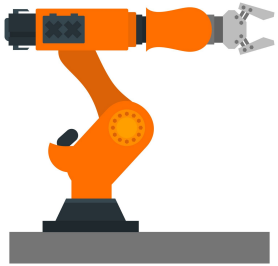
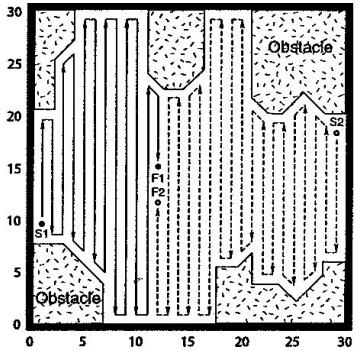
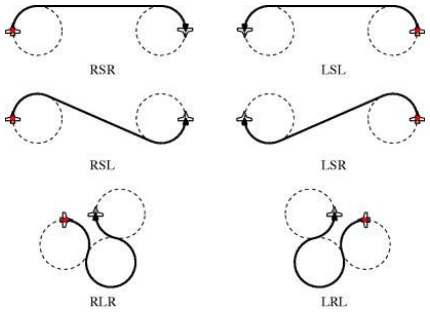
Kinematic coverage planning for object searching with autonomous underwater vehicle

Emilia Szymańska
Florin Kümin, Rik Bähnemann, Jonas Wüst

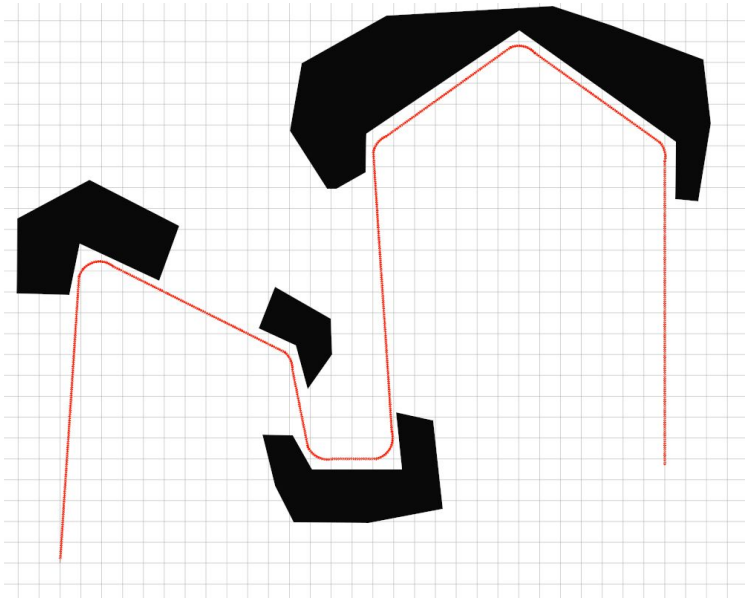
Motivation

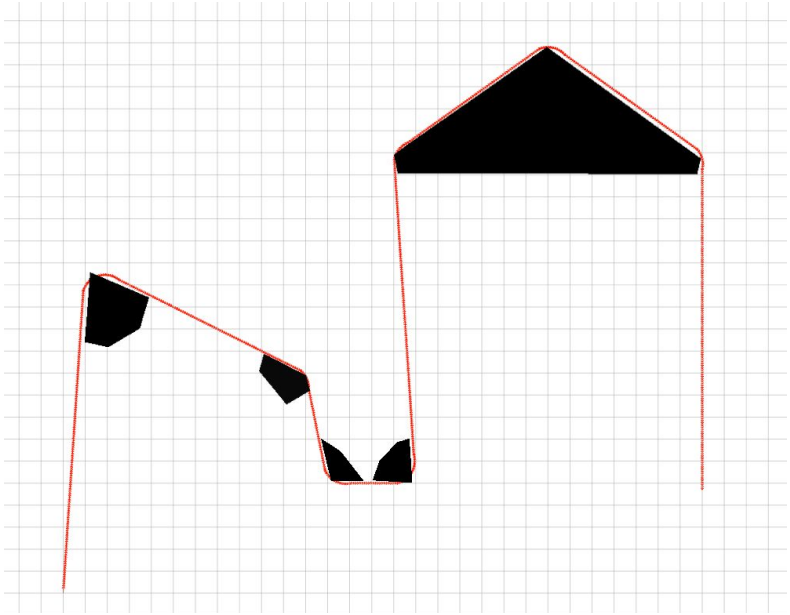



Obstacle
Obstacle
S1
S2
F1
F2
0
5
10
15
20
25
30

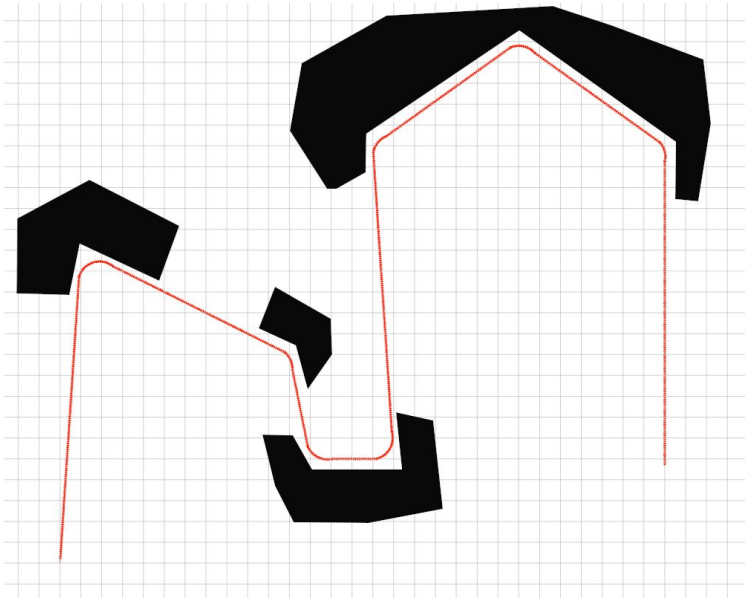

RSR
LSL
RSL
LSR
RLR
LRL

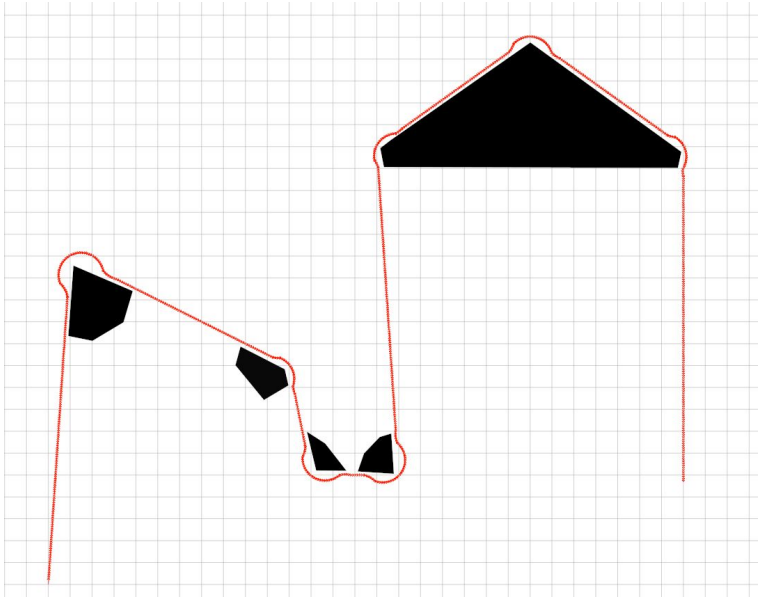
Motivation



