FACULTY OF ENGINEERING
AND ARCHITECTURE

DEPARTMENT OF INDUSTRIAL SYSTEMS ENGINEERING AND PRODUCT DESIGN

Geozone-Aware Unmanned Aerial Vehicles (UAV) Path Planning Using RRT* and Jellyfish-Inspired Optimization for Urban Air Mobility (UAM)

Authors: Judit Salvans Baucells, Elham Fakhraian, Ivana Semanjski

Presenter: Judit Salvans Baucells

Master's Student in Industrial Engineering and Operations Research, Ghent University

GHENT UNIVERSITY

IARIA

Judit Salvans Baucells

Judit Salvans Baucells is a master's student in Industrial Engineering at Universitat Politècnica de Catalunya (UPC), currently completing this paper at Ghent University through the Erasmus+ program. Her academic interests include operations research, autonomous systems, and sustainable urban logistics.

Her thesis focuses on geozone-aware UAV path planning for Urban Air Mobility (UAM), integrating RRT* algorithms with bio-inspired optimization. She also has hands-on experience in process optimization, mechanical system design, and regulatory-compliant engineering.

GHENT UNIVERSITY

OVERVIEW

GHENT UNIVERSITY

APPLICATIONS

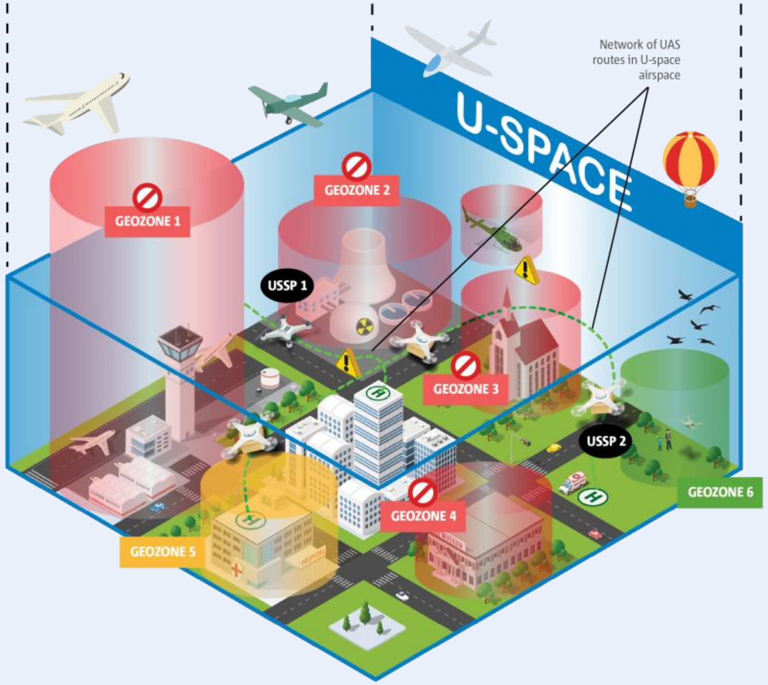
- Agriculture
- Search and Rescue
- Delivery Services
- Weather
- Logistics
- Emergency Management

UAV OPERATIONS

Autonomus Navigation	Sensors Cameras Radars ...	→	Real-time Data
Path Planning	Lenght Security Viability ...	→	Optimal Path

GHENT UNIVERSITY

REGULATIONS



Technologies for drones and Vertical Take-Off and Landing (VTOL) aircraft are evolving all the time. As drones and VTOLs are becoming a fixture in all our lives, we at **EASA set up rules for flying drones and VTOLs in Europe**, to define how they are designed, manufactured and operated. We will **also set up rules and standards for a specific type of airspace called U-Space, which will enable drones & VTOLs to fly safely across European skies**. In short, we are enabling innovative air mobility with drones and VTOLs.

EASA
European Aviation Safety Agency

GHENT UNIVERSITY

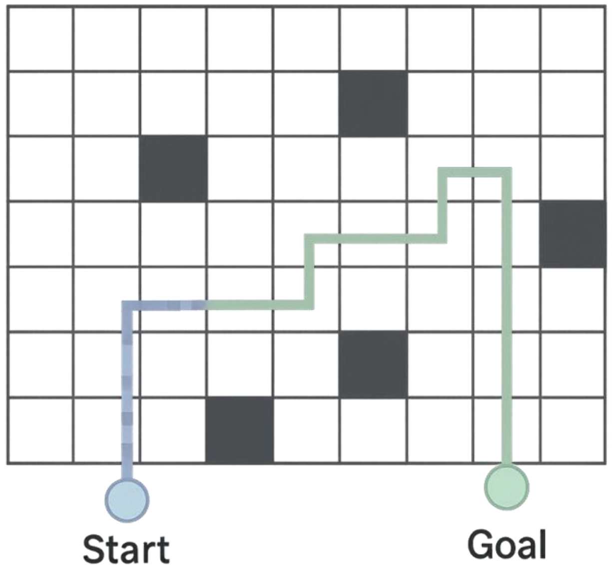
OBJECTIVES

First Goal	Integrate geozone constraints directly into the path planning process.
Second Goal	Optimization process to improve paths quality.
Third Goal	Test the method in real urban environment.
Fourth Goal	Support future U-space integrations.

