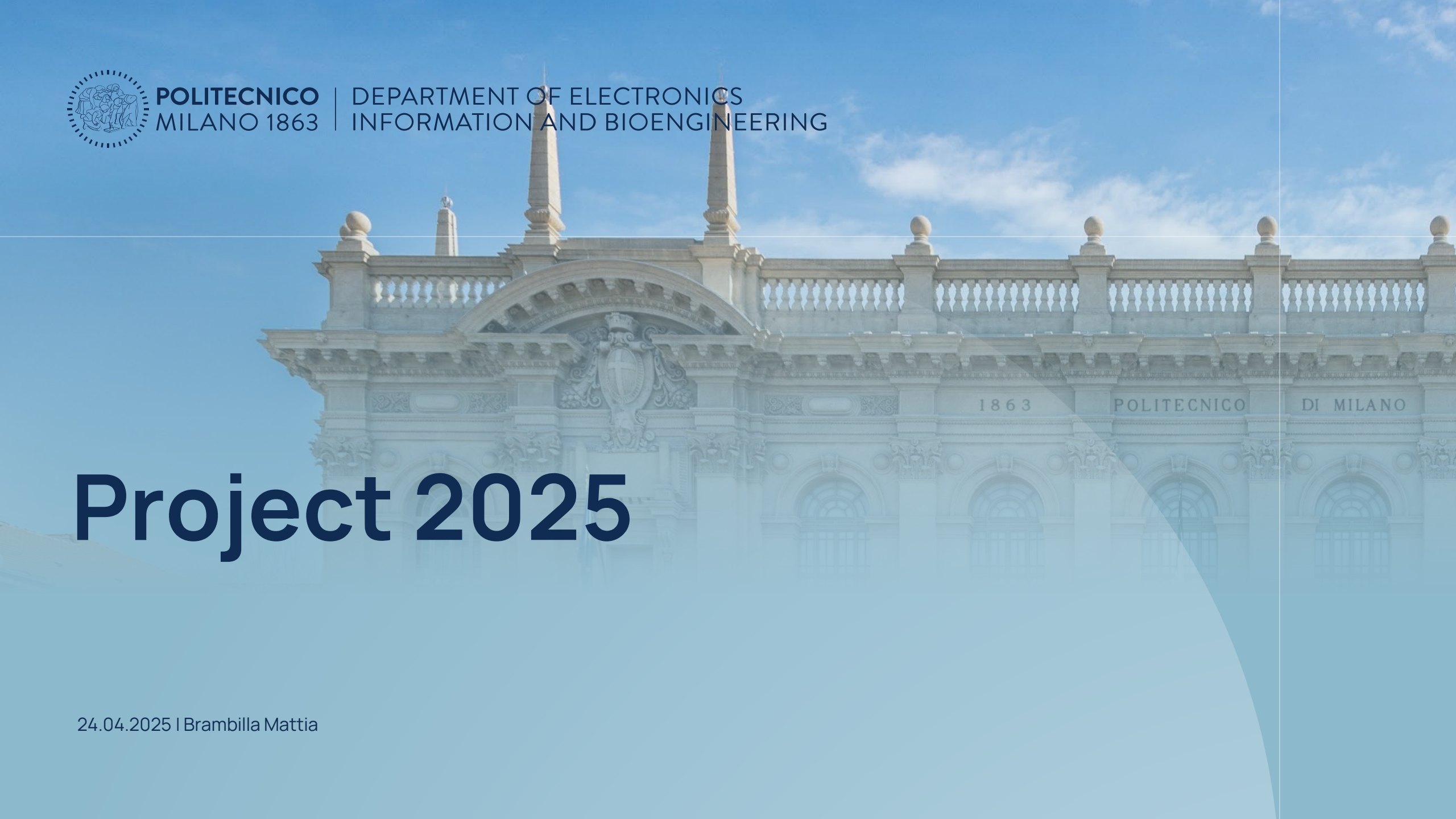


Project 2025

24.04.2025 | Brambilla Mattia

General rules

- Project mark
  - July 2025 up to **+4 points**
  - September 2025 up to **+4 points**
  - January 2026 up to **+3 points**

- The project is **valid only for the current academic year**.

- The project can be done **individually or in group** (up to 4 members). All group members will get the same score (unless disparities or issues are motivated by group members).
  The project data are available in WeBeep.

- The project is independent w.r.t. to the exam but it has to be officially registered once.

- Evaluation strategy: **15 min presentation** of the results. Delivery material: Matlab code and the slides/ppt.

- There will be one day for presenting the project at the end of Jul25, one at the end of Sep25, and one at the end of Jan26. The exact day of presentation will be provided.

Groups

Please organize yourselves in groups by writing the members in this file:

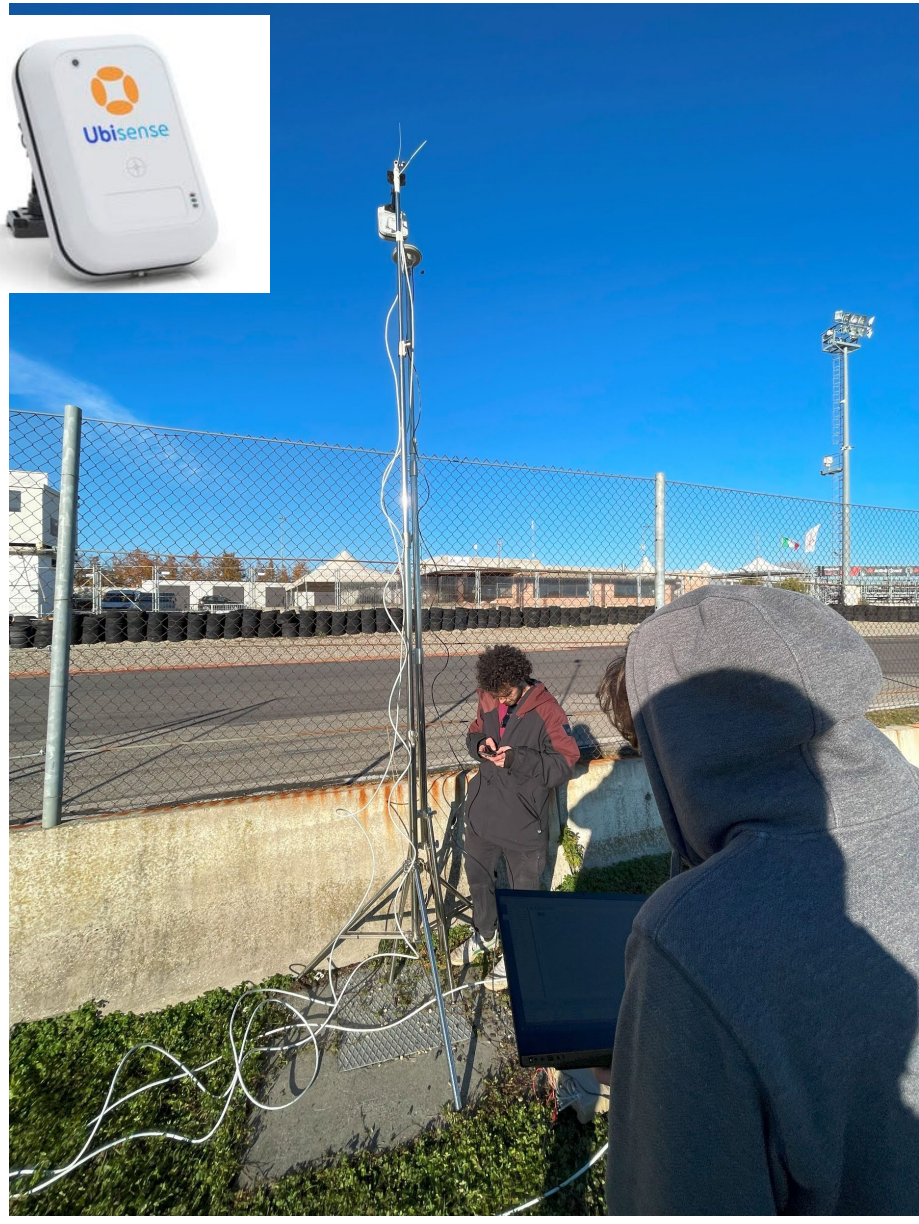
Groups.xlsx

Deadline: 31 May 2025.
After the deadline, no group variations are accepted.
The sooner you organize, the sooner you can start (even tomorrow).

