

# Main Features of the ScientificVR<sup>®</sup> Visualization Package.

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**Abstract:** This article is devoted to description of architecture and abilities of new visualization system **ScientificVR<sup>®</sup>**, visualizing different data formats and handling the abstract type of information. Most outstanding features of the package are plug-in architecture, semitransparent voxel graphic and full color 3D stereoscopic presentations. The **ScientificVR<sup>®</sup>** is based on modular architecture, which makes it possible to endow the already installed package with new capabilities by way of hooking up required external modules. Thus, the same package could be used for handling diverse data in wide range of applications.

**Keywords:** Visualization, Voxel, Stereoscopic Vision, Animation, Plug-ins, CFD.

## 1. Introduction

Data visualization in scientific research projects is an indispensable part of modern investigation of all kinds of phenomena in practically every branch of natural science. Graphic presentation in the form of color distributions or functional dependences considerably simplifies the perception of large blocks of data by human brain. This feature is especially important for handling complex 3D data arrays, which are usually peculiar to numerical modeling procedures.

Existing PC-based visualization systems do have certain limitations. It is therefore deemed highly appropriate to create a new system of visualization with expanded performance, which would be devoid of the abovementioned drawbacks.

This article is devoted to description of architecture and abilities of new visualization system **ScientificVR<sup>®</sup>**. Historically this system was created on the base of **GasDynamicsTool<sup>®</sup>** (Zibarov, 1999) software package (<http://www.cfd.ru/>) where visualization functions were used for its internal needs. The idea of visualization block detachment into separated program product with considerable expansion and deepening of its abilities occurred parallel to beginning of works at creation a fifth generation of package **GasDynamicsTool<sup>®</sup>** in February 2000 year. The development of package architecture which would be allowed to visualize both the GDT package data and one the another formats are the main aim of this work.

Most outstanding features of the package are plug- in architecture, semitransparent voxel graphic and full color 3D stereoscopic presentations. The **ScientificVR<sup>®</sup>** is based on modular architecture, which makes it possible to endow the already installed package with new capabilities by way of hooking up required external modules (plug-ins). Thus, the same package could be used for handling diverse data in wide range of applications.

Both software designers and package users can well elaborate plug-in modules for the **ScientificVR<sup>®</sup>** system. This kind of architecture has made it possible to score considerable flexibility in abstract data complex visualization.

## 2. Basic principles of the ScientificVR<sup>®</sup> architecture

Traditional visualization systems consist of three main parts: the data loading subsystem, the image creation subsystem and the image output subsystem. The data loading subsystem read the data in the format it knows and hand it over into the image creation subsystem. It, for it's turn, forms the image using the inputting data. Then obtained image is given up to the image output subsystem, which takes out the image into the screen or saves it in the appointed format.

What disadvantages does the traditional system have?

- ❑ The data loading subsystem can to process the data presented only in the appointed format, seldom in a few different formats. However, most of all user data is stored in its own format, which cannot support to the visualizer data loading subsystem usually. So, to use this data one needs to apply the special means transforming users data into appropriate format supported by the visualizer data loading subsystem.
- ❑ The image creation subsystem also is confined to one or several formats of storing the images. If the user want to output the image in another but supported format, he would be had to use the image transformation facilities into needed format.
- ❑ The image creation subsystem is able to create only that type of image, which is putted into. As far as the different categories of users demand to make one type of images and do not need another types, one can see the situation, when having the vast set of visualization abilities user cannot choose the one he wants to.

**ScientificVR<sup>®</sup>** visualizer is the attempt to eliminate these shortcomings. Its architecture is consummate and more flexible due to plug-in modules, allowing unlimited extension each of five its subsystems (Figure 1.):

- ❑ Data input
- ❑ Transformation of coordinates
- ❑ Functional transformation
- ❑ Image creation
- ❑ Image output

It achieves due to any subsystem represents the family of plug-in modules; each of them carries out for one special function. For example, each plug-in module for the data input subsystem supplies with data input into single format. So, the addition of plug-in modules to subsystem can provide for data input stored in absolutely various format. At the same time the ability of synchronous data processing is occurred and the data may have a different origin (for example, one can create the image with simultaneous visualization of experimental and numerical results)

If the set of plug-in modules furnished with system do not satisfy with the user requirements, it is possible to find appropriate modules (for example, in the Internet) or to make it itself using any accessible instrumental tools.

