Notes

CANADIAN HYDROGRAPHIC SERVICE'S MODERN APPROACH FOR BATHYMETRY COMPILATION

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1. BUILDING A NATIONAL WORKFLOW ARCHITECTURE

The CHS is seeking optimizations in its ENC production and updating workflows. After conducting an extensive literature review on the bathymetry compilation subject in 2019, it was concluded that no usable solution existed to process automatically the generation of ENC-ready depth contours and soundings respecting the chart specifications described in IHO's S-4 document. The CHS took a collaborative approach with Teledyne CARIS to develop and enhance tools built-in *Process Designer* which would fill its needs. The tools allowed the CHS to develop a mostly automated nationally harmonized workflow to create ENC-ready bathymetric features with minimal human interactions, decision-making and manual work. This workflow takes the shape of Process Models needing simple inputs and executing actions in a precise order using predetermined parameters. These models were proven relevant with multiple seabed types and have significantly cut the level of effort required to create new ENCs. The process models allow the creation of the coastline, the depth contours and the sounding selection. They are described below.

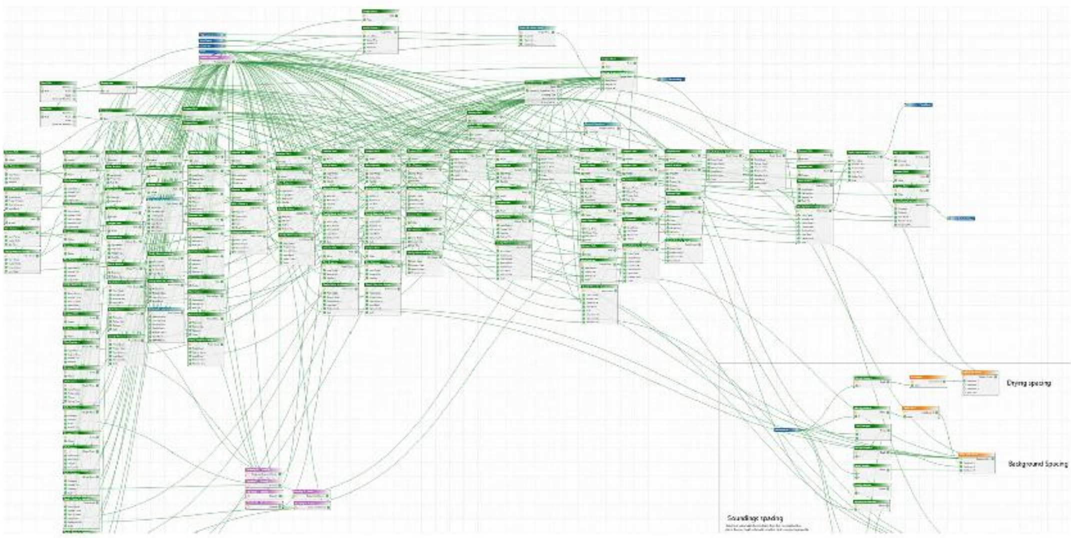

Figure 1. *CHS Process Model Architecture*

The intent of the above Figure 1 is not to be able to understand simply what it is, but rather to illustrate the complexity of the processes in term of relationships and sequences. It looks more like an unreadable "spaghetti" lines throughout many processes, than a clear and simple graphic. *Because it is often more complex to get processes simple, while it is simple to make it more complex!*

The following steps represent the sequences of contouring and sounding selection workflow components being developed and being improved through the project. Starting from the perspective that the deconficted combined surface is the surface validated with the best available data at the time of a compilation, considering the variable quality and density of overlapping data coming from different epochs, acquisition methodologies, accuracies, precisions, sources.

Contouring Workflow

A. Point cloud preparation

a. Convert the deconflicted combined surface to a point cloud at a resolution based on the compilation scale for the product focused on (e.g., 1:25,000 = 250 cm).

B. Coastline creation and generalization

The creation and generalization of the coastline are optional. They are relevant when new data are available and there is a need to create a new coastline or update an existing one by change detection in an ENC.

a. Generate a triangulated irregular network (TIN) from the initial deconflicted point cloud surface.
b. Interpolate a seamless surface from the TIN.
c. Smooth the interpolated surface which aggregates nearby islands together or to the continent, exaggerate tiny islands and give a smoother look to the coastline.
d. Extract the coastline (COALNE) using a High-Water Level value or a reference surface.
e. Create the land areas (LNDARE) features inside the COALNE features.
f. Identify inland lakes that are deeper than the coastline and dissolve them into the land areas.
g. Gently smooth the vector coastline to reduce the number of edges and to give it a smoo-ther look.