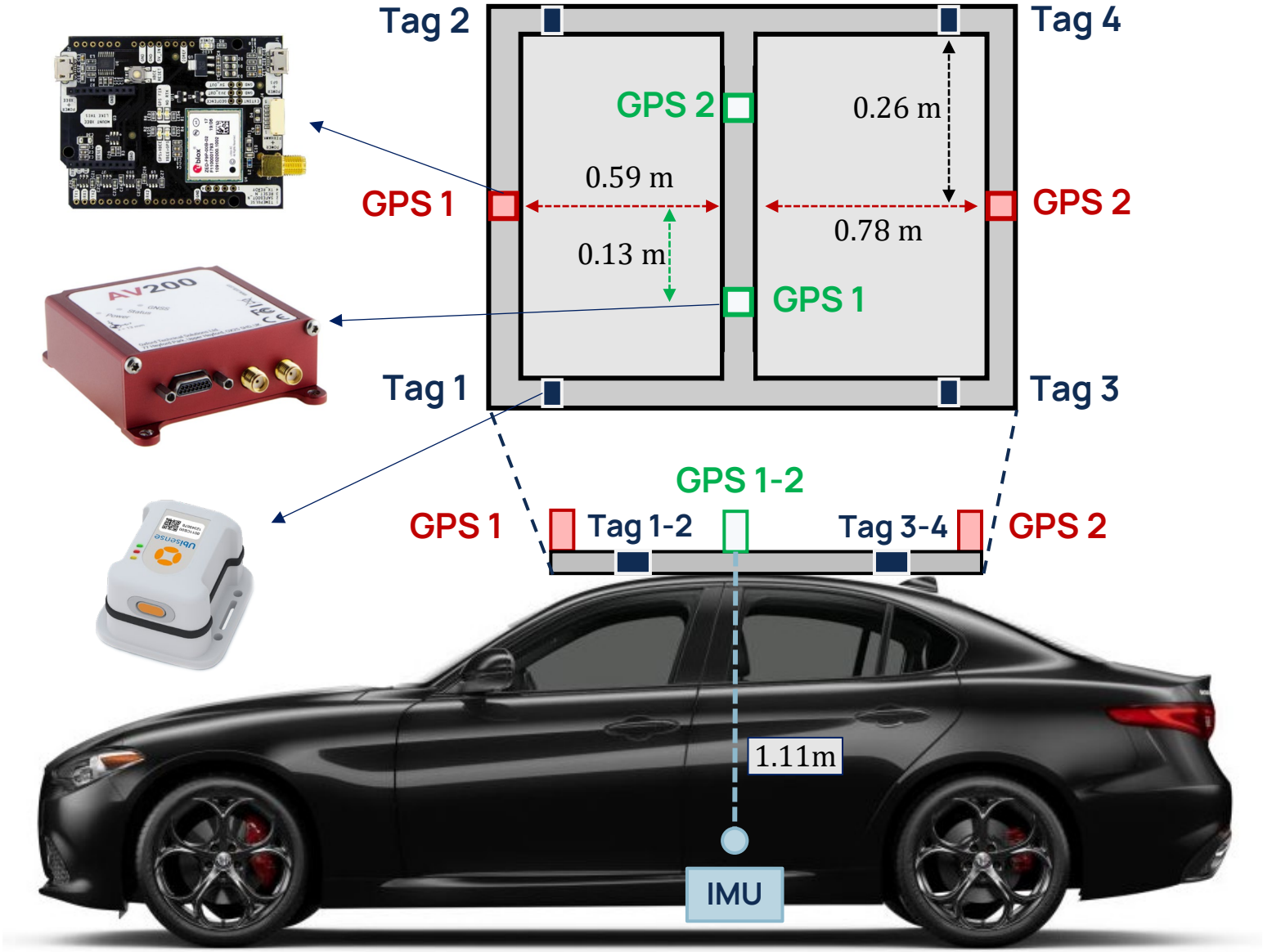
Vehicle localization in a racetrack

10 UWB antennas from Ubisense Dimension 4.

Nominal sample rate: 10 Hz

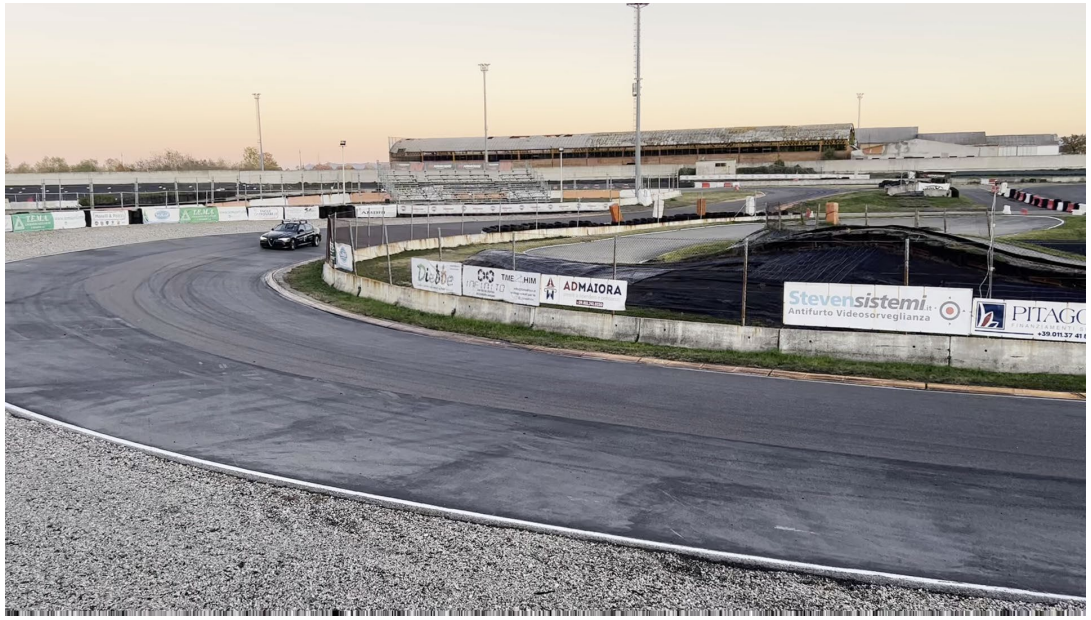


Vehicle setup

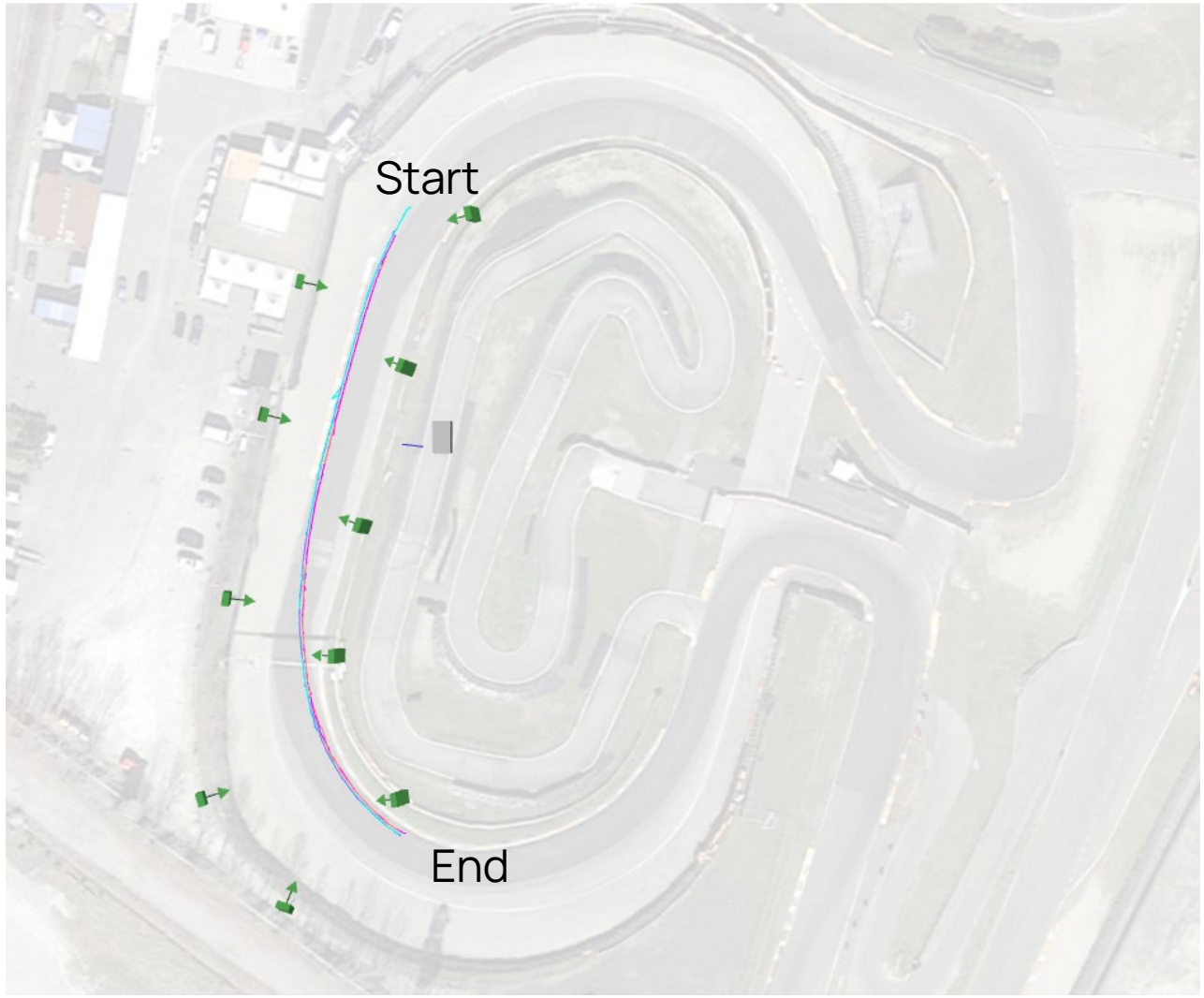


