KU LEUVEN
FACULTEIT INGENIEURSWETENSCHAPPEN
DistriNet

Scalable Multirotor UAV Trajectory Planning using Mixed-Integer Linear Programming

Master Computer- wetenschappen

Masterproef
Jorik De Waen

Promotor
Prof. dr. ***Tom Holvoet***

Academiejaar
2016 -2017

Background

- Mixed-Integer Linear Programming (MILP) is powerful trajectory planning approach
- MILP is flexible, can model UAV dynamics
- Widely used for online short-term planning
- However: MILP scales poorly beyond ~10 obstacles and with long trajectories
- Flying through city with 10 000s of obstacles with trajectory of several km: not possible

→ Offline long-term planning is not possible

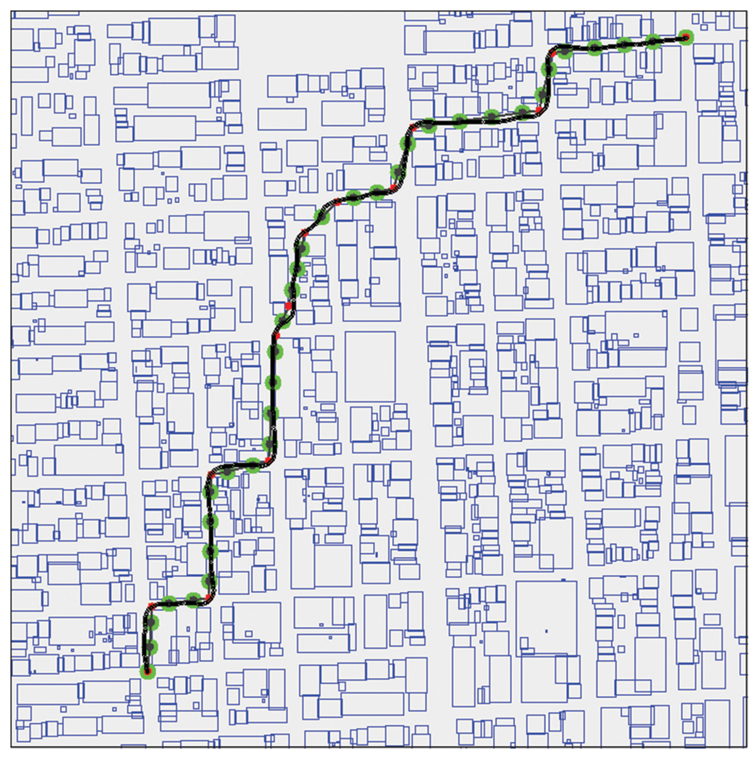
Leuven Scenario

A new approach

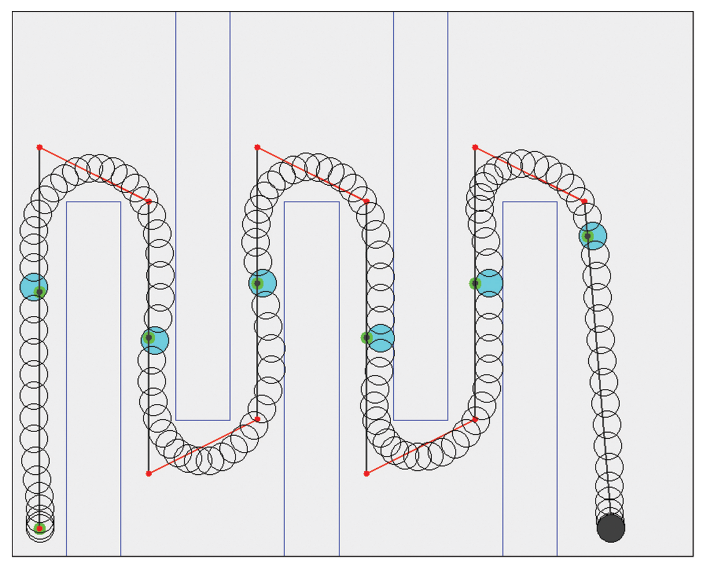
- Split MILP trajectory planning problem into many smaller subproblems
- Each subproblem: small part of trajectory
- Less time steps and obstacles per MILP subproblem

GOAL: generate subproblems around turns in trajectory → efficient and safe navigation

