

Technology of 3d relief modelling based on Delaunay triangulation algorithms

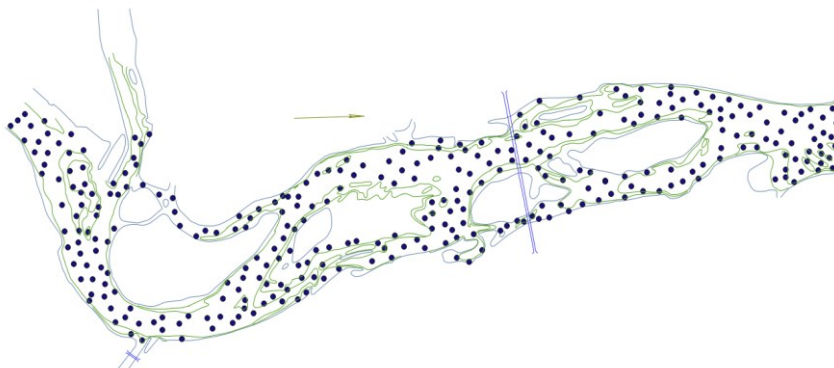
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Abstract. This paper represents the algorithm of superimposing underwater relief and land relief basing on heterogeneous initial data with the use of Delaunay triangulation. As a result of superimposition a qualitative 3D relief model has been created. This model can be used in generating forecasts of reservoir shoreline alterations related to hydroelectric power plant flushing. The described technology has been appropated in various practical tasks and has shown its efficiency.

In the course of flooded area calculation in the lower pond of the Irkutsk HPP there appeared the necessity of creating the relief model which includes the river bottom contour. The land relief being represented with different sophistication on topographic vector electronic maps in various scales, no information on the underwater relief of the Angara River could be found. The existing soundings information for certain navigators is only presented fragmentally, and, according to specialists, is not accurate. The only reliable source was the atlas [1], which was distributed in paper form. It brought up the necessity of digitizing the maps presented in the atlas and superimposing the maps on the available topographic base.

The digitizing of the paper atlas was made with the use of Easy Trace 7.99 shareware vector map generator. Depth contour lines, depth marks, shoreline have been digitalized.



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Fig. 1. Result of digitizing

The atlas sheets are oriented in arbitrary directions in order to place the reaches of the river on the pages in a more compact way. For the future use of the atlas sheets a rotation and a shift into the relief model map coordinate system have been performed. To choose rotation parameters, the distinguished points (capes, bays, island top ends) of the two maps have been juxtaposed. Supporting software has been designed to calculate the transformation parameters from the given list of positioning data pairs and to transform the map. The least square method is used to search for the transformation parameters. The method requires only two pairs of corresponding points, but the use of a bigger number of points allows obtaining more accurate results as well as evaluating the accuracy by standard deviation. In this respect, the standard deviation is 25-70 m. The deviation value is accounted for by the significant contour divergence, as the divergence may touch upon the distinguished points used for the juxtaposition of the maps.



Fig. 2. Juxtaposition of the maps

An attempt to superimpose the contours of the vectorized shoreline on the shoreline of the topographic base has shown that the atlas was created schematically, without a reference to any map (Fig. 2). That is, the atlas shows distinguished shoreline curves, but it is impossible to superimpose this shoreline on a more accurate contour by means of rotation and shift. The experience of the use of the rotation and shift transformation calculated from the juxtaposed distinguished points has demonstrated that the obtained result cannot be significantly improved by means of making transformation parameters more precise.

In order to make it possible to use insufficiently accurate data to create a relief model, software for electronic map morphing has been developed. To perform morphing it is necessary to find continuous plane transformation which can superimpose inaccurate shoreline contours on more accurate ones. The layers of the shorelines are used to superimpose the maps because they are present on both maps. Thereafter, the same transformation is applied to other layers of the underwater relief (isobaths and depth

marks). The obtained data accord better with the land relief data, at least the transformed isobaths and depth marks do not lap over the shoreline. The transformed shoreline contours are not used as they are, as more accurate shorelines are already available, that is why the target line deviation is excusable, for example, as a result of adding superimposition interdiction. The crucial thing is that contour deviation areas should not contain the data of the used layers of the inaccurate map. To perform map morphing two separate software modules are designed: the first one is for semi-automatic parameter setting for contour superimposition and the second one is for performing transformation.

