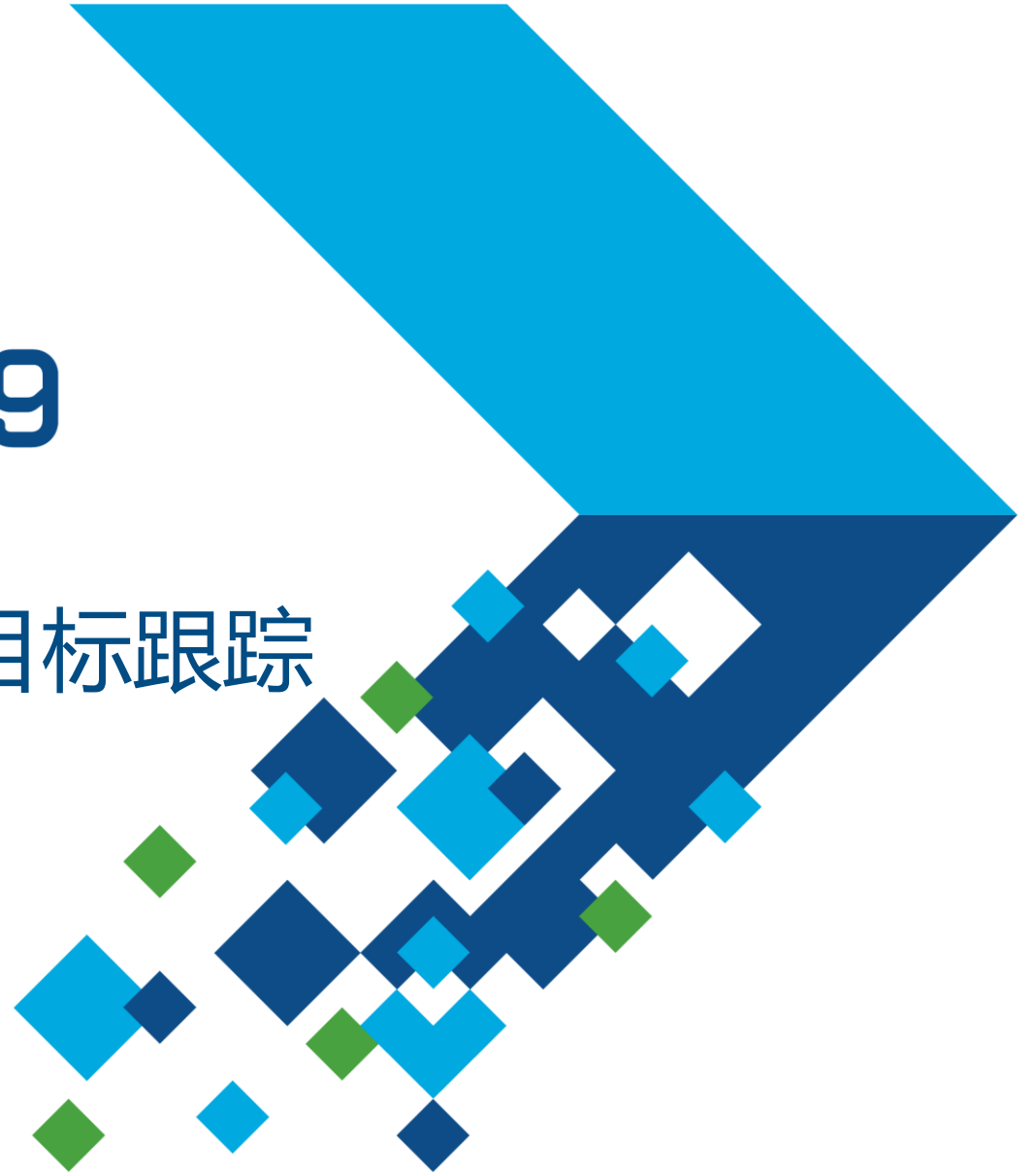


MATLAB EXPO 2019

智能无人系统的传感器融合与目标跟踪



提纲

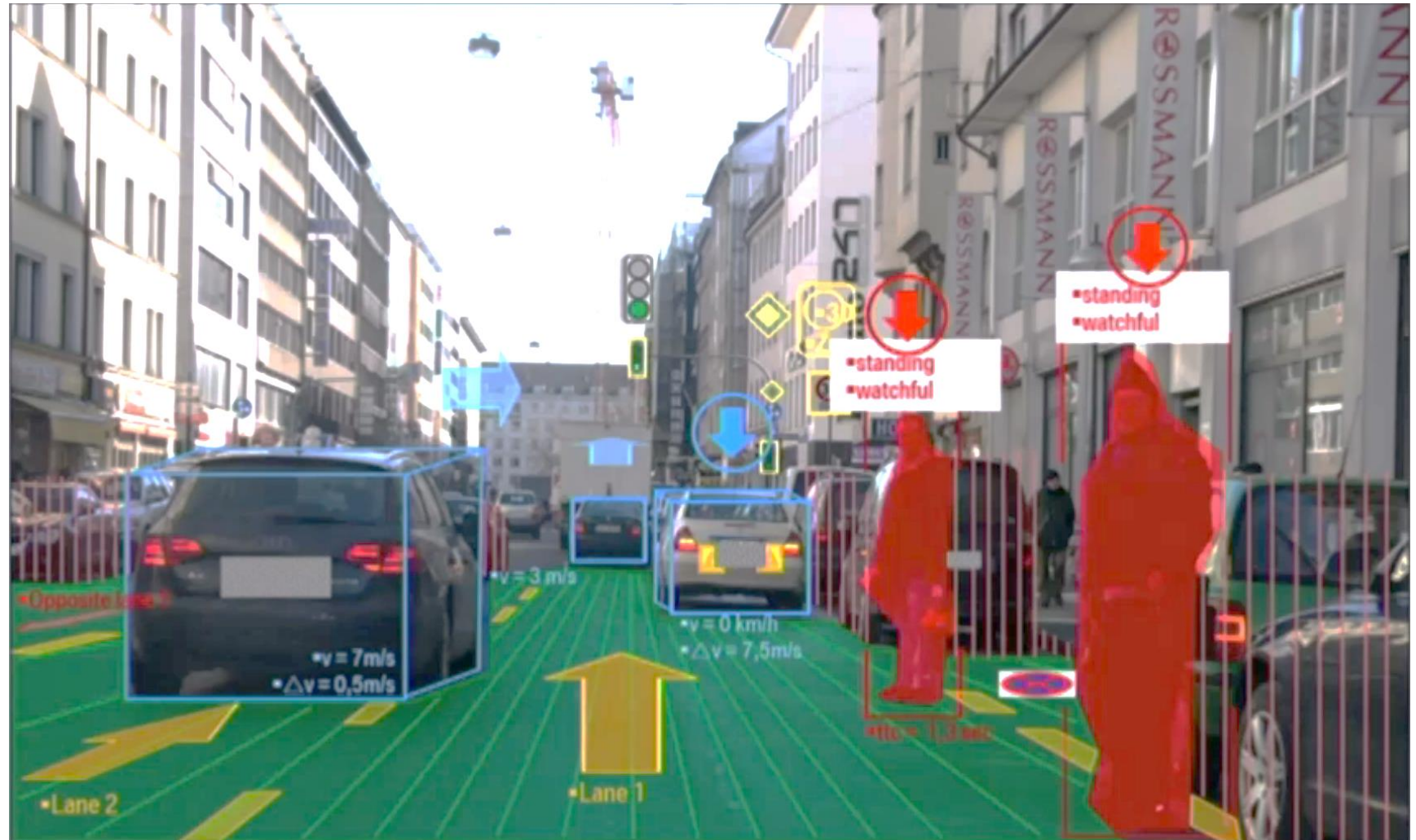
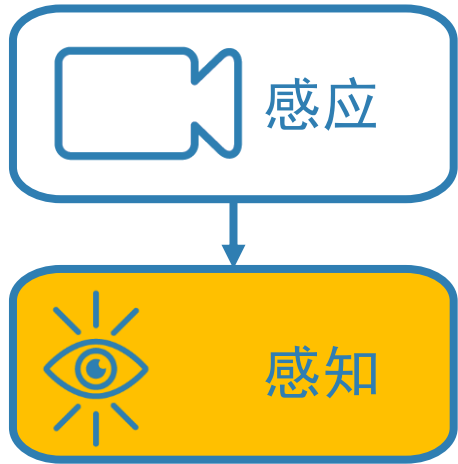


- 简介
- 感知技术总览
- 传感器融合与目标跟踪算法开发
- Q&A
- 进一步探索所需资源

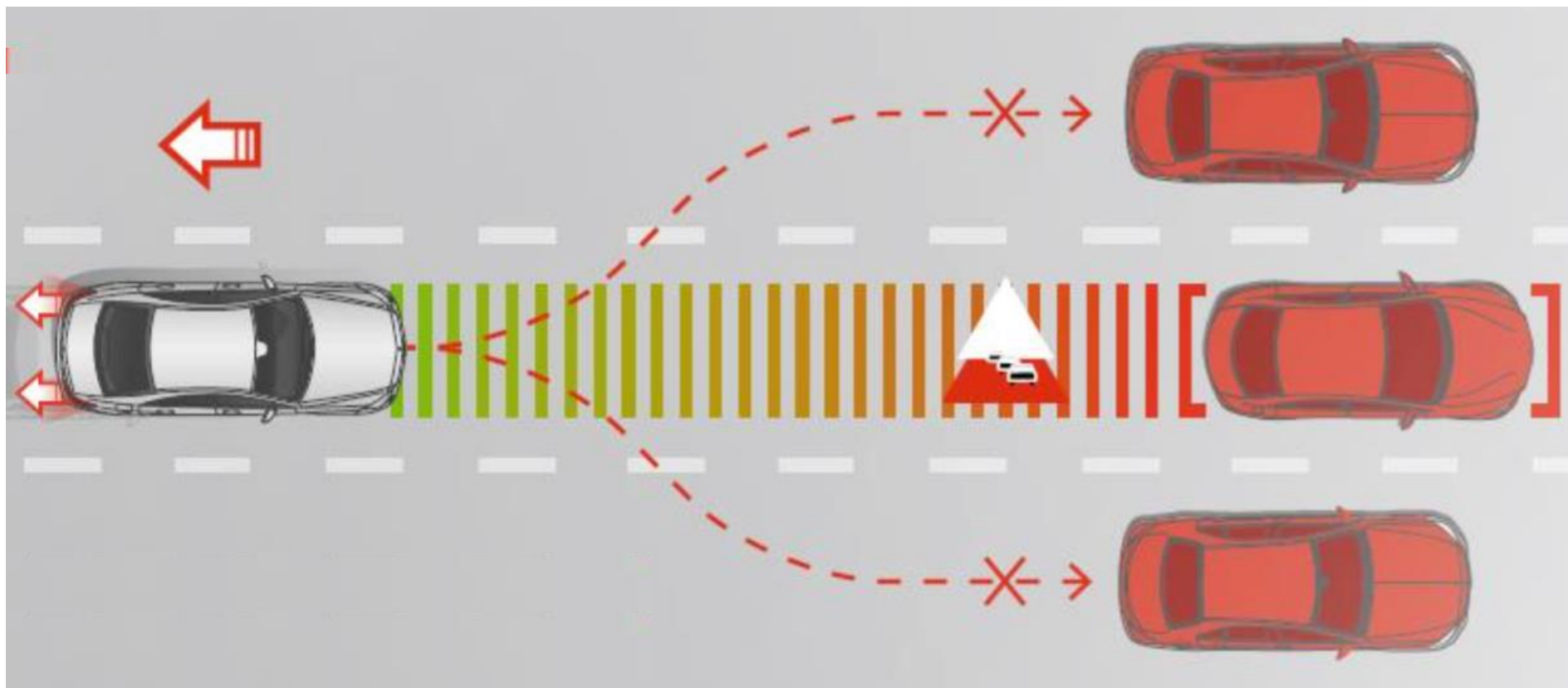
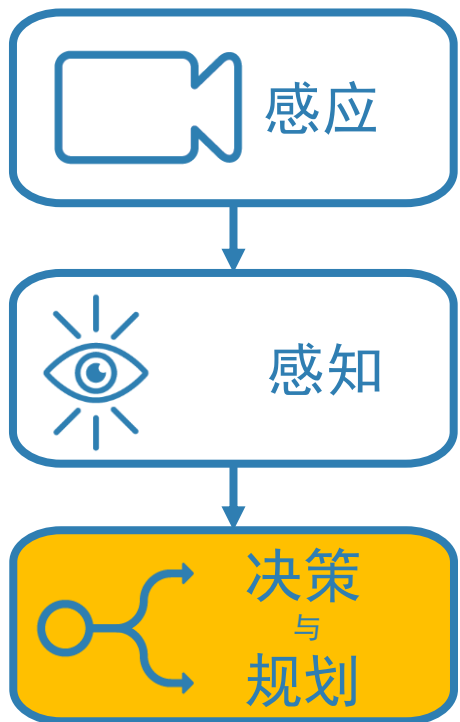
智能无人平台所具备的能力



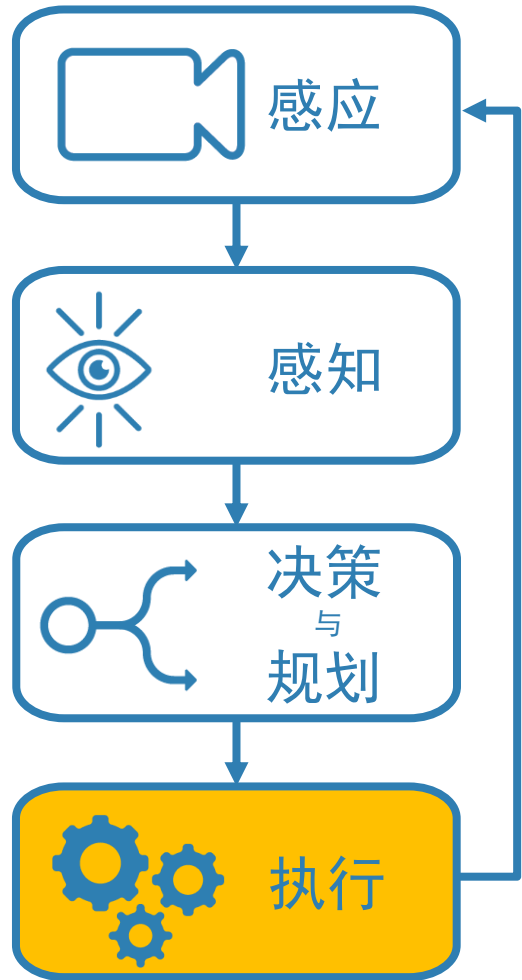
智能无人平台所具备的能力




智能无人平台所具备的能力



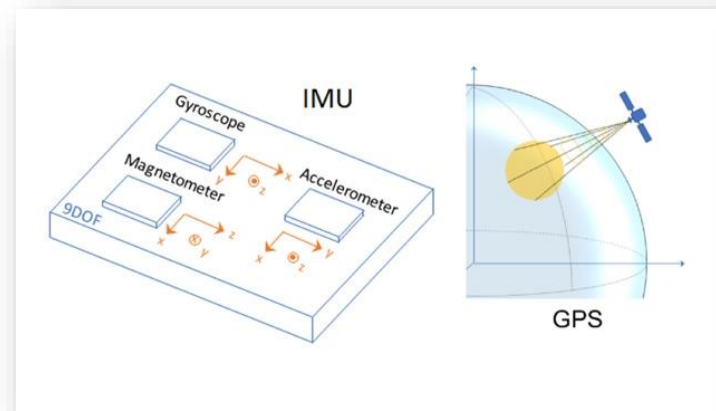
智能无人平台所具备的能力



提纲

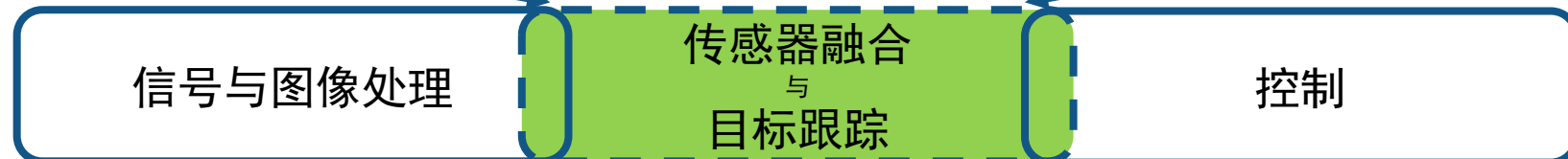
- 简介
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- 传感器融合与目标跟踪算法开发
- Q&A
- 进一步探索所需资源

传感器融合与目标跟踪是...



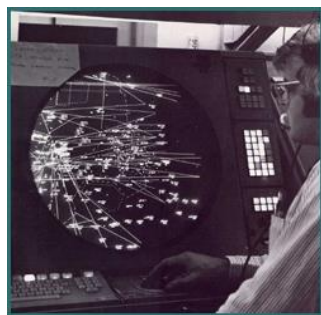
加速剂, 磁力计, 陀螺仪, GPS...

雷达, 摄像头, 红外摄像头, 声呐, 激光雷达, ...

