Traffic Route Extraction and Anomaly Detection from AIS Data

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Abstract. *Automatic Identification System (AIS) technology is useful for collision avoidance and on-line vessel monitoring, but also provides valuable information for historical analysis of vessel traffic. The paper presents an approach to learn maritime traffic patterns in an unsupervised way. The methodology effectively processes raw AIS data and extracts different levels of contextual information. An enhanced picture of maritime domain is automatically derived in order to support the knowledge of maritime patterns of life. Furthermore, the understanding of historical traffic enables the detection of low-likelihood behaviours, their classification and the prediction of future vessel positions. The knowledge extraction process is here demonstrated using real AIS data provided by the Naval Academy Research Lab in the area of Brest.*

Keywords: AIS data, traffic patterns, route extraction.

1 Methodology

Automatic Identification System (AIS) provides a large amount of information in real-time which can be exploited to obtain a spatial, temporal and attribute-related (*e.g.*, given a ship type) traffic characterisation. The presented tool, called TREAD (Traffic Route Extraction and Anomaly Detection), learns traffic patterns in a fully automatic way from both terrestrial and satellite AIS data. The ultimate goal of TREAD is to assist operational activities and downstream analysis tools with a prior knowledge of vessel traffic over the area of interest (*e.g.* anomaly detection and route prediction). TREAD builds the traffic knowledge using AIS data only, *i.e.*, no contextual information or input from the user is needed. The achieved results are stored in a compact structure which includes Vessel objects (Vs), Waypoints objects (WPs) and Route objects (Rs) [1–3]. The objects are incrementally created and dynamically updated on the basis of meaningful events generated by vessel state vector sequences, *e.g.*, a break in observation updates. The clustering of such events leads to the detection of

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WPs, which are created, expanded and merged progressively using incremental DBSCAN (Density-Based Spatial Clustering of Applications with Noise) algorithms (see [4]). Two classes of WPs are identified: Entry ENs/Exit EXs Objects which are created and updated whenever a vessel enters/leaves the selected region of interest, causing "birth"/"death" events, and Stationary Objects POs such as ports, offshore platforms and stationary areas in general.

Route Objects Rs, connecting the WPs, are created when a consistent number of vessels are observed transiting between such waypoints. Rs are not simple density clusters of the registered transiting vessels but integrate the spatial, temporal and attribute-related (*e.g.*, ship type) features inherited by the related vessels. The set of main active routes (*i.e.* routes showing a minimum number of transits) is organised in historical atlases, which are a compact representation of the maritime traffic over the area, together with the derived stationary areas.

2 Results

The analysis of the methodology is here illustrated using data acquired over three months in the area of Brest (see *e.g.* [5]) as illustrated in Fig. 1. The data processed cover the period February-April 2009. Stationary areas are in proximity of the main ports in the area but also include fishing areas. In particular, the port of Brest is clustered into multiple PO objects in correspondence of different terminals. The identified routes (Fig. 1, right) are oriented set of points connecting consecutive waypoints. Route objects are detected when a specific pattern is consistently observed. As a consequence, not all the vessel movements are mapped into the discovered knowledge. In this specific area, more than 80% of the AIS messages are included into the traffic knowledge discovered by TREAD, suggesting that the movements in the area are fairly regulated.

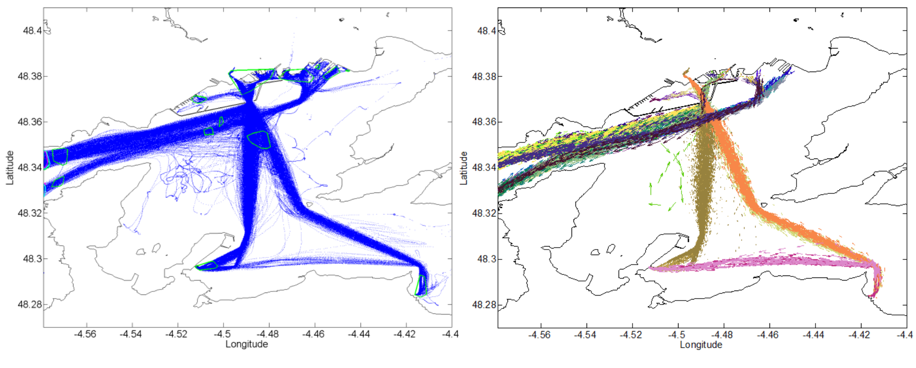

Fig. 1. Left: AIS positioning information (blue) and detected stationary (green), entry (cyan) and exit waypoints (magenta). Right: colour-coded oriented route objects.

In Fig. 2, the system of detected route objects is decomposed into a set of elements. Some of them are not easy to be highlighted by glancing at the AIS traffic messages reported in Fig. 1 (right) where information about directionality and starting and destination areas can hardly be grasped.

