[EN-037] Airborne Conflict Modeling and Resolution for UAS Insertion in Civil Non-Segregated Airspace

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Abstract: In this paper we present a Genetic Algorithm designed to manage the mission of an UAS that has to visit a set of mission points into a congested airport TMA (Terminal Area) .

The genetic approach is useful to model the presence of different avoidance options: populations of pilots that have different "avoidance philosophy" are crossed in order to obtain a good mix of avoidance technique.

Our methodology is based on a strategic, intent-based, non-cooperative (only one aircraft – the UAV –maneuver), geometric (prediction is based on geometrical projections) and distributed (as opposed to centralized) approach.

Finally, real piloted traffic data from the Milano Linate (LIML) Terminal Area are used to test the algorithm.

Keywords: Airborne conflict resolution, UAS insertion

1. INTRODUCTION

One of the most interesting challenge of the next years will be the Air Space Systems automation. This process will involve different aspects as the Air Traffic Management, the Aircrafts and Airport Operations and the Guidance and Navigation Systems. The use of UAS (Uninhabited Aerial System) for civil mission will be one of the most important steps in this automation process.

The UAS insertion in civil non-segregated airspace addresses quite a number of issues such as the level of priority that unmanned air traffic should have relative to manned air traffic, the coordination between the UAV controller and the air traffic control, the level of automation of the UAS, the sense & avoid capacity of the UAS.

The management of potential conflicts between UAS and manned air traffic is a challenging issue that is often considered as an instance of the general Conflict Detection & Resolution (CD&R) problem.

Since the first concepts concerning Free Flight were envisaged, both the industry and the academia research communities paid attention to CD&R problem.

In order to study the feasibility of self separation, many prototype tools such as the Autonomous Operations Planner (AOP), Future ATM Concepts Evaluation Tool (FACET) [1] developed at NASA and the Airborne Separation Assurance System (ASAS) [2] developed at the National Aerospace Laboratory (NLR) in the Netherlands have been proposed. All these tools implement CD&R algorithms.

CD&R algorithms can be airborne or centralized. Usually airborne conflict detection and resolution algorithms are suitable for tactical use, whereas centralized CD&R algorithms can be used both for tactical and for strategic control. CD&R algorithms can be state-based or intent-based. State-based refers to the use of aircraft state information as opposed to those algorithms that use intent information, e.g. flight plan.

The airborne algorithms used in the Autonomous Mediterranen Free Flight (AMFF) simulations have proved to be effective with limitations for dense traffic conditions [3]. AMFF is a state-based conflict detection and resolution concept with a level of automation such that the pilot follows the automatically generated conflict resolution advices by steering the aircraft.

Farley et al. [4] assessed the performance of a conflict resolution algorithm developed as part of the Automated

Airspace Concept [5] for conflicts detected in any phase of flight - including arrival merging operations - in a simulation environment designed to represent the complexity, variety and volume of current and future air traffic operations.

Afterwards, the literature has expanded to include approaches based on genetic algorithms [6][7][8] and arrival-time constraints.

In this paper we present a Genetic Algorithm designed to manage the mission of an UAS that has to visit a set of mission points into a congested airport TMA (Terminal Area) .

The genetic approach is useful to model the presence of different avoidance options.

Our methodology is based on a strategic, intent-based, non-cooperative (only one aircraft – the UAV –maneuver), geometric (prediction is based on geometrical projections) and distributed (as opposed to centralized) approach. It is comprised by two steps.

In a first step a geometric analysis allows to identify all possible UAS paths among the mission targets and their related potential conflicts with the piloted aircraft (traffic aircraft).

Air Traffic Management operative techniques are used to model different options of conflicts resolution: vertical and horizontal avoidance, speed regulation and the use of the holding patterns. These avoidance options are then compared taking into account the mission constraints and objectives, minimum time or minimum fuel, in order to define a cost for each UAS path and its related conflict avoidance options.

In the second step the problem of find the mission targets visit order is considered. It consists in a combinatorial problem that concerns the sequencing of both targets and conflict resolution options.