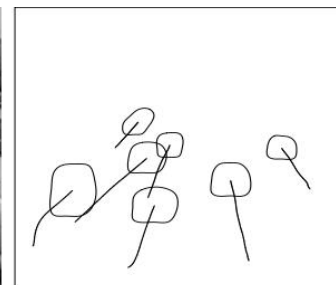
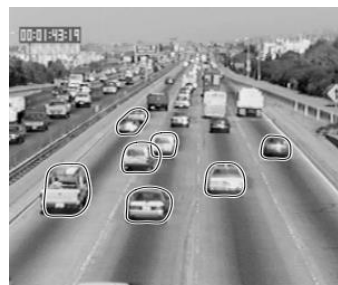


技术发展历程

多目标跟踪



航空交通管控

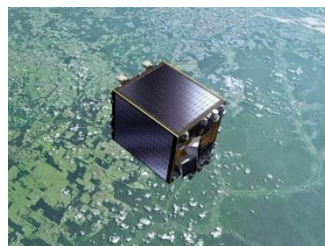


交通运输中的计算机视觉

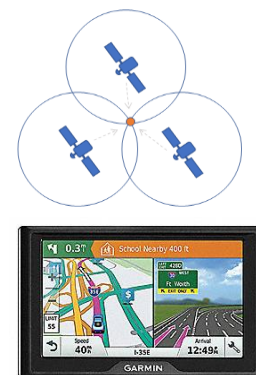


无人系统的多传感器融合

定位



军用



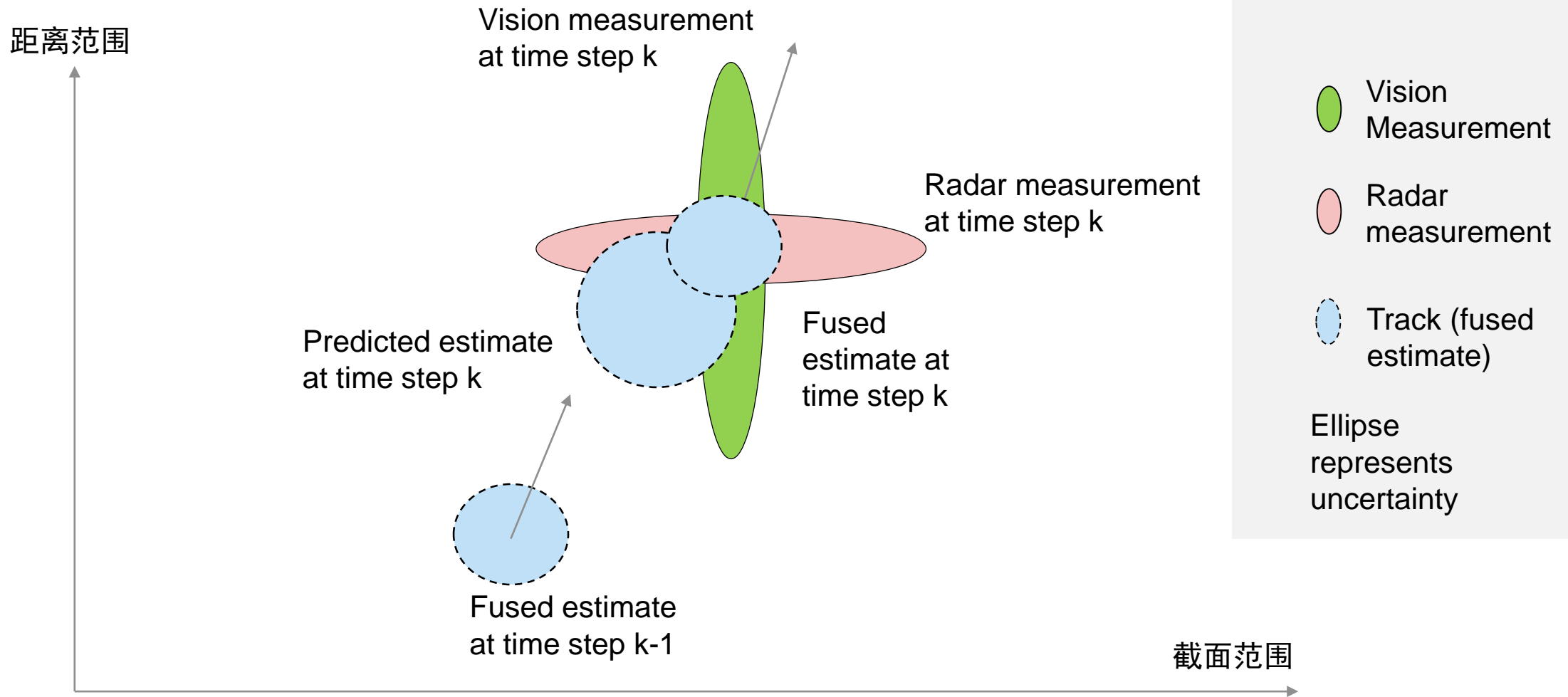
商用




无处不在

当今

将各传感器的优势融合

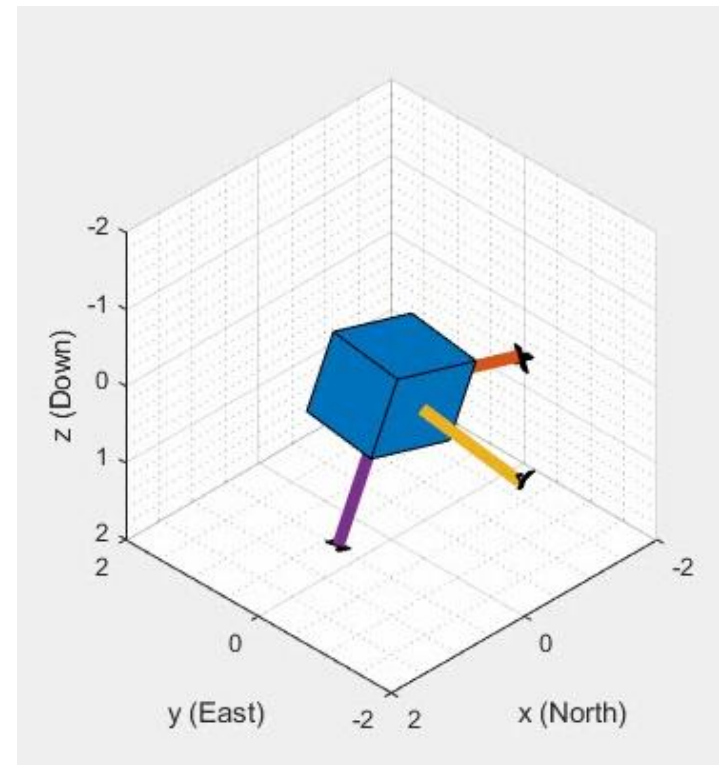


提纲

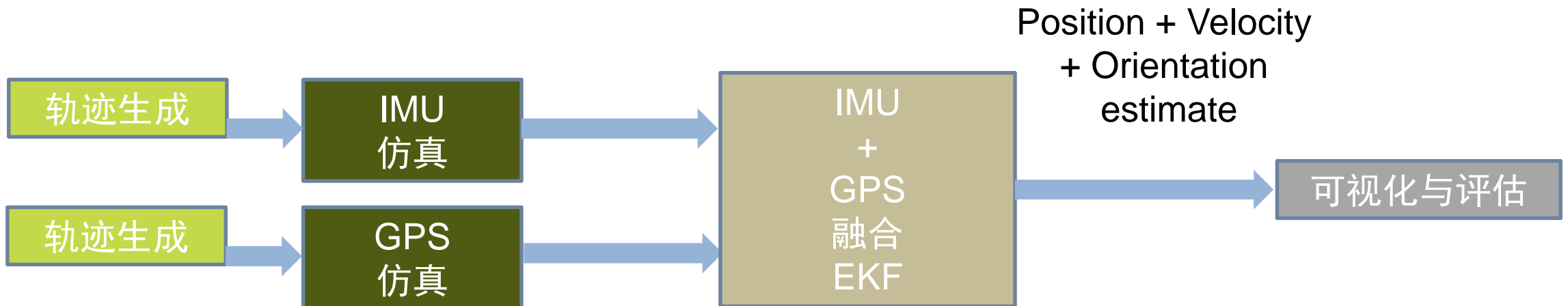
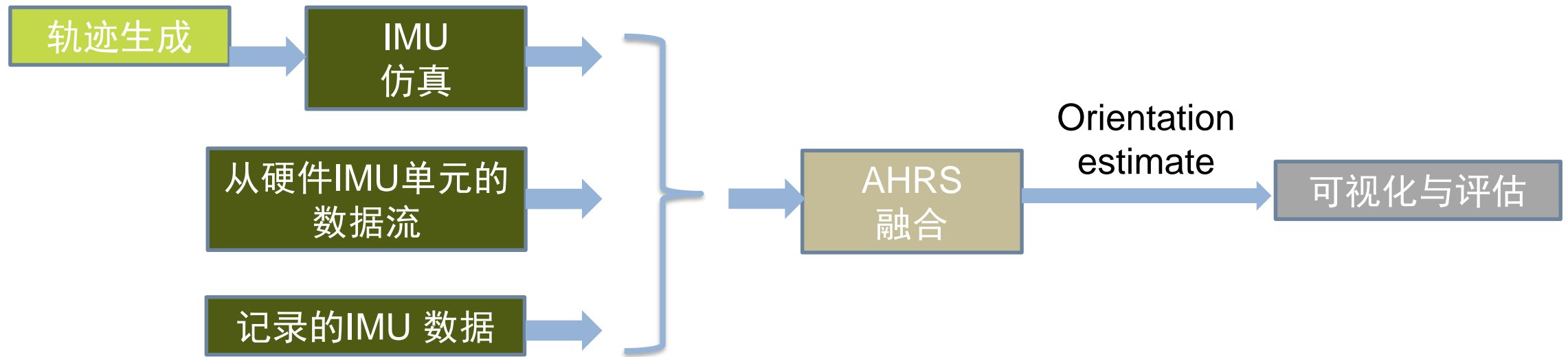
- 简介
- 感知技术总览
-  ▪ 传感器融合与目标跟踪算法开发
- Q&A
- 进一步探索所需资源

定位

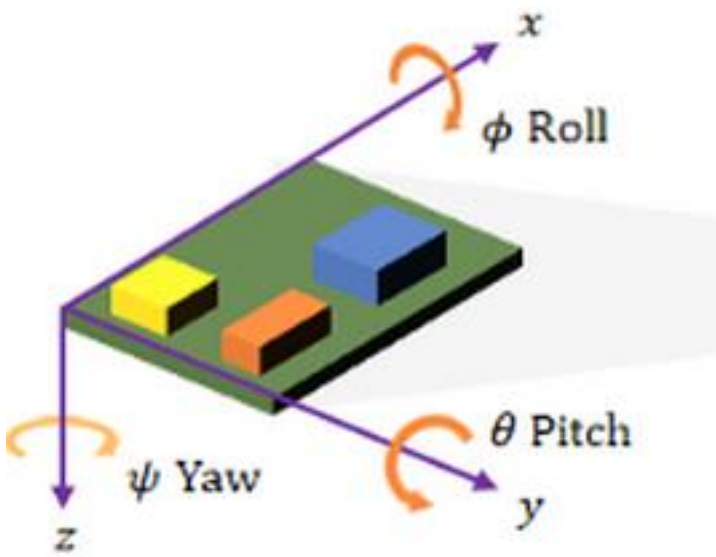
- 流程
- IMU 与 GPS 传感器模型
- 方向估计 (6-DOF, 9-DOF, 10-DOF)
- 姿态估计 (*IMU+GPS, IMU+Visual Odometry*)



