

Technique for digitizing bathymetry information using personal computer*

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In the paper the technology for creating detailed digital bathymetry on personal computer is given. Such data is necessary for numerical modeling of tsunami waves. Information about depth is based on bathymetry charts (on paper). Two methods of digitizing are proposed. Given examples illustrate fitness of this technology for this purpose.

1. Introduction

One of the methods for estimation of probable submerging zones on a shore as a result of tsunami attack is so called numerical tsunamizone using finite difference computations of differential equations. To make this, one needs the values of depth in the points of rectangular grid. The array of such numbers we will call the digital bathymetry. Now there is no global detailed bathymetry, so for precise numerical simulation of tsunami propagation it is necessary to obtain detailed digital bathymetry of our small region. In the paper the method of obtaining digital bathymetry using bathymetry charts is proposed.

2. Digitizing technique

Algorithm proposed here is able to create and to input into computer regular bathymetry data on rectangular grid with any desired special step. The original source of the data is marine bathymetric charts with isolines of depth. There are no another requests to the charts.

There are three steps of digitizing process. First step – getting graphic image of some part of chart (in PCX or TIFF format) with the help of

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scanner. The second step – input into computer and ordering screen coordinates of points along isolines. And the last step is the computation of depth values in all grid points.

Let us begin with first step. At first we will describe the chain of actions when we use black and white scanning of original bathymetry chart. The process of scanning can be done with the different resolution. The usual values of scan resolution are 75, 150 and 300 dots per inch (dpi). It means that 1×1 inch rectangle on the paper will have the size 75×75, 150×150 and 300×300 pixels on the screen correspondingly. VGA monitor for IBM PC has usual screen capacity 640×480 pixels. It means that if we use less scan resolution, then we can display on the screen the bigger part of the original chart. Usually the graphic image size of scanned rectangular piece of the original chart is much more than screen size (640×480 pixels). So we have to use the graphic editor for cropping and scaling our image to reduce its size to the screen standard. Usually the working units of the initial bathymetry chart are bounded by some values of geographical latitude and longitude. For this purpose it is better to have geographical grid drawn on the chart. Later lines of geographical grid will be used for transferring screen coordinates into geographical. So we have the screen-scaled (fit-to-screen) graphic image of rectangular part of original bathymetry chart.

On the second step we have to input into computer the memory screen coordinates of points along the isolines of depth. This can be done by several ways. At first we describe the so called “mouse” technology. Here it is necessary to convert fit-to-screen image into graphical format which can be used in FORTRAN programs. Then we run the digitizing program and begin to move mouse cursor along isolines. During this procedure we input into computer screen coordinates of cursor position by pressing the right mouse button, therefore, all the points we want to input will be plotted and connected by green color on the screen (the drawing color can be chosen by user). The end of every depth level is indicated by <Esc> button on keyboard. The program permits to input up to 400 points on 20 depth levels. If 20 levels is not enough, one can run this program again and input another 20 levels. For linking screen coordinates to geographical grid it is necessary to input screen coordinates of upper left and lower right corners of the digitizing area. It is useful to begin this process with smallest depth (for example from the coastlines (depth=0)) coming to bigger depth. We do not need to input all depth levels which we have on the bathymetry chart. After this step we will have two arrays of screen coordinates (horizontal and vertical) of points along the depth isolines we take into account.

Some years ago the author used table digitizer for input coordinates of points along isolines. Resolution was good enough (0.1 mm). Advantage of this kind of equipment is the possibility to work with large sheets of paper (up to 1×1 m). But disadvantages are difficulties with correct orientation of the chart, difficulties with fixing of the paper chart on the digitizer during whole process of digitizing and impossibility of determination line segments which already digitized. But in some cases using of large table digitizers is more useful than "mouse" technology described here.

