Event Processing for Maritime Situational Awareness

Manolis Pitsikalis[1], Konstantina Bereta[2], Marios Vodas[2], Dimitris Zissis[3,2], Alexander Artikis[4,1]

1 Introduction

Numerous illegal and dangerous activities take place at sea, such as pollution (illegal discharges of oil and garbage, violations of ship emission rules, etc), illegal fishing, smuggling (drugs, arms, oil, etc), piracy and many more. Often the vessels involved in such activities attempt to behave as common commercial ships, concealing their true intentions. Nowadays, numerous monitoring systems, such as the Automatic Identification System (AIS), that relies on VHF communication, produce constant streams of surveillance data, often revealing the true intentions of suspicious vessels.

The data streams produced by maritime monitoring systems may be consumed by stream reasoning systems, in order to support *Maritime Situational Awareness* , i.e. the effective understanding of activities, events and threats in the maritime environment that could impact the global safety, security, economic activity and the environment.

The contributions of this chapter are the following: (a) We describe a formal, computational framework for composite maritime event recognition, based on the Event Calculus[1]. (b) We present an industry-strong maritime anomaly detection service, processing daily real-world data volumes. Our integrated system aims to pave the way for the real-time recognition of a wide variety of significant maritime events, including illegal/suspicious activities.

2 System Architecture

We support maritime situational awareness following online tasks: (a) computing a set of spatial relations among vessels, such as proximity, and among vessels and areas of interest (e.g., fishing areas), and (b) labelling position signals of interest as 'critical'—such as when a vessel changes its speed,

[1]Institute of Informatics & Telecommunications, NCSR Demokritos, Athens, Greece
[2]MarineTraffic, Greece
[3]Dept. of Product & Systems Design Engineering, University of the Aegean, Greece
[4]Department of Maritime Studies, University of Piraeus, Greece
manospits@iit.demokritos.gr, {konstantina.bereta,marios.vodas,dzissis}@marinetraffic.com a.artikis@unipi.gr

[1] http://cer.iit.demokritos.gr/cermm

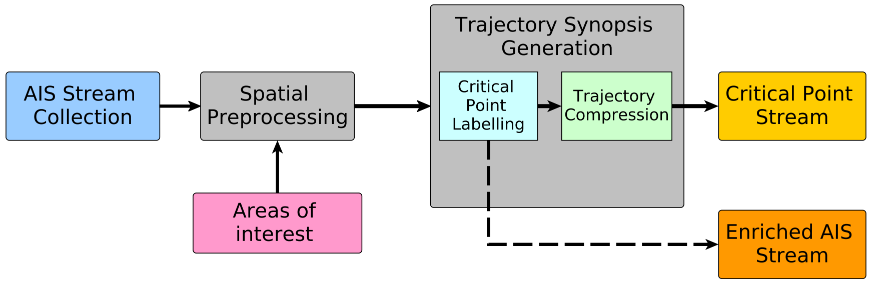

Fig. 1: Steps required for Maritime Situational Awareness.

turns, stops, moves slowly or stops transmitting its position. Figure 1 illustrates these steps. Streaming-in AIS position signals go through a spatial pre-processing step, for the computation of the spatial relations required by maritime situational awareness. Then, the relevant position signals are annotated as critical. Subsequently, the position signals may be consumed by our stream reasoning technology either directly (see 'enriched AIS stream' in Figure 1), or after removing all signals that have not been labelled as critical

Critical point labelling is performed as part of trajectory synopsis generation, whereby major changes along each vessel's movement are tracked (e.g., a stop, a turn, or slow motion).

2.1 Maritime Stream Reasoning

We describe two stream reasoning technologies for maritime situational awareness. We developed a formal, computational framework for composite maritime event recognition, based on RTEC, a logic programming implementation of the Event Calculus . RTEC is designed to compute continuous narrative assimilation queries for pattern matching on data streams. The 'Event Calculus for Run-Time reasoning' (RTEC) is an Event Calculus dialect optimised for composite event recognition over high-velocity data streams. For example, RTEC may detect the composite events displayed at the bottom of Table 1. The time model in RTEC is linear and includes integer time-points. An *event description* includes rules that define the event instances with the use of the happensAt predicate, the effects of events on *fluents*—time-varying properties—with the use of the initiatedAt and terminatedAt predicates, and the values of the fluents with the use of the holdsAt and holdsFor predicates.

Table 1: Events for Maritime Situational Awareness: Input events are presented above the double horizontal line, while the output stream is presented below this line. The input events above the single horizontal line are detected at the spatial preprocessing step while the remaining ones are detected by the trajectory synopsis generator (critical events).

