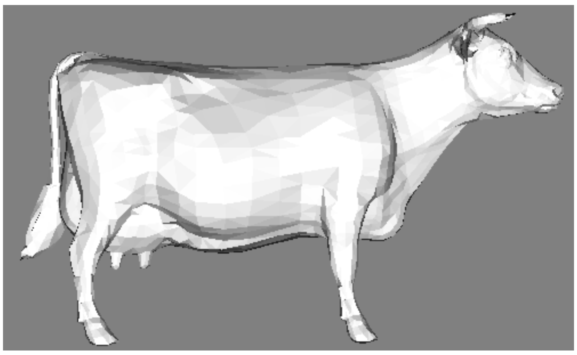


Figure 11: After the mesh optimisation

7. Conclusion

Several aspects of visualization have been presented based on experience of larger data sets processing on Intel PC platform with some expectation for the nearest future. The author believes that there should be high importance given to the precision, robustness of new algorithms for visualization as well as to the other aspects of new algorithm's implementation.

8. Acknowledgments

The author would like to thanks to all who contributed to this work, especially to MSc. and PhD. students at the University of West Bohemia in Plzen who have stimulated this thoughts and development of this new algorithms mentioned. This paper benefits from several discussions with them a lot. Special thanks belong to P.Bartos, M.Franc, M.Krejza, J.Doubek, M.Krocak for experimental implementation and especially to M.Rousal for careful implementation of MVE the run-time module.

9. References

[Bail98a] Bailey,M.: SDSC, Univ.of California, http://www.sdsc.edu/~mjb, 1998.

[Bart99a] Bartos,P. (Supervisor Skala,V.): Surface Models of Volumetric Data, MSc.Thesis (in Czech), UWB, Plzen, 1999.

[Brod92a] Brodlie,K,W. & others (Eds.): Scientific Visualization, Springer Verlag, 1992.

[Chro99a] ChromaDepth lenses, ChromaTek, Inc., http://www.chromatek.com, 1999.

[Earn92a] Earnshaw,R.A., Wiseman,N.: An Introduction Guide to Scientific Visualization, Springer Verlag 1992.

[Fake00a] VR Raves, Fakespace Comp., http://www.fakespace.com, 2000.

[Fran00a] Franc,M., Skala,V.: Parallel Triangular Mesh Reduction, Algorithms'2000 Int.Conf. proceedings, Slovak Republic, 2000.

[Fran00b] Franc,M. (Supervisor Skala,V.): Methods for triangular mesh Reduction, MSc.Thesis (in Czech), UWB, Plzen, 2000.

[Krej00a] Krejza,M. (Supervisor Skala,V.): Methods for Iso-surface Visualization and Iso-Surface extraction from Volumetric Data, MSc.Thesis (in Czech), UWB, Plzen, 2000.

[Kroc00a] Krocak,M. (Supervisor Skala,V.): Methods for Direct Volume Data Visualization, MSc.Thesis (in Czech), UWB, Plzen, 2000.

[Panc96a] Pancake,C.M.: Is Parallelism for You? Rules-of-Thumb for Computational Scientists and Engineers, *Computational Science & Engineering*, Vol. 3, No. 2pp., 18-37, 1996.

[Rous00a] Rousal,M., Skala,V.: Modular Visualization Environment, CEI Int.Conf., accepted for publication, Slovak Republic, 2000.

[Rtvi00a] VolumePro Graphics Card, Real Time Visualization, http: //www.rtviz.com, 2000.

[Skal00a] Skala,V., Brusi,A.: Two Methods for Iso-Surface Extraction from Volumetric Data and Their Comparison, Machine Graphics&Vision, Vol.9, No.1/2, GKPO2000 Conf.Proceedings, Poland, 2000.

[Ska00b] Skala,V.: Precision of Iso-surface Extraction from Volume Data and Visualization, Algorithms'2000 Int.Conf. proceedings, Slovak Republic, 2000.

[Tray99a] Traner,D., Orr,E.: Autostereoscopic Display Using Holographic Optical Elements", Stereoscopic Displays and Virtual Reality Systems III SPIE proceedings, Vol.2653, Advanced Imaging, May 1999.