There is another way to get screen coordinates of line points without using mouse. This technique is more automated but also needs some handling. In this technology the black-and-white (b/w) raster image of chosen part of original bathymetry chart is transformed into bitmap, using structure of graphical format (usually we use TIFF format). Then program transfers raster graphic image into vector form. It means that all elements on the picture will be recorded as pen movements with indicators of pen rising, while coming from element to element. The result of this procedure will be the sequence of pairs of integer screen coordinates of points along all lines on the initial picture. As usual the size of scanned image (with resolution 150 dpi) is up to 1000×1000 pixels. Personal computer is powerful enough to vectorize such bitmaps. As the illustration of vectorization process let us look to Figure 1, where the raster image (after scanning) is shown in the upper part and the vector image is in the bottom.

In the vector image we have got that all the segments of isolines have no order and no indicator of depth level, because on b/w picture all isolines of depth look like each other. So we must make some kind of sorting of all line segments of the vector image. Only on this step some handling with the help of keyboard is needed. Now we will briefly describe the procedure of sorting. At first vector picture in grey color is displayed on the screen with zoom (to make picture fit-to-screen). After this, program begins to overdraw with another color segments of lines and stops (waiting for operator's decision) at the end of every line segment. Operator can throw away the segment or input it into the memory of computer with level indicator (1, 2, 3, ..., n). Finally we obtain the same type of data as in "mouse" technology.

Now we came to the final step of our digitizing technology – calculation of depth values on the regular rectangular grid. At first we must choose step length or dimensions of the array (this values are mutually dependent). There is no limits for dimension of digital bathymetry we want to create. So it depends on numerical algorithm which would be used later for mathematical modeling. For computations it is necessary to input into computer dimension of future array of bathymetry data, number of depth

