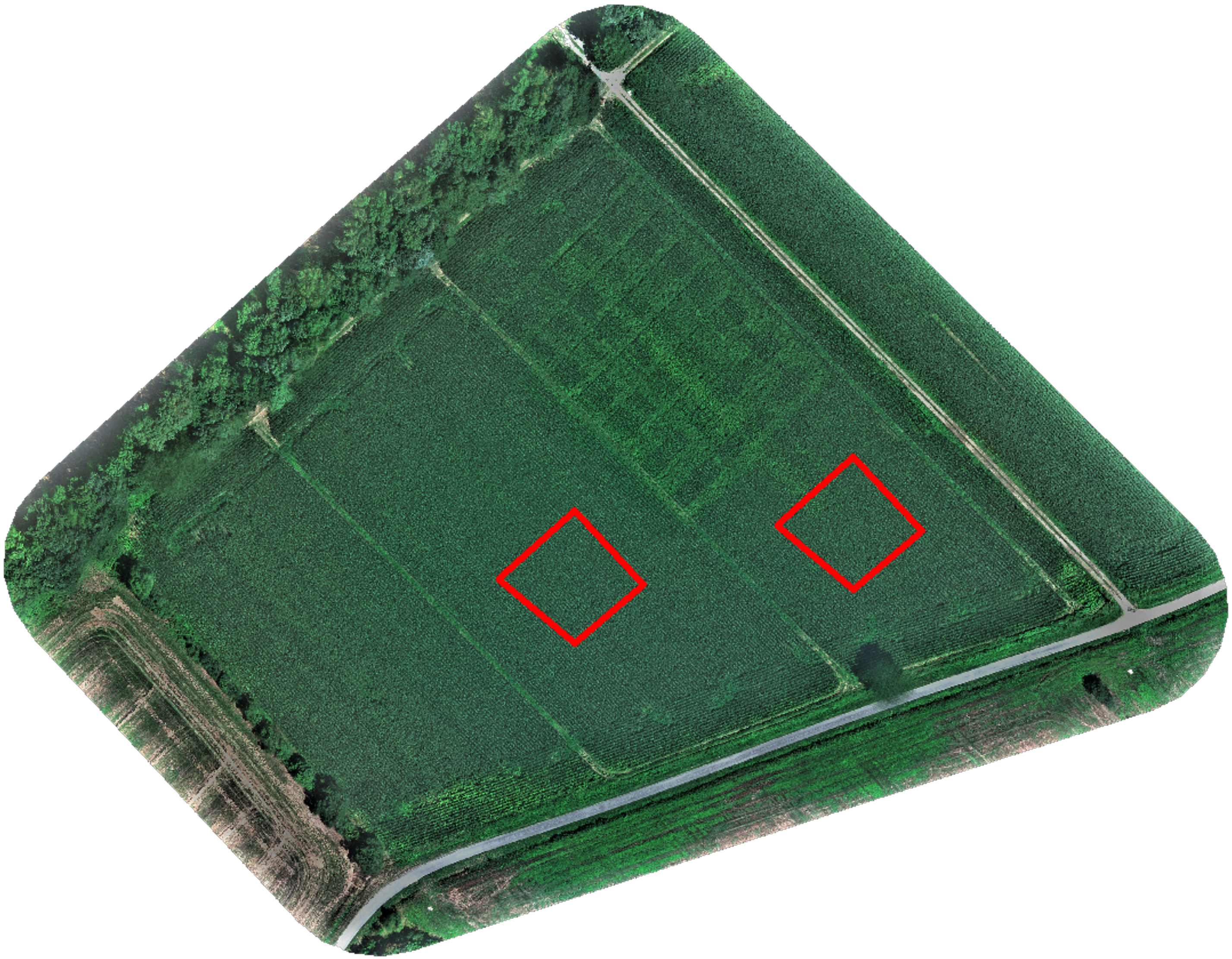
Mapping crop fields: active perception using SLAM and online path optimization

