Characterizing free and open-source tools for ocean-mapping

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Abstract: Over the last years, scientists and professionals have made available several free and open-source software tools meant for geophysical survey planning, underwater remote sensing data processing, and geospatial data visualization. However, the use of these tools is limited within hydrographic offices. One of the reasons could be the lack of awareness about the functionalities and the performance of the available solutions. The purpose of this paper is to present an overview of free and open-source tools that may be applied to a Hydrographic Office workflow including data acquisition, data processing, quality control, and data visualization.

Key words: FOSS4G, Hydroffice, Hydrography, MB-System, Seabed2030.

1. INTRODUCTION

Ocean mapping is mostly intended to provide an accurate model and characterization of the seafloor and a measurement of the sea level, with the purpose of nautical chart production in support of marine navigation. The workflow comprises topographic and bathymetric data collection, post-processing, surface modeling, visualization, and validation, before submission to the respective division for nautical chart production.

Hydrography, an applied science encompassed in Marine Geomatics, is influenced by advancements is relevant fields such as civil and ocean engineering, data science, and robotics. New technologies, such as high-resolution swath systems, topographic and bathymetric LiDAR, aerial photogrammetry, robust sub-decimeter positioning systems, and unmanned systems, are gradually implemented in hydrography. These new technologies have made the processing, management, dissemination, and visualization of massive 3d point clouds necessary (Kulawiak and Lubniewski, 2019). This need is expected to increase in the context of the Seabed2030 initiative for the mapping of the global seafloor with modern technologies (Wölfl *et al.*, 2019).

To perform the above tasks and to obtain hydrographic derived products, hydrographic offices predominantly use commercial software in their workflows. On the other hand, marine research centers and academic institutions conducting geophysical surveys often develop their own tools or adapt and customize existing Free and Open Source Software (FOSS). Thereby, not only licensing costs are reduced, but features unavailable with commercial software can be attained.

Nowadays, the use of FOSS is widespread in industry, academia, and among individual users. Particularly when it comes to FOSS for Geospatial Applications (FOSS4G), there is already at least one mature solution available for each geo-technology area (Brovelli *et al.*, 2017). Indeed, FOSS4G are key elements in major Earth Observations Programmes, such as Copernicus, and public sea mapping initiatives like EMODNET and AusSeabed (see Coetzsee *et al*., 2020; Schaap and Moussat, 2013; Picard *et al*., 2018). Also, Hydrographic Offices like SHOM and NOAA's Office of Coast Survey (OCS) are recognized producers of open source software and have implemented them in their work procedures (Massetti *et al*., 2018).

Nevertheless, the use of FOSS4G by Hydrographic Offices is limited as most of these nautical charting authorities rely on commercial software for their ocean mapping workflow. Several reasons can be identified: the performance and reliability of the commercial software packages, the customer support, the familiarity of users with specific software, and the liability exposure in charting, to name a few. Furthermore, we can also identify as reasons for the limited use of FOSS4G the unawareness of their availability for use in the workflow, and, most importantly, the absence of a comprehensive study on their features and their performance compared to the commercial software.

The purpose of this developing research work is to fill this gap with performing a comprehensive study of the capabilities of FOSS4G for use in ocean mapping, offshore and at the office, as an alternative or a complement to commercial software.

2. RESEARCH METHODOLOGY

Online search to identify potential software was conducted, including marine research centers, ocean related academic institutions, hydrographic offices, the Open Source Geospatial Foundation, and popular repositories and research supporting websites, such as GitHub and ResearchGate. A total of 102 relevant software packages were identified. This list of the

Table I. FOSS4G under evaluation

Name	Intended use	O.S.	Main Developer	Homepage
AMUST	Multibeam uncertainty modeling	Windows	Delft TU	https://www.rijkswaterstaat.nl/
Blender	3D modeling	W/L/M	Blender foundation	https://www.blender.org/
CesiumJS	3D maps visualization	W/L/M	Cesium Lt	https://cesium.com/cesiumjs/
Cloud Compare	Point cloud and mesh analysis and edition	W/L/M	CloudCompare community	https://www.danielgm.net/cc/
CMST-GA MB Process	Multibeam data processing	Windows	CMST (Curtin University)	https://cmst.curtin.edu.au/
Entwine	Massive point cloud data organization and display	Linux	Entwaine community	https://entwine.io/
GeoMapApp	Geoscience datasets analysis and visualization	W/L/M	Lamont-Doherty Earth Obs.	http://www.geomapapp.org/
Globe	Multibeam processing and visualization	W/L/M	IFREMER	https://www.flotteoceanographique.fr
GMT	Geographic data manipulation	W/L/M	University of Hawaii	https://www.generic-mapping-tools.org/
HydroBib	Multibeam calculations	Windows	HydroCharting ApS	https://hydrocharting.com/
Hydroffice	Hydrographic workflow enhancement	Windows	NOAA/UNH	https://www.hydroffice.org/
MB-System	Swath sonar data processing and visualization	Linux	MBARI	https://www.mbari.org/
Meshlab	Automatic 3D mesh optimization	W/L/M	Visual Computing Lab of ISTI	http://www.meshlab.net/
MGET	Geoprocessing	Windows	Duke University	https://mgel.env.duke.edu/mget/
Panoply	NetCDF and GRIB format data visualization	W/L/M	NASA	https://www.giss.nasa.gov/tools/panoply/
PDAL	Point cloud data translation and manipulation	Linux	A. Bell et al	https://pdal.io/
PFMABE	Hydrographic and LIDAR data edition	Windows	NAVO	http://pfmabe.software/
Pydro	Hydrographic workflow automation	Windows	NOAA Office of Coast Survey	https://svn.pydro.noaa.gov/
QGIS	Geospatial data edition, analysis and visualization	W/L/M	QGIS community	https://www.qgis.org/
Rayshader	3D data visualization in R	W/L/M	Tyler Morgan-Wall	https://www.rayshader.com/
Sonar2Mat	Multibeam data parser	Windows	CMST (Curtin University)	https://cmst.curtin.edu.au/
SonarScope	Backscatter processing and MBES diagnostics	Windows	IFREMER	https://www.flotteoceanographique.fr
WebTide	Tidal prediction tool	Windows	Bedford Institute of Oceanography	http://www.bio-iob.gc.ca/