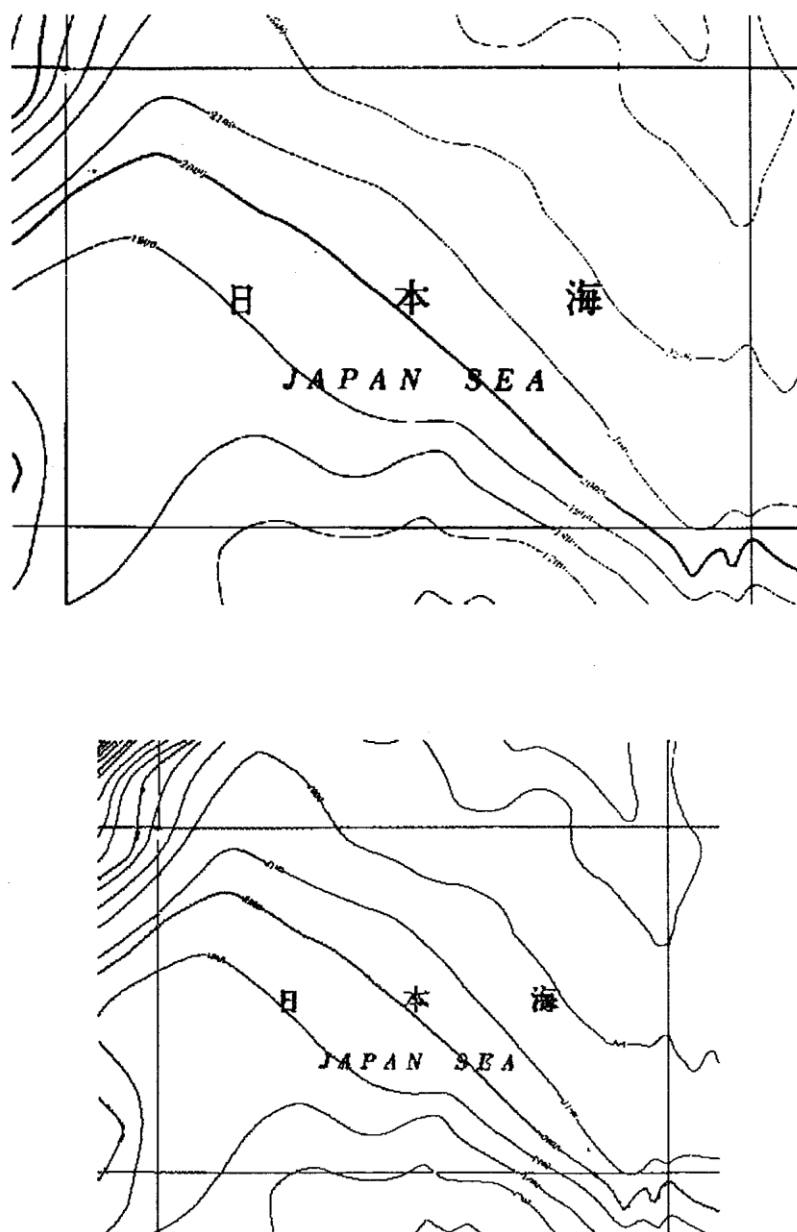


Figure 1. Comparison of scanned graphical image of the initial bathymetry chart (upper picture) with vectorized one, which was produced from scanned raster image (lower picture)

levels we have prepared on previous step, corresponding depth values and screen coordinates of two corners of the part of initial chart which we want to digitize. Using the linear interpolation the program calculates values of depth in all grid points. Digitizing process is complete.

When you have made all these steps for every fragment of the initial bathymetry chart, you can glue all digital data you have got and obtain a large array which covers whole initial bathymetry chart.

A few words about color scanning. If on the original map isolines of depth are drawn with different colors, then we can use this to avoid the procedure of sorting line segments. But here some new problems arise. Number of depth levels can be more than 16 (number of pure colors in standard EGA palette). And the other problem is: during color scanning the number of colors sometimes is much more than 16, so we have to transform image to standard EGA palette using graphic editor.

3. Digitizing bathymetry for Okusiri Island

Let us show as an example the process of digitizing bathymetry near Okusiri Island. On the 13th of July, 1993 a very strong earthquake had taken place in Japan Sea near Hokkaido Island. This earthquake produced big tsunami waves. The most damage was brought to small Okusiri Island near the west coast of Hokkaido. A few days after this a lot of tsunami specialists tried to simulate mathematically the process of 1993 Japan sea tsunami generation and propagation. So detailed digital bathymetry of that region was required. This is the reason the author prepared the digital bathymetry of that region and distributed it among tsunami specialists from different countries.

The initial material was Japanese bathymetry charts with scale 1:200000. Rectangular fragments of original chart with size 20' on longitude and 10' on latitude were digitized one by one. In Figure 2 the graphic image (after scanning) of rectangular fragment with the north half of Okusiri Island is shown. The image was reduced to screen size (640×480) and with the help of mouse 25 depth levels from 0 to 3000 m were inputted into computer. The following depth values were used: 0, 20, 50, 100, 200, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 2000, 2300, 2500, 2700, 2900, 3000 meters. In Figure 3 all inputted lines are shown.

The next step was the obtaining digital bathymetry with 0.1' steps in both directions. The dimension of each depth array in this case was 200×100 numbers (every rectangle has size 20' × 10'). Here arrays do

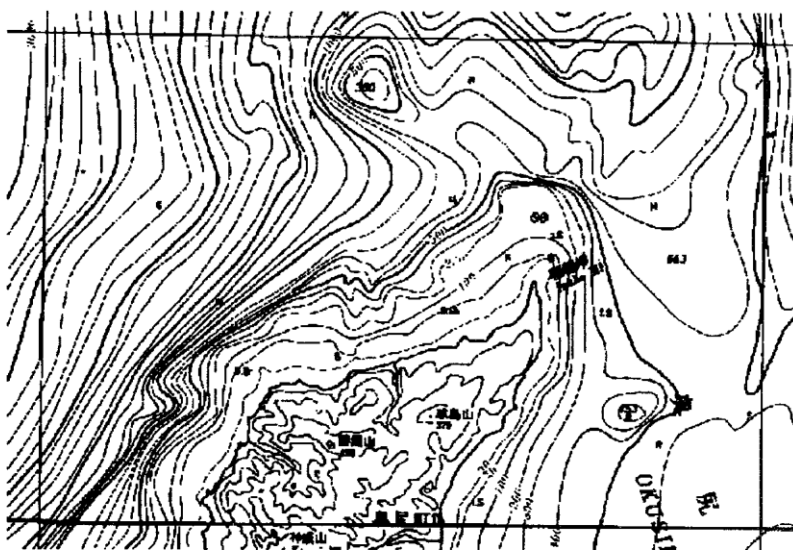


Figure 2. Fit-to-screen graphic image of the rectangular area near Okusiri Island



Figure 3. Isolines of depth, which were inputted into computer from Figure 2 using "mouse" technology

not include points on right and bottom boundaries (this was done for easy composition of large array from these smaller ones). In Figure 4 one can see depth isolines of created digital bathymetry. They are in good accordance with the initial chart (Figure 2). And Figure 5 shows us the bottom relief of this small region (the point of view is from the north-west of Okusiri Island).