C. Depth contours creation and generalization

a. Generate a triangulated irregular network (TIN) from the prepared surface.
b. Add the coastline (existing or automatically created) to the TIN.
c. Interpolate a seamless surface from the TIN.
d. Smooth the interpolated surface which aggregates nearby shoals.
e. Identify shoals that do not contain an island.
f. Extract the surface over the identified shoals.
g. Smooth the extracted surface which exaggerates tiny shoals that do not contain an island.

h. Combine both smoothed surfaces using *Least Depth, True Position*.
i. Smooth the resulting surface to give a smoother look to the depth contours.
j. Extract the depth contours using values accounting for rounding (e.g., 0.049 m, 2.049 m, 5.049 m).
k. Gently smooth the vector depth contours to reduce the number of edges and to give them a smoother look.
l. Remove small deeps.
m. Convert the VALDCO value to standard depths values (e.g., 0 m, 2 m, 5 m).
n. Create depth areas (DEPARE) with the appropriate intervals of DRVAL1 and DRVAL2 values.
o. Identify depth areas with incomplete DRVAL1 and DRVAL2 attributes, consult neighbouring depth contours and depth areas and assign the correct values.

Sounding selection workflow

A. Point cloud surface preparation

a. Cut from the deconflicted combined surface the areas without navigable waters and outside of the area of interest.
b. Convert the deconflicted combined surface to a point cloud using an appropriate resolution based on the compilation scale of the product focused on (e.g., 1:25,000 = 250 cm).
c. Convert existing features which bear a sounding value as an attribute (obstructions, wrecks, rocks) to a point cloud and select them. This will ensure the model will not select any sounding in their vicinity.
d. Combine both point clouds.

B. Sounding selection

a. Calculate the density of significant and background soundings needed based on the maximum depth of the dataset and the target spacing input by the cartographer.
b. Densify the numbers of edges of the vector features so that the mathematical interpretation of the existing features matches the one made by the mariner.
c. Suppress soundings deeper than their DEPARE.
d. Suppress soundings inside dredged areas (DRGARE).
e. Suppress soundings too closed from the docks.
f. Select soundings along the docks.
g. Select the shoalest sounding in each isolated shoal.
h. Select the deepest sounding in each isolated deep.
i. Suppress soundings too closed from the coastline.
j. Suppress soundings too closed from the depth contours on the deep side.

k. Select soundings along ranges and routes.

l. Select soundings in anchorage areas and around anchorage points.

m. Suppress sounding deeper than obstructions, rocks, wrecks or marine farms in the area.

n. Select local shoals (soundings shoaler than their neighbours).

o. Select significant soundings in user-designated high-density areas.

p. Select background soundings in user-designated high-density areas.

q. Select significant soundings.

r. Select significant soundings in user-designated low-density areas.

s. Suppress soundings that are too close to the depth contours on both sides.

t. Select background soundings.

u. Select the significant soundings with a second iteration which may catch a few soundings that became unsafely covered by the selection of the background ones.

v. Select the significant soundings in the drying areas.

2. FIRST RESULTS

Automated software functions are proving to be outstanding tools for cartographers in their daily cartographic operations. They provide a safe and useful navigational product to the mariner while requiring much less effort from the CHS staff both in the creation and quality control steps of the workflow. By removing simple and repetitive chores from the cartographers' task list, it frees them up to perform more complex jobs benefiting from their knowledge and expertise such as vetting the automated results, assessing and validating the quality of newly acquired data coming from different sources. Most importantly, the results are reproducible if processed using the same parameters and are optimal given that the computer does not make any misstep. The aspect of the contours and the sounding selection is consistent across the product and across the entire portfolio of products. An unforeseen benefit of using such tools is that it highlights where the codification or the data validation practices have been insufficient. Assessment of abnormal results from the automation often leads to the conclusion that there has been inadequate cartographic work or a deficient data validation decision made in the past.

3. FUTURE DEVELOPMENTS

Pleased with the results of the automation of the bathymetric features creation so far, CHS is currently working with CARIS to develop new tools to automate the creation of the Quality of data features (M_QUAL) based on the attributes of each cell in the deconflicted combined surface. Such an approach will allow their accurate, fast and effortless creation and updating.

The CHS is envisioning a near future where any new product or update to an existing ENC is compiled using automated tools. New models are being currently worked on where the resulting automatically generated bathymetry and quality of data features are replacing the existing features in the relevant product usage band into the hydrographic product database. Such models can fit the new features in place and fix the topology making sure the result is near ENC-ready. The cartographer will then simply verify that the integration of the new features went as expected and proceed with the creation or the update of the ENC. Streamlining the cartographic workflows is essential for the CHS to keep up with the demand and the needs of its clients related to up-to-date data, dynamic hydrographic products and services.

4. CONCLUSION

Capacity building is of actuality in the world of hydrography to ensure an optimal contribution to the safety of life at sea (SOLAS) and to the various aspects of the blue economy. Thus, modernizing and standardizing the way to update hydrographic products for electronic navigation is timely. It will result in increased efficiency for Hydrographic Organisations (HOs) operations' and fluidity of up-to-date data release while preventing or reducing mismatch of consistency between S-57/S-101 and S-102 data products.

Adopting, developing and improving this modern approach to classify bathymetry and automated workflows provides valuable and necessary teaching and support tools for cartographers, enabling them to take part in this complex decision-making process.

Early positive preliminary results of these new tools have earned the confidence of cartographers, hydrographers and encouraged their use. The development of complete and integrated automatic compilation tools and automated workflows meets the needs of modern cartographers and hydrographers.