Finally, real piloted traffic data from the Milano Linate (LIML) Terminal Area are used to test the algorithm.

2. PROBLEM FORMULATION

Let us consider a UAV mission performed in Controlled Air Space. The mission consists in departing from a ground base, taking pictures over a set M_{wp} (Mission Way Points) of m targets at a given mission altitude and coming back to the same airfield. During this mission a set A of n piloted aircrafts fly into the same Air Space following authorized routes: the UAV has to maintain a minimum separation from the piloted air traffic. We suppose that the position and the altitude of each aircraft during the entire mission (off-line approach) are known. Currently ICAO regulations concerning minimum separation between piloted and not piloted traffic do not exist: we assume a minimum longitudinal separation of 5 NM and a minimum vertical separation of 1000 ft. According to its performance, the UAV has different options to avoid the piloted air traffic: holding over a way point, reducing or increasing its speed or using a vertical or horizontal avoidance. The goal consists in planning the UAV minimum-time and minimum-fuel routes (in terms of succession of mission targets) that allow to visit the targets maintaining the minimum separation from the piloted traffic. This problem has two decisional dimensions: the choice of the best order of visiting a set of way points and the choice of the avoidance manoeuvres that have to be used. The first problem can be considered as the well known Travelling Salesman Problem (TSP), while the second is pertaining to an UAV path planning problem that has been investigated using several approaches. These two problems can be joint considering that the avoidance of the piloted air traffic in a sub-path between two mission way points depends on the moment by which the UAV starts flying between this couple of way points. In this way it is possible to formulate the problem as a Time-Dependant Travelling Salesman Problem (TDTSP). The temporal dimension can be introduced by dividing into time steps the temporal horizon. If t_{end} is an upper bound on the mission duration obtained by the UAV endurance and Δt is the duration of a time step, the set $T = \{1,...h\}$ is the set of the time steps where $h = t_{end} / \Delta t$ represents the number of time steps used. For a mathematical formulation of this problem see [9].

Considering long endurance missions (7/8 hours and up to 40/50 targets) and different avoidance options, the problem calls for heuristic solution. Our approach uses a first pre-processing step by which the function of the time $w^k_{(i,j)}(t)$ is calculated for each UAV sub-path: it represents the weight (as estimation of the time and fuel consumption) of the sub-path *(i,j)*started by the UAV at time step $t \in T$ using the k avoidance manoeuvre. These weights are then used by the genetic algorithm to calculate the population fitness. Populations of pilots that have different "avoidance philosophy" are crossed in order to obtain a good mix of avoidance technique.

3. CONFLICT GRAPH AND AVOIDANCE MANOEUVRES

As the TSP is associated to a graph, the UAV mission environment can be modeled using a "Conflict Graph". We define a Conflict Graph a "six-tuple" $G = \{V, M_{wp}, A, C, K, T\}$.

$V = \{(i, j) / i \in M_{wp}, j \in M_{wp}, i \neq j\}$ is the set of possible paths between the mission way points: if no conflict occurs, the UAV flies direct from *i-th* to *j-th* target. Due to the different altitude values required to overfly the targets, the path *(i,j)* is different from the path *(j,i)* in terms of time and fuel consumption: the Conflict Graph is an asymmetric and direct graph. C is the set of possible conflicts: a conflict $c \in C$ between the UAV u and an aircraft $a \in A$ occurs if the minimum separation requirement is not satisfied during all the time steps $t \in T$. K is the set of all possible avoidance options: holding, speed control and avoidance on vertical and horizontal planes.