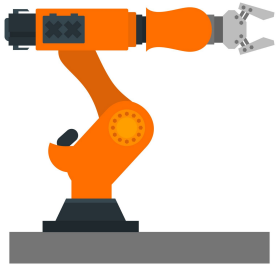


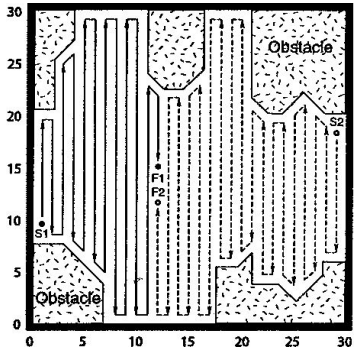
Motivation

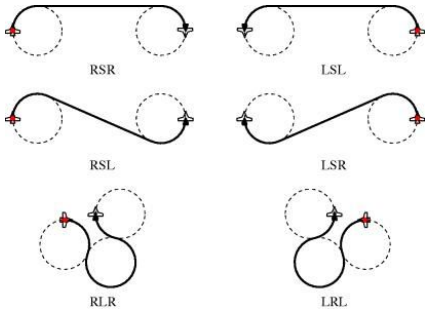


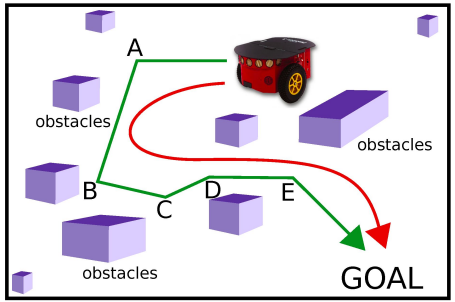


Motivation

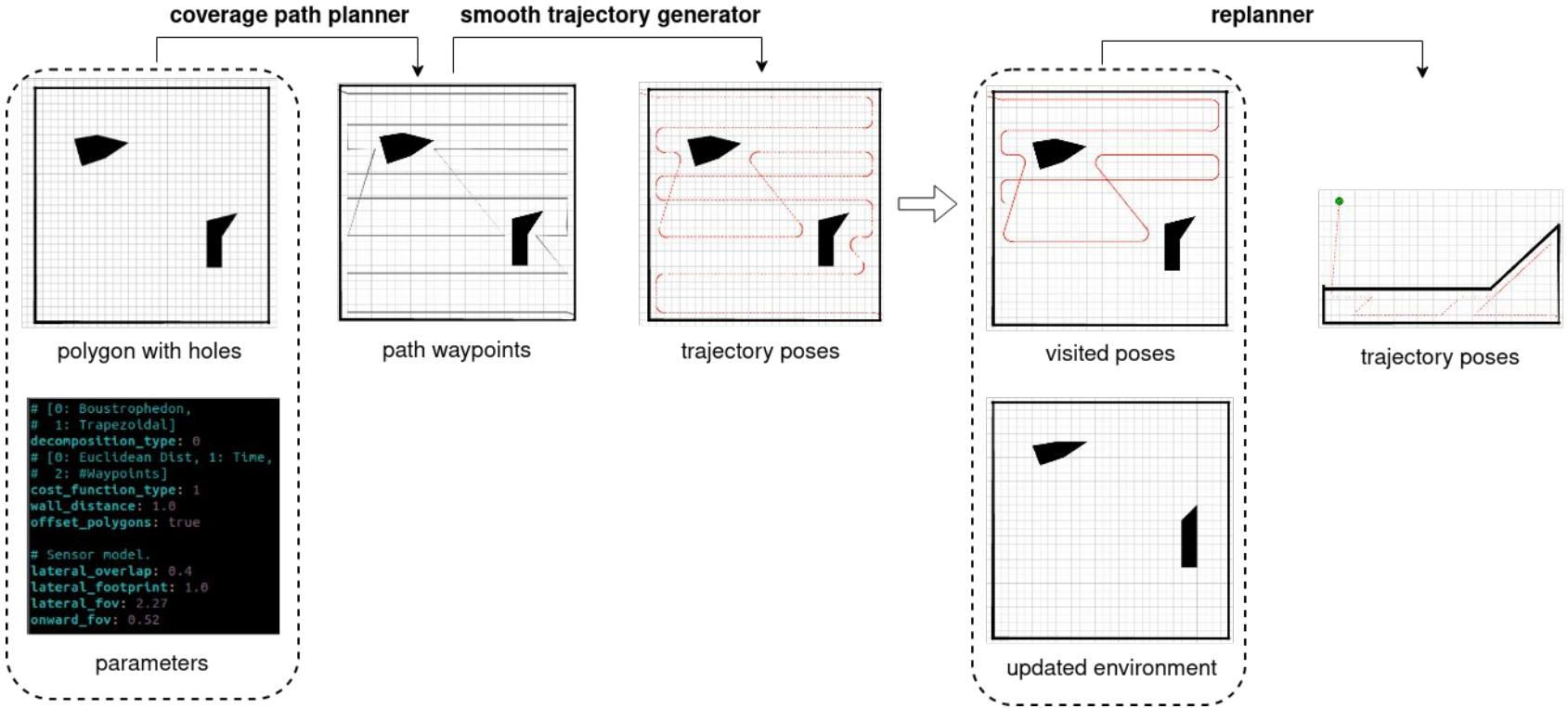



Obstacle
Obstacle
S1
S2
F1
F2
0
5
10
15
20
25
30

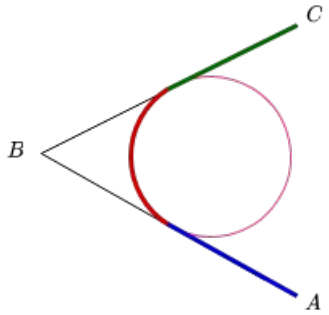

RSR
LSL
RSL
LSR
RLR
LRL


A
obstacles
obstacles
B
C
D
E
obstacles
GOAL

System pipeline

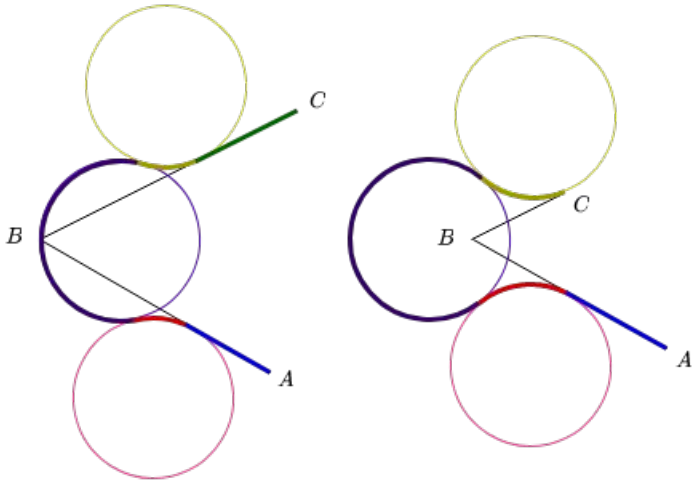


Smoothing



inner smoothing

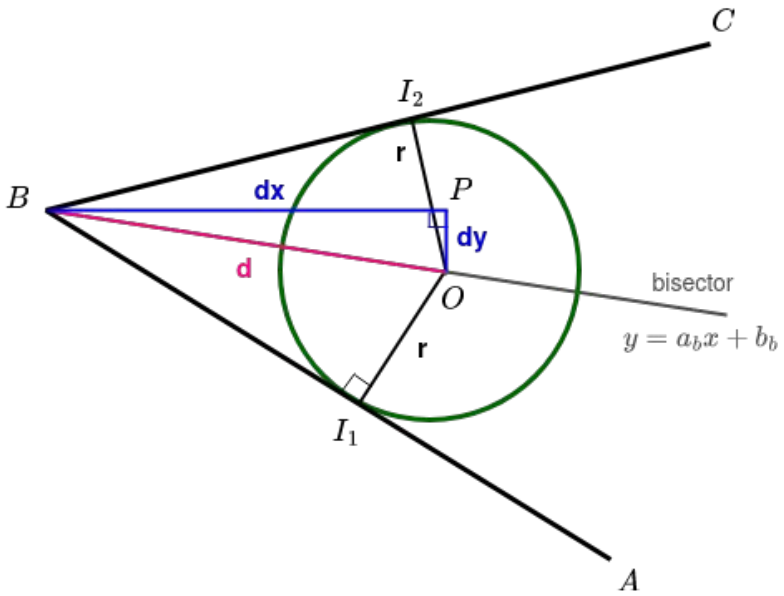
