A Hybrid Approach for the Analysis of Abnormal Ship Behaviors

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ABSTRACT

Current maritime traffic monitoring systems are essentials for a maritime situational awareness. However, they are not always adapted to the identification of risky behaviours of ships. It is very difficult for operators responsible for monitoring traffic to identify which vessels are at risk among all the shipping traffic displayed on their screen [1, 2, 3].

We present in this paper a hybrid approach for analysing dangerous behaviours of ships based on AIS data. This approach is based on supervised and unsupervised analyses and it was developed in the frame of PhDs. Our approach is based on three complementary methodologies: (1) data mining for knowledge and pattern extraction for behaviour modelling, (2) ontological modelling of behaviour for an unsupervised detection and (3) geovisual analysis of large volume of data for a supervised detection of threats at sea. Three prototypes were developed to test our approach.

Index Terms— Maritime Domain Awareness, Ontology, Data Mining, Geovisual Analytics

1. INTRODUCTION

The maritime surveillance centres (MRCC) integrate monitoring systems in order to have in real time a large vision of the traffic of ships. Data acquisition operates heterogeneous data like AIS data, meteorological data, bathymetry data, but all the data are not integrated in a unique interface.
Moreover, the surveillance systems are in general not equipped with analysis support or decision support allowing to detect dangerous behaviours.
Since 2007, in the frame of PhD and R&D projects, our research centre focus its work on the design and the development of maritime surveillance systems and specially on automatic or supervised detection of abnormal behaviours of ships.
We can identify two kinds of behaviours:

- Known behaviours that we can model with expert knowledge [4, 5];
- Unknown behaviours or behaviours interpretable with difficulties, to be characterized with automatic methods like data mining [6].

Then, the modeled behaviours can be integrated into a real-time system of detection of abnormal or dangerous behaviours.

The hybrid approach is designed on both unsupervised and supervised analysis methods. We present in the following sections the components of the approach:

- An unsupervised method for the analysis of the abnormal behaviours, based on data mining;
- An ontological framework for the modelling of behaviours; this framework is used into a real-time detection system of abnormal behaviours, relying on case-based reasoning;
- A geovisual analytics frameworks allowing supporting the operator in his task of behaviour analysis;
- A maritime surveillance system integrating all the components of the methodology.

2. A DATA MINING SUPPORT SYSTEM

The unknown behaviours can be founded with data mining methods that can detect characteristic patterns. The patterns define a ship behaviour that can be modelled for further analysis. In our research (PhD of Idiri), we developed a prototype of AIS data analysis system based on data mining methods [7, 8]. This system named ShipMINE (Fig. 1) is inspired by the system MoveMine [9] that integrates algorithms for the analysis of different kind of trajectories (animals, cyclones, etc.).

Different algorithms are integrated into ShipMINE for the detection of:

- Zones with a lot of accidents (algorithm DBSCAN),
- Abnormal trajectories into a group of trajectories (algorithm TROAD), (Fig. 2),
- Usual trajectories of ships (algorithm TRACLUSS),
- Parallel trajectories like trajectories of parallel fishing that is forbidden (algorithm CONVOY).

The patterns detected with ShipMINE are interpreted by experts of the domain. The useful patterns are then used for the modelling of abnormal or dangerous behaviours.

Fig. 1: The prototype ShipMINE

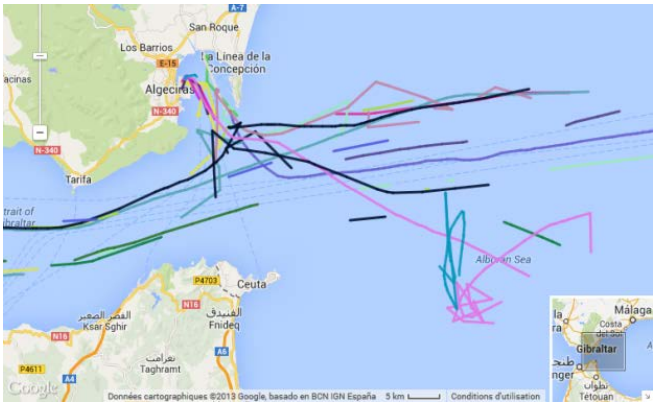

Fig. 2: Extraction of abnormal trajectories with ShipMINE in [7]

3. AN ONTOLOGICAL FRAMEWORK

Ontologies and the semantic enrichment of maritime trajectories are necessary in order to characterize the sequences of the behaviours. In the frame of the PhD of Vandecasteele [10, 11], we based our research on the extension of the ontological framework developed by Yan and his colleagues [12]. We decided to consider not only the spatio-temporal positions of the trajectory but also semantic trajectory units (e.g. begin, stop, moves, end). These semantic units can be enriched with different types of knowledge (e.g. spatio-temporal, geographic, domain) to provide end-users with high-level semantic descriptions of trajectories and a better understanding of the situation (step (a) in Fig. 3). This step allows performing further analyses of trajectories identifying potential alerts related to abnormal movement (step (b) in Fig. 3). Then, the proposed framework allows interpreting vessels' activities and behaviours (step (c) in Fig. 3), using a case-based reasoning approach to compare previous behaviours defined by operators with the current facts. Then the semantics behaviours are integrated through a specific user interface that provides a better understanding of the situation (step (d) in Fig. 3). This approach was integrated into the prototype OntoMAP (Fig. 4).