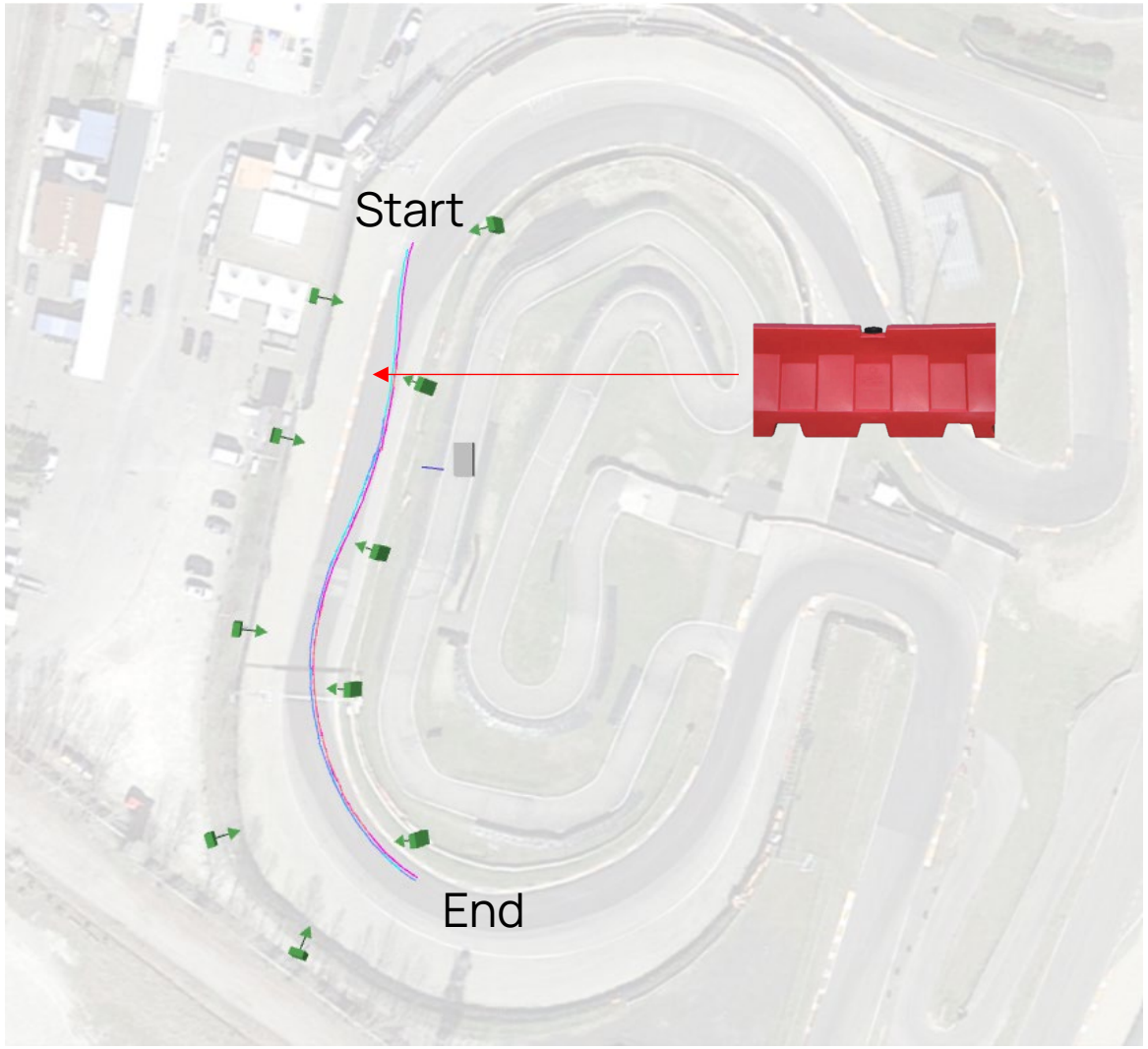
Test video

Different tests, free tracks or obstacle avoidance

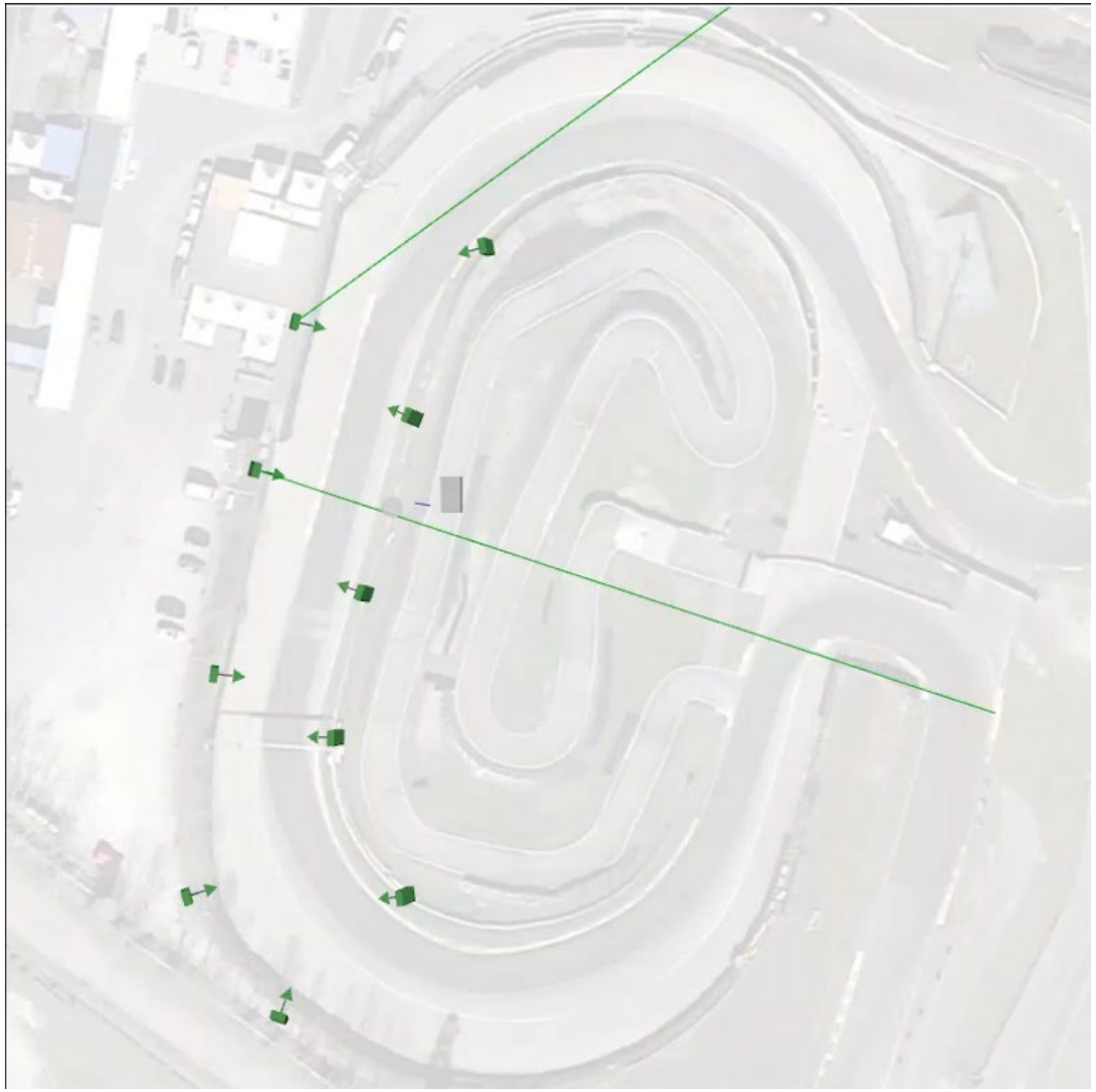


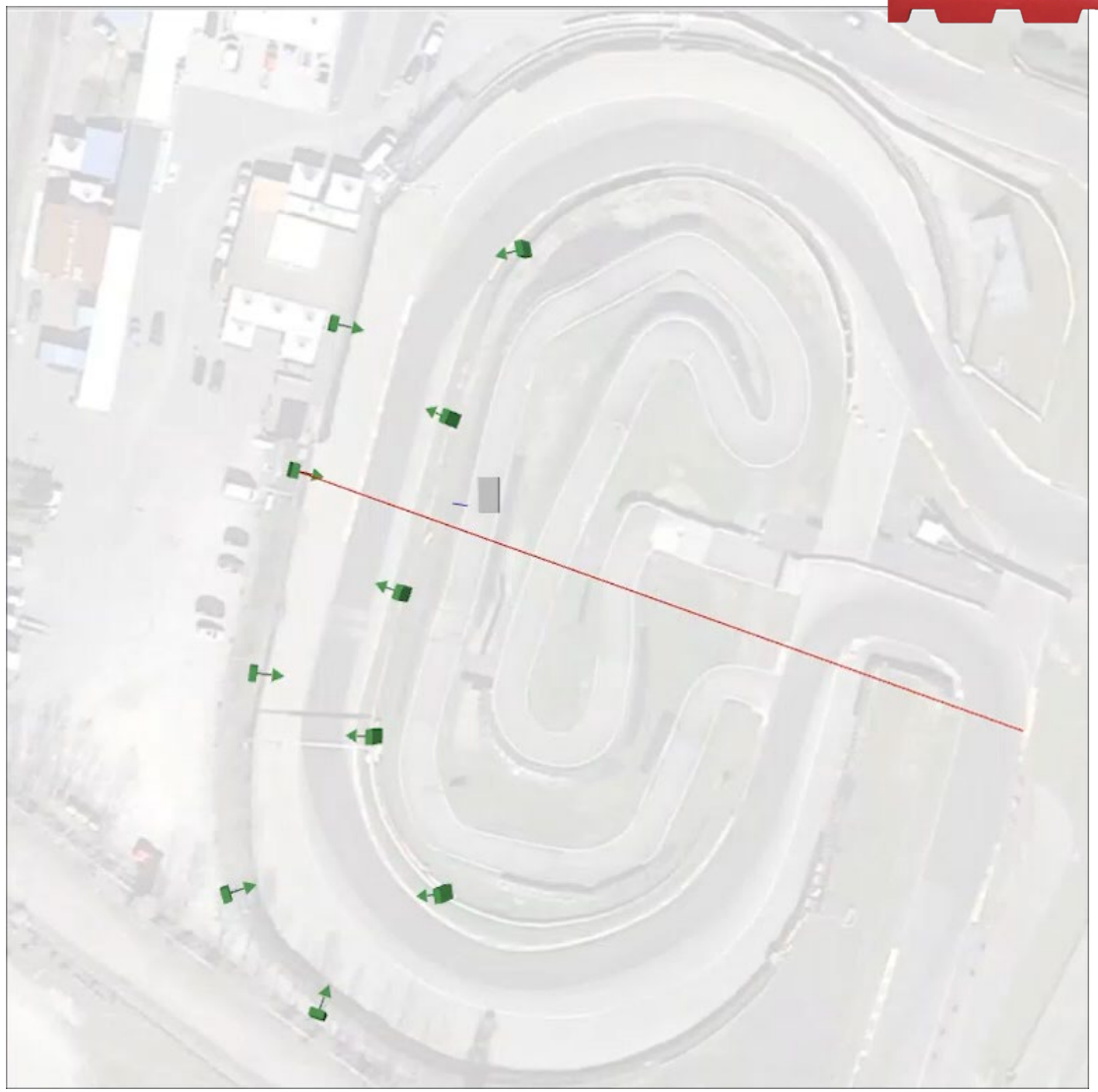
Localization results



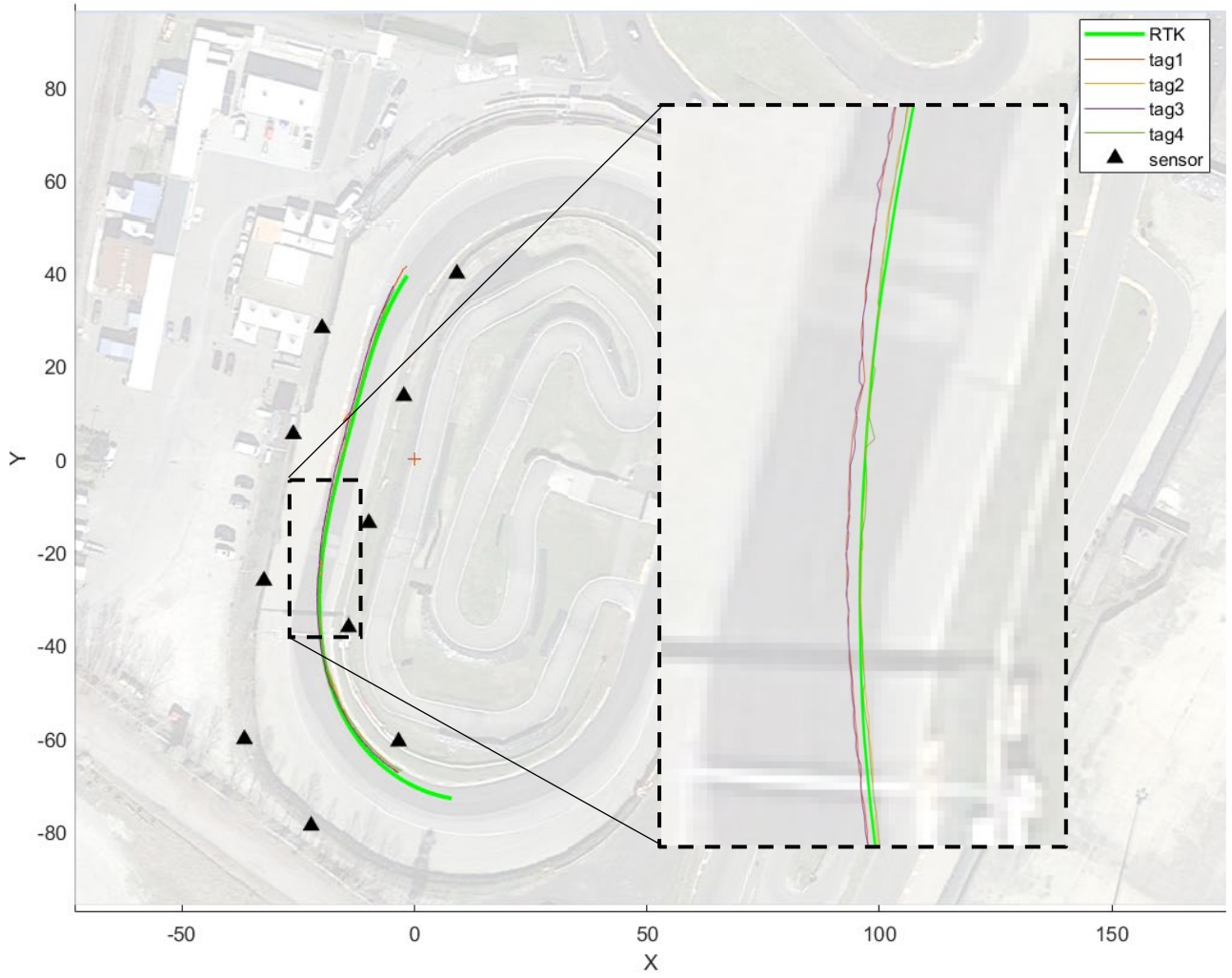


Video replay





