

Design and Implementation of an AIS Vessel Trajectory Visualization System Based on AMap

Yujuan Zou, Taizhi Lv

College of Information Engineering, Jiangsu Maritime Institute, Nanjing, China

Abstract: To address the challenges posed by the large volume and dense spatial distribution of AIS position data, as well as the limited support for interactive queries in conventional static displays, this paper designs and implements an AIS vessel trajectory visualization system based on AMap. By integrating AMap with ECharts, the system provides coordinated representations of spatial positions and speed variations. It supports two primary functions. First, vessel positions are rendered using the MassMarks layer; point icons are switched according to the map zoom level, while their rotation angles are set from vessel heading. Selecting a vessel displays its MMSI, longitude, latitude, speed, course, vessel heading, and reception time in a table. Second, users can search for a vessel by MMSI and retrieve its historical trajectory for a specified time range. The resulting trajectory includes directional cues and start/end markers, while a speed time-series chart is generated in parallel. Selecting a time instant on the chart locates the corresponding trajectory point on the map. Together, these functions provide a continuous workflow from multi-vessel distribution browsing to single-vessel historical-trajectory inspection and offer a reusable Web-based solution for intuitive AIS data visualization.

Keywords: Automatic Identification System; AMap; Vessel trajectory; MassMarks rendering; Interactive visualization.

1. Introduction

The Automatic Identification System (AIS) continuously exchanges information such as Maritime Mobile Service Identity (MMSI), longitude, latitude, speed, course, and vessel heading through very high frequency communications. It is an important data source for vessel identification, traffic organization, and maritime situational awareness. As shore-based reception coverage expands and observation periods become longer, AIS data exhibit high volume, frequent updates, temporal continuity, and strong spatial dependence. Transforming dense geospatial records into vessel positions, trajectories, and attribute-based visualizations that users can readily interpret and explore has therefore become a fundamental requirement in smart maritime applications.

Existing studies have addressed AIS data management, preprocessing, and system services from several perspectives. Distributed storage and query mechanisms based on Hadoop have been used to manage massive AIS datasets [1], while trajectory denoising and compression methods have been developed to improve data quality and reduce processing costs [2]. For system construction, the BlueNavi platform adopts a microservices architecture to provide AIS-based maritime information [3], AISdb supports AIS data collection, cleaning, integration, and spatiotemporal querying [4], and a Lambda-architecture-based supervision system combines batch and real-time processing with multi-level storage [5]. In the visualization domain, existing research has explored trajectory display and playback, speed charts, multi-view interaction, and visual analysis of vessel behaviour [6-8]. These studies provide a useful technical foundation for AIS data processing and visualization. However, simultaneously displaying large numbers of vessel positions can still lead to overlapping point icons and insufficient visual differentiation across map zoom levels. In addition, the relationships among historical trajectories, speed changes, and geographic locations are not always presented intuitively.

Against this background, this paper develops an AMap-

based vessel trajectory visualization system for spatial display and interactive querying of AIS data. The system is organized around two functional threads. First, AIS position points are rendered collectively in the MassMarks layer, and point icons are switched according to the map zoom level; users can select a vessel and inspect its attributes in a table. Second, users can search by MMSI and specify a time interval to retrieve a vessel's historical trajectory, with a speed time-series chart providing a complementary view of trajectory-related changes. Rather than emphasizing complex prediction algorithms, this study focuses on the WebGIS implementation of these two core functions.

2. System Requirements and Overall Design

2.1. Requirements Analysis and Overall Architecture

The system targets AIS position browsing and historical-trajectory queries. Its functions follow a three-stage workflow: overview of the overall distribution, selection of a target vessel, and historical-trajectory inspection. Users first examine the spatial distribution of vessels on the map, select a target from the AIS position points in the MassMarks layer, and then retrieve its trajectory over a specified period. The two core functions can be used independently but are connected through MMSI and map interactions.

The multi-vessel MassMarks display presents vessel positions within a selected area. The system loads large volumes of AIS position data and switches point icons according to the map zoom level: lower zoom levels emphasize the overall distribution, whereas higher zoom levels make individual vessels easier to identify. When the map reaches a zoom level at which individual vessels can be distinguished, users can select an AIS position point and view its MMSI, longitude, latitude, speed, course, vessel heading, and reception time in a table.