Another distinguishing feature of Visualization Package **ScientificVR<sup>®</sup>** is the presence of transformation of coordinates subsystem and functional transformation subsystem. Orthogonal projection is an example of coordinate transformation. Each coordinate transformation is realized by single plug-in module and they are gathered into subsystem.

Functional transformation subsystem consists of modules, which create secondary data from the input data stream by the appointed rule. The examples of functional transformation are scalar field gradient, vector field divergence, and function of scalar or vector argument. Transformation of coordinates and functional transformation subsystems can be used more than once and in random order, what allows to get any quantity of important secondary data values from the input ones. For example, ones spatial scalar field  $F$  is given then applying transformation of coordinates “projection into plane” generated by some coordinate axis and functional transformation “scalar function gradient” one can get following secondary data: spatial vector field  $grad F$ , two-dimensional scalar fields  $F_{XOY}$ ,  $F_{XOZ}$ ,  $F_{YOZ}$  and two-dimensional vector fields  $grad F_{XOY}$ ,  $grad F_{XOZ}$ ,  $grad F_{YOZ}$ .

Image creation subsystem includes plug-in modules each of them applies for creation images of appointed type, for example, spatial semi-transparent 3D voxel graphics, vectors, iso-line, iso-surfaces, stream lines and so

on. Images created by this plug-in modules are combined by user to get most impressive visual and informative data recognition.

Each of plug-in modules image output subsystem is able to store the image in single format, and user has the ability to store image in random formats using appropriate modules.

### 3. Functioning and abilities

The package possesses wide field of functional abilities, types of data visualization, and different operation under scalar and vector arrays, and types of output formats. Among them:

