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Experience of Constructing and Carrying Out the R&D "Scientific Visualization and Visual Analytics" at RTU-MIREA in 2024

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Abstract

This work presents the experience of constructing and conducting the research project "Scientific Visualization and Visual Analytics" at RTU-MIREA in 2024. The research project was conducted for 3rd-year students of the Department of Higher Mathematics of the Institute of Artificial Intelligence at RTU-MIREA. The construction and organization of the research project are described. Examples of tasks and their implementation are given. This work may be of interest for teaching similar disciplines in this subject area.

Keywords: Experience in conducting research, scientific visualization, visual analytics.

1. Introduction

This work presents the experience of building and conducting the research and development project "Scientific Visualization and Visual Analytics" at RTU-MIREA in 2024. In 2024, I was offered to conduct research and development on the topic "Scientific Visualization and Visual Analytics" for 3rd-year students of the Department of Higher Mathematics of the Institute of Artificial Intelligence at RTU-MIREA. In the past (more than 20 years ago), I prepared and delivered a similar author's course at the Department of Automation of Scientific Research in Computational Mathematics and Cybernetics of Moscow State University. Naturally, everything was interesting for me here - both the current level of students and the current level of visualization systems, so I certainly agreed. The research and development course was built and conducted. The main goals and objectives of the research and development were to provide students with the basics of processing and visual representation of calculated data and to develop practical skills in using visualization systems. The main leitmotif of the research and development was the following: "You will be taught to solve numerical problems of mathematical modeling. You will solve specific problems. And how will you show others and yourself that you did anything at all? Such attitudes were understood by the students. When creating the R&D course, there was a temptation to use the materials of the previous course from 20 years ago, but this had to be abandoned, since all the programs for reading and processing data of that time were implemented in Fortran, which modern students do not study and do not know at all. Therefore, the course was structured as follows: first, 3 introductory lectures were read on the basics of scientific visualization and visual analytics, then the students were given individual tasks on visualization of calculated data, which the students had to complete while mastering visualization systems. As calculated data, we used real open calculated data obtained by me and my colleagues at the IPM named after M.V. Keldysh Institute of the Russian Academy of Sciences.

2. Choosing a visualization program to master

When creating research, the question of choice naturally arose visualization programs for students to master. The most powerful and popular software packages, as 20 years ago, are the software packages - TecPlot [1], Paraview [2], VisIt [3], Avizo [5]. Previously, there were also a large number of open programs with limited functionality (mainly French), which, however, allow you to successfully visualize 1D graphs, 2D distributions of quantities and 3D distributions of quantities in volumes. I and the staff of the Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences conducted a preliminary analysis of the current situation with software in this area. The following was revealed. The current situation has changed radically. Firstly, there are no programs with partial functionality on the Internet. That is, the thesis "The Internet remembers everything" in this case is incorrect. Secondly, the "large" programs listed above have also changed. The Paraview [2] and VisIt [3] programs have changed significantly in the direction of complicating the processing of initial data, and it clearly made no sense to give them to students for training. My colleagues and I spent several evenings solving fairly simple examples of data for visualization. As a result, the TecPlot [1] complex (which has a trial version) and gnuplot [4], which was widely used in the Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences, and which there was preliminary information that most students had experience working with, were chosen as software packages for mastering.

3. Construction of the task

The research work was conducted for 4 groups of students, each group having an average of 25 people. The total number of students was about 100 people. 30 tasks were prepared for these groups. 26 tasks were focused on using the TecPlot system and 4 tasks were focused on using the gnuplot system. The initial data set for each task included previously calculated and published results of solving aerogasdynamic problems obtained in the Department of Computer Graphics and Machine Vision of the Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences. Each student was asked to install a visualization program, study this program, visualize the results from the initial data and write a short report on the main functional properties of the program used and the results obtained. Examples of tasks and the results obtained can be seen in Section 5.

4. Difficulties and curiosities

It should be said that the vast majority of students successfully completed the task, but at the same time, completing the task required a certain amount of persistence and enthusiasm from them. While completing the task, they constantly received consultations from me online. On average, completing the task took 3 iterations. Most of the errors were related to insufficiently thorough study of the program manuals.

For example, the rather elementary construction of cross-sections caused difficulties. If you use the section construction tool in TecPlot, then when changing the coordinate direction of the section, the section itself is not saved. An example of a consultation tip: "...How to make perpendicular sections in one drawing? First, build one section, for example along X, then according to the manual, turn on Data > Extract > Current Slices, then in the section builder change the direction to perpendicular. Save the drawing. You can continue changing directions. ...».