segment-arc-segment



outer smoothing

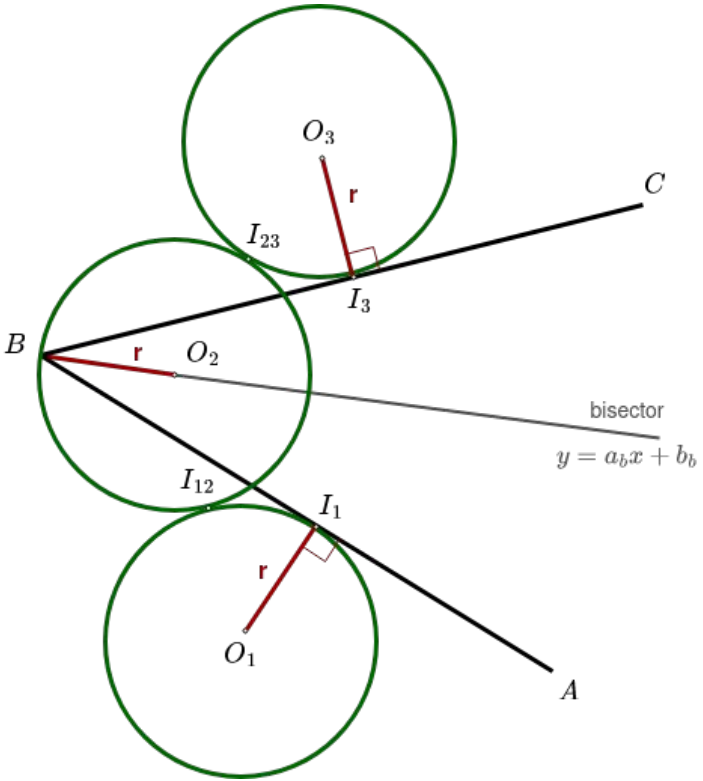
segment-arc-arc-arc-segment

Inner smoothing



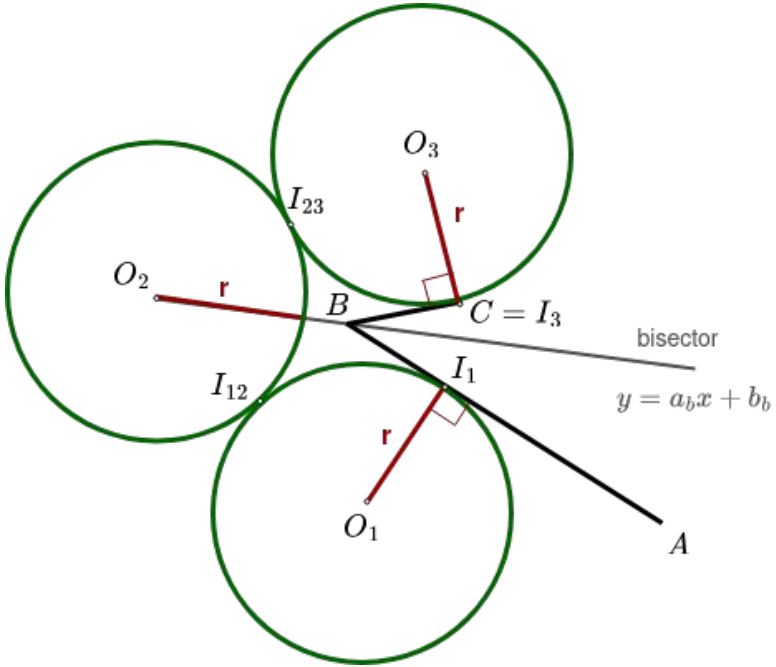
$$\begin{cases} r = dist(\overline{\mathrm{AB}}, O) \\ r = dist(\overline{\mathrm{BC}}, O) \end{cases}$$

Outer smoothing - minimum at bisector boundary



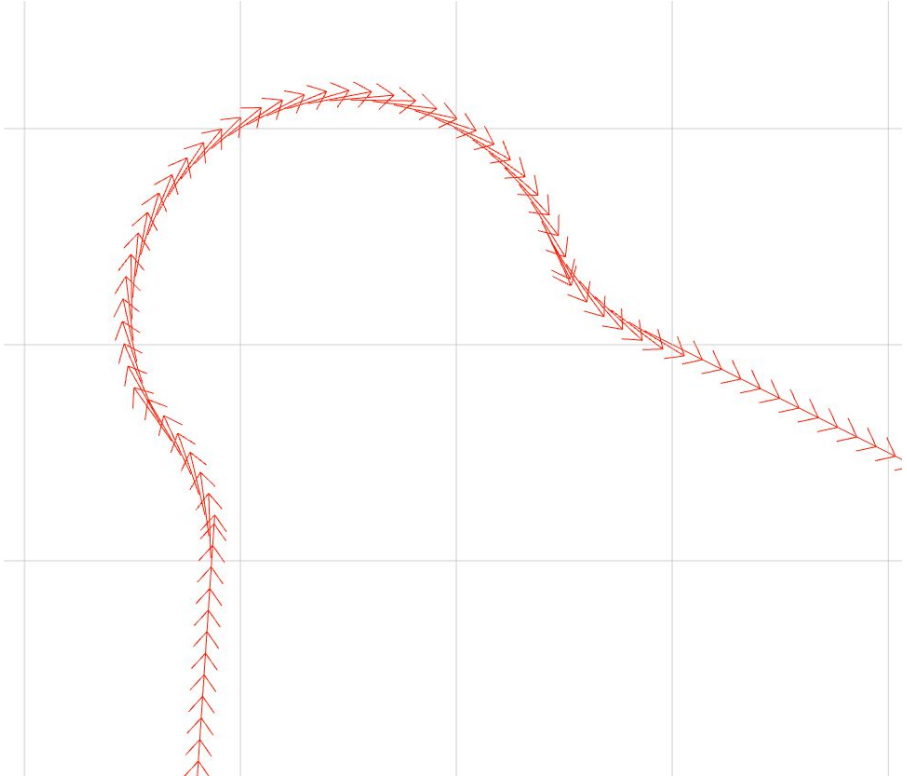
$$\begin{cases} r \geq |BO_2| \\ |O_1O_2| = 2r \\ |O_2O_3| = 2r \\ r = dist(\overline{\mathrm{AB}}, O_1) \\ r = dist(\overline{\mathrm{BC}}, O_3) \end{cases}$$

