Prediction of Vessels Trajectory Using Different Coordinate Systems

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Abstract

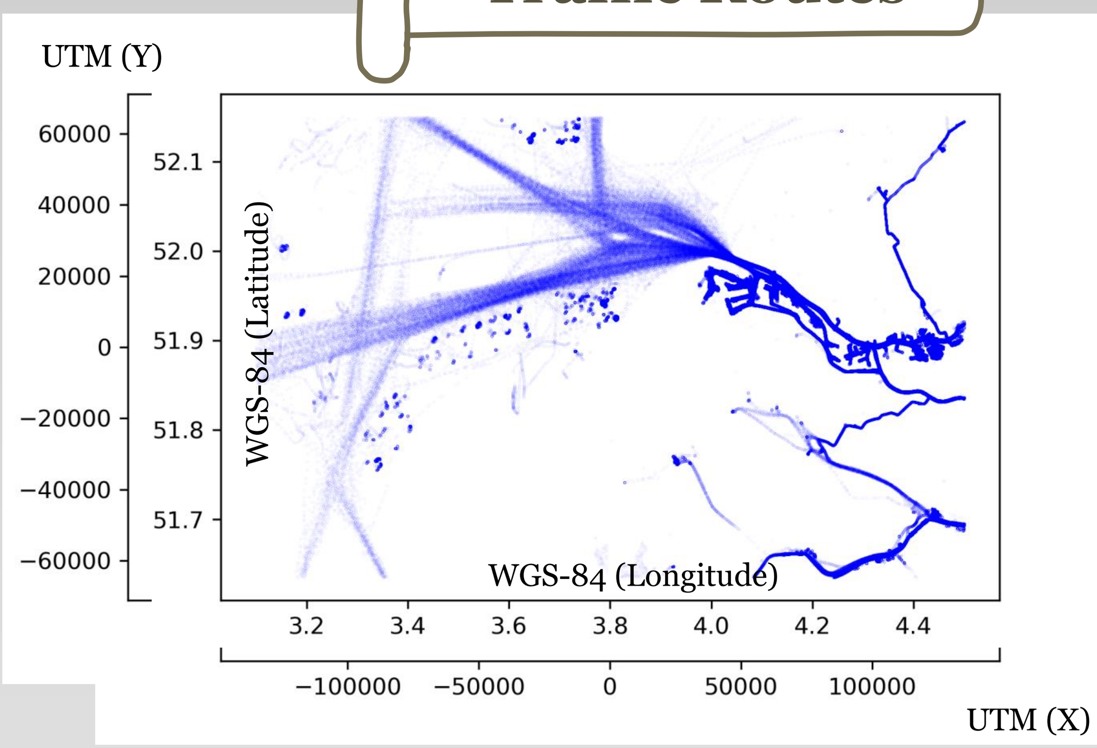
The global marine insurance report announces that the growing risk of major events (both human and non-human) remains among the ongoing challenges in maritime transport. One of the factors is vessel collisions and anomalies at the sea. Large historical data from automatic identification systems (AIS) are analysed to solve the problem of ship trajectory prediction. The most common attempt to improve accuracy is by evaluating the historical ship behaviour, learning the patterns and similarities of the predicted vessel movements. However, this paper shows that a better prognosis also may be reached by chosen a different trajectory calculation strategy. Typically, such features are the values of the polar coordinate system, so it has been proposed to transform the coordinates into two-dimensional space. The positioning of the vessels motion transformations were tested: coordinates transformation into a Cartesian system using Universal Transverse Mercator (UTM) projection. This case allowed to reduce the forecast error of almost 30% in the available data sample (it is almost 300 meters) by using the autoencoder architecture, compared to the longitude and latitude predictions. Overall, the research compares three recurrent network architectures (including their hyperparameter - cell size changes): bidirectional Long Short-Term Memory, autoencoder and gated recurrent unit networks. The model is applied to a real AIS historical dataset of the cargo vessel type trajectories in the Netherlands (North Sea) coastal region.