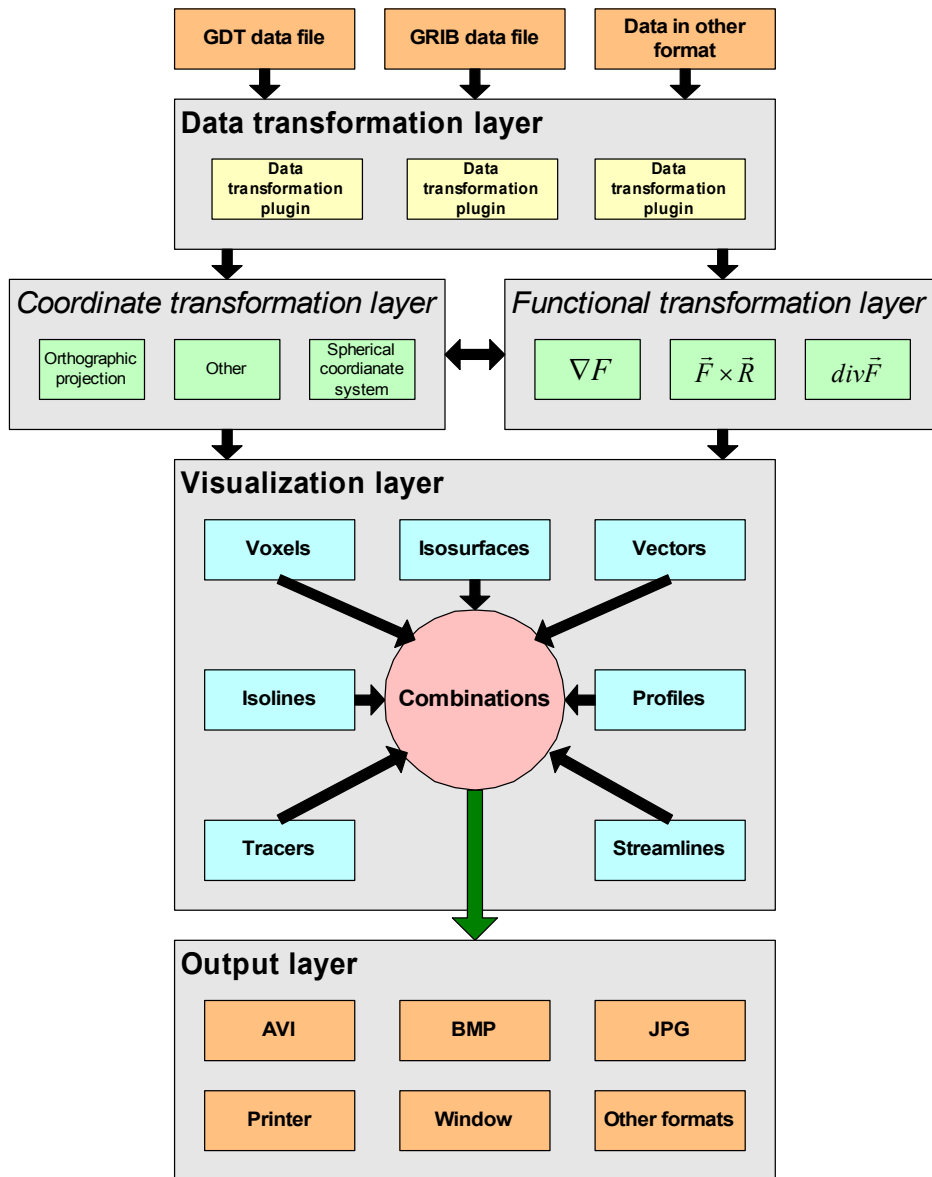


Fig. 1 Structure Scheme of **ScientificVR®** Visualizer

### 3.1 Types of data visualization

#### □ Graphs

This way of one-dimensional scalar value presentation in the form of a plot holds its place among the simplest and most usable ones.

#### □ Color presentation of two-dimensional scalar data

One of the most pictorial and effective ways of presenting a two-dimensional distribution of a scalar value in graphic form is depicting it on the computer screen in the form of dots, each one of them being colored from a certain palette according to the numerical magnitude of the value represented. (Figure 2)



Fig. 2 Pressure Distribution for Supersonic Flow Around a Wedge with Mach Reflection

#### □ Altitude presentation of two-dimensional scalar data

Another way of presentation of two-dimensional distribution of scalar data like some surface in three-dimensional space is altitude presentation of two-dimensional scalar data. Here each point of two-dimensional distribution associates with point on surface with altitude proportional to value of parameter. (Figure 3)

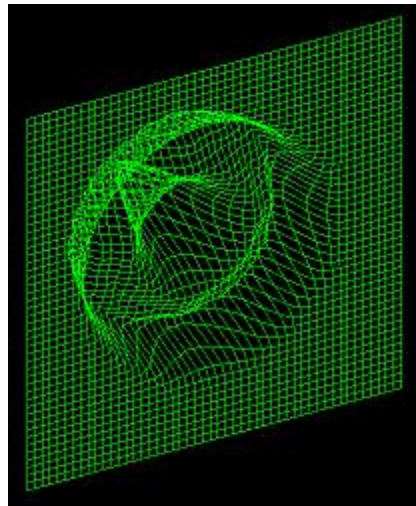


Fig. 3 Altitude Representation of 2D Data

□ Iso-lines

Often a convenient way of presenting the distribution of a two-dimensional parameter is to plot its iso-lines. Their color is determined by the numerical magnitude of the given parameter. (Figure 5)