Outer smoothing - minimum at tangent intersection boundary

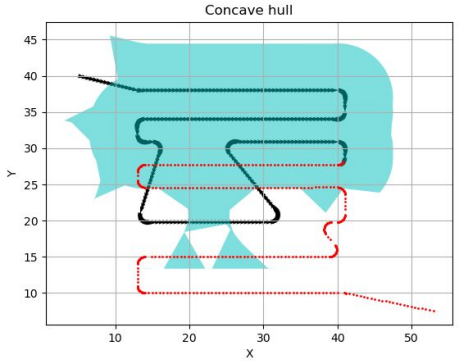


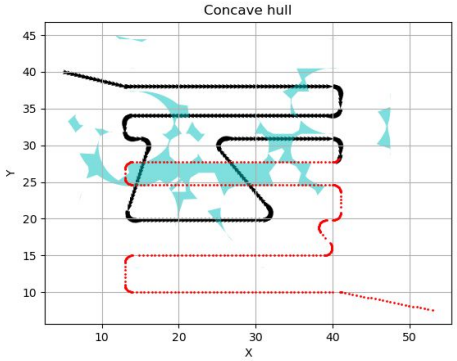
$$\begin{cases} |O_1O_2| = 2r \\ |O_2O_3| = 2r \\ r = dist(\overline{\mathrm{AB}}, O_1) \\ r = dist(\overline{\mathrm{BC}}, O_3) \end{cases}$$