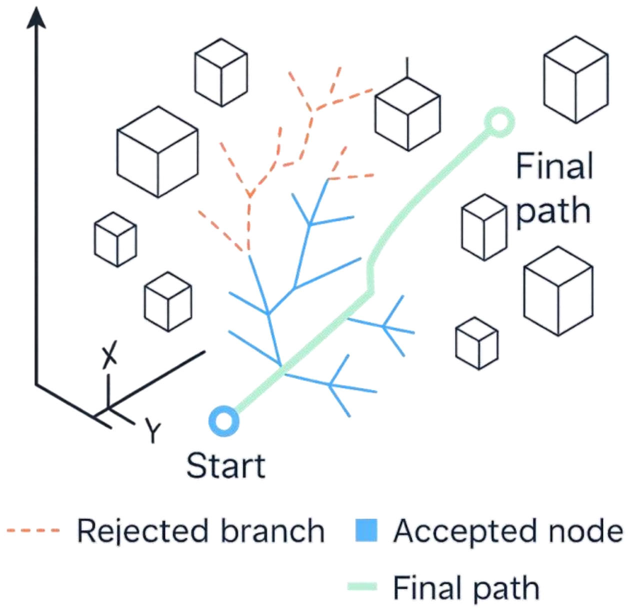
GHENT UNIVERSITY

LITERARY REVIEW

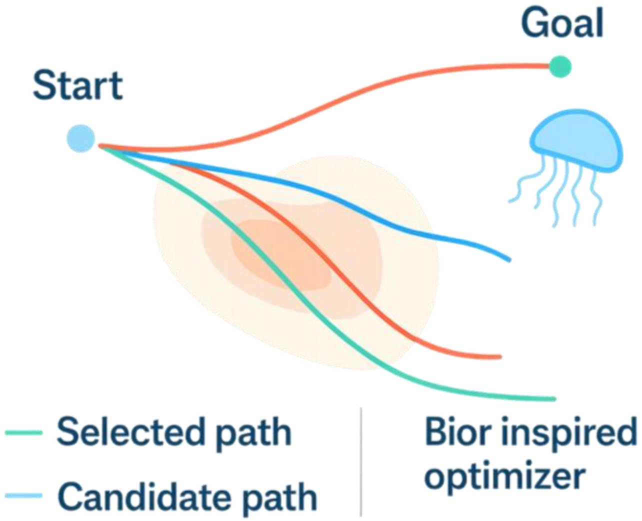
Graph-Based Algorithms: Dijkstra and A*



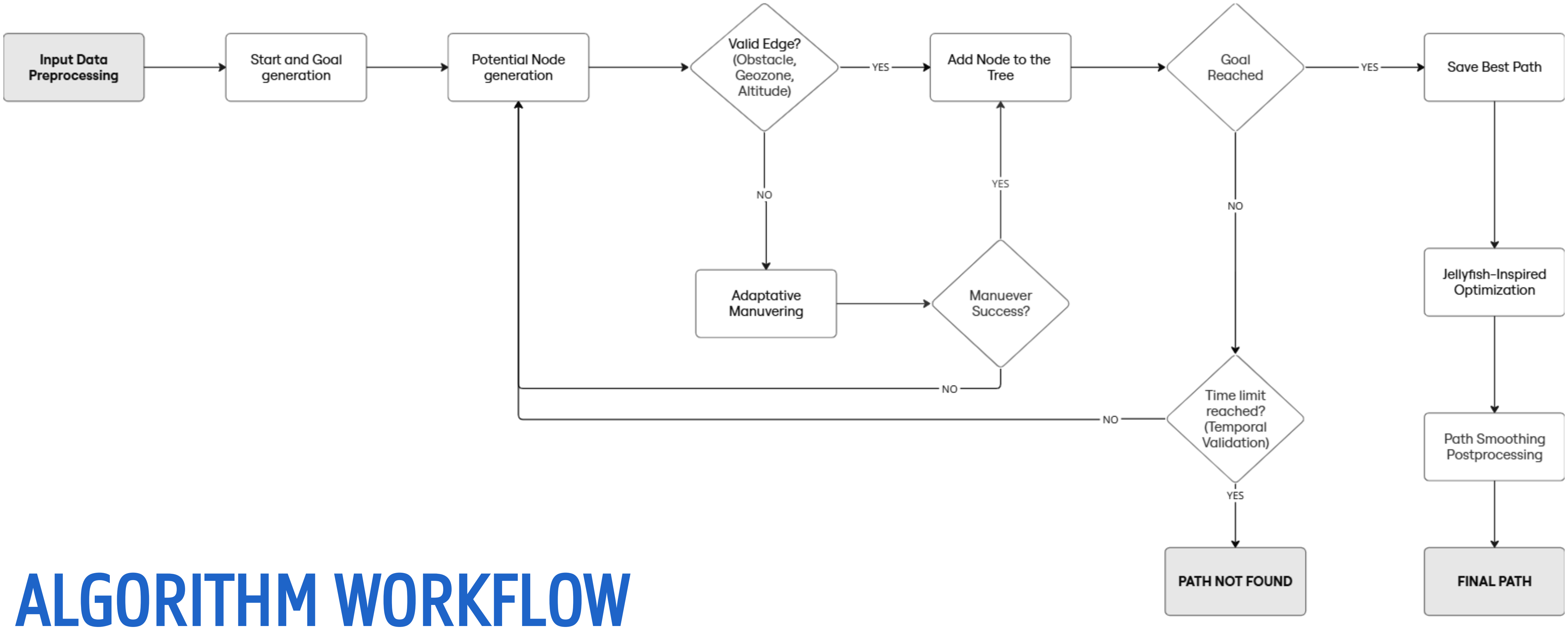
Sampling-Based Algorithms: RRT and RRT*



Metaheuristic and Bio-Inspired Algorithms



GHENT UNIVERSITY



ALGORITHM WORKFLOW

GHENT UNIVERSITY

IMPLEMENTATION

Start & Goal

- <80m height
- Ground Level
- Rooftop Point

Node Candidate

- 30% Goal Point
- 60% Existing Nodes Surroundings
- 10% Random

RRT* Tree

- Collision Free
- Between height limits
- Outside Geozones

Adaptative Maneuver

- Take off maneuver
- Landing maneuver
- Fly over an obstacle

IMPLEMENTATION

Path Found

- Goal Reached
- Time límit NOT reached

Jellyfish-Inspired Optimization

