A Framework for Discovering Maritime Traffic Conflict from AIS Network

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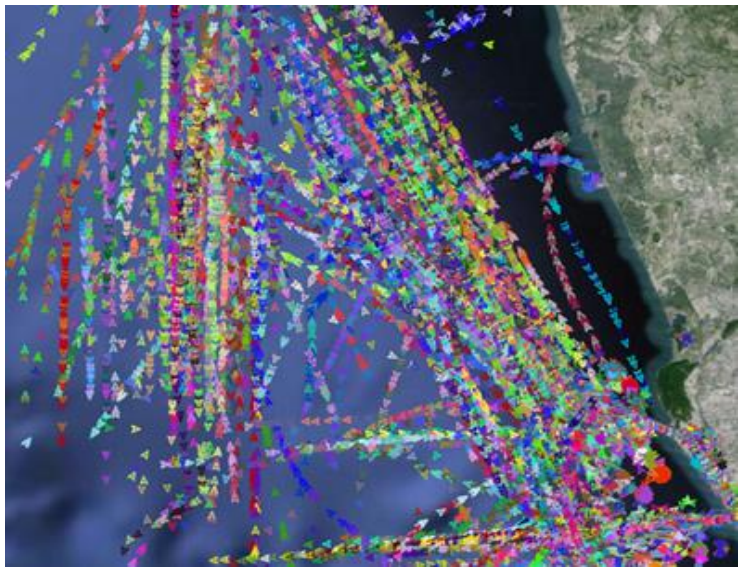
Outline

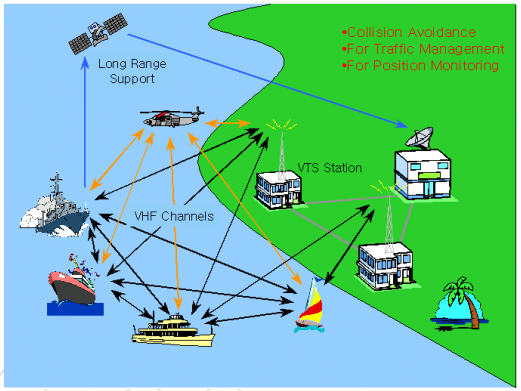
- Introduction
- Framework
- Experiments
- Conclusion
- Q & A



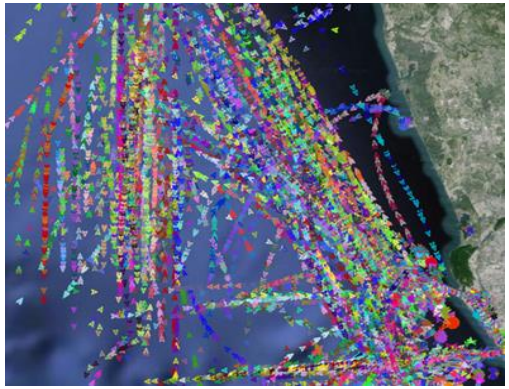
Introduction

Maritime Traffic Data: Trajectory data collect from AIS Network

- AIS Trajectory Data
  - A rich trajectory data collected from ships' movement by Automatic Identification System (AIS)
- Mining maritime traffic knowledge hidden in AIS trajectories



AIS System
(http://www.digitalmarine.kr/info/ais.html)



AIS trajectory data

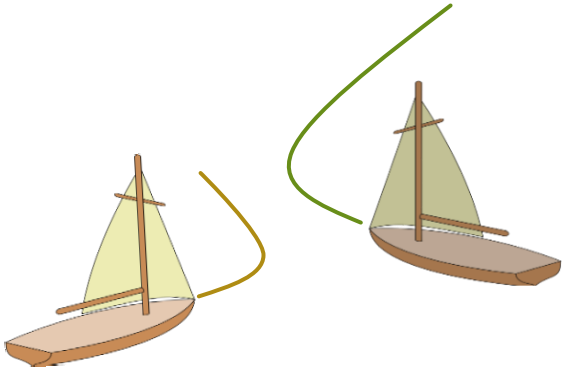
Introduction
Maritime Traffic Near-Collision Detection

- Traffic accident: Few samples, high randomness
- Near-collision: cause accident, more data
- Traffic Conflict: Near collision

Introduction

Discovery maritime traffic conflict from AIS network

- Applications:
  - conflict behavior analysis
  - conflict early detection for maritime management
  - collision avoidance

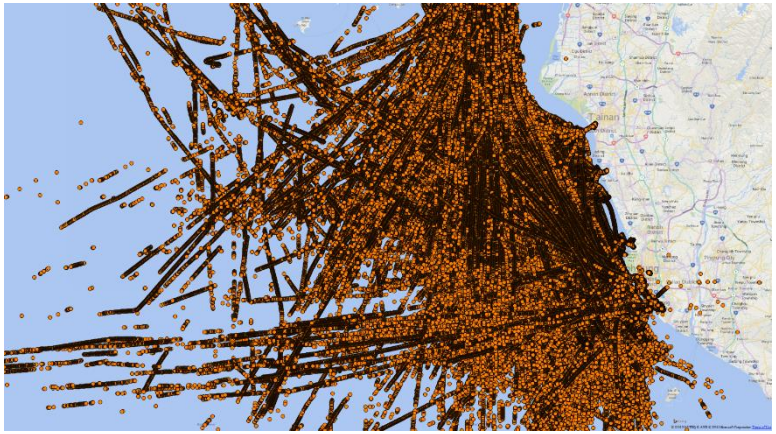


Introduction

More challenges in AIS conflict detection

- The vehicles' movements are constrained by road network
- The ships could move free in the maritime area
  - ✓ **More Complex to discover the trajectories with similar movement behavior**

Trajectory from road network

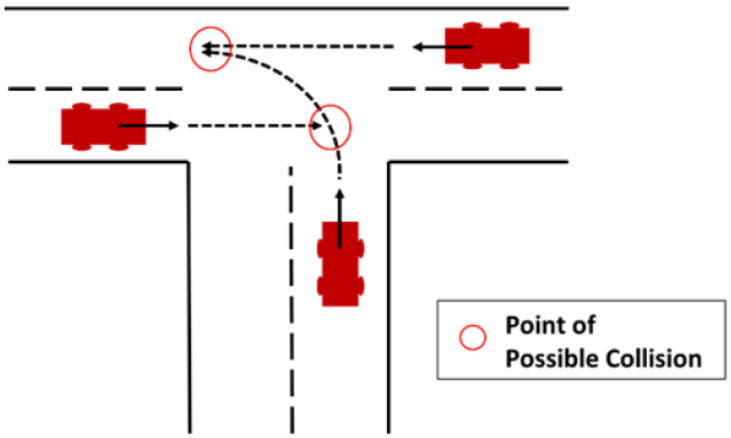


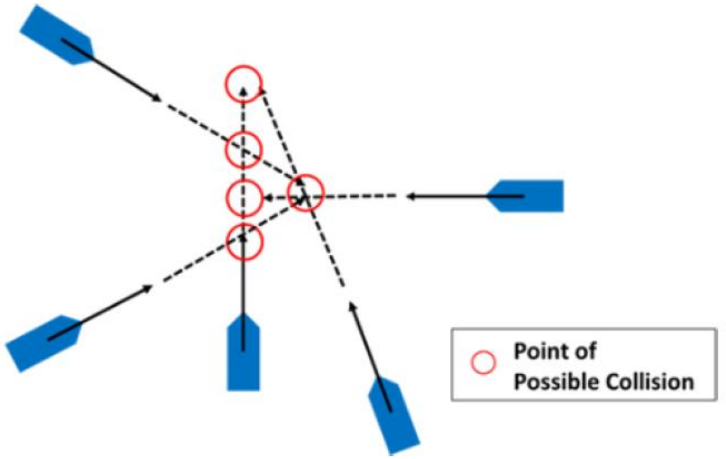
AIS Trajectory in maritime

Introduction

More challenges in AIS conflict detection

- In road networks,possible collision points are in the intersection
- But in maritime traffic, there are no such intersection and collision may happen in every place.
- Further more, collision in maritime may not only involve two ships,but more ships can get hurt in one accident.