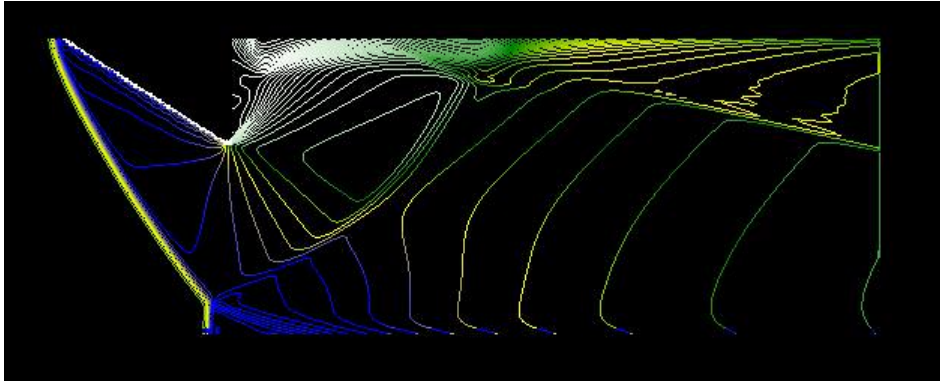


Fig. 4 Iso-Lines of X Component Velocity Colored According to Density Distribution

□ Two- and three-dimensional vectors

Vectors are traditionally depicted to visualize 2D and 3D vector fields. The length of the vector and its color may stand for several parameters simultaneously. (Figure 5)

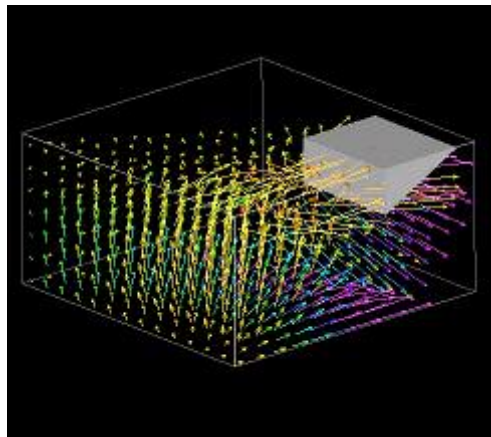


Fig. 5 Vectors Colored by Pressure

□ Stream lines and tracers

Streamlines give considerable information about structure of vector fields. Stream lines realized in diverse variants: stream tubes, stream belts, trackers, stroboscope and so on. (Figure 6)

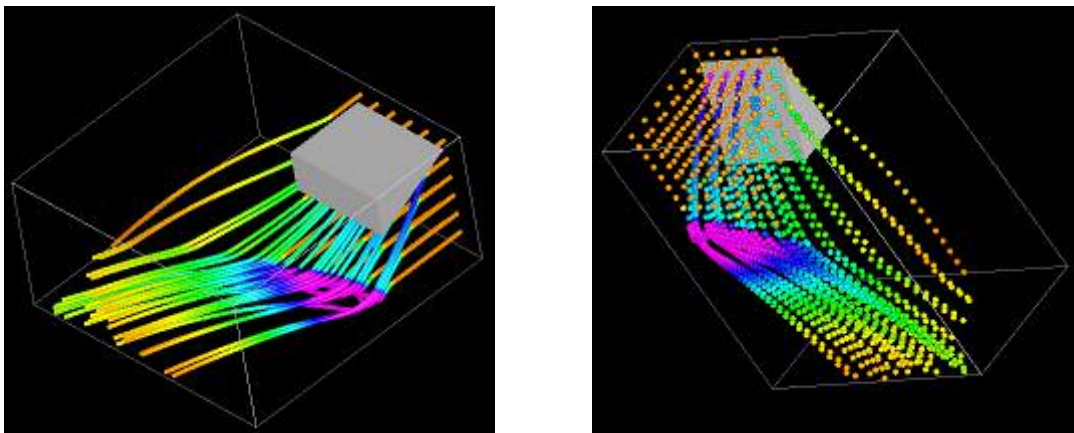


Fig. 6 Stream Tubes and Stream Tracers

□ Three-dimensional voxel graphics

To depict three-dimensional parameter distribution a unique technique of data presentation developed since 1998, which is based on voxel graphics using semi-transparent color palettes. (Figures 7a, 7b)