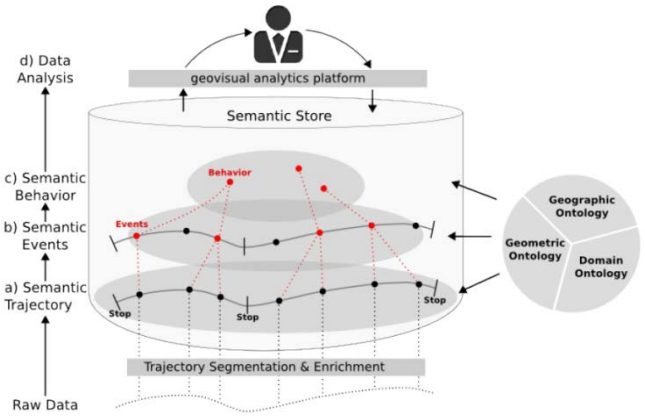

Fig. 3: Conceptual architecture of the system. Raw data are extracted, enriched and then analyzed to identify potential abnormal behavior (in [11])

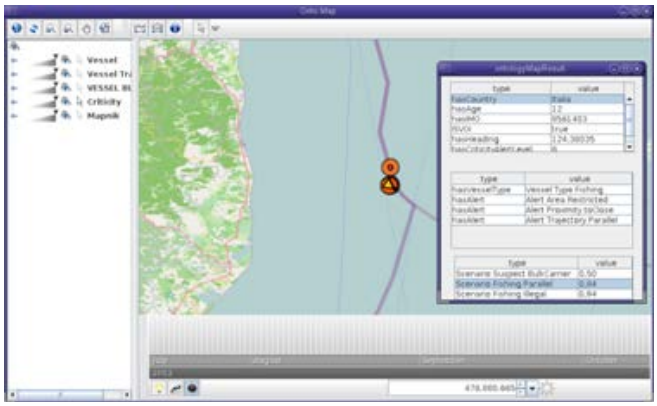

Fig. 4: The prototype OntoMAP in [10]

4. A GEOVISUAL ANALYTICS SUPPORT SYSTEM

The community of geovisual analytics develops a lot of visualizing methods for geographical information [17, 18, 19, 20]. During the PhD of Vatin [13, 14, 15, 16], we developed a methodological approach of ship trajectory analysis based on geovisual analytics (Fig. 5).

Our system proposes to an operator, information and visualizing method the most adapted to the analysis of risky situations. Our approach is based on (1) the modelling of the normal or abnormal situations to be analyzed, (2) the

modelling of the information and the visualizing methods to be used and (3) the modelling of the profile of the operator and his capacity to handle the information and the visualizing methods.

Because the operator of the MRCC is not accustomed to handling these methods, our system proposes to him, based on the analyses of his capacity and of the situation to be detected (pirate attacks, etc.), the visualizing methods the most adapted to the context.

We developed a system allowing a real-time analysis as well as delayed analysis of ship traffic. It can be adapted to every situation and every user profile. This prototype is integrated into our maritime surveillance system FishEYE.

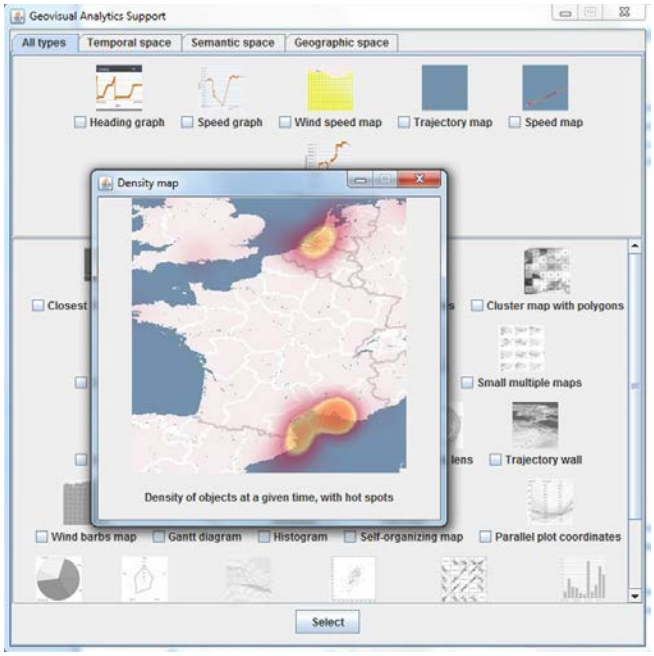

Fig. 5: The Geovisual analytic interface in [13]

5. A MARITIME SURVEILLANCE SYSTEM

In order to monitor data in real time and to test the researches introduced in previous sections, we developed a prototype of maritime surveillance system named FishEYE (Fig. 6). This system integrates heterogeneous data (ship localizations, meteorological and oceanic data, bathymetry, etc.) and different functions (analysis filters, drift models, etc.). Prototypes presented in the previous sections have been integrated as modular functions of the system. The design and the development of FishEYE are still in progress and improved continually.

Fig. 6: The prototype FishEYE

6. CONCLUSION

The proposed approach allows analyzing identified and unknown behaviours thanks to supervised and unsupervised analysis methods. Unknown behaviours are detected with unsupervised methods (data mining). Similarly to known behaviours, the detected behaviours can be interpreted with a system based on supervised methods (geovisual analytics). Then, the behaviours can be formalized within an ontological framework.

Different prototypes were developed, integrating the methods chosen (data mining, geovisual analytics, case based reasoning). Finally the maritime surveillance system FishEYE was developed to integrate all methods into a unique interface, easier to be handled by an operator.

Next step of our research will focus on a geocollaborative support system allowing supporting operators to solve a problem like a huge accident or oil spill. This framework will be integrated into FishEYE.

7. REFERENCES

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