Graph deep learning recognition of port ship behavior patterns from a network approach
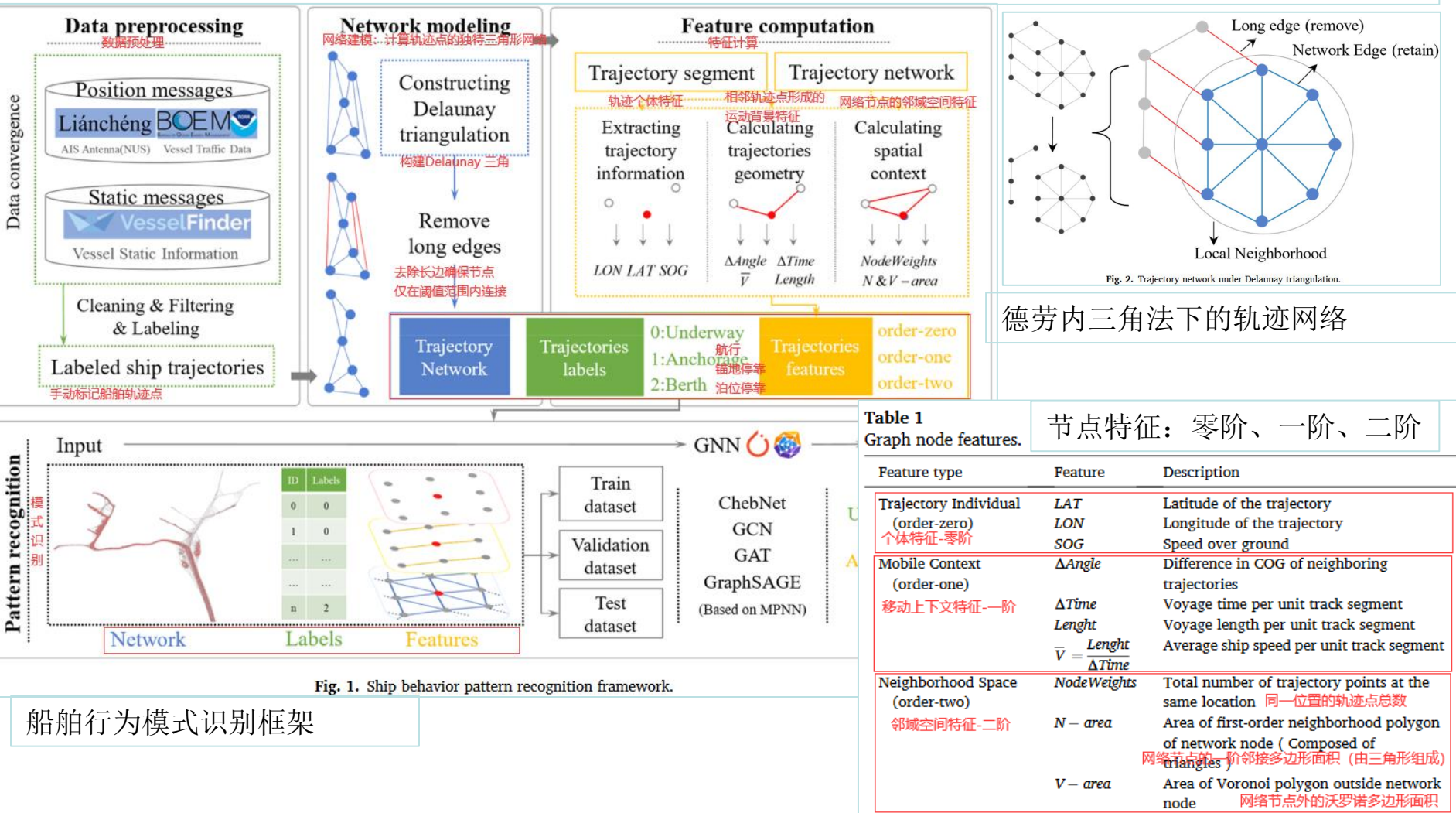基于网络方法的港口船舶行为模式的图形深度学习识别
2024Ocean Engineering 中科院2区 ，未被SCI收录
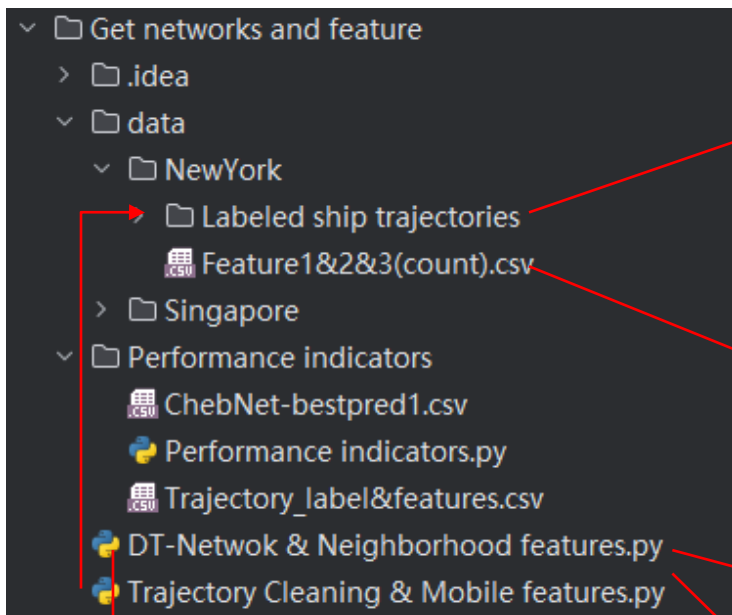Code：https://github.com/destiny1103/DT-GNN