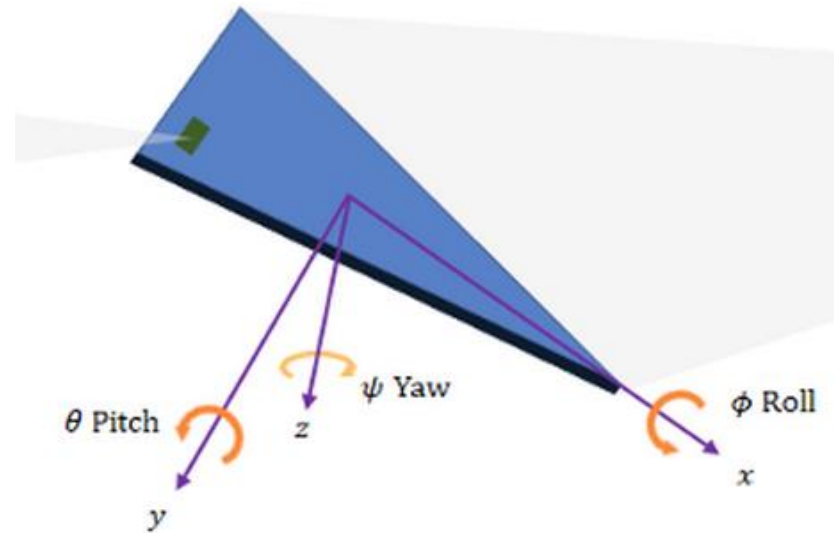
定位算法开发流程



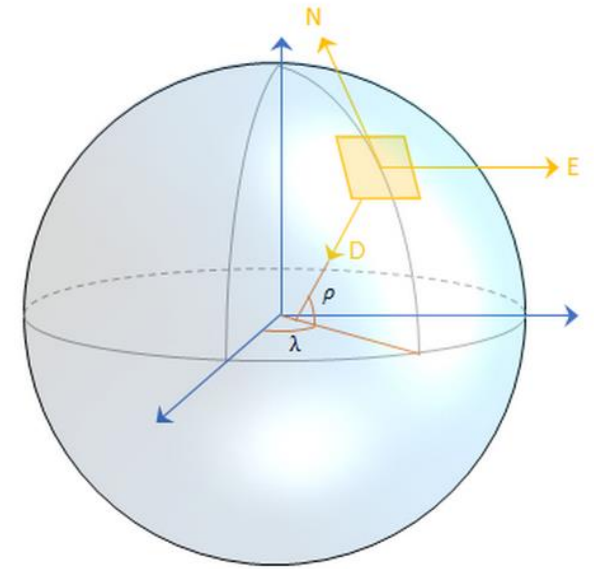
什么是定位？



惯性传感器



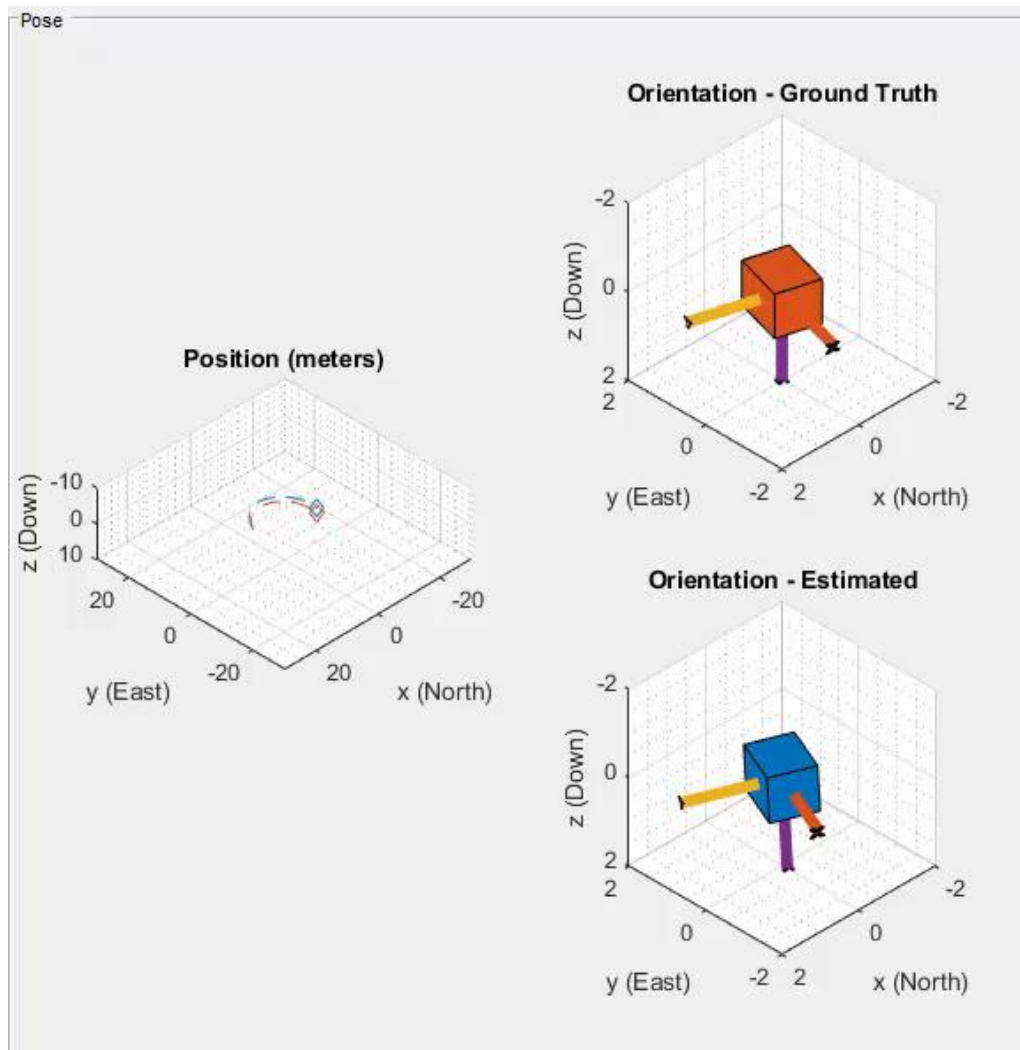
姿态



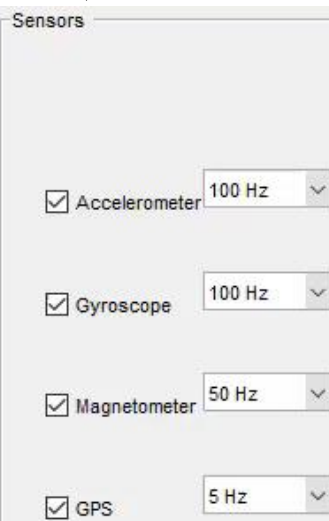
位置

多传感器数据融合提高定位精度

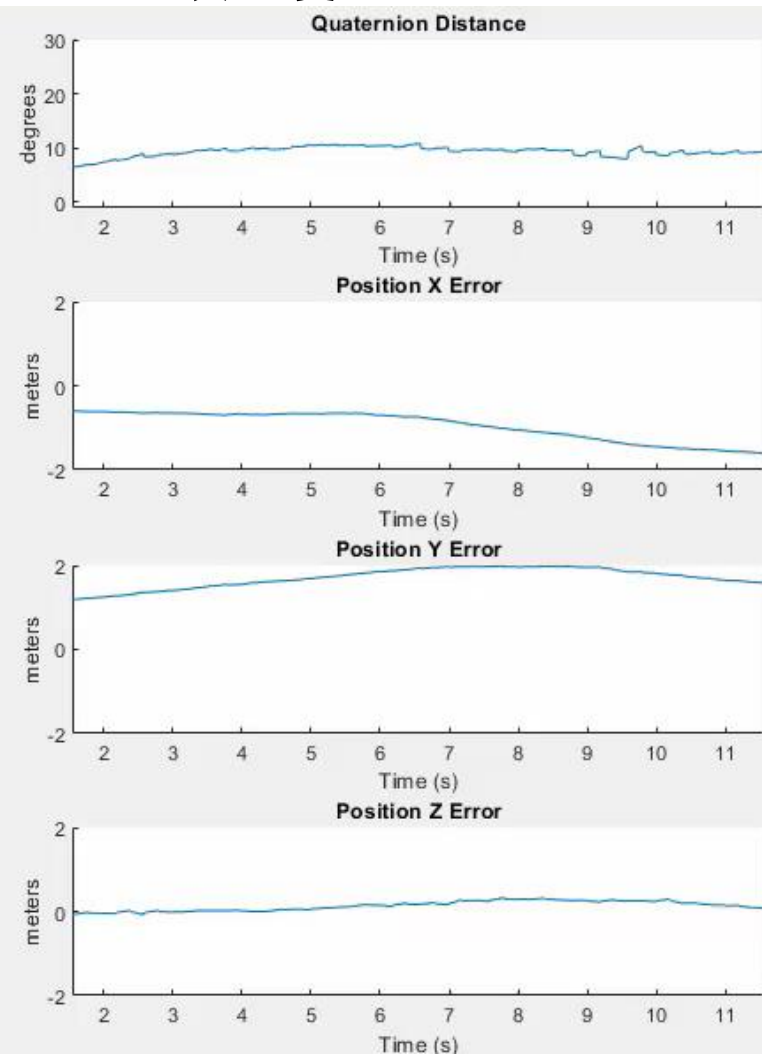
真实值vs. 估计值



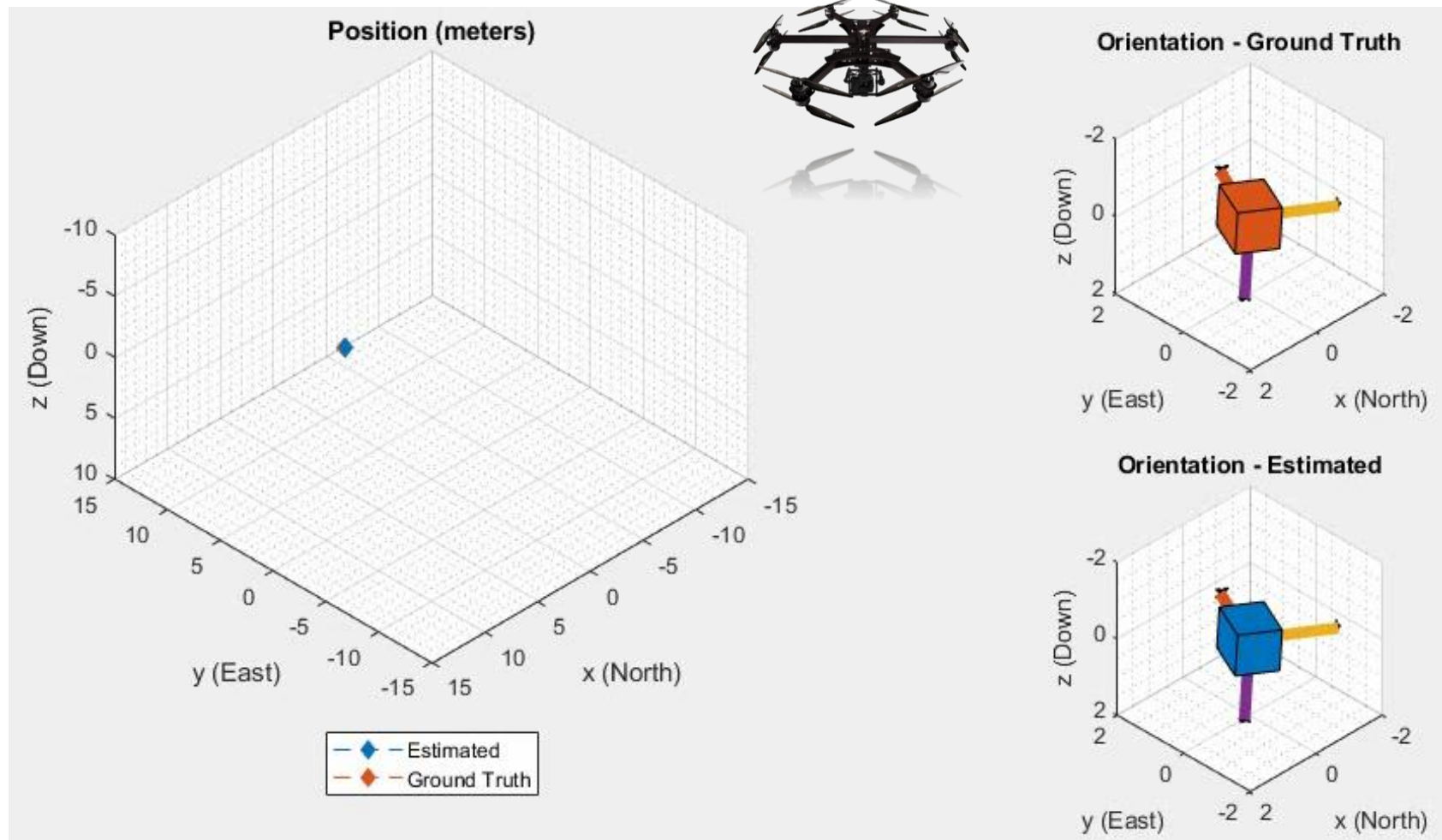
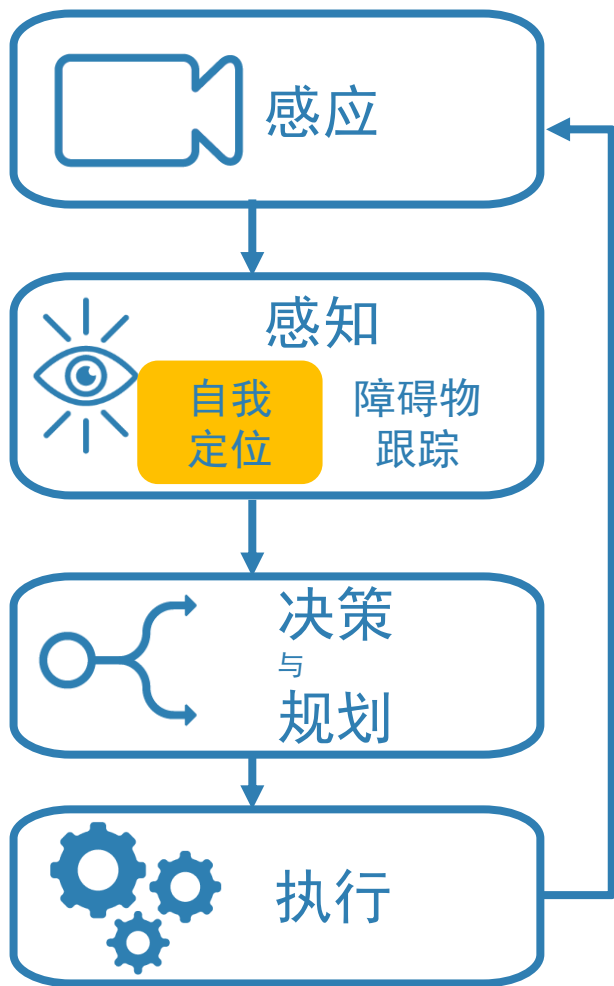
传感器



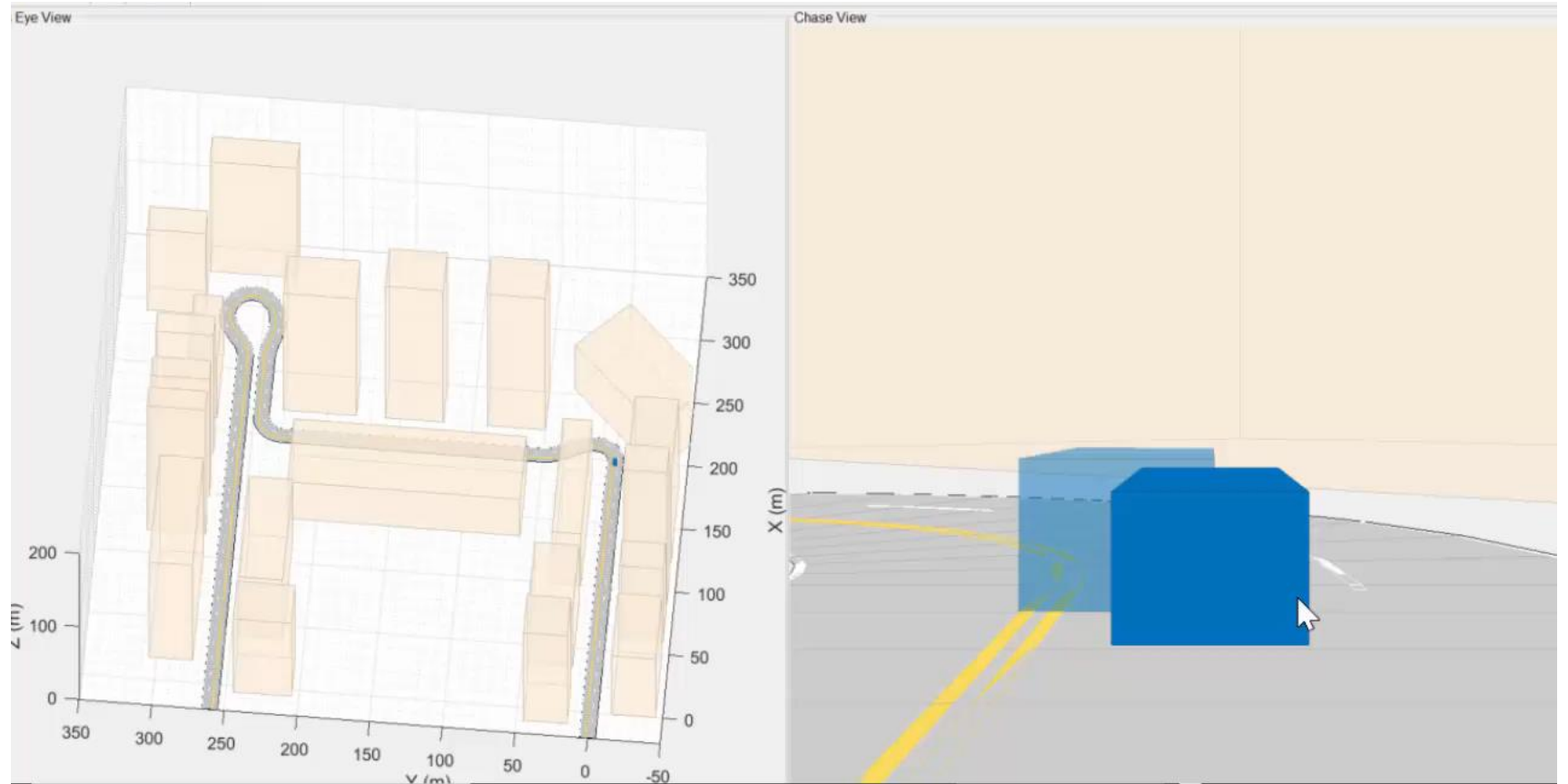
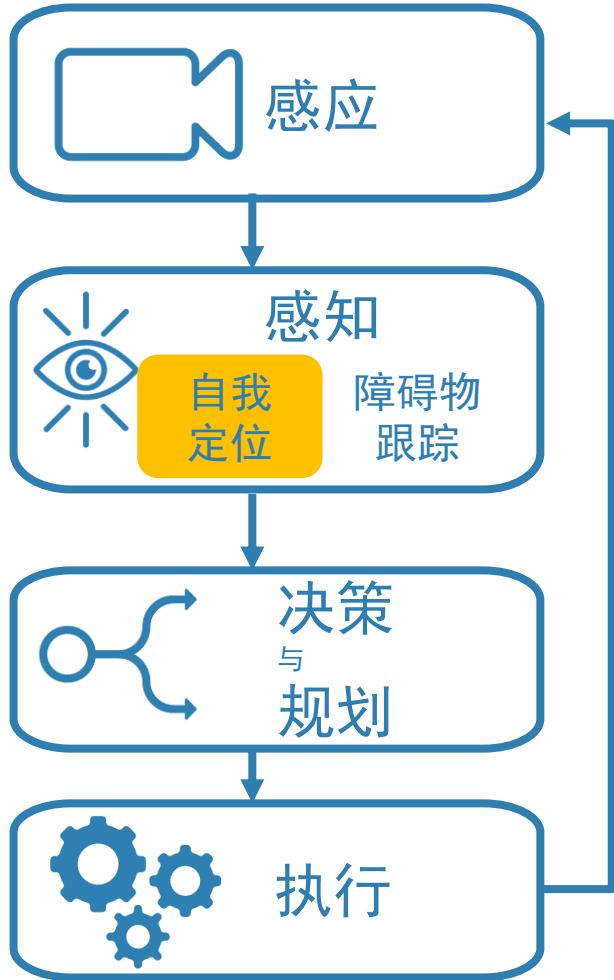
误差度量



将惯导和GPS数据融合，用于无人机自我定位



将惯导和测距数据融合，用于GPS阻断区的自我定位



多目标跟踪

- 记录数据流程
- 生成数据流程

跟踪算法开发

记录的传感器数据

场景定义与传感器仿真

主体平台
轨迹生成

惯导传感器
仿真

参与者/平台
轨迹生成

雷达、红外、
声纳传感器
仿真

Documented
Interface
for detections

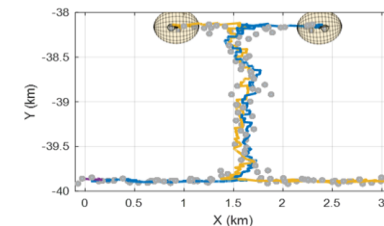
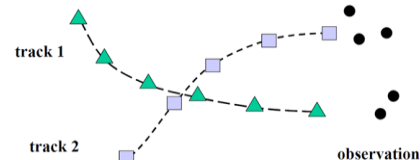
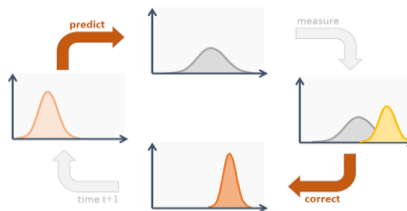
算法

惯导滤波器,
跟踪器等..

