Using Multiclass Classification for Ship Route Prediction

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Within the National Research Council in Pisa, a Ship Route Prediction algorithm was implemented, based on Multiclass Classification. The algorithm was part of the OSIRIS project [1], which aimed at building a decision support system for maritime surveillance.

Multiclass Classification (MC) is a type of supervised learning which assigns a sample to one of many classes, by measuring some attributes associated to the sample. MC is a generalization of the binary classification, where there are only two classes. MC can be exploited to build a Ship Route Prediction (SRP) system [1], which aims at predicting the next position of a ship, given its current status, determined by its current position (latitude, longitude), speed over the ground, heading, time and date, as well as a historical database of past routes. In detail, the area to be monitored, called Area of Interest (AoI), is splitted in m rows and n columns, and each cell of the obtained matrix constitutes an output class of the MC algorithm. Thus, the total number of possible classes is m x n. Given the current status of a ship, the SRP system predicts the probability that each cell of the matrix will be occupied after a given period of time (e.g. 30, 45 or 60 minutes).

Different MC algorithms were tested to perform SRP, including Naive Bayes, K-Nearest Neighbors, Decision Trees, Linear Algorithms and Extension from Binary. Every MC algorithm was trained and tested with actual data contained into a historical database of past routes, extracted from Automatic Identification System (AIS) messages sent by other ships around the island of Malta. Then, a Web application was implemented to to predict the next position of a ship [L2]. The K-Nearest Neighbors and Decision Tree algorithms outperformed all the other MC algorithms.

With reference to the state of the art, the proposed SRP system is a point-based system, which is able to predict only the next position of a ship, given the current one. Other systems, defined in the literature, instead, can predict also the whole trajectory. To the best of our knowledge, the proposed SRP system is the first SRP algorithm which considers time and date as input features..

We performed a qualitative test of the SRP system, which involved testing the SRP performance in the following real scenario: *On 2019 December 30 at 11:11, the Ship ASTRAEA [PA] was directed towards the Marsaxlokk port and the estimated time of arrival was 12:30. SRP was exploited to predict the next position after 60 minutes.* All the information used for this scenario was extracted from Marine Traffic [L2], a global ship tracking intelligence website. We ran all the implemented MC algorithms to predict the ship's next position after 60 minutes. Results are shown in Fig. 1: only K-NN and Decision Tree predicted the correct position.

The SRP system was implemented within the OSIRIS project, funded by the European Space Agency (ESA) [1]. OSIRIS considered the area around the island of Malta as AoI, in order to extract the behavior of the ships contained in it. This monitoring is done through the periodic capture of satellite images in the AoI. Because of the high cost of high-resolution satellite images, in the first instance only low-resolution images are captured. These images, which are less expensive, are processed by two modules, identification and classification, in order to extract the ships present in the area and their general status. Then, the extracted status is sent as input to the SRP system, which identifies the position of the ship after a certain time interval. The position extracted from the SRP system is used to direct the satellite to capture a new image, exactly in the area where the ship is predicted to be found. The new captured image will be more fine-grained so more information could be extracted. This information will be used by another system, the behaviour analysis module, which will try to understand if the ships present in the subarea are behaving correctly or not. In summary, the OSIRIS system involves the capture of two satellite images, one coarse-grained (larger and less expensive), one fine-grained (smaller and more expensive). For this reason, the SRP system does not need to predict the exact position of a ship, but only a restricted area in which the ship will be after a certain time interval.

Although SRP has been widely studied in the literature, this work represents the first approach which compares different SRP algorithms based on multiclass classification. The use of Machine Learning techniques on the maritime field is being consolidating, thus helping decision support systems to profile ships behaviors and then identify anomalies in ships behaviors. Thanks to the naive theoretical framework and apparently over-simplified assumptions, the methodology described in this paper can be easily reproduced and used by other researchers to compare other families of algorithms, not necessarily in the field of SRP.

Links:

[L1]: http://wafi.iit.cnr.it/osiris1/srp viewer

[L2]: https://www.marinetraffic.com/

References:

[1]: Reggiannini, M., Righi, M., Tampucci, M., Lo Duca, A., Bacciu, C., Bedini, L., and Mercurio, C. (2019). Remote Sensing for Maritime Prompt Monitoring. Journal of Marine Science and Engineering, 7(7), 202.

[2]: A. Lo Duca, C. Bacciu, A. Marchetti. A K-Nearest Neighbor Classifier for Ship Route Prediction, OCEANS 2017 - Aberdeen, UK 2017.

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Figures:

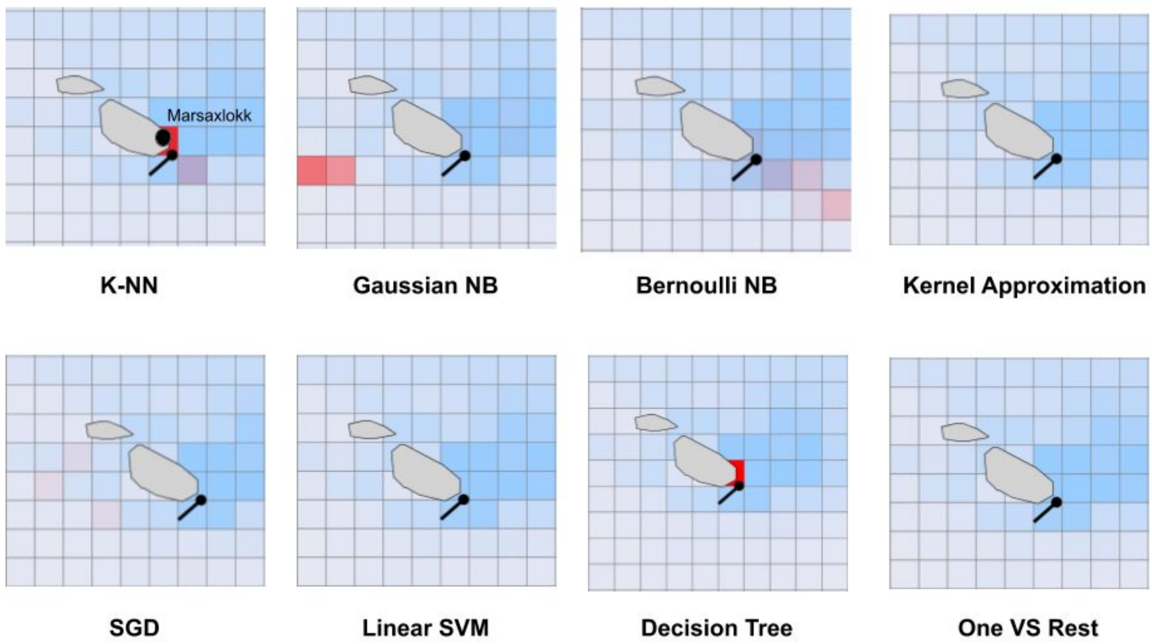

Fig 1 The output of SRP for the Ship ASTRAEA [PA]. The position of the destination (Marsaxlokk port) is shown only for K-NN. Predicted probabilities are shown in red. The brighter the red of the cell, the higher the probability value.