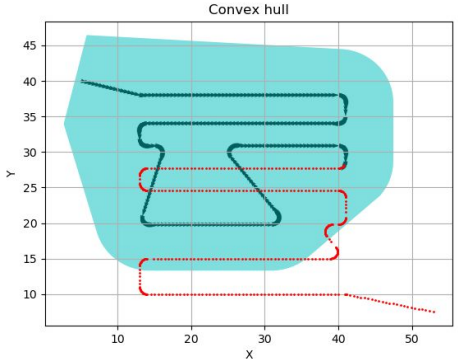
Trajectory generation

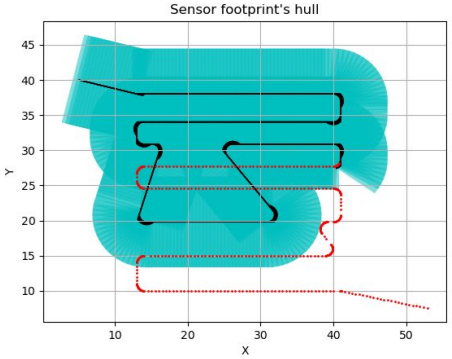


Replanning





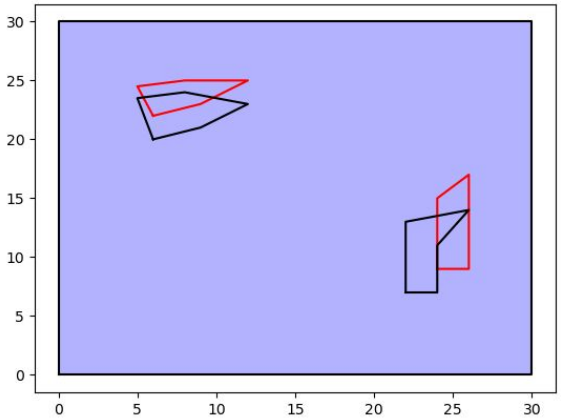


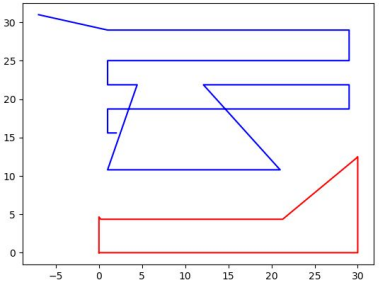


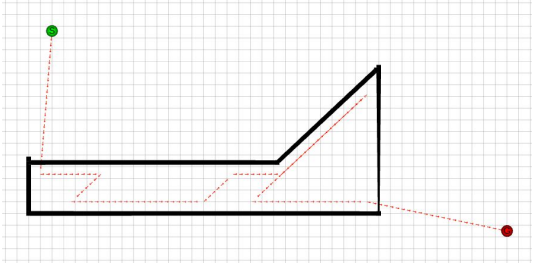
to-visit poses

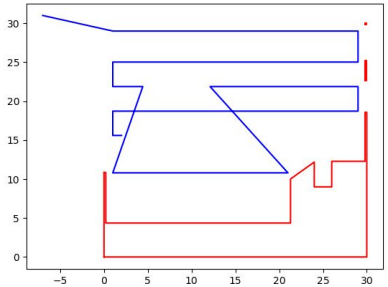
visited poses

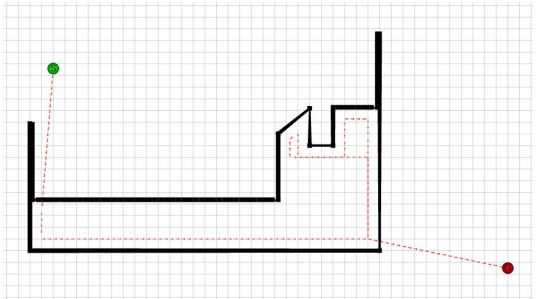
Replanning


30
25
20
15
10
5
0
0
5
10
15
20
25
30

