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ANALYSIS OF DIGITAL SEA BOTTOM MODELS GENERATED USING ENC DATA

ABSTRACT

In the article basis of modeling the surface for spatial presentation of sea bottom hale been included. There have been shown typical, well known, method for generating TIN (Triangulated Irregular Network), GRID and mathematical methods using C++ environment. For presentation the sea bottom ENC (Electronic Navigational Charts) encoded in S-57 Standard have been used.

Keywords:
ENC, digital bottom model.

INTRODUCTION

In order to analyse the pros and cons of different methods, algorithms describing these methods have been encoded in C++. Thus we could observe and study the impact of parameters on the modelization. But before describing any results, it is important to mention that comparing generated sea bottoms to Electronic Numerical Charts data they come from is not a simple task, as we have in fact no idea of what reality is, we only get information in some places such as depth contours or soundings. So studying modelizations should refer to the most sensible representation of reality we could imagine.

FIRST STEPS IN VISUALIZATION

Analysis will be made from ENC PL4P3030 which represents the Gulf of Gdansk and Hel Peninsula. Data used for modeling are contained in an .emif file.

This file is built from a .mif file created by ENC MIF. Unfortunately, ENC MIF doesn't decode sounding values from ENC data, so modeling will only use depth area, depth contours and land area. This is why some areas in the sea bottom might stay unfilled after modeling.

The first method encoded was the nearest neighbour method, as it is a very simple algorithm. This appears in appendix B of S-57 Standard. Displaying maps with nearest neighbour method is, as we expected, a very fast way for modeling. An advantage of this method is that depth values can be determined for each node of the grid, so there won't be blank nodes on the grid, as can be the case for the inverse distance power method. But the model is very rough, and even if it gives an idea of what the sea bottom might be, a 'stairs' effect betrays a blatant lack of realism.

It is necessary, for nearest neighbour improvement, but it is also available for all methods, to exaggerate depths so as to enhance sea bottom slopes. To do this, the ratio of a characteristic depth scale to a characteristic horizontal scale should be greater than 1, which is equivalent to using a non-orthonormal coordinate system. After a few trials, the following ratio has been chosen :

$$\frac{\sqrt{(x_{\max}-x_{\min})^2+(y_{\max}-y_{\min})^2}}{Z_{scale}}=100$$

with Z_{scale} a coefficient which multiplies depth values for display.

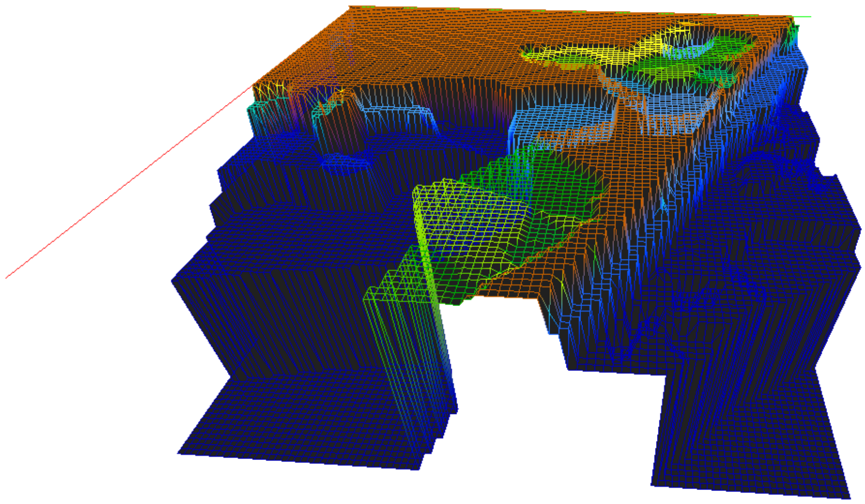


Fig. 1. Hel Peninsula modelized with nearest neighbour method [own study]

COMPARISON BETWEEN GRID AND TIN METHODS

Encoding inverse distance to a power method (Appendix C of S-57 Standard) shows — at first sight — surprising results. Indeed, this method works with a certain 'range', so in some areas algorithm may have no influence, if there is no close data. This results in no depth values for some nodes. 0-depth being the default value, it leads to the creation of islands.

