Nautical chart data uncertainty visualization as the means for integrating bathymetric, meteorological, and oceanographic information in support of coastal navigation

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Most navigational charts are an amalgamation of geospatial information of varying quality collected using different techniques at different times. Data collected with high resolution multi-beam echo sounders or lidar systems may co-exist on the chart with data collected with lead-line as far back as the 18th century. A few decades ago, the requirements for high quality charts were not that of today. Back then, mariners were typically obtaining position fixes with methods that were an order of magnitude less accurate than the horizontal accuracy on charts [1] and ships were significantly smaller than those navigating the waterways nowadays.

To facilitate the constantly increasing needs of contemporary merchant navigation for a better and more accurate knowledge of the sea-bottom topography, new systems and techniques for the collection, processing, and dissemination of information have been introduced by the hydrographic community. A significant development in nautical cartography and marine navigation in the last three decades has been the Electronic Navigational Chart (ENC) and the shipborne systems loaded with them, which are known as Electronic Chart Display and Information Systems (ECDIS). ECDIS, besides displaying the information included in the ENC, integrate navigation-related systems and sensors aboard ships, such as GPS, AIS, and RADAR/ARPA and allow mariners to easily and accurately perform simple or composite tasks that were difficult to perform in the past, e.g., plotting the vessel's course or activating alarm functions when the vessel is in proximity to hazards (e.g., shallow waters) or impending dangers (e.g., collision course with vessel sailing alongside) [2]. In addition, metrological and oceanographic information (e.g., sea currents) exist as additional layers that can be activated and de-activated in ECDIS helping mariners to plot and execute their voyage.

In the effort to support safe navigation through better-informed decisions of the mariners, the cartographic and hydrographic community has been continuously investigating methods for the inclusion of data quality on charts and the integration of marine navigation related information on ECDIS. Data quality on charts is currently provided as a series of Category Zone of Confidence (CATZOC) values [3]. For every part of the chart, CATZOC values provide information about the horizontal and vertical uncertainty of bathymetric information, as well as the seabed coverage and feature detection. Currently, CATZOC is portrayed in ECDIS as an additional layer with glyphs using a rating system of stars: six to two stars for the best to lowest quality data and “U” for unassessed data (Figure 1). With the provided information, mariners may more effectively interpret the seabed morphology, identify shoals that pose a threat for the plotted voyage, and select routes that maintain under-keel clearance (see Figure 1), however it is not always well understood and utilized by mariners.

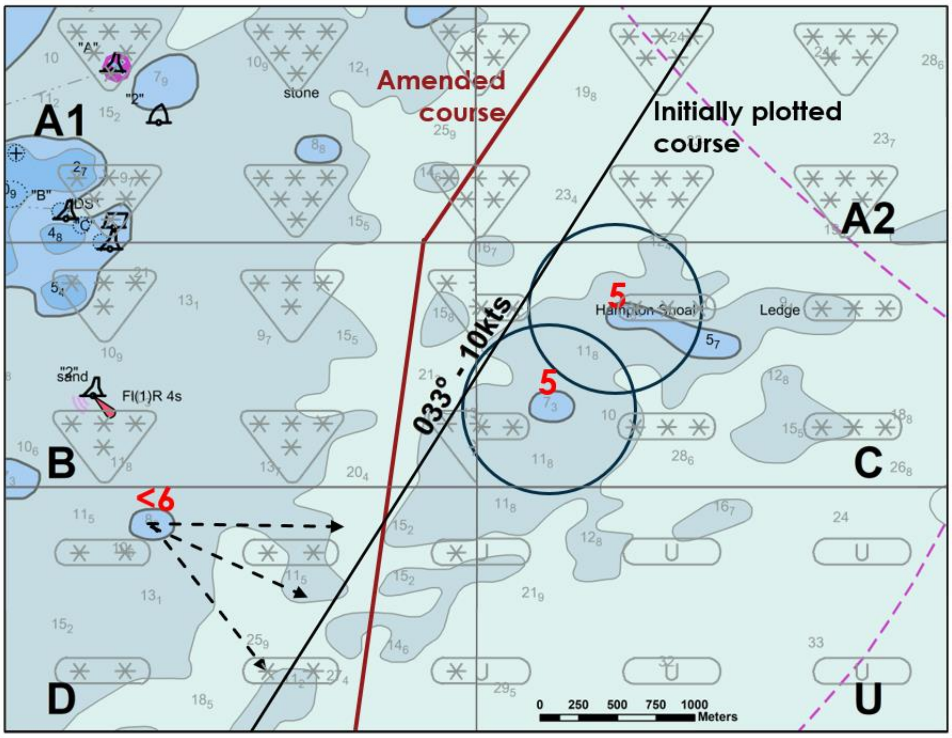

Figure 1. An example of an intended course before (black) and after (red) the appraisal of the shoal features in vicinity and taking into account the horizontal and vertical uncertainty of bathymetric information derived from the assigned CATZOC values.

