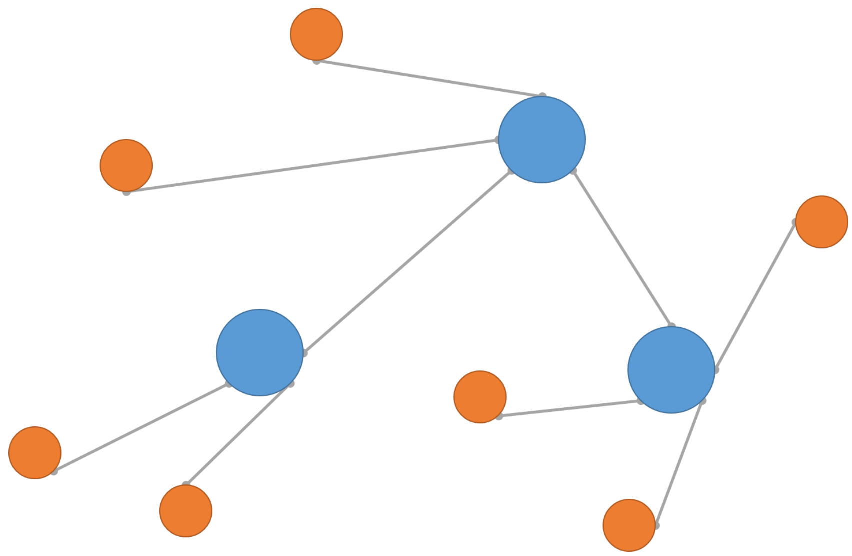
Trusted Crowd-Sourced Bathymetry

From the Trusted Crowd to the Chart



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ABSTRACT

The increasing maturity of the current technologic landscape makes the adoption of Trusted Crowd-Sourced Bathymetry (TCSB) finally achievable. Especially for very sensitive areas like the Arctic region, TCSB has the potential to become one of the primary sources of geospatial information both for safety and security of the maritime territory as well as climate adaptation research.

The installation of a network of low-cost and reliable bathymetric data loggers aboard designated partners' vessels is not only already achievable, but national hydrographic offices should pursue it as a concrete answer to the increasing demand of updated and extended nautical information.

The target of this whitepaper is to combine our efforts for the creation of a modern and open infrastructure able to handle large amounts of TCSB data. This document outlines a data-centric vision – commonly developed by the Canadian Hydrographic Service and the Danish Geodata Agency – where the hydrographic office directly handles the continuous acquisition and automated processing of TCSB streams from a network of selected partners into nautical charts and publications.

PROBLEM STATEMENT

For maritime countries like Canada and Denmark, safety and security have a close correlation with the ability to monitor, control and exploit the maritime territory in connection with its pathways, resources and transportation corridors. At the same time, knowledge of the oceans has a primary role in climate modelling and change adaptation. Thus, there are concurrent requirements of both supervising the collection and management of spatial data (i.e., agency data ownership) and facilitating the availability of this data (data distribution and accessibility) for research and development.

Environmental protection and resilience is even more relevant for the Arctic region that is very sensitive to climate change (e.g., sea level rise) and under significant threat from pollution. The use of advanced and safe technology is an essential element for the development of activities and research in such an area. For instance, tourism along coastal waters and through the fjords is growing together with the challenge to keep it both eco-friendly and safe.

Nowadays, there are encouraging results from operating autonomous surface vessels. However, the traditional approach for hydrographic surveying requires high cost and relevant efforts that cannot be easily reduced. Those costs and efforts become even higher in remote areas of the Arctic region, characterized by a lack of data collected by modern hydrographic and cartographic standards, coupled with narrow survey seasons. This situation directly conflicts with the requirements for timely updates and accurate nautical information that are steadily increasing.

As such, it is necessary to seek a different approach for hydrographic data collection and processing that, under the supervision of the hydrographic office, leverages cooperation and synergy with existing infrastructures and activities: Trusted Crowd-Sourced Bathymetry (TCSB).

We have developed our approach starting from the official definition of crowdsourced bathymetry (CSB) provided by the International Hydrographic Organization (IHO) – *"[t]he collection of depth measurements from vessels, using standard navigation instruments, while engaged in routine maritime operations"* [1] – and a review of several past and ongoing efforts to develop effective CSB workflows (e.g., [2-7]). In the remainder of this document, we outline the key elements on how we envision to collect and use CSB from the trusted crowd to the chart.

