THE OHIO STATE UNIVERSITY
COLLEGE OF ENGINEERING

DeepTracks: Geopositioning Maritime Vehicles in Video Acquired from a Moving Platform

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1. INTRODUCTION

Geopositioning and tracking a moving boat at sea is a very challenging problem, requiring boat detection, matching and estimating its GPS location from imagery with no common features.
This poster presents a moving boat geolocalization approach based on single camera imagery.

2. PROBLEM STATEMENT

Figure 1 reflects the white target boat trajectory from previous video, from 'Start' to 'End'. From pre-collected dataset, we have moving target boat video stream, corresponding target boat GPS and camera GPS. Our problem is to predict target boat GPS known target boat image and camera GPS. In training we known all those three. But in testing we know the first two as listed below in details.

Training
- Image at time t
- Camera GPS at time t
- Target boat GPS at time t

Testing
- Image at time t
- Camera GPS at time t

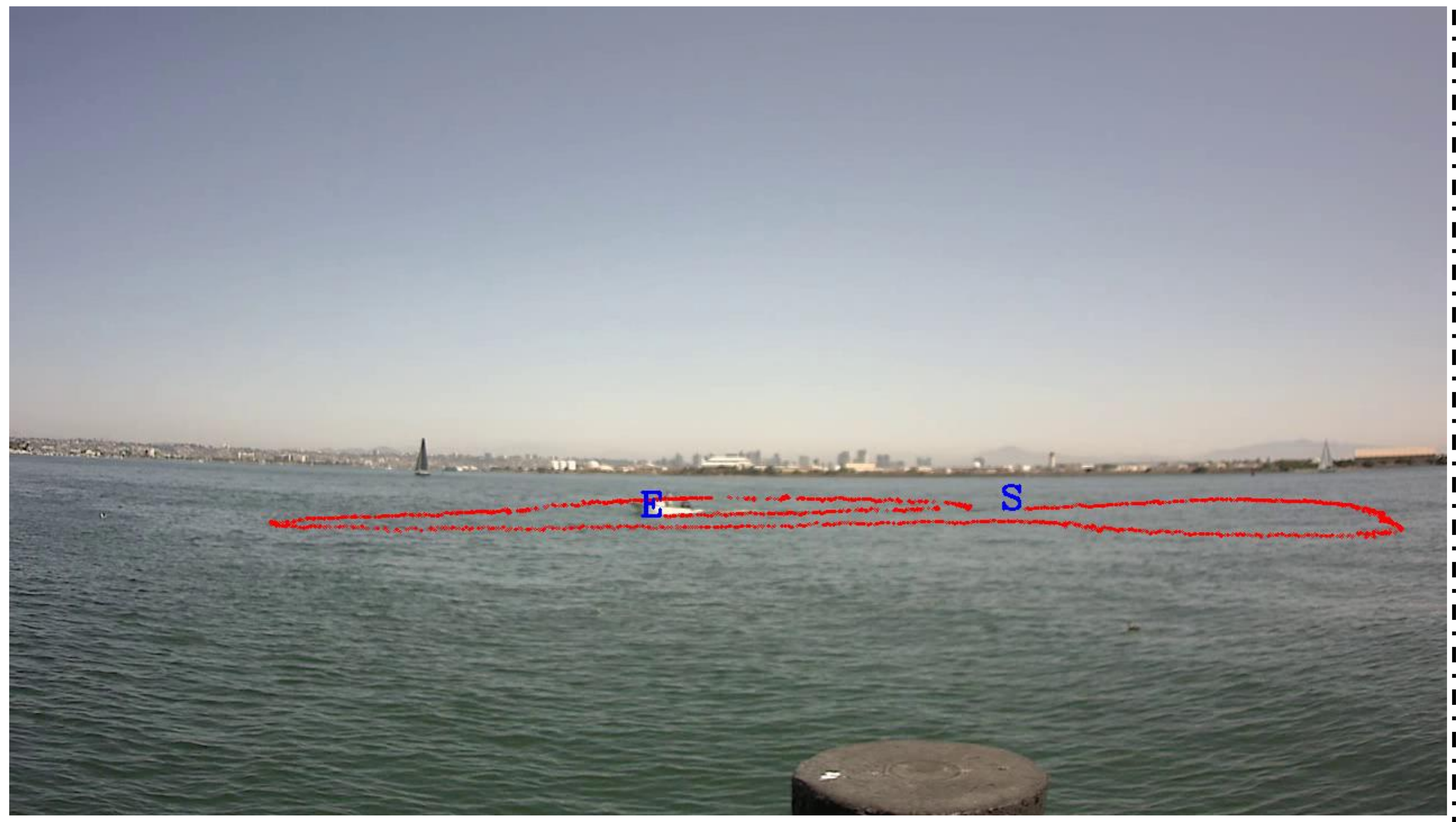

Fig. 1. Boat trajectory on the video frame, 'S' and 'E' indicates where the boat start and end its trajectory. Target boat GPS info located on the red point position is also recorded in the training set.