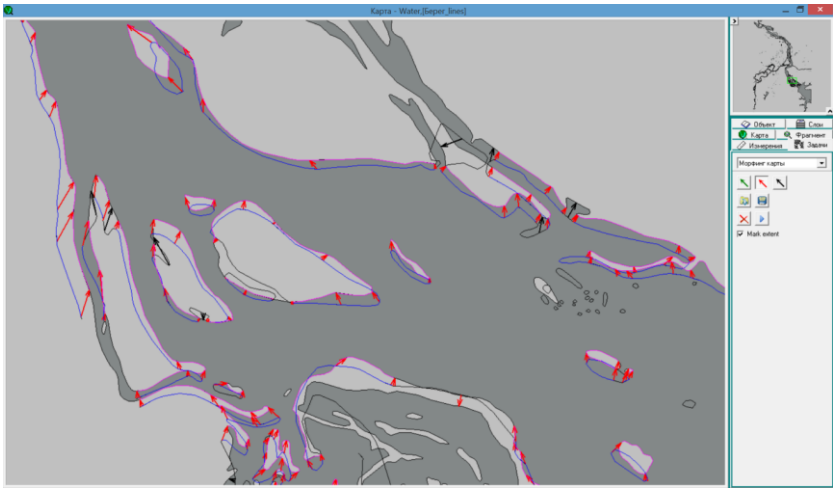


Fig. 3. Transformation adjustment for contour superimposition. The accurate map is shown with painting, the transposed map is in contour representation

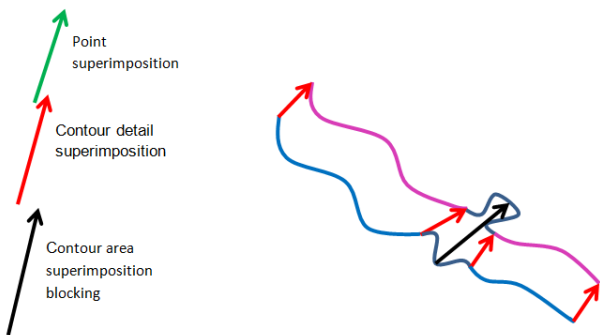


Fig. 4. Map superimposition operations

The map superimposition is performed as a special task with the help of IrkGV map viewer (Fig. 3). The task constitutes in setting arrows which superimpose the points of the original (inaccurate) map and the target-oriented (accurate) map. Three types of arrows are used to superimpose significant points, to superimpose contour points, and to interdict the

superimposition of contour details (Fig. 4). When superimposing contours, the initial point and the finishing points of the arrows drawn by the user are projected into the closest contour points of the corresponding maps. Next, we draw display of every contour detail of the original map object into the specified contour detail of the target-oriented map object. It is done for each pair of arrows which are closely spaced on both contours. Thus, if we, for instance, add an arrow between the points of one of the contours which superimposes this point on the third contour, there will be no superimposition of the contour details.

Juxtaposition of two closed contours is to be processed separately. Without taking it into account, we would have to set no less than three pairs of correspondent points in order to bind the contour details. When choosing details to juxtapose by a smaller number of correspondent points, contour tracing direction is to be taken into account: the contour details which have identical contour tracing are to be juxtaposed. It allows setting correspondence between contours using only one pair of points.

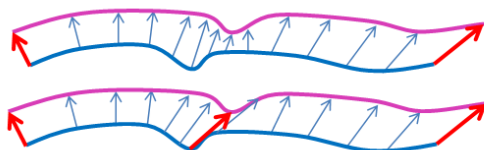


Fig.5. Adjustment of distinguished points superimposition by means of adding their obvious juxtaposition.

The display of the points that belong to the juxtaposed contour details is performed with the help of the linear transformation of parametric curve coordinates. If the result is not satisfactory, one has to clearly juxtapose the distinguished points of the contours to ensure juxtaposition of the contours (Fig. 5). After imputing data on the superimposition of the maps a transposition file is formed which includes not only obviously set shifts, but also the shift that have been calculated for temporary points of the contours. Superimposition interdiction is required in cases when the juxtaposed fragments are represented with different sophistication. For example, the accurate contour depicts a bay which is not present on the less accurate one. In this case, one had better avoid juxtaposing the fragment correspondent to the bay and the straight part of the transformed contour (Fig. 4).

Morphing was executed with the help of triangulation building software [2]. In doing so, limited triangulation is built by the initial points from the transformation file. Ties are added for the nearly points of one contour. Shift vector to the target point is memorized for each triangulation point. Then, layer processing in Shift format is performed: each point is transposed onto the vector which was obtained by linear interpolation from triangulation points.

To juxtapose the data on the underwater relief and the land relief, map layer triangulation building form has been improved. The role of each layer in triangulation building is now specified. The layer may contain the following information: land relief, standing water level, shoreline contour, underwater relief. Underwater relief operations require standing water level information. These data are used to build subsidiary triangulation which

provides hypsometric data. The shoreline contour, in regard to which the depth is measured, is linked to these data.