In order to build the Conflict Graph it is necessary to consider the intersection between the UAV Mission Graph $G_m = \{V, M_{wp}\}$ and the route of each aircraft $a \in A$. Such routes consist in a set of IFR (Instrumental Flight Rules) points (RadioAssistance or Fix Points): $\forall a \in A$, $R_a = \{a_1, \ldots a_{n_a}\}$, $n_a \in N$. As input of the problem (off-line problem) the altitude $h^a_{a_i}$ and the time $t^a_{a_i}$ of the aircraft a over its routing point a_i are known for each aircraft $a \in A$. An intersection between a UAV path *(i,j)* and an aircraft sub-route (a_i, a_j) occurs if the distance between the closest points of these segments is less than 1000 ft on the vertical plane or 5 NM on the horizontal plane. In this case a conflict $c \in C$ in the path *(i,j)* and its related time step t_c are identified. The "weights" (in terms of time and fuel consumption) of the avoidance manoeuvres of the conflict c depends on:

- the departing time step from i to j;
- the geometry of the conflict;
- the UAV performances.

Naturally, starting a path in a specific time step and maintaining a defined speed could implicate a conflict while another departing time step could be conflict free. The fuel and the time consumption function of the departing time step are estimated using, for each UAV path, the geometric model described below.

3.1. Holding

An holding is an avoidance manoeuvre that consists in performing an orbit over the initial way point i of the path *(i,j)*. The manoeuvre is comprised by an in-bound leg and by an out-bound leg. An holding over a target point i can be modeled by forbidding the departing from that point for a subset of time steps $T^i_f = [t^i_{hstart} \ldots t^i_{hend}]$ $T^i_f \subseteq T$, where t^i_{hstart} is the time step of holding start and t^i_{hend} is the time step of holding end. For given UAV performances, these time steps are determined considering the geometry of the conflict c and the related time step t_c. Let us consider Fig.1 where an intersection between the UAV path p_{1u}-p_{2u} and the aircraft a sub-route p_{1a}-p_{2a} occurs in the point p_{cnf} .

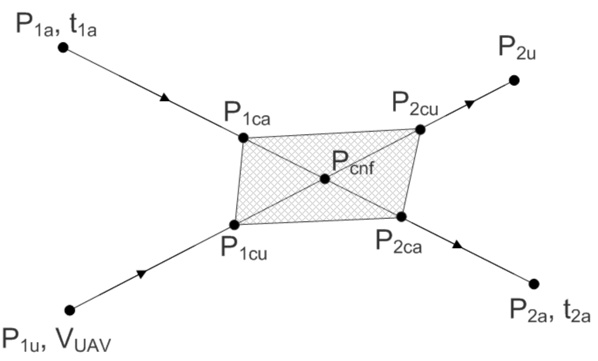


Figure 1. A conflict between a UAV path and an aircraft sub-route defines a conflict zone and its related characteristic points.

The conflict time step t_c is the overflying time step of the point p_{cnf} . A "sub-separation stretch" over p_{1u}-p_{2u} is identified between p_1c_u and p_2c_u . We define the point p_1c_u as the first point over the UAV path between p_{1u} and p_{cnf} that presents a distance of 1000 ft on the vertical direction or 5NM on the horizontal direction, whichever happens first, moving from p_{cnf} to p_{1u}. Analogously the point p_2c_u is the first point over the UAV path between p_{cnf} and p_{1u} that presents a distance of 1000 ft on the vertical direction or 5NM on the horizontal direction, whichever happens first, moving from p_{cnf} to p_{2u}. In the same way the points p_1c_a and p_2c_a are defined over the aircraft a route. The points p_1c_u , p_2c_u ,p_1c_a , p_2c_a define a "sub separation" zone around the conflict point p_{cnf} . Considering a fixed speed for the UAV v_{uav} (for example the best range speed, the best climb speed or the best glide speed), its last departing time step from the target point p_1u is such that it can arrive in p_2c_u when the aircraft a is in the point p_1c_a. If $\Delta t_{p_{1u} - p_1c_u}$ is the time step interval necessary for the UAV to fly from p_{1u} to p_1c_u maintaining v_{uav} , the holding over p_{1u} starts at time step:

$$t^{p_{1u}}_{hstart} = \max\{0, t_{1a} + \Delta t_{p_{1a}\_p_1c_a} - \Delta t_{p_{1u}\_p2c_u}\}$$