In this two-fold work, we begin with investigating new visualization methods for the bathymetric data uncertainty on charts. We subsequently utilize the results of the visualization work for the integration of marine navigation related information in support of decision making and safe navigation of ships. In detail, in the first part of this work we review the visual variables (i.e., color hue, lightness, and saturation, size, shape, orientation, and texture) for their suitability for the application. Furthermore we discuss the size of the area to be visualized, which, contrary to prior solutions that cover either the entire extent of the chart or a zone around the plotted course, we propose the use of zone of width equal to the horizontal uncertainty in the area, and present the advantages of this approach (Figure 2). Lastly, in the second part of this work we demonstrate how the visualized area may be used for the development of an integrated solution that considers the ship’s characteristics, bathymetry and data uncertainty from the chart, along with layers of meteorological, oceanographic and other marine related information in determining the ship’s under keel clearance and potential hazards in proximity. These techniques are expected to improve upon the awareness of mariners during the planning and execution phases of the voyage in the coastal environment and waterways.

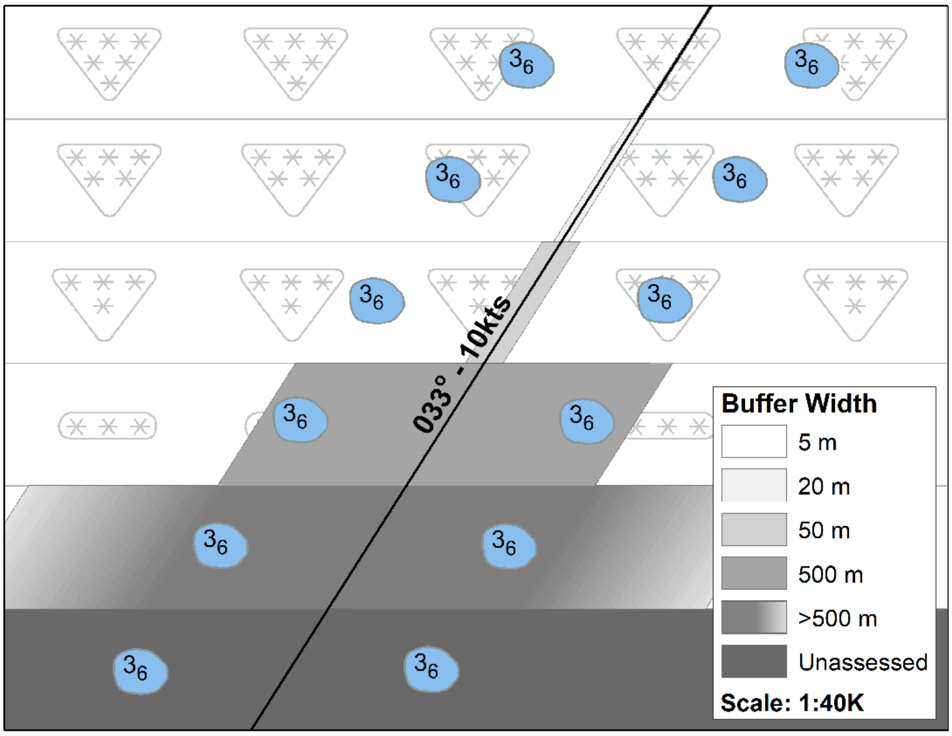

Figure 2. Example of a course plotted through zones of increasing (towards the top of the image) CATZOC values, overlaid with our uncertainty visualizations with zone widths equal to the horizontal uncertainty in each area.

References:

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[2] Kastrisios, C., and M. Pilikou. 2017. “Nautical Cartography Competences and Their Effect to the Realisation of a Worldwide Electronic Navigational Charts Database, the Performance of ECDIS and the Fulfilment of IMO Chart Carriage Requirements.” *Marine Policy* 75: 29-37, https://doi.org/10.1016/j.marpol.2016.10.007.

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