Introduction
Existing approaches for detecting conflict

- Road network
  - K. El-Basyouny and T. Sayed, “Safety Performance Functions using Traffic Conflicts,” Safety Science, Vol. 51, No. 1, pp. 160-164, 2013.
  - U. Shahdah, F. Saccomanno, and B. Persaud, “Integrated Traffic Conflict Model for Estimating Crash Modification Factors,” Accident Analysis and Prevention, Vol. 71, pp. 228-235, 2014.

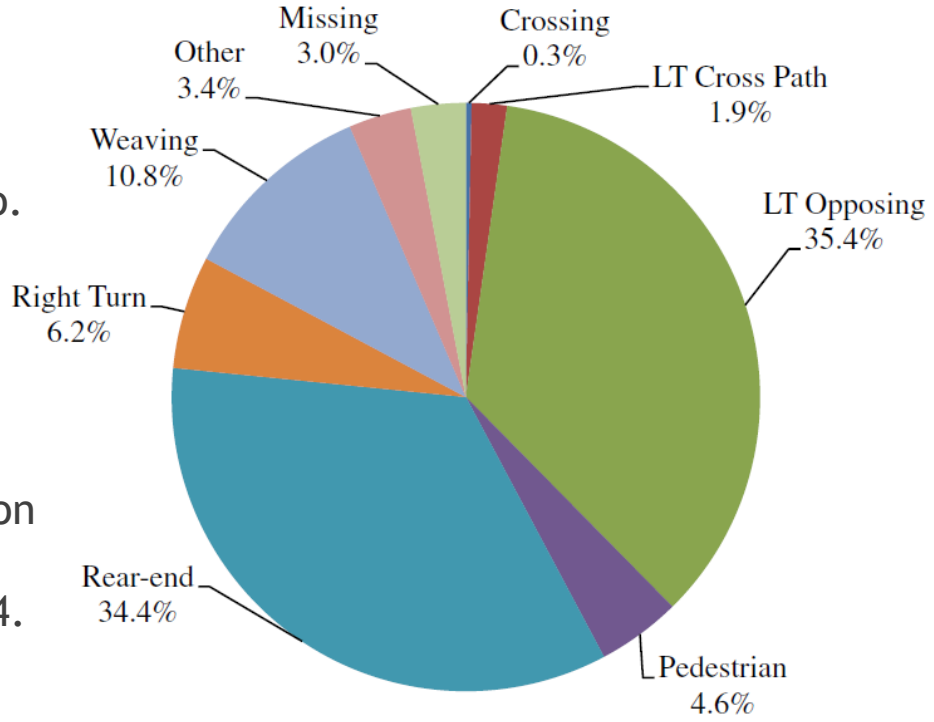
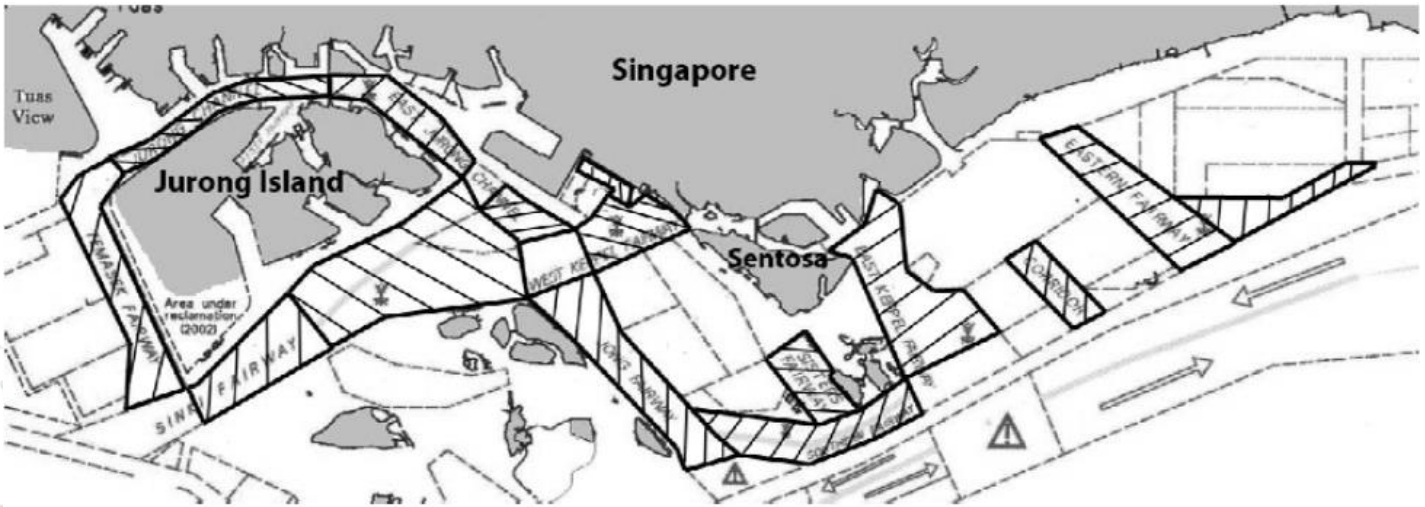


Fig. 1. Distribution of observed conflicts by type.

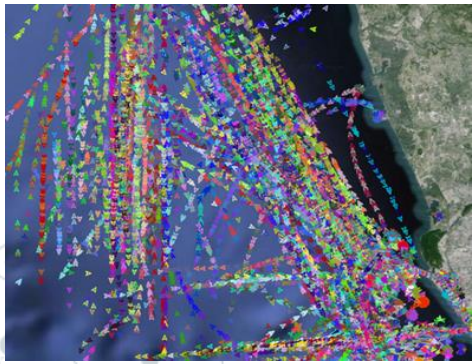
Introduction
Existing approaches for detecting conflict

- Maritime traffic
  - D. A. Kumar, H. C. Chin, and M. M. HAQUE, “Modelling Port Water Collision Risk using Traffic Conflicts, ” Journal of Navigation, Vol. 64, No. 4, pp. 645-655, 2011.
  - Q. Li, J. S. L. Lam, and H. S. L. Fan, “Multi-link-ahead Conflicts Prediction in Dynamic Seaport Environments.” Simulations, Serious Games and Their Applications, pp. 69-84, 2014.

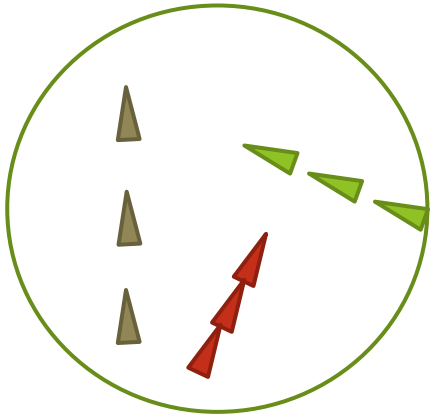


Maritime Traffic Conflict Mining

- Input : AIS trajectory dataset D_A
- Output : Clusters of conflict trajectories CCT
- Conflict Trajectories:
  - Set of ships that their distance are getting closer and closer

