Airborne Conflict Modeling and Resolution for UAS Insertion in Civil Non-Segregated Airspace

Carlo Alfredo Persiani, Sara Bagassi

University of Bologna

Introduction

UAS Technological improvement

Advances in military technologies lead to the use in civil context:

•Surveillance

•Fire fighting

•…

•Dirty-Dull-Dangerous

ATM (Air Traffic Management)

Main goals in ATM:

•Avoiding collision between aircraft

•Expediting and maintaining an orderly flow of air traffic

↓

ATM Automation Process

UAS Insertion in Civil Non-Segregated Airspace

Theoretical Framework

CD&R: Conflict Detection and Resolution Problem

Airborne		Centralized
Non-cooperative	VS	Cooperative
Tactical		Strategic
State-based		Intent-based

Problem Formulation/1

UAS has to visit a set of mission waypoints:

Maintaining separation with air traffic;

Optimizing a selected function (Minimum Fuel, Minimum Time).

Assumptions:

The piloted air traffic has priority on the unmanned one;

If a conflict occurs, the UAS will modify its route in order to resolve it.

Problem Formulation/2

Two decisional dimensions:

1)Best visit order of the m mission waypoints

2)Type of avoidance manoeuvre:

- Holding
- Speed Variation
- Vertical/Horizontal Avoidance

Algorithm Overview

Pre -processing

- For each UAV sub-path *(i,j)*, started at time *t*

Weight estimation

- $W^k_{(i,j)}(t)$ is estimated
- For each type *k* of manoeuvre

Genetic Algorithm

- Different "*avoidance philosophies*"
- Fitness function: minimum Time or minimum Fuel

Pre-processing: weight estimation

A conflict *c* occurs at the time *t* on the arch between *i* and *j*

↓

The weight, for each avoidance manoeuvre, is calculated

$$w_{(i,j)}^{k}(t)$$

It depends on:

- The delay generated by the manoeuvre (time optimization)
- The fuel burnt during the manoeuvre (fuel optimization)

Manoeuvre modeling

Each conflict resolution manoeuvre has to be:

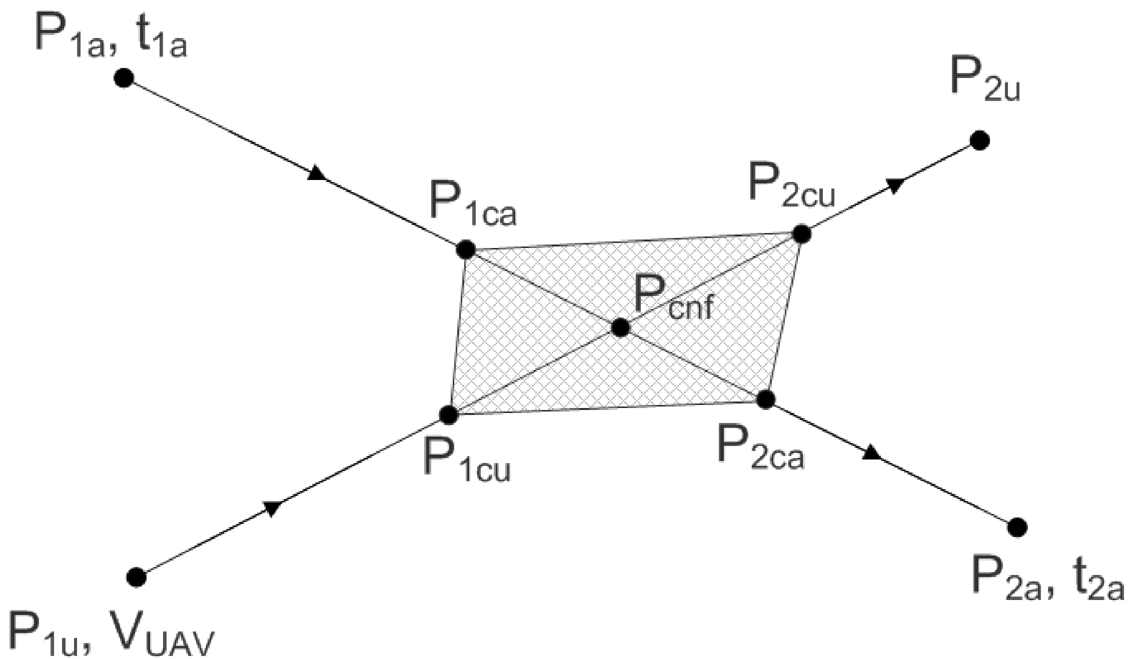
•**Feasible**, taking into account UAV performances