To solve this issue that appeared while using .mif files (that don't contain soundings information), three solutions can be proposed. The first one consists in increasing the distance parameter *d* in inverse distance to a power algorithm, but doing so is not good as it increases computation time, and softens the sea bottom in a way which is not necessarily wanted. Another one is to think 'There is no information, so nothing should be displayed'. So 0-depth default value should be changed to an aberrant value that will be recognised by the application when displaying the surface.

The last one is to use the nearest neighbour algorithm when no data are detected in the d rayon circle around the node. This will display some 'stairs', but gives information everywhere on the map.

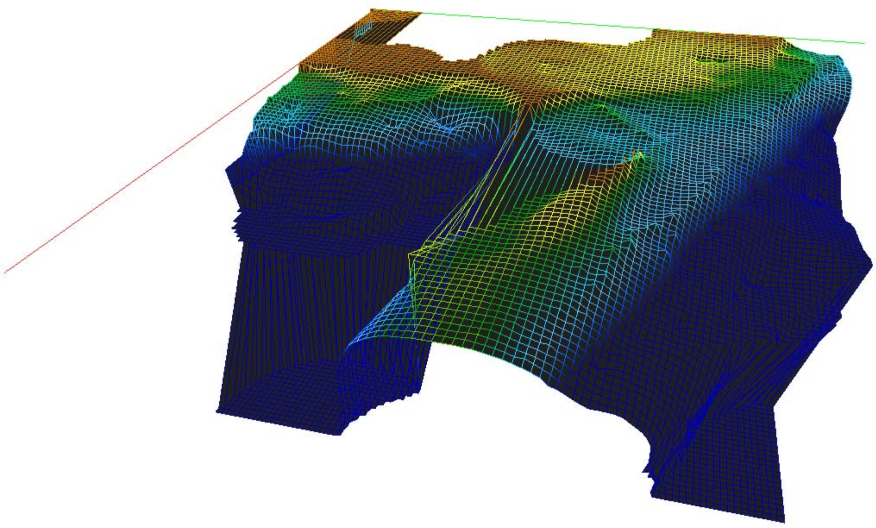


Fig. 2. Hel Peninsula modelized with inverse distance to a power method [own study]

The distance parameter in inverse distance to a power algorithm is quite visible in the displayed sea bottom model (see Fig. 3), so to avoid this β parameter should be increased: the terrain will be rougher and the impact of far points will be reduced, erasing the visible aspect of distance parameter.

At the same time, Hel peninsula, which is very thin, becomes more visible.

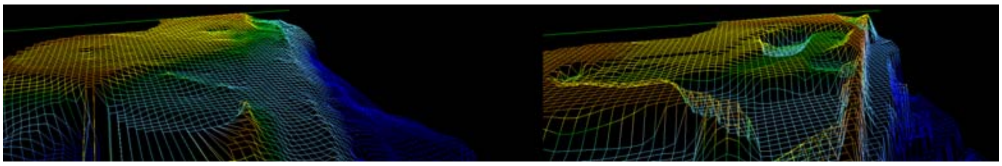


Fig. 3. Hel Peninsula modelized before and after changing β value [own study]

To be sure such a land contour will be displayed, a triangulation method can be used. Thus, each point of the peninsula contour will be kept in memory to build triangles. Applying the TIN method to the map gives the following display (Fig. 4).