potential free-to-use or FOSS4G in ocean mapping was filtered out following the selection process described by Chen *et al*. (2010) for FOSS4G for use in hydrology. That includes factors such as the level of complexity, maturity, popularity, and functionalities of the software. It is noted that web apps, mobile apps and interpreted and not executable software are not considered by this work. Furthermore, only desktop software running on Windows, Linux, or MacOS and updated at least once since 2017 were further considered. All in all, after the initial selection process, 35 different pieces of software were downloaded and installed for further evaluation on a workstation equipped with an Intel processor i7 8850H, GPU Quadro P2000, 32 GB of RAM and 1 TB SSD. These programs were qualitatively assessed and compared to the capabilities and features available in commercial and privative software packages used in ocean mapping by vendors such as CARIS, EIVA, QPS, ESRI, and BeamWorx. Lastly, low performance software and software lacking relevant features were excluded from further consideration. The final list of candidates is presented in Table I.

3. PRELIMINARY RESULTS

Almost every functionality that the commercial software offer can be covered by combining those found in one or more of the investigated FOSS4G. The most important limitation of FOSS4G is the Multi-beam echo-sounder (MBES) and Side-Scan Sonar (SSS) acquisition capability since only GPS data logging was achieved using free tools. Nevertheless, and considering hydrographic data processing and visualization, it could be stated that, from the list of the software of Table I, MB-System is the best alternative to CARIS HIPS, Qimera, and NaviEdit. MB-System accepts the majority of current data formats and includes most of the capabilities offered in these commercial packages. On the other hand, features that need a license, such as CUBE or the TU Delft Sound Speed Inversion Algorithm, are not available in MB-System. Furthermore, knowledge of Linux and the use of command lines are required. In addition, the processing of GPS tide is not possible with MB-System, which can be an issue in shallow water surveys.

IFREMER Globe offers a range of functionalities similar to MB-System with the addition of a complete graphical Windows interface and a better visual experience. However, only Kongsberg ".all/.kmal", Reson "s7k" and Caraibes formats are accepted as input data.

Pydro provides sophisticated and automatized tools for quality control of hydrographic data and a seamless integration with CARIS HIPS and the NOAA field procedures. Pydro may be easily adopted by Hydrographic Offices using similar methodologies and systems to that used by NOAA/OCS. Hydroffice, a set of programs also included in Pydro, provides tools for the hydrographic workflow enhancement (Masetti *et al*, 2018).

There are software products with unique features like CloudCompare (Westley *et al*, 2019) and PDAL for advanced point cloud analysis and manipulation. Survey planning can be complemented with GeoMapApp by collecting publicly available Digital Elevation Models at global and regional scales. Multibeam uncertainty can be modeled with the free-to-use software "Apriori Multibeam Uncertainty Simulation Tool" (AMUST). QGIS, a very popular open source GIS software with a considerable collection of available plugins, allows for spatial analysis and visualization of post-processed data.

Online 3D data dissemination and visualization can be attained using CesiumJS and Entwine without the need of powerful workstations or huge data streaming volumes, features useful when surveying offshore. When it comes to social networks and online publishing, Rayshader provides quick realistic or artistic 3d renders and animations but the user is required to code a few lines in R.

4. CONCLUSION

There has not been identified a single free-to-use or FOSS4G offering the same range of functionalities of the popular commercial software used by most hydrographic offices. Nevertheless, the preliminary results showed that the software under evaluation offer features that can be beneficial for the hydrographic offices (e.g., in quality control) either for offshore surveys or office work. In future work, we conduct an in-detail analysis and evaluation of the individual tasks that FOSS4G can perform compared to commercial software and identify areas that they can be incorporated in ocean mapping.

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