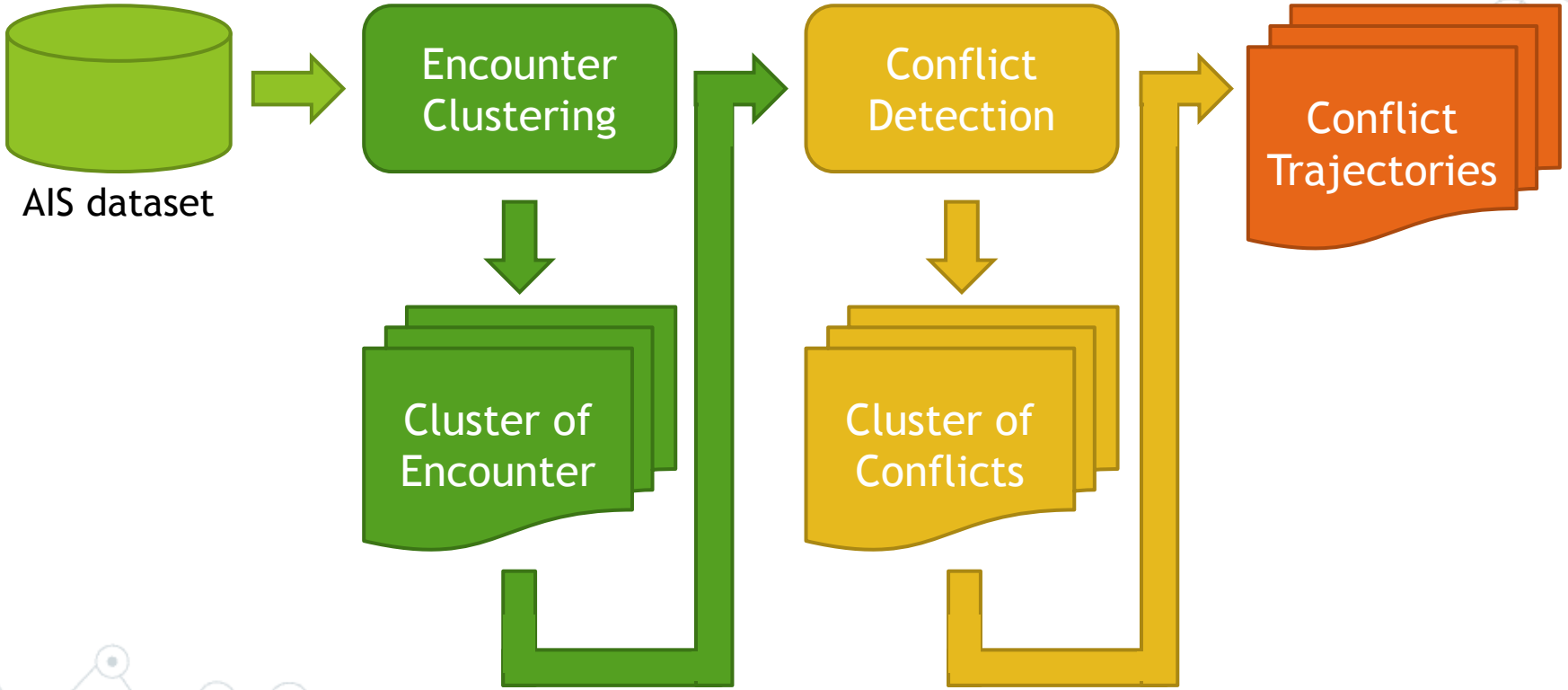


AIS dataset

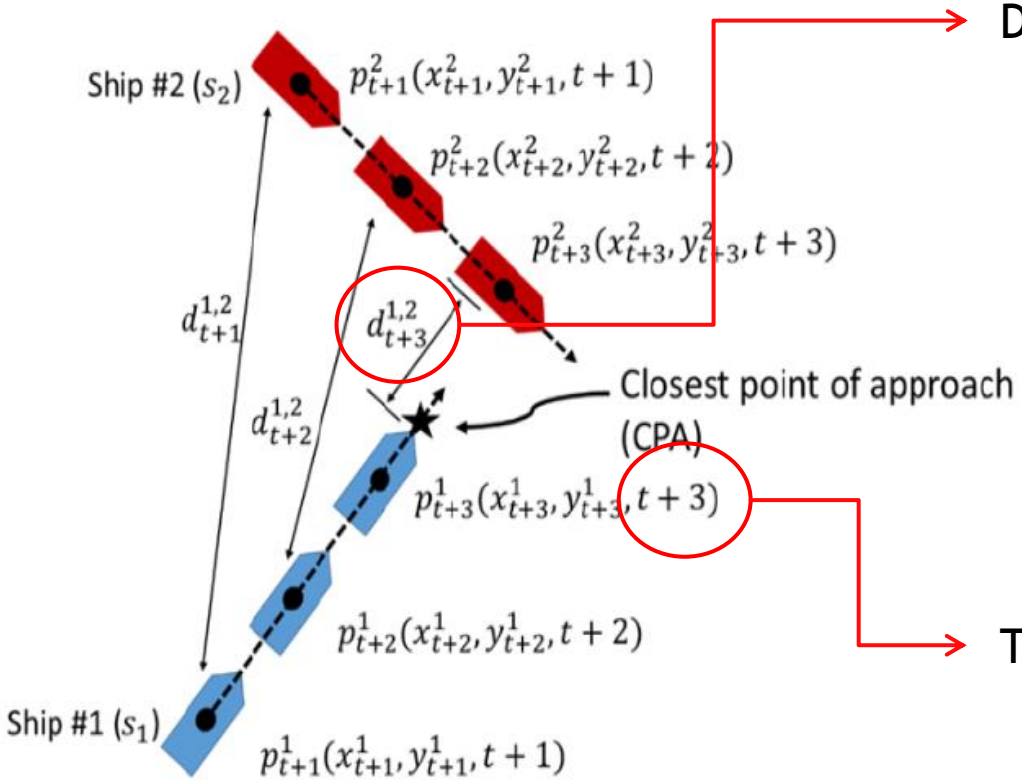


Conflict trajectory

Framework


AIS dataset
Encounter Clustering
Cluster of Encounter
Conflict Detection
Cluster of Conflicts
Conflict Trajectories

