ENC Depth Areas

Quality control of sea-bottom surface continuity and error fixes

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***Abstract*—The Electronic Navigational Chart (ENC) consists of point, line, and area features compiled following the node-chain topological model. To ensure that the topological structure is valid, the International Hydrographic Organization (IHO) has developed a number of checks defined in Publication S-58. Many of the checks deal with the vertical component of the nautical chart with the aim to validate consistency among compiled geo-objects. Nevertheless, validation checks are not exhaustive and spatial relationships may be violated. The presented work identifies vertical discontinuities between depth areas and adjoining geo-objects in the ENC and following an iterative approach proposes fixes to the attributes and the geometry of the depth areas with errors.**

Keywords— ENC validation checks; automated nautical cartography; digital terrain modelling; topographic surface; nautical surface; surface reconstruction;

I. Introduction

The Electronic Navigational Chart (ENC) is a database, standardized as to content, structure and format that contains information useful for safe navigation at sea. It consists of a set of point, linear, and area features encoded using the chain-node topology model. Spatial objects in ENCs are divided into the area type objects of Group 1 (known as the "skin of the earth" that must cover the entire data cell without overlap and always be visible in the Electronic Chart Display and Information Systems - ECDIS) and all the other geo-objects that fall within Group 2. To validate the topological consistency of ENCs the IHO has developed a number of validation checks defined in the Publication S-58. Software that perform the checks provide reports for errors among the Group 1 and 2 objects of the ENC in question as well as errors with objects in the adjoining ENCs. The classification of errors is in three categories according to the risk they pose for the safety of navigation (i.e., "warnings", "errors", and "critical errors").

II. Problem Statement

The list of validation checks in S-58 is not exhaustive; new validation checks are added and others are upgraded/ downgraded from one category to another as a result of the lessons learned from real-world situations and research in the field. With the current set of validation checks, the vertical continuity of depth areas is not guaranteed and discontinuities of the sea bottom may exist within the ENC. In specific situations depth discontinuities are expected (e.g., in the crisp boundaries of shoreline constructions or dredged areas and the adjoining depth areas), however, discontinuities of the sea-bottom surface should not, in principal, occur (e.g., the fuzzy boundaries of two depth areas or a depth area and shorelines). Discontinuities appear when two depth values have been assigned for the same location. Consequently, instead of being a smooth surface, the sea-bottom appears with faults in locations where they should not exist. The said discontinuities have a negative effect in research in relevant topics (e.g., automated cartography, automated navigation), undermine the quality of the product, contribute to the "mariner's deafness" with triggering useless alarms, and, most importantly, may pose a danger to navigation.

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III. Research Approach

For the quality control of the vertical continuity in ENCs we follow an iterative approach. First, we identify the edges where discontinuities exist. For this, we incorporate objects such as depth areas, land areas, depth curves, coastlines, and shoreline constructions, and determine their common geometries (i.e., edges) assigned with different depth values. Locations such as those previously discussed where discontinuities are expected are excluded from the error identification process. Subsequently, we iterate the found polylines with errors and correct those that attribute changes fix or improve the current situation. Lastly, for the remaining errors we work on making changes in the geometry of the respective depth areas.

IV. Discussions

Testing has showed that the most commonly found discontinuities are between depth and land areas (shorelines). In the said discontinuities, the populated least depth value of the depth area (i.e., "DRVAL1") is greater than zero, thus the water depth appears deeper than it actually is. In different situations, and contrary to the former, depth areas appear shoaler than they actually are when their populated least depth value is equal to that of adjoining depth areas. Furthermore, other cases of vertical discontinuities are where depth areas have been encoded in different units, e.g., fathoms instead of meters. The research work recognizes that the complete elimination of discontinuities may, possibly, be incompatible with the legibility constraint and cartographic design principles. Therefore, it currently focuses on introducing a mixed machine/human process, but future work will investigate the feasibility of a fully automated solution.