基于消息传递范式的GNN模型，通过构建AIS轨迹网络并通过Delaunay三角剖分计算多阶节点特征，识别船舶的行为模式（航行中、锚地停靠、泊位停靠）
四个主要部分：数据预处理→网络建模→特征计算→模式识别

Data preprocessing 数据预处理

Network modeling 网络建模：计算轨迹点的独特三角形网络

Constructing Delaunay triangulation 构建Delaunay 三角

Remove long edges 去除长边确保节点 仅在阈值范围内连接

Feature computation 特征计算

Trajectory segment 轨迹个体特征

Trajectory network 相邻轨迹点形成的运动背景特征 / 网络节点的邻域空间特征

Extracting trajectory information → LON LAT SOG

Calculating trajectories geometry → $\Delta Angle$ $\overline{V}$ $\Delta Time$ $Length$

Calculating spatial context → NodeWeights $N \& V - area$

Position messages
Liánchéng BOEM
AIS Antenna(NUS)   Vessel Traffic Data

Static messages
VesselFinder
Vessel Static Information

Data convergence

Cleaning & Filtering & Labeling

Labeled ship trajectories 手动标记船舶轨迹点

Trajectory Network
Trajectories labels
0:Underway 航行
1:Anchorage 锚地停靠
2:Berth 泊位停靠
Trajectories features
order-zero
order-one
order-two

Fig. 2. Trajectory network under Delaunay triangulation.
Long edge (remove)
Network Edge (retain)
Local Neighborhood
德劳内三角法下的轨迹网络

Pattern recognition 模式识别

Input

ID	Labels
0	0
1	0
...	...
...	...
n	2

Network   Labels   Features

Train dataset
Validation dataset
Test dataset

GNN

ChebNet
GCN
GAT
GraphSAGE
(Based on MPNN)

Fig. 1. Ship behavior pattern recognition framework.
船舶行为模式识别框架

节点特征：零阶、一阶、二阶

Table 1
Graph node features.

Feature type	Feature	Description
Trajectory Individual (order-zero) 个体特征-零阶	LAT	Latitude of the trajectory
	LON	Longitude of the trajectory
	SOG	Speed over ground
Mobile Context (order-one) 移动上下文特征--阶	$\Delta Angle$	Difference in COG of neighboring trajectories
	$\Delta Time$	Voyage time per unit track segment
	$Lenght$	Voyage length per unit track segment
	$\overline{V} = \frac{Lenght}{\Delta Time}$	Average ship speed per unit track segment
Neighborhood Space (order-two) 邻域空间特征-二阶	NodeWeights	Total number of trajectory points at the same location 同一位置的轨迹点总数
	$N - area$	Area of first-order neighborhood polygon of network node (Composed of triangles) 网络节点的一阶邻接多边形面积（由三角形组成）
	$V - area$	Area of Voronoi polygon outside network node 网络节点外的沃罗诺多边形面积