Documented
Interface
for tracks

可视化
与
评估

A rich library of tracking algorithms



Filters

- Alpha Beta filter
- Kalman filters
 - Linear, EKF, UKF, CKF, MSCEKF
- Particle filter
- Multiple models
 - GSF, IMM

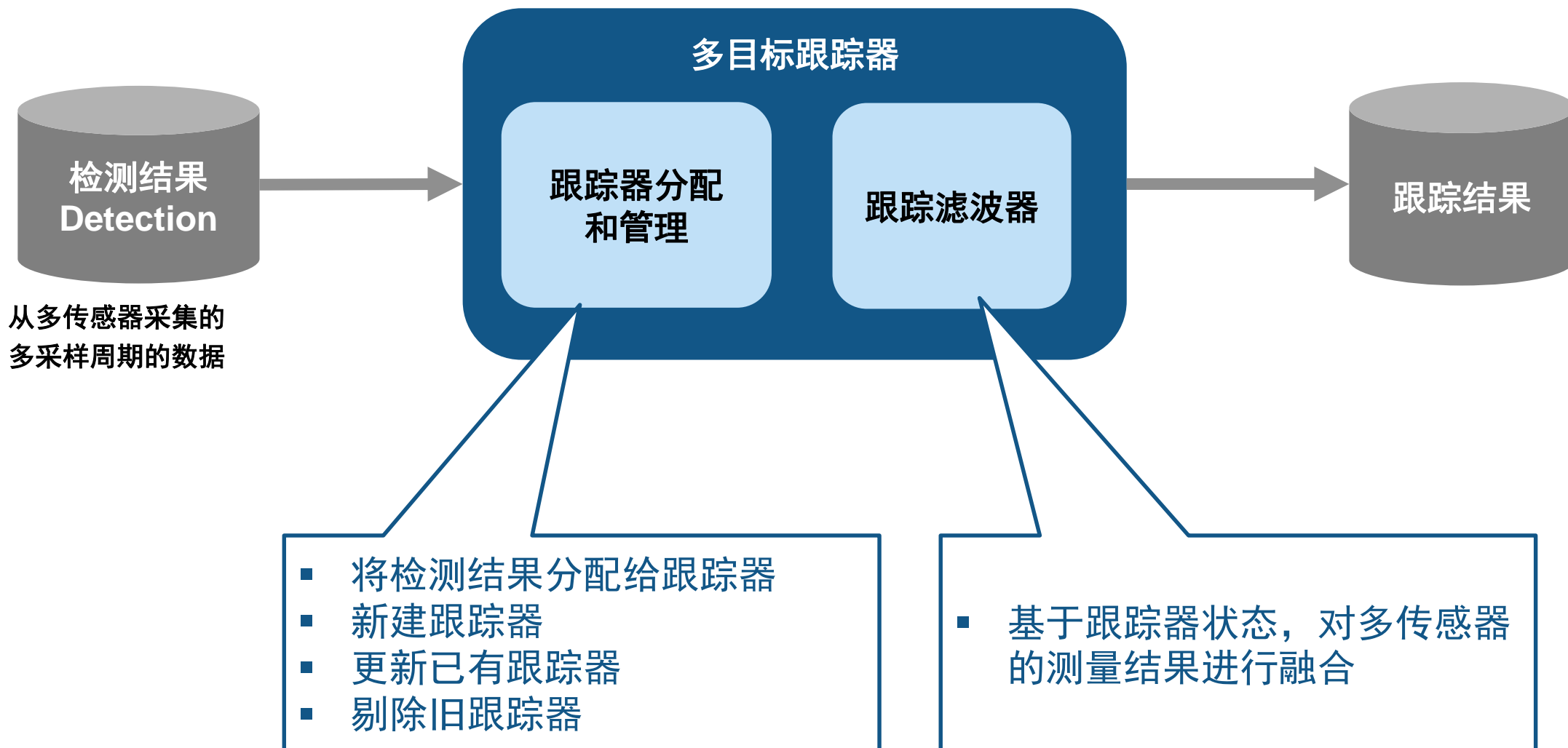
Data Association

- 2D assignment
- S-D assignment
- K-best assignment

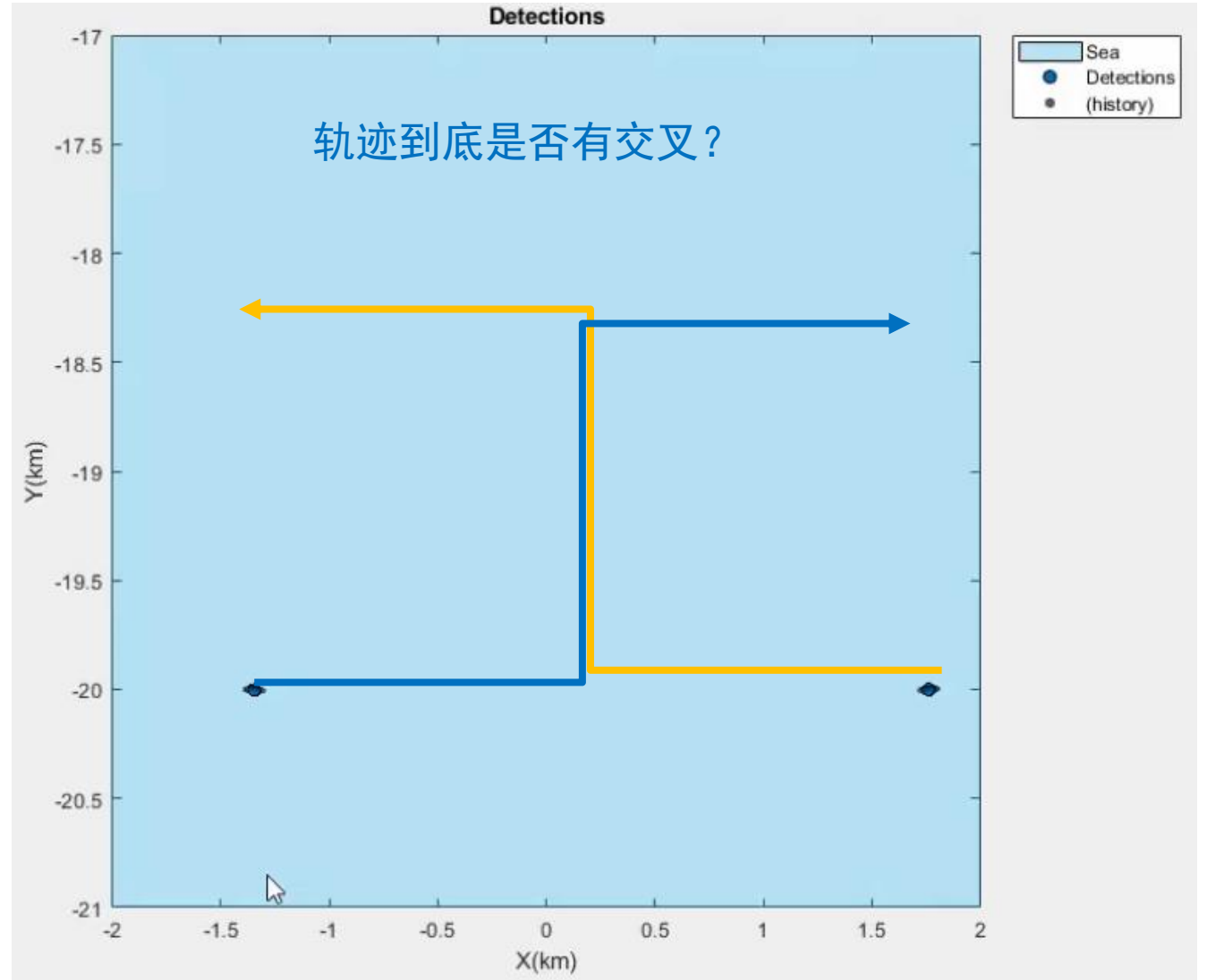
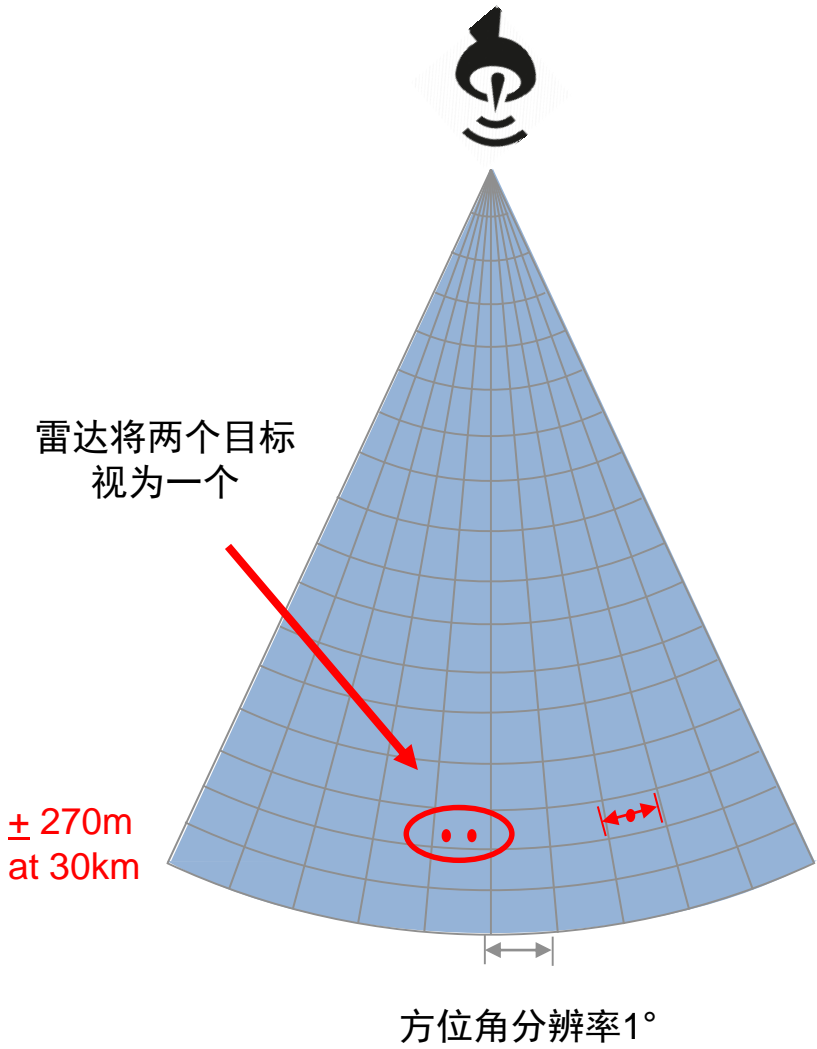
Trackers

- GNN
- MHT (track-oriented)
- Trackers components
 - History and score logic
 - etc.....

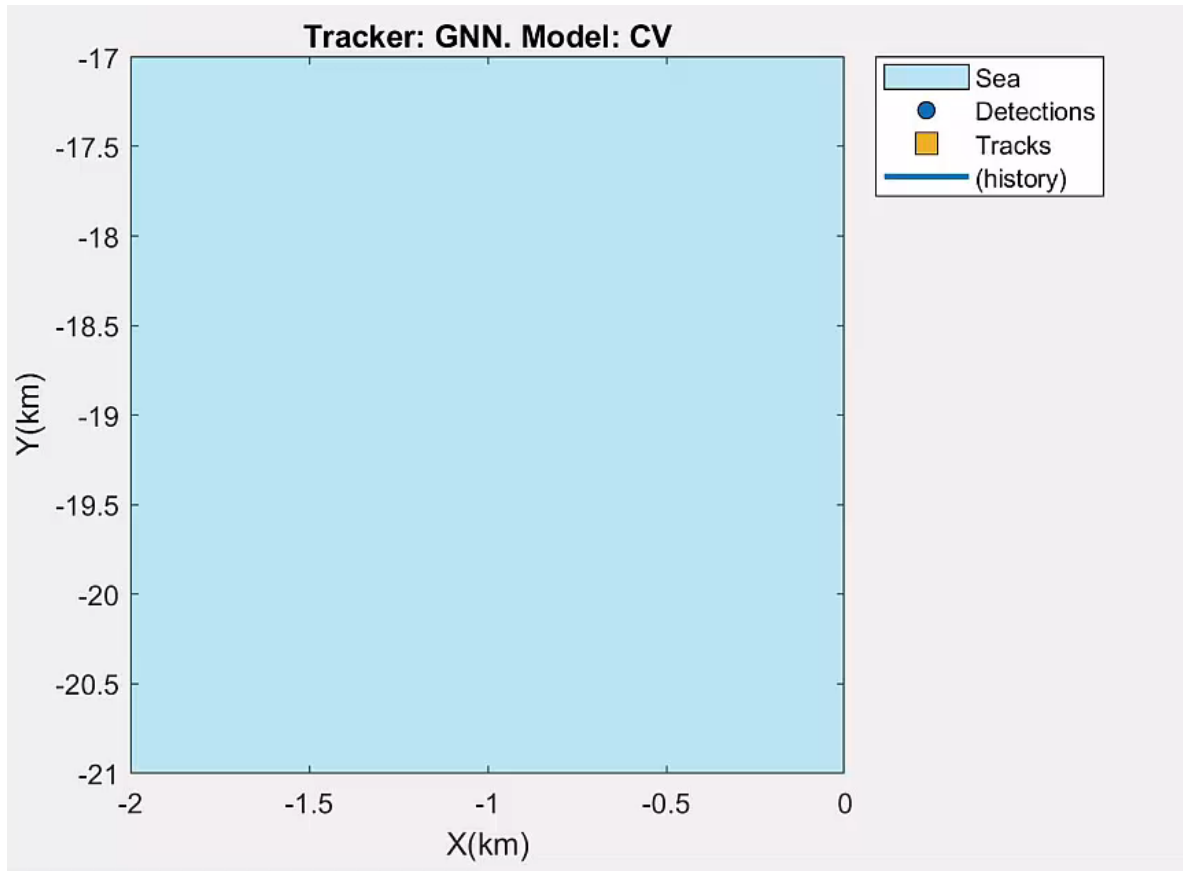
多目标跟踪器不仅是卡尔曼滤波器



执行假设分析



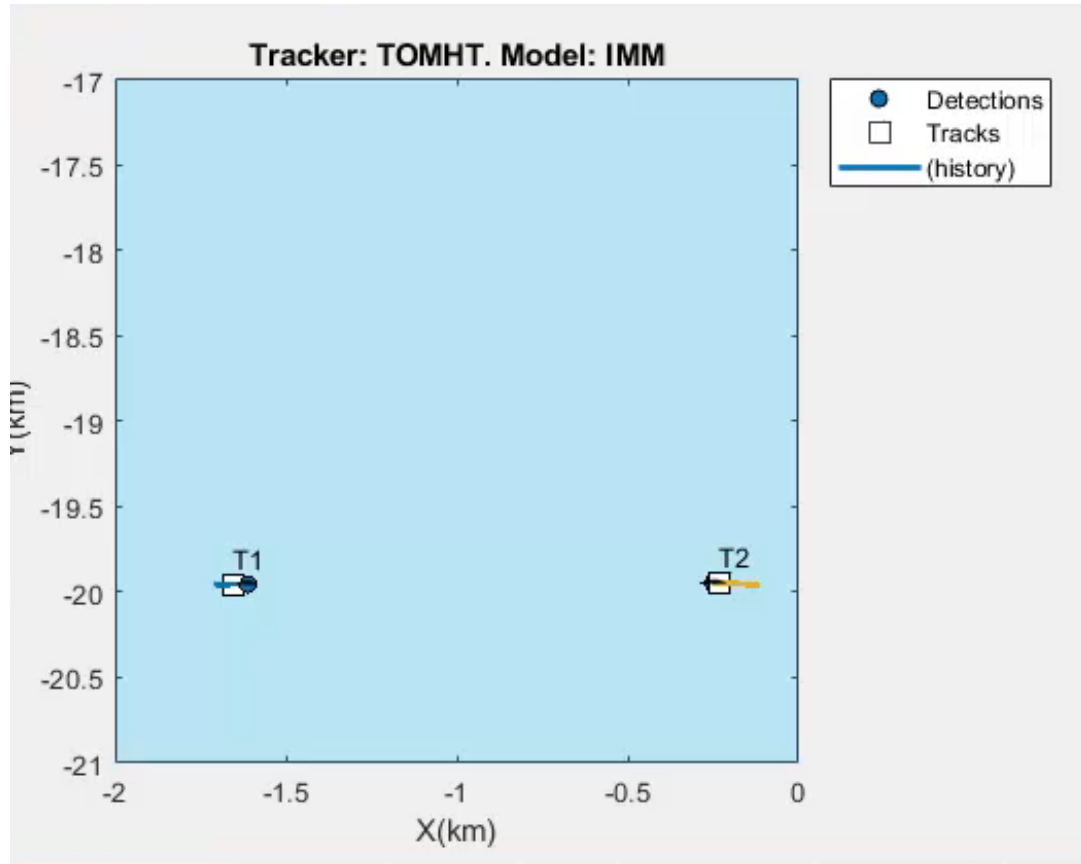
执行假设分析



```
tracker = trackerGNN( ...  
    'FilterInitializationFcn',@initCVFilter,...  
    'MaxNumTracks', numTracks, ...  
    'MaxNumSensors', 1, ...  
    'AssignmentThreshold',gate, ...  
    'TrackLogic', 'Score', ...  
    'DetectionProbability', pd, ...  
    'FalseAlarmRate', far, ...  
    'Volume', vol, 'Beta', beta);
```

```
tracker = trackerGNN( ...  
    'FilterInitializationFcn',@initIMMFilter,...  
    'MaxNumTracks', numTracks, ...  
    'MaxNumSensors', 1, ...  
    'AssignmentThreshold',gate, ...  
    'TrackLogic', 'Score', ...  
    'DetectionProbability', pd, ...  
    'FalseAlarmRate', far, ...  
    'Volume', vol, 'Beta', beta);
```

执行假设分析



```
tracker = trackerTOMHT( ...  
    'FilterInitializationFcn', @initIMMFilter, ...  
    'MaxNumTracks', numTracks, ...  
    'MaxNumSensors', 1, ...  
    'AssignmentThreshold', [0.2, 1, 1]*gate, ...  
    'TrackLogic', 'Score', ...  
    'DetectionProbability', pd, ...  
    'FalseAlarmRate', far, ...  
    'Volume', vol, 'Beta', beta, ...  
    'MaxNumHistoryScans', 10, ...  
    'MaxNumTrackBranches', 5, ...  
    'NScanPruning', 'Hypothesis', ...  
    'OutputRepresentation', 'Tracks');
```