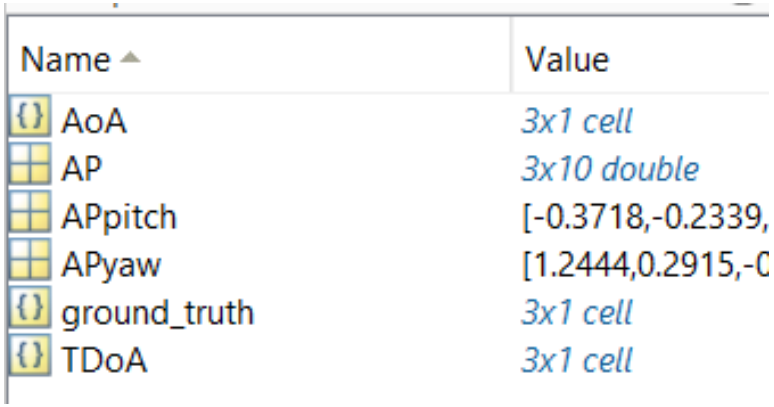
Example of GPS vs UWB positioning



3D reconstruction (Matlab)

Data

3 datasets, same data structure (next slides)



Name	Value
AoA	*3x1 cell*
AP	*3x10 double*
APpitch	[-0.3718,-0.2339,
APyaw	[1.2444,0.2915,-0