•**Modeled**, in order to understand how it affects time delay (or fuel consumption)

Type of avoidance manoeuvre:

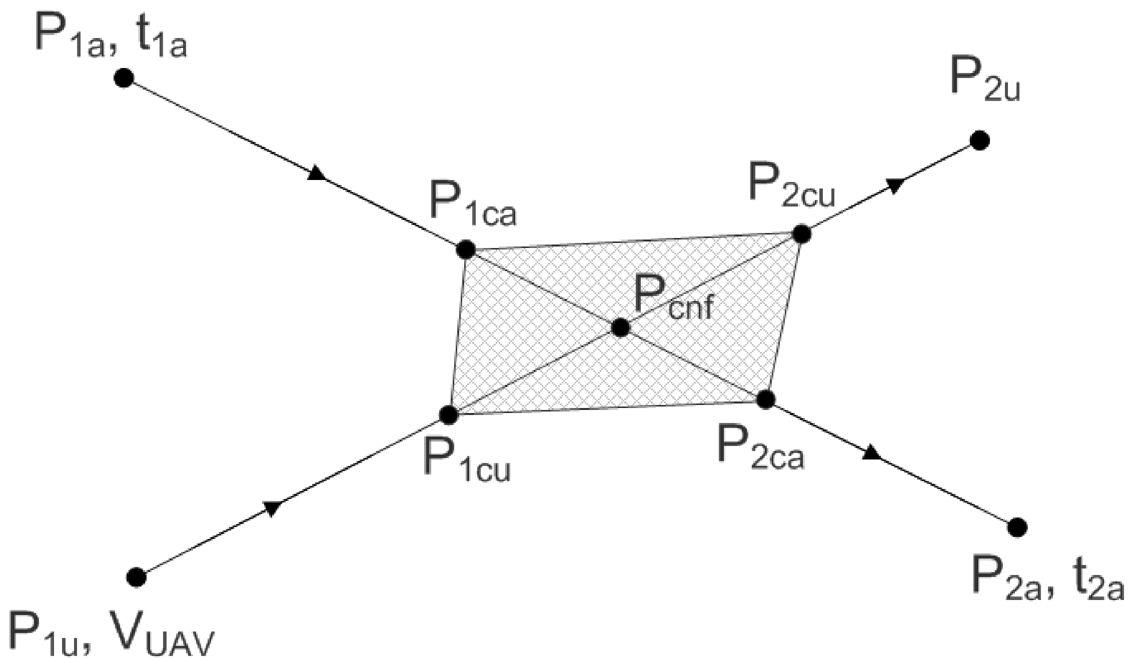
- Holding
- Speed Variation
- Vertical/Horizontal Avoidance

Holding



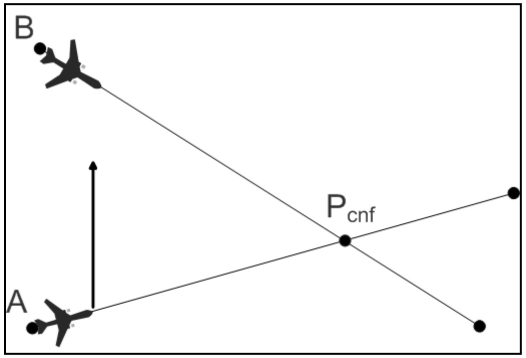
$$w_{(i,j)}^{holding}(t) \quad \alpha \quad (h_{i,j}^{t} + (p_{1u} - p_{2u} / v))$$