WHY TRUSTED CROWDSOURCED BATHYMETRY?

Geospatial data used for updating nautical products and, thus, for safety of navigation have stringent requirements, not only in the realm of uncertainty and accuracy of the measurements, but also on the reliability of the collected data. Historically, the latter has represented a tough obstacle to the use of CSB for any practical use that requires modifications to the existing nautical documentation [2, 6]. To our knowledge, only CHS has published to date an official chart (ENC CA479239 / PaperChart 1360 ; edition date 2018-10-17) including soundings coming from a CSB survey [8].

By adopting a data-centric focus, our strategy is to evaluate whether the data are reliable enough to be *"chartable"*. This is based on the consideration that CSB data should not be treated by an hydrographic office differently from other bathymetric data sources.

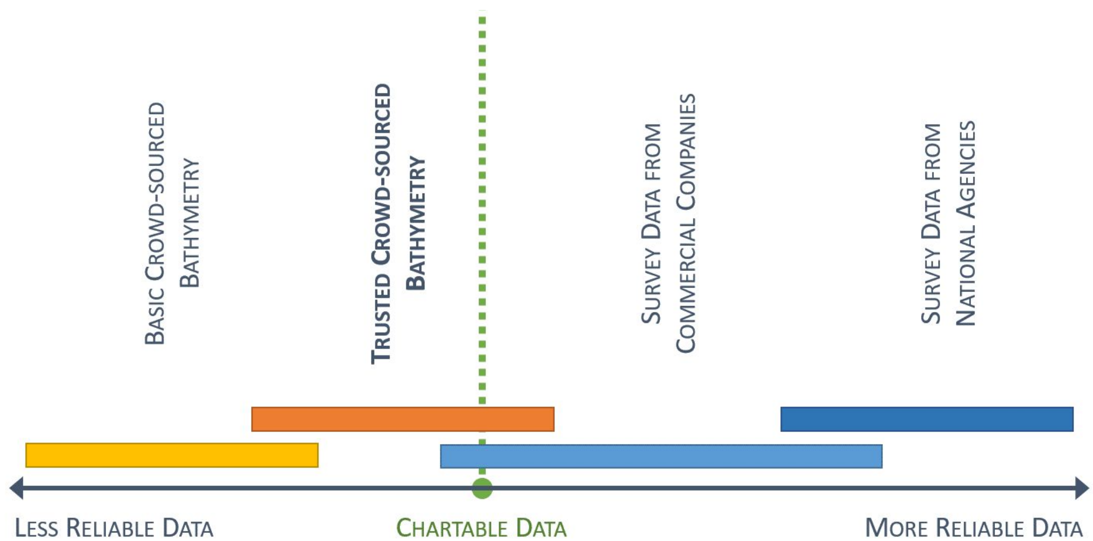

Figure 1 - Example of a plot showing the data chartability of different sources from the point of view of an hydrographic office. The minimum level of reliability for 'chartable data' is marked in dashed green. The shown level is an example of 'chartable data'; each hydrographic office will set/modify it based on contingent evaluations.

Figure 1 illustrates such a concept by setting the ‘chartable data’ level (that is, the minimum level of estimated reliability required for geospatial data to be used to update a nautical chart) outside of the reliability range for ‘basic’ crowd-sourced bathymetry. The ‘basic’ term is here adopted to differentiate CSB from Trusted Crowd-Sourced Bathymetry (TCSB) where relevant efforts are dedicated to support the collectors, as well as in monitoring the quality of the collected data, by comparing against data from other collectors and/or more credible sources (i.e., survey data collected by commercial mapping companies and national agencies). We may also try to infer the data reliability by assessing/tracking the collector reputation [9] (e.g., the surveyor credibility model in [10]).