ground_truth	*3x1 cell*
TDoA	*3x1 cell*

1 obstacle

2 Free track

3 obstacle

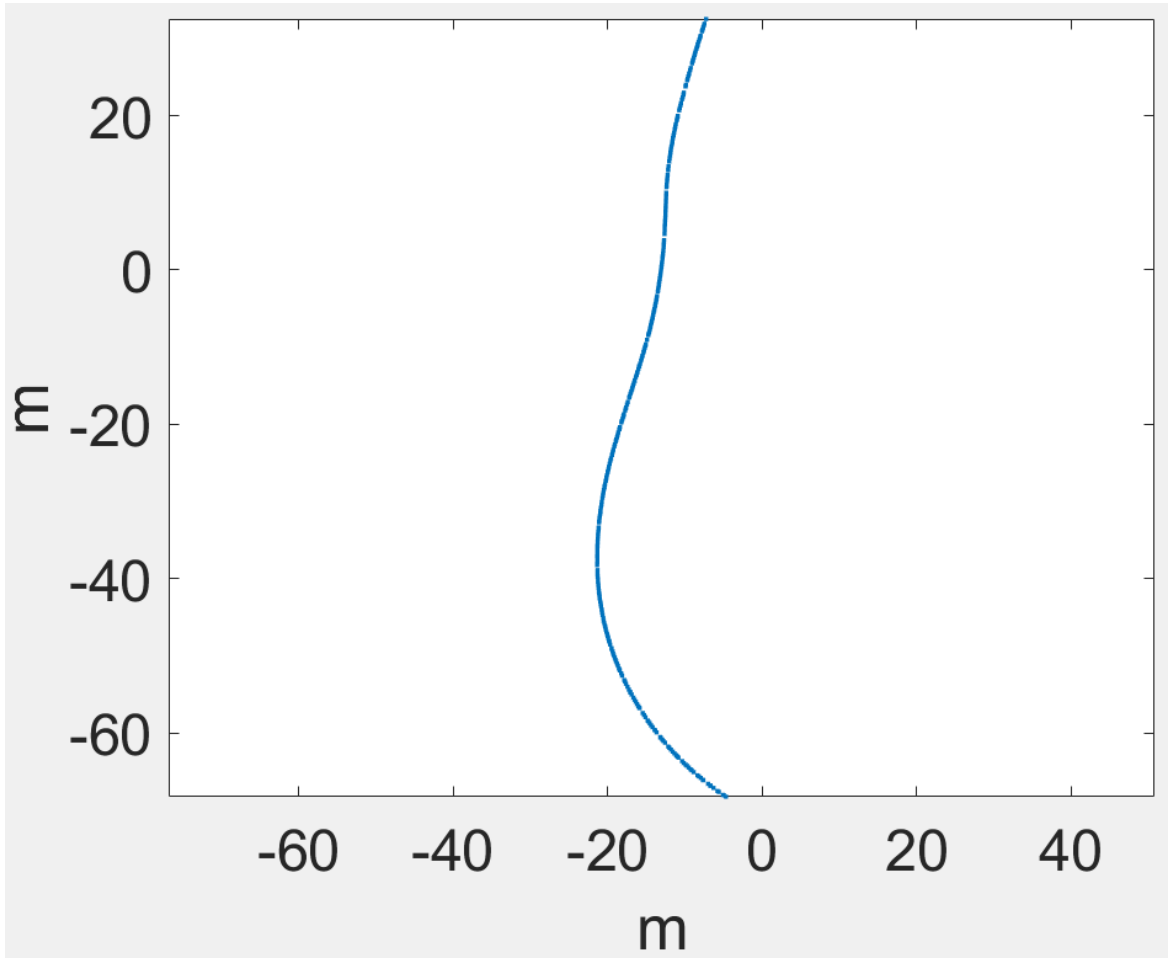
Ground truth

Name	Value
AoA	*3x1 cell*
AP	*3x10 double*
APpitch	[-0.3718,-0.2339,
APyaw	[1.2444,0.2915,-0
ground_truth	*3x1 cell*
TDoA	*3x1 cell*