3. METHODOLOGY

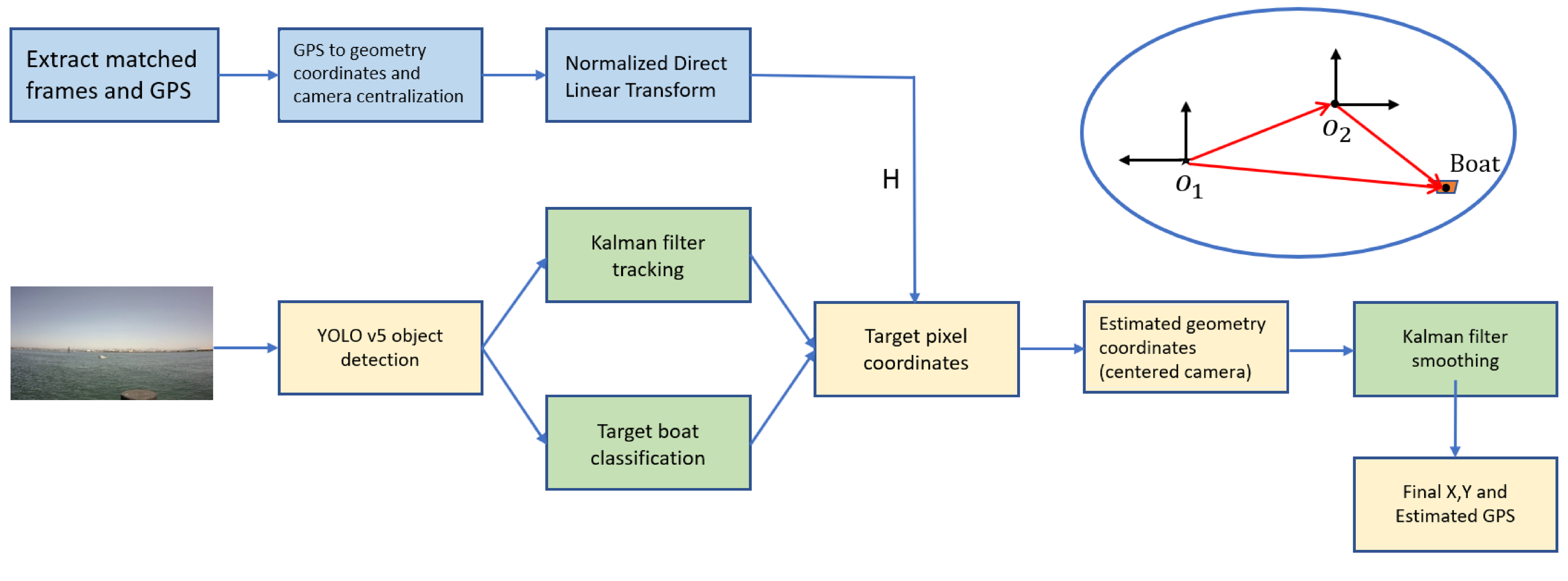

Fig. 2. Flow diagram showing the relation between the geometric, detection, classification, tracking and geopositioning modules.

Modules	Function
Coordinate Transformation Module	Transfers detected target boat pixel location to absolute sea coordinates
Detection Module	Detect target boat and return the bottom center of bounding box
Classification and Tracking Module	Keep detecting and geopositioning the same boat in consecutive frames
Post Processing Module	Generate consistent latitude longitude information and provide smooth boat trajectory

Coordinate Transformation: Figure 3 introduces a linear MLP based geometry model that transfers pixel location to absolute sea coordinates which is modeled as piece-wise plane. Here the MLP parameters are estimated using the training set provided with the dataset which contains the image position (x, y) of a boat and its corresponding GPS position (lat, lon). Using this quadruplet $\langle (x, y), (lat, lon) \rangle$, we set the north and east directions of the camera as x and y axes of the quasi sea-plane that overlap with the GPS coordinates in western hemisphere.