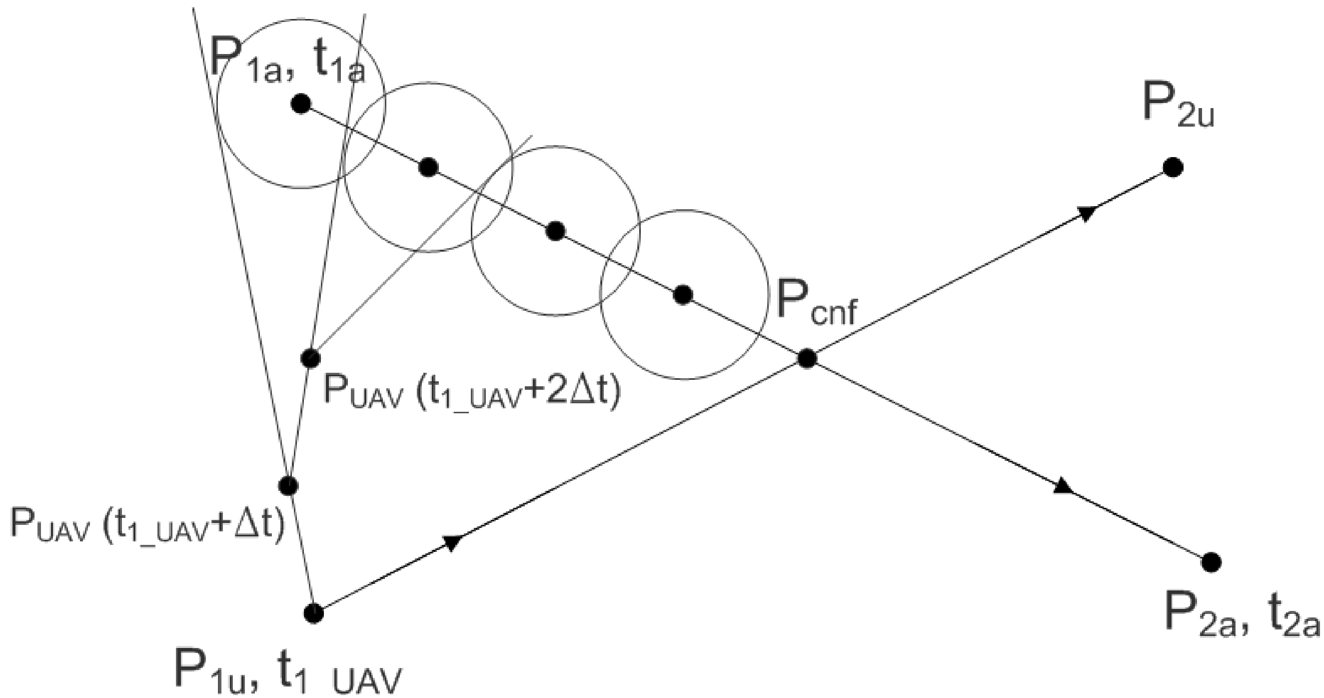
Speed variation



$$w_{(i,j)}^{scontr}(t) \quad \alpha \quad (p_{1u} - p_{2u}) / v_m^{inc/red}(t)$$

Vertical/Horizontal avoidance





$$w_{(i,j)}^{Havoid}(t) \qquad \alpha \qquad n_v \Delta t + n_p \Delta t$$

$k \in K$

Genetic algorithm: Pilot Philosophy

A first population of η_p UAV routes R_u is generated.
At each route a "Avoidance Philosophy" k_r is randomly assigned.

It consists in one of the following avoidance techniques:

- holding(k=0),
- speed control (speed reduction k=1, speed increasing k=2),
- avoidance on vertical plane (k=3),
- avoidance on horizontal plane (k=4).

GA: Fitness function

1. An optimization criterion is chosen: minimum time or minimum fuel;
2. The fitness (time or fuel consumption) of each route is calculated - considering the weight of the arches function of the departing time step;
3. The population is sorted by decreasing fitness.
4. The evolution to the next population starts.

GA: Evolution &Termination criteria

Evolution:

•The first half of the population, sorted by decreasing fitness, is considered ”good”: the second part of the population is built from the chromosome of the previous part.

Termination:

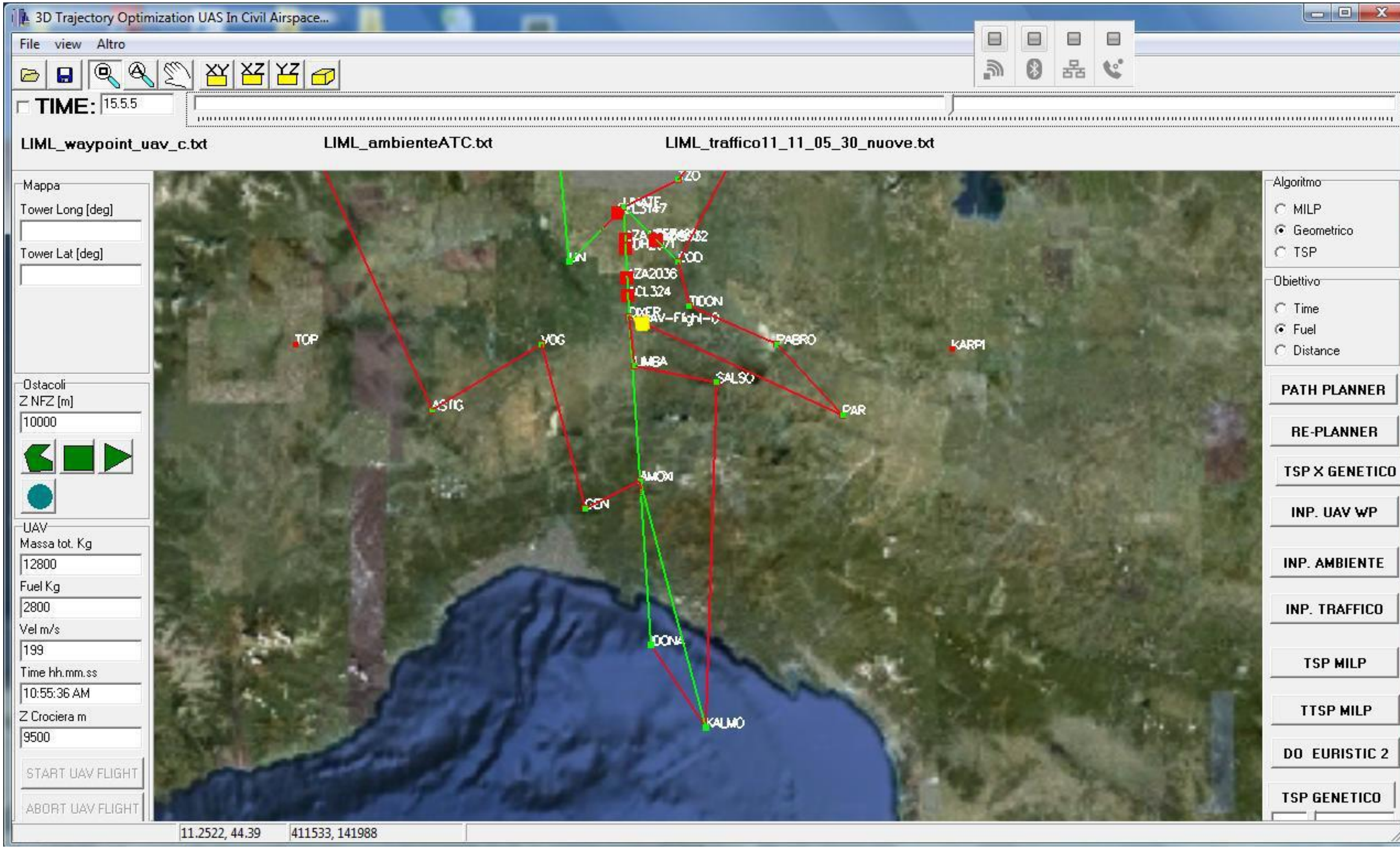
•Repeat η_t times the evolution;

•If the improvement in the last η_c individuals is less than 1% then the evolution is terminated.