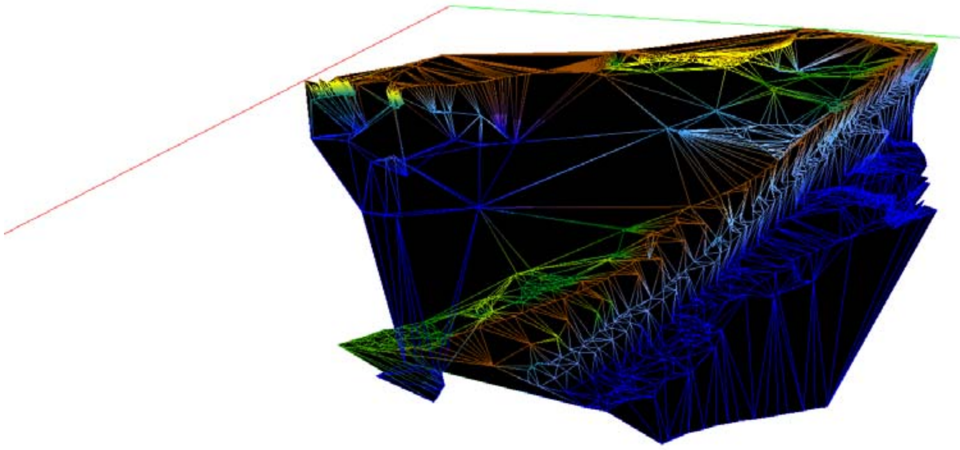


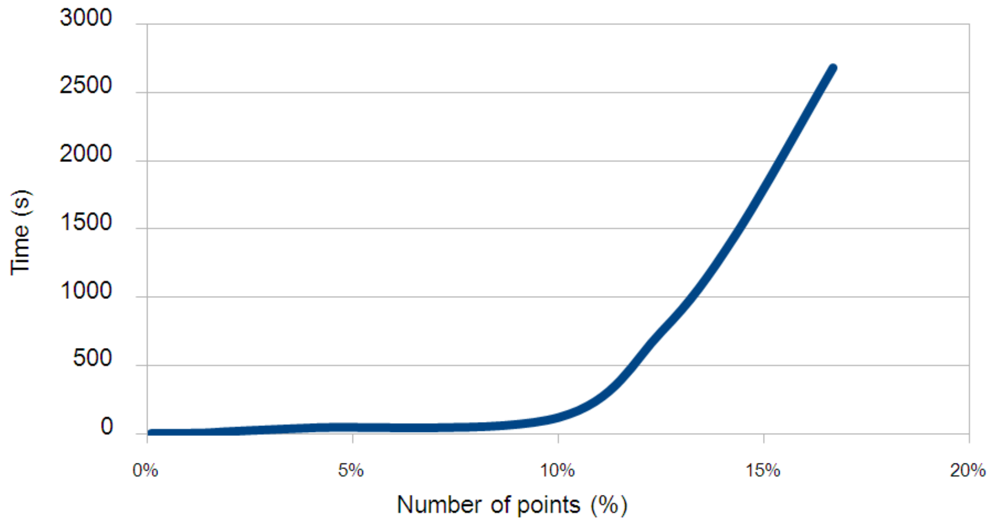
Fig. 4. Hel Peninsula modelized with TIN method [own study]

As it was the case for the grid files, it has been decided to save triangles in a .tin file, which is in fact a text file which contain all triangles. Each line contains the three-dimensional coordinates of three points which can then simply by reading the file, be reused to display triangles without needing to reapply the algorithm of Delaunay triangulation.

It is easy to notice the difference between grid and TIN methods according to the center area of the chart. TIN shows a very light and heterogeneous placement of the points in this spot due to the low quantity of information given by the ENC chart used. On the opposite edges of the seabed are a very detailed part giving a high accuracy for special and interesting parts.

The time requested to mesh the 17770 points is therefore very important, since we have chosen to insert new points in a chosen triangle, the biggest, it supposes that the computer will constantly increase the accuracy of the global chart, so increase the time needed to achieve the meshing process. To quantify the duration we have measured the time needed and have then figured that it increased a lot after a special number of points depending on the point density of the area treated. But this limit can not be defined for the global chart, as the density of points changes according to the place studied, the limit is then difficult to set for a chart and imply to perform tests to be evaluated.

Most of points from ENC data are very closed (depth contours or depth area are very precisely described with a lot of points). So one solution for gaining time is to pick only one point among a certain number in each set of points, so that there will be less points to insert. It will lead to a worse resolution but the results show it is still precise enough for displaying contours. The following figure shows how much time can be gained.



% of points collected	1/6	1/7	1/8	1/10	1/25	1/50	1/75	1/1000
Duration	44'45"	24'13"	12'30"	1'59"	43"	16"	5"	1"

Fig. 5. Duration of TIN generating depending on points collected [own study]

However, the less points are used, the better they should be placed, so as to describe the sea bottom in a right way: points should be placed on land contours, specific points such as rocks outcropping, breaks in the seabed, remarquable depth contours. Fortunately, these special points are those saved in ENC database.