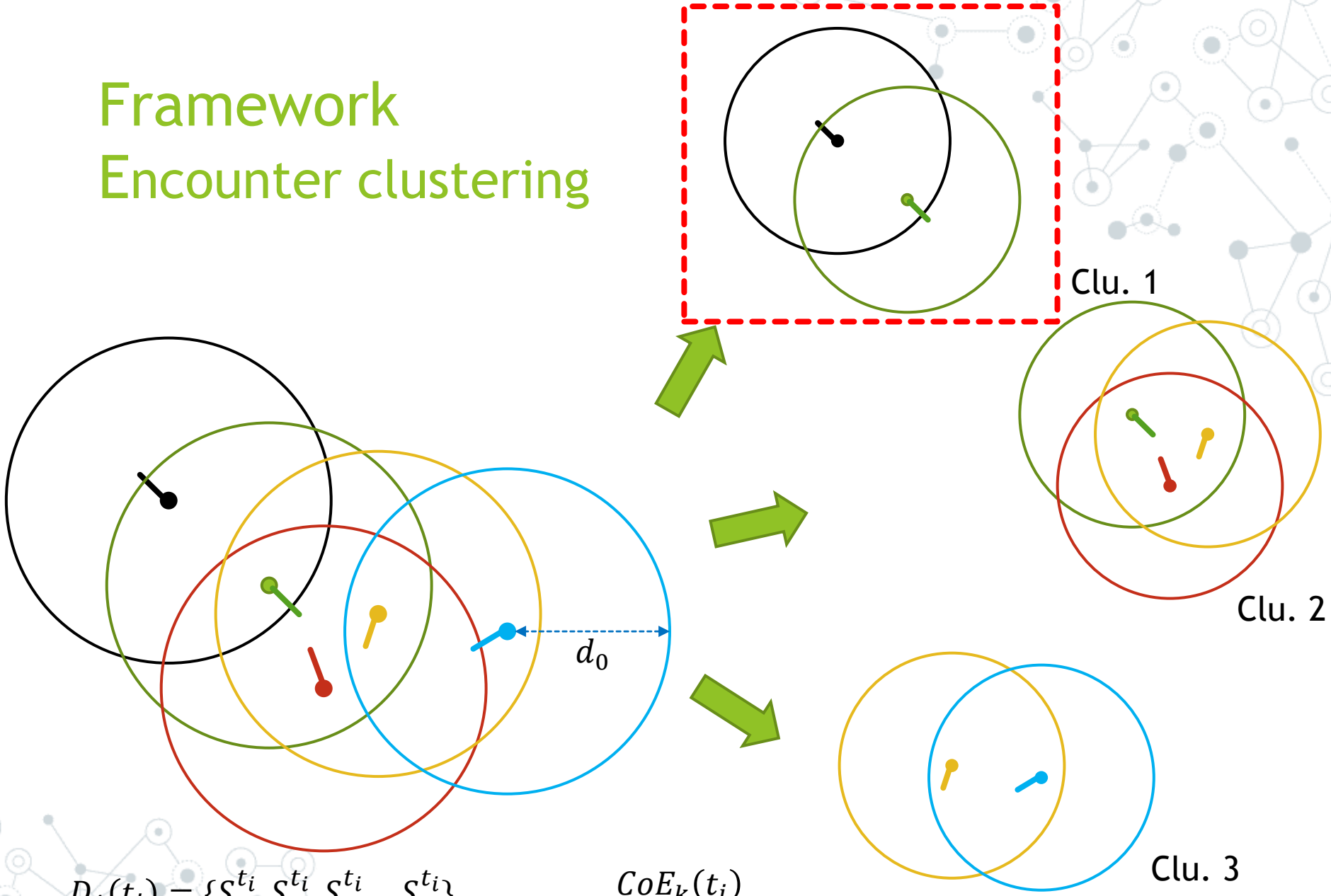
Framework
DCPA and TCA



Distance at CPA (DCPA)

Time-to-Collision Avoidance (TCA)

Framework
Encounter clustering



$$D_A(t_i) = \{S_1^{t_i}, S_2^{t_i}, S_3^{t_i} \dots S_n^{t_i}\}$$

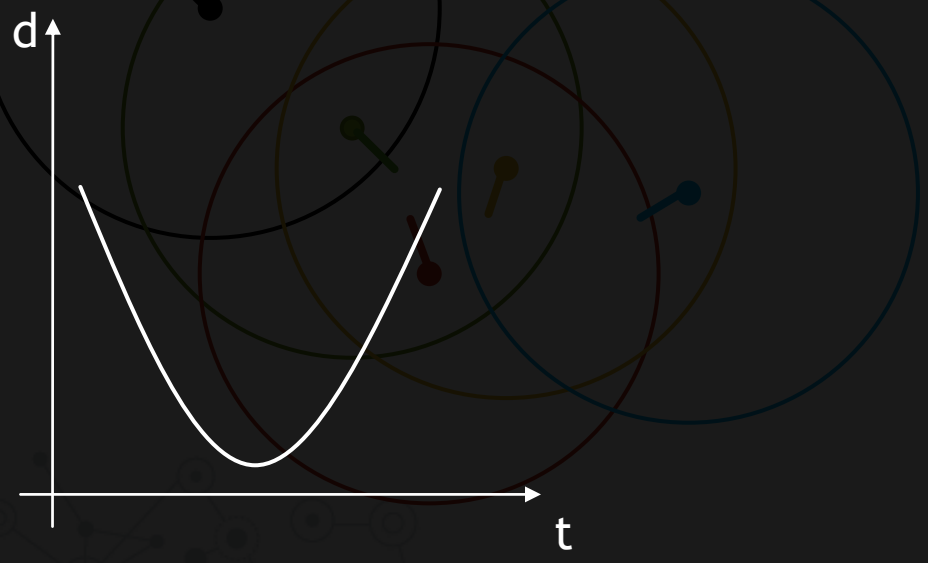
$$CoE_k(t_i) = \left\{S_{k,1}^{t_i}, S_{k,2}^{t_i}, S_{k,3}^{t_i} \dots S_{k,m}^{t_i} | dist\left(S_{k,x}^{t_i}, S_{k,y}^{t_i}\right) < d_0\right\}$$

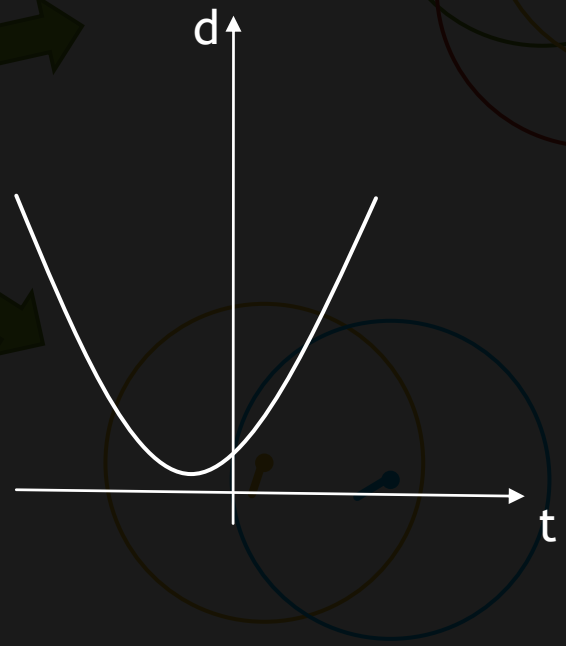
Framework

$$Dist_{i,j}(t) = \sqrt{[(x_i + v_{i.x}t) - (x_j + v_{j.x}t)]^2 + [(y_i + v_{i.y}t) - (y_j + v_{j.y}t)]^2}$$

