A FISHING MONITORING USE CASE IN SUPPORT TO COLLABORATIVE RESEARCH

A.-L. Jousselme, E. Camossi*, M. Hadzagic*, C. Ray+, C. Claramunt+, E. Reardon*, K. Bryan*, M. Ilteris**

*NATO STO Centre for Maritime Research and Experimentation La Spezia, Italy

+Naval Academy Research Institute (IRENav) Brest, France

ABSTRACT

This work reports on the design of a Maritime Use Case in support to the *Big Data Analytics for Time Critical Mobility Forecasting (datAcron)* project funded by the European Union Horizon 2020 Programme, which aims to develop novel methods to detect threats and abnormal activity among a very large number of moving entities in large aerial and maritime areas. The use case aligns with the European Union Maritime Security Strategy (EUMSS) and both scientists and operational partners participated in its design. It focuses on the monitoring of fishing activities, which encompass several maritime scenarios such as preventing environmental destruction and degradation, maritime accidents, Illegal, Unreported, and Unregulated (IUU) fishing, Illegal migrations, as well as suspicious vessel tracking.

Index Terms— Big spatio-temporal data, Maritime Moving Objects, Maritime Situational Awareness, Vessel Trajectories, Fishing Use case

1. INTRODUCTION

Reaching appropriate *Maritime Situation Awareness (MSA)* for the decision maker requires monitoring the real time maritime traffic and assessing it against contextual information such as maritime routes or loitering areas inferred from the analysis of historical data (e.g., [1]). This requires not only detecting, tracking and classifying vessels but also detecting, classifying and predicting their behaviour.

Sensor networks mixing cooperative self-identification systems (e.g., Automatic Identification System - AIS) and non-cooperative systems (e.g., coastal radars or satellite imagery) provide the necessary complementarity and redundancy of information to help overcome signals deception (e.g., GPS manipulation and spoofing are frequent for AIS [2]) in order to increase the clarity and accuracy of the mari time picture. In many cases, intelligence reports or expert opinions can also be helpful in refining and guiding the search in the huge amount of data to be processed, filtered and analysed, as well as representing the contextual information for decision support systems in MSA applications [3].

This work was supported by project *datAcron*, which has received funding from the European Unions Horizon 2020 research and innovation programme under grant agreement No. 687591.

Facing the huge *volume* of *various* information with high *velocity* which often lacks *veracity*, a system to automatically process both historical and timely information would greatly support the Vessel Traffic System (VTS) operator such as the in monitoring and analysis tasks. This is the aim of the three-year *Big Data Analytics for Time Critical Mobility Forecasting (datAcron)* project[1] that has started in January 2016 and whose main research objectives address the development of highly scalable methods for advancing:

- Obj.1 Spatio-temporal data integration and management solutions;
- Obj.2 Real-time detection and forecasting accuracy of moving entities' trajectories;
- Obj.3 Real-time recognition and prediction of important events concerning these entities;
- Obj.4 General visual analytics infrastructure supporting all steps of the analysis through appropriate interactive visualisations;
- Obj.5 Producing streaming data synopses at a high-rate of compression.

datAcron addresses two critical domains: maritime and aerial traffic, which will guide the research and development and will drive the assessment of the *datAcron* approach. In this paper, we present the maritime use case of *datAcron*, which describes possible operational uses of *datAcron* for *Fishing Activity Monitoring* focusing on relevant practical challenges and operational questions. It emphasises a human-centric automatic processing of data, stressing the role of the user (or decision maker) in his/her interaction with the system.

The paper is organised as follows. In Section 2, the methodology adopted to develop the use case is presented. In particular, the use case requirements and how the use case is aligned with the *datAcron* objectives and challenges are described. In Section 3, the fishing monitoring use case and six operative scenarios are described, discussing the operational relevance of *datAcron* and how user and operative information needs are formalised through a list of relevant Maritime Situational Indicators (MSIs). In Section 4, the use

[1] datAcron project website: `http://www.datacron-project.eu/`.

case driven validation and assessment of *datAcron* is also presented. Finally, Section 5 concludes the paper highlighting future directions.

2. USE CASE DESIGN

The methodology used to develop the use case described herein relies on the previous experience of some of the authors, where use cases were designed to support collaborative research project on context-based reasoning in high-level information fusion [4, 5], and adopts the definition of use case given by McBreen et al. in [6], where a *use case* describes the interaction of a user with a system to be designed, to achieve a specific goal or accomplish a specific task. The system requirements can then be derived enabling the user to achieve his/her objectives in different scenarios. The *scenarios* illustrate different usages of the system, and eventually define success (if the goal is achieved) or failure (if the goal is not achieved).

The resulting use case provides a tool to address different aspects of a large research problem, describing users needs, operational problems and underlying challenges. Illustrating research findings on a common use case, sharing the same datasets, and utilising outputs from other teams are all benefits of having an integrated picture of the general research problem.