GIS micro drones: 5th Garden Workshop

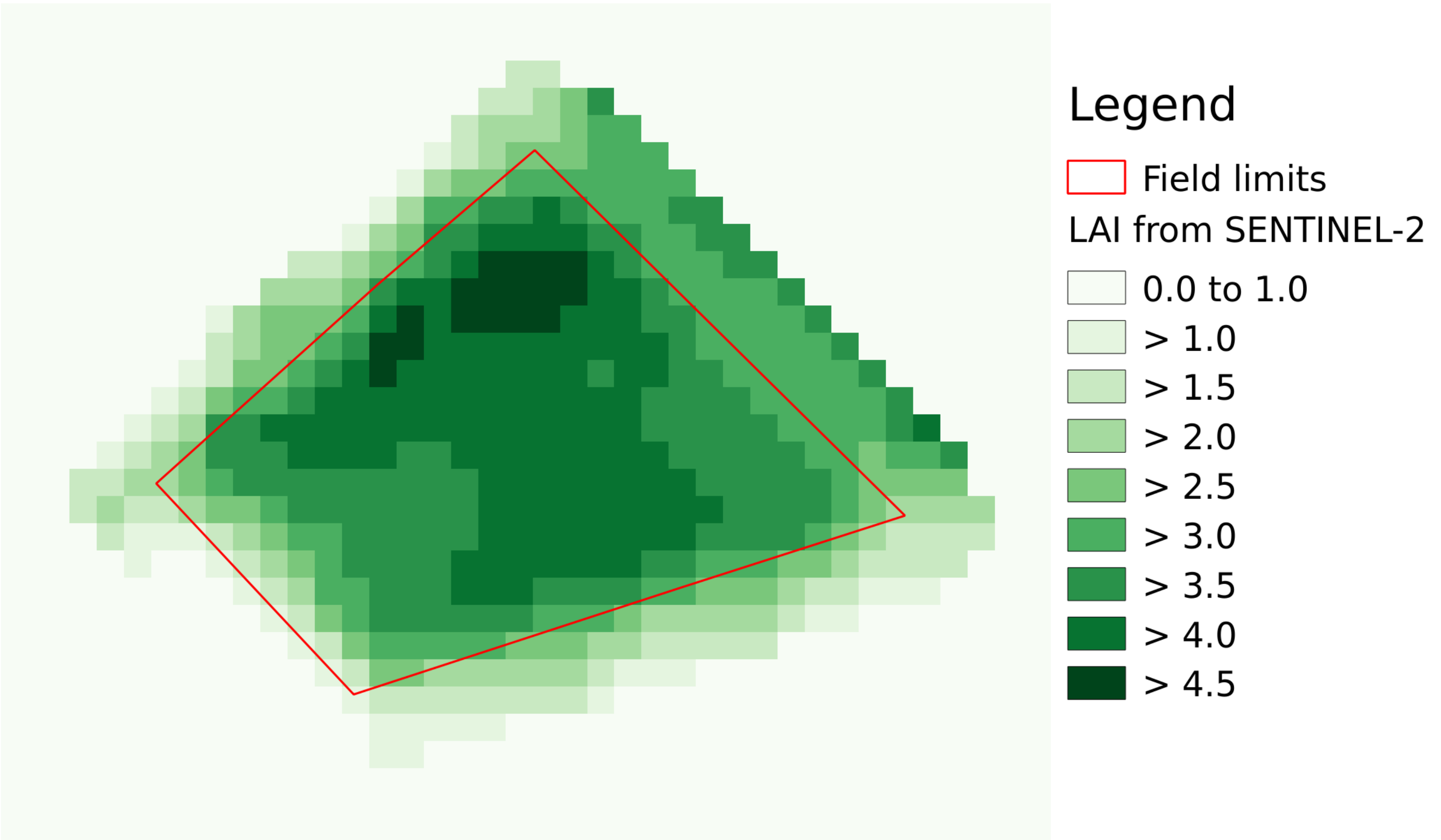
- July 10, 2018 -

UAVs for precision agriculture

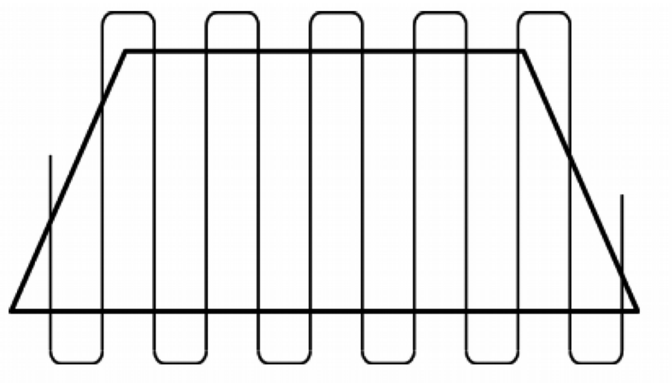
UAVs for precision agriculture

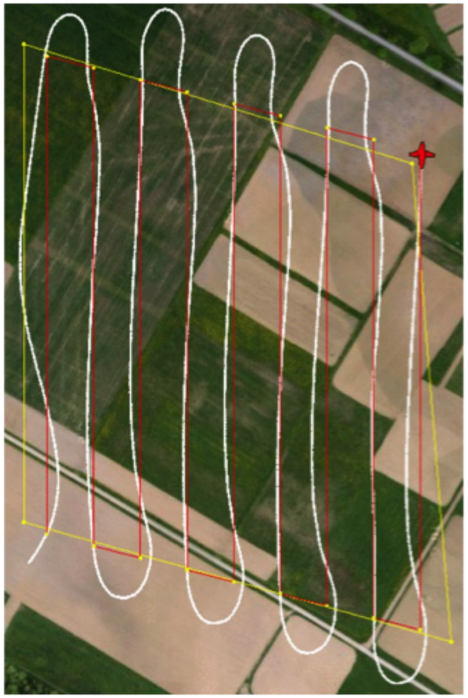


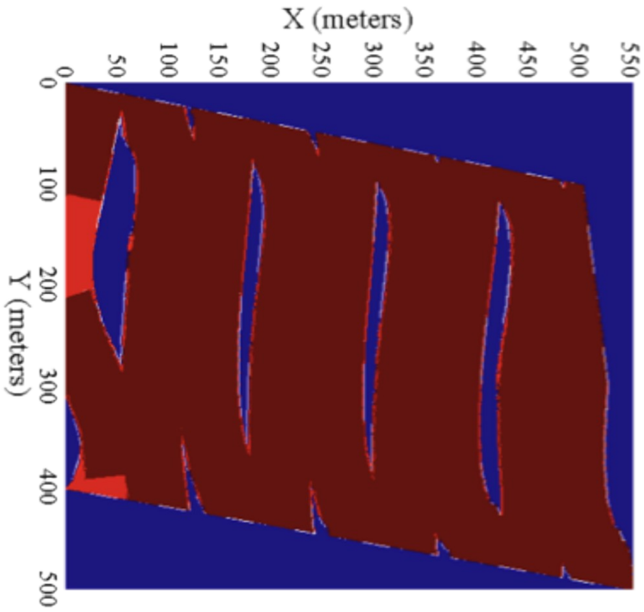
UAVs for precision agriculture



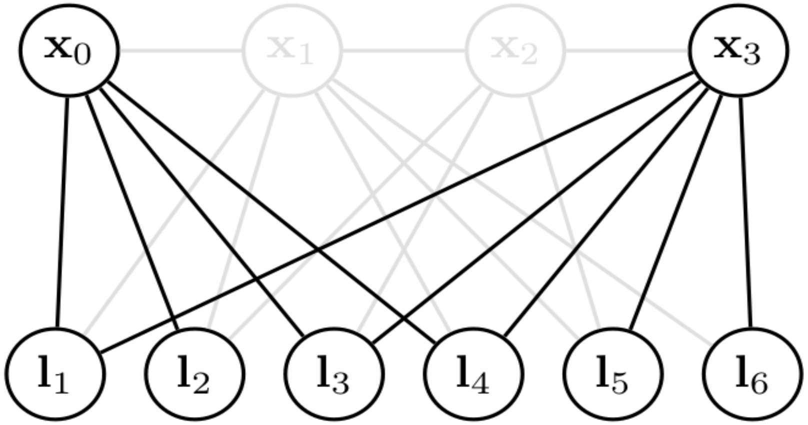
Offline Planning



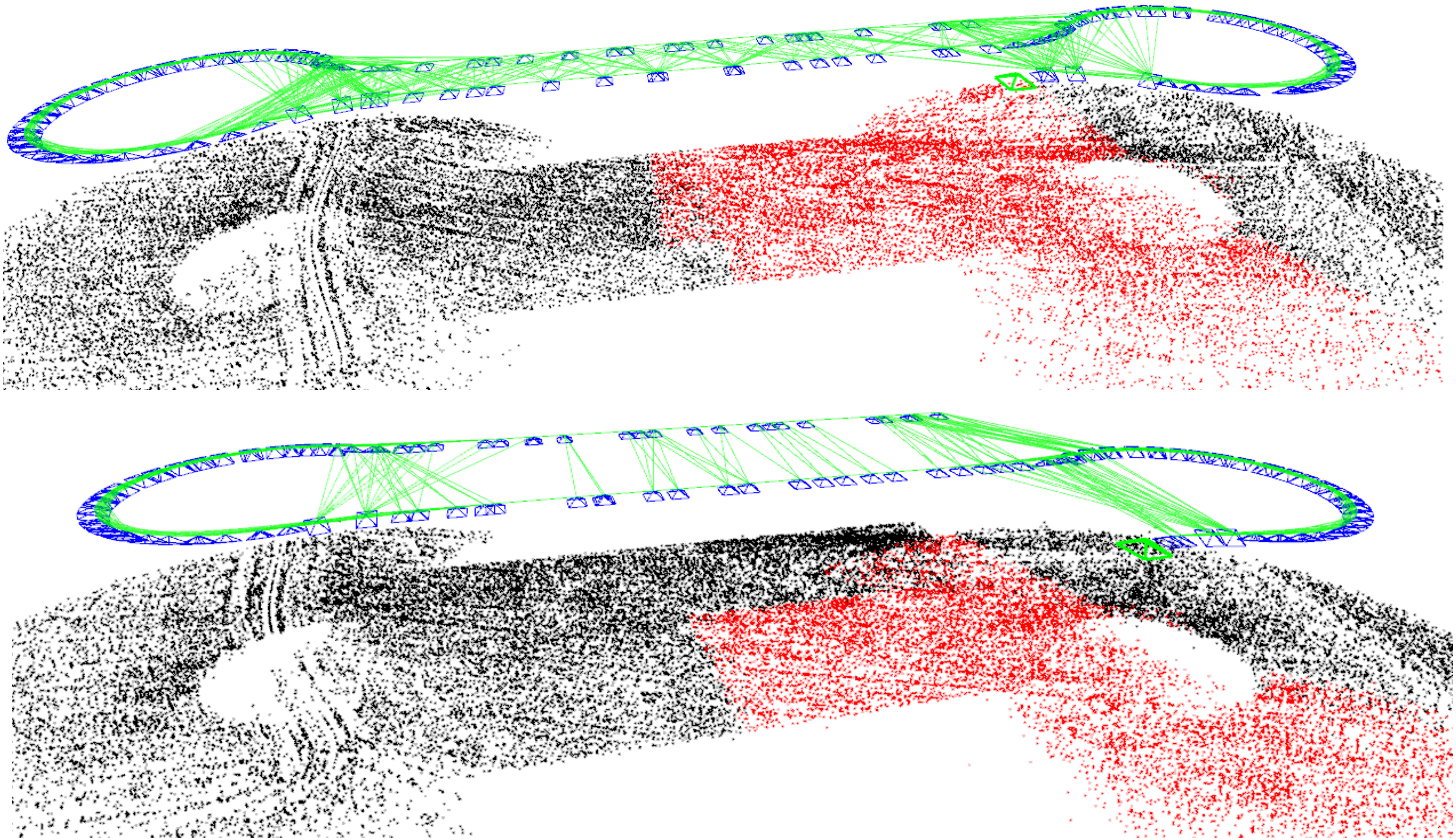




Monocular Graph SLAM

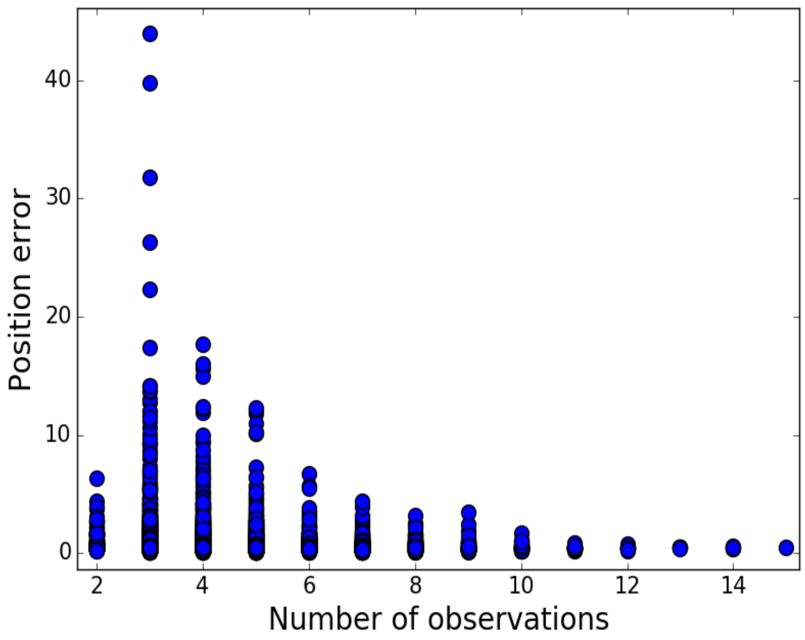


Monocular Graph SLAM



Monocular Graph SLAM

Map point position error
(Keyframe RMSE is 0.25m)