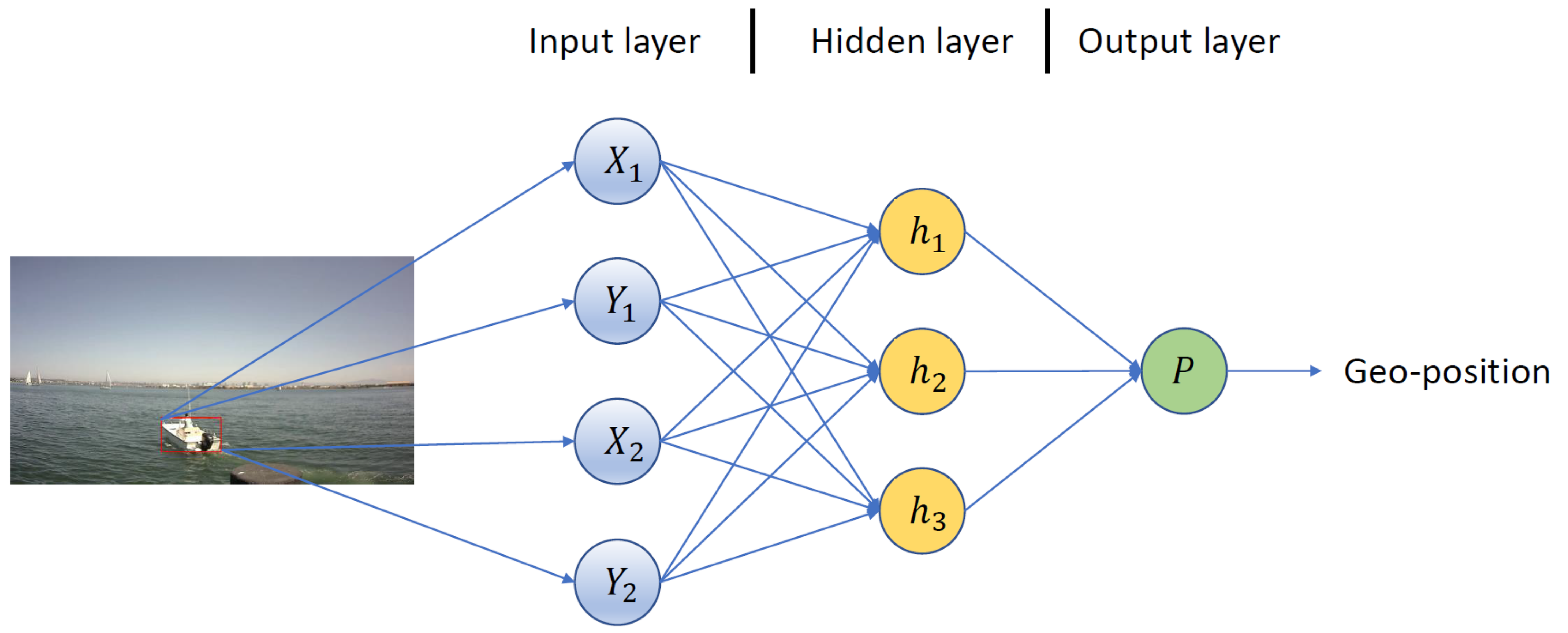

Fig. 3. Linear MLP modeling the geometric transformation between the camera and world reference frames.

The boats in the image are detected by pretrained YOLO5 object detector from which the bottom center of the boat's bounding box that lies on the sea surface is used as the boat location. This and its corresponding GPS location is then used to compute the plane-projective transformation that estimates the homography matrix H between the two coordinates:

$$T_{world} * X_{world} = H * T_{local} * X_{local}$$

where T_{world} and T_{local} are normalization matrices that serve as preconditioning transformations to decrease condition number of H.