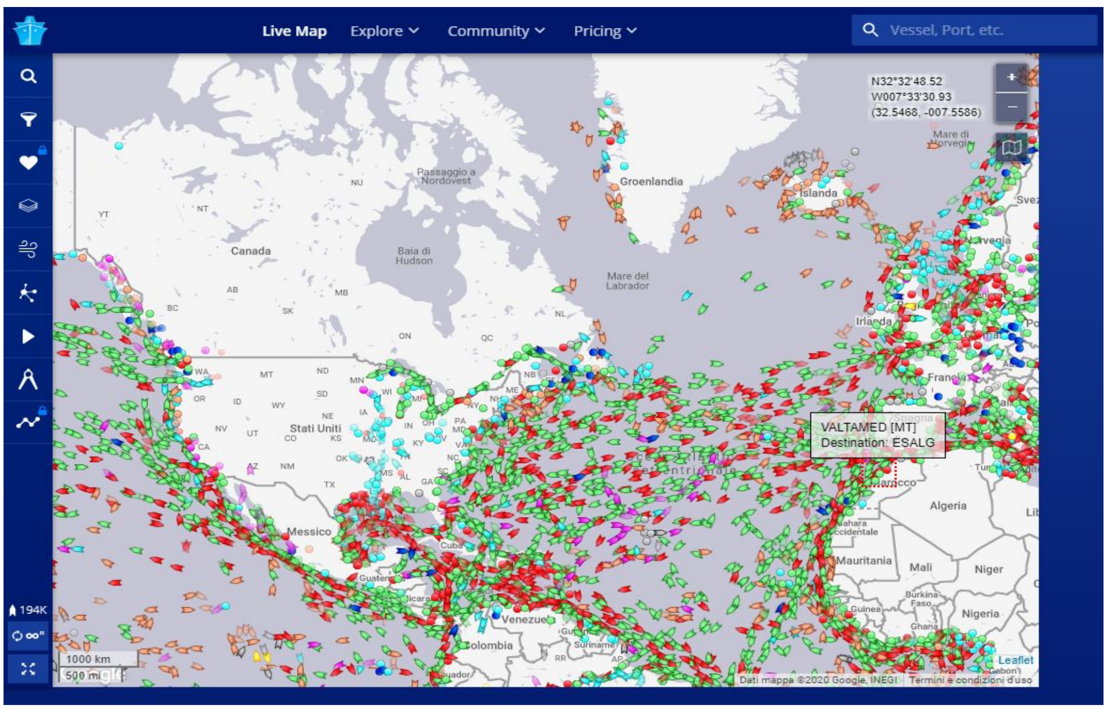

Figure 2 – Publicly-available live map of AIS tracks retrieved from the MarineTraffic website (https://www.marinetraffic.com).

By analyzing automatic identification system (AIS) tracks (see Figure 2), it is possible to designate not only priority areas (e.g., local hot spots of maritime traffic with limited and/or old supporting geospatial data), but also to identify best partners that, by frequently sailing in those areas, could potentially be ideal contributors to the TCSB cause.

We foresee a network of hundreds of TCSB collectors that deliver a constant stream of data with a better quality than the potential storm of low-quality data from basic CSB collectors. Limiting the number of low-quality data is also a good strategy to keep a high level of agency responsiveness in case a potential danger to navigation is remotely identified.

LOW-COST, HIGH-PERFORMING TCSB DEVICES

Based on published CSB projects and a preliminary assessment of the maturity of current technologies (e.g. [5, 6]) we evaluate that it is already possible to assemble low-cost, but high-performing TCSB devices.

Such a device requires the following components:

- A data logger that collects and applies an accurate timestamp to the sensor data.
- A GNSS receiver supporting GPS, GLONASS, and Galileo systems. It is a requirement to also log raw GNSS observations to improve the accuracy in post-processing using Precise Point Positioning (PPP) and Post-Processed Kinematic (PPK).
- A motion reference unit providing measurements of pitch and roll for the vessel.
- Communication means between sea (the device) and the shore (the TCSB control center). A connectivity manager should be in charge of handling the dynamic switch between costly satellite communications (adopting an operation mode that minimizes the data exchange) and low cost solutions (e.g., GSM) that provides wider data access whenever the service coverage is available.

The described TCSB devices must be connected to standard navigation instruments of the host boat to receive the depth measurement (e.g., using NMEA messages). The fusion of the inputs from the sonar, the GNSS receiver and the motion reference unit in the data logger makes it possible to geo-reference the depth of the seafloor. Open formats for both raw and processed data will be embraced.

A key requisite of such devices is to be able to collect data with the quality required to be used for charting aims. As such, the minimum specifications of the components should be evaluated in function of the accuracy after the whole data integration. However, the resulting technical solutions adopted in the TCSB devices should represent an acceptable trade off based on a target price of the order of a few thousand of euros.