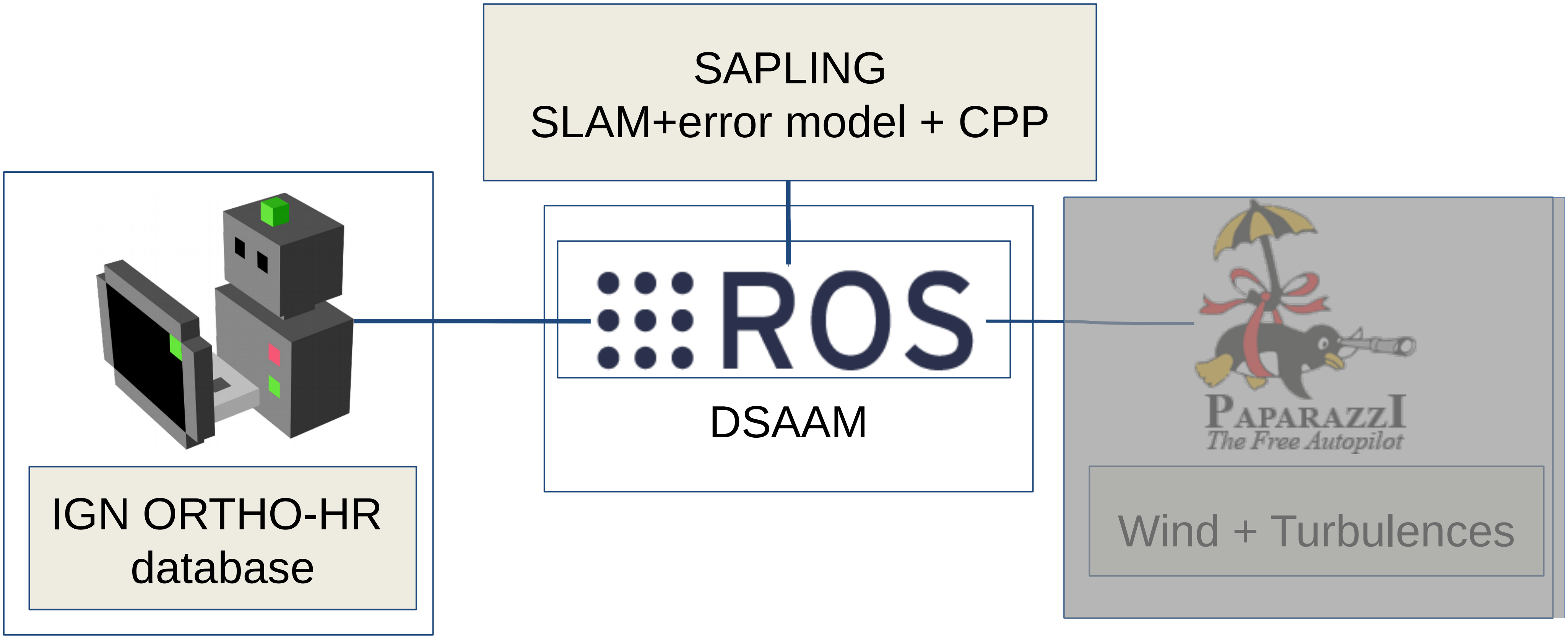
*** Good keyframe position precision**

*** Worse map quality :**

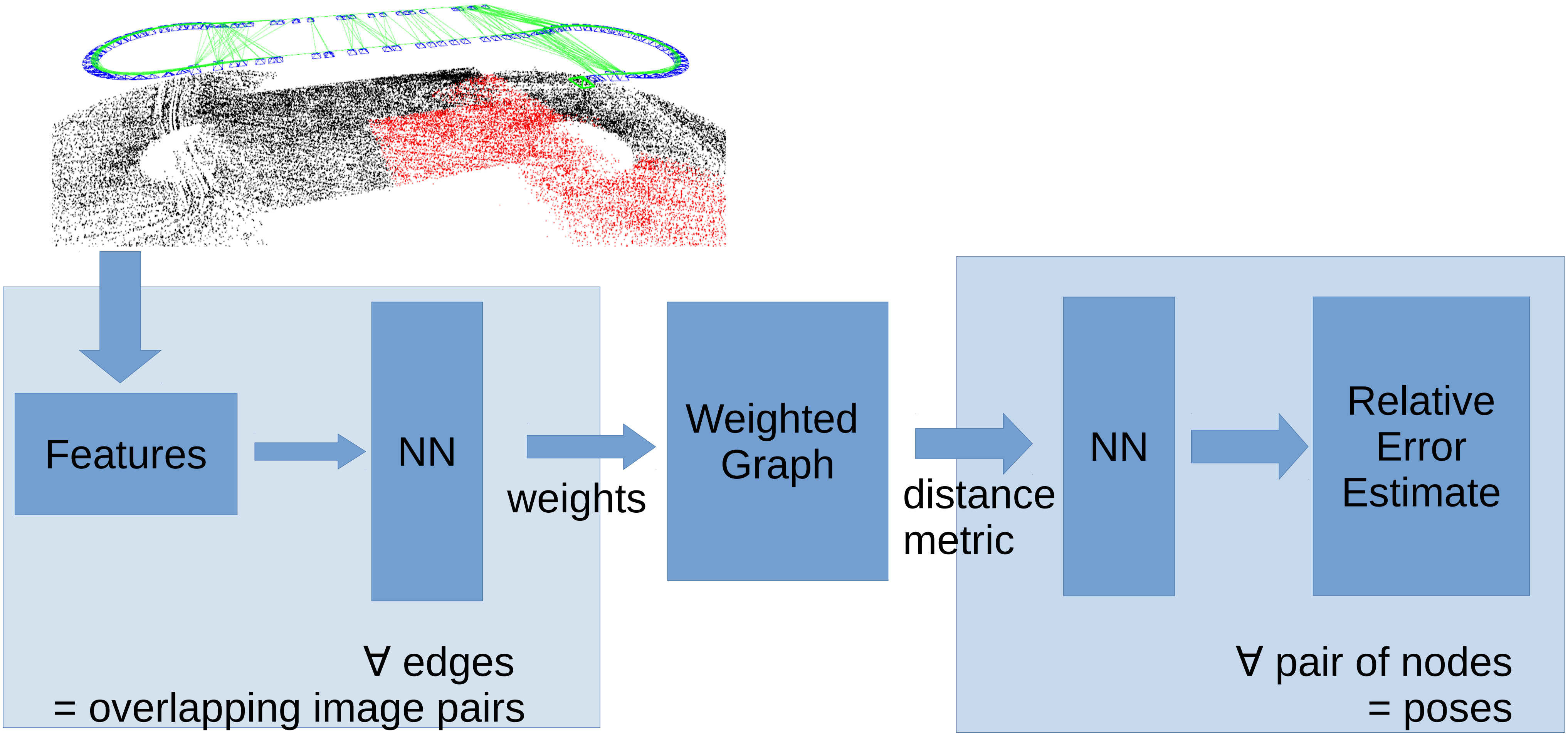
- Keypoint matching errors
- SLAM marginalizes map points
- Covariances = too optimistic

--> Wrong error estimate

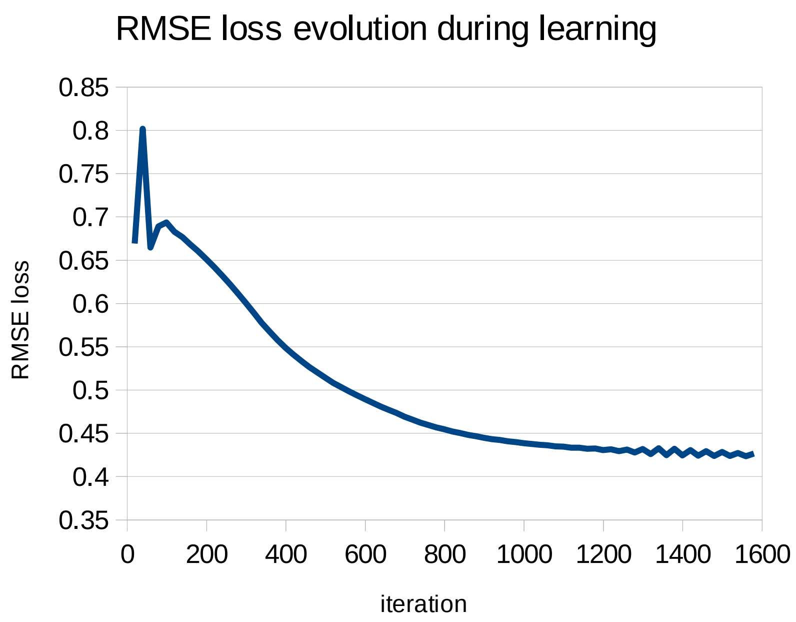
Simulation Framework architecture



Learning the relative error



Learning the relative error



First results are promising

Ongoing work :

- Better loss function
- Generating large simulation database
- Features selection
- Features for prediction
- Integration with planning

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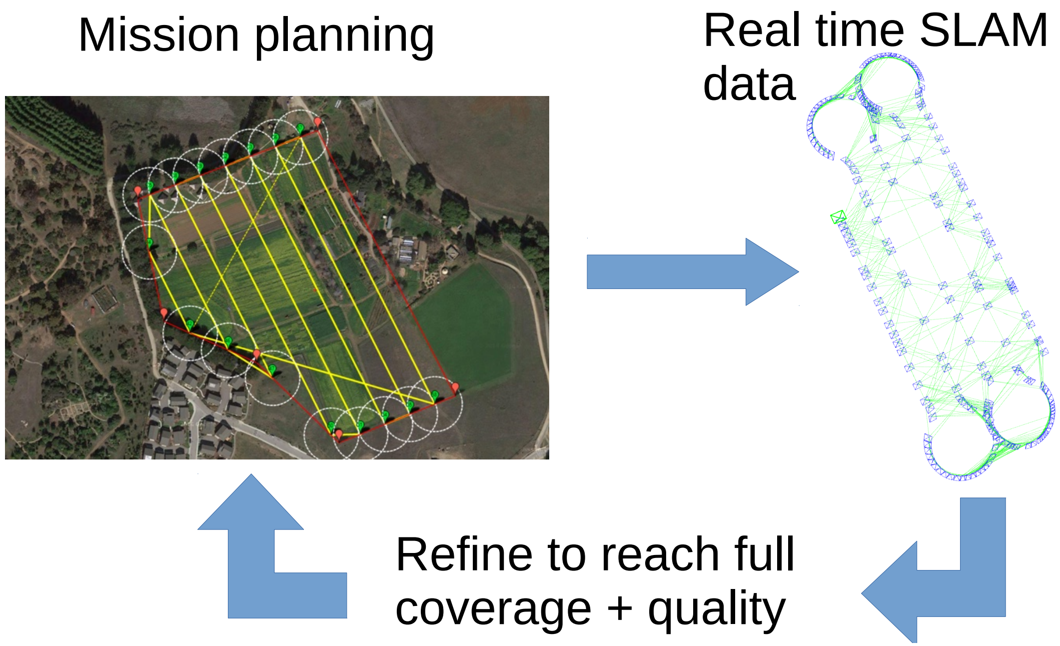
LAAS RIS Group
ENAC

