# VISUALIZATION AND SPATIAL PERCEPTION

**Václav Skala**

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**

Generally the expression "visualization" means data processing so 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 field must be understood and the human perception must be understood and respected as well.

Significant change caused by the latest technology development has brought traditional visualization closer to users especially to users of the Intel IA32 (PC) platform. Several features of visualization in this platform are described including some new results obtained recently and expected development and open problems as well.

**Keywords:** algorithm complexity, computer graphics, visualization, parallel and distributed processing, visualization precession.

## 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 card with graphics accelerators has changed many things in visualization. Also the power-cost ratio is nearly of one magnitude better for Intel based systems.

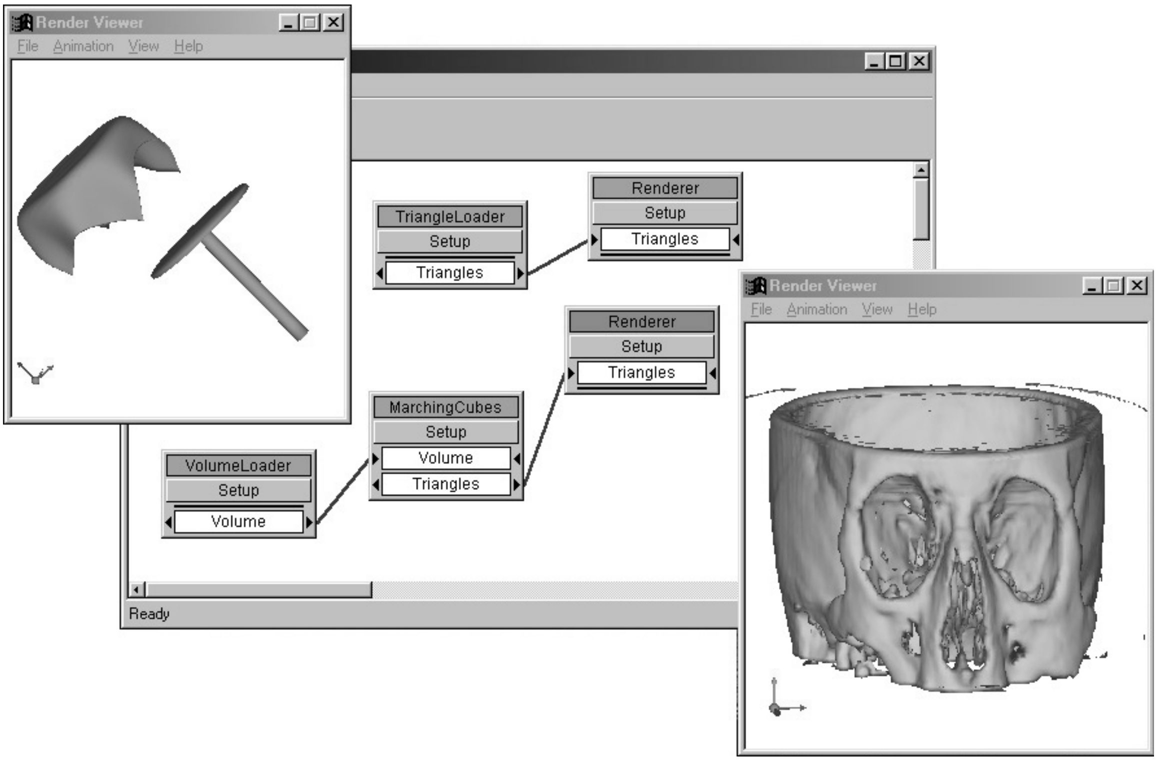
Many algorithms presented in the last period have been developed for standard environment under the UNIX operating system, mostly based on

- SGI or SUN workstations with R10000 processors and "reasonable" size of memory,
- Intel IA 32 standard architecture, mostly using processors upto 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, but the computational power and graphics acceleration has been increased significantly.

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), 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.