The single-vessel historical-trajectory query presents the

movement of a target vessel over a specified period. Users can either search by MMSI or select a target directly from the MassMarks layer and then define the start and end times. The system connects the returned records chronologically to form a continuous trajectory, marks its start and end points, and plots speed against time in a speed time-series chart. Linked

interaction between the map-based trajectory view and the speed time-series chart allows users to associate a speed change with the vessel's geographic position at the corresponding time.

The inputs, processing steps, and outputs of the main system functions are summarized in Table 1.

Table 1. Functional Requirements of the System

Module	Input	Main Processing	Output
MassMarks display	AIS position data	Organize MassMarks data and load them in batches	Multi-vessel position distribution map
Zoom-based icon switching	Map zoom level	Switch point icons according to the map zoom level	Point icon display at different zoom levels
Selected-point information display	AIS position point selection	Retrieve the AIS attributes associated with the selected point	Vessel information table
Historical-trajectory query	MMSI and time range	Extract trajectory coordinates, speed values, and timestamps	Historical trajectory, start/end markers, and speed chart

The system adopts a layered front-end/back-end architecture. The interaction and presentation layer handles map operations, query inputs, the vessel information table, and interface-state control. The visualization layer integrates AMap and ECharts to represent AIS position points, historical trajectories, start/end positions, and speed variations. The data service layer provides AIS position data and historical-trajectory data in response to front-end requests. The interaction and presentation layer invokes the data services through AJAX, after which the visualization layer updates the map and charts with the returned data. This separation keeps interface interaction, visual representation, and data querying relatively independent, thereby supporting system maintenance and functional extension. The layers and their responsibilities are listed in Table 2.

Table 2. Layered Architecture of the System

Layer	Key Technologies	Responsibilities
Interaction and presentation layer	HTML, CSS, JavaScript, jQuery, AJAX	Vessel search, time-range selection, information table, interface-state control, and asynchronous data exchange
Visualization layer	AMap JavaScript API, ECharts	MassMarks layer, historical trajectory, start/end markers, speed chart, and linked interaction between the map-based trajectory view and speed chart
Data service layer	Back-end services, database access	Receive query conditions and provide AIS position data and historical trajectories for specified vessels

2.2. Data Organization and Interaction Flow

The system organizes AIS data around the vessel identifier (MMSI), spatial coordinates, vessel heading, course, speed, and reception time. During MassMarks display, spatial coordinates are associated with vessel attributes so that each AIS position point both represents a vessel's location and responds to user interaction. During historical-trajectory

queries, consecutive records are retrieved by MMSI and time range and then organized into trajectory coordinates, speed values, and timestamps. The map-based trajectory view and the speed time-series chart are derived from the same AIS records, which preserves the correspondence among spatial position, speed variation, and reception time.

The interaction flow consists of AIS position data loading followed by historical-trajectory querying. The front end first retrieves AIS position data asynchronously and loads them into the MassMarks layer, providing the basis for multi-vessel distribution browsing and target selection. After a user selects a vessel and specifies a time range, the front end asynchronously retrieves the corresponding historical records and passes them to the map and chart components. The map presents spatial positions and vessel trajectories, while the chart shows speed variation over time. Because both views use the same AIS records, their contents remain mutually consistent. The detailed implementations of MassMarks interaction, trajectory drawing, and map-chart linking are described in Section 3.

3. Implementation of Key Functions

3.1. AMap Initialization and Basic Interaction

The system first creates an AMap instance and loads basic controls for zooming, panning, and view manipulation, thereby providing a unified map environment for AIS position browsing and trajectory queries. During initialization, an appropriate center and initial zoom level are configured so that the page opens with an overview of vessel distribution in the selected area. Users can adjust the visible area with the mouse and map controls before inspecting local vessel positions, selecting a target vessel, or viewing its historical trajectory.

Within the same map environment, the system maintains two interaction states: multi-vessel distribution browsing and single-vessel trajectory viewing. The former supports an overview of vessel positions and target selection, whereas the latter focuses on the sailing history of a specified vessel. Unified control of map objects and interface states enables smooth switching between the two views while preserving consistent map behavior.

3.2. Zoom-Level-Dependent Rendering of AIS Position Points

Conventional point markers are suitable for displaying a small number of targets. When the number of vessel positions becomes large, creating and drawing each marker individually increases the processing burden on the browser and can reduce the responsiveness of map zooming and panning. The system therefore uses the MassMarks layer to load and render AIS position data in batches, while associating each spatial coordinate with the corresponding vessel attributes. Figure 1 shows a local view of the resulting large-scale AIS position display.