Detection and Tracking: YOLO5 detects all boats. Given the detected boats in consecutive frames, tracking is accomplished by a two stage operation. The first stage is using Kalman Filter to operate on the consecutive images that ensures consistent boat trajectory and reduce object detection errors that are assumed Gaussian. Besides, an additional VGG-16 based boat classifier trained using the training data improves methods robustness by assisting the Kalman filter and ensures proximal and similar boat is associated to the boat in the previous frame. We compute a detection score by convexly combining the classification network probability P_C and Kalman filter distance distribution P_K: $P = \alpha * P_C + (1 - \alpha) * P_K$

Post Processing: The second stage Kalman filter operates in the world frame to generate consistent latitude longitude information and provide smooth boat trajectory shown in Figure 4.

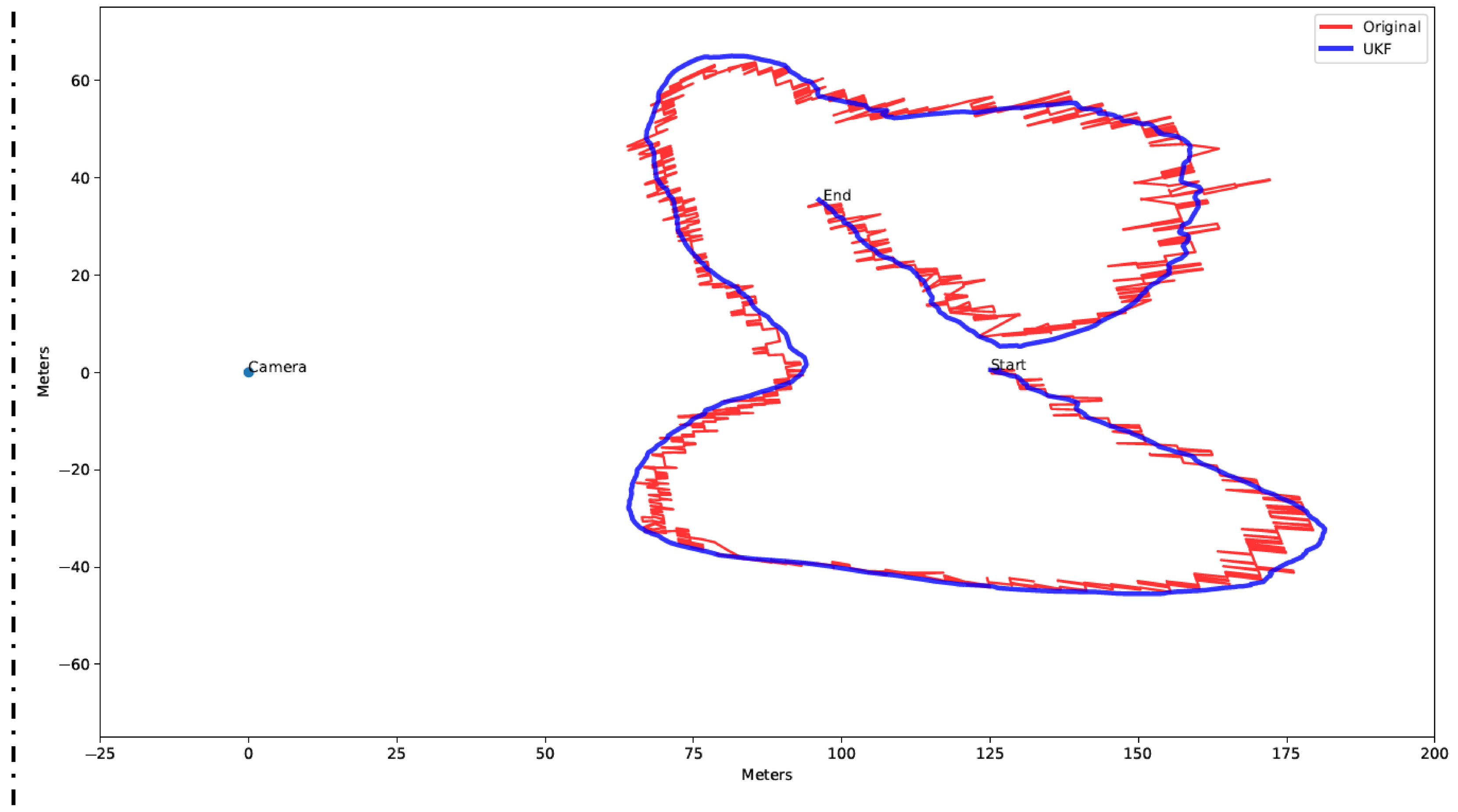

Fig. 4. Predicted raw geo-trajectory and post processed geo-trajectory using UKF in the world frame.