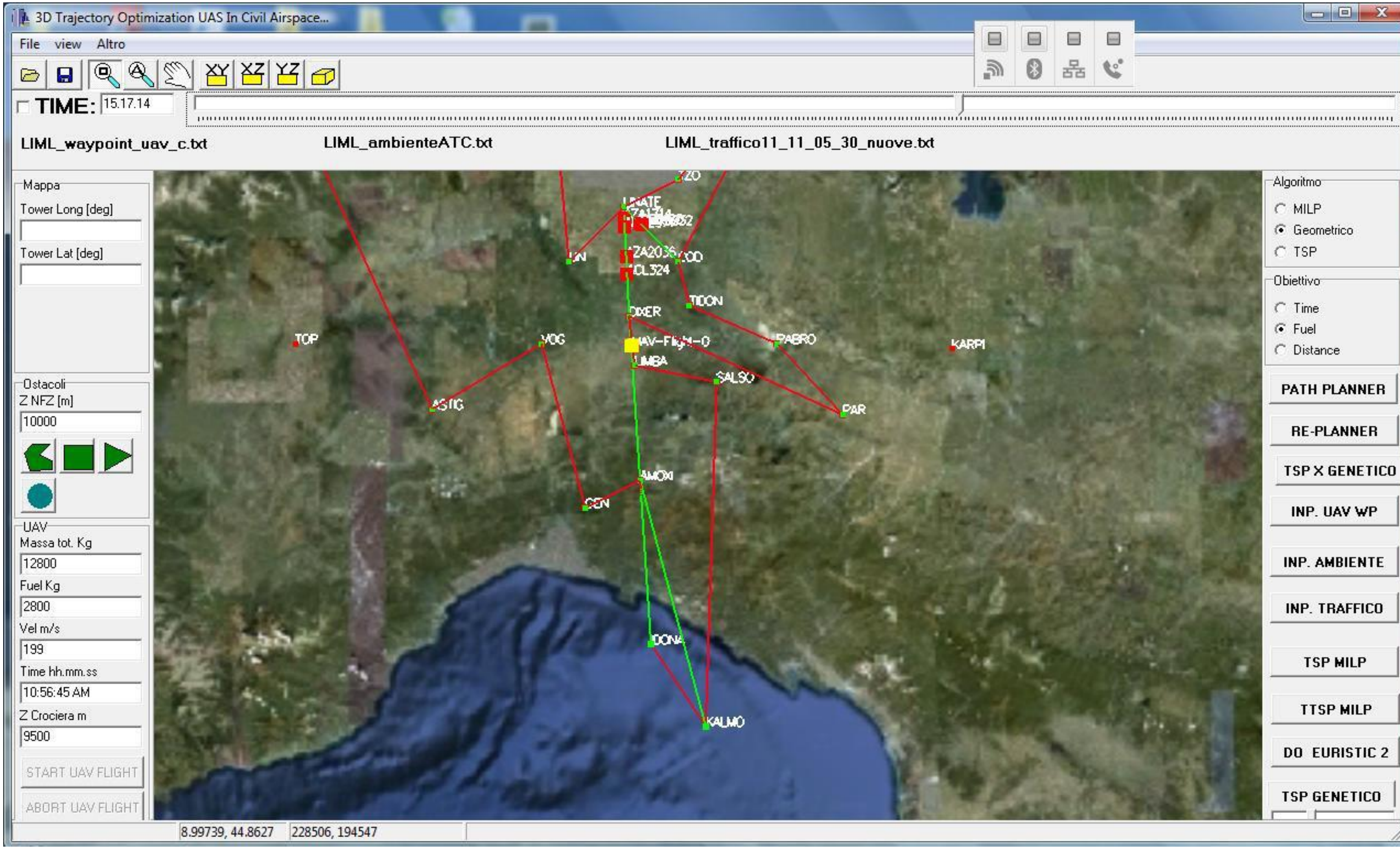
Simulation set-up

- **Real air traffic scenario**: the TMA (Terminal Manoeuvring Area) of Milano Linate (ICAO code LIML).
- Navigation Points as Radio-Assistance and Fix Points (radial and distance by a radio assistance) are reported; SID (Standard Instrumental Departure) route and STAR (STandard arrival Route) of the airport are modeled using **graphic tools**.
- Air traffic data are acquired by AOIS (Aeronautical Operational Information System) and Radar Track provided by ENAV S.p.A (Italian Agency for Air Navigation Services).
- Position and altitude of **115 aircraft** (arrival, departure and overflying traffic) are simulated for **6 hours of simulation**.
- The UAV target points are generated considering that some of the UAV target points correspond to the aircraft navigation points, the others have been randomly generated.