跟踪器与跟踪滤波器比较



False track
Dropped track

TrackID	AssignedTruthID	Surviving	TotalLength	DivergenceStatus
1	2	true	190	false
2	NaN	false	77	true
8	3	true	111	false

TruthID	AssociatedTrackID	TotalLength	BreakCount	EstablishmentLength
2	1	192	0	4
3	8	192	1	2



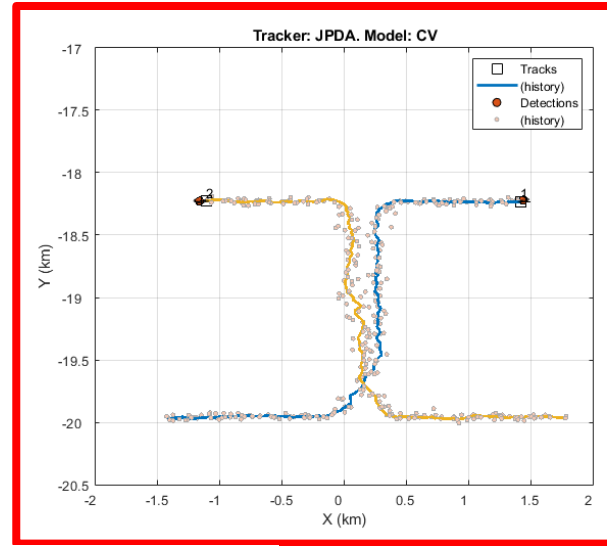
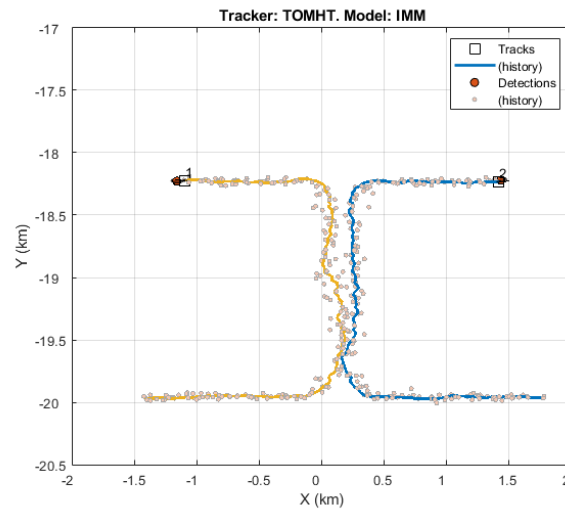
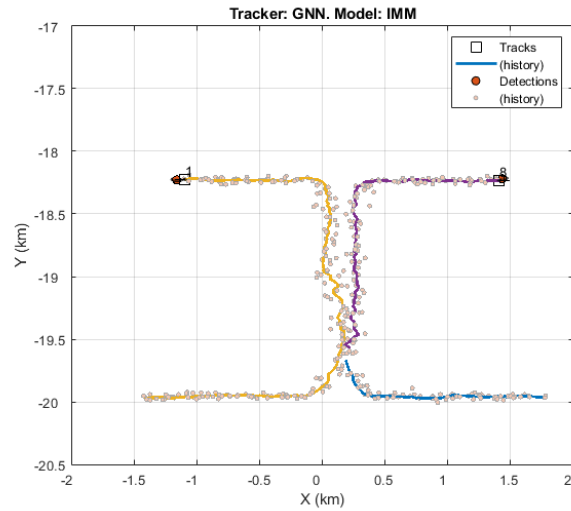
TrackID	AssignedTruthID	Surviving	TotalLength	DivergenceStatus
1	2	true	190	false
2	3	true	191	false

TruthID	AssociatedTrackID	TotalLength	BreakCount	EstablishmentLength
2	1	192	0	2
3	2	192	0	2



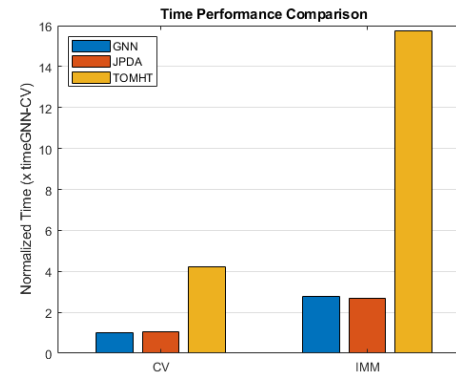
TrackID	AssignedTruthID	Surviving	TotalLength	DivergenceStatus
1	2	true	191	false
2	3	true	191	false

TruthID	AssociatedTrackID	TotalLength	BreakCount	EstablishmentLength
2	1	192	0	1
3	2	192	0	2

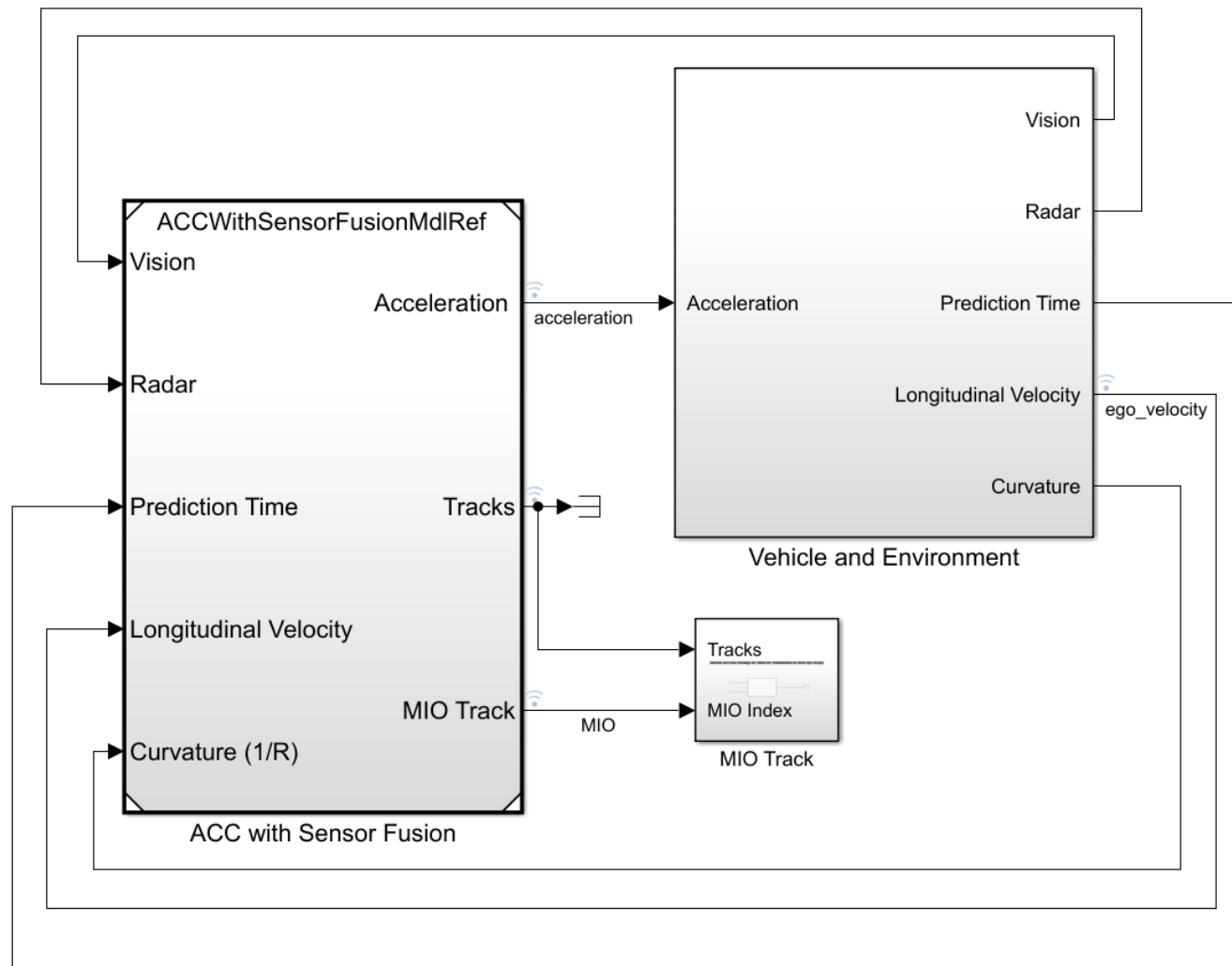
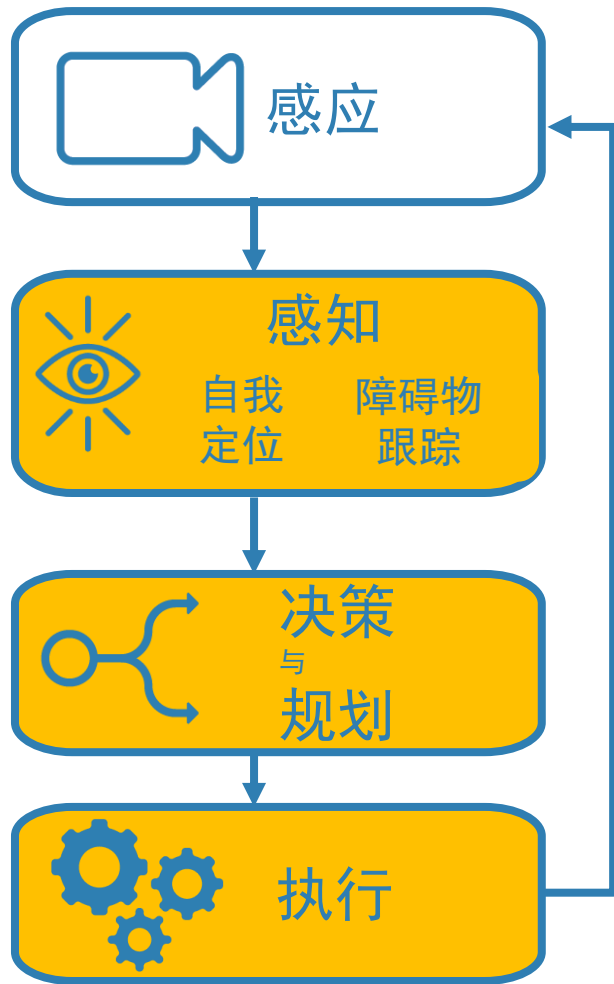


Slower

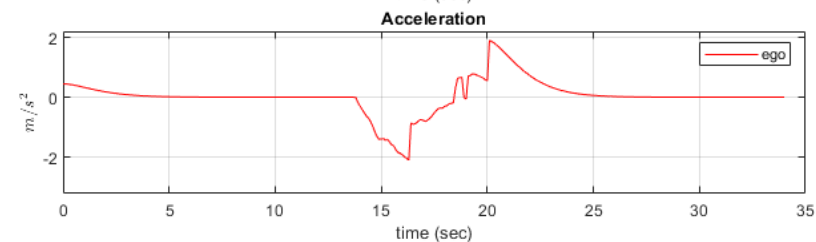
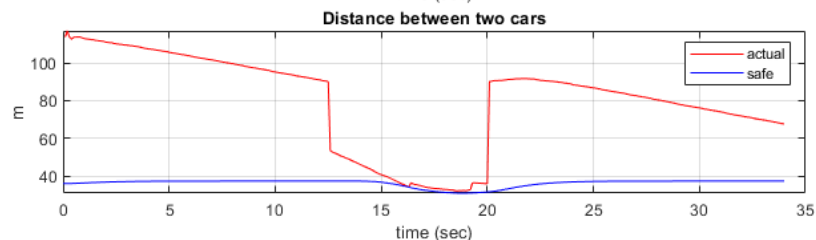
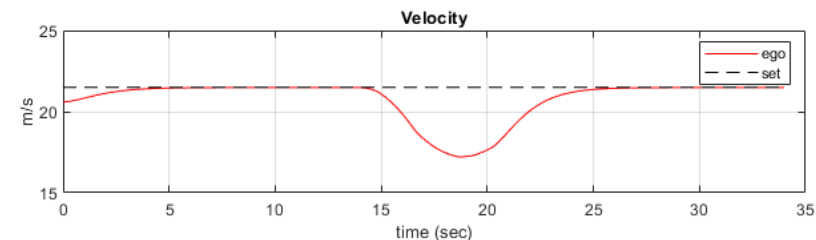
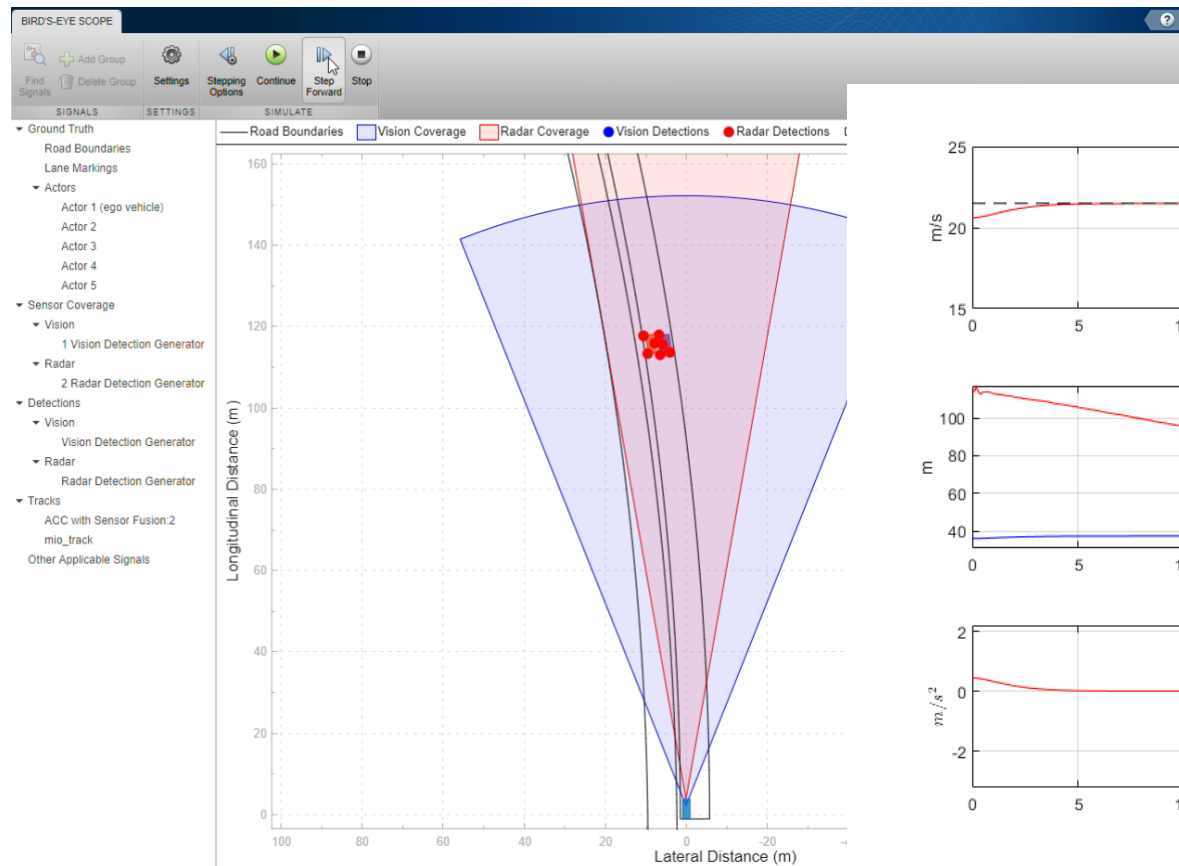
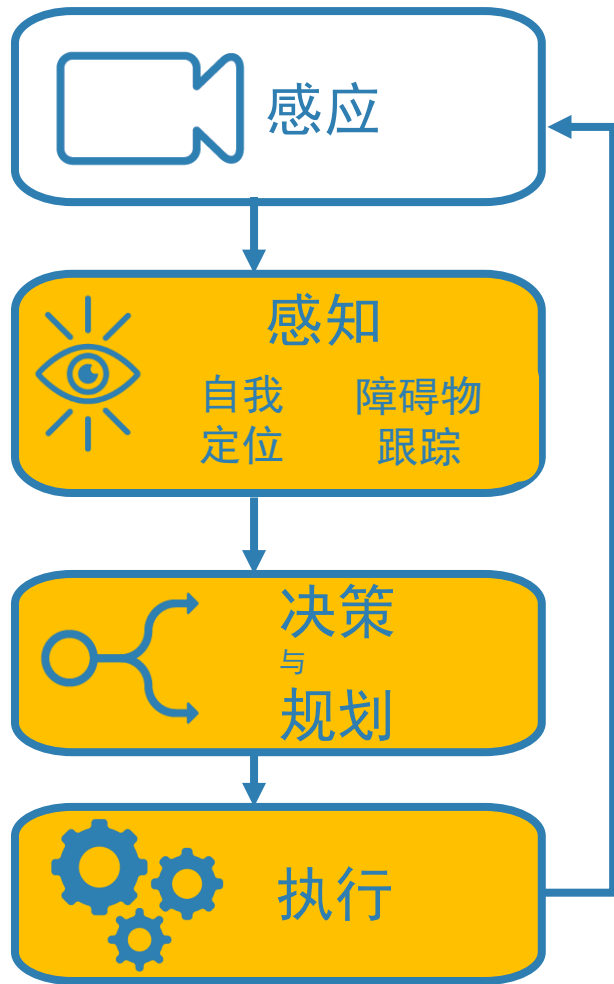
Faster