July 10, 2018

Introduction



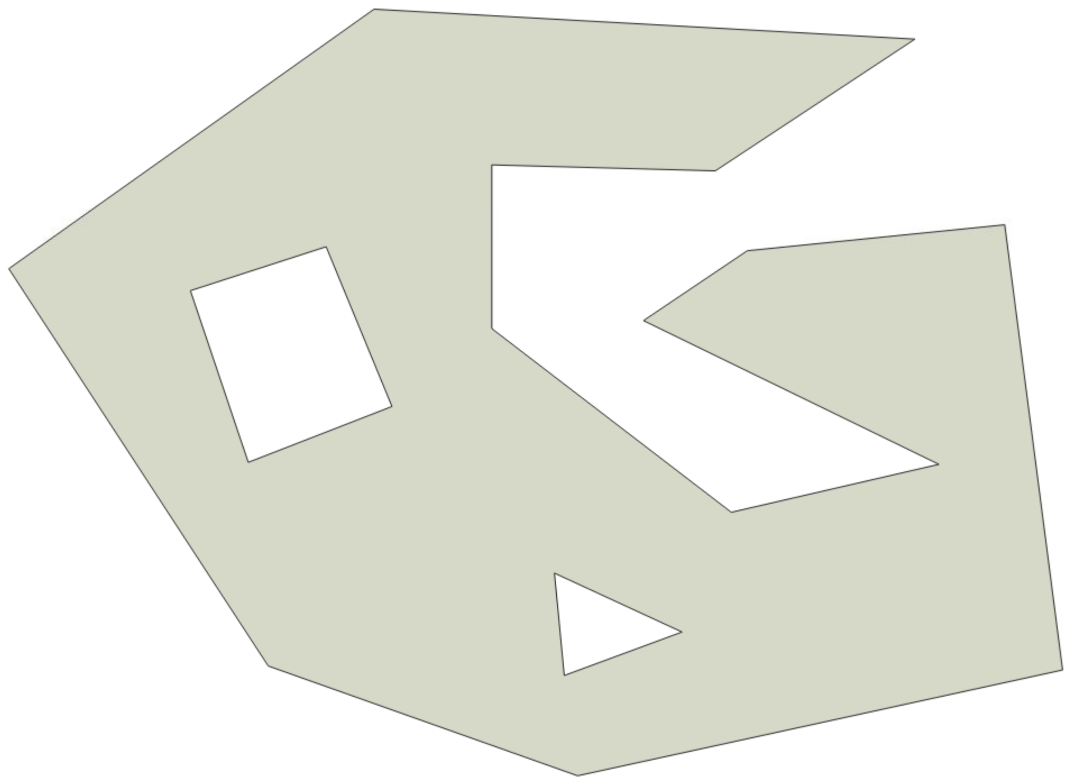
Goal: fully complete the mapping mission within a minimum time

Plan goals deduced online from a vision-based SLAM:

- areas which are not covered yet
- areas with bad acquisitions (blur, wind...) and thus low quality
- areas which would strategically reinforce the map (predictive model)

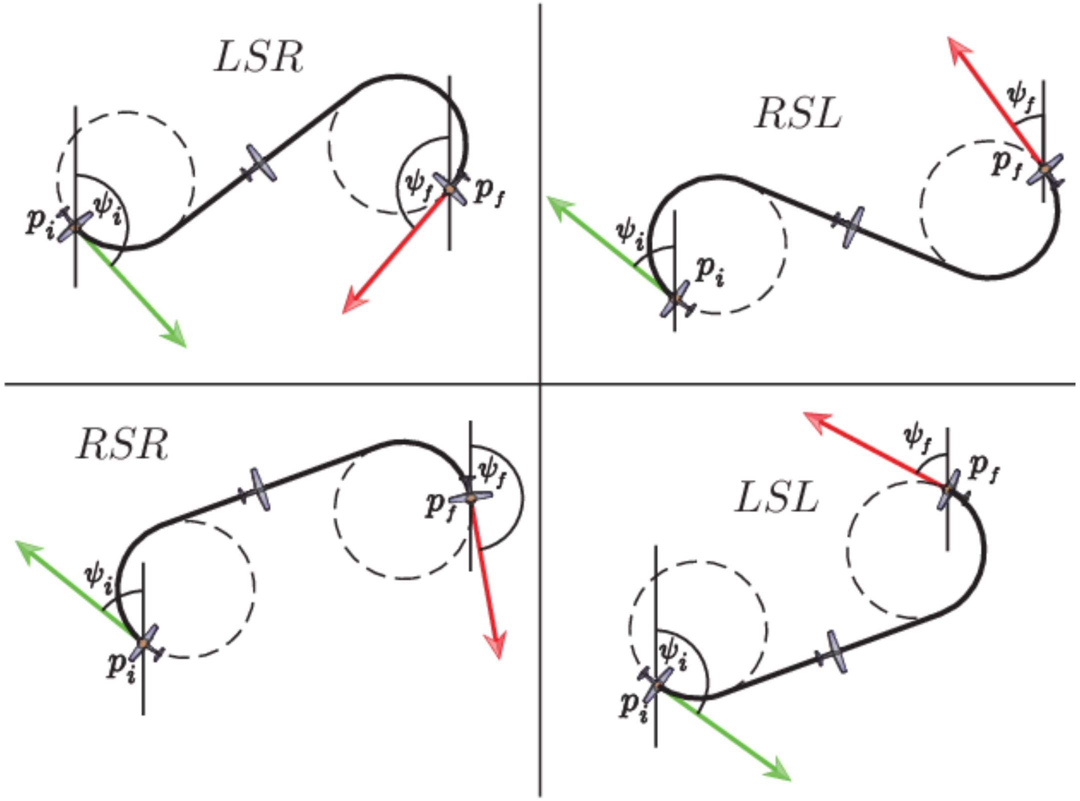
Field

Polygon, possibly non-convex with non-convex holes



Dynamic vehicle model: Dubins path

Shortest curve that connects two points with prescribed initial and terminal headings for a constant-speed vehicle with a minimum turning radius (non-holonomic).



State of the art

Abundant literature for the coverage path planning (CPP) problem, but great variety of subproblems:

- known or unknown environment
- with or without "obstacles"
- convex or non-convex shapes
- with or without wind
- holonomic or non-holonomic vehicle
- with or without energy/time/... minimization

Common approaches for the coverage of known environments:

- exact cell decomposition (e.g. trapezoidal, Morse...)
- approximate cell decomposition (e.g. grid, treemap...)

State of the art

Main constraints:

- non-holonomic, fixed wing, constant speed UAV
- Dubins paths
- constant altitude
- wind: hard, depends on the controller
  For now, just integrate the speed over the Dubins trajectory
- performance

Intuition:

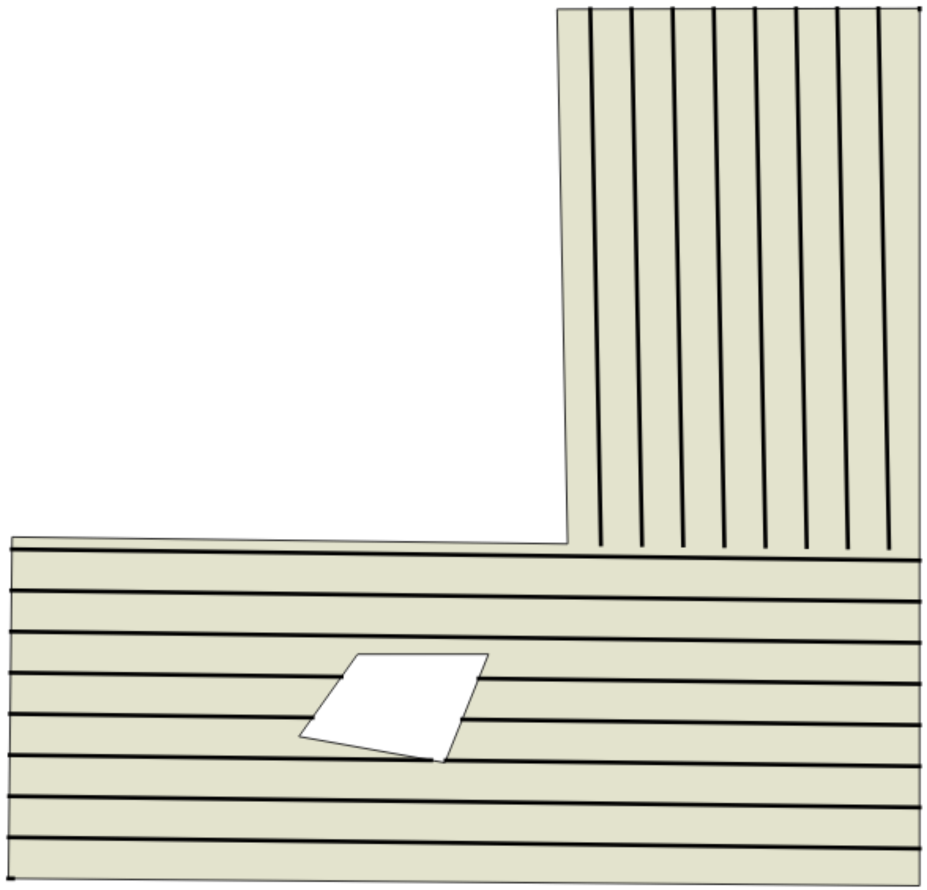
- straight acquisition segments: boustrophedon/lawnmower patterns
- segments' direction should reflect locally the shape of the field
- holes shouldn't matter too much

