Aid to maritime route detection in the bay of Brest using Mean Shift algorithm

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Abstract. The mandatory requirement for passenger ships, tankers and large ships to carry an AIS device have simplified the collection of data representative of the maritime traffic in coastal seas. Detecting maritime routes is a matter of interest for risk analysts. Quantitative risk assessment methods based on AIS data are usually based on traffic characterization and often use user-defined maritime routes as input before calculating collision risks. User-defined maritime routes can be used to the study of the network topology and traffic characteristics. In order to precisely identify maritime routes, the simple display of AIS positions proves to be of limited use in high density traffic zones because of the spreading of positions along the maritime routes and the potential high number of points. Our method is focused on simplifying the display of large datasets of position data in order to assist humans when defining maritime routes in GIS systems.

Keywords: Risk Analysis, Maritime Safety, Maritime Routes, Trajectories, Display, Ais Data.

1 Introduction

In order to enhance maritime safety, including protection of life, health the marine environment and property, IMO [1] and IALA has recommended for years that Formal Safey Assessment (FSA) should be undertaken whenever it is possible. Usually, FSA methods focused on equipment failures, human failures, and situations through the use of fault tree analysis, event tree analysis, or by incorporating Human Reliability Analysis (HRA). Recent trends in FSA applied to the maritime domain have focused on identifying dangerous areas of collision in order to adapt safety measures such as buoyage, Traffic Separation Schemes (TSS), pilotage, VTS Centres, positioning of towing vessels or antipollution materials.

In these FSA approaches, detecting maritime routes is still often a difficult task for experts though different tools may help them in this task when displaying geolocalized maritime data. Techniques such as large scale display, density computation, logarithmic intensity scaling, kernel density computation, may give the user a better perception of where the maritime routes are passing [2]. Nonetheless, it is still difficult for experts to precisely determine the location of maritime routes. It is only once the maritime routes are defined that the characterization of the traffic may be undertaken with automatic tools allowing to estimate the distribution of speeds along the routes, the spreading of the ship trajectories or the risk of collision in case of crossing or overlapping of the maritime routes [3, 4].

In this paper, we use a modified Mean Shift algorithm in order to simplify the visual appearance of maritime routes while preserving the network topology of shipping. Mean shift is an algorithm that can be used for different purposes such as data mining, clustering, segmentation, *etc.* Mean Shift was introduced in Fukunaga and Hostetler [5] and has been extended to be applicable in other fields like Computer Vision. We show that it can be applied to ship trajectories in order to help experts identify main maritime routes, specifically in high density areas.

First, we recall the principle of the Mean Shift process. Then we detail the adaptation of this algorithm to AIS positions. Finally, the application and results are presented and discussed.

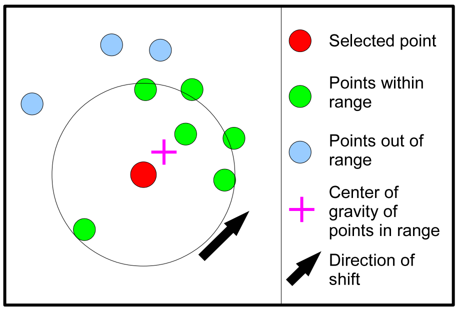
2 Mean shift

2.1 Original Mean shift

Mean shift considers the feature space as an empirical probability density function. If the input is a set of points, then Mean shift considers them as a sample from an underlying probability density function. If dense regions (or clusters) are present in the feature space, then they correspond to the mode (or local maxima) of the probability density function. Originally, Mean shift was meant to identify clusters associated with the modes detected this way.

In our case, we understand that ship trajectories are not based on the realization of a stochastic process. These trajectories represent the achievement of the will to go from departure to destination. In ideal situations, all ships would go along the optimal trajectory (the shortest) if not subject to environmental constraints. We hypothesize that lateral positioning along the routes could be considered as a stochastic process depending on numerous constraints related to the environment, the bathymetry, the currents and winds, and all potential obstacles at sea (buoyage, other ships, *etc.*).

The purpose of applying Mean shift on ship trajectories is to reduce the lateral spreading of positions along the maritime routes and thus, to ease the work of experts when drawing the maritime network. For each data point, Mean shift associates it with the nearby peak of the dataset probability density function. As illustrated on Fig.1(a), for each data point, Mean shift defines a window around it and computes the mean of the data points in the window. Then it shifts the center of the window to the mean and repeats the algorithm until it converges. After each iteration, we can consider that the window shifts to a more denser region of the dataset.