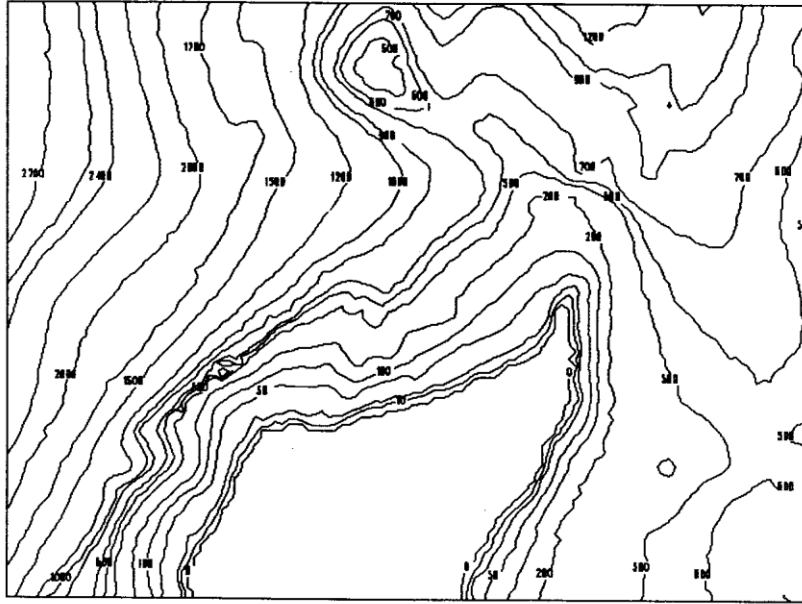


Figure 4. Depth isolines of digital bathymetry, drawn with the help of SMOG graphics

Nine such rectangles were digitized (mainly without “mouse” technology) and finally we obtain 600×300 numbers array, which covers Okusiri neighborhood from $41^{\circ}50'$ to $42^{\circ}20'$ N and from $139^{\circ}00'$ to $140^{\circ}00'$ E.

4. Conclusion

Here the quality of result data will be determined by quality of initial bathymetry charts on paper. This technology is now in progress and requires about 1 hour for producing digital bathymetry for region shown in Figure 2. So it is not difficult to cover with numerical bathymetry all the area to the west of Hokkaido.

With the help of this technology digital bathymetry of the large region to the north-east of Kamchatka was prepared for numerical modeling of tsunami propagation.

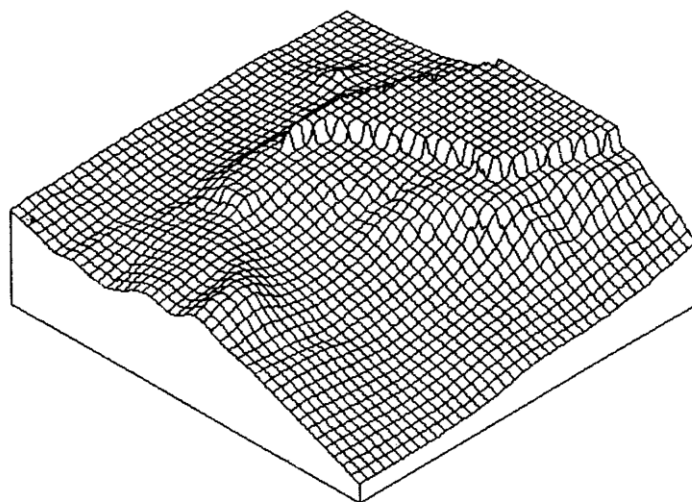


Figure 5. The picture of bottom relief, produced with the help of digitizing technology

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