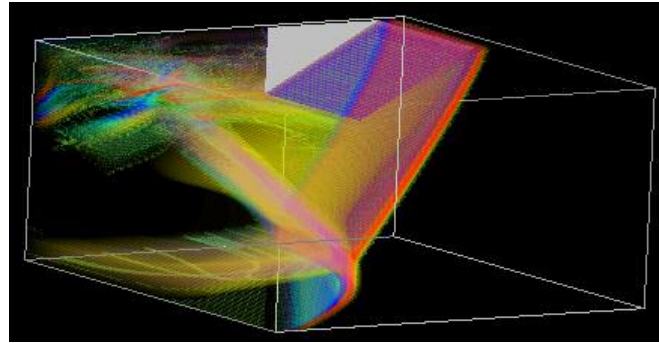
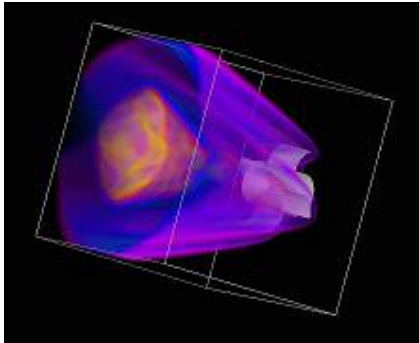


Fig. 7a Flow Around Missile Fin Block Fig. 7b Supersonic Flow Around a Wedge with Mach Reflection

□ Iso-surfaces

Iso-surfaces serve to visualize three-dimensional fields and are similar to iso-lines. Apart from color presentation of parameter, iso-surfaces feature a capability to vary the degree of surface transparency. (Figures 8a, 8b)

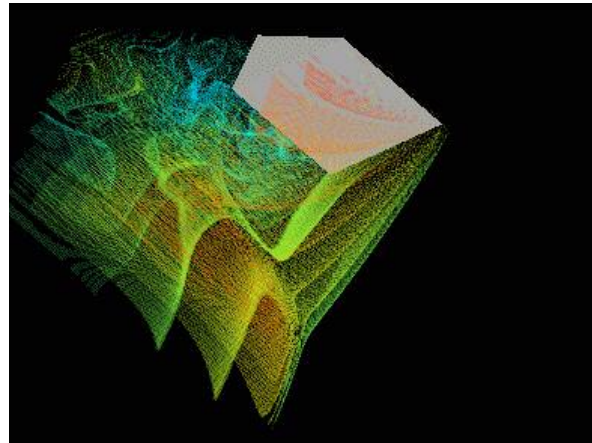
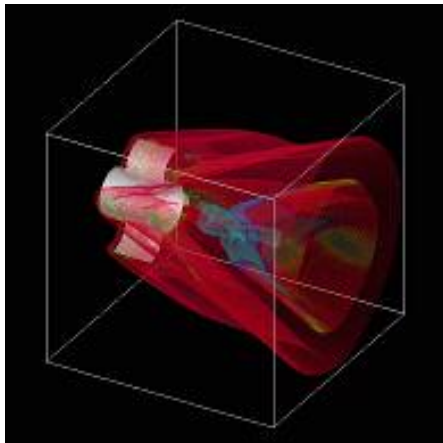


Fig. 8a Flow Around Missile Fin Block Fig. 8b Supersonic Flow Around a Wedge with Mach Reflection

□ Texture

Texture allows to show distribution of any parameter on some surface particularly on body surface.