AP | ground_truth | ground_truth{1, 1}

ground_truth{1, 1}

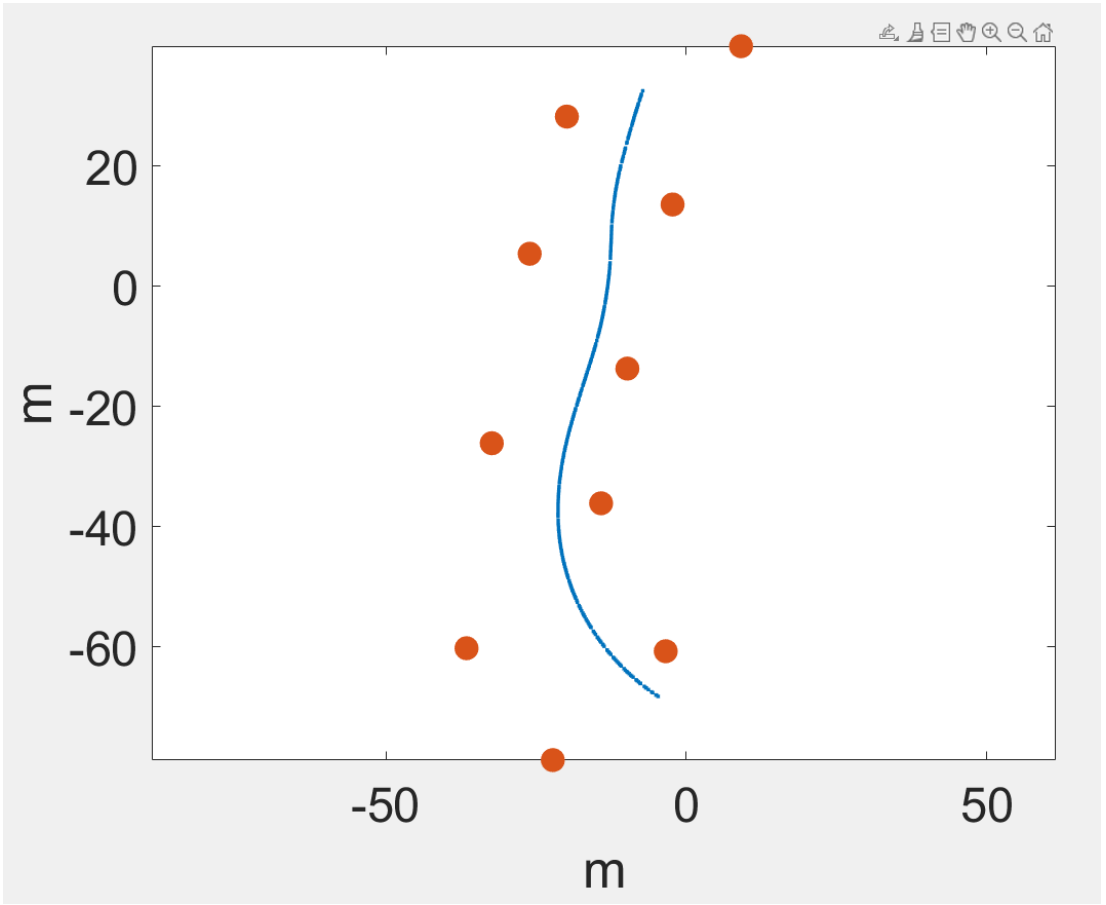
	1	2	3	4	5	6	7	8	
1	-7.2792	-7.4854	-7.5517	-7.6472	-7.7403	-7.8071	-7.9927	-8.0544	X [m]
2	32.4963	31.9012	31.7028	31.4076	31.1138	30.9177	30.3266	30.1284	Y [m]
3	2.0509	2.0509	2.0509	2.0489	2.0456	2.0434	2.0371	2.0351	Z [m]
4									



The vehicle true position is given by a combination of GPS RTK positioning.
You need to use it only for performance assessment.

Antenna position

Name	Value
AoA	*3x1 cell*
AP	*3x10 double*
APpitch	[-0.3718,-0.2339,
APyaw	[1.2444,0.2915,-0
ground_truth	*3x1 cell*
TDoA	*3x1 cell*



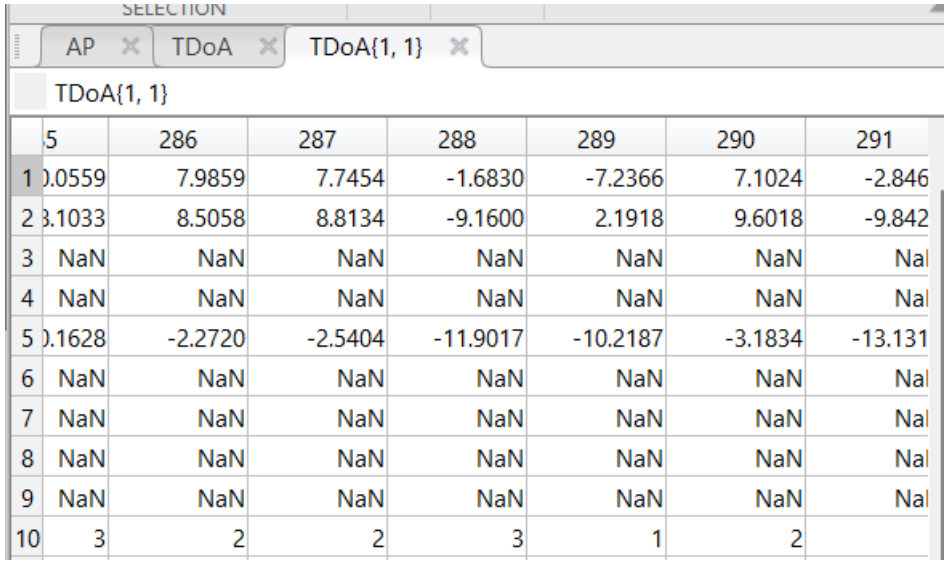
AP

3x10 double

	1	2	3	4	5	6	7	8	9	10
1	-22.2400	-36.6000	-32.4000	-26.0900	-19.9000	-3.4400	-14.2000	-9.8300	-2.3000	9.1000
2	-78.8000	-60.2000	-26.1100	5.3900	28.2000	-60.7000	-36.1000	-13.7000	13.5800	39.9000
3	6.1600	6.4200	5.1500	5.0900	5	3.4500	3.8100	3.6000	3.7700	3.6900
4										

X [m]
Y [m]
Z [m]

Data structure – TDOA measurement



SELECTION

AP | TDoA | TDoA{1, 1}

TDoA{1, 1}

	5	286	287	288	289	290	291
1	0.0559	7.9859	7.7454	-1.6830	-7.2366	7.1024	-2.846
2	3.1033	8.5058	8.8134	-9.1600	2.1918	9.6018	-9.842
3	NaN	NaN	NaN	NaN	NaN	NaN	Nal
4	NaN	NaN	NaN	NaN	NaN	NaN	Nal
5	0.1628	-2.2720	-2.5404	-11.9017	-10.2187	-3.1834	-13.131
6	NaN	NaN	NaN	NaN	NaN	NaN	Nal
7	NaN	NaN	NaN	NaN	NaN	NaN	Nal
8	NaN	NaN	NaN	NaN	NaN	NaN	Nal
9	NaN	NaN	NaN	NaN	NaN	NaN	Nal
10	3	2	2	3	1	2	

10 APs -› 9 TDOA meas., expressed in meters
The master AP m is indicated in row 10 (last row)

TDOA meas: $\rho_i = d_i - d_m$

d_i: distance of the i-th AP

d_m: distance of the master AP

TDOA indexes are incremental, and the master is excluded from the count (see next slide)

TDOA explanation

$\rho_2 = d_2 - d_1$

$\rho_3 = d_3 - d_1$

28	29
-5.6409	6.4293
7.9177	13.3964
NaN	28.0594
NaN	NaN
NaN	NaN
NaN	NaN
NaN	NaN
NaN	NaN
NaN	NaN
1	2