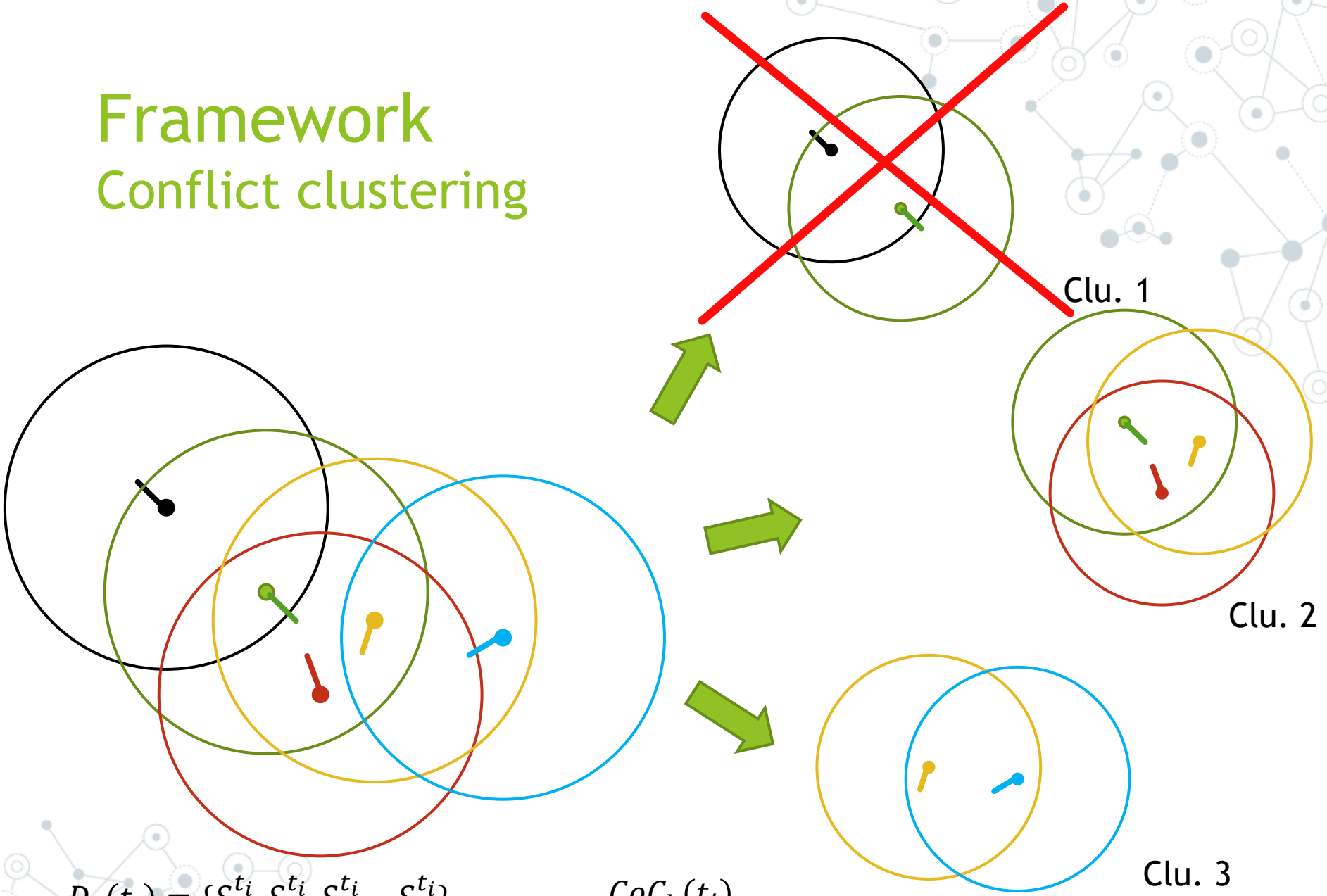
$$DCPA = min\ Dist_{i,j}(t)$$

$$TCA = argmin_t\ Dist_{i,j}(t)$$





Framework
Conflict clustering

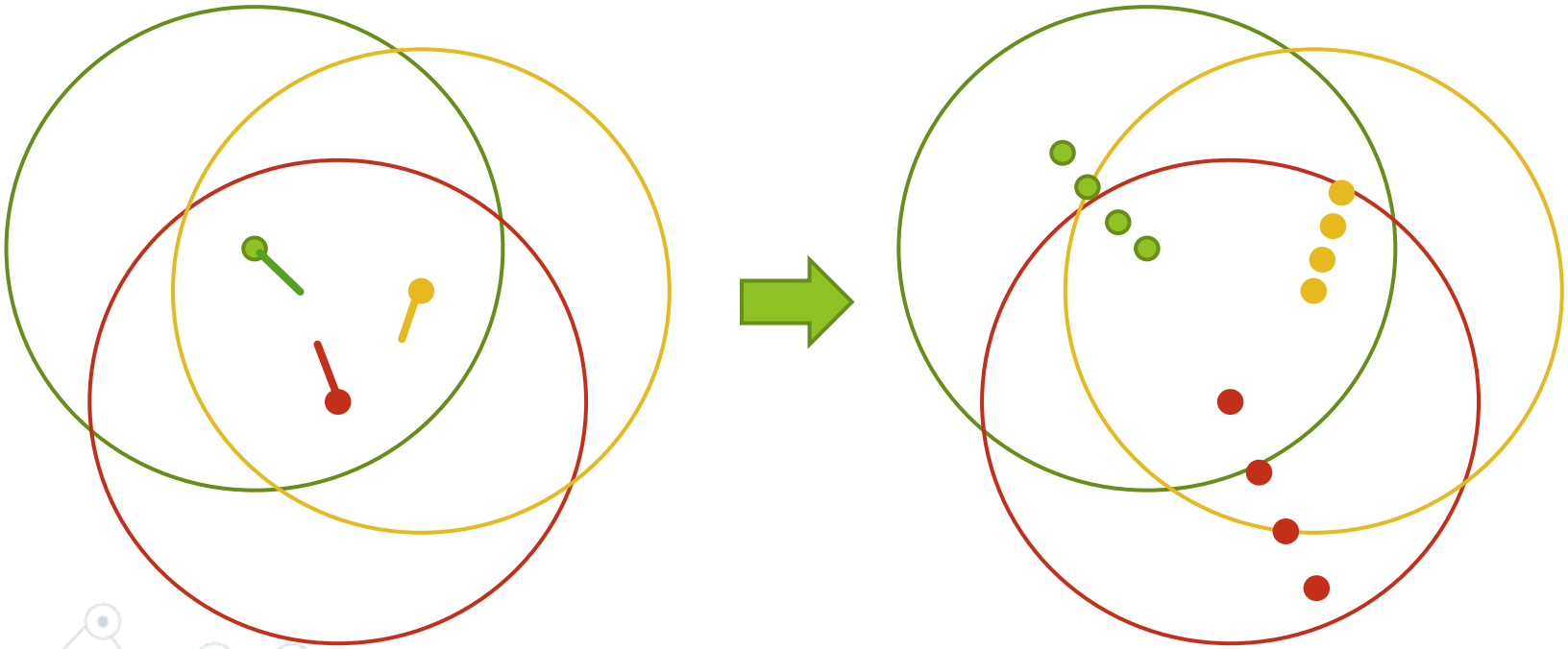


$$D_A(t_i) = \{S_1^{t_i}, S_2^{t_i}, S_3^{t_i} \dots S_n^{t_i}\}$$

$$CoC_k(t_i) = \left\{S_{k,1}^{t_i}, S_{k,2}^{t_i}, S_{k,3}^{t_i} \dots S_{k,m}^{t_i} | TCA\left(S_{k,x}^{t_i}, S_{k,y}^{t_i}\right) > 0\right\}$$