It should be noted that mastering the programs caused great enthusiasm from mastering new skills and abilities. Which sometimes led to some funny incidents. In a burst of enthusiasm, some students tried to build streamlines for obviously scalar quantities, such as temperature or pressure. Here it was necessary to draw the students' attention to the physical nature of the solved aerogasdynamic problem.

It should also be noted that fairly simple tasks with gnuplot caused the greatest number of difficulties for students. This should be attributed to the less user-friendly interface of this program. Here, completing tasks required up to 4 corrections in practice.

5. Results

This section provides typical examples of tasks and general results of completing tasks.

Example of a task for TecPlot

1. TARGET SETTING: Mastering and practical application of the universal data visualization program TecPlot .

2. CONTENT OF PRACTICE:

2.1 Learn: the universal data visualization program TecPlot,

write a brief study report including the main data types and a list of the main functions provided to the user.

2.2 Practical implementation: Construct a visualization of the numerical array on the figure based on the data from the MPrSh . lay file as a set of planes. The file contains a three-dimensional data array representing the critical velocity of transition between different flow regimes for variations of the Mach, Prandtl, Reynolds and Strouhal numbers. Present the figure as a set of cross-sections using the program tools. Provide the figures in the report.

2.3 Get acquainted with the possibilities provided by this program.

The results of the task are presented in Figures 1, 2, 3, which show 2 cross-sections, 3 cross-sections and 4 animation steps, where one of the cross-sections moves.

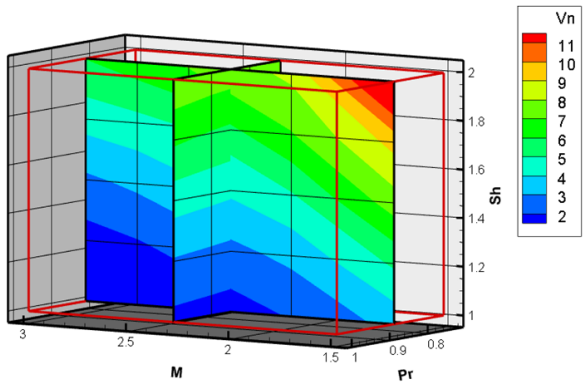

Figure 1. A set of two cross-sections (along the OX and OY axes).

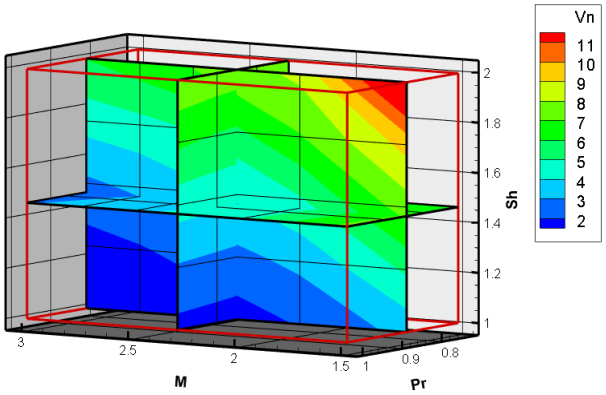

Figure 2. A set of three cross-sections (along the OX, OY , O Z axes).