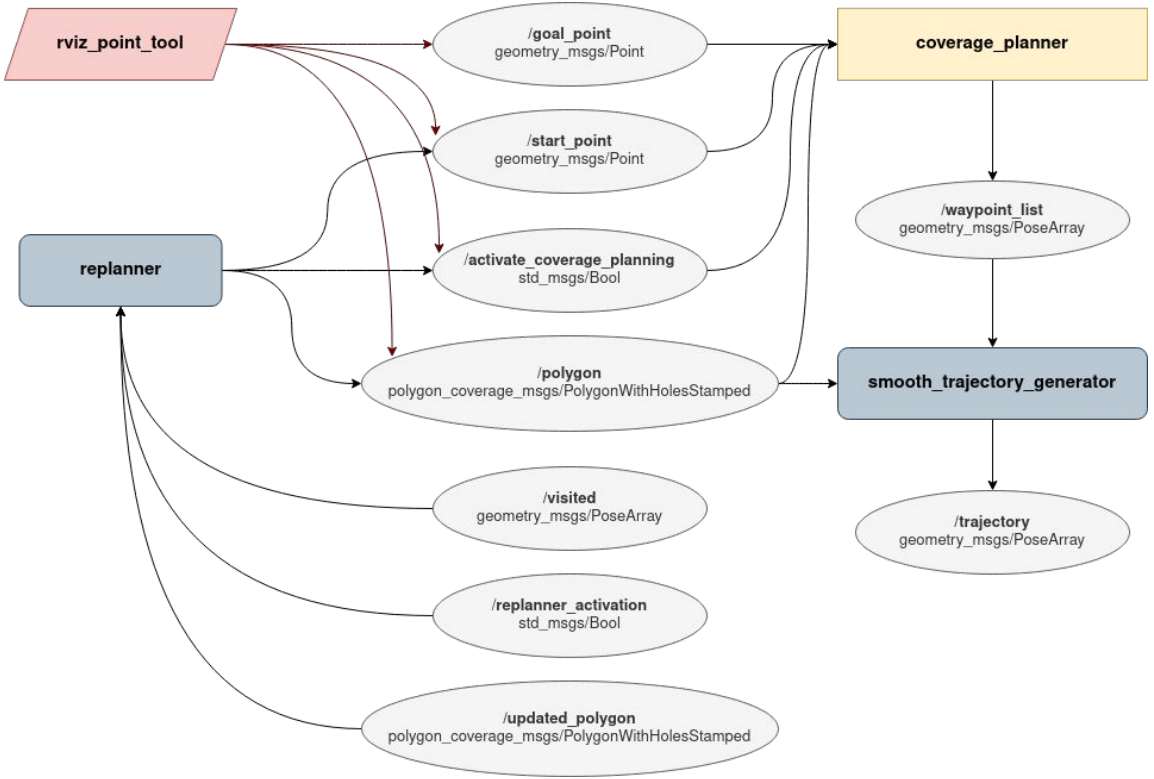

30
25
20
15
10
5
0
−5
0
5
10
15
20
25
30



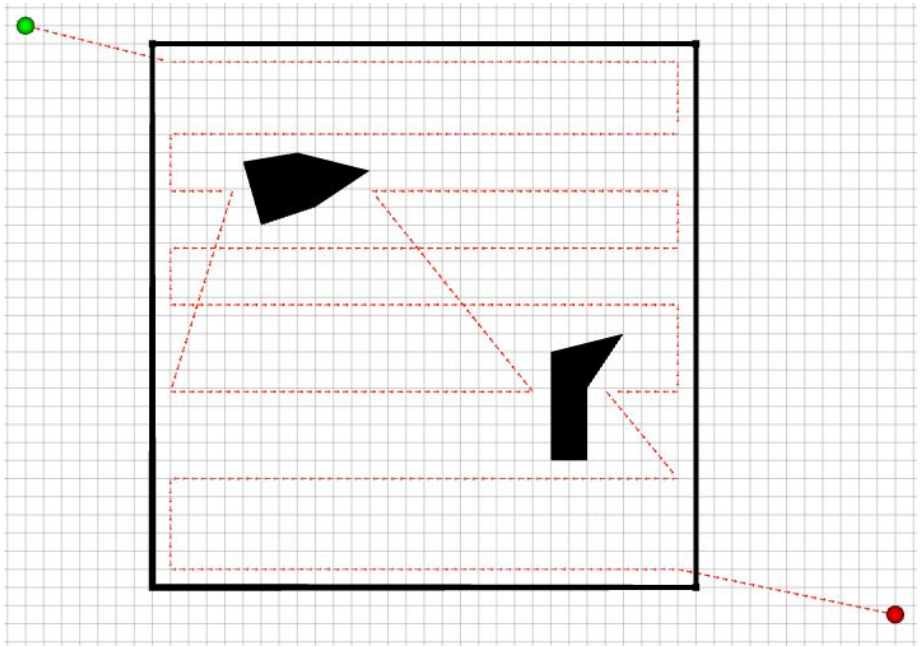

30
25
20
15
10
5
0
−5
0
5
10
15
20
25
30

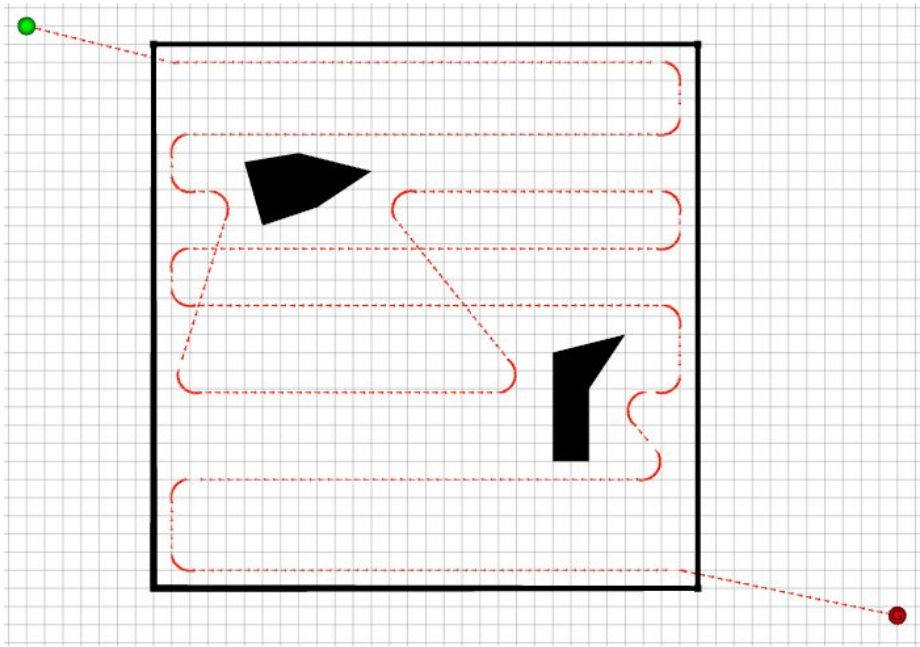


Software pipeline

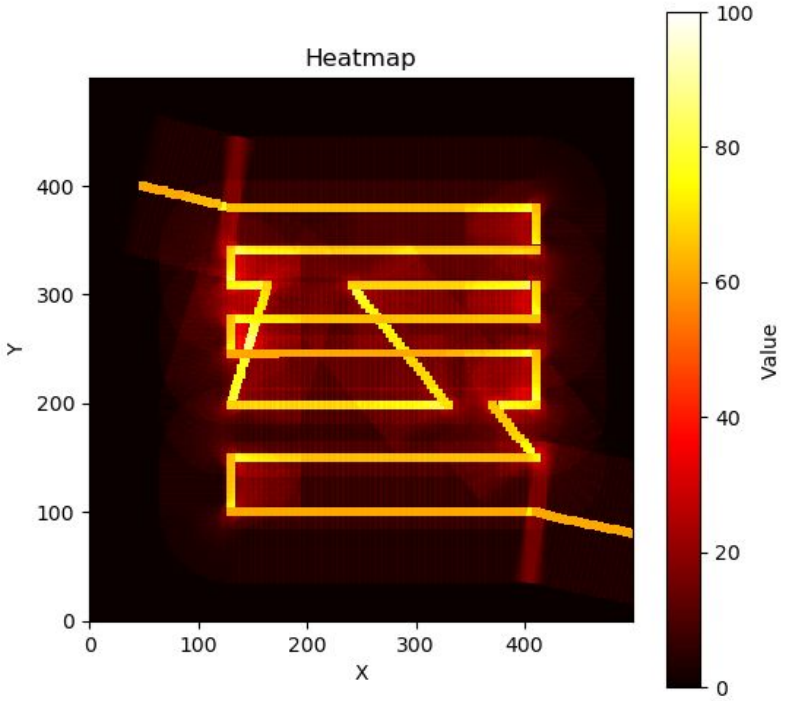


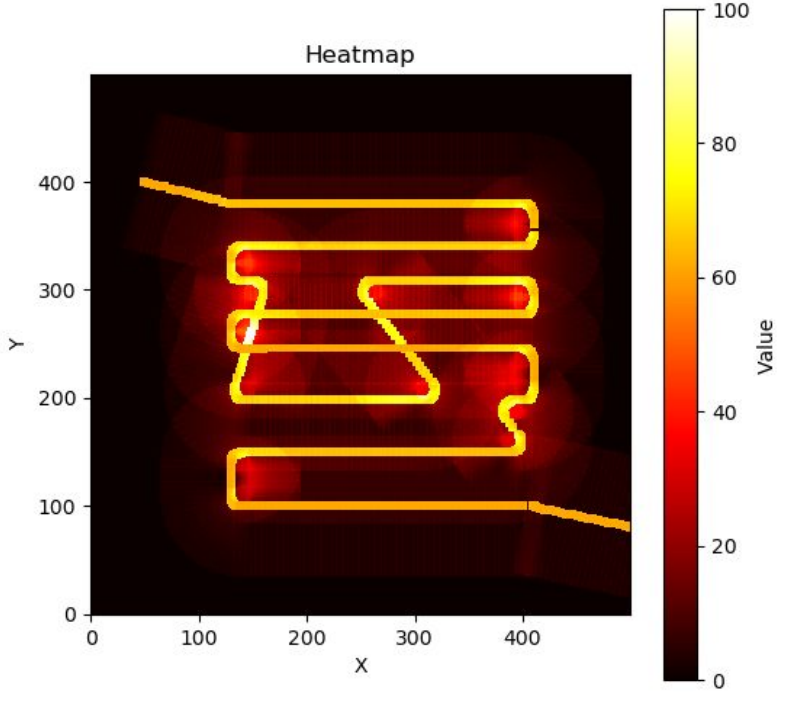
Results



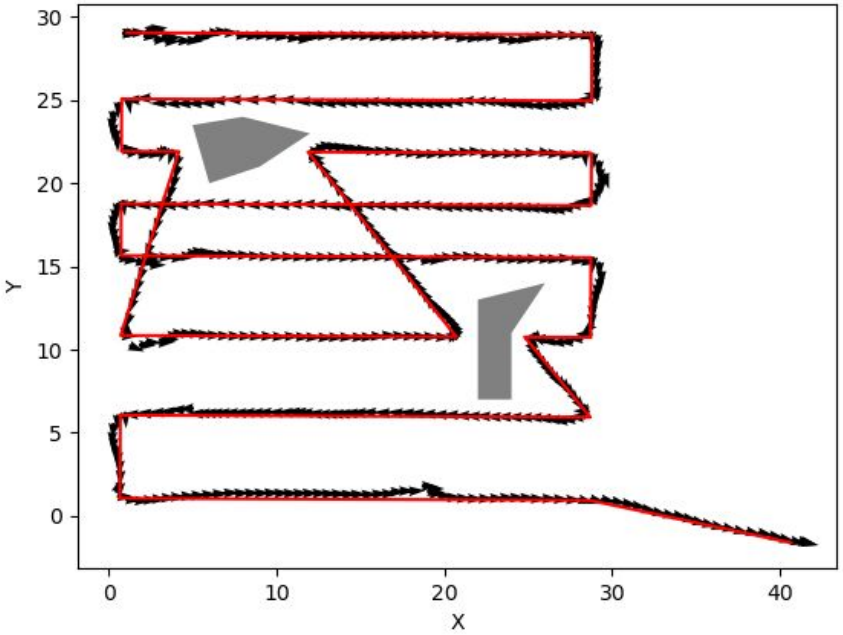


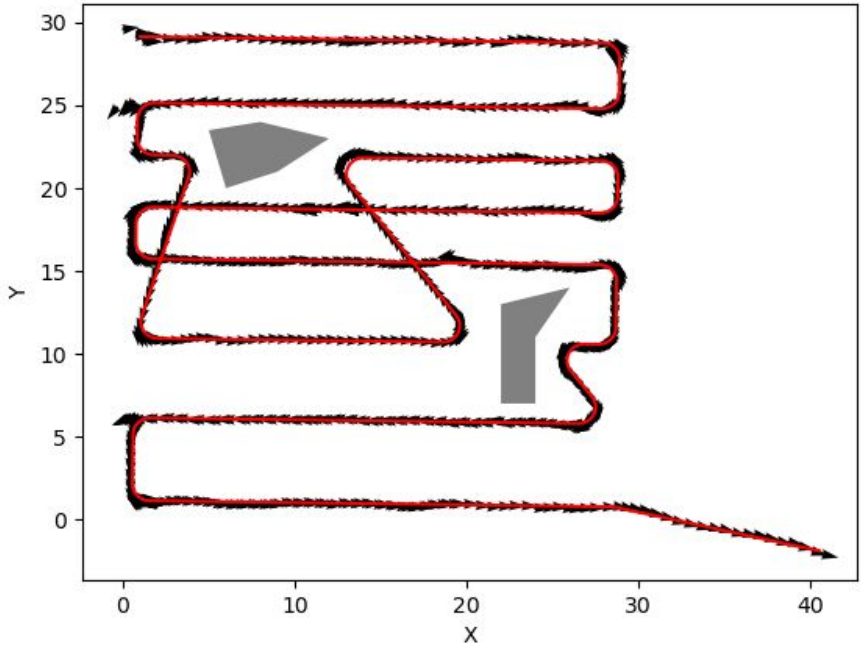
Results


Heatmap
Y
X
Value
0
100