- Path Length
- Threat Cost
- Smoothness

Smoothing Process

- Sharp Turns
- Abrupt Direction Changes
- Respect Viability

GHENT UNIVERSITY

IMPLEMENTATION

RRT* Tree Constraints

$$isValid(e) = \begin{cases} 1, if\ e \cap O = \emptyset, e \cap G = \emptyset, & h(e) \in [h, H] \\ 0, & otherwise \end{cases}$$

e → candidate edge,

O →set of obstacle volumes

G →restricted geozones

$[h, H]$ →edge's altitude range.

Jellyfish-Inspired Optimization

$$\mathrm{Score_i} = \sum_{k=1}^{3} \mathrm{w_k} \,.\, \mathrm{normalized_{k.i}}$$

$w = [w_1, w_2, w_3]$ → randomly sampled weight vector

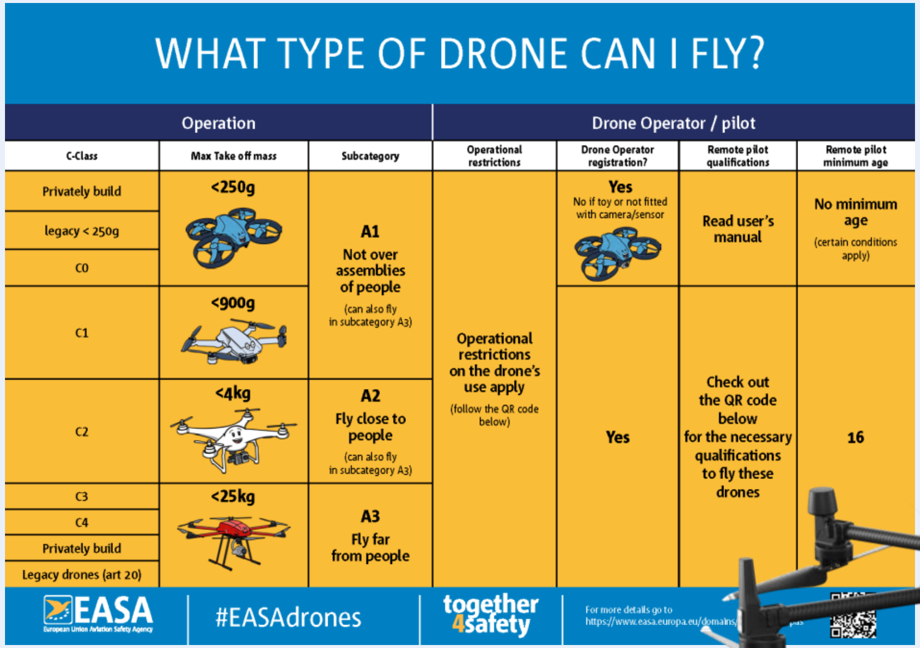
$$\sum_{k=1}^{3} w_k = 1$$

GHENT UNIVERSITY

CASE STUDY

Piombino, Italy

DJI Matrice 300 RTK



WHAT TYPE OF DRONE CAN I FLY?

