Making Sense of Heterogeneous Maritime Data in a Near Port Environment

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Introduction

- **Motivation:** Despite the abundance of maritime information, there are still many instances in which ships are found to be engaged in dangerous or illegal activities.

  Currently:
  - the Automatic Identification System (AIS) is a valuable source of maritime information, however "dark vessels" may turn off their transponders or spoof their data,
  - many maritime monitoring applications rely solely on AIS data,
  - finally, it is often the case that vessel monitoring applications don't take into account knowledge of domain experts but rely on supervised/unsupervised learning.

- **Contribution:** In this poster, we offer an overview of [1], which involves:
  - a maritime monitoring application that uses several sources of heterogeneous data (e.g., AIS, radar, maritime areas of interest, static vessel data etc.),
  - our open-source Complex Event Processing system, Phenesthe,
  - an evaluation of the efficiency of our application.

System architecture

Our architecture is divided in three components:
- the input component (merges the input data and produces the input stream for the processing component),
- the processing component (performs Complex Event Processing on the input stream, and produces the output stream),
- and the visualisation component (visualises detections, live, on the map).

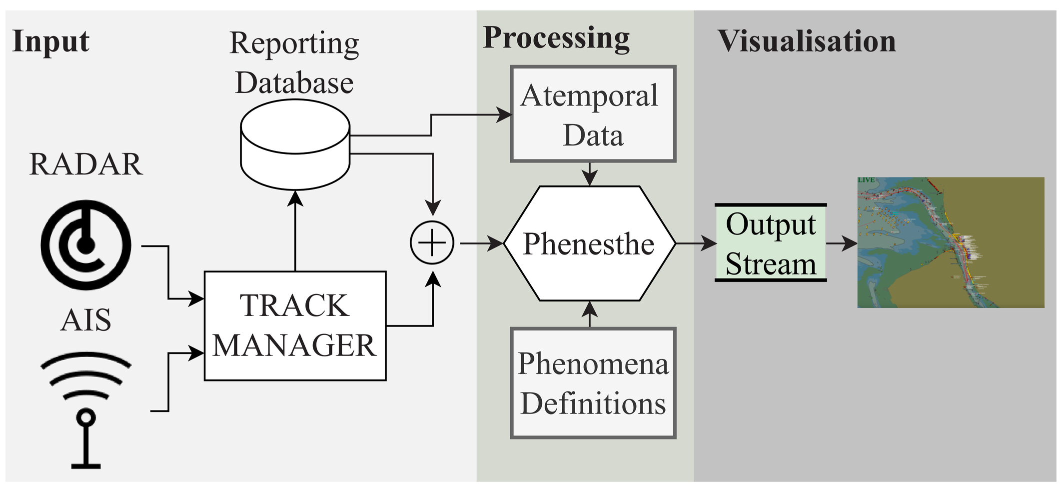


Figure 1: Architecture of our maritime monitoring application.

The Phenesthe system

- Phenesthe [2], allows the definition of **instantaneous** and **durative** temporal phenomena and the relations between them.
- Given an input stream and a set of temporal phenomena definitions, Phenesthe will perform temporal queries over a window and produce a stream of time associated temporal phenomena.
- Phenomena in phenesthe are divided in events, states, and dynamic temporal phenomena.

Table 1: Syntax summary of the language used by Phenesthe. 'l, r' correspond to left and right operands, while the □ may be one of the following symbols $\{<, \geq, =\}$.

Phe. Definition	F. Type	Symbol	$\Phi^{\bullet}$	Φ^{-}	$\Phi^{=}$	Duration
events	$\Phi^{\bullet}$	$\wedge$	l, r			
		$\vee$	l, r			
		$\neg$	r			
		start		r		
		end		r		
		$\in$	l	r		
states	Φ^{-}	$\rightarrowtail$	l, r			
		$\sqcup$		l, r		
		$\sqcap$		l, r		
		$\setminus$		l, r		
		$@_{\square}$	l			r
		filter$_{\square}$		l		r
dynamic temporal phenomena	$\Phi^{=}$	before	l, r	l, r	l, r	
		overlaps		l, r	l, r	
		contains	r	l, r	l, r	
		meets		l, r	l, r	
		starts	l	l, r	l, r	
		finishes	l	l, r	l, r	
		equals		l, r	l, r	