Get networks and feature
- .idea
- data
  - NewYork
    - Labeled ship trajectories
    - Feature1&2&3(count).csv
  - Singapore
- Performance indicators
  - ChebNet-bestpred1.csv
  - Performance indicators.py
  - Trajectory_label&features.csv
- DT-Netwok & Neighborhood features.py
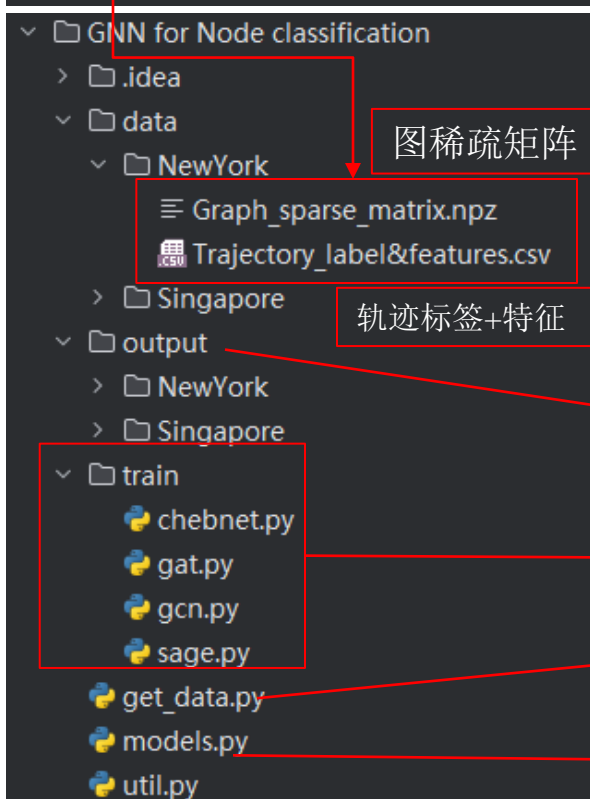- Trajectory Cleaning & Mobile features.py

209087000.csv（以MMSI为名的csv）
MMSI,BasedDateTime,LAT,LON,SOG,COG,Heading,VesselName,IMO,CallSign,VesselType,Status,Length,Width,Draft,Cargo,Transceive

MMSI,BasedDateTime,LAT,LON,SOG,COG,Heading,VesselName,IMO,CallSign,VesselType,Status,Length,Width,Draft,Cargo,Transceive,Berth,Anchorag,Moving,length_last,length_next,length,angle_Heading,angle_COG,angle_COG_abs,time_difference,velocity,acceleration,count

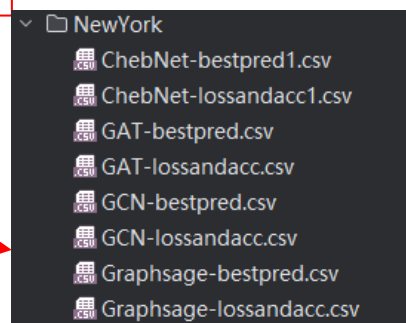计算邻域空间特征（N-area、V-area）、用于模型训练的图稀疏矩阵文件

基于已标记的船舶数据过滤出符合规则的国际段，并计算个体特征、移动上下文特征、邻域空间特征中的节点特征权重。

GNN for Node classification
- .idea
- data
  - NewYork
    - Graph_sparse_matrix.npz ← 图稀疏矩阵
    - Trajectory_label&features.csv ← 轨迹标签+特征
  - Singapore
- output
  - NewYork
  - Singapore
- train
  - chebnet.py
  - gat.py
  - gcn.py
  - sage.py
- get_data.py
- models.py
- util.py

NewYork (output)
- ChebNet-bestpred1.csv
- ChebNet-lossandacc1.csv
- GAT-bestpred.csv
- GAT-lossandacc.csv
- GCN-bestpred.csv
- GCN-lossandacc.csv
- Graphsage-bestpred.csv
- Graphsage-lossandacc.csv

添加数据，完成每个GNN模型的训练，并返回测试集上的精度、训练时间、验证集上的损失和测试集上的结果。

加载轨迹和特征数据，处理

构建GNN模型：Chebnet、GCN、GAT、GraphSAGE