Operation			Drone Operator / pilot			
C-Class	Max Take off mass	Subcategory	Operational restrictions	Drone Operator registration?	Remote pilot qualifications	Remote pilot minimum age
Privately build legacy < 250g C0	<250g	A1 Not over assemblies of people (can also fly in subcategory A3)	Operational restrictions on the drone's use apply (follow the QR code below)	Yes No if toy or not fitted with camera/sensor	Read user's manual	No minimum age (certain conditions apply)
C1	<900g			Yes	Check out the QR code below for the necessary qualifications to fly these drones	16
C2	<4kg	A2 Fly close to people (can also fly in subcategory A3)				
C3 C4 Privately build Legacy drones (art 20)	<25kg	A3 Fly far from people				

EASA European Union Aviation Safety Agency | #EASAdrones | together 4safety | For more details go to https://www.easa.europa.eu/domains/

TERRAIN & OBSTACLES DATA

{'NAME': 'sisw-test-area-piombino',

'CLOSED': 'YES',

'PERIMETER': '4.401 km',

'ENCLOSED_AREA': '0.94 sq km',

'coordinates': [(10.536867583333333, 42.939028638888885), (10.5340785, 42.93482538888889), (10.528657500000001, 42.93246844444444),

...,

(10.536867583333333, 42.939028638888885)]}

{{ 1: {'CLOSED': 'YES', 'suolo_id': 'RT0201010300340938',

..., 'coordinates':

↪ [(10.53534725, 42.93442638888889, 40.19), (10.535718833333334, 42.935072805555555, 40.19)

...]},

13: {'CLOSED': 'YES', 'suolo_id': 'RT0201010300341633',

..., 'coordinates':

↪ [(10.533123777777778, 42.932537888888889, 37.74),(10.533304222222222, 42.931349277777778, 37.74)

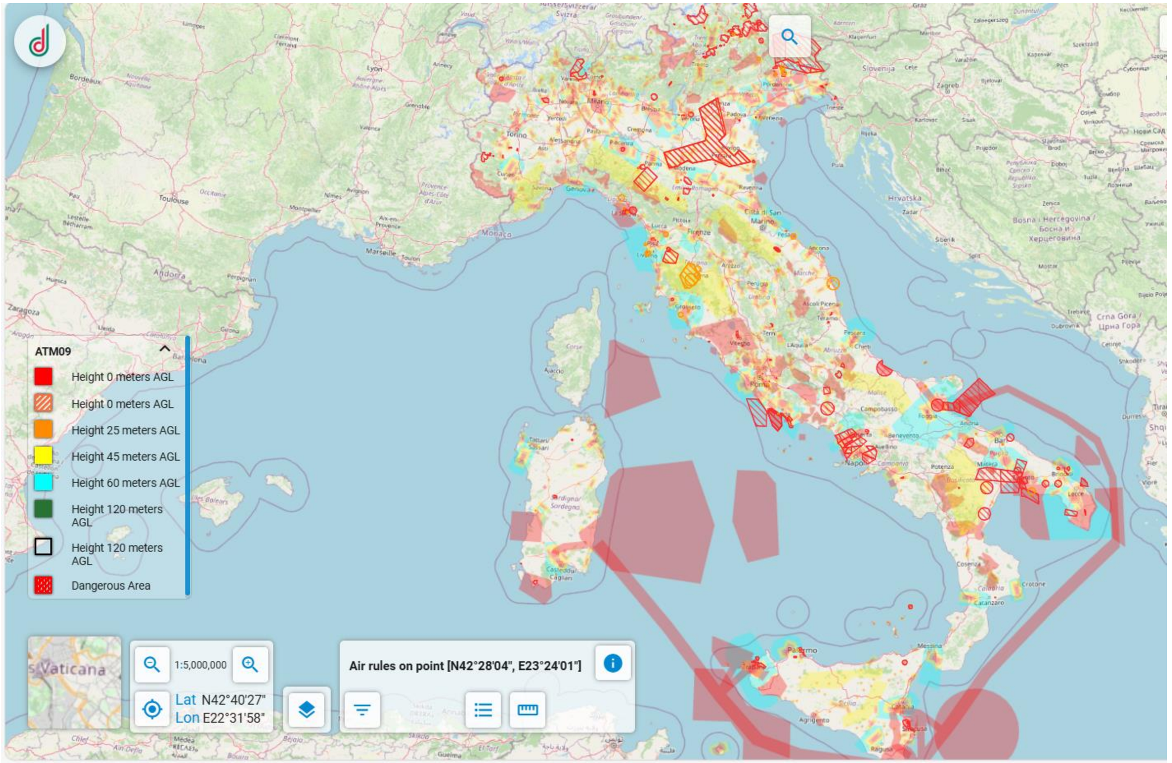
...]}}

Regione Toscana

GHENT UNIVERSITY

GEOZONES DATA

Input Data



{'title': 'ITA ZoneVersion 31/03/2025 07:25:02’, 'description':

↪ 'ITA ZoneVersion - GeoZones[4317] - ATM09[4013]/NFZ[304]/NOTAM[0]',

↪ 'features': {'A557281’: { 'identifier': 'A557281',

.....