Isoline contouring by triangulation is used to calculate the flooded area. The height of isoline points are determined by the difference of height of the original relief and the calculated water level after flooding. This approach allows obtaining more accurate results and covering a bigger area in comparison with commonly used isoline contouring by terrain model for the height equal to the water level at a certain point increased by the height of water lift at this point.

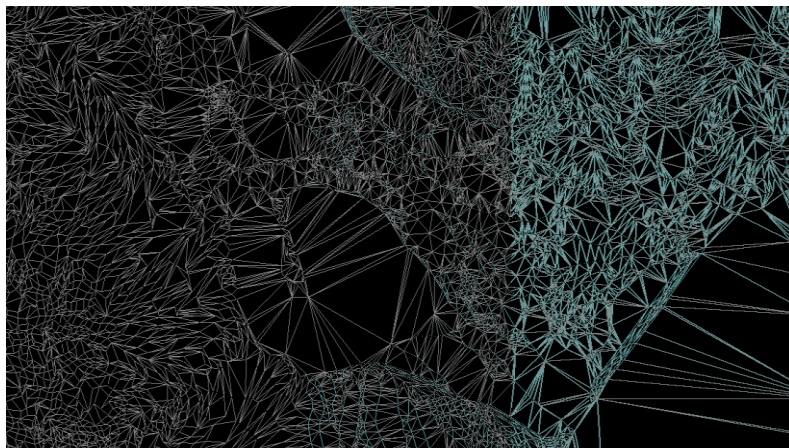


Fig 6. A fragment of built triangulation containing information on land and underwater relief

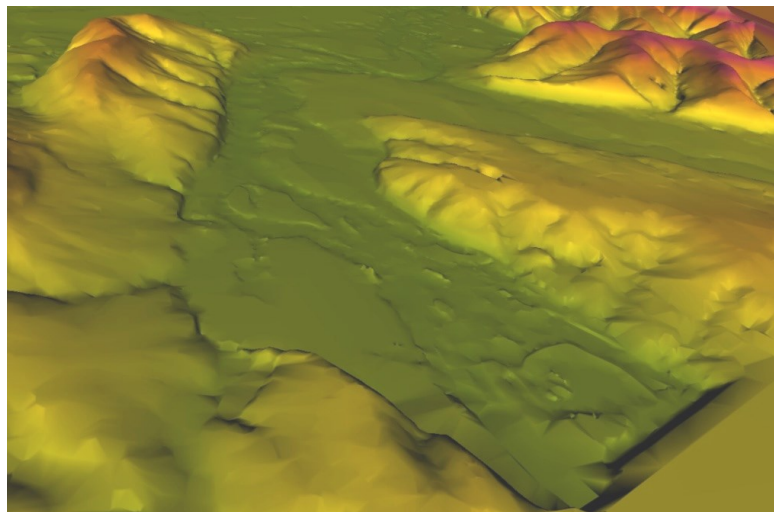


Fig. 7. Superimposed relief (the picture is blown up for clarity)

The created relief model is saved in the triangulation file (.trg files) and can be used for future analysis with the application of TrigLib.dll dynamic library designed to deal with

these data. This library allows deriving relief height from the triangulation at an arbitrary point and tracing the line, i.e. to obtain contour interval along a fragment or a curve.

Apart from principal triangulation, which contains relief data, subsidiary triangulation is formed, being built by standing water level, which contains data on water level surface used to create the general relief model.

Triangulation building program implements the algorithms for river valley cross section building by the coordinates specified in the file, relief contour building by specified triangulation, as well as subtracting heights specified by one triangulation from the height points of another triangulation. Thus, the triangulation based on the calculated water level is built to plot flooded areas.

Using the TrigLib.dll dynamic library, the software for altimetric data generation by arbitrarily given contour of the Angara River has been elaborated.

Conclusion

As a result of extreme flooding evaluation under various cases of extreme water content in the basin of the Angara River and Lake Baikal the hybrid information geographic system has been created, which allows simulating various flooding and shallowing scenarios and determining flooded zones with account of underwater and land relief. The described technology has been approbated in various practical tasks and has shown its efficiency.

References

1. *The map of the Angara river from Irkutsk HPP to 142 km* (the Ministry of Transport of the Russian Federation, River Transport Department, Glavvodput', "Water Routes of the East-Siberian basin" state owned enterprise, Irkutsk, 1994)
2. A.V. Skvortsov *Delaunay triangulation and its application* (Tomsk: Tomsk University Publishing House, 2002)