$\rho_1 = d_1 - d_2$

$\rho_3 = d_3 - d_2$

$\rho_4 = d_4 - d_2$

AOA measurements

AoA | AoA{1, 1}

AoA{1, 1}

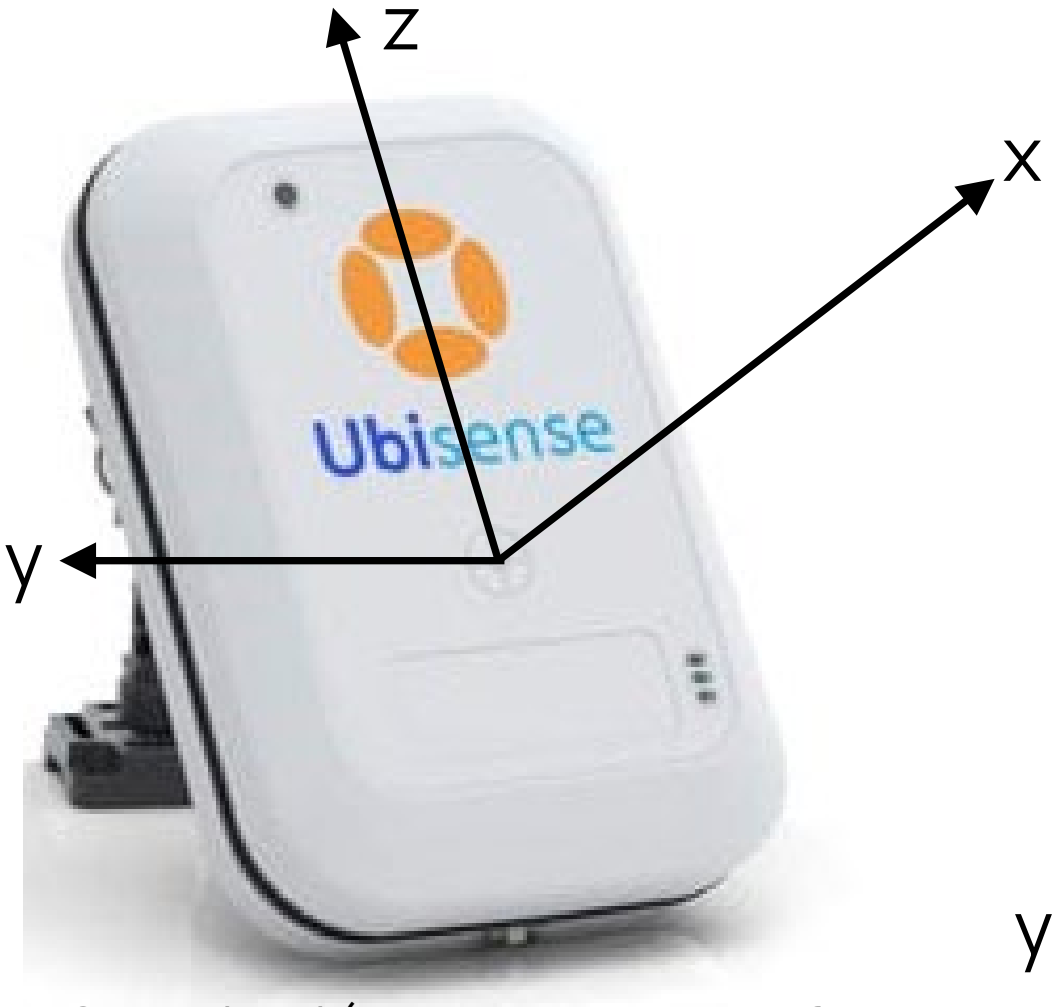
78	79	80	81	82	83	84	85	86	87	88
NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
0.5114	0.4843	0.4770	0.4595	0.4431	0.4175	0.4077	0.3789	0.3608	0.3241	0.3124
-1.0151	-1.0165	-1.0249	-1.0467	-1.0524	-1.0345	-1.0697	-1.1023	-1.0594	-1.0591	-1.0964
NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
0.8357	0.8604	0.8716	0.9006	0.9149	0.9285	0.9732	0.9695	1.0025	1.0381	1.0720
NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
0.1004	0.1136	0.1192	0.1105	0.1107	0.1234	0.1147	0.1243	0.1283	0.1393	0.1246
0.0700	0.0499	0.0567	0.0559	0.0625	0.0490	0.0504	0.0590	0.0572	0.0698	0.0398
NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
0.1119	0.0887	0.1038	0.0696	0.0641	0.0616	0.0773	0.0625	0.0532	0.0709	0.0482
NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN

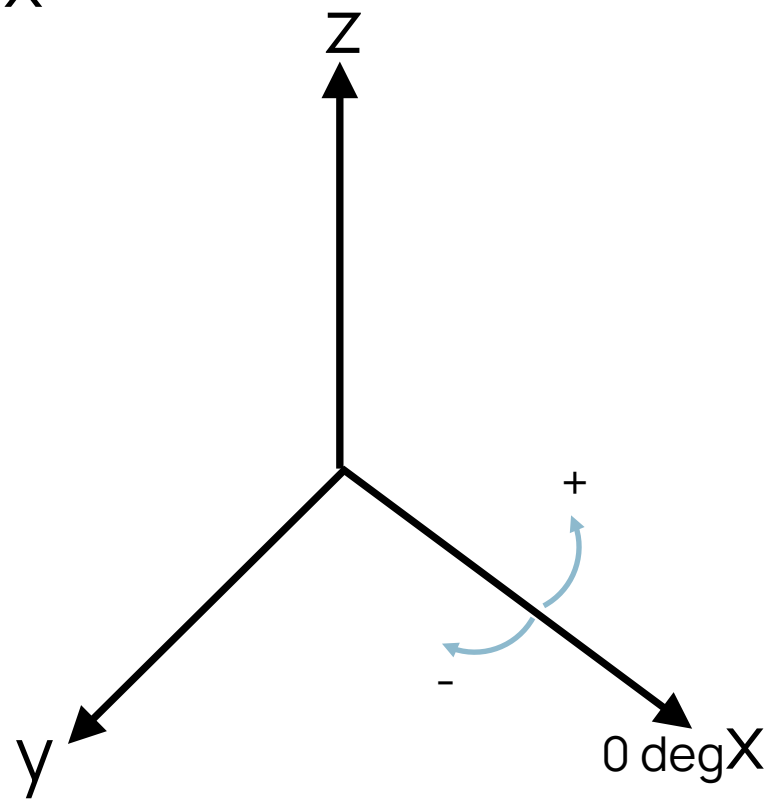
10 azimuth

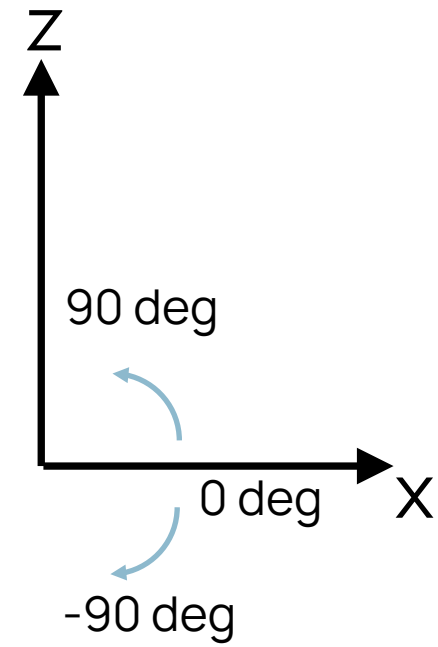
10 elevation

radians

AOA reference system

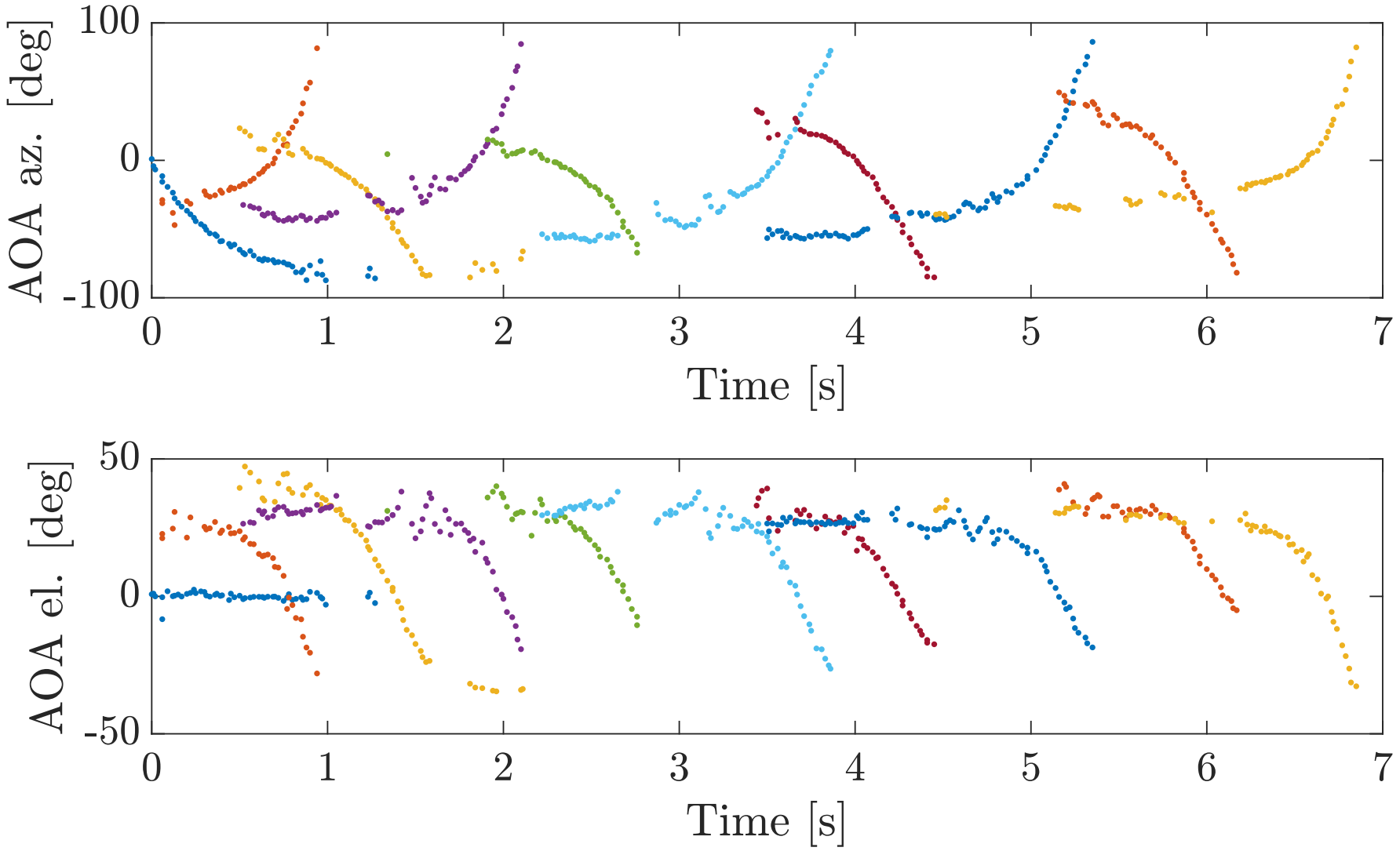






AOA are local (w.r.t. the antenna reference system).
To convert from local to global, a correction by pitch and yaw must be applied.

Raw AoA


AOA az. [deg]
100
0
-100
0
1
2
3
4
5
6
7
Time [s]
AOA el. [deg]
50
0
-50
0
1
2
3
4
5
6
7
Time [s]

Adjusted AoA

APyaw

1x10 double

	1	2	3	4	5	6	7	8	9	10
1	1.2444	0.2915	-0.1326	-0.2496	-0.2199	-3.0037	3.1172	2.7978	2.7646	-2.9409

rad

APpitch

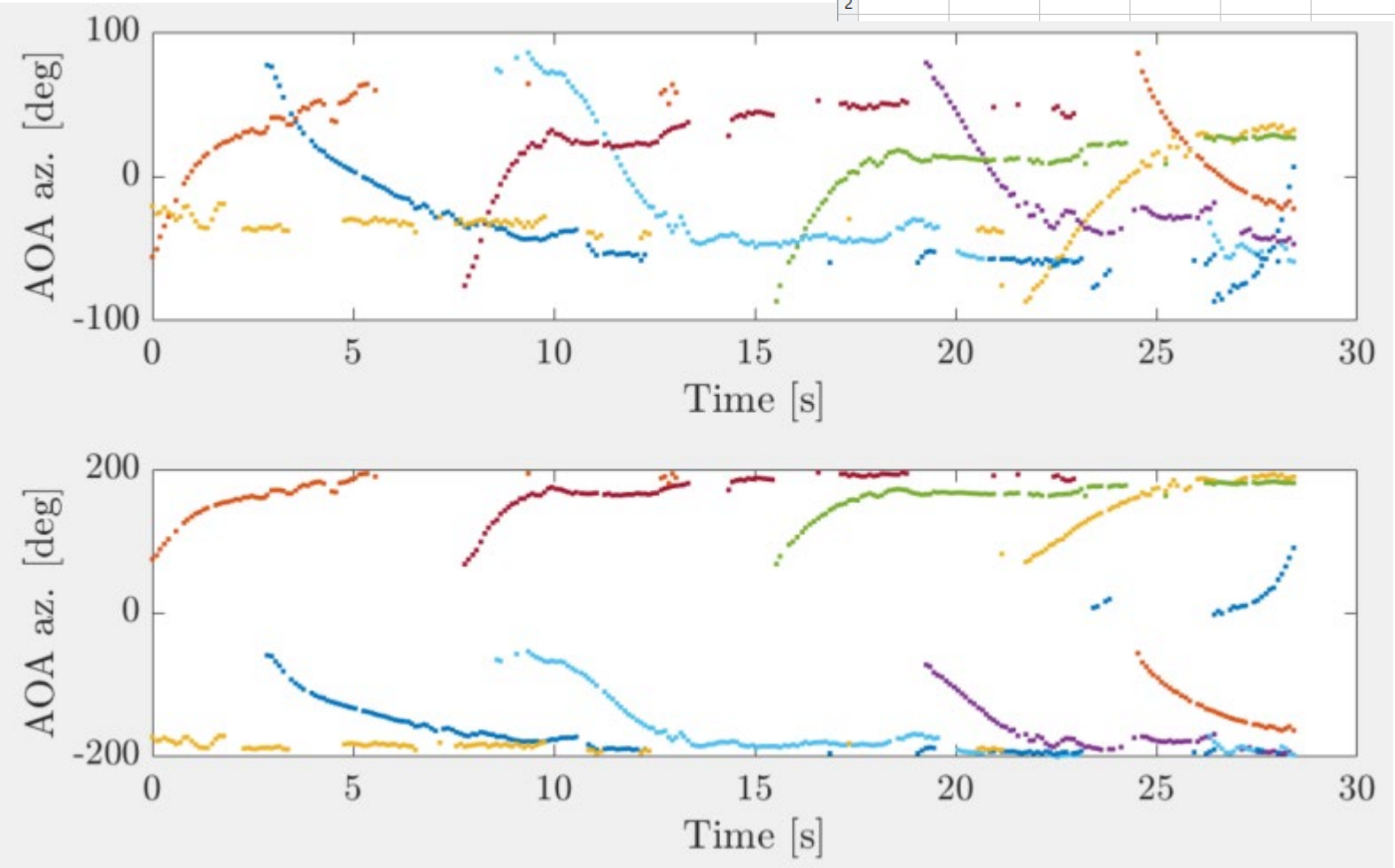
1x10 double

	1	2	3	4	5	6	7	8	9	10
1	-0.3718	-0.2339	-0.2321	-0.3927	-0.2915	-0.3299	-0.2182	-0.2339	-0.3595	-0.2182
2										

rad

Raw meas.

Post-conversion into global coordinates



Conversion into global coordinates: APyaw + AoA_azimuth and APpitch + AoA_elevation

Tasks

1. Measurement analysis: load, analyze, understand and **visualize data.**

2. Localize the vehicle **(2D required, 3D optional)**
   Compare TDOA-only, AOA-only, TDOA+AOA localization methods. Choose the best tracking algorithm. **The choice is up to you** (choose correctly ☺).
   Minimum requirement: 1 algorithm. A comparison of 2+ methods is appreciated.

3. Compare different algorithm parametrizations by analyzing the results in terms of:
   - positioning accuracy (mandatory),
   - visualization of the positioning estimate and errors (mandatory)
   - velocity estimate (optional)
   - more (up to you). E.g., availability, reliability, any other analyses you believe relevant

   Specify all the parametrization in the presentation!

4. You can use static plots as well as videos/GIFs. **Graphs should be self-explanatory**.
   It is highly recommended to provide different error metrics/graphs for a broader perspective of the performance analyses. Carefully select the way to present the results, the types of analysis and graph. Motivate your choices and provide critical analyses.