		Event/Activity	Description
Input	Spatial	$enters Area(V, A)$	Vessel V enters area A
		$leaves Area(V, A)$	Vessel V leaves area A
		$proximity(V_1, V_2)$	Vessels V_1 and V_2 are close
	Critical	$gap\_start(V)$	Vessel V stopped sending position signals
		$gap\_end(V)$	Vessel V resumed sending position signals
		$slow\_motion\_start(V)$	Vessel V started moving at a low speed
		$slow\_motion\_end(V)$	Vessel V stopped moving at a low speed
		$stop\_start(V)$	Vessel V started being idle
		$stop\_end(V)$	Vessel V stopped being idle
		$change\_in\_speed\_start(V)$	Vessel V started changing its speed
		$change\_in\_speed\_end(V)$	Vessel V stopped changing its speed
		$change\_in\_heading(V)$	Vessel V changed its heading
Output	Composite	$highSpeedNC(V)$	Vessel V has high speed near coast
		$anchoredOrMoored(V)$	Vessel V is anchored or moored
		$drifting(V)$	Vessel V is drifting
		$trawling(V)$	Vessel V is trawling
		$tugging(V_1, V_2)$	Vessels V_1 and V_2 are engaged in tugging
		$pilotBoarding(V_1, V_2)$	Vessels V_1 and V_2 are engaged in pilot boarding
		$rendezVous(V_1, V_2)$	Vessels V_1 and V_2 are having a rendez-vous
		$loitering(V)$	Vessel V is loitering
		$sar(V)$	Vessel V is engaged in a search and rescue (SAR) operation

3 Anomaly Detection Service

MarineTraffic is currently the world's leading platform offering an end-to-end service that tracks vessel positions across the globe based on AIS and disseminates this information through its website[2]. MarineTraffic has also deployed an anomaly detection service, which is based on a modified Lambda architecture, which allows the decoupling of batch processing, performed upon historical data, and on-line streaming analysis, which exploits the knowledge extracted from the batch processing.

The batch layer performs the analysis of historical positional data of vessels and extracts the so-called 'Patterns of Life', that is, 'normal' maritime

[2] `MarineTraffic.com`

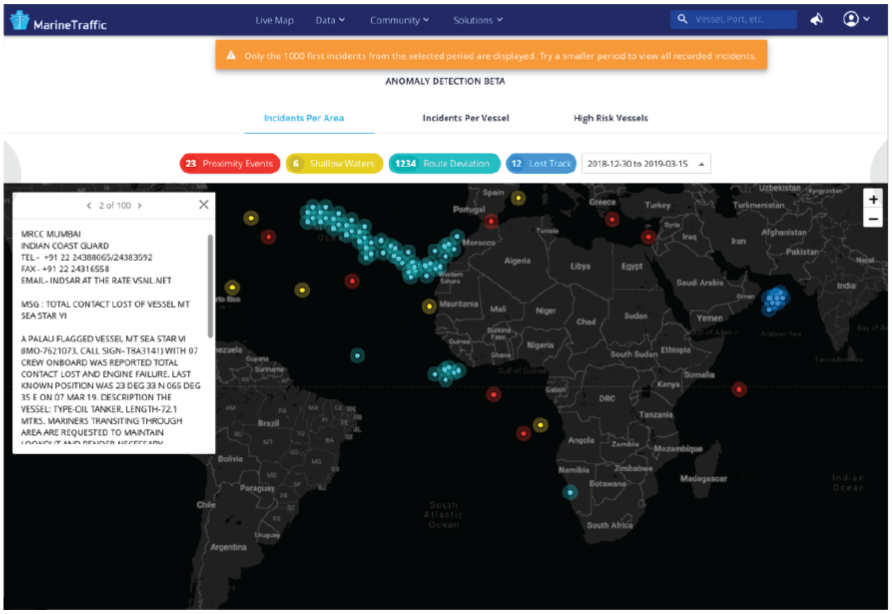

Fig. 2: Area's incidents page: the incidents/events occurring in an area are displayed on the map. Red dots display potential 'rendez-vous' incidents.

activity. Anomaly detection, then, is a method for indicating objects and situations that deviate from the expected, known or 'normal' behavior.

The on-line component is based on the actor model, specifically the Akka framework, for concurrency and event-driven processing. Actors are versatile, light-weight objects that have a state, communicate with each other, and process the messages sent to them sequentially. By designing different types of actors and flows of information between them, we can create quite complex topologies, where each actor is responsible for recognising a maritime event.

The main goal of the anomaly detection platform is to reduce fatigue and the cognitive overload of the operators when having to search through numerous surveillance datasets and alerts, by offering a GUI that displays alerts when an event is detected. The MarineTraffic anomaly detection service is capable of detecting in real time the following events:

- Route deviations, i.e., when a ship navigates outside the "normal route" it is expected to follow in a given area and time, out of normal limits (e.g. speed patterns) or there is a mismatch in its type of activity reported for the given area or time period (e.g. fishing in a forbidden area).
- Sailing in shallow or dangerous waters, i.e., when a vessel is travelling in areas where the sea depth is less than the ship's draught.
- Vessels sailing within close proximity to each other (e.g., imminent collision, transhipment, etc.).