As such, the *datAcron* maritime use case has to satisfy the following requirements, which drove the design of the use case:

- Req.1 Address challenging problems deemed of interest for the maritime operational community in general;
- Req.2 Be aligned with the European Union maritime policies and needs in particular;
- Req.3 Be aligned with *datAcron* research objectives and expected outcomes such that the use case challenges the *datAcron*'s technical solutions to be developed, while accommodating the research interests of the different partners;
- Req.4 Describe the problem in a simple way as a kind of "skeleton", flexible enough to allow further evolution and developments as possibly requested by partners' interests;
- Req.5 Provide the necessary information to understand the user's goal, from which the corresponding sub-goals, associated levels of granularity required, the information needs and the desired output quality can be deduced;
- Req.6 Act as an "integrator" for the different aspects to be pursued so that teams can illustrate their findings within a common story;
- Req.7 Provide a background and support for close interactions between the different work packages and teams involved with the team in charge of the maritime use case;
- Req.8 Rely on the available datasets (unclassified, shareable) among the teams and others of interest in the research community (e.g., AIS data, radar datasets, databases of past events, intelligence reports, etc).

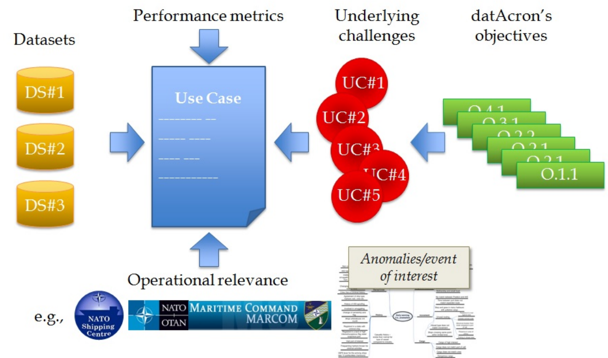

Fig. 1 Methodology for the maritime use case development

The diagram displayed in Fig. 1 illustrates the idea behind the methodology. The *datAcron* objectives (cf. Obj.1 to Obj.5 in the previous Section) describe the general goals for the algorithms to be designed. They involve several underlying challenges and may drive specific research foci of interest for the project partners.

In particular, the design of systems supporting an enhanced MSA needs to tackle Big Data challenges: it requires processing in real-time a *voluminous* and high *velocity* information of different nature (numerical, natural language statements, objective or subjective assessments, ...), originating from a *variety* of sources (sensors and humans - hard and soft), which often lacks *veracity* (data are either uncertain, or imprecise, vague, ambiguous, incomplete, conflicting, incorrect).

The *datAcron* Maritime Use Case comprises multiple scenarios that describe how actors in the use case perform a set of operations in order to achieve a specific goal. Scenarios describe the current operations that will serve as a basis for understanding and validating the *datAcron* technology, while demonstrating how it can be effectively used in the maritime domain.

The collaboration with the operational partners ensures that the use case is operationally relevant. In particular, the use case describes the general context of use of *datAcron* algorithms. The operational information needs are captured by relevant Maritime Situational Indicators (MSI), which formalise events of interest for the operator and the information required to detect them (cf. Table 1 in the next Section). Operational performance criteria will need to be defined to specify user expectations and to drive the assessment of the *datAcron* prototype, closely tying the experimental plan to the use case development (cf. Section 4). The use case requirements (Req.1-Req.8) may also be used as qualitative system performance metrics, while, at the implementation level, they may act as result validation measures.

3. MONITORING FISHING ACTIVITIES

The *datAcron* Maritime Use Case focuses on fishing activity monitoring, which is a complex maritime surveillance mission that encompasses several maritime risks and environmental issues such as environmental destruction and degradation but also maritime accidents, Illegal, Unreported, and Unregulated (IUU) fishing and trafficking problems, which will be addressed in different scenarios.

Ensuring *security* and *control* of fishing activities is one of the most important aspect of the European Union Maritime Security Strategy (EUMSS) - Action Plan[2], which defines several strategic interests for the European Union and the Member States in terms of maritime security. Europe, as the world's biggest market for seafood wants to promote better international governance across the world's seas and oceans to keep them clean, safe and secure. Since fishing is an activity that exploits common natural resources, it needs to be regulated to safeguard fair access, sustainability and profitability for all.

In particular, IUU fishing is a global threat to the marine environment and honest fishermen alike, whose global cost is estimated in about 10 Billion Euros per year. The European Union, in collaboration with International organisations, is committed to fighting IUU fishing worldwide.