Availability of multi-processors 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




Example of the MVE use
Figure 1

utilities available on the Internet has made also significant change to 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 (September 2000 is expected) and some limitations (like addressability of 4 GB etc.) and barriers will just disappear.

## 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 data exploration experiments the Modular Visualization Environment (**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 accurately, see fig.1, where a simple example is presented.

This approach enabled a significant speed-up of data exploration. Because of the huge data processing the very important part of the MVE is the way how data are transferred from a module to another one. The reasonable way is to transfer just the pointer do data structure allocated in the common memory, but it makes some things 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.

## 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 field. 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 are not restricted to medical data and they are used in technical problems etc., too

The "standard" volume data are organised as a cube of voxels with resolution of 128x128 upto 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 cubical with the resolution of the data. It means that we have to process data of 10MB to 10GB size.

There are some highly special hardware 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.

The very often way to display volume data is visualization of the iso-surface when 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.2a.
- iso-surface extraction using triangular mesh, but the size of the mesh is very high, usually about $10^5$ - $10^6$ triangles are extracted; the advantage is that all geometric transformation including viewing are made in hardware of the graphics cards if the graphics card support the OpenGL.

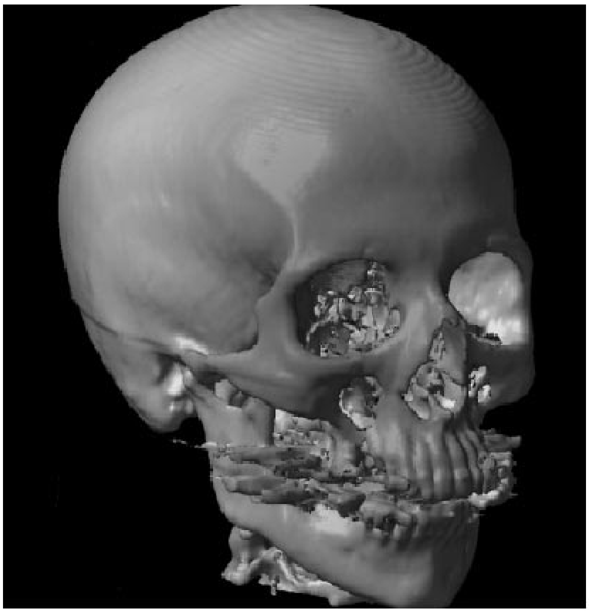
The favourite Marching Cubes (MC), or Marching Tetrahedra (MT) methods [Bart99a], Krej00a], see fig.2b, are used in vast majority.

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], see fig.3.

The considered data size can be processed by systems based on IA 32 platform if the acceptable processing time is in seconds. If this response time is too high there seems to be a possibility to use parallel and distributed processing.

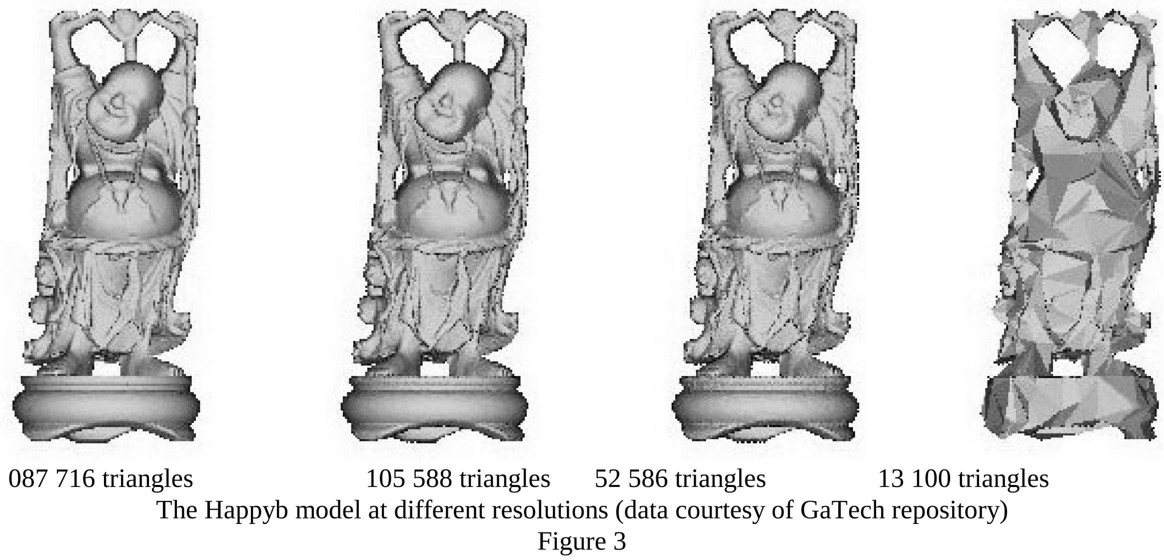
## 4. PARALLEL AND DISTRIBUTED PROCESSING

