A program system for seismic fields visualization

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Abstract. In this paper, we describe a 64 bit version of the visualization system for seismic fields. The system supports well-known SEG-Y, SDS-3, SDS-5 file formats or their scientifically adapted versions without headers. This system is used for several years as a part of industrial seismic data processing system in the ICM&MG and Siberian Geophysical Expedition for processing seismic exploration data in Russia, China, and some other countries. The visualization modes include a wave field, an amplitude color filling and a color map. Also, the user can create the full-color palettes. The system is industrially used for a few years for seismic data processing in Russia, China and some other countries. In this paper, the algorithms, visual modes and visualization examples of real seismic data, and results of direct numerical modeling were described.

1. Introduction

For the past few years, we can see a rapid progress in the field of computer devices instruments that now are used almost in all kinds of the human activity.

In geophysics and seismic explorations, the appearance of powerful graphical stations, which can work with terabyte files and huge full-color images, give us the possibility to use graphics and color to detect insufficient data changes at the time of their passing through a processing graph.

The program Seismic View (Figure 1) is intended for visualization and high-resolution analysis of filed seismic data which is accepted in both: the Soviet SDS-3, SDS-5 and the American/Canadian SEG-Y formats. In addition, it can work with data that are presented as sequence traces in I2, I4, R2, R4 formats. Sizes of traces and headers can be dynamically changed "on the fly". This allows us to work with a wide range of data including real seismic data and synthetic seismograms [1].

The complexity of dealing with real seismic data and results of numerical experiments [2] is clearly shown in the 3D case. There exist many commercial systems that solve similar tasks, for example ASPIS system, that was created in the ICM&CM. A bulk of information of real seismic exploration data does not allow us to use the direct data reading into memory for forming a resulting image that brings about the necessity of creating and using special algorithms for showing, zooming, and scrolling information.

The program allows us to have arbitrary 3D cuts by flats, which are parallel to X, Y, Z axes.
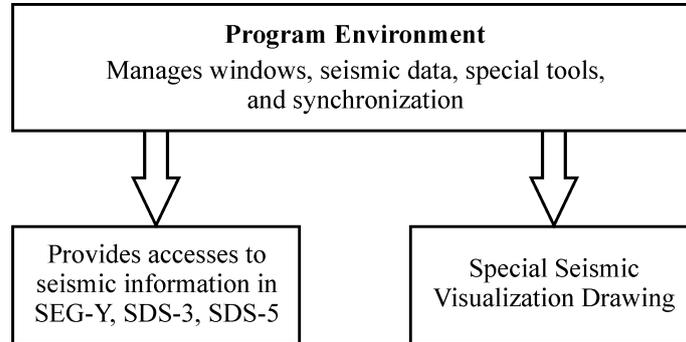
Figure 1. Program structure

2. The structure and functionality of the visualization system

The basis of the program is a shell in the form of the MDI (Multiple-document interface) and the user's communication.

With this environment, the user has a full set of operations with seismic data: he can load, choose the form of visual presentation, use automatic procedures for the adjustment of important visual parameters. The user can open many seismic sections in different windows, control the windows and modes of synchronization.

A wave field is one of classical types of visualization of seismic wave fields which is used all around the world (Figures 2, 3).

This kind of mode is characterized by representing a wave field as a sequence of traces, when each of them shown as wave graphic with positive
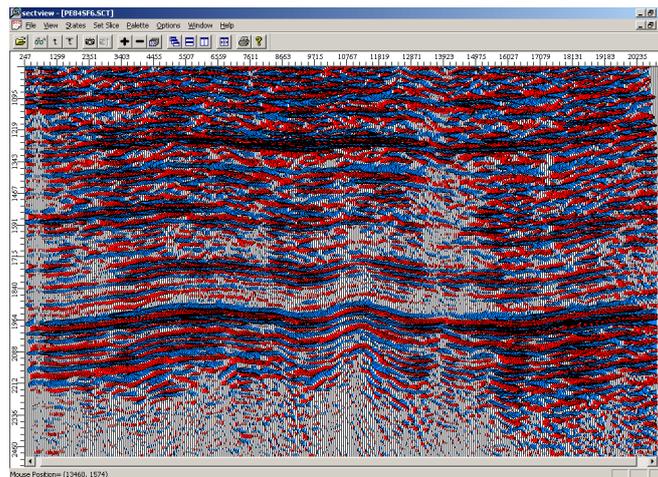

Figure 2. Typical site of real seismic field with red-blue filling

and negative components, which usually have different color of filling. The main problem with this kind of visualization is overlapping of the left and of the right parts of waves when the visual amplitude is much higher than the visual distance between traces.