4. EXPERIMENTS

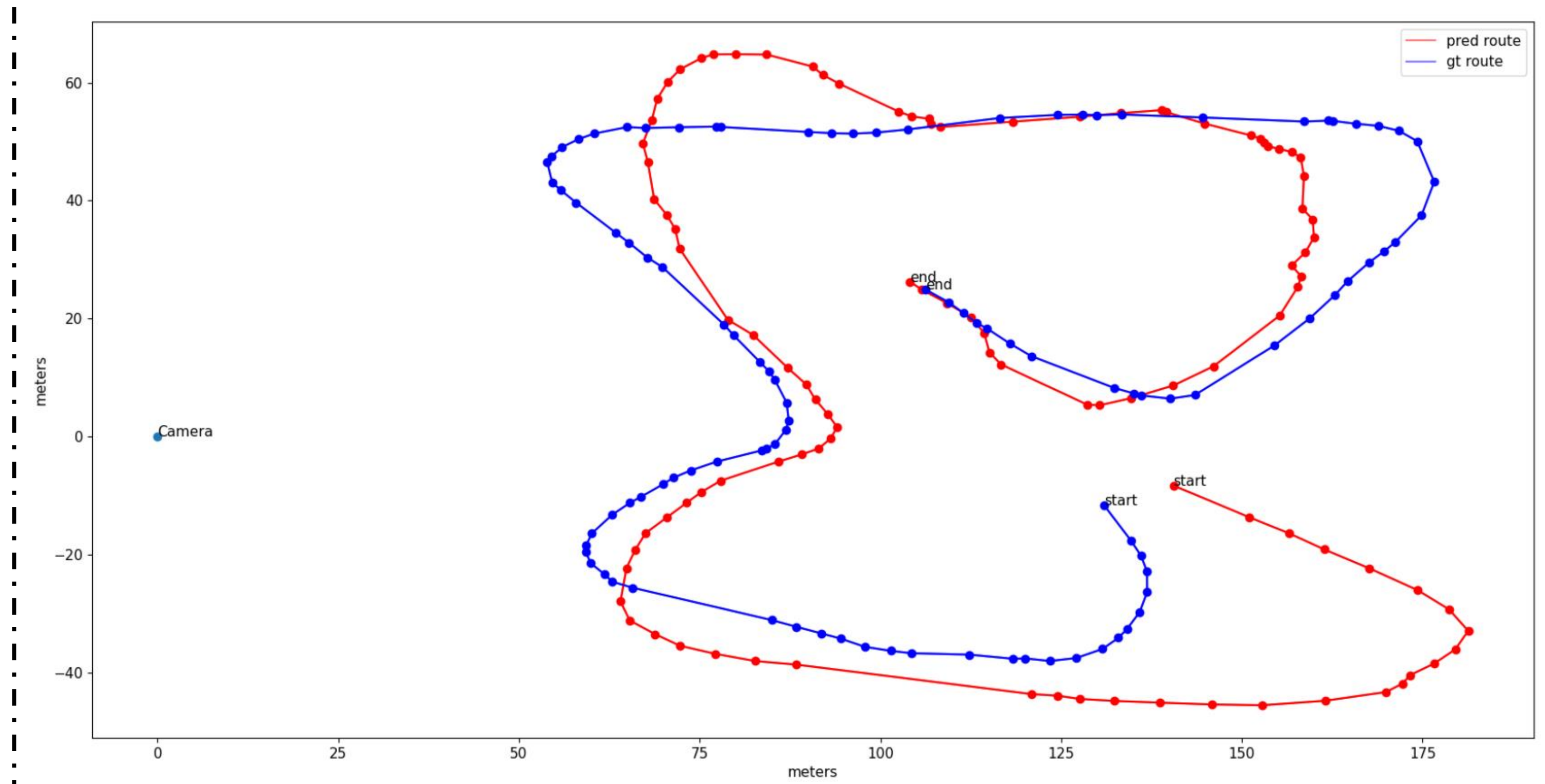

Fig. 5. Predicted boat trajectory in the world frame plotted against its ground truth with position denoted as blue dot.

GitHub JianliWei1995/AI-Track-at-Sea