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# Spatio-Temporal Visualisation of Outliers

Laurent ETIENNE, Cyril RAY  
Naval Academy Research Institute  
Lanveoc-poulmic, France  
firstname.lastname@ecole-navale.fr

Gavin McARDLE  
National Centre for Geocomputation  
National University of Ireland Maynooth, Ireland  
gavin.mcardle@nuim.ie

## 1 Data Mining and Pattern Recognition in Movement Data

The increase of maritime location-based systems broadcasting information about ship movements is providing large sets of positioning data. Detecting outliers that behave in an unusual way in such large amounts of data is an active research field linked to data mining, statistical analysis and geovisual analytics. Assuming that moving objects following the same itinerary behave in a similar way, these behaviours can be derived by data mining on spatio-temporal databases (*STDB*). This allows for the understanding of common trajectories (considered as the normality) over a long period of time from which location dissimilarities should raise attention. Such trajectory analysis tied with a geovisualisation process is essential for safety applications. This allows traffic operators to focus on possible outliers and reduce cognitive load in overcrowded areas. The following details a process to qualify the position and trajectory of a moving object both on spatial and temporal criteria and discusses the benefits of geovisualisation for pattern understanding. Figure 1 presents the functional process used to extract spatio-temporal patterns

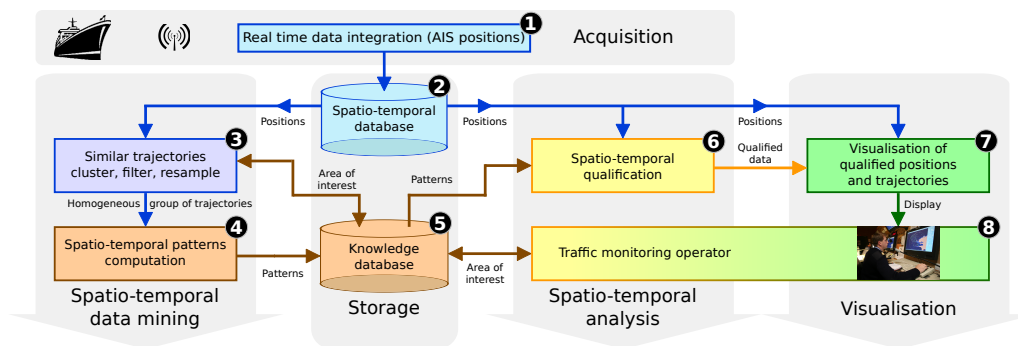


Figure 1: Functional process

from the *STDB* and qualify ship positions and trajectories [3]. A data integration step (Fig. 1, step 1) relies on a monitoring system providing real-time AIS data integration [2]. Trajectories derived from AIS data are clustered in order to get a Homogeneous Group of Trajectories (*HGT*) which is filtered and re-sampled (step 3). Every positions of each trajectory of the *HGT* are paired to a reference trajectory using Fréchet matching [5] to produce clouds of matched positions. A statistical analysis of these clouds gives the median trajectory of the *HGT* and spatio-temporal normality bounds (step 4) which are combined together to define the spatio-temporal pattern of the *HGT*. Every trajectory of the *HGT* is also compared to this pattern in order to compute similarity measurements statistics such as maximum or mean spatial and temporal distance. Finally, this pattern and its statistics are stored in a knowledge database (step 5). These spatio-temporal patterns can be used either for geovisual analysis or to qualify in real-time ship positions and trajectories. In the latter approach, every newly acquired position is matched to a spatio-temporal pattern. The selected spatio-temporal pattern are used to qualify the position and the trajectory (step 6) using fuzzy logic to obtain a combined spatio-temporal similarity rating and visualise it (step 7).

## 2 Introducing Geovisualisation for Anomaly Detection

Traditional data mining techniques can be aided by visual analysis tools to support human reasoning through interactive visual interfaces [1]. The term geovisual analytics represents this process in the spatial domain. In many cases, geovisual analysis can detect outliers or unusual behaviour which data-mining approaches miss. To support maritime anomaly detection, we are investigating the use of a geovisual analysis environment based on the space-time cube [4], in which, the  $x$  and  $y$  planes represent the spatial context while the  $z$  plane represents the temporal component. Trajectories are represented as a 1-dimensional mathematical piece-wise linear curve in the three-dimensional space, forming a 3D polyline in a space-time cube. Figure 2 shows an example of the visual environment displaying vessel movements for a particular route. Vessels which are not following the route in terms of progress (temporal positioning) and geographic locations can be visually identified. For example, it is clear to see a trajectory (in black) which is not following the typical route of other vessels in terms of its progress through the space.

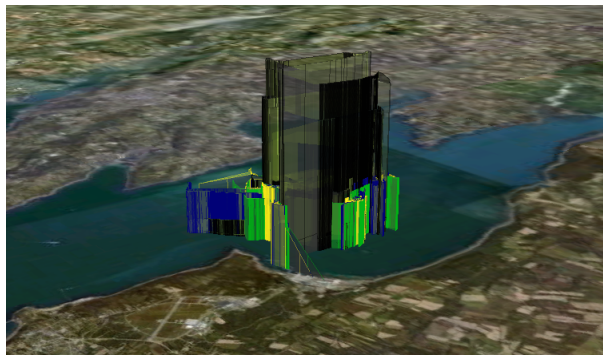


Figure 2: Space-time cube showing the path of vessels with one abnormal trajectory

When the quantity of trajectories becomes larger, visually identifying anomalies can be difficult. As a result, it is necessary to combine the space-time cube visualisation with the clustering and data mining approaches described above in order to visualise the most salient patterns. This assists human cognition while still providing appropriate tools to explore the spatial data.<sup>1</sup>

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