State of the art

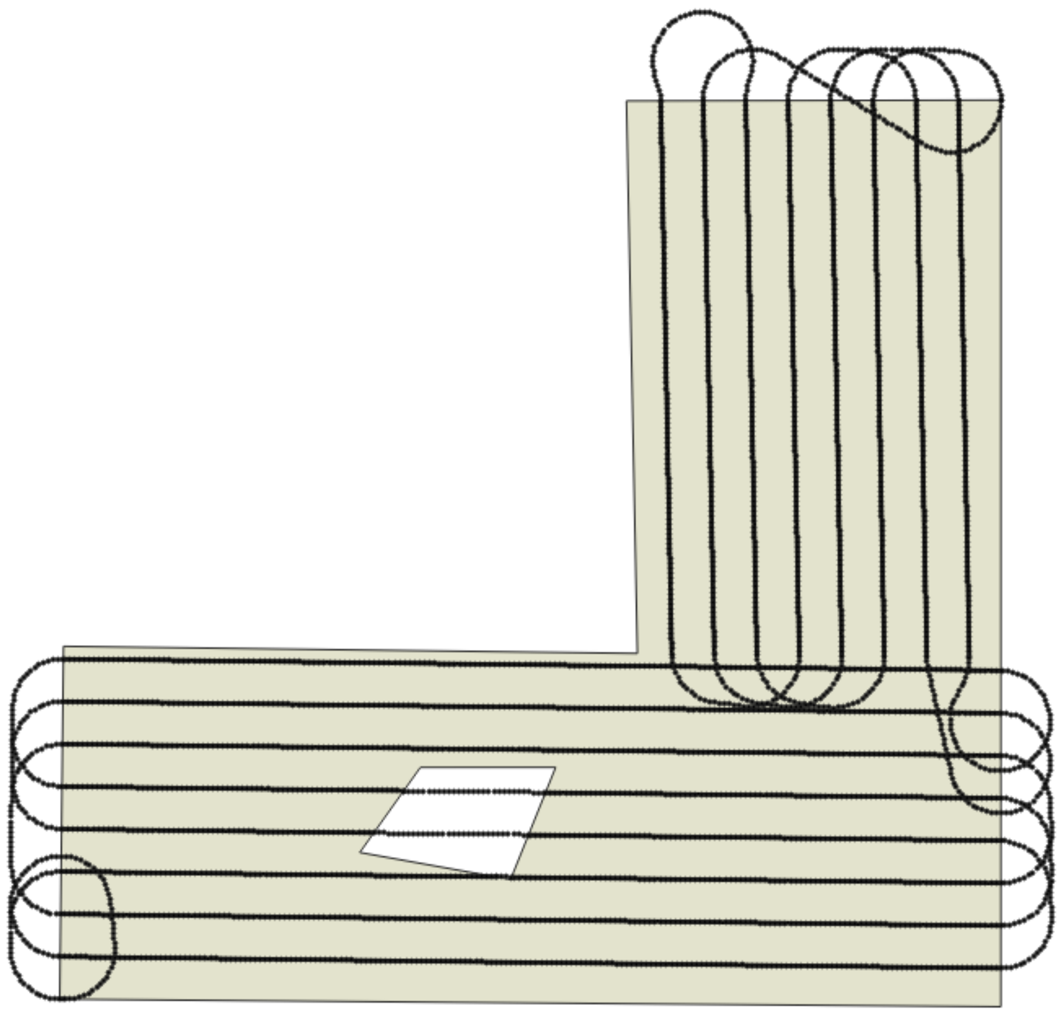
Most promising approach:

- find a good decomposition of the field
- cover each subfield wih parallel segments in the optimal direction
- connect the segments by solving a Generalized Traveling Salesman Problem

Connecting the segments with a GTSP

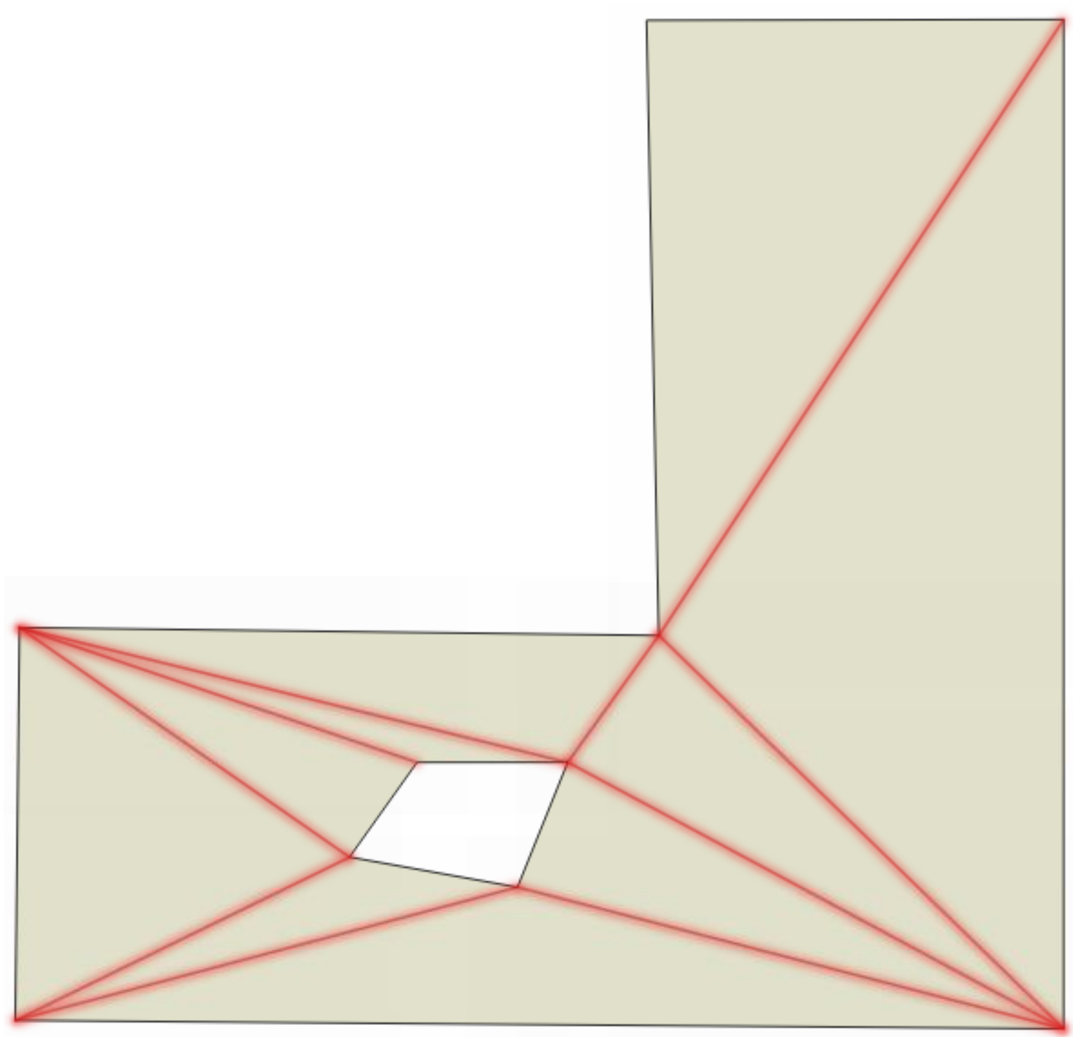


Connecting the segments with a GTSP



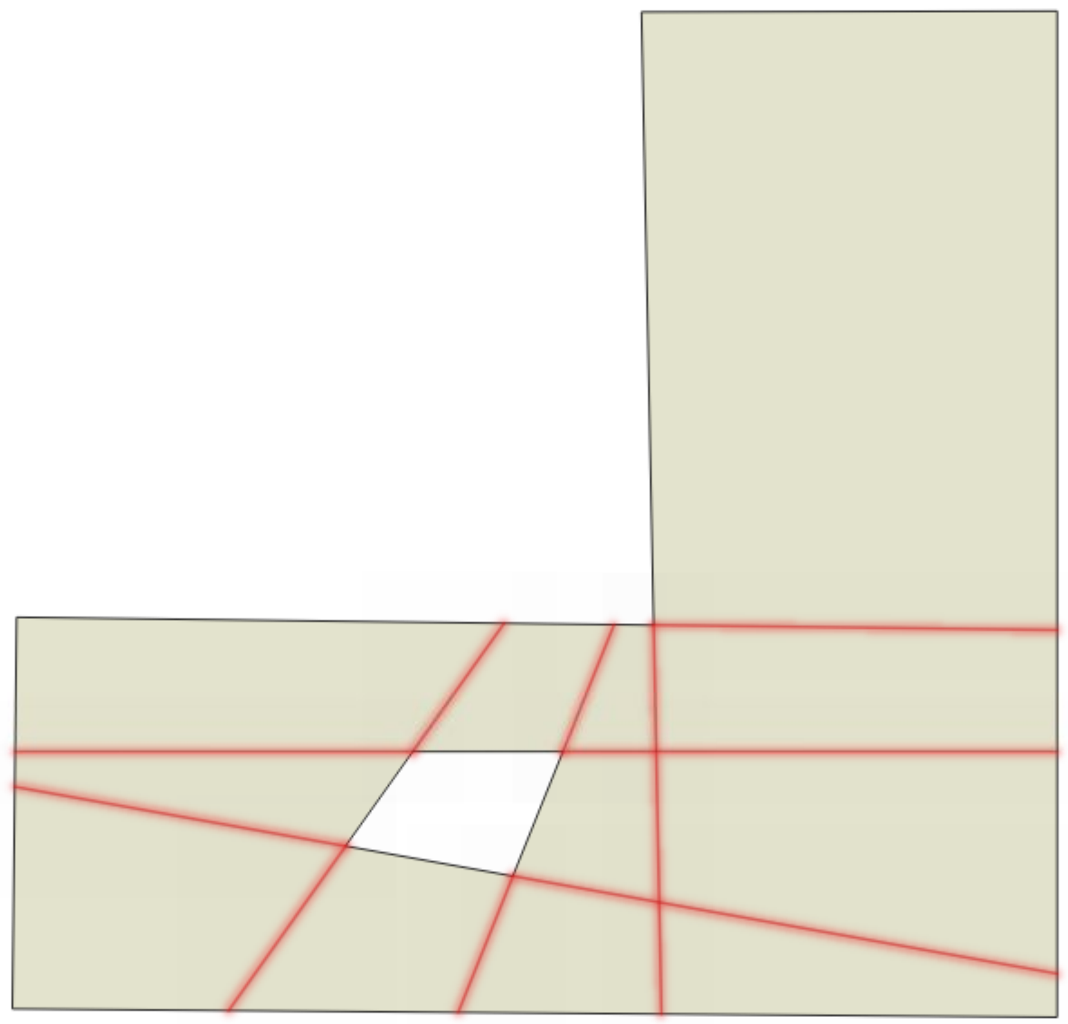
Finding a good decomposition

Reduce the complexity by generating a set of potential "cut edges"
e.g. convex decomposition with triangles