In the program in question, we have realized the fast one-way algorithm of drawing with double, left and right overlapping traces, and

Figure 3. Black-and-white wave field

with the possibility to change all significant visual parameters. The program gives the possibility to change colors of positive and negative components, to change amplitude, magnitude (only for R2 and R4 data formats), to switch on/off positive and negative fillings, the border line, the "zero" line, to use averaging for highly-oscillating traces.

A special visualization mode for cutting overlapping traces was created, which is quite useful together with the amplitude color filling (see next section).

In addition, the two-level optimization for traces and samples was realized which can be switched off if necessary. Optimization in the image building process was realized with the concept of "minimal visible element", when its minimal limit is a pixel on the screen. By changing the size of a minimal element in pixels, the user can make image more or less accurate, that can be useful when applying a too high screen resolution on the operational system level and thus essentially accelerating the drawing process.

The time of drawing is an important characteristic for program of this class, because the amount of data could be very big up to a few terabyte when working with industrial data. As a result of using this optimization concept, the drawing time is about two times reduced and practically does not depend on the size of a seismic file.

3. The amplitude color filling

For this kind of the drawing mode (Figure 4), in addition to conventional presentation of the wave amplitude, it is usual to use different colors depending on the resulting amplitude at a particular point of the wave field. To do this, the concept of the "color scale" is introduced, that corresponds to a special table, where each of amplitudes corresponds to the index from a color palette. The number of colors and the palette can be arbitrary.
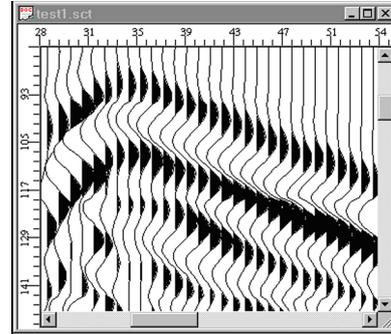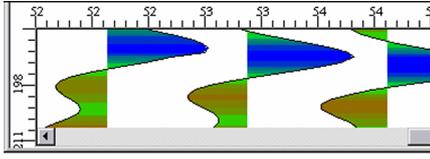
Figure 4. Amplitude color filling example

This type of the drawing mode is especially useful, if it is necessary to extract or to underline a precise amplitude range. In this case, we can create a high-colored palette for the range of amplitudes values. In the black-and-white case, we can see lines of constant amplitudes.
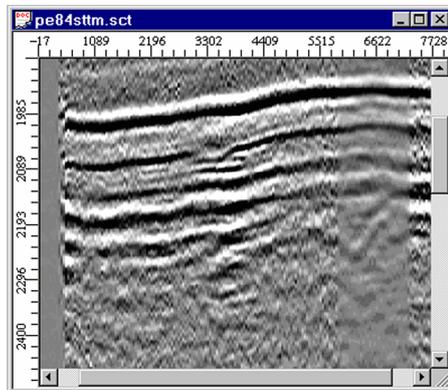
4. A color map

Figure 5. Color map in gray palette

In addition to the above mentioned kinds of drawing, there exists one more that is called a color map (Figure 5). For it, it is typical to show an amplitude by changing only color without drawing the wave. As in the color-fill case, here always exists a table that contains the dependence between the color on the screen and the wave amplitude.

This type combines demonstrativeness and a high resolution. To its drawbacks we can refer high requirements to resolution of a seismic section.
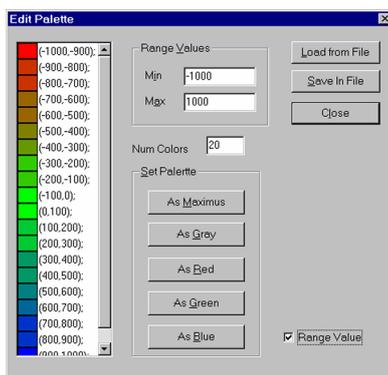
5. Creating palettes

Figure 6. The palette edit dialog

The program gives a possibility to create, edit, store and read from a file any full color (more than a million) palettes. Each palette has its own amplitude range that corresponds to the colors of the amplitudes of waves in the picture. There is a possibility to "pre-generate" a number of simple continuous palettes and selectively indicate to colors for a certain amplitude range.

In Figure 6, a dialog window for working with a palette is shown. The example includes a palette with 20 colors for an amplitude range from -1000 to 1000.

Each color from a palette could be arbitrarily set. The user has the possibility to generate and to select color palettes depending on specific features of a processing graph. For example, for accurate extracting some amplitude (or a set of amplitudes) it is possible to create a special palette, which will show a small change of an amplitude by very different colors, or on the opposite, uninteresting small changes could be hidden by showing them with the same color.