□ Combined images

The abovementioned types of data presentation can randomly be combined, which makes possible the accomplishment of intricate phenomena complex analysis. (Figure 9)

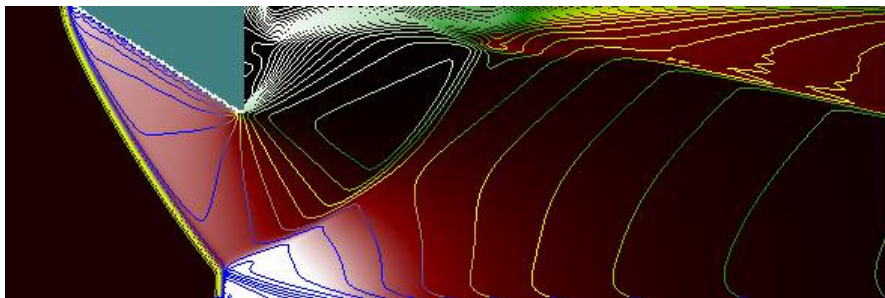


Fig. 9 Pressure Distribution with Isolines of Horizontal Velocity Component Colored by Density

#### □ Geometrical streams

In the **ScientificVR**<sup>®</sup> package has been realized various tools for complex geometries representation. Besides the GDT package geometrical modeler abilities, **ScientificVR**<sup>®</sup> is partially compatible with STEP standard (ISO 10303), what allow to carry out the interface with most modern CAD/CAE system. (Figure 10)

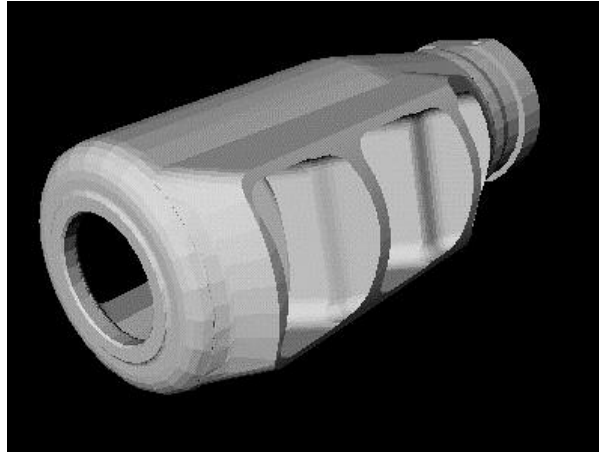


Fig. 10 The Example of Complex Geometry Object Imported by **ScientificVR**<sup>®</sup> Package

### 3.2 Functional operations with scalar and vector quantities

**ScientificVR**<sup>®</sup> can perform the following functional operations with scalar and vector data: Gradient, Derivate, Second derivate, Divergence, Scalar product, Mixed product, Modulus, Rotor, Linear combination. This set can be easily expanded with plug-ins.

### 3.3 Output formats

Currently **ScientificVR**<sup>®</sup> supports the following output formats (via plug-ins): BMP, JPEG, TIFF, PNG, AVI, Stereo, Printer

### 3.4 Combination

The **ScientificVR**<sup>®</sup> package has abilities of unlimited combination of images. For example, in one picture can be combined voxel density distribution with iso-surfaces of pressure, texture colored by concentration distribution, and all of this can be put on velocity vectors and/or temperature gradient (vectors itself can be colored according to some other parameter distribution) and so on.

### 3.5 Stereo

One of the latest innovations in visualizer is stereoscopic distribution of free dimension images. To see stereoscopic effect user should use a proper video card and stereoscopic glasses (for example, ASUS V7100 Deluxe). Creation of stereo images is able to any three-dimensional visualization type – voxel images, iso-surfaces, three-dimensional body, vectors or they combination distribution.

Stereo images may be stored into AVI file with all additional opportunities of animation. As an example the stereoscopic movie file (Movie 2) is attached to this work. This file describes the flowfield of density derivative for shock wave diffraction from a tube. Main blast, Mach disk, barrel and reverse shocks are very good visible and create nice stereoscopic effect.

### 3.6 AVI

The package has ability to create various animation effects. Besides traditional AVI files shown the evolution of nonstationary processes from one fixed point, now available to create rotating AVI files, which can be use for visualization of static distribution and in combination with evolution of nonstationary processes. All animation function for three-dimensional distribution can be supplied in stereo mode.