200
300
400
0
20
40
60
80
100


Heatmap
Y
X
Value
0
100
200
300
400
0
20
40
60
80
100

Results



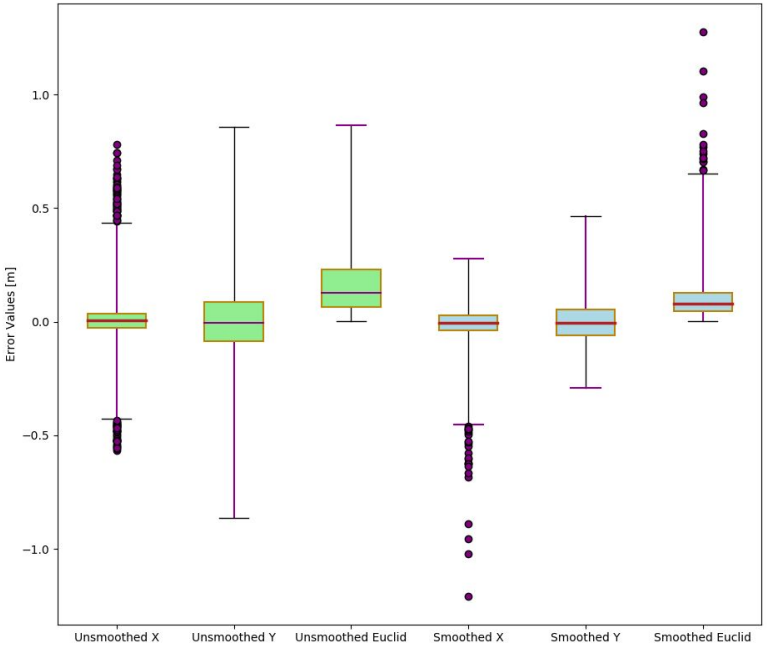


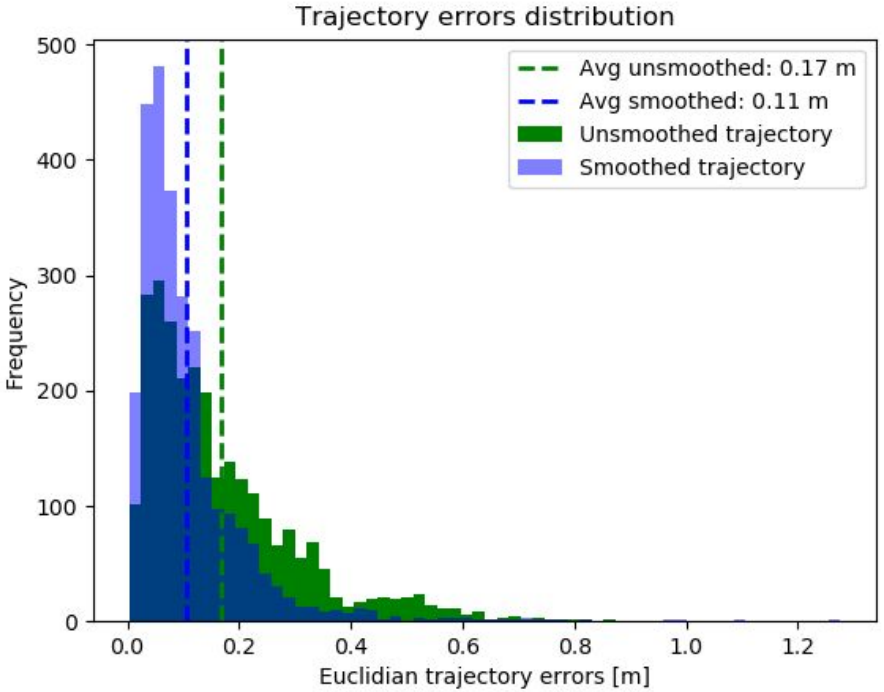
Traversal time:

1241 s

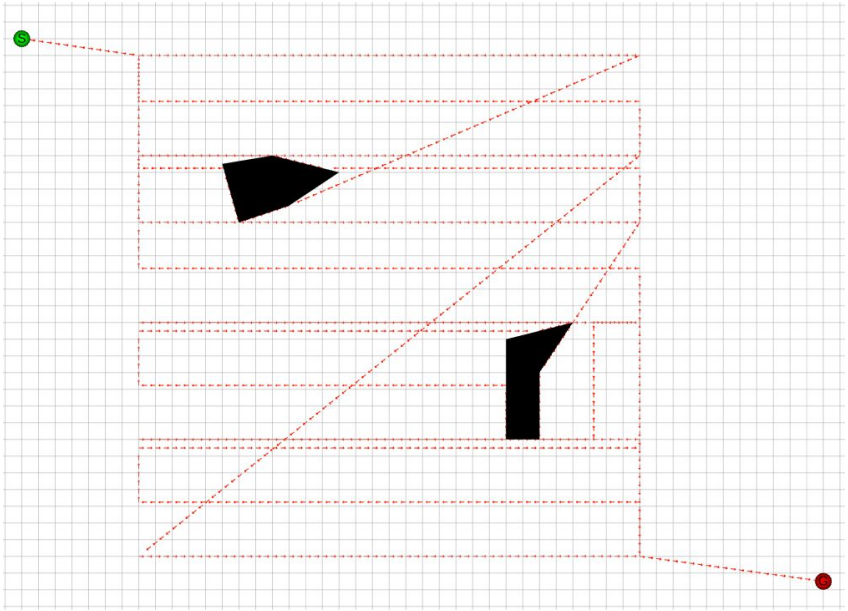
1529 s

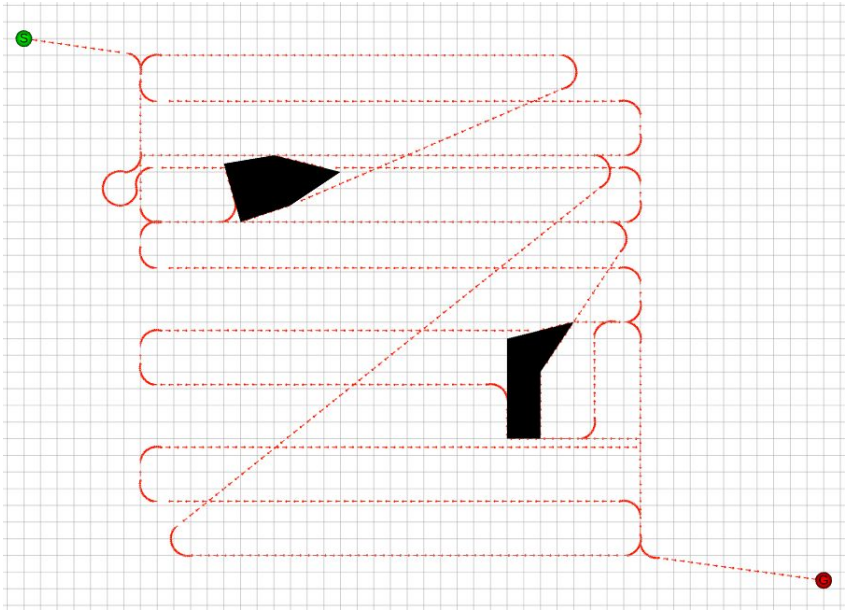
Results


Error Values [m]
1.0
0.5
0.0
−0.5
−1.0
Unsmoothed X
Unsmoothed Y
Unsmoothed Euclid
Smoothed X
Smoothed Y
Smoothed Euclid