'geometry': [{

'lowerLimit': 45,

'upperLimit': 120,

'horizontalProjection': {'type': 'Polygon',

'coordinates': [[[10.5552691, 42.942228],

...,

↪ [10.5430489, 42.941751]]]

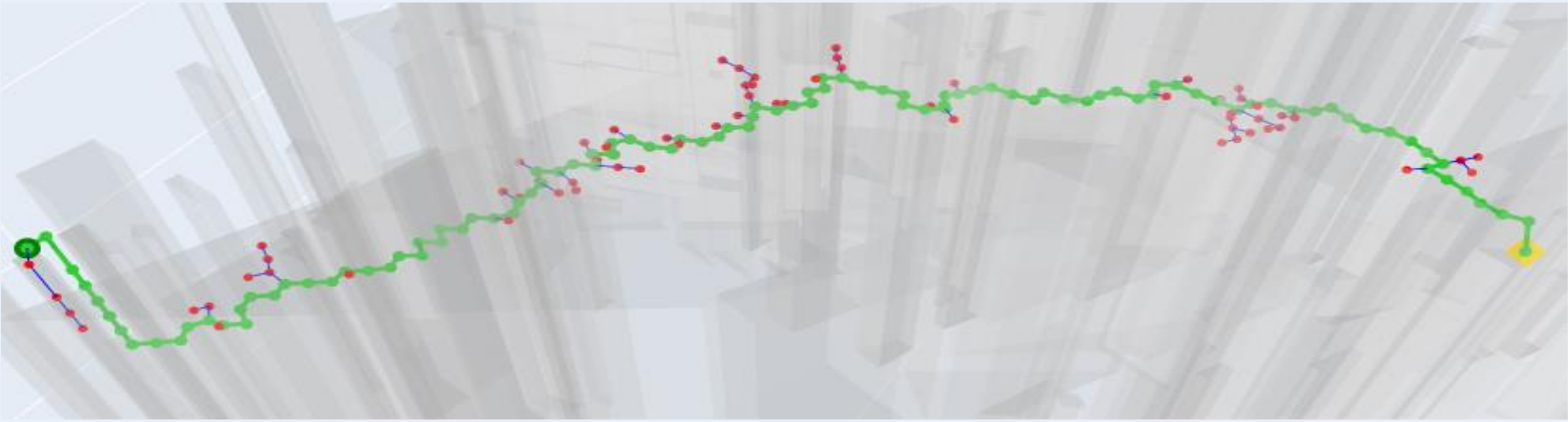
}}]}}}

GHENT UNIVERSITY

d-flight
enabling autonomous flight

EXPERIMENTS

A	(10.5375 , 42.9361, 30.9) (10.5313, 42.931, 22.7)	G	(10.5332, 42.9303, 32.1) (10.5384, 42.9339, 0.5)	L	(10.5335, 42.9289, 40.9) (10.5296, 42.9288, 26.1)
B	(10.535, 42.9307, 25.2) (10.5335, 42.9295, 0.5)	H	(10.5398, 42.9298, 0.5) (10.5314, 42.9289, 34.4)	M	(10.5339, 42.9343, 0.5) (10.5399, 42.9261, 0.5)
C	(10.5326, 42.933, 27.7) (10.5301, 42.932, 22.9)	I	(10.5363, 42.9293, 21.5) (10.5336, 42.9349, 28.4)	N	(10.5320, 42.9301, 0.5) (10.5334, 42.9303, 32.1)
D	(10.536, 42.9308, 29.5) (10.5377, 42.9376, 20.5)	J	(10.5381, 42.9345, 30.6) (10.5327, 42.9329, 0.5)	O	(10.5375, 42.9361, 30.9) (10.5377, 42.9296, 28.1)
E	(10.536, 42.9308, 29.5) (10.5377, 42.9376, 20.5)	K	(10.5353, 42.9292, 0.5) (10.5333, 42.9320, 0.5)	P	(10.5358, 42.9369, 23.3) (10.5374, 42.9308, 25.7)
F	(10.536, 42.9308, 29.5) (10.5377, 42.9376, 20.5)				