Analogously the first UAV restarting time step from the target point p_1u is such that it can arrive in p_1c_u when the aircraft a is in the point p_2c_a. The holding over p_{1u} finishes at time step:

$$t^{p_{1u}}_{hend} = \max\{0, t_{1a} + \Delta t_{p_{1a}\_p_2c_a} - \Delta t_{p_{1u}\_p_1c_u}\}$$

The holding over p_{2u} is determined in the same way considering the UAV flying from p_{2u} to p_{1u}.

$$t^{p_{2u}}_{hstart} = \max\{0, t_{1a} + \Delta t_{p_{1a}\_p_1c_a} - \Delta t_{p_{2u}\_p_1c_u}\}$$

$$t^{p_{2u}}_{hend} = \max\{0, t_{1a} + \Delta t_{p_{1a}\_p2c_a} - \Delta t_{p_{2u}\_p_2c_u}\}$$

The intersection case presented in Fig.1 is the general case by which several particular cases can be derived.

Fig.2 represents an intersection between the UAV path p_{1u}-p_{2u} and an aircraft route such that more than one aircraft sub-route is involved: the aircraft direction change in the sub separation zone.

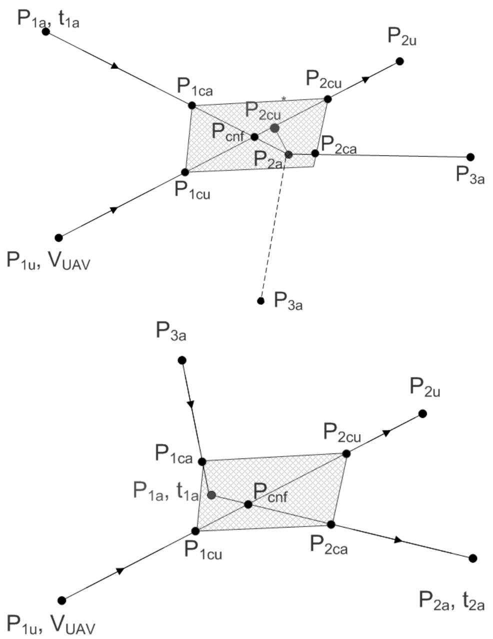


Figure 2 and Figure 3. The conflict zone involves more the one aircraft sub route

The point p_2c_u is defined through the distance from the sub-route p_{2u}-p_{3u} and the UAV path p_{1u}-p_{2u}; moreover the point p_2c_a is on the sub-route p_{2u}-p_{3u}. In case the point p_2c_u is between p_{1u} and p_1c_u ,then $t^{p_{1u}}_{hstart}$ is defined using the approximation of the point $p_2c_u^*$ that corresponds to the projection of p_{2u} over the UAV path. The same happens for the point p_1c_u if the direction change occurs as in Fig.3.

In case the point p_{1u} or p_{2u} is in the sub-separation area as in Fig.4, the points p_1c_u and p_2c_u are defined using a "safe sphere" with radius of 5NM and center in p_{cnf} . For example, let us consider the case represented in Fig.4, when the UAV flies from points p_{1u} to points p_{2u} . The direction of the UAV after p_{2u} is not known, so it is necessary to consider a safe buffer zone through the construction of a sphere around p_{cnf} . Whatever the UAV direction is, in the subsequent path the holding over p_{1u} allows to avoid the mentioned conflict. Moreover, once a conflict free time step for the departure from the ground base has been identified and this procedure is repeated for each conflict $c \in C$ for the all UAV path $(i,j) \in V$, the departure from p_{2u} to p_{1u} cannot happen during a conflict.

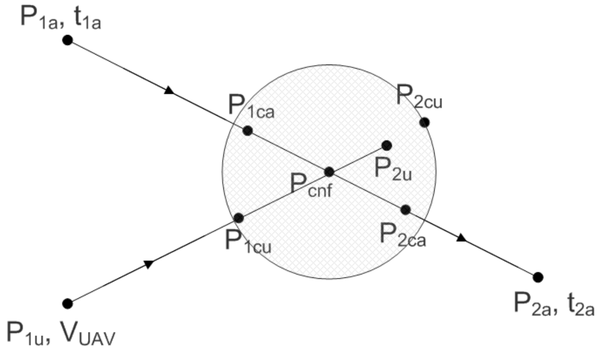


Figure 4 The conflict zone involves more than one UAV path

Finally for each departing time step it is now known the related holding $h^t_{i,j}$ to reach the next target point avoiding the conflicting traffic.