与决策/控制部分集成：ACC自动定速巡航案例



与决策/控制部分集成：ACC自动定速巡航案例



多平台跟踪

- 自定制轨迹
- 可视化检测和跟踪轨迹的不确定度
- 跟踪算法评估

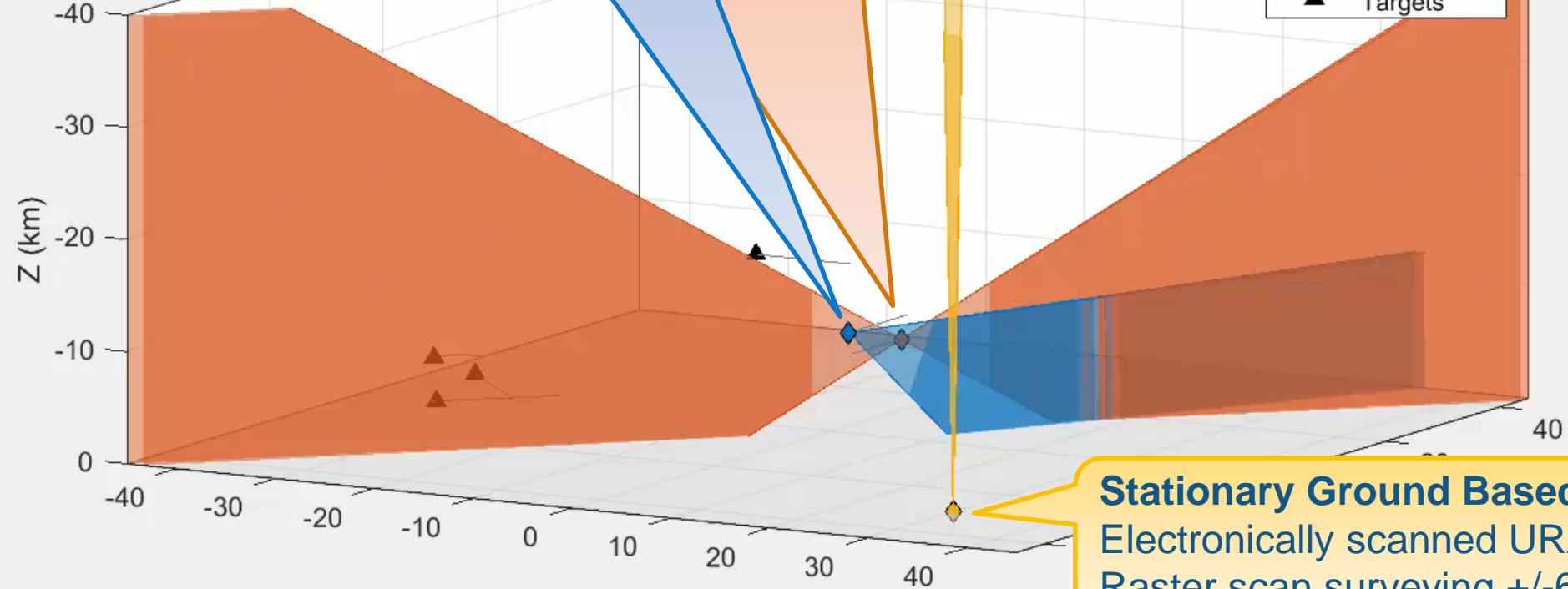
多平台场景数据生成

Moving
2 ULAs
Electron

Moving Airborne Radar (blue)
360° mechanical scan in az
No electronic scanning

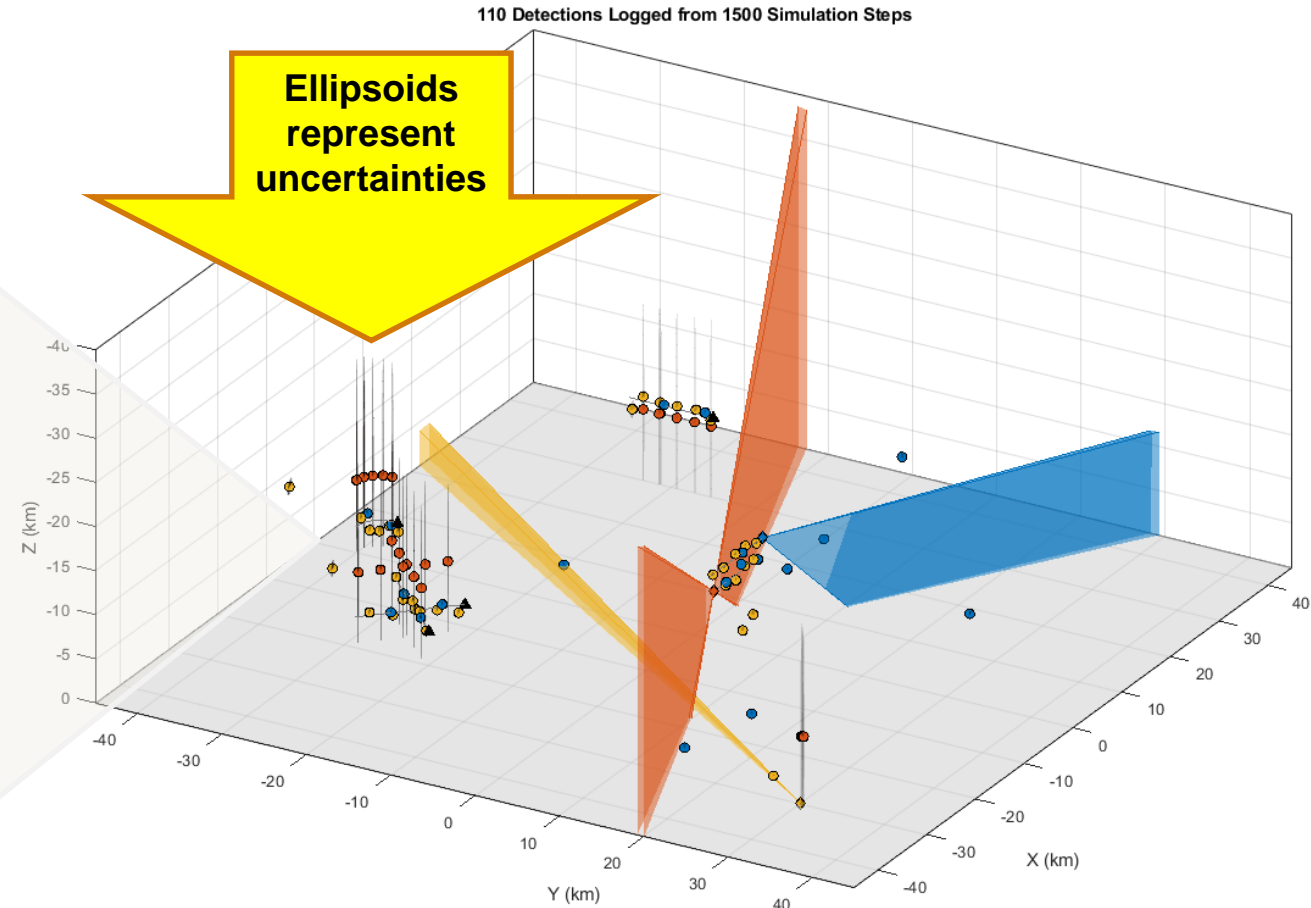
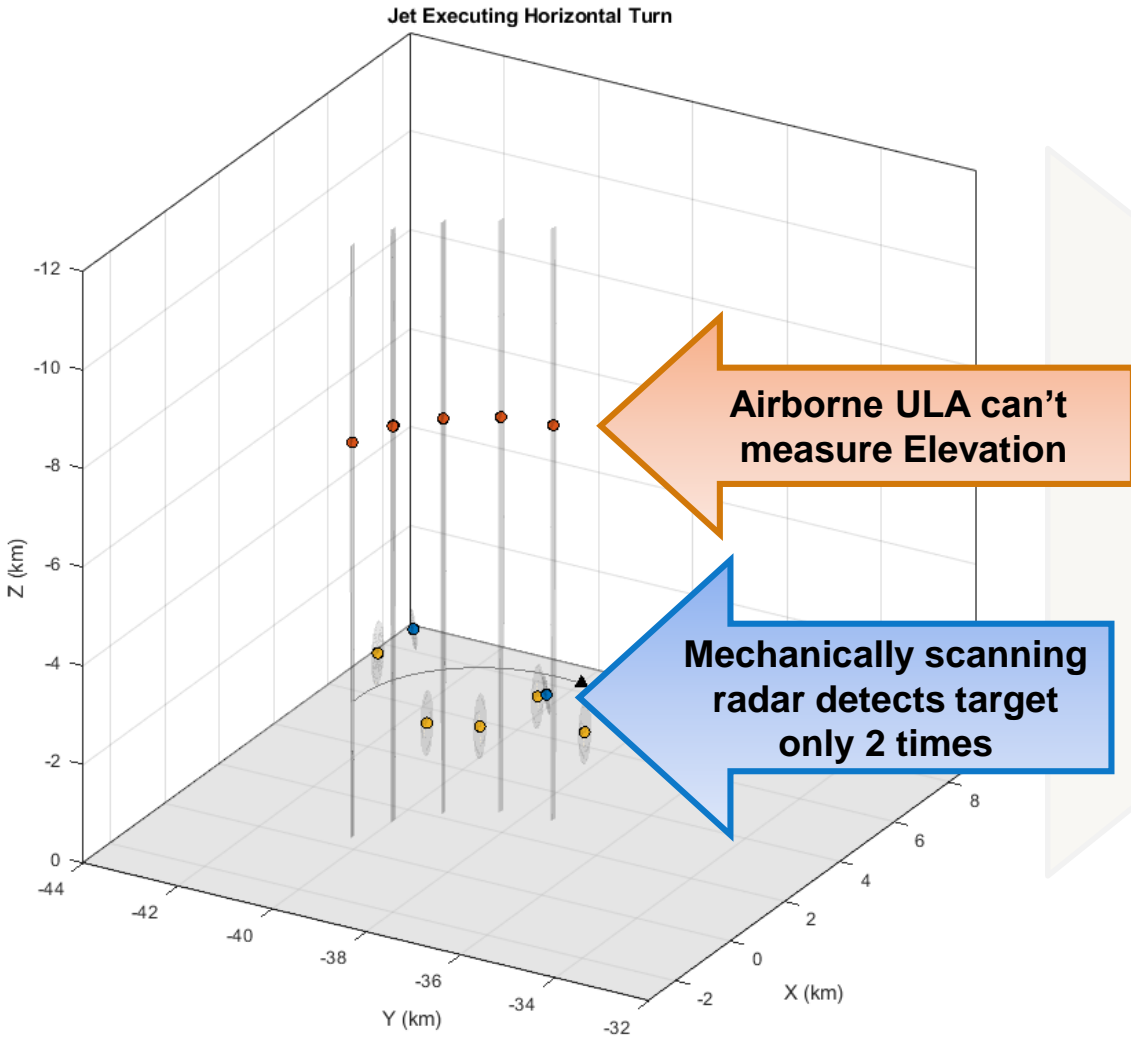
es of airframe

Radar Scenario



Stationary Ground Based Radar (yellow)
Electronically scanned URA
Raster scan surveying +/-60° az and -20 to 0° el

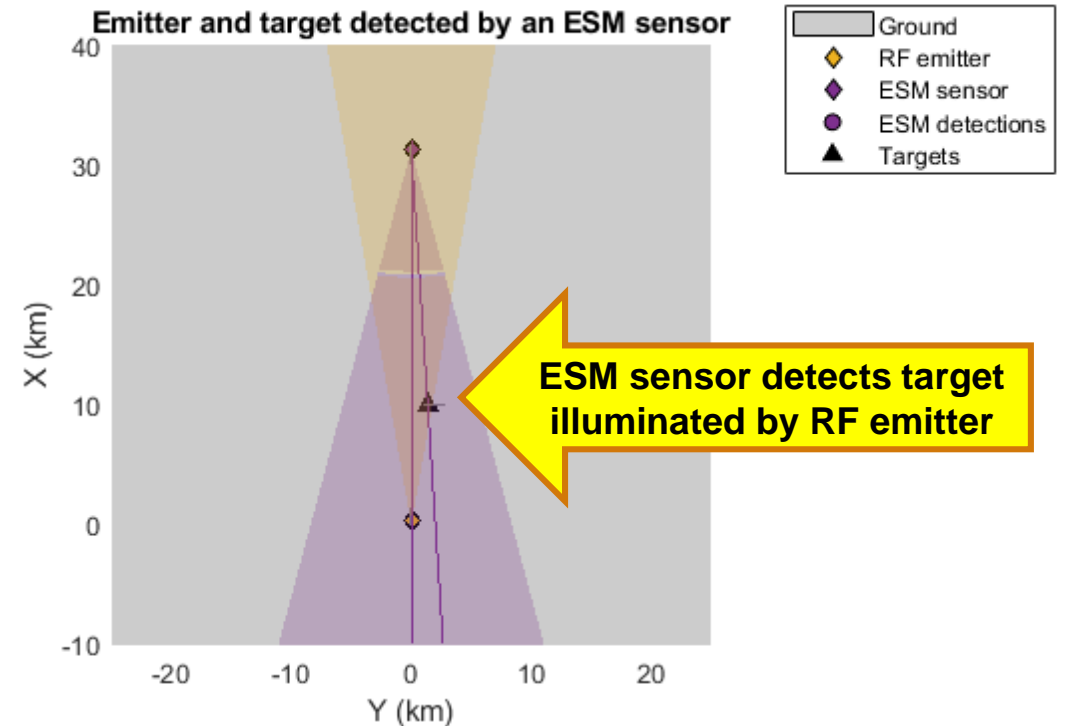
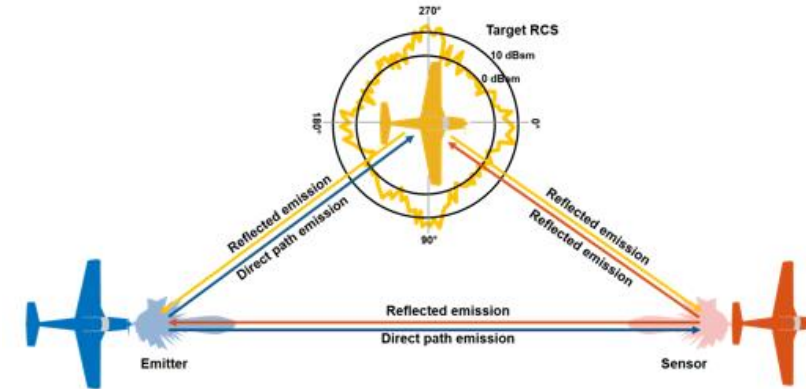
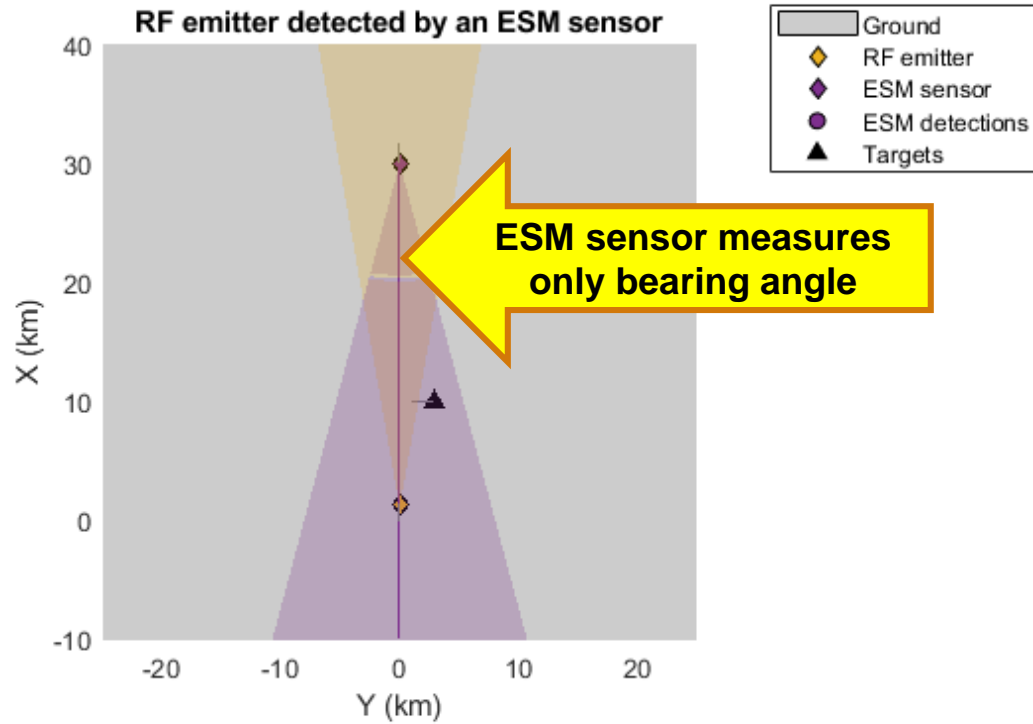
可视化检测和测量中的不确定性