Figure 1. Local Display of AIS Position Points

For zoom-level-dependent MassMarks display, the system listens for map zoom events and switches the point icons used by the MassMarks layer according to the current zoom level. At lower zoom levels, the map must accommodate many AIS position points at once; compact dot icons are therefore used to emphasize the overall vessel distribution and reduce icon overlap. As users zoom in with the mouse wheel, the displayed spacing between AIS position points increases, and the system switches to larger, more recognizable point icons, allowing a natural transition from regional distribution analysis to individual-vessel identification. Point selection is enabled once the map reaches a zoom level at which individual vessels can be clearly distinguished, thereby reducing unintended selections in dense areas. By changing point icons across zoom levels, the system regulates information density and improves both readability and operability.

To represent vessel orientation, directional point icons are used after the map reaches a relatively high zoom level. When the MassMarks data are loaded, the rotation angle of each icon is set from the corresponding vessel heading so that the icon points in the same direction as the vessel's bow. Unlike static icons with a uniform orientation, this approach presents both vessel position and bow direction, helping users identify vessel orientation in local waters and providing an intuitive basis for target selection and historical-trajectory inspection.

3.3. MassMarks Selection and Vessel Information Display

A click event is bound to the MassMarks layer. When a user selects an AIS position point, the program retrieves the AIS attributes associated with that point, adds a highlighted marker to the map, and updates the vessel information table. The table displays MMSI, speed, course, vessel heading, longitude, latitude, and reception time, providing a direct correspondence between map position and vessel attributes.

Closing the information table clears the selection state and restores the multi-vessel distribution view.

In addition to map-based selection, the system allows users to search for a vessel by MMSI. The target is matched against the loaded AIS position data; when a match is found, the map centers on the corresponding location and reuses the vessel information table to display its attributes. Map selection and MMSI search share the same information-display procedure, avoiding duplicate processing logic.

3.4. Historical-Trajectory Query and Visualization for a Single Vessel

A historical-trajectory query is defined by the currently selected vessel and the time range specified by the user. The front end submits these conditions to the back end through AJAX. The back end retrieves the corresponding AIS records and returns them to the front end, where they are organized into trajectory coordinates, speed values, and timestamps. The coordinates are used to draw the trajectory in the map-based trajectory view, while speed and time are used to generate the speed time-series chart. These processed data provide the basis for trajectory rendering and speed-variation display.

The system chronologically connects the longitude and latitude coordinates recorded at successive times to construct a vessel trajectory from the sequential AIS records, with directional cues shown along the line. The first and last records are marked as the start and end points using distinct icons. After the trajectory has been drawn, the map center and zoom level are adjusted automatically. When the single-vessel trajectory view is activated, the multi-vessel AIS position points are temporarily hidden to prevent unrelated vessel positions from obscuring the target trajectory.

The same query result is also used to generate a speed time-series chart, which supports zooming along the time axis for closer inspection of speed changes over selected intervals. Because each AIS record contains reception time, longitude, latitude, and speed, selecting a time instant on the speed time-series chart allows the system to retrieve the corresponding coordinates, locate the associated trajectory point in the map-based trajectory view, and display its longitude, latitude, speed, and time in an information window. This interaction links the speed time-series chart with the map-based trajectory view.

4. Conclusion

This paper has designed and implemented an AMap-based Web visualization system for the spatial display and interactive querying of AIS position data. The system provides two core functions. First, the MassMarks layer displays the positions of multiple vessels; point icons are switched according to the map zoom level, and their rotation angles are set from vessel heading, while selecting a point displays the associated vessel attributes in a table. Second, users can identify a target through map selection or MMSI search, query historical records over a specified time range, and generate a directional vessel trajectory with marked start and end positions. Linked interaction between the speed time-series chart and the map-based trajectory view further reveals the correspondence between speed changes and trajectory positions. Together, these functions form a visualization workflow comprising multi-vessel browsing, single-vessel selection, historical-trajectory inspection, and spatiotemporal linking. Future work may incorporate spatial indexing,

trajectory simplification, and tiled loading to improve responsiveness in larger-scale data scenarios.

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