If the UAV is flying maintaining the speed v, it is possible to estimate the weight of the UAV sub-path (i,j) as:

$$w^{holding}_{(i,j)}(t) = (h^t_{i,j} + (p_{1u}\_p_{2u}/v))$$

3.2. Speed Control

The speed control is often used by the Air Traffic Control to maintain or to provide a minimum separation between aircraft of different performances without changing their routes.

Using the same geometric model presented for the holding, it is possible to find the medium speeds v^{red}_m and v^{inc}_m that the UAV has to maintain to avoid a conflict by reducing or increasing respectively its medium speed. Considering only the case reported in Fig.1, v^{red}_m is the medium speed that the UAV has to maintain to arrive in p_1c_u when the aircraft is in p_2c_a starting the path p_{1u}-p_{2u} at time step t_{1u}:

$$v^{red}_m(t_{1u}) = (p_{1u}\_p_1c_u)/(t_{1a} + \Delta t_{p1a\_p2ca})$$

Similarly, $v_m^{inc}(t_{1u})$ is the medium speed that the UAV have to maintain to arrive in p_2c_u when the aircraft is in p_1c_a :

$$v_m^{inc}(t_{1u}) = (p_{1u}\_p_2c_u)/(t_{1a} + \Delta t_{p1a\_p1ca})$$

Once identified the medium speeds, it is necessary to analyze if they are consistent with the UAV performances: both speeds must be smallest or equal to the UAV maximum speed and greater than the UAV stall speed. Furthermore the thrust available should allow the UAV to reach the calculated speed in a manner consistent with the conflict: we suppose the acceleration/deceleration phase is consistent with the conflict. If it is possible to reduce or increase the UAV speed, the estimation of the weight of the path *(i,j)* due to speed control $w_{(i,j)}^{scontr}(t)$ can be written as:

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

3.3. Horizontal and vertical avoidance

Several models have been developed for the horizontal or for the vertical avoidance. MILP techniques, for example, allow to obtain an optimal trajectory that avoids a fixed or moving obstacle by modeling an exclusion zone around it.

Instead our approach for the horizontal avoidance is based on Air Traffic Management operative technique that uses vectoring to avoid collision between converging traffic. This manoeuvre is represented in Fig.5: the aircraft A is vectored and directed toward the aircraft B.

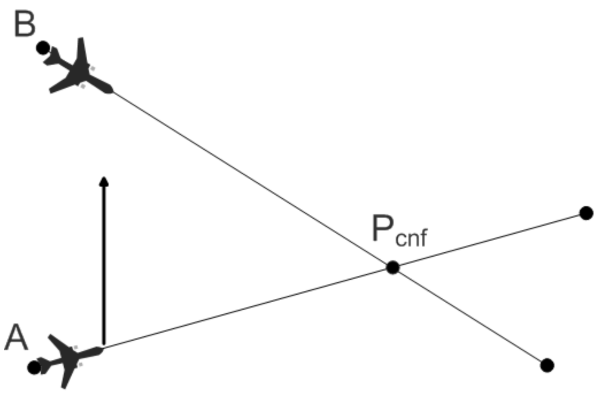


Figure 5 : ATC avoidance technique on the horizontal plane: the aircraft A is vectored to the position of B in order to pass behind it

"Opening" its route, the aircraft A reaches the position of B when B will be in a safe position. Naturally this technique is applicable only for particular convergence angles between the paths. In Fig.6 the manoeuvre is modeled using our geometric approach. A safe sphere is built around the position of the aircraft *a* at each time step starting from t_{1u}. The vectoring is modeled considering the tangent to the safe sphere that passes through the current position of the UAV and behind the aircraft position.