被动传感器的跟踪

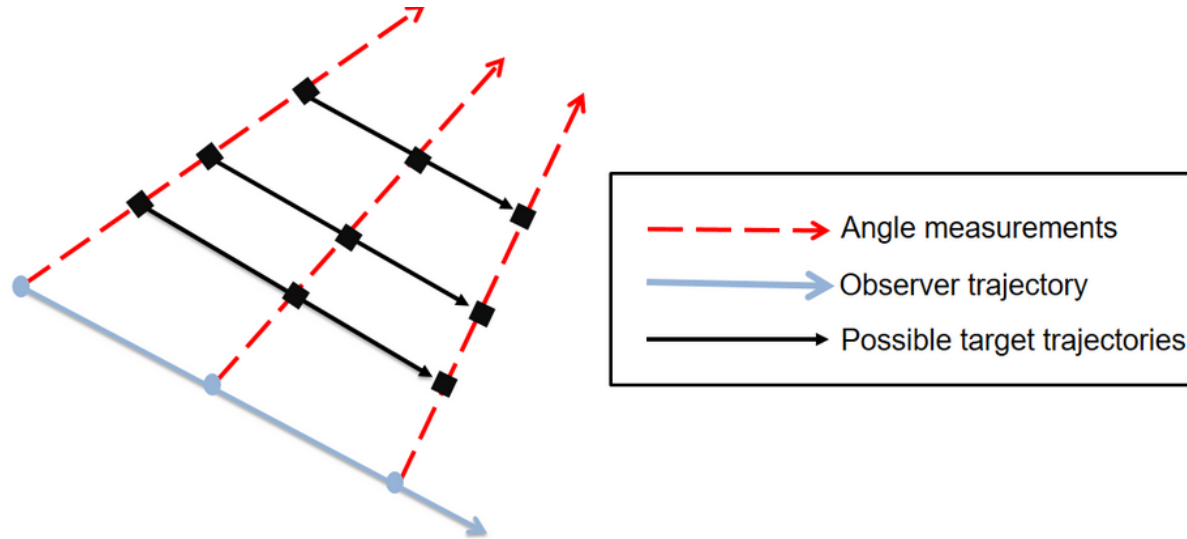
- ESM/RWR, EO/IR 及声呐模型
- 被动测距
- 分布式同步被动传感器

生成ESM检测数据

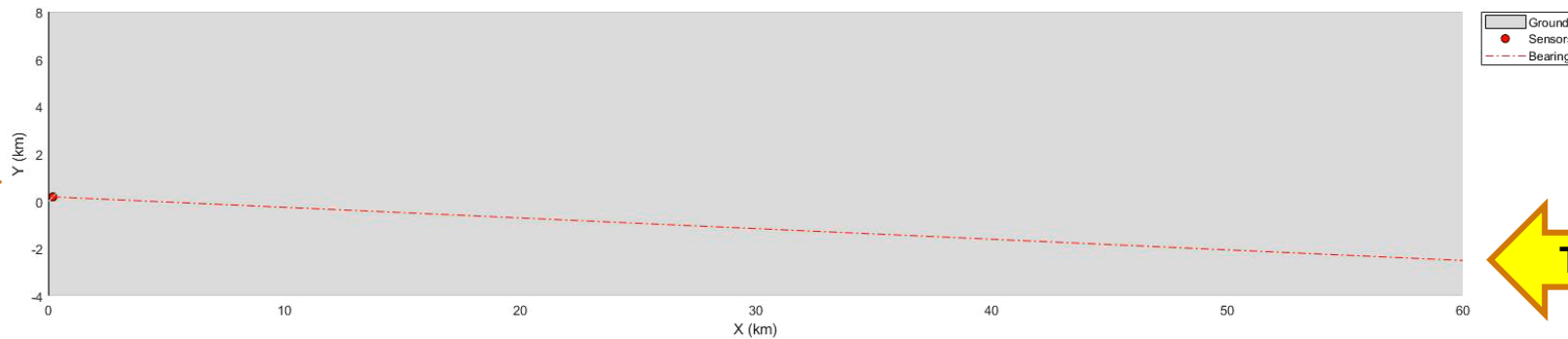


Challenges of Passive Ranging Using a Single Maneuvering Sensor

Sensor must out-maneuver the target



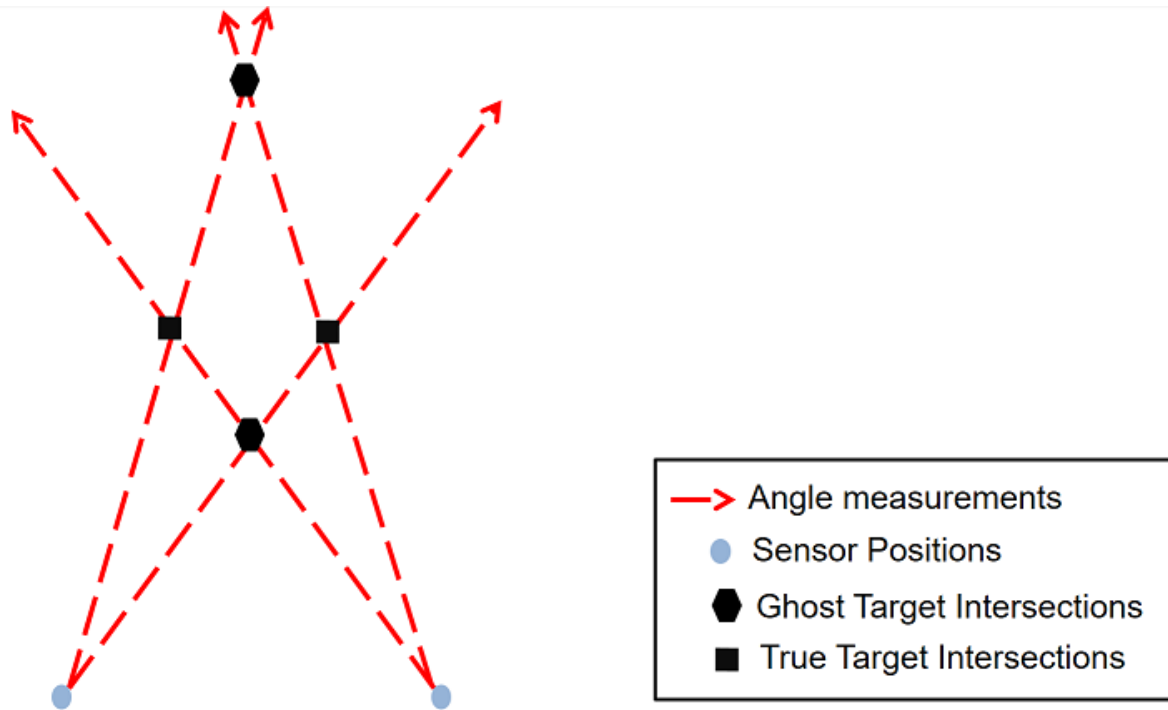
ESM (RWR),
EO/IR, or
sonar sensor



Target

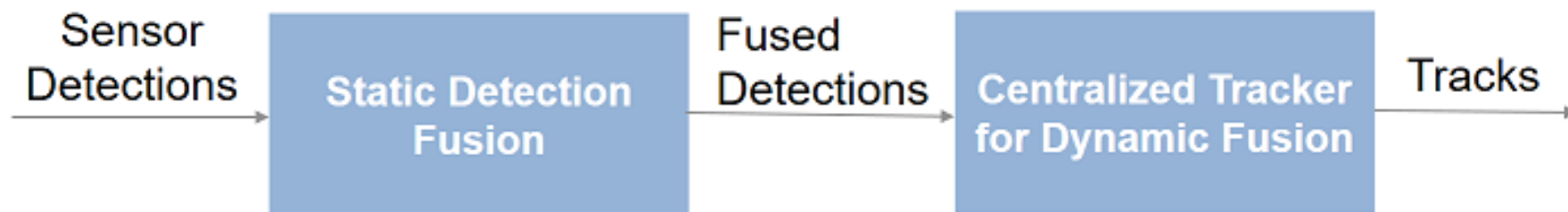
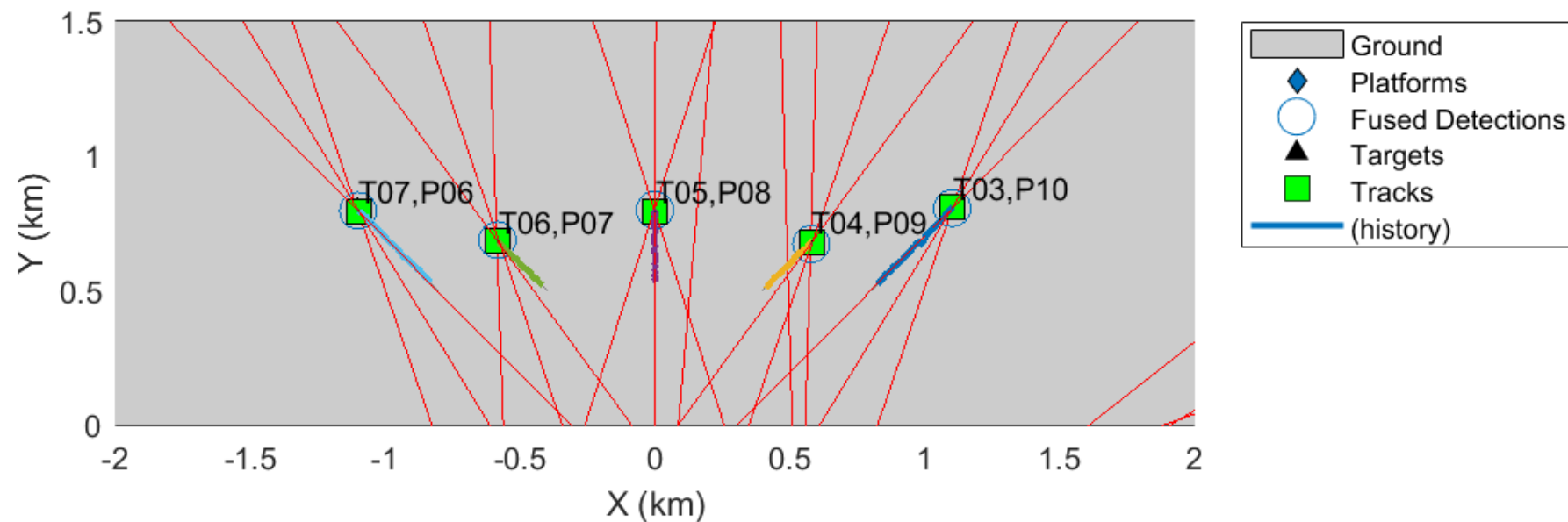
多目标场景生成

真实目标在哪里？ 如何去除“虚影”？



分布式同步被动传感器跟踪

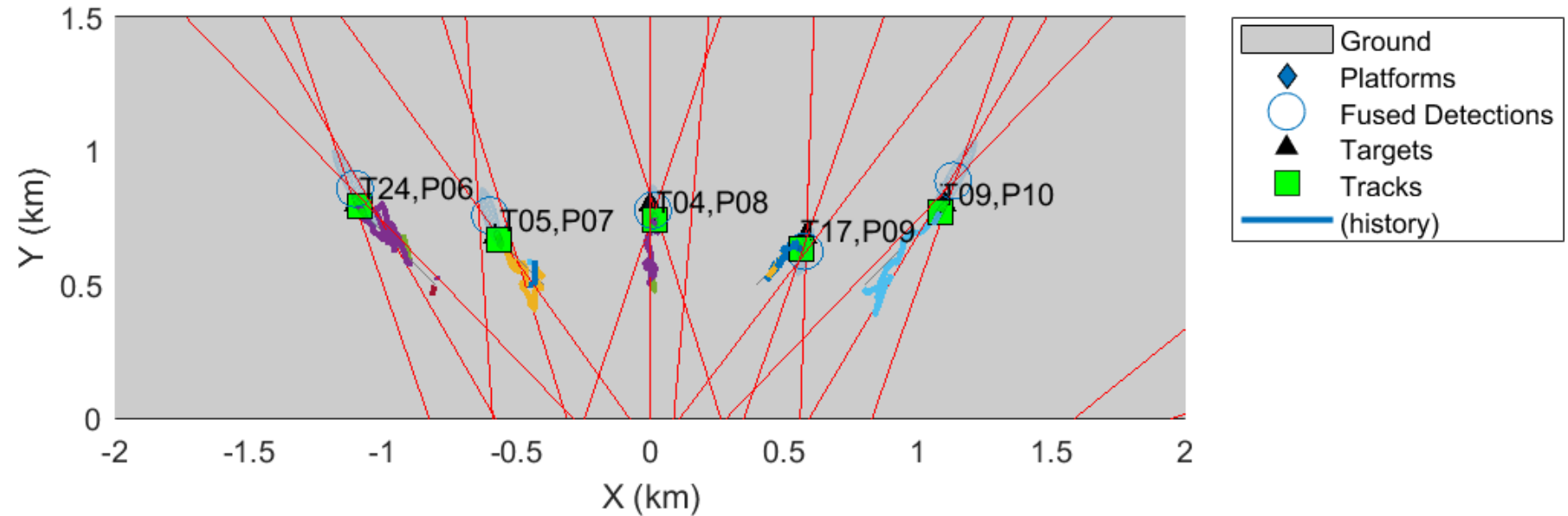
3 high quality sensors
5 targets



Static Fusion Before Tracking

Compare Scenarios Using Assignment and Error Metrics

3 low quality sensors
5 targets



Metrics API

False tracks

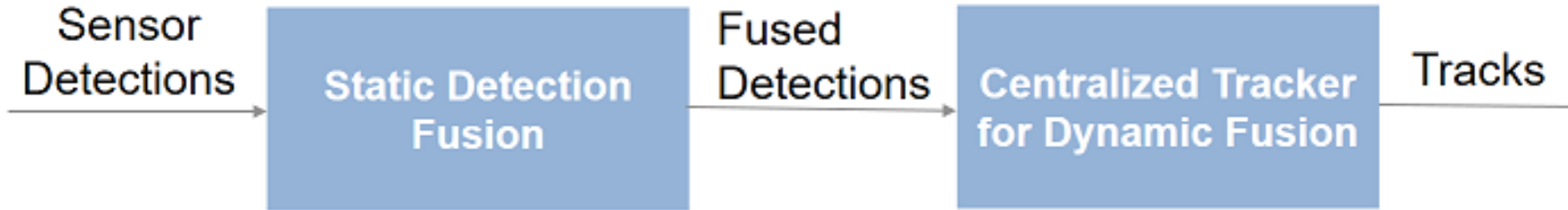
Dropped tracks

Swapped tracks

...

TrackID	AssignedTruthID	TotalLength	FalseTrackStatus
2	NaN	1	false
3	NaN	1	false
4	8	55	false
5	7	56	false
6	NaN	2	false
7	NaN	2	false
9	10	50	false
11	NaN	1	true
15	NaN	2	false
17	9	48	false

用并行计算和代码生成，为跟踪算法加速



+
Generate C code

MATLAB Code Execution time = 45.427

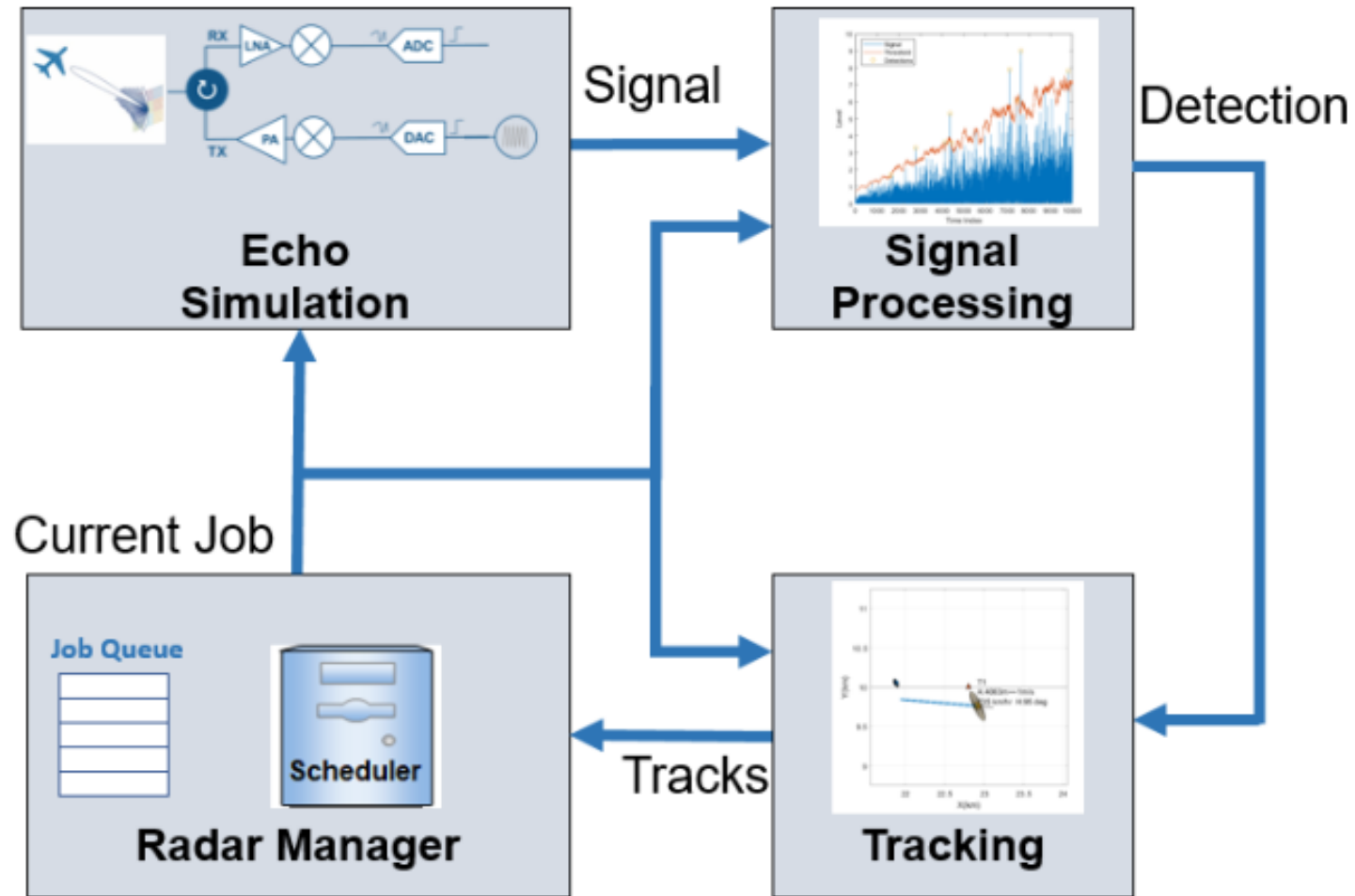
MEX Code Execution time = 0.27536

多功能雷达闭环仿真

- **Combine signal processing and data processing (tracking)**
- **Search and track with resource management**
- **Integrate with Phased Array System Toolbox**