Parallel and distributed processing seems to be very promising for the visualization purposes, in deed. There are several approaches to the parallel



Marching cube method
Figure 2a

Direct visualization method
Figure 2b



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

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

Figure 3

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.

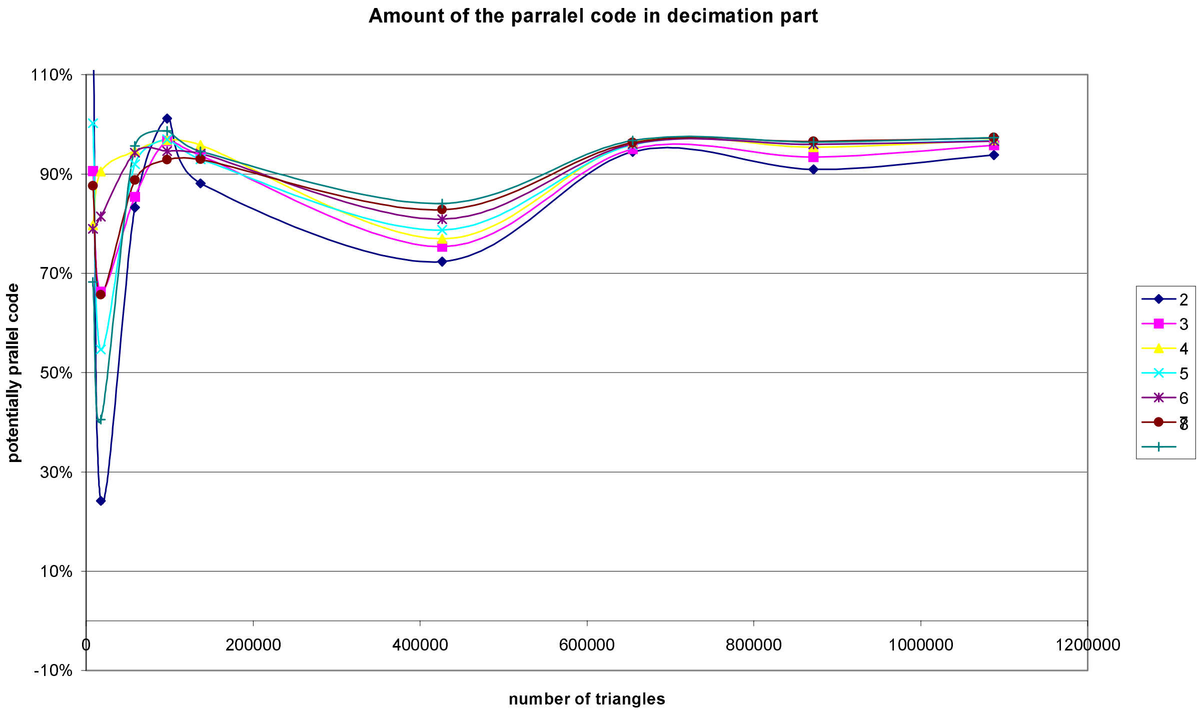
Fig.4 shows the behaviour of the triangular mesh decimation, see [Fran00b] for details, where 97% of the code has been done in parallel. It presents a stability of the approach taken for large triangular meshes, about $10^6$ of triangles, and high stability according to the number of processors used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

The maximal theoretical speed-up for the infinite number of processors $a_\infty$ 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].