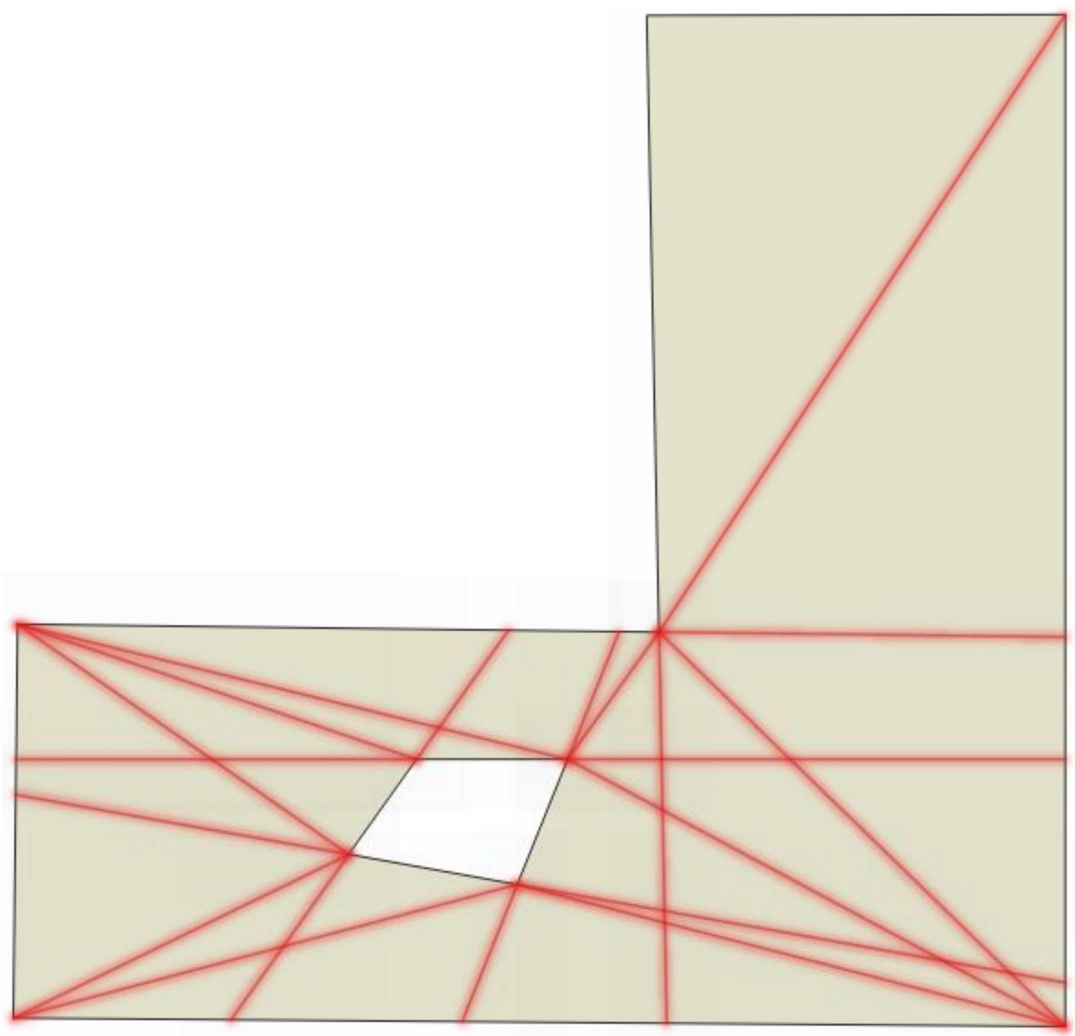
Finding a good decomposition

Reduce the complexity by generating a set of potential "cut edges"
e.g. extend the edges at reflex (concave) vertices



Finding a good decomposition

Reduce the complexity by generating a set of potential "cut edges" all together



Finding a good decomposition

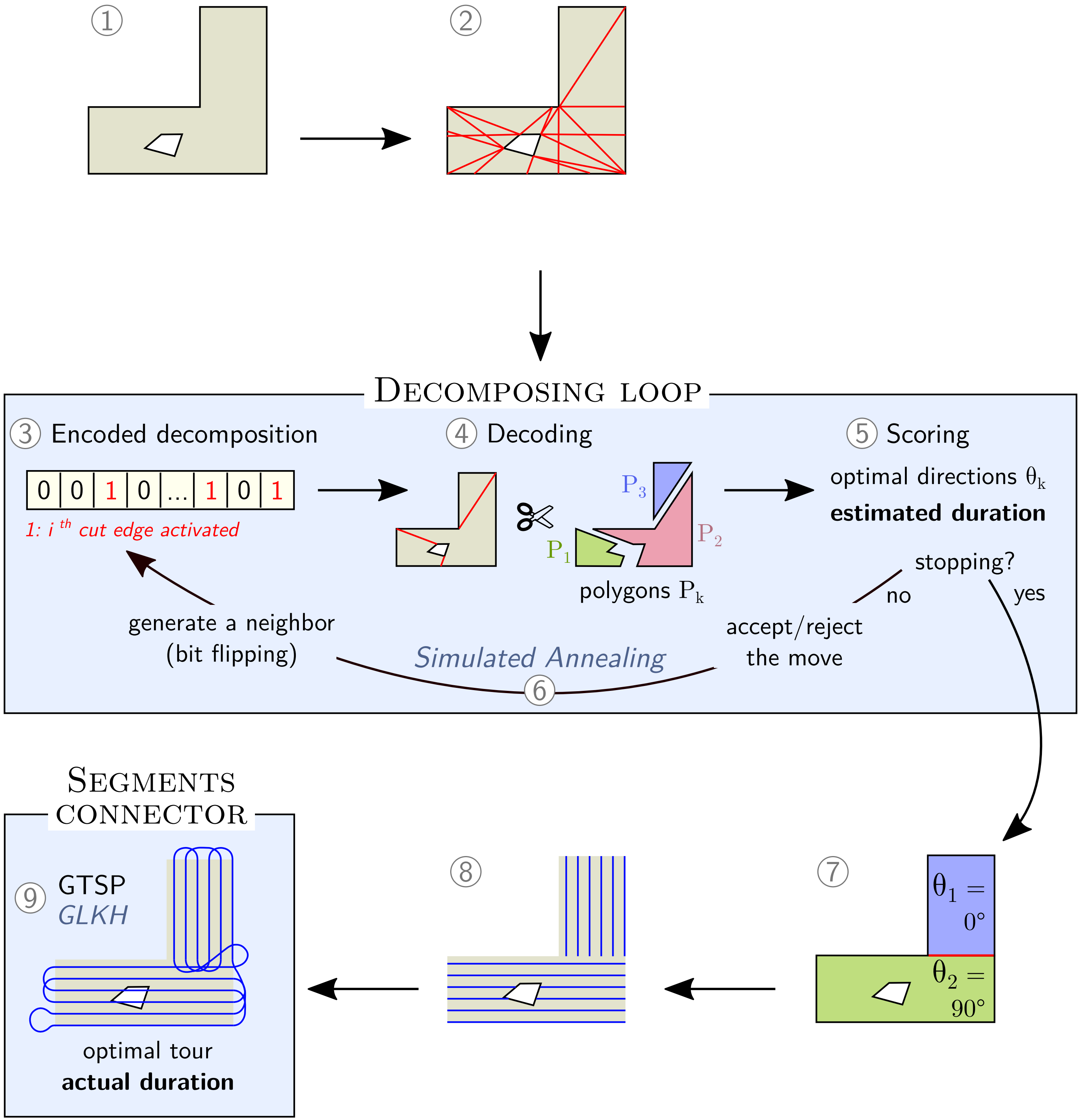
Idea: find the best combination of cut edges