Besides the detection of IUU fishing activities, another core issue of the EUMSS is safety. Fishing, in peace situation, is known as one of most dangerous activity. An issue here is that fishing vessels are intentionally switching off their AIS devices while fishing. Therefore, ensuring fishing safety requires processing and predicting fishing trajectories in real-time, detecting fishing events, identifying movement patterns, predicting possible collisions between surrounding ships, within a typical time scale of 5 to 15 minutes.

datAcron will support the European Union's control and enforcement strategy, providing the necessary scientific support for processing, analysis and visualisation of fishing vessels at the European scale, together with the capability of predicting the movement of maritime objects and the identification of patterns of movement and navigational events that shall improve existing solutions to monitor the compliance to the European common fisheries policy.

In order to support *datAcron*'s challenges within the fishing monitoring use case six scenarios have been considered. All scenarios highlight the need for continuous (real-time) tracking of fishing vessels and surrounding traffic, as well as contextually enhanced offline data analytics. They have been elaborated in order to stress *datAcron*'s algorithms in terms of *velocity*, *veracity*, *variety* and *volume*. They should provide a complete support for trajectory and event detection, prediction and visualisation. For each scenario, the user information needs are expressed through a corresponding list of MSIs. In Table 1, scenarios are summarised with corresponding objectives, possible actions, and example MSIs.

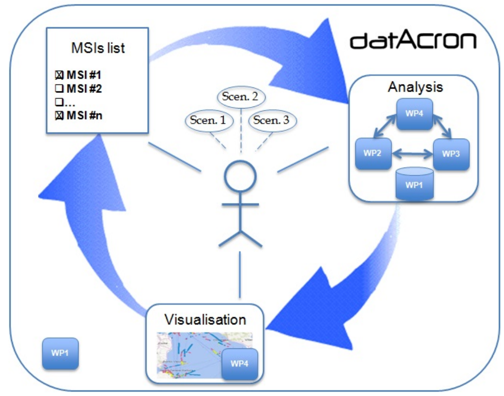

Fig. 2 Operation flow of the Maritime Use Case

The MSIs defined for fishing monitoring in *datAcron* formalise the events of interest for the use case, capture the required information while formalising the goals of *datAcron* algorithms and driving the analysis. The list of the MSIs used in *datAcron* is extracted from the outcomes of different workshops held in Sweden [7], Canada [8] and a recently updated NATO standard [9], abstracted to address *datAcron* needs. Specifically, the MSIs have been filtered out considering only (1) the MSIs that *datAcron* can provide, (2) the MSIs that are relevant to the fishing monitoring scenarios.

The conceptual diagram in Fig. 2 illustrates the operational flow and the interaction of the *datAcron* software in the fishing monitoring use case. Depending on the scenario, the user may accomplish different tasks (i.e., monitoring, detecting or preventing the events described by the scenario), and may express his/her information needs through a list of MSIs of interest at a given time. He/she selects the appropriate algorithms and parametrises them accordingly to run the analysis. He/she is able to observe results of the selected algorithms using the visualisation tools and additional visual analytics, allowing to refine the analysis varying the parameters of the MSIs (e.g. change the areas of interest, speed thresholds).

4. VALIDATION AND ASSESSMENT

The quality of the maritime picture can be assessed according to the five criteria of *Completeness* (ratio of detected indicators), *Accuracy* (ratio of correctly detected or classified indicators), *Clarity* (confidence degree about the detection or classification of indicators), *Continuity* (if these detections or classifications are maintained in time) and *Timeliness* (time to obtain the detection or classification result). Each criterion may be defined relatively to a given area, a given pe-

[2]EUMSS Action Plan: `http://ec.europa.eu/maritimeaffairs/policy/maritime-security/doc/20141216-action-plan_en.pdf`, published in December 2014

Table 1. Scenarios objectives, user's role and actions, MSI

Scenario			Objective	Actions	MSI examples
Secure fishing	SC11	Collision prevention	Protect fishing vessels from collision with large vessels (cargos, tankers, ferries)	Warn fishing vessels at risk, warn vessels heading to fishing areas	Vessel is: in proximity of other vessels; drifting
	SC12	Vessel in distress / MOB (SAR)	Provide early assistance to a vessel in distress	Warn the closest vessels for early assistance, provide precise location of the vessel for the SAR team	Vessel is drifting; AIS emission has interrupted
Sustainable development	SC21	Protection of ecological areas	Protect specific areas from illegal fishing activities	Send control patrol boat to suspicious vessels location	Vessel's course is not compatible with expected destination; AIS emission has interrupted
	SC22	Fishing pressure	Estimate and predict fishing pressure, identify areas at risk	No direct action, but could modify the fishing policies on the mid-term	Vessel is: engaged in fishing; within a given areas
Maritime security	SC31	Migrants and human trafficking	Detect possible human trafficking involving fishing vessels (or the like)	Communicate to security boarder control authorities, provide possible assistance (see SC12)	Vessel's course is not compatible with expected destination; AIS emission has interrupted
	SC32	Illicit activities	Detect suspicious activities involving fishing vessels	Send control boats for further checking	Vessel is on a maritime route; AIS emission has interrupted

riod of time, and a given MSI. Hence, for a given scenario, the user expects *datAcron* algorithms to provide answers to the relevant MSIs with a quality defined by these five dimensions. The user chooses the MSIs to detect the scenario-related events (collision, vessel in distress, smuggling, etc). Another layer of performance criteria is related to human factor tasks while dealing with scenario-events.