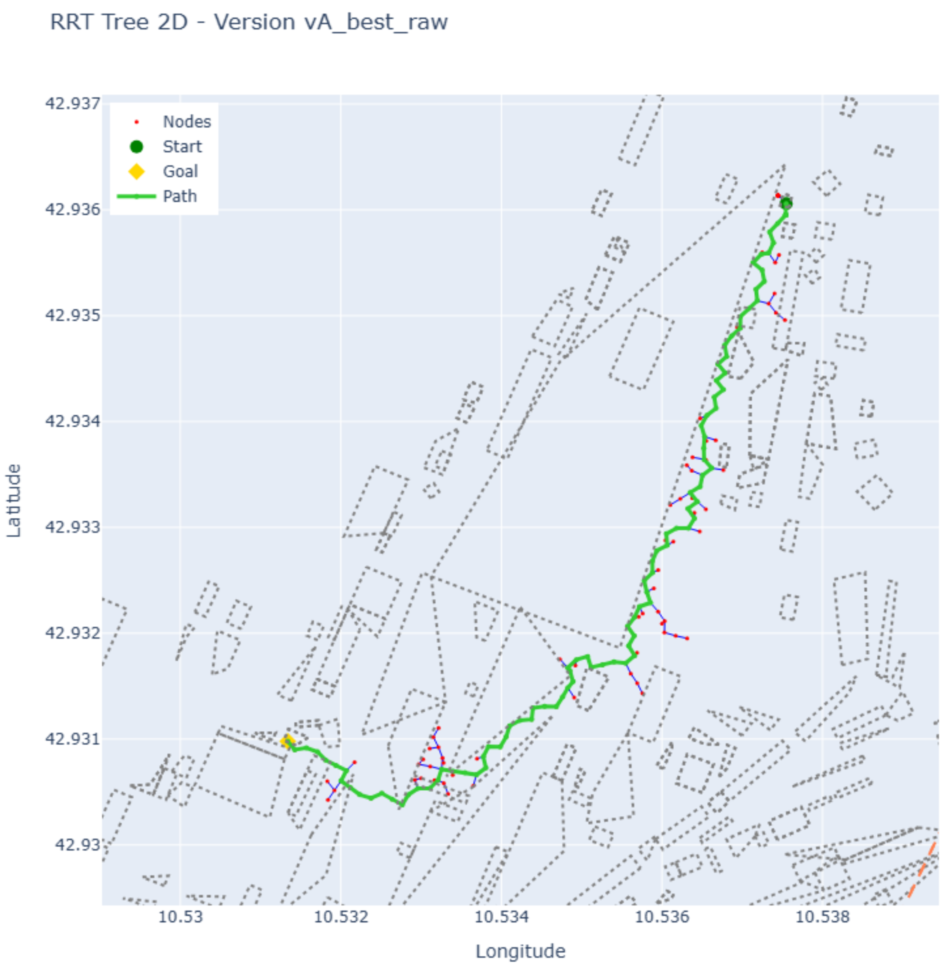


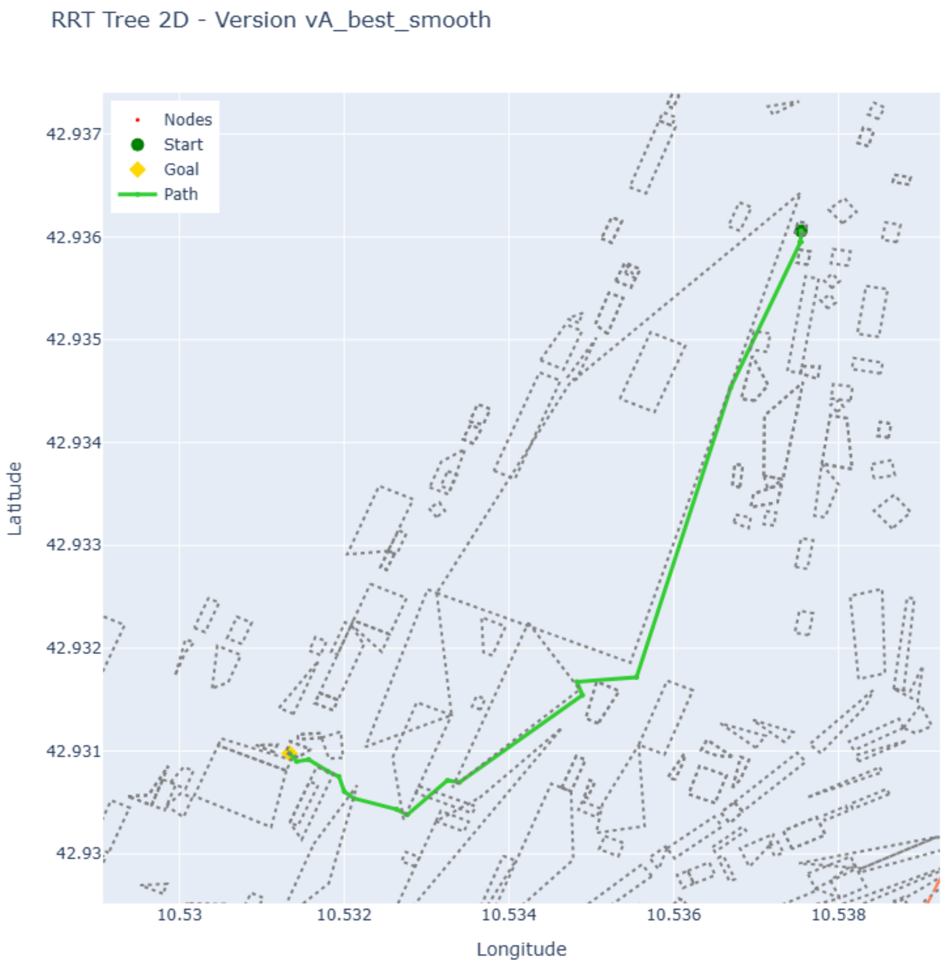
STEP - SIZE ANALYSIS

Metric	4	8	10	12	14
Success Rate (%)	40	70.62	71.88	79.38	77.5
Execution Time (s)	68.06	45.22	43.55	24.81	25.26
Path Length	4.34*	4.02*	4.0*	4.22*	4.07*
Threat Cost	2.67*	1.32*	0.96*	0.69*	0.6*
Node Count	2.01*	2.01*	1.62*	1.71*	1.39*
Smoothness	6.15*	3.16*	2.64*	2.42*	2.03*