Scoring function: estimated duration of the mission with this decomposition

Complexity: roughly 2^n with n the number of potential cut edges

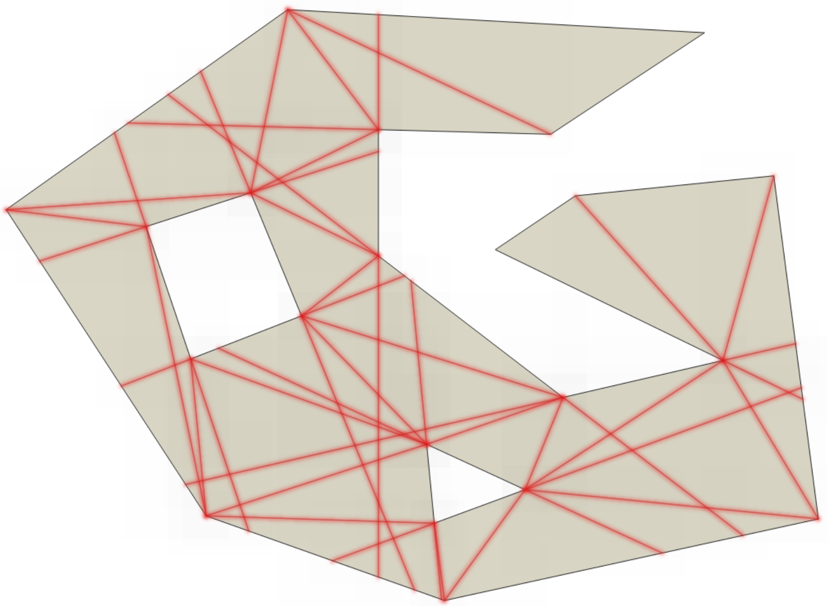
Approaches:

- exhaustive (optimal but can be extremely slow, e.g. dynamic programming)
- greedy (fast but suboptimal)
- **metaheuristics** (in between)

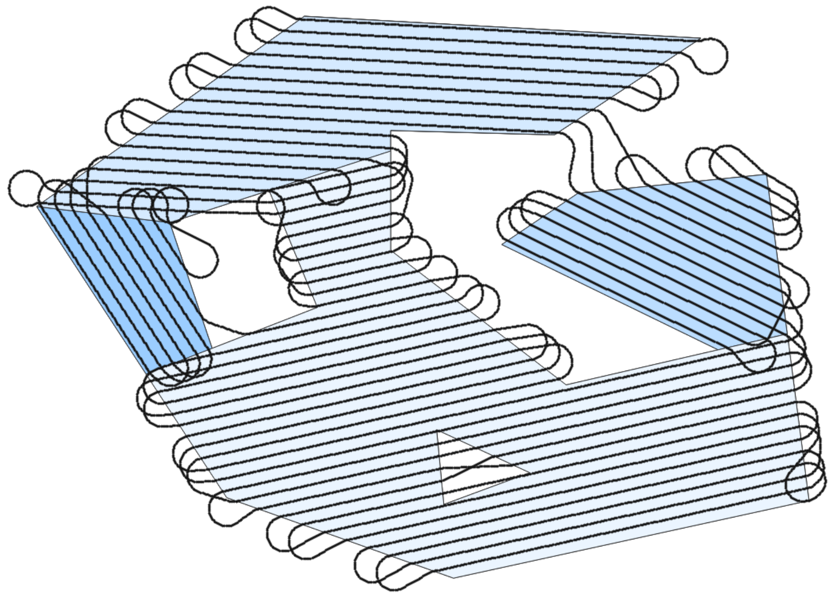


①
②
Decomposing loop
③ Encoded decomposition
0 0 1 0 ... 1 0 1
1: i th cut edge activated
④ Decoding
P3
P2
P1
polygons Pk
⑤ Scoring
optimal directions θk
estimated duration
stopping?
no
yes
accept/reject
the move
generate a neighbor
(bit flipping)
Simulated Annealing
⑥
⑦
θ1 = 0°
θ2 = 90°
⑧
Segments connector
⑨ GTSP
GLKH
optimal tour
actual duration

Results

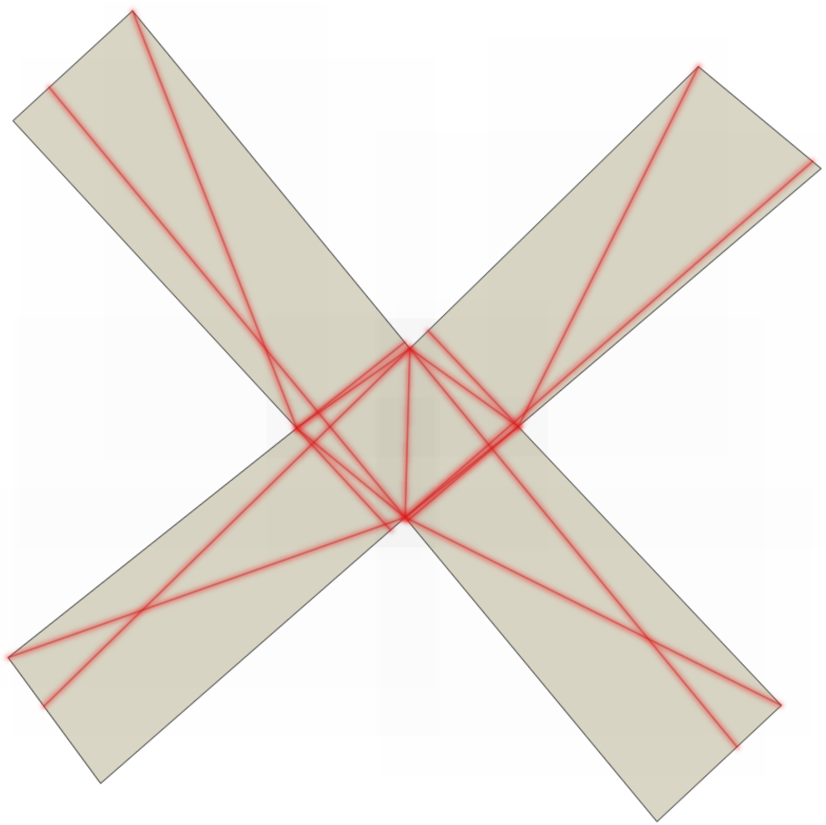


(a)

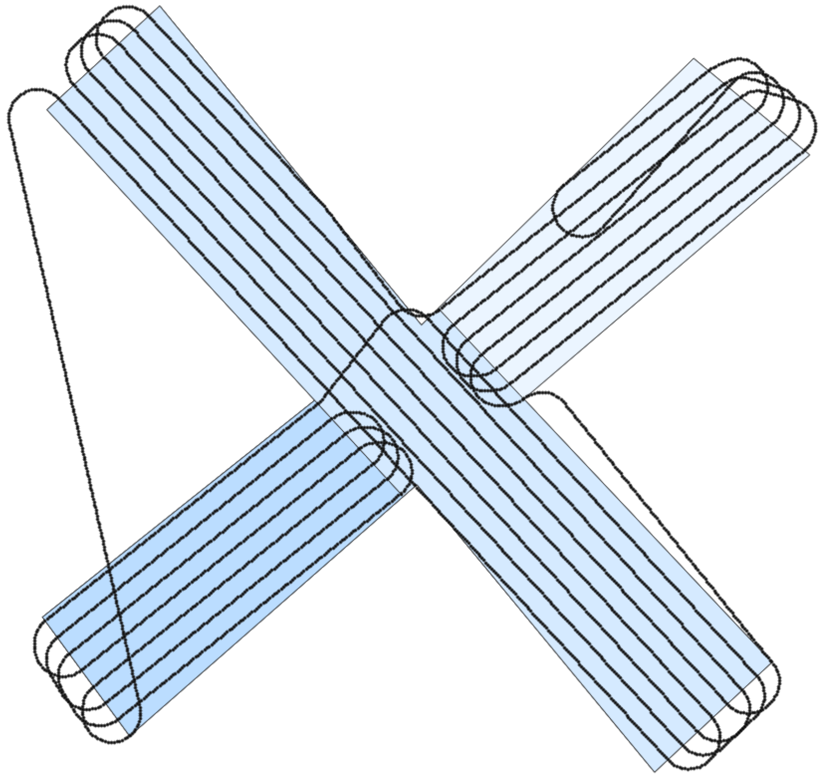


(b)

Results

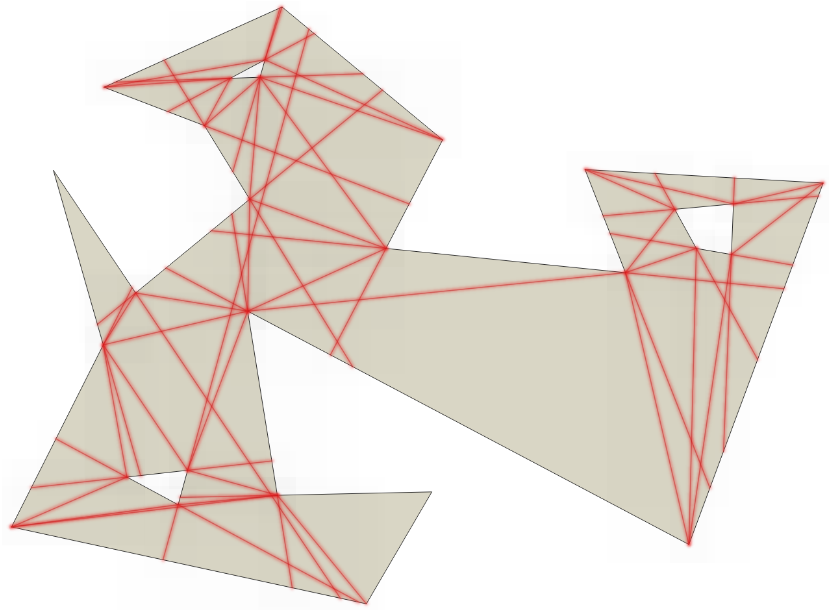


(c)