Fig. 3 illustrates the two levels of assessment of *datAcron*: the MSI level and the scenario level. The *datAcron* algorithms will be evaluated along both the operational and technical criteria (some may overlap). The data would be degraded to study the impact of the different Big Data dimensions on the algorithms outputs. The datasets would be controlled to provide some ground truth information to be able to assess some robustness to the *veracity* of data. The *volume* and *velocity* of data will vary to observe the impact on the timeliness of the algorithms. The *variety* of the data would vary depending on the sources selected to feed the algorithms.

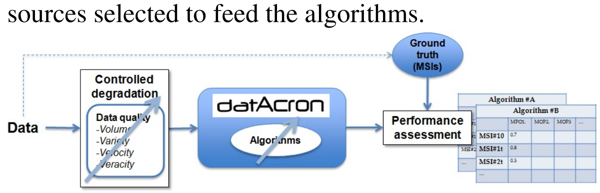

Fig. 3 (a) MSI level assessment

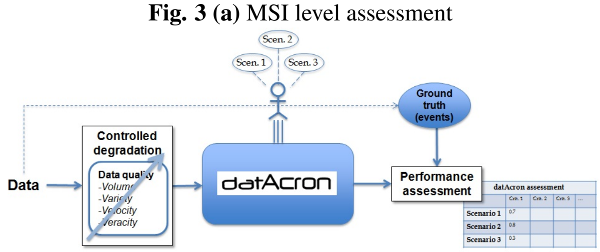

Fig. 3 (b) Scenario level assessment

5. CONCLUSIONS

In this paper, the design of the fishing activity monitoring use case of the H2020 project *datAcron* has been presented. The use case addresses operative scenarios of interest for the European Union Maritime Security Strategy as well as Big Data challenges. The use case will be a bridge between the operational and the scientific communities, will facilitate collaborative research work among the different project partners and work packages, and will drive the integration the different work package contributions. Future work will address the design of the experimental, which will rely on the maritime use case and associated datasets to structure the assessment and validation of *datAcron* algorithms and prototype.

6. REFERENCES

[1] Rikard Laxhammar, "Anomaly detection for sea surveillance," in *Proc. of the Int. Conference on Information Fusion*, Firenze, Italy, July 2008.

[2] C. Ray, C. Iphar, A. Napoli, R. Gallen, and A. Bouju, "Deais project: Detection of ais spoofing and resulting risks," in *OCEANS15 MTS/IEEE, Genoa, Italy*. 2015, IEEE.

[3] Jim Llinas, Anne-Laure Jousselme, and Geoff Gross, "Context as an uncertain source," in *Context Enhanced Information Fusion: Improving real world performance with domain knowledge*, L. Snidaro, J. Garcia, J. Llinas, and E. Blasch, Eds. Springer, 2015.

[4] Anne-Laure Jousselme, Karna Bryan, Michael Ilteris, and Eric Reardon, "Selection of use cases to support Maritime Situation Awareness algorithmic development," Technical memorendum, NATO Centre for Maritime Research and Experimentation (CMRE), La Spezia (IT), 2016, To be published.

[5] Lauro Snidaro, L. Vaci, J. Garcia, E. D. Marti, A.-L. Jousselme, K. Bryan, D.D. Bloisi, and D. Nardi, "A framework for dynamic context exploitation," in *Proceedings of the 18th International Conference on Information Fusion*, Washington, D. C. (USA), July 2015.

[6] Pete McBreen, "Using use cases for requirements capture," www.mcbreen.ab.ca, McBreen.Consulting, 1998.

[7] Sten Andler, M. Fredin, F. Gustafsson, J. va Laere, M. Nilsson, and P. Svenson, "SMARTracIn - a concept for spoof resistant tracking of vessel and detection of adverse intentions," in *SPIE Defense, Security, and Sensing*, Orlando, FL, 2009.

[8] Jean Roy and Mike Davenport, "Exploitation of maritime domain ontologies for anomaly detection and threat analysis," in *Proc. of the IEEE int. Waterside Security Conference (WSS)*, 2010.

[9] STANAG 4162, "Identification Data Combining Process (edition 3) - AIDPP-01 Edition 1," Tech. Rep., NATO Standardization Agency, 2015, NATO UNCLASSIFIED.