GHENT UNIVERSITY

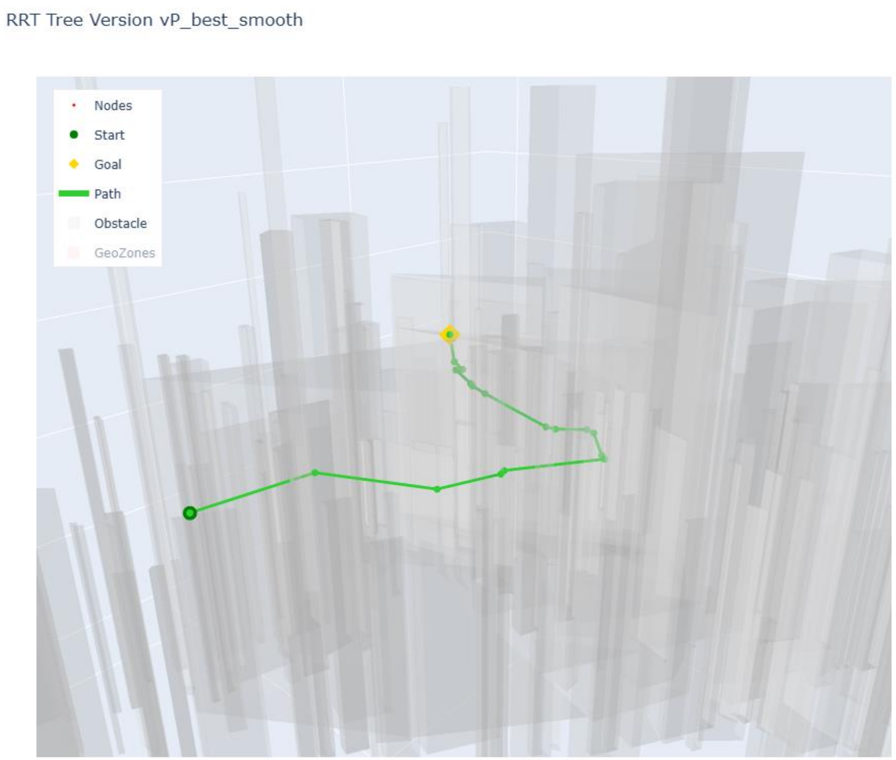
PATH SMOOTHING





GHENT UNIVERSITY

PATH SMOOTHING

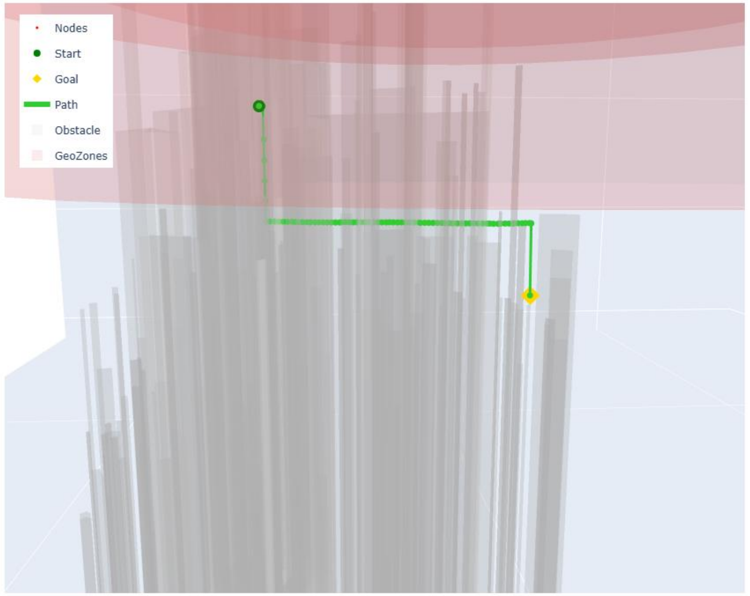


Results

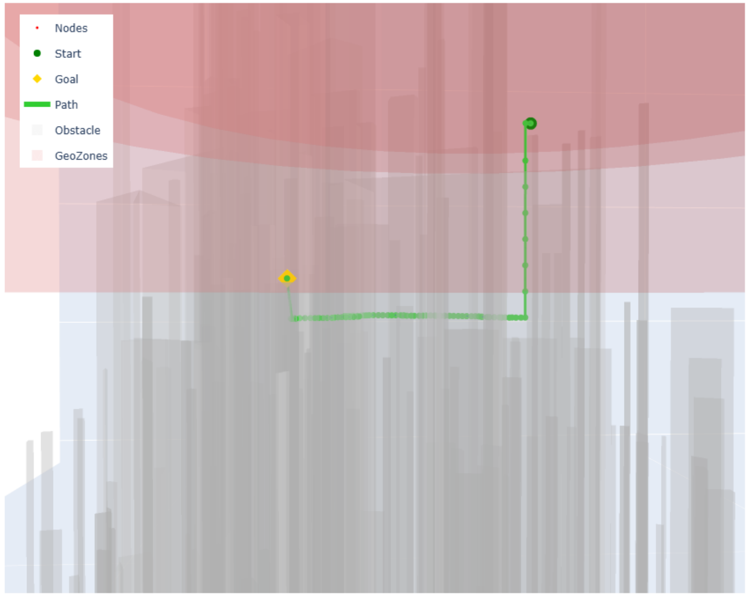
Trajectory	Version	Threat*	Nodes*	Smoothness*
A	raw	4.286	2.355	8.167
A	smooth	2.857	0.242	1.085
B	raw	7.143	10	2.484
B	smooth	5.714	0.081	0.487
C	raw	4.286	0.431	0.66
C	smooth	1.429	0.027	0.121
…	…	…	…	…
K	raw	2.857	7.51	3.279
K	smooth	2.857	0.188	0.896
L	raw	5.714	1.373	1.8
L	smooth	2.857	0.296	0.283
…	…	…	…	…
O	raw	2.857	2.032	4.081
O	smooth	1.429	0.121	0.396
P	raw	0	4.361	6.722
P	smooth	0	0.175	0.92

GEOZONE-AWARE PATH PLANNING

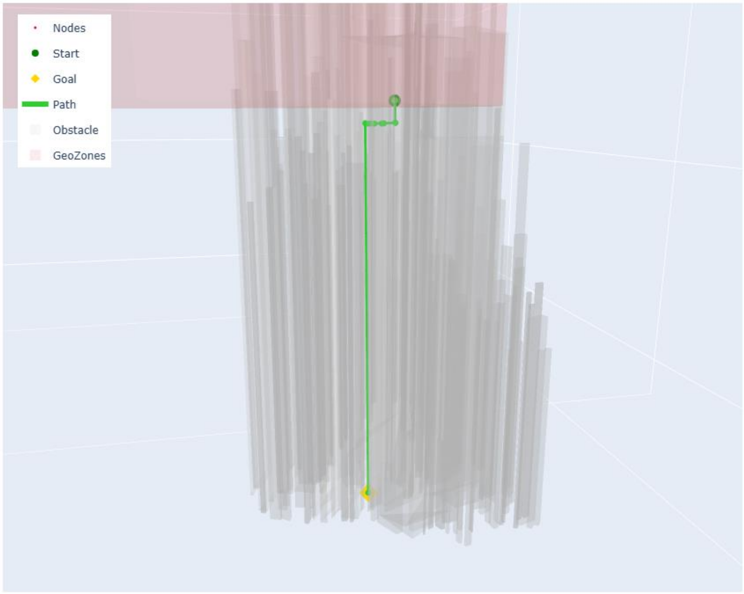
RRT Tree Version vD_best_raw



RRT Tree Version vE_best_raw



RRT Tree Version vB_best_smooth



GHENT UNIVERSITY

CONCLUSIONS

1	We developed a geozone-aware RRT* algorithm for safe UAV navigation.
2	Jellyfish-inspired multi-objective decision finds the most optimal path.
3	Tests over Piombino showed strong performance in dense environments.
4	The method supports scalable, regulation-compliant urban UAV flights.

FUTURE WORK

1	Define complex zones where the algorithm shows low success rates.
2	Use zone analysis to plan UAV infrastructures like take-off platforms.
3	Integrate real-time weather data to adapt paths dynamically.
4	Extend the algorithm to multi-drone coordination scenarios.
5	Test in other urban environments to validate scalability.

THANK YOU

ACKNOWLEDGMENT

This work was supported by the funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 101007134 and Regional and community funding: Special Research Fund's project Robust and Trustworthy Smart Mobility Systems (grant number BOF/STA/202209/004).

JUDIT SALVANS BAUCELLS

judit.salvansbaucells@ugent.be

ELHAM FAKHRAIAN

elham.fakhraian@ugent.be

Universiteit Gent

@ugent

@ugent

Ghent University

youtube.com/ugent

www.ugent.be