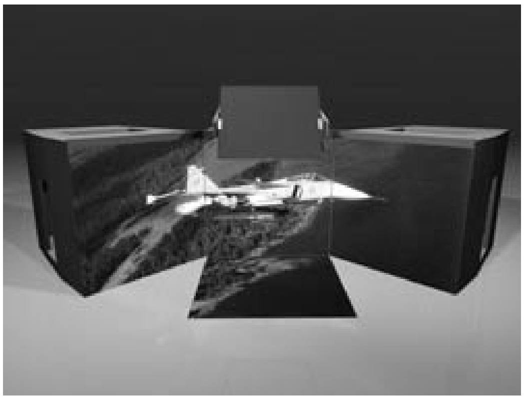
Another possibility is the distributed processing that is very often discussed. Unfortunately due to the very large amount of data that are processed our experience proved that the data transfer is significantly longer on the 100Mb/s switched Ethernet than the processing on a computer with a single processor. 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.



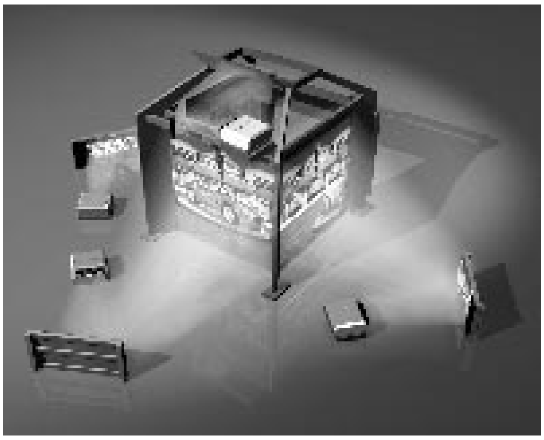

Behavior of $p$ according to the number of processors used and triangular size mesh
Figure 4

## 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 genaral, 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.



VR Rave, courtesy of Fakespace Comp.
Figure 5



VR working room, courtesy of Fakespace Comp.
Figure 6

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 space.

Several devices for spatial perception have been developed and 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 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 can be seen nowadays. They are based on new principles, like Holographics autostereoscopic displays [Tray99a] etc.

On the other hand there are simple devices available, like the ChromaDepth 3D glasses [Chro99a]. They are made of a high precision micro-optics lenses which creates 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 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,
- images can be printed on 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.2 and fig.11 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.

## 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 obtained results. There are two main aspects: precision of visualized phenomena and perception interpretation.

development of this new algorithms mentioned. This paper benefits from several discussions with them a lot. Special thanks belong to J.Doubek for the experimental implementation and to anonymous reviewers of this paper as they shared some valuable insights on this problem solution.

## REFERENCES

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

[Bart99a] Bartos,P. (Supervisor Skala,V.): Surface Models of Volumetric Data, MSc.Thesis (in Czech), Univ.of West Bohemia, 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., accepted for publication, Slovak Republic, 2000.

[Fran00b] Franc,M. (Supervisor Skala,V.): Methods for triangular mesh Reduction, MSc.Thesis (in Czech), Univ.of West Bohemia, 2000.

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

[Kroc00a] Krocak,M. (Supervisor Skala,V.): Methods for Direct Volume Data Visualization, MSc.Thesis (in Czech), Univ.of West Bohemia, 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.

[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.

[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.: Precission of Iso-surface Extraction from Volume Data and Visualization, accepted for publication at Algorithms'2000 Int.Conf., Slovak Republic, 2000.

Map of the world, courtesy of M.Bailey and SDSC Center, Univ.of California, USA

Figure 11