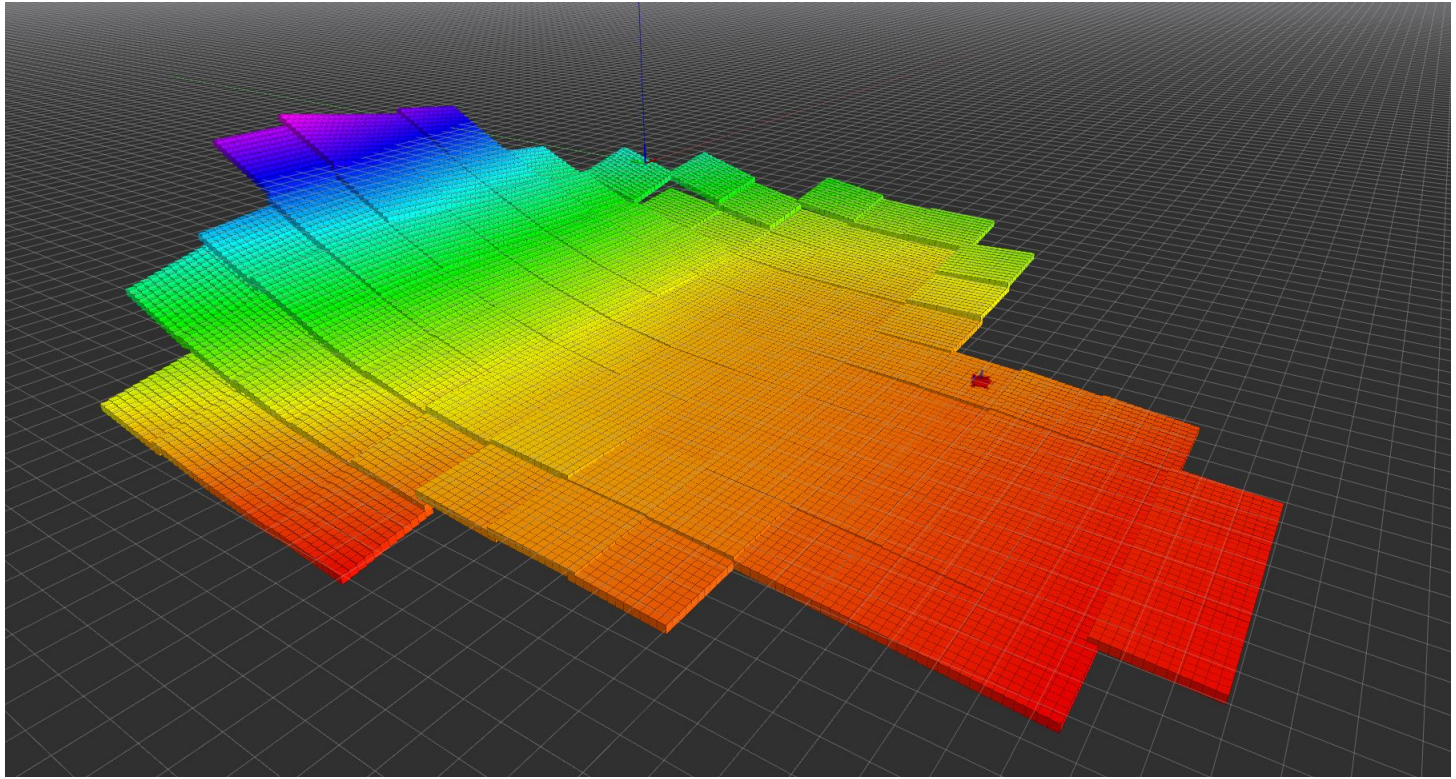

Trajectory errors distribution
Avg unsmoothed: 0.17 m
Avg smoothed: 0.11 m
Unsmoothed trajectory
Smoothed trajectory
Frequency
500
400
300
200
100
0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Euclidian trajectory errors [m]

Results





Results



Conclusion & future work

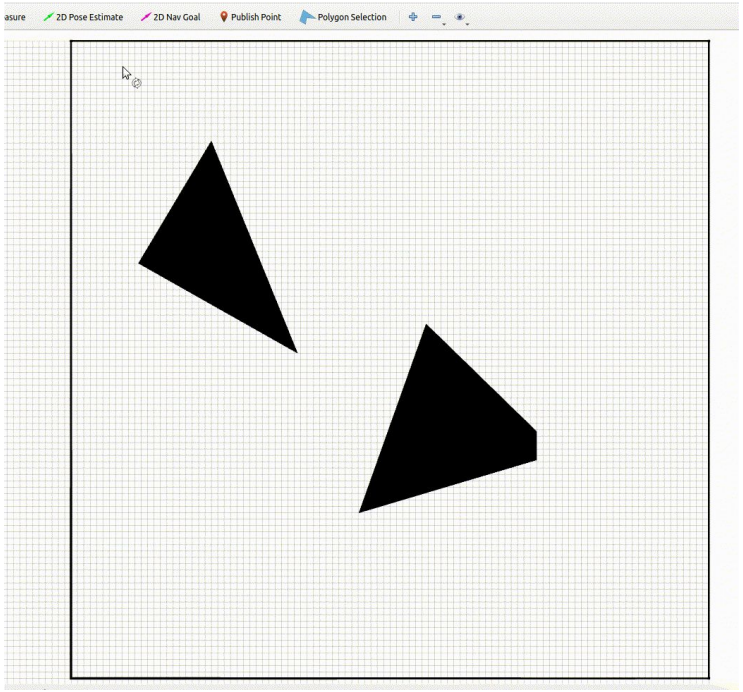
- smoothing with Dubins curves
- replanner investigation
- tests on a real robot
- comparison of smoothed and unsmoothed trajectory

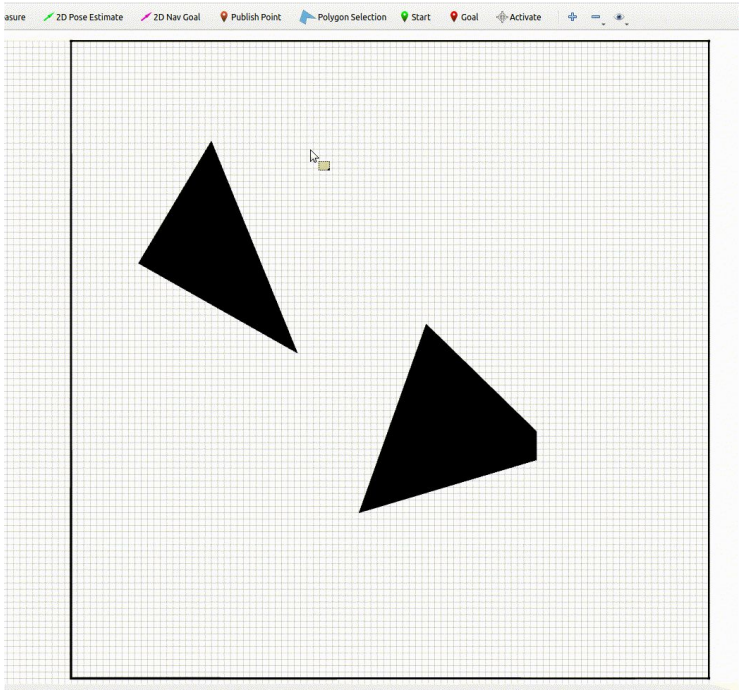
Conclusion & future work

1. Smoothing
   - other smoothing methods + comparison
   - variable circles' radii
   - global optimization
2. Replanner
   - algorithm for hulls simplifications
   - exploration of other methods
3. Experiments
   - robots with different properties
   - case with 0% overlap

Thank you for attention!

RVIZ tool


asure
2D Pose Estimate
2D Nav Goal
Publish Point
Polygon Selection


asure
2D Pose Estimate
2D Nav Goal
Publish Point
Polygon Selection
Start
Goal
Activate