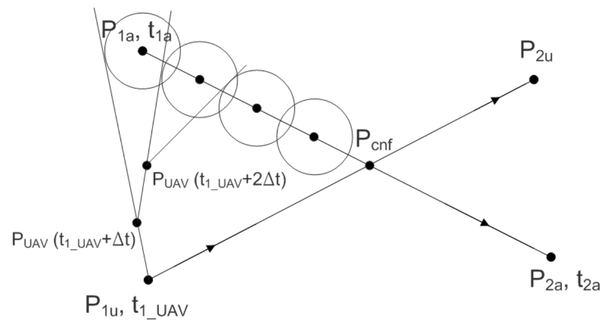


Figure 6. The geometric approach used to model ATC avoidance technique

The position of the UAV is updated for the next time step by a shift of $v\Delta t$. Once the UAV passed behind the aircraft it may proceed direct to the point p_{2u}. If n_v is the number of time steps required to pass behind the aircraft and n_p is the number of time steps required to proceed back to the original route to point p_{2u}, it is possible to estimate the weight of the UAV subpath *(i,j)* as

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

The vertical avoidance is modeled creating an alternative UAV sub-route over or under the aircraft route. The model detects possible further conflicts of the alternative sub-route. The weight $w_{(i,j)}^{Vavoid}$ of the path *(i,j)* is estimated directly from the UAV performances (rate of climb, max efficient speed, rate of descent) and from the length of the alternative generated path.

4. CONFLICT DETECTION ALGORITHM

In the following pseudo-code, we present a simple geometric algorithm (with complexity $O(|A||V|)$) based on the Conflict Graph that allows to compute the weight $w_{(i,j)}^{k}(t)$ of the UAV path *(i,j)* as a function of the departing time step from i. The conflict condition between the UAV path *(i,j)* and the aircraft *a* route, considering a UAV speed *v*, is indicated as $c(R_a,(i,j),v)$

$$\begin{array}{l}
\forall a \in A \\
\quad \forall (i,j) \in V \\
\qquad \text{if } c(R_a,(i,j),v) == true \\
\qquad \text{find } [t^i_{hstart}, t^i_{hend}] \subseteq T \\
\qquad \forall \bar{t} \in [t^i_{hstart}, t^i_{hend}] \text{ find if exist } w^{hold}_{(i,j)}(\bar{t}),\ w^{scont}_{(i,j)}(\bar{t}),\ w^{Havoid}_{(i,j)}(\bar{t}), w^{Vavoid}_{(i,j)}(\bar{t}) \\
\qquad \forall t \notin [t^i_{hstart}, t^i_{hend}] \text{ the arch weight corresponds to the flight time between i and j} \\
\quad \text{else the arch weight corresponds to the flight time between i and j}
\end{array}$$

Using this model, the presence of a conflict on a path *(i,j)* is related to the departing time step: if a conflict occurs at speed *v*, the arches weight depends on the avoidance option and it is calculated by the model presented. Instead, if no conflict occurs, the arches weight corresponds to the flight time, considering the Euclidean distance at speed *v*.

The UAV path weight allows to provide an estimation of the mission endurance, while to calculate the fuel consumption it is necessary to use the specific look-up table of the UAV. These table provides the fuel consumption per time unit as a function of the TAS and of the altitude.

5. SOLUTION APPROACH: GENETIC ALGORITHM

The Travelling Salesman Problem has been hardly discussed in past years: many exact and heuristic approaches have been proposed in literature. Instead researches on the TDTSP (Time Dependant TSP) are quite rare; interesting algorithms have been proposed to deal with traffic jam. Frequently, algorithms that provide good solution for the TSP do not allow to obtain valid results in the TDTSP. For example, let us consider a solution that presents crossing arches: it is non-efficient circuit for the TSP. Instead that solution could be valid for the TDTSP. Moreover the problem we are dealing with requires the choice of the avoidance techniques coupled with the choice of the path. In this context, a genetic algorithm represents a valid approach.