As this database suits to the production of TIN, the triangulation method becomes more efficient than the grid method which doesn't always modelize peaks or ridges of land in a right shape.

NURBS DISPLAY

To go further, a C++ function has been implemented in order to generate digital sea bottom model using NURBS.

Using gluNurbsSurface() function from OpenGL is quite simple provided that data are well prepared: 11 parameters are used to describe the way the surface should be created. There is also a matrix made of control points. This matrix is in fact a grid of control points, because the NURBS surface drawn by OpenGL is like a grid whose points are influenced by control points. So to know which control points influence which nodes, control points have to be defined as a grid.

But geospatial data from ENC are not set as a grid, a way to create the control points matrix should be found. The solution that has been chosen is to reuse inverse distance to a power algorithm to create a matrix of control points from ENC data. Thus, parameters from the grid method could be reused, and NURBS would provide the smooth as for real terrains.

After trying the algorithm with a few control points, it has been tried to generate maps with more control points. But it appears that if the matrix contains more than a hundred control points, the program needs too much memory that it stops. It reveals that using NURBS implies spending time to optimize calculation, but the training period was not long enough to develop this aspect.

IMPROVEMENTS FOR FUTURE DEVELOPMENTS

Computation duration

The main issue that emerges from the implementation of algorithms is the computation duration. How to reduce computation length? We can either reduce resolution or simplify the method. Simplifying the method leads to algorithms such as nearest neighbour process. Reducing resolution depends on the method: it can be made by reducing the number of nodes in grid method or by reducing the number of control points in mathematical methods.

But in any case, speeding up generating of digital sea bottom model can be made through a reduction of the number of points from ENC data, as it was the case in the triangulation method. It will result in a reduction of the quality of the model for huge scales, so the question of scales in the model is raised.

Model resolution

Model scales is a major issue for improving generation of numerical model of terrain, as it has not been handled in algorithms implemented. It should not be forgotten that modeling is used for responding to seamen's desires, so a model of seabed should be created by adopting their point of view.

Modeling could be used for a general overview of navigational charts. In this case, all data are not necessary for generating a terrain, only main shapes are enough for presenting a global environment to the browser. A simple algorithm such as nearest neighbour could be used in this case.

However, if the browser wants to zoom in the map, loading new points would be necessary for a better display, using a more powerful algorithm highlighting dangers in the navigation area. In return, only a small part of the chart, the one that has been zoomed in, needs to be loaded, and methods used for generating this small part of ENC would go faster in the measure as many points will not be used in this method. And as it is often the case in 3D numerical landscapes representing, a fog could be display to hide blank parts of the map (those which have not been loaded) and give users the same field of view as in reality.

The issue of computing duration introduced the concept of model scaling, which both enables to choose the right algorithm and avoid using unnecessary ENC data. This also underlines the strong link between modeling and visualization, because one does not exist without the other.

Data operating

As regards extracted ENC data themselves, they were all considered as sets of points reusable for the model. Contour lines, sounding values, depth areas or land areas contours were mixed points used as input data in algorithms. But to go further, there are many other elements from ENC databases which can be reused in the model. Taking this into account, algorithms are not simple procedures with sets of points anymore, they are procedures parameterized by other components from ENC data. These components could be for example characteristics of the bottom type: sand, rocks, etc. Parameters of methods are not frozen anymore, now they are directly linked to the database.