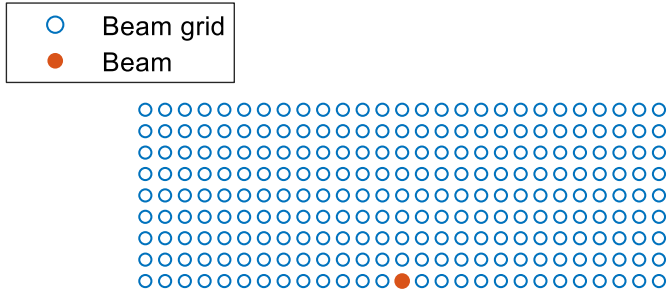


多功能雷达：搜索与跟踪

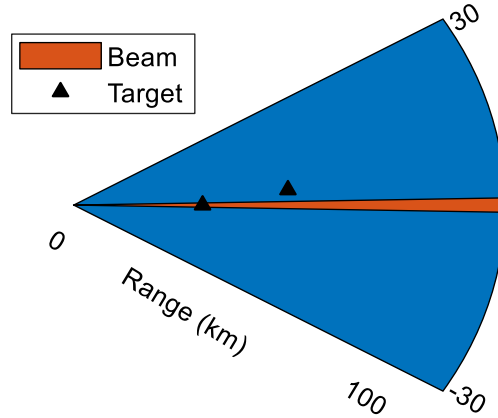


Target 1 Detected

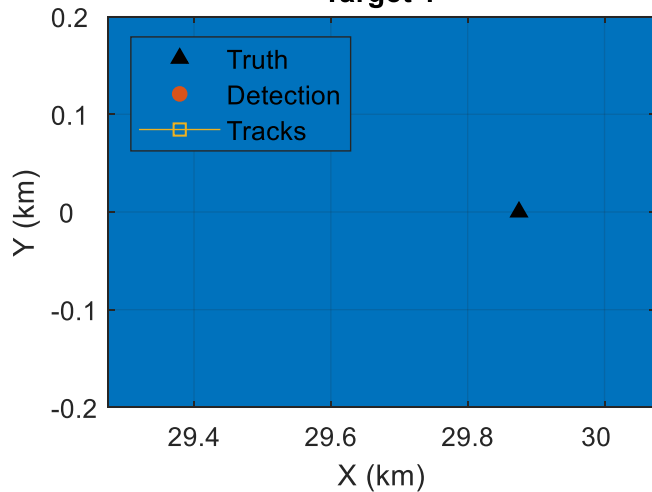
Search Beam Grid



Radar Azimuth Coverage



Target 1

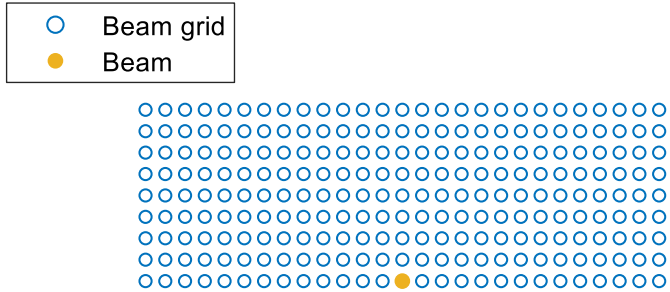


```

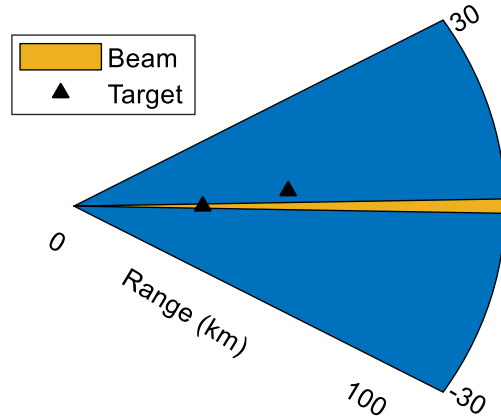
0.000000 sec: Search [-30.000000 0.000000]
0.010000 sec: Search [-27.692308 0.000000]
0.020000 sec: Search [-25.384615 0.000000]
0.030000 sec: Search [-23.076923 0.000000]
0.040000 sec: Search [-20.769231 0.000000]
0.050000 sec: Search [-18.461538 0.000000]
0.060000 sec: Search [-16.153846 0.000000]
0.070000 sec: Search [-13.846154 0.000000]
0.080000 sec: Search [-11.538462 0.000000]
0.090000 sec: Search [-9.230769 0.000000]
0.100000 sec: Search [-6.923077 0.000000]
0.110000 sec: Search [-4.615385 0.000000]
0.120000 sec: Search [-2.307692 0.000000]
0.130000 sec: Search [0.000000 0.000000] Target detected at 29900.
    
```

Detection Confirmed and Track 1 Created

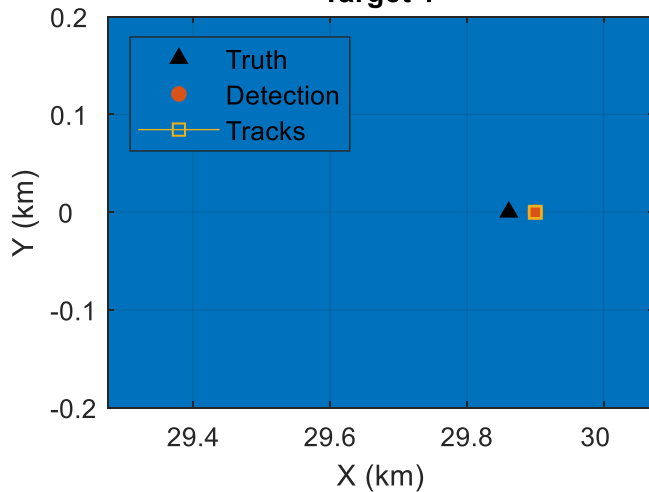
Search Beam Grid



Radar Azimuth Coverage



Target 1

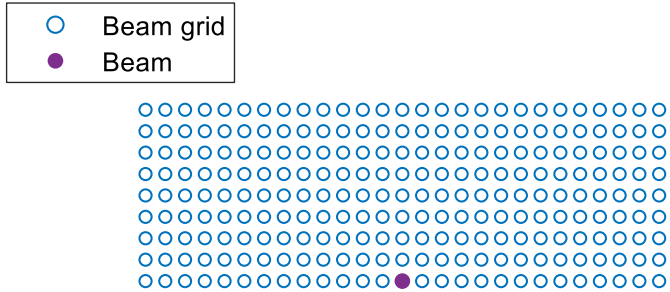


```

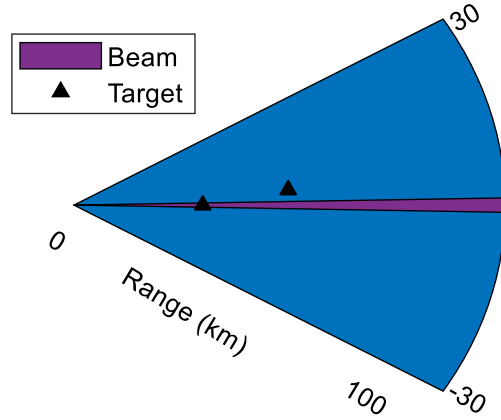
0.000000 sec: Search [-30.000000 0.000000]
0.010000 sec: Search [-27.692308 0.000000]
0.020000 sec: Search [-25.384615 0.000000]
0.030000 sec: Search [-23.076923 0.000000]
0.040000 sec: Search [-20.769231 0.000000]
0.050000 sec: Search [-18.461538 0.000000]
0.060000 sec: Search [-16.153846 0.000000]
0.070000 sec: Search [-13.846154 0.000000]
0.080000 sec: Search [-11.538462 0.000000]
0.090000 sec: Search [-9.230769 0.000000]
0.100000 sec: Search [-6.923077 0.000000]
0.110000 sec: Search [-4.615385 0.000000]
0.120000 sec: Search [-2.307692 0.000000]
0.130000 sec: Search [0.000000 0.000000] Target detected at 29900.000000 m
0.140000 sec: Confirm [-0.000586 -0.000034] Created track 1 at 29900.000000 m
    
```

Track 1 Updated

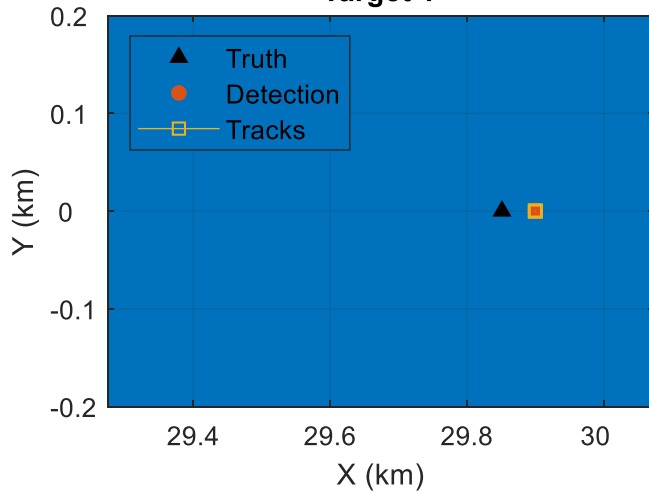
Search Beam Grid



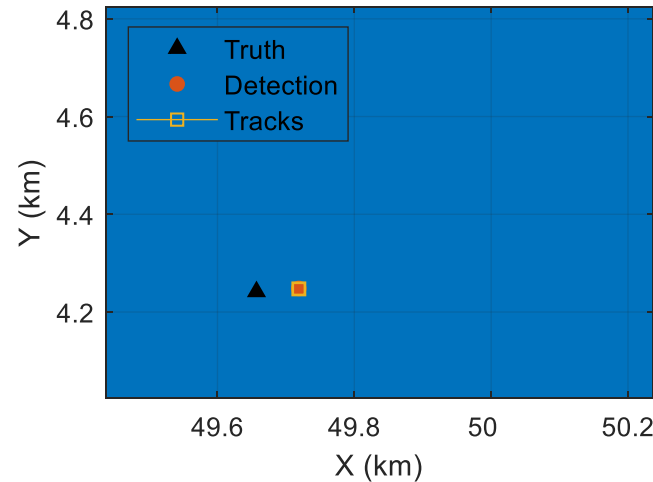
Radar Azimuth Coverage



Target 1



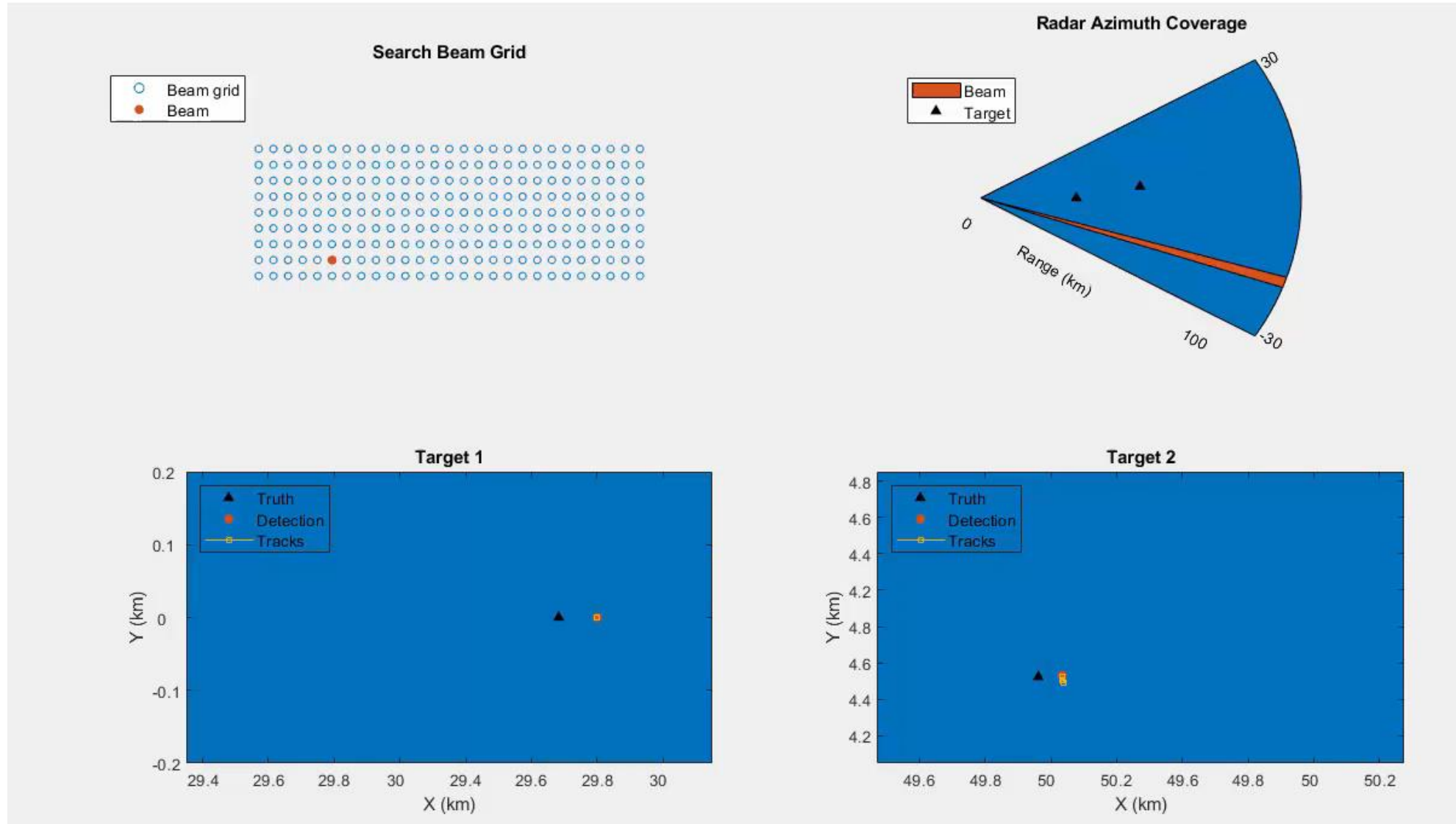
Target 2



```

0.000000 sec: Search [-30.000000 0.000000]
0.010000 sec: Search [-27.692308 0.000000]
0.020000 sec: Search [-25.384615 0.000000]
0.030000 sec: Search [-23.076923 0.000000]
0.040000 sec: Search [-20.769231 0.000000]
0.050000 sec: Search [-18.461538 0.000000]
0.060000 sec: Search [-16.153846 0.000000]
0.070000 sec: Search [-13.846154 0.000000]
0.080000 sec: Search [-11.538462 0.000000]
0.090000 sec: Search [-9.230769 0.000000]
0.100000 sec: Search [-6.923077 0.000000]
0.110000 sec: Search [-4.615385 0.000000]
0.120000 sec: Search [-2.307692 0.000000]
0.130000 sec: Search [0.000000 0.000000] Target detected at 29900.000000 m
0.140000 sec: Confirm [-0.000586 -0.000034] Created track 1 at 29900.000000 m
0.150000 sec: Search [2.307692 0.000000]
0.160000 sec: Search [4.615385 0.000000] Target detected at 49900.000000 m
0.170000 sec: Confirm [4.881676 0.000739] Created track 2 at 49900.000000 m
0.180000 sec: Search [6.923077 0.000000]
0.190000 sec: Search [9.230769 0.000000]
0.200000 sec: Search [11.538462 0.000000]
0.210000 sec: Search [13.846154 0.000000]
0.220000 sec: Search [16.153846 0.000000]
0.230000 sec: Search [18.461538 0.000000]
0.240000 sec: Track [-0.000399 0.000162] Track 1 at 29900.000000 m>>
    
```

Multifunction Radar: Search and Track



- Search
- Track (confirm)
- Track (update)

Summary



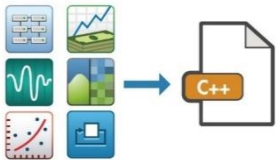
改善开发和测试工作流程。我们不仅提供算法，还提供传感器模型、场景生成和评估。



可重复使用和共享，从而提高整体效率



执行快速算法和系统权衡，可在开发早期消除错误。



从跟踪器和传感器融合模型直接生成C代码，用于原型设计和初始部署。