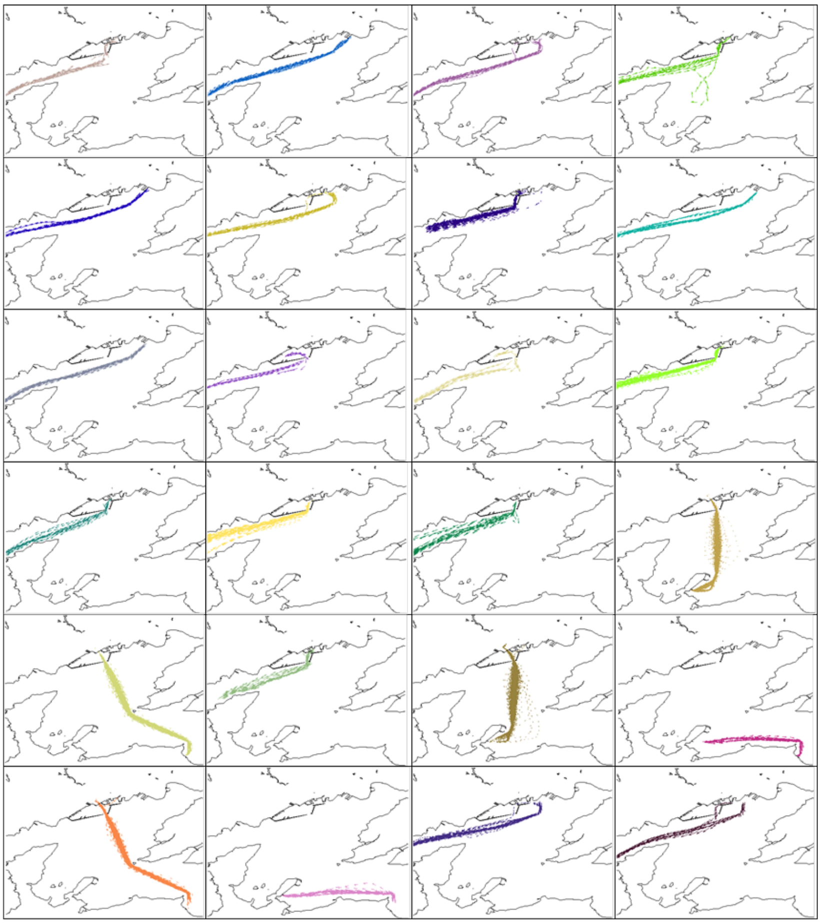

Fig. 2. Atlas of most significant detected routes into which the traffic is decomposed.

Every route also integrates information about the vessels originating it, their ship type, the time required to cover the route, daily patterns. Such attributes can effectively be used to detect unusual behaviours or predict future vessels positions. As an example, the route between Brest and Lanvéoc is analysed in Fig. 3. The trajectories in the second part of the route are more concentrated with respect to the segment between the north of the Île Ronde and Brest, where fishing activities force ferries to more consistently manoeuvre.

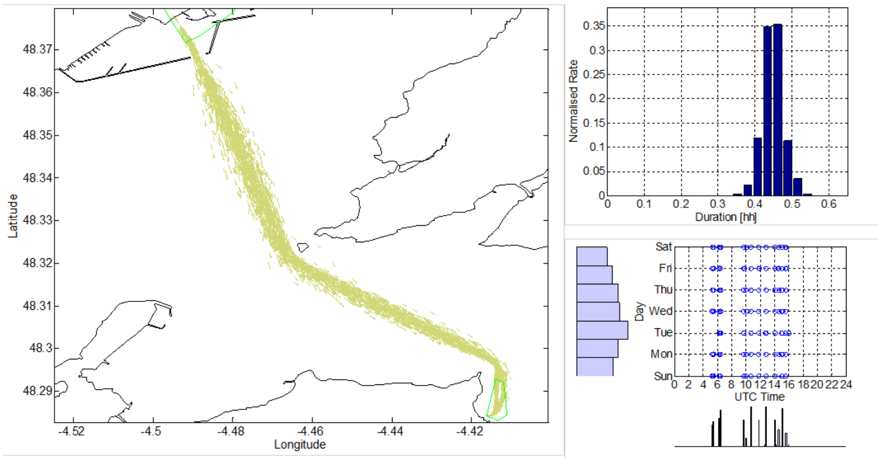

Fig. 3. The Brest - Lanvéoc route is covered by five passenger ships. The travel time histogram between the port polygons (top right) and the UTC daily patterns (bottom right) show a relatively regular behaviour in the period Jan-March 2009.

3 Conclusions

The paper presented the results of a tool that automatically derives maritime traffic knowledge (ports, offshore platforms, entry and exit points and routes) from AIS data with no prior domain information of the area. The discovered routes are characterised by spatial, temporal and attribute information, thus enabling the detection of low-likelihood behaviours and the prediction of future vessel positions and probable destinations. The derived knowledge from this unsupervised approach can be combined with other real-time information sources to enhance situational awareness in a given area of interest.

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