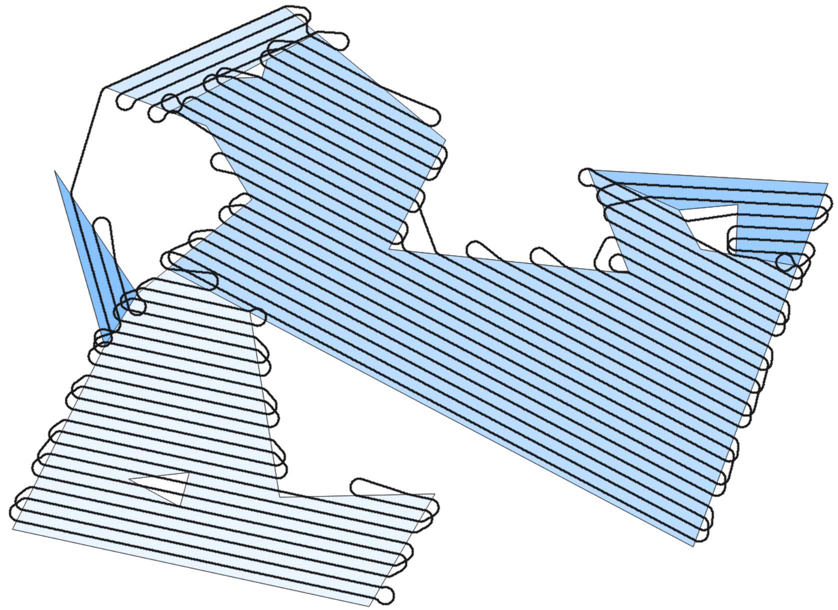


(d)

Results

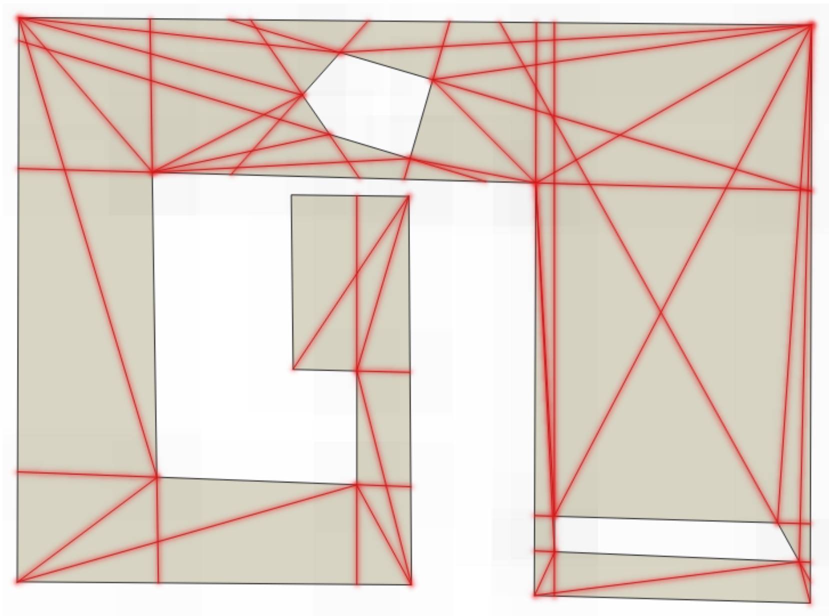


(e)

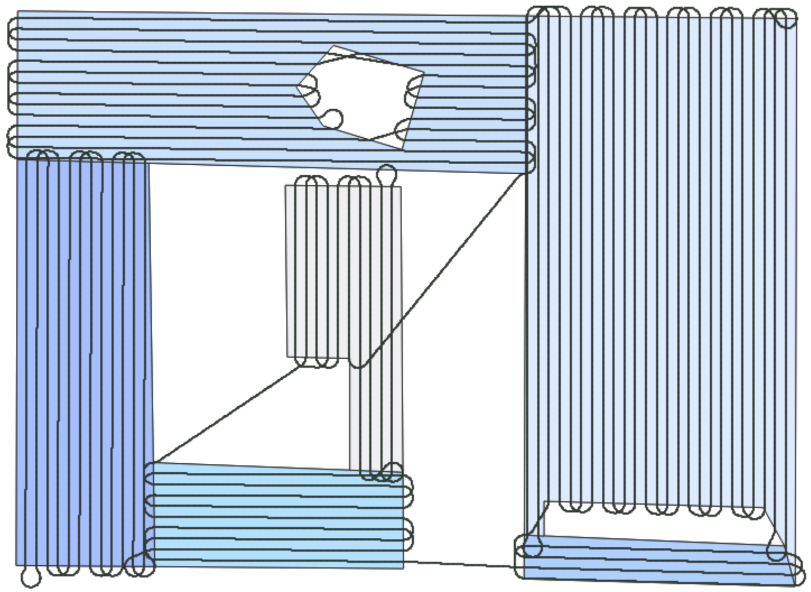


(f)

Results

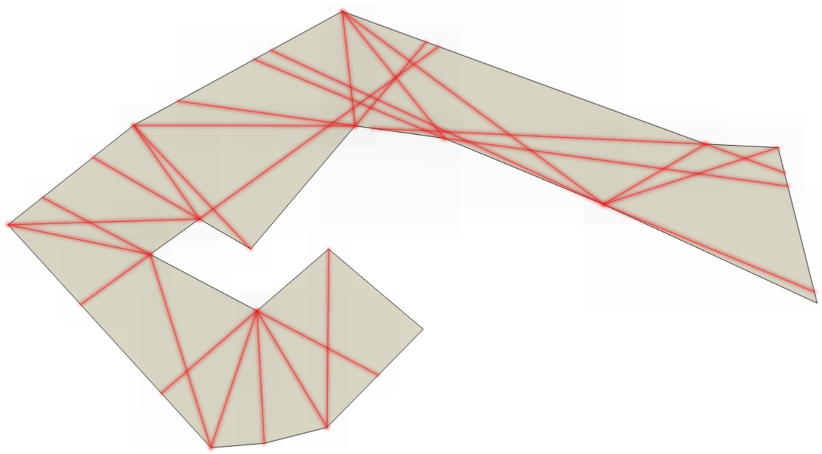


(g)

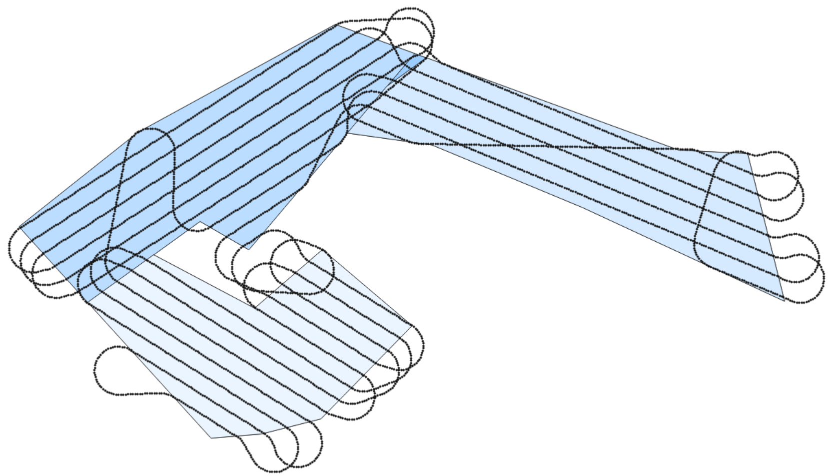


(h)

Results

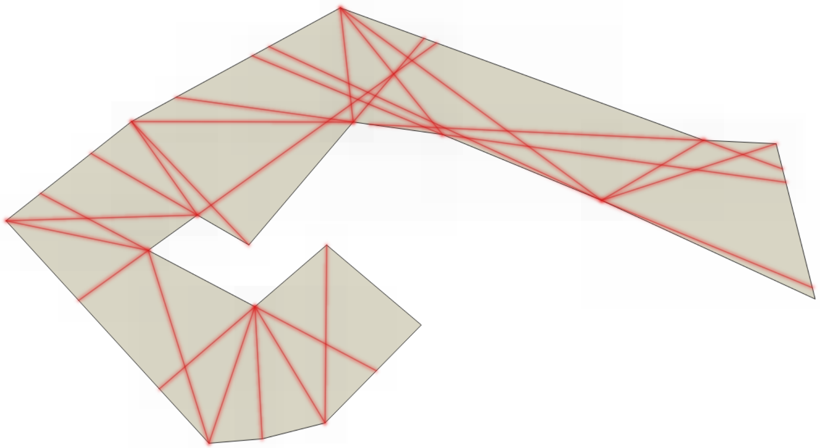


(i)

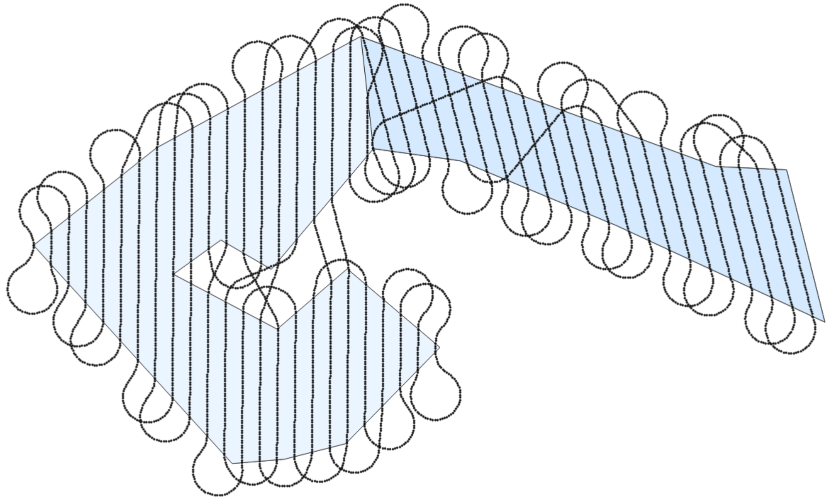


(j)

Results



(k)



(l)

West wind, 12 m/s (UAV speed: 15 m/s)

What's next?

Online replanning