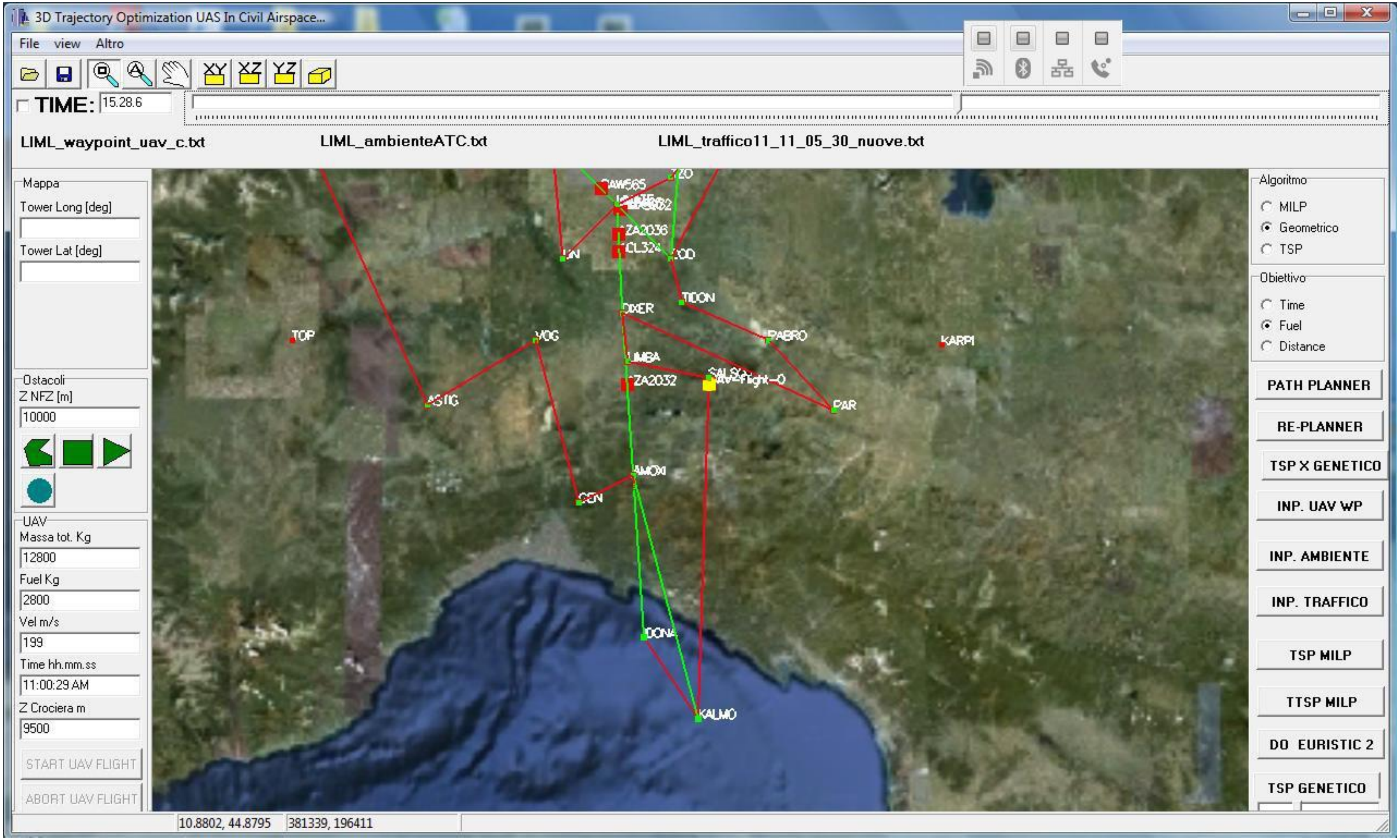
Simulation results/1



Simulation results/1



Simulation results/1



Simulation results/2

minimum fuel objective

	Obj Value	N° of Conflicts	Holding	Speed Red.	Speed Inc.	H Avoidance	V Avoidance	CPU time
20 targets	249	3	0	0	0	0	3	3,78
25 targets	310	4	1	0	1	1	1	6,12
30 targets	317	4	0	1	1	1	1	7,41
35 targets	332	2	1	0	0	0	1	15,66
40 targets	354	5	1	1	1	1	1	17,47
45 targets	433	4	1	0	0	0	3	21,98

$\eta_p = 200$, $\eta_t = 3500$, $\eta_c = 330$, and $\Delta t = 1$ minute, computed on an IntelCore Duo 2GHz

Simulation results/3

minimum time objective

	Obj Value	N° of Conflicts	Holding	Speed Red.	Speed Inc.	H Avoidance	V Avoidance	CPU time
20 targets	260	5	1	2	1	1	0	3,83
25 targets	298	2	1	0	0	1	0	5,67
30 targets	304	5	1	0	2	0	2	13,69
35 targets	325	5	4	1	0	0	0	16,8
40 targets	404	4	0	0	1	2	1	12,48
45 targets	416	4	0	1	0	1	2	18,53

$\eta_p = 200$, $\eta_t = 3500$, $\eta_c = 330$, and $\Delta t = 1$ minute,
computed on an IntelCore Duo 2GHz

Conclusion

- We present the problem of the management of an UAV mission into controlled non-segregated air space.
- A genetic algorithm has been presented to solve the problem in real traffic scenarios.
- The genetic algorithm allows to deal efficiently with the problem's time dependence, moreover it is useful to identify a proper avoidance manoeuvre.
- Simulation results show how the proposed geometric model efficiently defines the arches weights to be used in the conflict resolution.
- Computation time shows that this approach could be applied to future real time applications.

Thank you for your attention