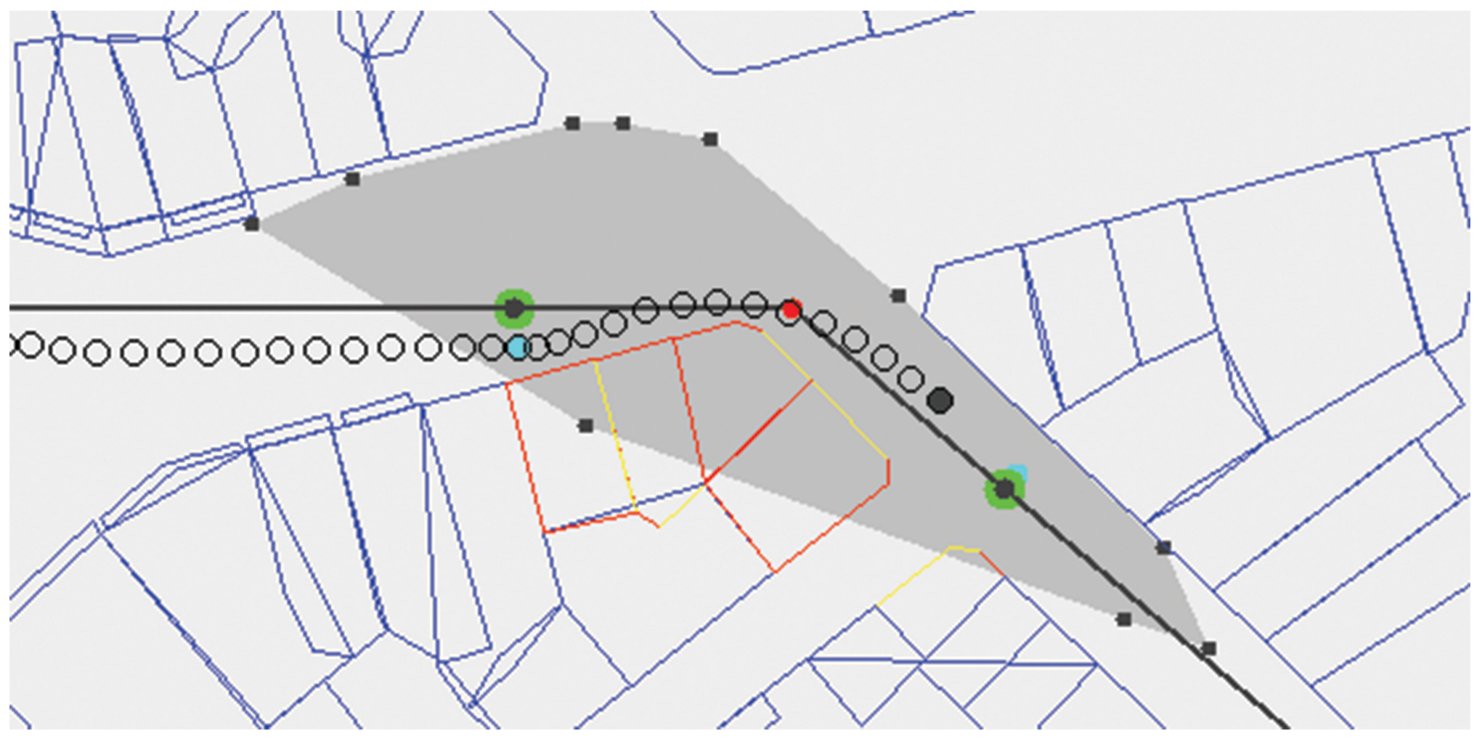
- Step 1) Use Theta* to find path to goal
- 2) Find turn events in Theta* path
- 3) Expand turn events to build segments, each segment defines MILP subproblem
- 4) Select obstacles to model in subproblem
- 6) Generate safe region using genetic alg.
- 7) Solve MILP subproblem with Solver
- 8) Combine subtrajectories into final result



San Francisco



Up/Down



UAV in flight with debug info visible

Scenario name	# obs.	# edges	world size	path (m)	# segments
Up/Down Small	5	5	25m x 20m	88	7
Up/Down Large	9	9	40m x 20m	146	11
Spiral	11	11	30m x 30m	96	10
SF Small 1	1235	4940	1km x 1km	1392	34
SF Small 2	1235	4940	1km x 1km	1490	38
SF Large	6580	26320	3km x 3km	4325	107
Leuven Small 1	3079	19941	1km x 1km	1312	34
Leuven Small 2	3079	19941	1km x 1km	864	22
Leuven Large	18876	111998	3km x 3km	3041	78

Scenario Information

Scenario name	Theta* (s)	GA (s)	MILP (s)	total (s)	score (s)
Up/Down Small	0.00	0.33	10.48	10.97	27.24
Up/Down Large	0.00	0.65	17.95	18.87	44.76
Spiral	0.01	1.06	7.17	8.46	28.72
SF Small 1	1.37	7.68	32.81	42.43	106.20
SF Small 2	1.82	7.98	36.81	47.32	114.36
SF Large	15.88	15.41	75.44	108.28	325.10
Leuven Small 1	1.51	23.49	135.86	161.85	97.44
Leuven Small 2	0.53	14.00	62.03	76.99	65.52
Leuven Large	14.65	67.55	460.46	544.73	227.27

Performance Results

Results

- Algorithm successfully handles large and complex environments like cities
- New algorithm: MILP scales linearly with trajectory length instead of exponentially
- MILP scales exponentially with obstacle density, not total amount of obstacles
- Theta*: still exponential, but much easier
- Algorithm is stable: predictable run time
- Many possible improvements still unexplored