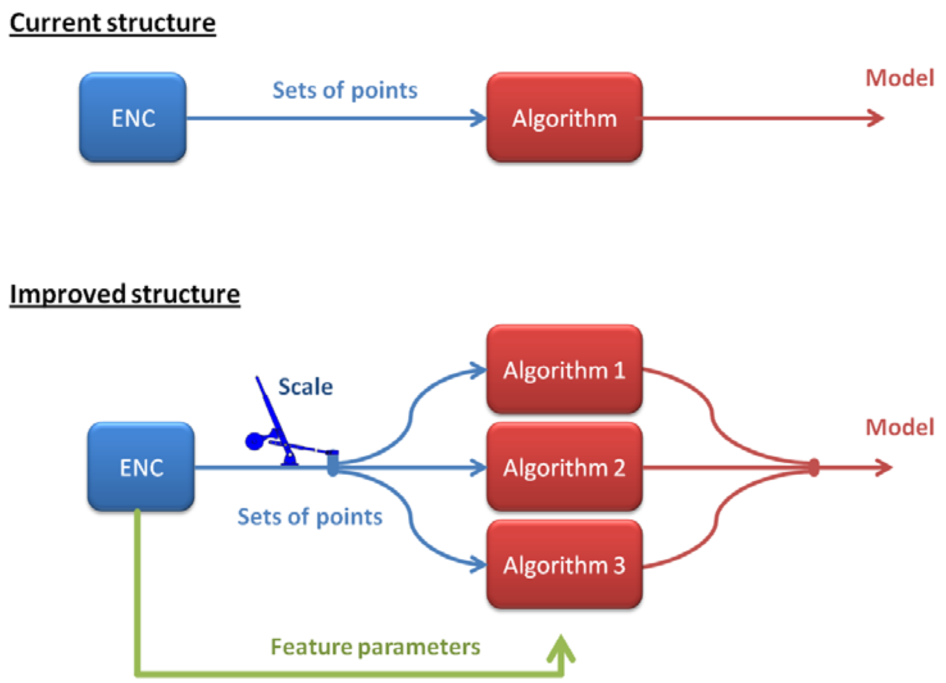


Fig. 6. Improvements in using ENC data [own study]

Moreover, algorithms certainly offer a wide range of possibilities for generating of sea bottom models, but they can be supplemented by other elements. Why not using colours to enhance special areas? Or reusing feature objects so as to display names? And veneering textures on the ground to point out interesting elements such as weed or kelp (see appendix A of S-57 Standard)?

Data operating — for both spatial and feature objects — should be encouraged by the use of S-100 standard for ENC, a new standard which is about to supersede the S-57 one: among its characteristics, 3D display is considered.

CONCLUSIONS

Focusing on the use of spatial items, several ways of modelling appear, and each of them has its own advantages and gaps. Nearest neighbour method is the fastest, Inverse distance to a power is quite easy to set up for a good visualisation, whereas Triangulated Irregular Networks are more complex but the shapes of sea bottom such as peaks, holes or depth contours are well represented. As regards NURBS, they can lead to the more realistic aspect of the terrain, but need a large optimization work in order to be displayed.

The pros and cons of each method have been made visible thanks to the creation of an application to read data from ENC, to code algorithms for modelling, and to display the models which have been generated, as visualization is inseparable from generating numerical models of terrain. Such an application also proved that computation duration is a key characteristic for modelling, and it has led us to wonder about the possibilities of reducing the computation time. Scale may be an important factor to limit the number of spatial objects to display, especially since these objects could be supplemented by the use of feature objects.

REFERENCES

[1] Boissonnat J. D., Cazals. Smooth surface reconstruction via natural neighbour interpolation of distance functions. Technical report, INRIA, 2000.

[2] Dupuy R., Makar A., Spatial Presentation of Sea Bottom Using emif Format, Annual of Navigation, 2010, No. 16, pp. 25–31.

[3] International Hydrographic Organization, S-57 Appendix B.1, 2.0 edition, November 2000.

[4] International Hydrographic Organization, IHO Transfer Standard for Digital Hydrographic Data, 3.1 edition, November 2000.

[5] Makar A., Naus K., Conception of spatial presentation of ENC, XIV International Scientific and Technical Conference The Part of Navigation Support of Human Activity on the Sea, 2004.

[6] Makar A., Naus K., Possibilities Analysis of Using ENC for Creating Digital Sea Bottom Model, Prace naukowe Politechniki Radomskiej, Transport, 2004.

[7] Makar A., Naus K., Mathematical Model of the Dynamic Perspective Projection for Presentation of ENC, La Revista del Instituto de Navegacion de Espana, 2003.

[8] Makar A., Modeling of sea bottom using NURBS functions, Reports on Geodesy, 2005.

[9] Par E., Ratti A., Algorithme de triangulation de Delaunay. Technical report, ENSIMAG, 1999.

[10] Piegl L., Tiller W., The NURBS Book, Springer 1997.

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