Firstly, it allows a better management of the time dependence than other heuristic approaches. In fact, while the fitness of a route is time dependent, the operations of chromosome recombination are not time dependent. This allows to by-pass several problems typical of some constructive heuristics in the TDTSP.

Moreover, the evolutionary process can easily be extended to the choice of the avoidance technique: different “Avoidance Philosophy” can be properly combined and selected in order to obtain a “good pilot” for a specific route.

Finally, the genetic algorithm presents fast computation time compatible with future real time applications: if the computation time is smaller than the time step, a replanning can be done at each time step considering tactical updating.

The algorithm we propose starts randomly generating a first population of η_p UAV routes R_u. At each route a “Pilot Philosophy” k_r is randomly assigned. It consists in one of the avoidance techniques $k \in K$ presented:

- 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).*

In each route of the first population, the UAV uses only one avoidance technique to solve all the conflicts: it looks like it is managed by a “not efficient pilot” that is able to avoid the traffic only in one way. The fitness (min time or min fuel) of each route is calculated considering the weight of the arches function of the departing time step (calculated trough the geometric pre-processing algorithm presented) and the population is sorted by decreasing fitness. Then the evolution to the next population starts. This process is repeated until the STOP criterion is satisfied. It consists in repeating η_t times this evolution, checking if the improvement in the last η_c individual is greater than 1%. If that improvement is less than 1% the evolution is terminated. During the evolution different “Pilot Philosophies” are combined each other as well as the paths of the routes are combined. The evolution process selects the most efficient pilot for a specific route.

The evolution to the following populations is based on cross over operations applied to the array used to store the route and the avoidances manoeuvres.

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. The operations used are “random shuffle, rotate and reverse” as available in the “Evolutionary Concert Tour” (ECT) for C++ Builder 6 (www.duke.edu/web/isis/gesser/borland/evolution.htm). Note that this evolutions operation are not applied to the first and to the last element of the array because they correspond to the departing/arriving aerodrome. The “Pilot Philosophies“ associated to the path are crossed too and the path obtained presents a better mix of avoidance options. Finally the population obtained is sorted again by decreasing fitness. The genetic algorithm used is described in the following pseudocode where the generic term “route” indicates the combine of a set of paths and a set of avoidances:

BEGIN

1) *Preprocessing: computation of w(t.);*

2) *Generation of the first population of η_p UAV routes and assignment of the “Pilot Philosophy”k_r ;*

3) *Sort the population by decreasing fitness (min time/min fuel);generation=1; STOP=FALSE*

4) *While STOP==FALSE*

begin

Evolve population: first η_p /2 routes in solution; second η_p /2 routes crossed;

Sort the population by decreasing fitness;

generation=generation+1;

if(generation<=η_t)or(improvement(η_c)<=0.01)

then STOP=TRUE;

end

END

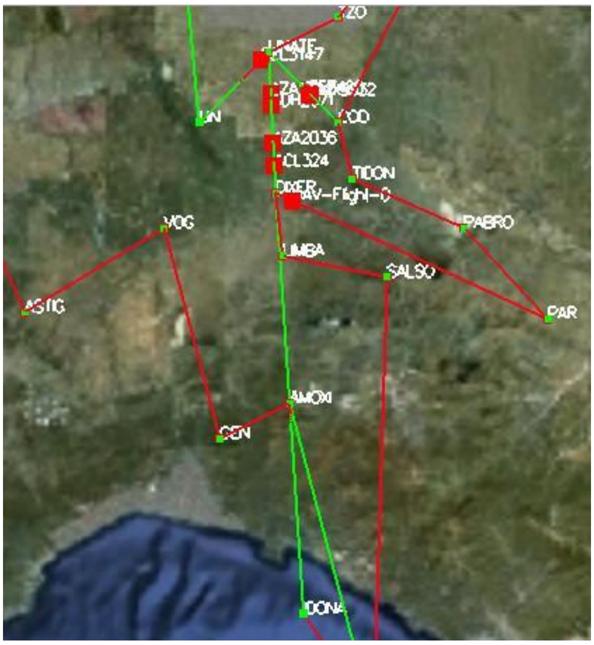
6. SIMULATION RESULTS

We test our approach on a real air traffic scenario: the TMA (Terminal Manoeuvring Area) of Milano Linate (ICAO code LIML), a major airport in the North of Italy with an average of 350 movement (air) per day. In this area 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 related to the day of November 12th 2009 are acquired by AOIS (Aeronautical Operational Information Sistem) 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 starting from 5:30 UTC (Universal Time Coordinated) for 6 hours of simulation. We generate the UAV target points considering that some of the UAV target points correspond to the aircraft navigation points, the others have been randomly generated.