Framework

Cluster of conflict trajectories

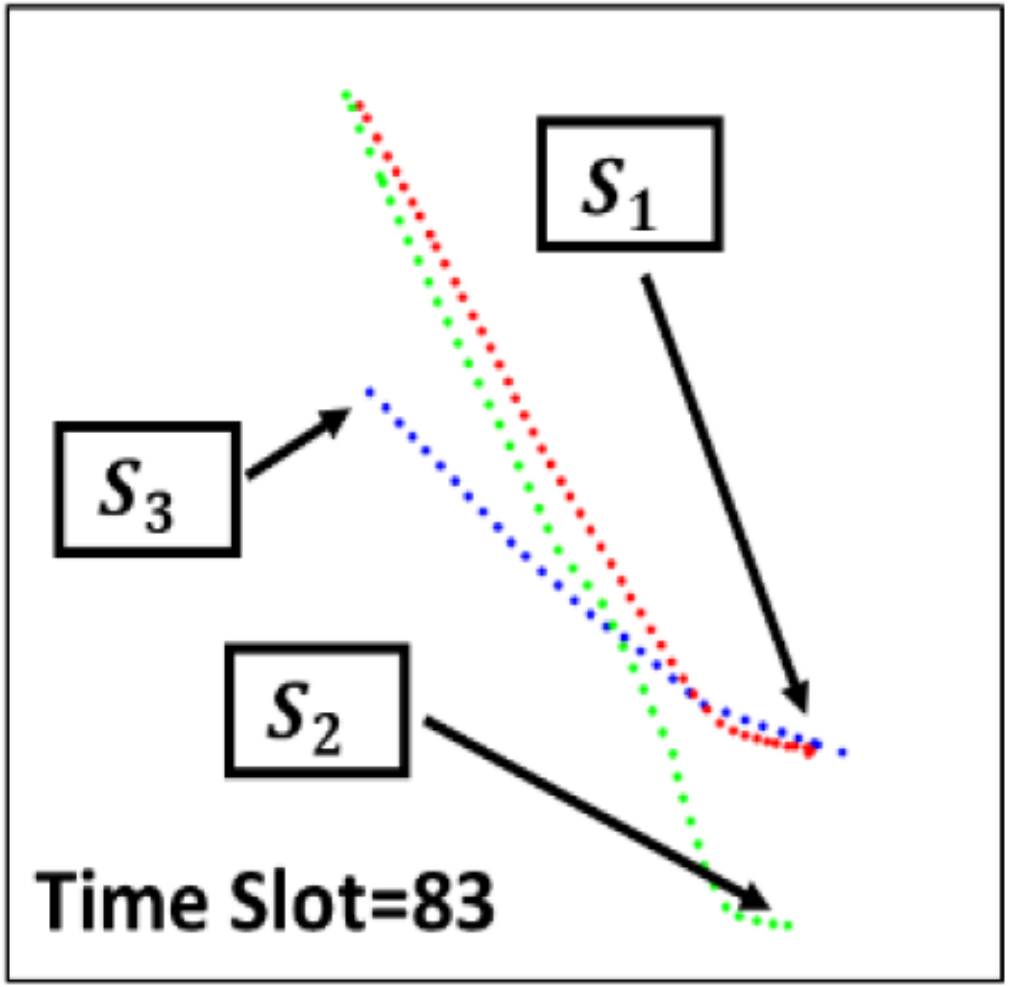


Experiments

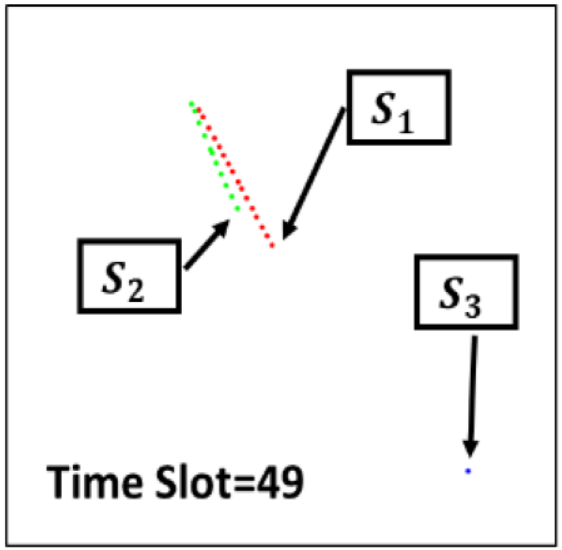
- AIS trajectory dataset: a nine-month dataset of 20639 trajectories (21202212 points)
- Maritime area: $100\ \mathrm{km} \times 100\ \mathrm{km}$.
- $D_0 = 2km$
- Result:
  - 452303 CoE
  - 236859 CoC
  - 185050 CCT(Cluster of Conflict Trajectories)

Experiments

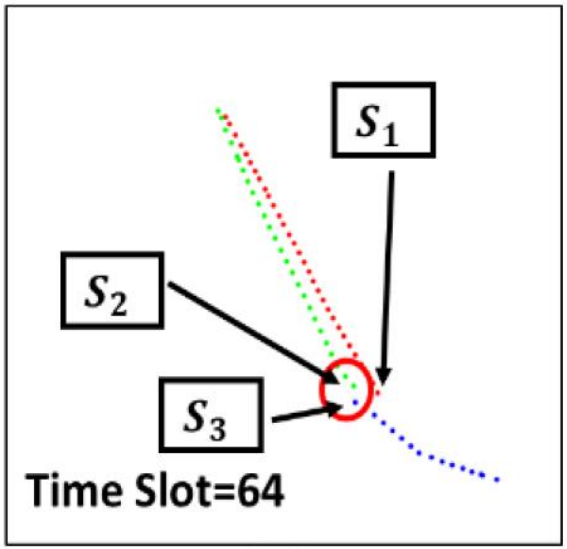
Case visualization



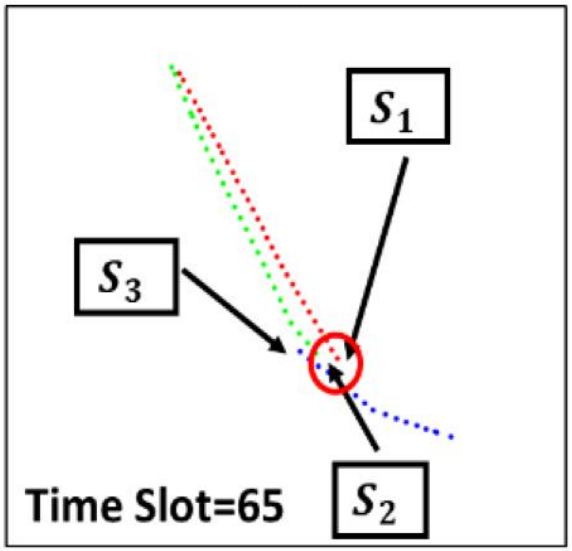
Experiments
Case visualization



(a)

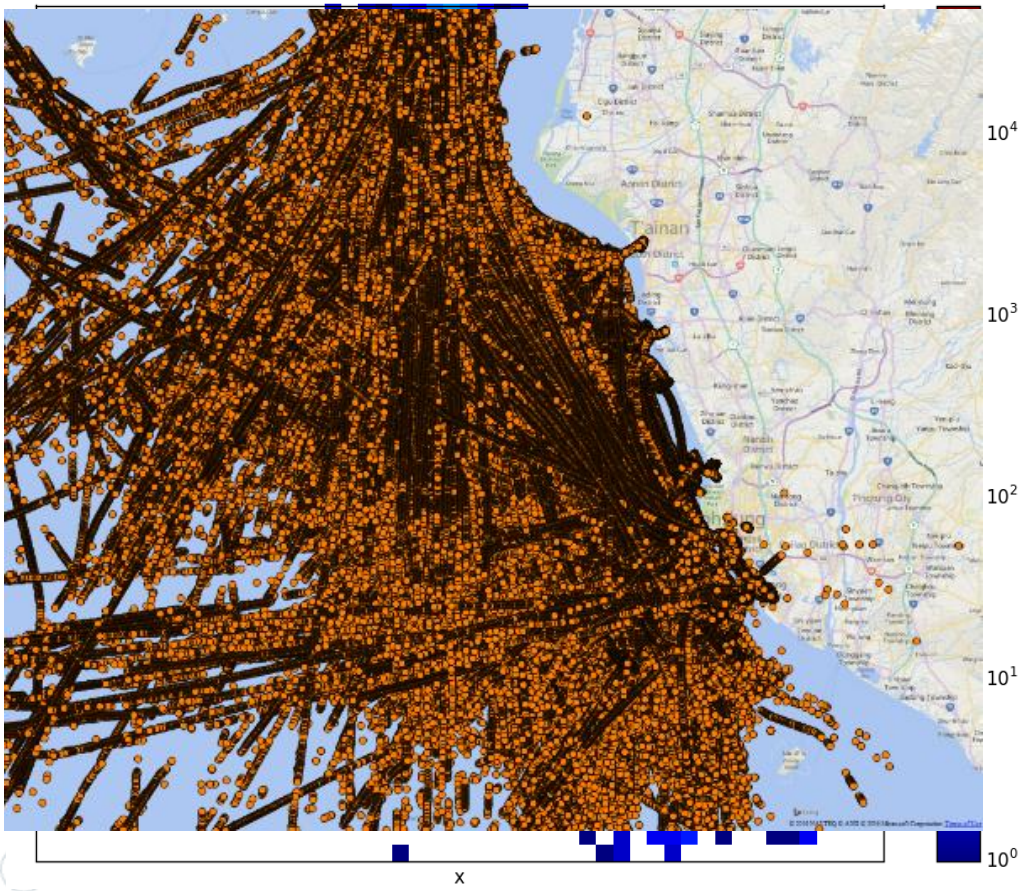


(b)