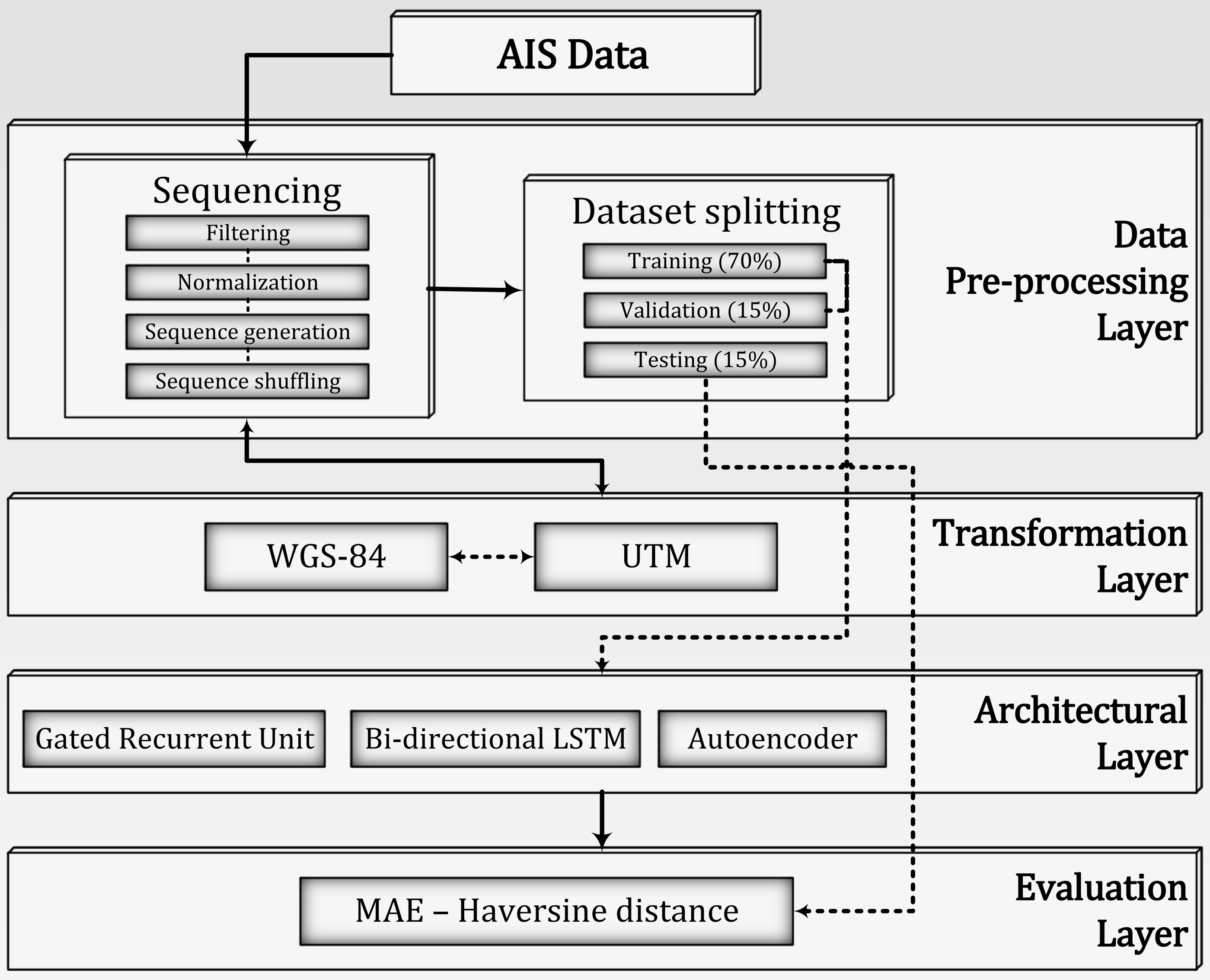
Research

The data used in the study are obtained from the Automatic Identification System (AIS) - ShipFinder. The study was conducted on vessels belonging to the Cargo vessel type. Key features of vessel observation: MMSI, latitude, longitude, speedKnt, headingDeg, dateDiff (computed difference between two time steps in the trajectory, calculated in minutes), and delta latitude, delta longitude features. These studies are a continuation work of the original article in order to improve the results obtained previously. The main idea is to change the orientation coordinates of the vessels position into different map projections.