We anticipate that those devices need to be developed in an open framework so that their production can benefit from open competition on the market and research contributions. Furthermore, an open TCSB solution could be easily adopted and improved by other hydrographic agencies.

AUTOMATED DATA VALIDATION: TRANSLATING RELIABILITY INTO DATA QUALITY

As previously mentioned, the reliability of the collected data represents a key requirement for TCSB devices. Since the flow of this data will be continuous, an automated procedure needs to be developed to validate the data quality [11] and, at the same time, update the reliability of the data collected by different TCSB collectors.

When a TCSB collector enters areas where modern nautical charts exist (e.g., based on recently-acquired swath sonar data, with full seafloor coverage), the collected data can be tested against the available geospatial information. When a bathymetric reference surface is available along the tracklines collected by the TCSB device, a more accurate calibration of the device is possible and, thus, should be applied [3, 5-6].

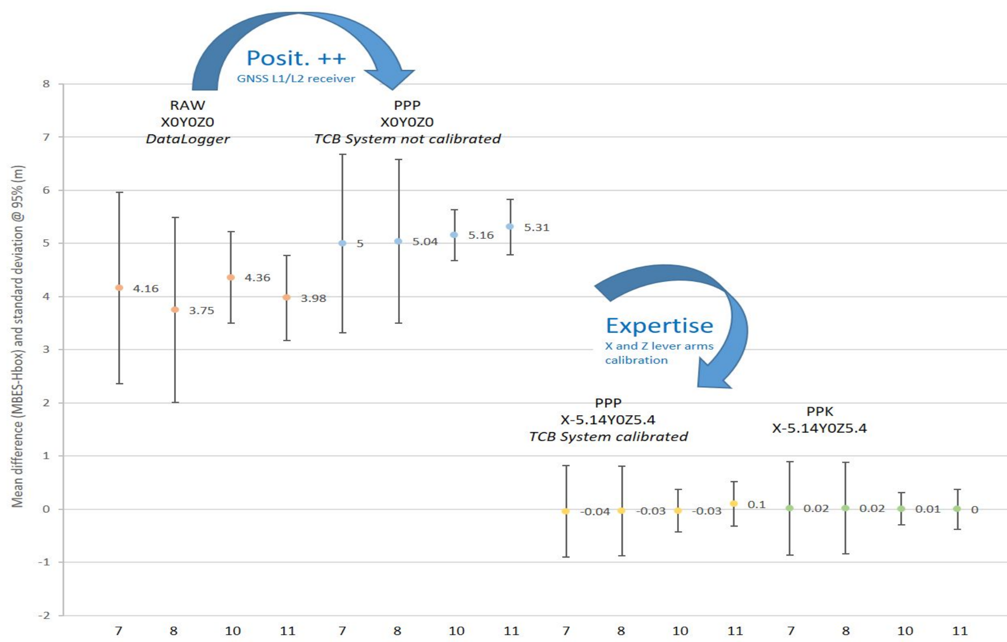

Figure 3 – Evidence of increased quality after data post-processing and calibration [6].

For instance, a 2-step calibration process was described in [7]. This calibration process for X and Z lever arms, combined with PPP and PPK techniques, has been proved to greatly increase the data quality (reducing both inaccuracy and uncertainty) in the pilot project (see Figure 3).

We will also explore mechanisms to encourage participation. For instance, a positive feedback could be provided to the TCSB collectors that have submitted data of good quality [9].

We foresee to implement in-house the described validation process. By following an open development paradigm, the resulting process might be easily adopted by the trusted-node model proposed by the IHO CSBWG [1].

CONCLUSIONS

This whitepaper collects and analyzes – from the perspective of an hydrographic office – specific needs and practical opportunities for the adoption of Trusted Crowd-Sourced Bathymetry as a primary source of geospatial information, stemming from national policies, past and ongoing initiatives, the user communities, and stakeholders.

Its aim is to trigger actions (studies, pilot projects, and programs) able to facilitate TCSB adoption with appropriate initiatives and solutions. We expect that several hydrographic agencies share the same desires identified in this whitepaper and that the envisioned approach will have the potential to cover all ocean areas.

Finally, we believe that several of the concepts described in this whitepaper (e.g., the automated validation process) also represent a relevant contribution towards autonomous hydrographic surveying.

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