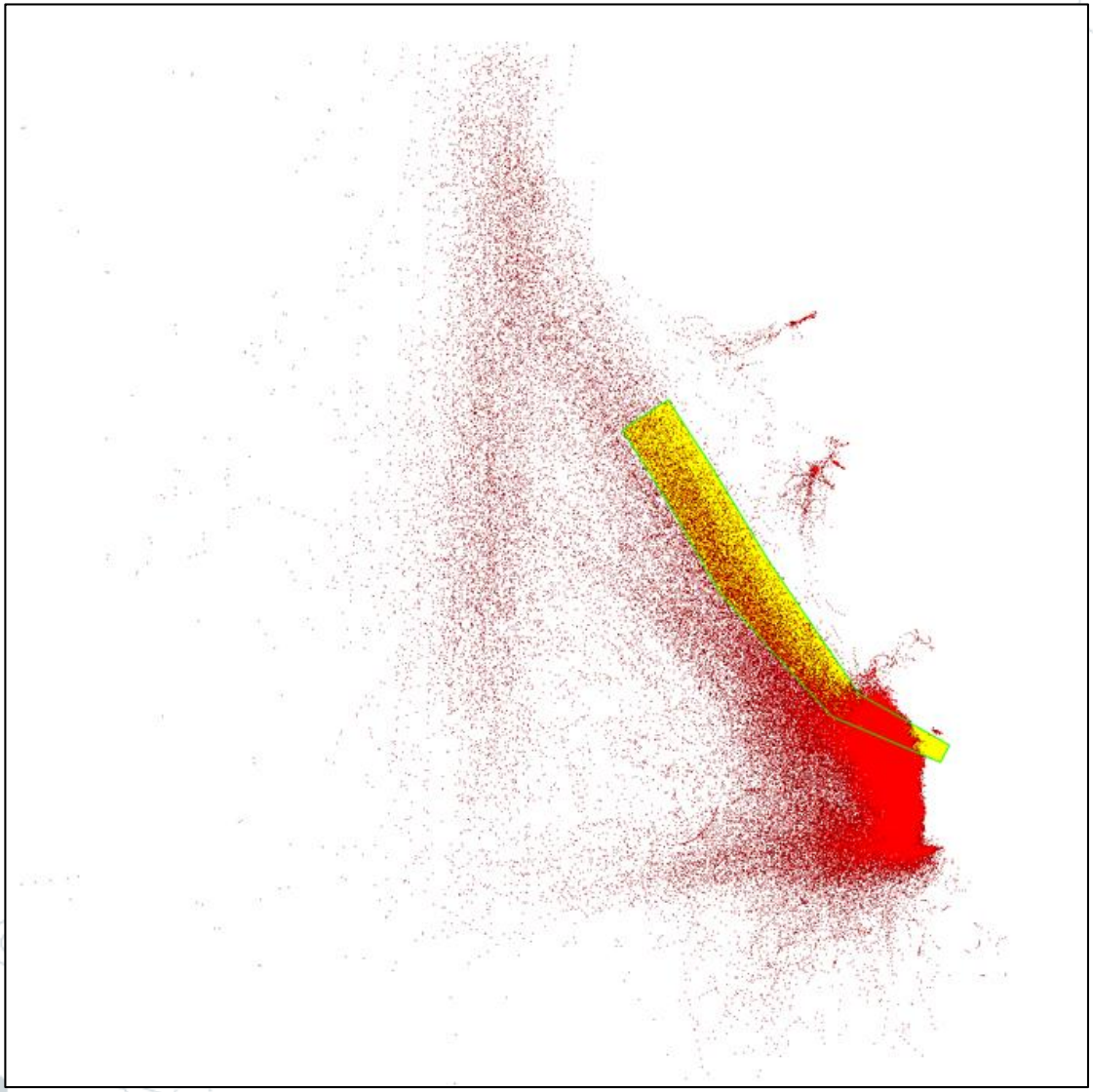


(c)