6. Synchronization mode

The main result of the seismic data processing is building a correct model of the Earth on the explored area. In this process, the data are passing the so-called "processing graph", which includes filtering, migration, interpretation and model building. At the interpretation stage, all adoptable data for this area are to be used, including the past experience, lithology data, data of test drilling (if exist one) and so on. As result, for each region we creating special processing graph is formed, which can include tens of stages.

In these process, it is very important for an interpreter to see small changes in data when the process graph is slightly changing [3]. Especially for this situation, a special mode of synchronization was realized that allows us to have many windows showing the same fragments of different seismic sections with exactly the same coordinates. In Figure 7, three synchronized seismic sections with different drawing types are shown.

Figure 7. Synchronous sections with different drawing types
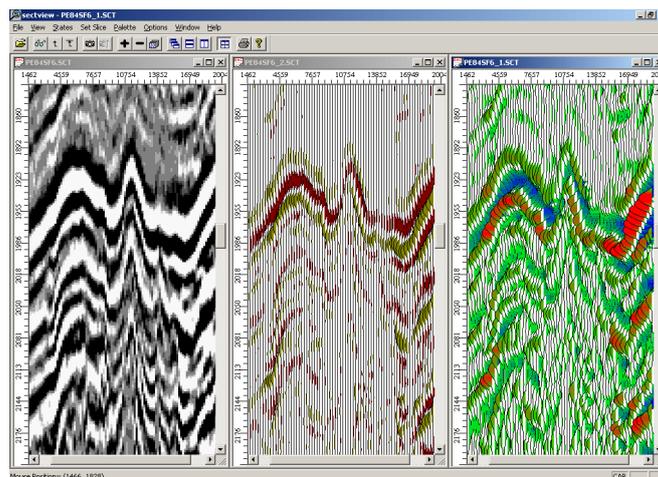
7. Visualization algorithms

The seismic section data are stored as a sequence of one-dimensional arrays in the binary format with different sizes of headers and traces. Significant data can be stored in formats I2, I4, R2, R4, where I is an integer, R are numbers with a floating point. A number after a letter means the size in bytes.

The size and components of a header, can be different depending on the data format (SEG-Y, SDS-3, SDS-5) or can be absent. This brings a specific character of algorithms for working with such data, because it appears necessary to realize a system for transforming the spatial and coordinate presentations from a file to the screen form and vice versa.

7.1. Algorithms for zooming and scrolling. The size of a real 3D seismic section obtained by a high-resolution method can exceed tens of tera-bytes. For such a volume of information it is not possible to use the direct reading into memory. In the program under consideration efficient algorithms without reading into memory for sifting in scrolling and zooming modes was realized. To this end, an intermediate coordinate space and the sifting rule are introduced. The seismic section driver, having the information about the current screen resolution, the sifting coefficient and the current mapping area, builds virtual cut, reading only the necessary for the moment information.

The screen coordinate is transformed to the coordinate of displacement from the starting point of the seismic section file and the screen resolution is transformed to a displacement distance inside the file at the current level of increasing an image.

It is possible to obtain and to map average values counted in a range between visible points if necessary, that could be useful when data have noise additions.

7.2. One-way algorithm of drawing a seismic field. The components of the wave of each trace are mapped superimposed by the following rule: the positive part is overlapped to the right and the negative part — to the left. Some difficulty arises in the cases, when visible amplitudes several times exceed a visible distance between traces as shown in Figure 8.

7.3. Three-dimensional cuts. As was shown above, the format for storing seismic data is rather complicated. In order to get a three-dimensional cut of a plane that is parallel to an arbitrarily axis, it is necessary to take into account the specifics of data storing. Otherwise, the drawing time of a 3D seismic section of the size of about 5 Gb can be up to 30 minutes even at very fast stations. This is clear if one imagines the sequence of file operations in the drawing process. If data are read randomly, we will not
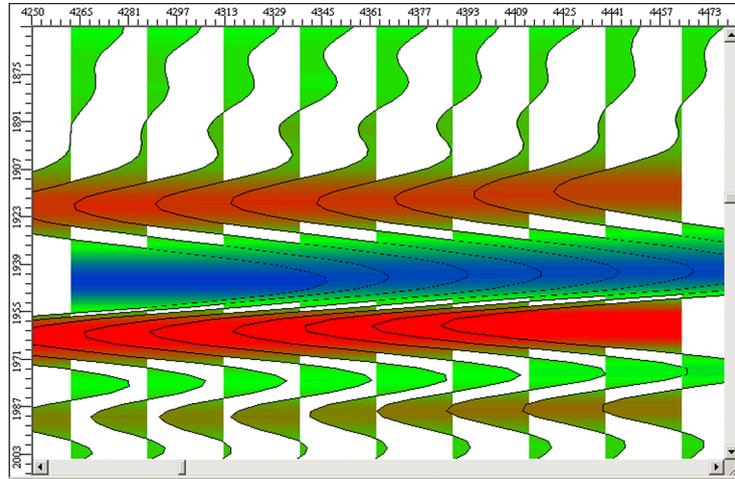
Figure 8. Left and right traces overlapping with high amplitude