In Fig.7 an example of mission simulation is reported. The UAV route is the red one while the aircraft routes are the green one; it is also possible to recognize the navigation points and the aircraft indicated with red squares.

Figure 7 Example of results of the simulation with 20 targets. The UAV route is red, the aircraft routes are green.

An interesting example of UAV conflict resolution is reported in Fig 8, 9, 10,11, that shall to be observed subsequently. The points AMOXI, LIMBA and DIXER are lined up to Runway 36, arriving aircraft coming from South follow this route. Looking the pictures in sequence it is possible to recognize an arrival sequence AZA2036, ACL324 and AZA2032. The UAV route includes the path between DIXER and LIMBA in opposite direction. However, this path is performed by the UAV between ACL324 and AZA2032 without separation minima infringement.



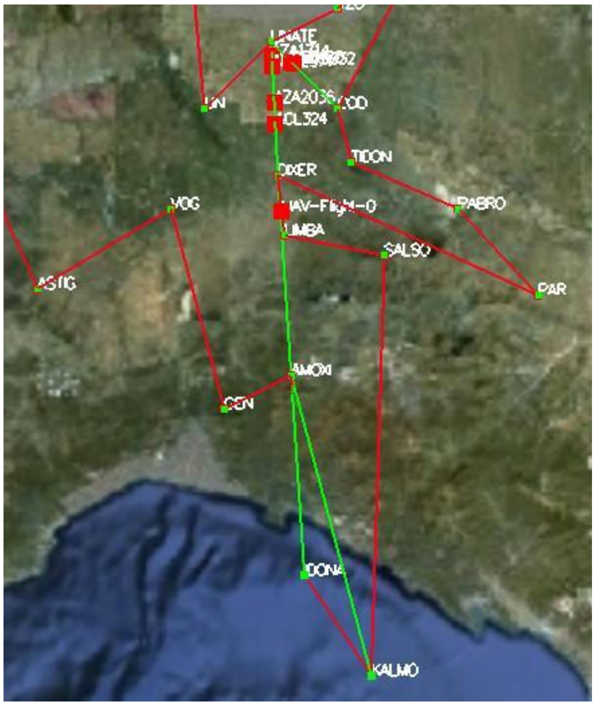


Figure 8, Figure 9, Figure 10, Figure 11. Examples of UAV route management in a critical area, the long final or ILS path: the UAV uses this path between sequenced aircraft without infringing the minimum separation.

Finally, in the tables below simulation results are reported. They consider different mission dimensions (10, 20, 25, 30, 35, 40 and 45 target points) for both objectives of minimum fuel (Table 1) and minimum time (Table 2).

The results provided consider the following parameters: $\eta_p = 200$, $\eta_t = 3500$, $\eta_c = 330$, and $\Delta t = 1$ minute, computed on an IntelCore Duo 2GHz.

Table 1 Simulation results with 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

Table 2 Simulation results with 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

7. CONCLUSIONS

We present the problem of the management of an UAV mission into controlled air space. In this paper the problem has been formalized as a TDTSP then a geometric model has been provided to calculate the weight of the UAV paths as a function of time. Finally a genetic algorithm has been presented to solve the problem in real traffic scenarios. Simulation results show how the proposed geometric model efficiently defines the arches weights to be used in the conflict resolution. The genetic algorithm allows to deal efficiently with the problem's time dependence, moreover it is useful to identify a proper sequence of avoidance maoeuvres. Finally computation time shows that this approach could be applied to future real time applications.

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