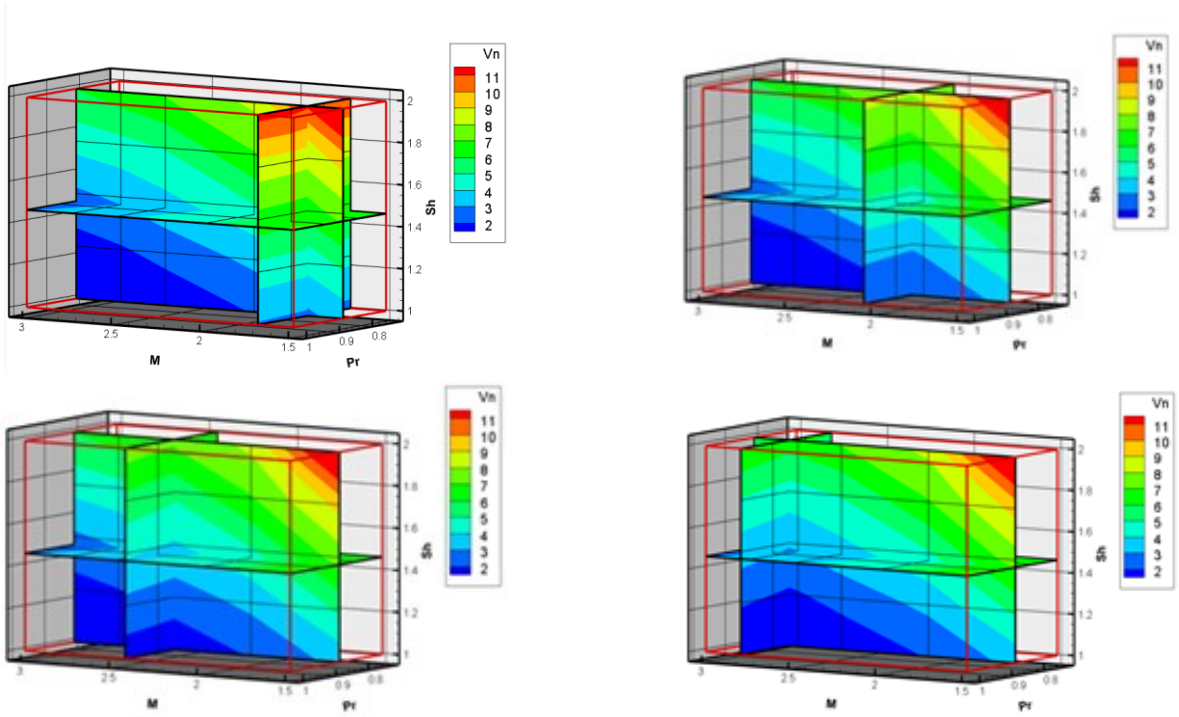

Figure 3. 4 steps of animation for a section parallel to the OX axis.

Example of a task for gnuplot

«**1. TARGET SETTING**: Mastering and practical application of the universal data visualization program gnuplot .

2.1 Learn: the universal data visualization program gnuplot.

write a brief study report including the main data types and a list of the main functions provided to the user.

2.2 Practical implementation: Plot an image of the two-dimensional array presented in the file Test 2 D . dat . The file contains a two-dimensional array of data representing the distribution of the scalar value F in a rectangular area. In reality, these data correspond to the temperature distribution on a plane. Plot an image of the data as a three-dimensional surface. Provide the drawings in the report.

2.3 Get acquainted with the possibilities provided by this program.

3. ADDITIONAL TASK:

4. ORGANIZATIONAL AND METHODOLOGICAL INSTRUCTIONS: use gnuplot for data visualization , take the program version from the site http : // www . gnuplot . info /

The results of constructing the data in the form of a three-dimensional surface are shown in Fig. 4.

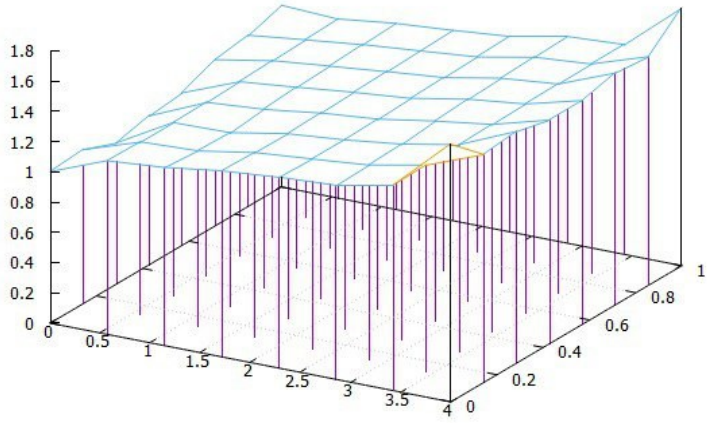

Figure 4. The model constructed using the gnuplot program

In general, the results of the research work can be assessed as quite successful. The majority (more than 90%) of students passed the research work with a positive assessment. Such independent work related to obtaining new specific practical skills aroused interest among students, which they reflected in many reports on the research work.

Conclusion

This paper describes the experience of constructing and conducting the research project "Scientific Visualization and Visual Analytics" at RTU-MIREA in 2024. The research project was conducted for 3rd-year students of the Department of Higher Mathematics of the Institute of Artificial Intelligence at RTU-MIREA. The construction and organization of the research project are described. Examples of tasks and their implementation are given. This work may be of interest for teaching similar disciplines in this subject area. Such organization of work serves as a source for students to acquire specific practical skills that are in demand in science and industry.

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