### 3.7 Interface

Graphical user interface is easy and friendly. Creating complex image user has wide set of options that give ability to change the parameters of output on the fly. Interface gives full range of tools for making high quality images for presentations and scientific works. (Figure 10)

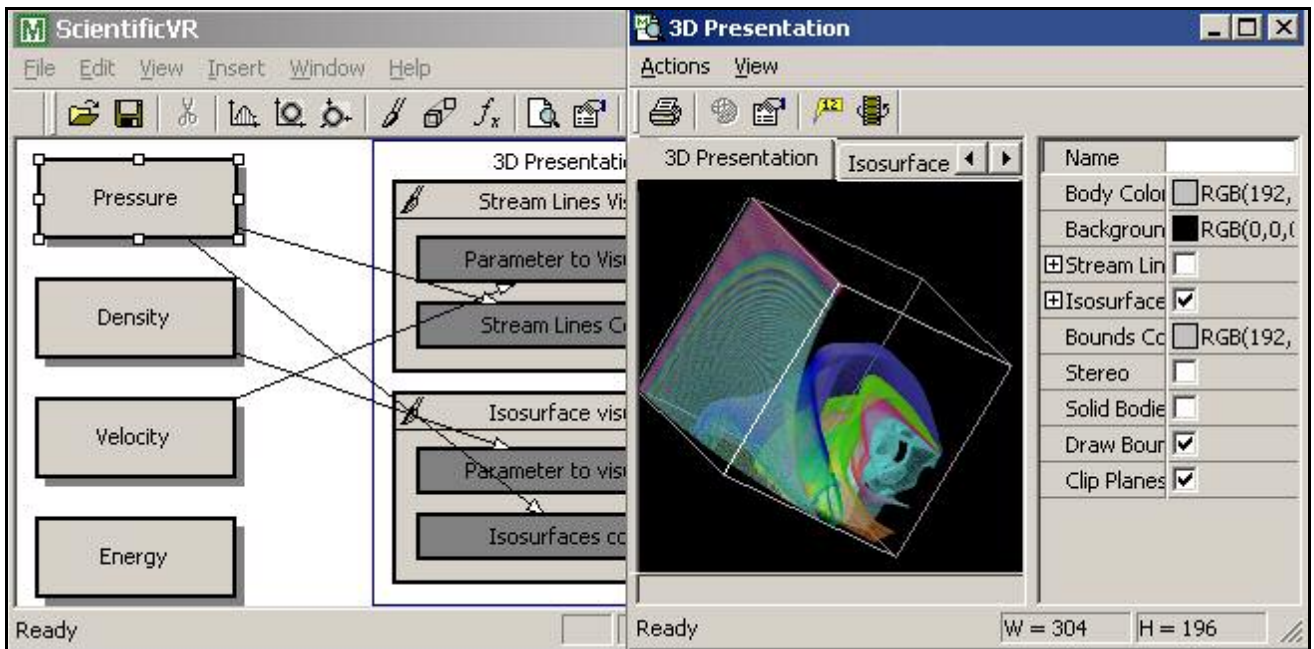


Fig. 11 User Interface

## 4. Conclusion

In conclusion it is necessary to emphasize that visualization system **ScientificVR**<sup>®</sup> is suitable and flexible and it works on PC platform remarkable well. Plug-in modules may easily expand visualizer abilities. That makes system **ScientificVR**<sup>®</sup> extremely attractive instrument for quick and quality visualization of data, which can be received from very different data sources both primary sensor and results of computational modeling or theoretical calculations. Currently versions for UNIX OS in multiprocessor and cluster variants are under development.

### References

Zibarov A.V. 1999, „Gas Dynamics Tool Package – System for Numerical Gas Dynamic Non-Steady Process Modeling“// ASME, PVP Vol. 397-1, pp. 117 –123,