have effective buffering for such a big data volume, and, respectively, the time of reading and drawing one trace will not be less than the time of the first reading into memory of 5Gb of information, and there are thousands of traces.

According to rules accepted in geophysics, the coordinate axes are directed as follows: axis X — to the right, Z — downward, Y — into the depth. The most often useable cut is XZ.

As we mentioned before, the traces are stored as a set of one-dimensional arrays with headers, and on the screen they will look like wavy lines that are parallel to the axis Z. Thereby we have no problems with building a cut on the XZ plane. The cut on the ZY plane is a more complicated case which requires a three-dimensional turn of a cube to the left by 90 degrees, but it does not make principal problems from the point of view of the drawing time.

The most complicated case is XY cut, because it requires a three-dimensional turn by 90 degrees from top to bottom around the axis X after that each point of a visible trace will be a point of the real trace and the common map of access to the section file becomes close to random, and the drawing time increases by thousands.

The solution obtained uses two rotations around axes instead one and it is adapted to the specific file operations. First, we build a cut of data on XY plane with traces parallel to the axis X, that allows reading the data sequentially, which is hundreds of times faster than a random access. After that, we have to make a rotation by 90 degrees around Z axis and only then we build a screen image.

8. Implementation and efficiency

The proposed program is industrially used for a few years in the Institute of Computational Mathematics and Mathematical Geophysics, in Siberian Geophysics Expedition as a basic visualization system for seismic data, but it is useful to present approximate times of visualization for real seismic section. For the experiment, we use a working station with Intel 3200 MHz processor, 1 Gb memory and an ordinary video card because it has not any real impact on the performance in this case. For 4 Gb seismic section XZ, any mode and zoom factor with the visualization time did not exceed 2 sec. For ZY cuts, it was up to 5 s, and in the cases with XY cuts — up to 10 s. In typical cases, the drawing time is less than a second or less than the time of the user's response.

9. Programm realization

The program was realized as an object oriented library of C++ classes with using the MFC (Microsoft Foundation Classes) classes, the MS Visual C++ and developed for any Windows-based operational system starting from Windows 95. Logically, the classes are divided into a few parts:

- Special classes that realize access to seismic information, header analysis, program presentation of a 3D seismic section as 3D ordinal array, drawing seismic fields, etc.

- Interface classes that organize the information exchange with the user, setting parameters, changing visual modes, etc.

- Classes that realize the window structure of application, message mechanism and synchronization. The classes are optimized for moving to other system platforms.

10. Conclusion

In this paper, we describe the program realization of a visualization system for 2D and 3D seismic fields, seismic exploration data, and data from the direct numerical modeling. The system can be used in any scientific and industrial organizations that are involved in the field of elasticity, wave propagation with small deformations and, especially, in seismic prospecting. In the current version, we have realized two main drawing methods that exist in the world — the wave field and the color map. Also, we have presented a modified method — the amplitude color filling. A special palette editor was realized, which enables a user accurately associate the amplitude of a wave and the drawing color on the screen. A fast one-way algorithm for drawing the overlapping waves was realized thus reducing the time of drawing. The

system allows the user to make three-dimensional cuts of seismic cubes in any directions, parallel to coordinate axes.

The spatial synchronization mode of many seismic sections was realized, which is especially useful in the real seismic data processing and seismic prospecting. The system is industrially used for years in SibNefte-Geophysics — the organization involved in processing of seismic data in the Siberian region.

Future trends of development of the system involve integration with specialized model-building systems of continuous media, extension of the algorithm visualization base, addition of new tools for analysis and interpretation of processing results.

References

[1] Mikhailenko B.G. Seismic fields in complex media: Atlas of Snapshots and Synthetic Seismograms. — Novosibirsk: Computing Center SB RAS USSR, 1988.

[2] Mikhailenko B.G. Synthetic seismograms for complex three-dimensional geometries using an analytical-numerical algorithm // Geophys. J. R. Astr. Soc. — 1984. — No. 79,3. — P. 963–986.

[3] Puzirev N.N. Methods and Objects of Seismic Explorations. — Novosibirsk: SB RAS, 1997.