The geoposition of objects on the ground is usually determined using the generally accepted WGS 1984 standard. Geographic location data includes geographic coordinates, that is, longitude and latitude which sets the units in degrees, and indicate the position or location of any place on Earth's surface. This information is also collected by satellite-based vessel monitoring systems. Meanwhile, the UTM projection is divided into 60 zones that segment the earth's surface by 6 degrees. Each zone has a central meridian of 500,000 meters. The Netherlands region belongs to zone 31. By converting the position values to two-dimensional coordinates, we get a wider scale in the sea traffic routes.

Traffic Routes





Workflow

The structure of a research workflow can be divided into several main layers: AIS data, data pre-processing, transformation, architectural, and evaluation. The first layers process the raw data from the AIS, in which the vessels historical sailing trajectories are cut into smaller segments and marked with input and output labels. At the transformation level, sequences are recalculated by two positioning projections:

- Polar coordinate system - World Geodetic System 1984 (WGS-84);
- Cartesian coordinate system - Universal Transverse Mercator (UTM).

Sequences with identical vessel characteristics, except for position features, which are in pairs (longitude, latitude) and (x, y), are divided into training, validation and testing samples. Training and validation data are used to train recurrent network models, and the test sample is designed to estimate the distance error of predicted trajectories.

Results

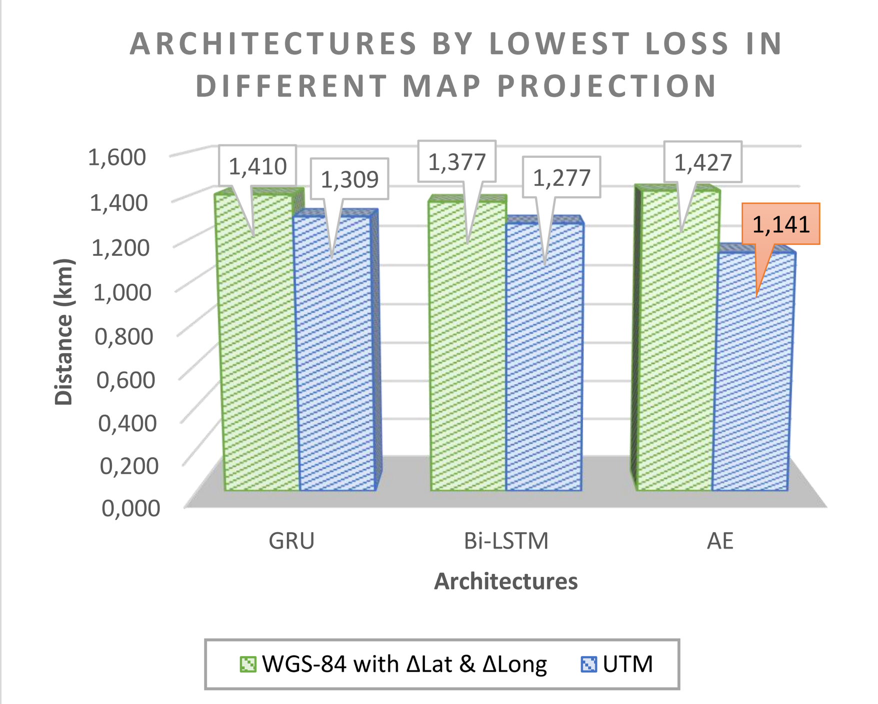
Adjacent chart shows the results obtained with the smallest average distance errors in different architectures and table shows the main statistical estimates (minimum, maximum, mean, and standard deviation values) obtained using a different vessel positioning projection. The trained models were evaluated by the mean haversine absolute error throughout the testing sample, measuring the difference between the points of the predicted and actual trajectory (in kilometers):

$$MAE(km) = \sum_{i=1}^{n} |haversine(y_i - \bar{y}_i)|$$

UTM projection transformation had the greatest influence on the autoencoder. This allowed the initial loss value to be reduced by an average of about 30 percent (or 300 meters), in different cell combinations - comparing results with networks when they were trained by polar coordinates with delta features.

WGS-84	GRU	Bi-LSTM	AE
MIN	1,410	1,377	1,427
MAX	1,850	1,762	1,641
AVG	1,509	1,448	1,485
STD	0,127	0,103	0,059

UTM	GRU	Bi-LSTM	AE
MIN	1,309	1,277	1,141
MAX	1,644	1,532	1,264
AVG	1,409	1,355	1,169
STD	0,101	0,069	0,035



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