Maritime Phenomena Definitions Examples

- **Moored:** A vessel is moored when it stopped and inside a port:

$$\text{state\_phenomenon } moored(TID, Port) : \\ stopped(TID, \_, \_) \sqcap \\ (in\_zone(TID, Port) \wedge port(Port)).$$

- **Vessel trips:** A trip starts when a vessel stops being moored or anchored, then gets underway, and finally reaches its destination port or anchorage area. We define vessel trips as follows:

$$\text{dynamic\_phenomenon } trip(TID, ZoneA, ZoneB) : \\ \text{end}(moored(TID, ZoneA)) \vee \\ \text{end}(anchored(TID, ZoneA, \_, \_)) \text{ before} \\ (underway(TID) \text{ before} \\ (\text{start}(moored(TID, ZoneB)) \vee \\ \text{start}(anchored(TID, ZoneB, \_, \_)))).$$

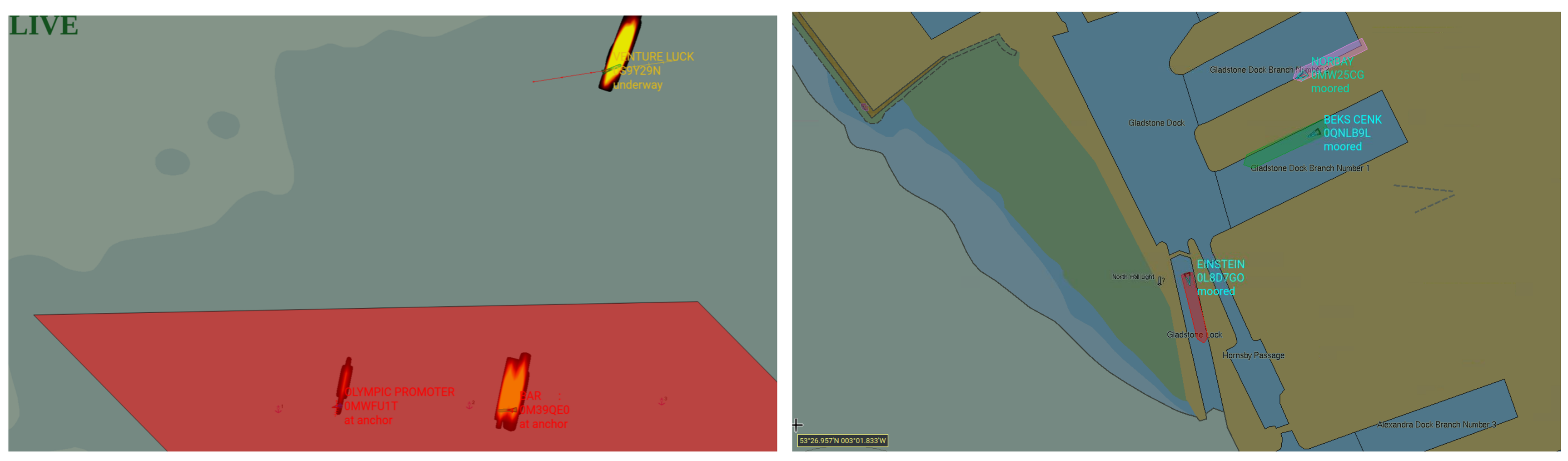
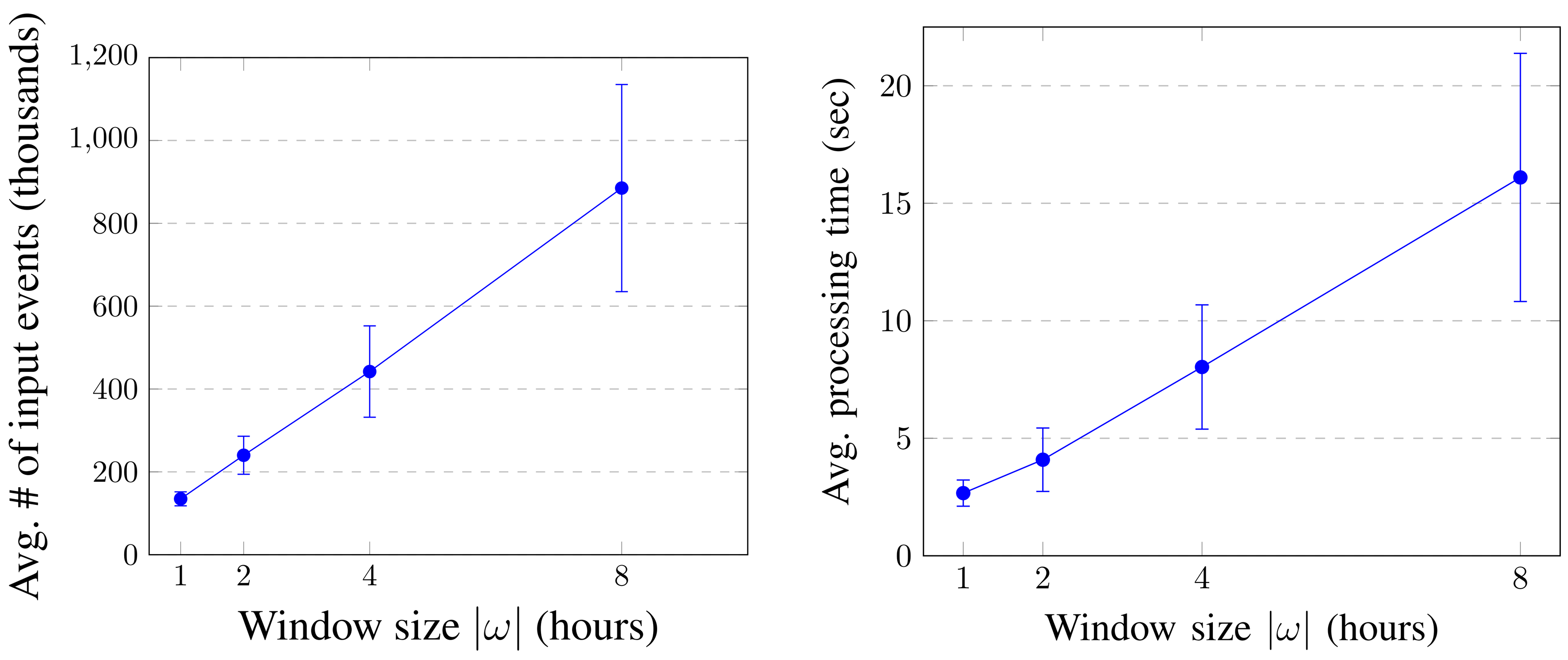


Figure 2: Example detections: two anchored vessels & a vessel underway (left) and a moored vessel (right).

Evaluation

- Efficiency evaluation with multithreading: 8 days of Complex Event Processing.



(a) Efficiency: input events. (b) Efficiency: processing times.

Figure 3: Results of our evaluation on efficiency.

Conclusion

- We presented:
  - a maritime monitoring application along with a set of indicative maritime phenomena definitions specified in the language of Phenesthe,
  - and an efficiency evaluation that show that our application is capable of providing maritime phenomena detections in real-time.
- Our future work involves:
  - Temporal phenomena definition learning from ground truth data,
  - theoretical and empirical comparison with other systems.

References

[1] M. Pitsikalis, A. Lisitsa, and P. Totzke, "Making sense of heterogeneous data," in *Maritime Big Data Workshop*, 2022.

[2] M. Pitsikalis, A. Lisitsa, and S. Luo, "Representation and processing of instantaneous and durative temporal phenomena," in *LOPSTR* (E. De Angelis and W. Vanhoof, eds.), (Cham), pp. 135–156, Springer International Publishing, 2022.

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