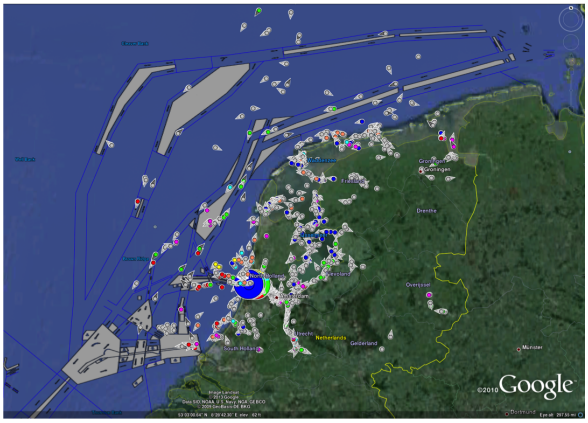
Enhancing operational work in maritime safety-and-security tasks

Steffen Michels [a] Marina Velikova [b] Bas Huijbrechts [b] Peter Novák [c]
Jesper Hoeksma [d] Roeland Scheepens [e] Jan Laarhuis [f]
André Bonhof [f]

[a] *Radboud University Nijmegen, The Netherlands*
[b] *Embedded Systems Innovation by TNO, The Netherlands*
[c] *Delft University of Technology, The Netherlands*
[d] *Free University Amsterdam, The Netherlands*
[e] *Eindhoven University of Technology, The Netherlands*
[f] *Thales Nederland B.V., The Netherlands*

1 Problem description and aims

On a yearly basis, at the North Sea there are thousands of ship movements, to and from Dutch ports, as well as vessels crossing over towards ports in other countries via shipping lanes that are considered the most busiest in the world (see the picture on the right). Adding complexity, the same shipping lanes are located near extreme sensitive environmental areas such as the Dutch Wadden Sea. Maritime safety and security demands understanding of all relevant activities occurring at sea where, compared to land, marked delineations, physical barriers and associated fixed sensors often lack or are only virtually present.



Such understanding involves the continuous monitoring of vessels to detect and predict certain events of interest such as accidents (e.g., collision) or illegal activities (e.g., smuggling), whose consequences can be devastating in terms of human life losses, financial costs or damage to the environment. This requires the real-time collection and processing of a vast amount of information, which is a great challenge for human operators.

Maritime safety-and-security systems have emerged to facilitate timely human decision-making. While recent systems allow automatic identification and warning of abnormalities, they lack capabilities for real-time prioritisation of the application tasks, selection and alignment of relevant information, and efficient reasoning at a situation level.

Such intelligent capabilities are embedded in the innovative system we developed within the Metis project based on the employment and integration of state-of-the-art artificial intelligence approaches. The general architecture of the Metis system is described in details in [1].

2 Deployed technology

The overall intelligence of the Metis system lies in the unique integration of the following components:

(1) Data collection & **semantic alignment**. Data about a vessel under investigation from heterogeneous and (un)structured sources is being automatically retrieved by the system. These typically involve messages broadcasted by the vessel itself, radars, ship tracking websites, and external vessel databases. We deploy *natural language processing* techniques to detect valuable clues inside large bodies of unstructured documents, such as newspapers or intelligence reports, that might indicate or confirm suspicious behaviour in the past. A detailed description of this component is described in [2].

(2) Interpretation of noisy, incomplete and dynamic maritime-related data. The goal is to best possibly predict (i) the true values of the ship's attributes such as identification number, name and type, and (ii) the ship's behaviour in terms of threats such as collision and smuggling, which are used to warn the operator. Given the heterogeneity and uncertainty in the collected ship information, and the dynamic number of sources and ships observed, we chose *first-order probabilistic logic* as a modelling technique. An earlier version of this component with tests of its performance is presented in [3].

(3) (Re)-configuration of the work of the system's components. The Metis system relies on a number of heterogeneous external information sources that can fail, become inaccessible over time, and their access can incur financial costs (e.g., pay-per-request). The goal of the re-configuration component is to compute relevant and resource-saving query plans depending on mission goals and costs to provide cost-effective data collection and interpretation. To do so, the reconfigurator models the Metis structure as a *non-monotonic multi-context system*. A formal description of the underlying theoretical principles of cost-aware reconfiguration is given in [4].

To allow autonomous and continuous running of the Metis system, the communication between its components is provided by a data distribution infrastructure. Finally, the interaction with the operator is supported by an advanced user interface that displays a tailored operational picture of the current situation. The results of the projects are validated into a demonstrable proof of concept and deployed as a plugin in the Thales' command-and-control industrial platform Tacticos.

3 The demonstrator

The full operation of the Metis system will be demonstrated with real-world vessel data, starting from automated data collection and interpretation to reconfiguration and advanced visualisation of the results obtained. The data is obtained from ship identification messages, a world register of ships, ship tracking websites such as marinetraffic.com and PressAssociation news about maritime events. A number of realistic scenarios will illustrate the complexity of the domain and the added value of the Metis system.

Acknowledgements

This work was supported by the Dutch national program COMMIT. The research was carried out as a part of the Metis project under the responsibility of the TNO-Embedded Systems Innovation, with Thales Nederland B.V. as the carrying industrial partner. We thank Tom Regelink for his valuable contribution on the system integration.

References

[1] T. Hendriks and P. van de Laar. Metis: Dependable cooperative systems for public safety. *Procedia Computer Science*, 16:542–551, 2013.

[2] J. Hoeksema and W.R. van Hage. A case study on automated risk assessment of ships using newspaper-based event extraction. In *Workshop of DeRiVE*, volume 1123, pages 42–52, 2013.

[3] S. Michels, M. Velikova, A. Hommersom, and P. Lucas. A decision support model for uncertainty reasoning in safety and security tasks. In *IEEE Intern. Conference on SMC*, pages 663–668, 2013.

[4] P. Novák and C. Witteveen. On the cost-complexity of multi-context systems. *CoRR*, arXiv:1405.7295, May 2014. `http://arxiv.org/abs/1405.7295`.