

# Application of Visual Analytics to Maritime Domain Analysis

Margaret Varga and Valérie Lavigne

**Abstract**— The North Atlantic Treaty Organization (NATO) Research Task Group on exploratory visual analytics works to promote the research and deployment of visual analytics techniques among NATO member and partner nations across a broad range of NATO application areas. The group has developed and applied visual analytics tools to support maritime domain analysis. The tools increase situation awareness and information superiority by helping intelligence analysts to overcome data / cognitive overload in the context of complex maritime situations: in order to detect anomalies such as vessels of interest (illegal migrants, drug smuggling, polluters, loiterers, etc.).

This paper describes a case study into the exploration of open source visualization and visual analytics software, in particular, the visualization extensions of Qlik Sense in addressing the user requirements of the the Canadian's Marine Security Operations Centres (MSOCs). The open source visualization and visual analytics tools provide a versatile and effective means for the exploration and analysis of maritime anomaly detection and vessel of interests analysis.

**Index terms:** Visual analytics, visualization, maritime domain awareness, open source

## INTRODUCTION

Maritime domain awareness is defined as “the effective understanding of everything on, under, related to, adjacent to or bordering a sea, ocean or other navigable waterway, including all maritime-related activities, infrastructure, people, cargo, and vessels and other conveyances that could impact the security, safety, economy, or environment” [1]. It is a multi-intelligence activity involving a number of heterogeneous data sources: vessel tracks, textual intelligence reports and knowledge gained through experience. These provide information related to the thousands of vessels that can cross an operator's / analyst's area of responsibility. Indeed, worldwide maritime domain operators / analysts have a mandate to be aware of all that is happening in the maritime domain at all times.

The Canadian Marine Security Operations Centres (MSOCs) maintains a 24/7 watch over Canada's three oceans to protect national security from threats such as drug trafficking, piracy, migrant smuggling, over-fishing, and polluters” [2]. Fig. 1 shows a Recognized Maritime Picture over a 24 hour period of unclassified vessels. This is built and maintained by a very small group of people. There is therefore a need for intuitive and simple to use tools to support the team.



Fig. 1: Unclassified Contacts in a 24 hour period

Visual Analytics is the science of analytical reasoning facilitated by interactive visual interface [3]. It is efficient in detecting the expected and more importantly *discovering the unexpected*. Visualization and Visual Analytics (VA) technologies could provide the necessary capabilities to increase situation awareness / information superiority, and help intelligence analysts overcome

- Margaret Varga is with Seetru Ltd. and Oxford University, Email: [margaret.varga@oncology.ox.ac.uk](mailto:margaret.varga@oncology.ox.ac.uk)
- Valérie Lavigne is with Defence R&D Canada, Email: [valerie.lavigne@drdc-rddc.gc.ca](mailto:valerie.lavigne@drdc-rddc.gc.ca)

data / cognitive overload. This paper reports the exploration of open source visualization and visual analytics for maritime domain awareness.

## USER REQUIREMENTS CAPTURE AND TASK GENERATION

Inter-agency requirements analysis sessions were conducted including both civilian and military staff in the MSOCs. A series of tasks that could benefit from VA tools were identified [4], but it was necessary to focus the limited research resources on the two tasks that presented the highest potential for improvement:-

1. Maritime anomaly detection.
2. Vessel of interest analysis.

### 2.1 Information Requirements

Three main sources of information are required to support Tasks 1 and 2, above, namely:-

1. Geospatial
2. Temporal
3. Factual; such as types of vessels, people, organizations, physical properties etc.

### 2.2 Tool Criteria

The tools must provide an easy to use, and intuitive interface due to frequent changes of staff and limited training time. Two types of tools were considered: (1) purpose built and (2) open source. In the purpose built Defence R&D Canada's Maritime Visual Analytics Prototype (MVAP), the visualization needs are split into a series of visual analytics tools (widgets) [4].

Much consideration was given to the selection of the most appropriate open source tool(s). The selection is based on visualization functionalities, analytics capabilities, as well as development environment (e.g. platform, language, ease of installation and use, accessibility, GUI, documentation) and current status and future plan. Business intelligence tools such as Tableau, Tibco Spotfire as well as Qlik Sense provide promising potential. After exploration of these tools, Qlik Sense [5] was chosen as its visualization extensions allow the creation and provision of open source interactive visualization capabilities [6]. It thus provides an operating framework into which open source plug-ins can be added.

## DATA

Two datasets were used in this case study: an operational dataset and the IEEE VAST 2008 migrant boat dataset [6].