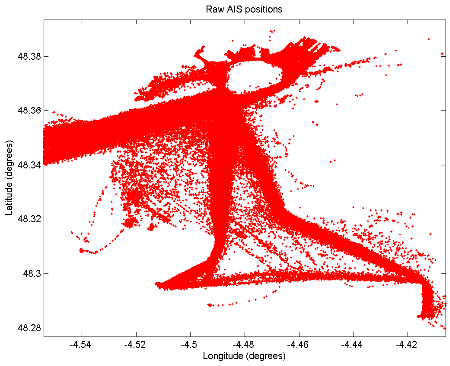


Fig. 1: (a) Shifting process (b) Original AIS Positions Received

2.2 Adapted Mean shift

In order to preserve the network topology, we don't want Mean shift to consider that a given point should be blindly shifted toward the mean position of surrounding points. In fact, points within range may often belong to other routes in high density areas so that it would have few meaning to consider these points in the process.

The Mean shift algorithm is adapted so that for each selected point, the surrounding points considered for mean position computation inside the window should share a common Course over Ground (CoG). These points sharing a nearby CoG probably belong to the same maritime route as the selected point and it is logical in to include them in the Mean shift process.

3 Results on the dataset of AIS positions in the bay of Brest

Fig.1(b) shows the AIS dataset provided by the French Naval Academy Research Institute (IRENav). In this high density areas, even with preprocessing of the dataset to compute density maps, the spreading and overlapping of positions make it impossible to precisely define where the maritime routes are. Even modifying the size of the cells of the density map or modifying the color intensity mapping gives poor results.

The results presented in Fig.2(a) is easier to use for experts willing to draw a picture of the maritime network. Also, the resulting positions preserve some special features that would not appear on the original display of the positions, such as parallel maritime routes presented in green or in blue in Fig.2(b) and that could not be distinguished among the large routes seen on the original display of Fig.1(b).

Fig.3 shows the evolution of the mean shift depending on the number of iterations of the algorithm and gives a hint on how to fix a criterion in order to stop iterating. It should be noted that on the maritime route presented in Fig.2(b),

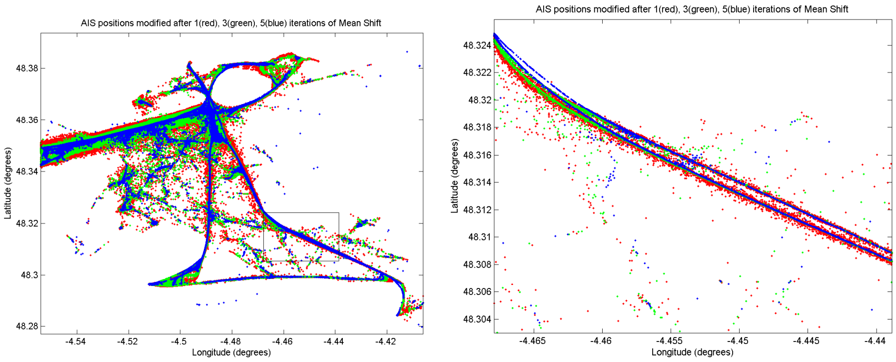


Fig. 2:(a) Results after 1, 3 and 5 iterations (b) Close-up on a maritime route

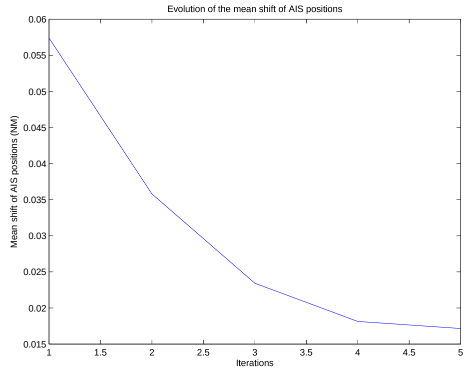


Fig. 3:(a) Evolution of the mean shift of points depending on the number of iterations

we clearly distinguish two parralel routes that probably present opposing courses over ground. These routes appear clearly whereas they were fused in the display of raw AIS positions. This type of information may have a major impact when estimating the risk of collision using models such as proposed in [3, 4].

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