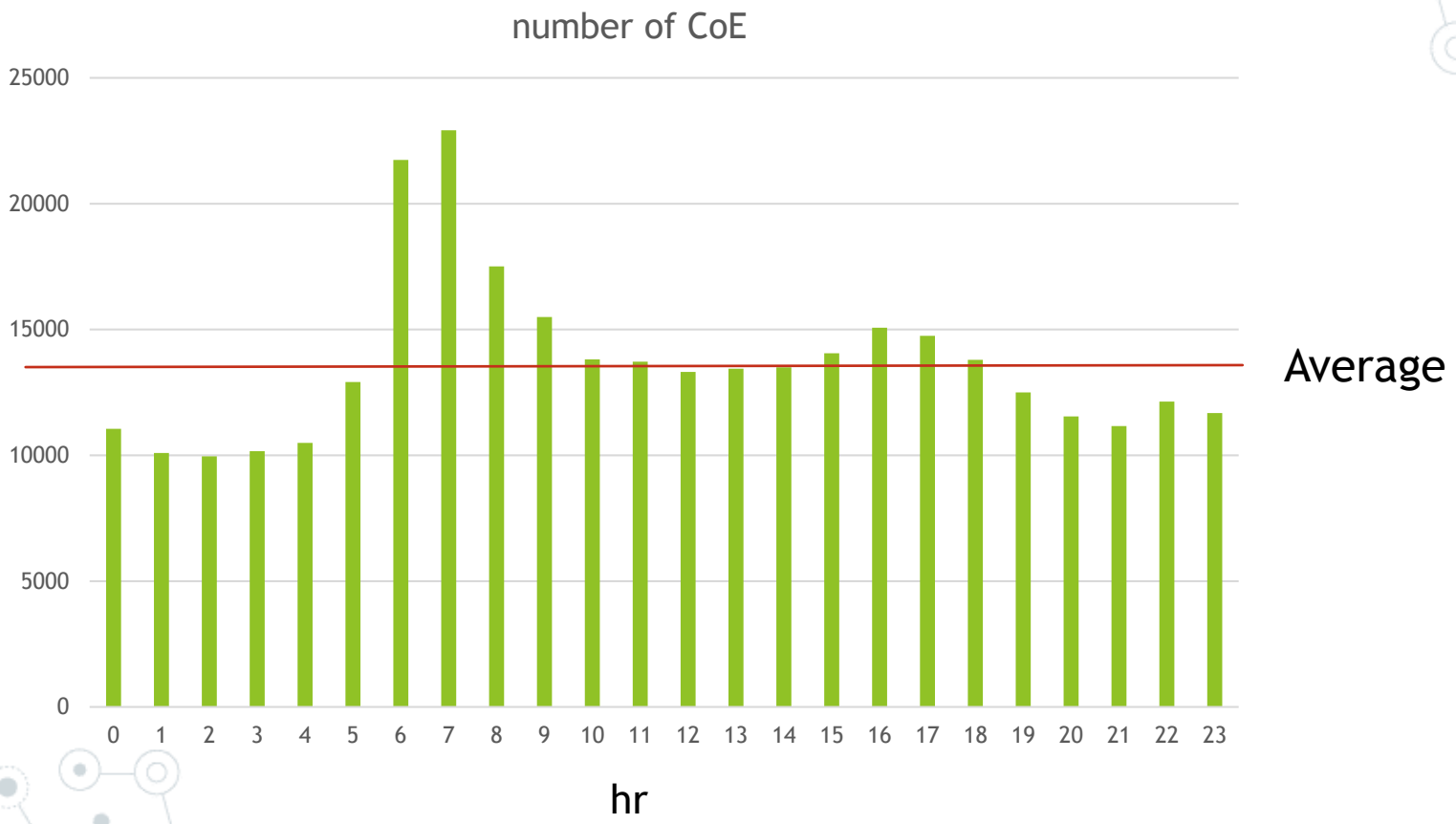
Experiments
Spatial distribution



Experiments
Cases for Effectiveness

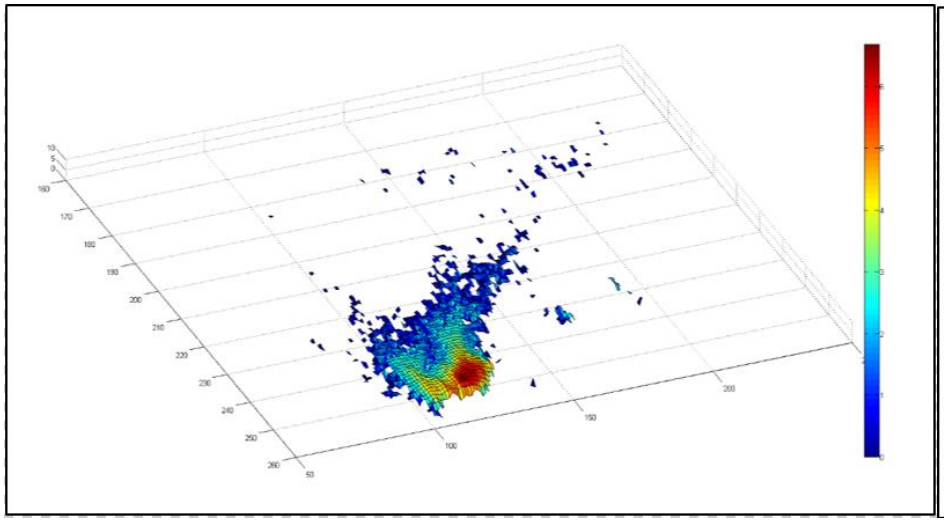


Experiments
Temporal distribution

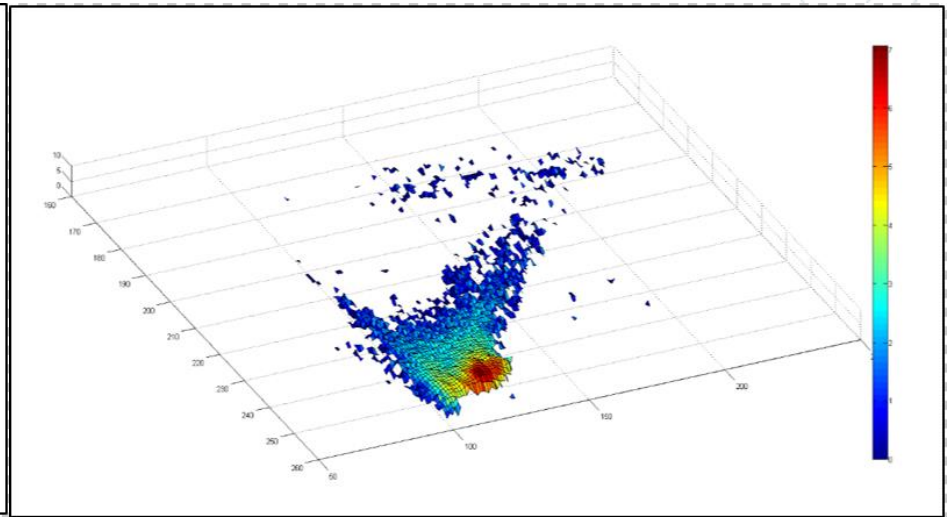


Experiments

Spatial-Temporal distribution



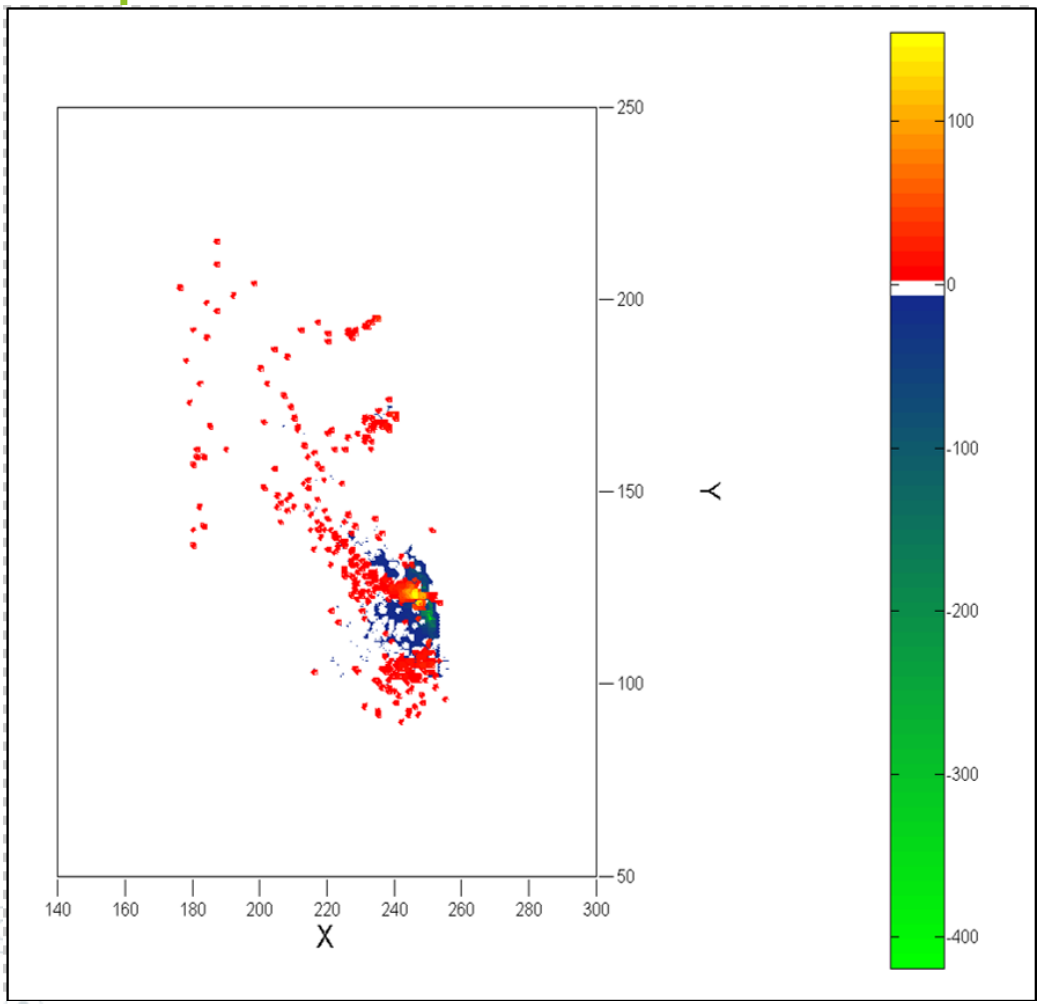
a.0600~1159



b.1500~1859

Experiments

Spatial-Temporal distribution



b-a

Conclusion

- We proposed a framework of maritime traffic conflict mining
  - Encounter Clustering
  - Conflict detection
  - Merge to conflict trajectories
- Future work:
  - conflict early detection
  - conflict behavior analysis
  - collision avoidance analysis

Q & A

Definition

- $D_A(t_i) = \{S_1^{t_i}, S_2^{t_i}, S_3^{t_i} \dots S_n^{t_i}\}$
  - Dataset in timeslot t_i
- $S_n^{t_i} = \left(x_n^{t_i}, y_n^{t_i}, v_n^{t_i}, c_n^{t_i}\right)$
  - Each raw data point include its position,speed and course
- $CoE_k(t_i) = \left\{S_{k,1}^{t_i}, S_{k,2}^{t_i}, S_{k,3}^{t_i} \dots S_{k,m}^{t_i} | dist\left(S_{k,x}^{t_i}, S_{k,y}^{t_i}\right) < d_0\right\}$
  - Cluster of encounter
- $CoC_k(t_i) = \left\{S_{k,1}^{t_i}, S_{k,2}^{t_i}, S_{k,3}^{t_i} \dots S_{k,m}^{t_i} | TCA\left(S_{k,x}^{t_i}, S_{k,y}^{t_i}\right) > 0\right\}$
  - Cluster of conflicts