The 40GB Operational dataset consists of 112 million position reports spanning a year and relating to over 75,000 vessels. The VAST data consists of records dealing with the mass movement of people on boats from the fictitious Isla Del Sueño to the United States during 2005 – 2007. It includes dates and locations of encounters, vessels' launch and encountered locations, outcomes (landed / interdicted), number of passengers, number of deaths, type of vessel (rustic, go fast or raft), coast guard vessels and passengers' names. This paper discusses only the work conducted on the VAST dataset.

## QLIK SENSE

Qlik Sense Desktop is free for single users [5] and can be downloaded and installed easily on Windows. There is a cloud-based version for desktop users that can be accessed with a standard web browser. Its user interface is intuitive and users can drag and drop different visualizations. Multiple data sources can be linked through the data editor. Users can create integrated dashboards and easily store / share their work through Qlik Sense Cloud if required. They host their open source visualization extensions on their dedicated website Qlik Branch [5] where users can share, collaborate and find open source projects. Plug-in extensions can be downloaded from GitHub and are easily installed into Qlik Sense. Users can see the list of templates available through their localhost:4848/dev-hub, the user can edit and create new mashups, visualization extensions as well as widget libraries. There are also wizards to embed objects into web pages. There are online tutorials to learn about Qlik Sense, install and create visualization extensions and widget libraries.

### 4.1 Exploration of Qlik Sense

In Fig. 2 Qlik Sense's standard visualization functions show the migrant situation over the three year period.

The geospatial display, top right, shows that over the years the vessels spread along the coast and that two coastlines were targeted (Florida and Yucatan). Each dot represents a vessel; different colours represent the different vessel types. The donut ring shows the number of times the different types of vessels were used. It can be observed on both the geospatial display and the donut ring that Rafts were used far less frequently than Rustic and Go Fast vessels.

The top-most bar chart shows the total number of interdictions (476) and landings (414). This is a worrying situation as the difference between the two is small. The middle bar chart shows the temporal pattern of each vessel type over the 3 year period. The bar chart on the bottom left shows that more vessels attempted journeys during the summer months (June, July and August) c.f. during the winter (January, February and December). The number of vessels interdicted by the different coast guards is shown in the bottom right bar charts.

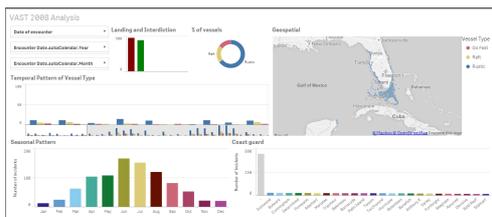


Fig 2. VAST 2008 Analysis

It was discovered that over the years, the number of attempts increased and geospatially the migrants travelled further north with

more successes. A new landing location was discovered in 2006 near the Mexican border which appeared to have 100% landing success rate. This shows the need for improvements in the coast guard patrol strategy.

### 4.2 Open Source Visualization Extensions

There are many different types of visualization extensions available on Qlik's Branch Website. They fall into two main categories, namely for Qlik Sense and QlikView. It is necessary to go through the list to identify the visualizations that could be useful; each has a brief description and the GitHub link to download.

Fig. 3 shows the use of some of the extensions to analyze the data: in particular, the relationship between individual coast guards and the types of illegal vessels they catch. The geospatial display, now colour coded by the coast guard vessels, shows where they interdict the vessels. The top left Sankey shows the link between the vessels and the interdictions. The bottom left Sankey shows clearly when the vessels were interdicted. The Sankey in the center shows which coast guards interdict which vessels, and links to the locations in the map. The bottom population pyramid chart shows the average number of passengers and deaths for each vessel type. It is easy to see from this the benefits of using open source visualization extensions.

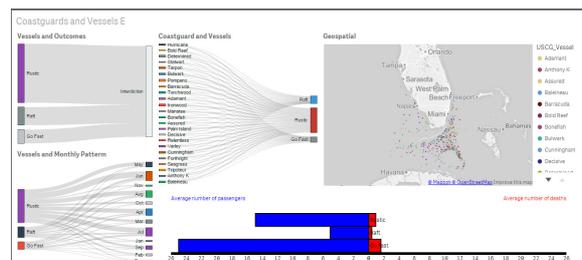


Fig 3. Coastguard and Vessel Analysis

## CRITIQUE

It takes time and effort to follow the Qlik Sense's tutorial to learn about the system, but once learnt it is very easy to use. The open source visualization extensions provide an effective means of exploring and exploiting different visualizations to gain insight into data. Furthermore, it is easy to modify and build tailored extensions. However, as the extensions are voluntary, when the Qlik Sense system was upgraded recently, some of the extensions became incompatible with the new version. The colour synchronisation across different displays is not straight forward.

## REFERENCES

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