Distributed Control and Stochastic Analysis of Hybrid Systems Supporting
Safety Critical Real-Time Systems Design

WP5: Control of uncertain hybrid systems

Hierarchical Decomposition of Conflict Resolution Tasks

A. Lecchini[1] , J. Lygeros[2] and D. Dimarogonas[3]

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[1] Department of Engineering, University of Cambridge, U.K.

[2] Department of Electrical and Computer Engineering, University of Patras, Greece.

[3] Department of Mechanical Engineering, National Technical University of Athens, Greece.

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	J. Lygeros	UCAM	
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Hierarchical Decomposition of Conflict Resolution Tasks

Prepared by:
A. Lecchini[*], J. Lygeros[†] and Demos Dimarogonas[‡]

Abstract

We discuss possible ways of organizing conflict resolution tasks hierarchically, with some tasks being performed using centralized information and decision making (e.g. by the Air Traffic Controllers) and others being performed in a decentralized way (e.g. by the aircraft's flight management system, or the pilot). We also discuss how concepts of airspace stability and complexity may play a role in quantifying the interaction between centralized and decentralized controllers.

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[*] Department of Engineering, University of Cambridge, Cambridge, CB2 1PZ, UK, Tel. +44 1223 33260, Fax. +44 1223 332662, `al394@cam.ac.uk`

[†] Department of Electrical and Computer Engineering, University of Patras, Rio, Patras, GR-26500, GREECE, Tel. +30 2610 996 458, Fax. +30 2610 991 812, `lygeros@ee.upatras.gr`

[‡] Department of Mechanical Engineering, National Technical University of Athens, Zografou, Athens, GR-15700, GREECE, `ddimar@mail.ntua.gr`

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List of Acronyms

ARTCC	Air Route Traffic Control Centre
ATC	Air Traffic Controller
ATM	Air Traffic Management
FMS	Flight Management System
SUA	Special Use Airspace
TRACON	Terminal Radar Approach Control
VOR	VHF Omni-directional radio Ranging

1 Aim and Scope

The main aim of Deliverable D5.1 of HYBRIDGE is summarized in Task 5.1 of WP5:

> Decomposing the conflict resolution task hierarchically, dealing with information sharing in the presence of uncertainty and establishing co-ordination requirements based on the decentralized control design.

The balance between centralized and decentralized control is a very complicated issue that has tantalized the Air Traffic Management (ATM) research community for a number of years. In this report we will limit our treatment to specific considerations that arise in the HYBRIDGE project out of the interaction of WP5 and WP6.

The report starts with a literature review highlighting the issues. In Section 2 we introduce the problem of distributing responsibilities between the Air Traffic Controller (ATC) and the pilots in the conflict resolution process. To do this we recall the notions of *delegation of separation* from [31] and the *automated airspace* concept of [8]. Since in HYBRIDGE we are interested in advanced decentralized schemes (in WP6) and advanced centralized schemes (in WP5), we concentrate on the so called *full delegation* notion and discuss the issues that arise out of the interaction of centralized and decentralized control in this framework. We also discuss how lower levels of delegation can be considered as stepping stones towards a system based on full delegation.

One of the aims of moving towards a more decentralized system is to reduce the workload of the ATC, while maintaining or improving the level of safety of the system. In Section 3 we discuss some possible measures of airspace stability that can be used to quantify some of the issues that arise when trying to ensure the safety of a hierarchical controller with both centralized and decentralized elements. We also recall from the literature the notion of airspace complexity, that can be used to quantify ATC workload [5, 12].

Finally, in Section 4 we outline our approach to centralized conflict resolution in the context of WP5. The details of the problem formulation will be the topic of D5.2.

2 Delegation of separation

2.1 Controller Conflict Resolution Process

One of the main tasks of ATC is to guarantee that aircraft maintain a minimum safe separation. The following model of how ATC resolves conflicts between aircraft was formulated in [10]:

1. Analyse, understand and characterise the conflict. This means understanding what is going to happen, where, which aircraft will be involved, how close will they come to one another, when and in which sector.
2. Determine the physically possible solutions. This means determining the physically possible "ways out" of this scenario, given the airspace constraints, rules, aircraft performance, environmental factors, flow metering and sequencing aspects of arrival, etc.
3. Select an optimal resolution for the current situation. This means trying to optimize the resolution according to factors such as individual aircraft intent, given other sectors requirements and individual controller workload.

The remarkable fact is that, in the current system, all the tasks listed above are performed by the single human ATC who is in absolute control and is fully responsible for governing the traffic and maintaining safe separation between aircraft.

To keep the workload of the air traffic controller under acceptable operational limits, the air space is organized in sectors and routes with several constraints that limit the capacity and efficiency of today's system. A schematic description of the organization of the air space in the current system was given in deliverable D1.1 of the HYBRIDGE project [27]; for convenience it is repeated here as Figure 1.

2.2 Automated Airspace

The main aim of Automated Airspace concepts is to considerably reduce the ATC workload while maintaining, or improving the safety of the system [8]. The key is the use of computational power of ground-based computers and of the Flight Management System (FMS) of suitably equipped aircraft. Pilots of equipped aircraft and the ground based automation will be jointly responsible for the tactical aspects of separation assurance. Controllers in automated sectors will be responsible for strategic control of traffic flow, handling exceptional traffic situations, reroutes due to weather as well as manual separation monitoring and control of unequipped aircraft. By relieving the controller of the workload associated with tactical separation monitoring and control for a large portion of

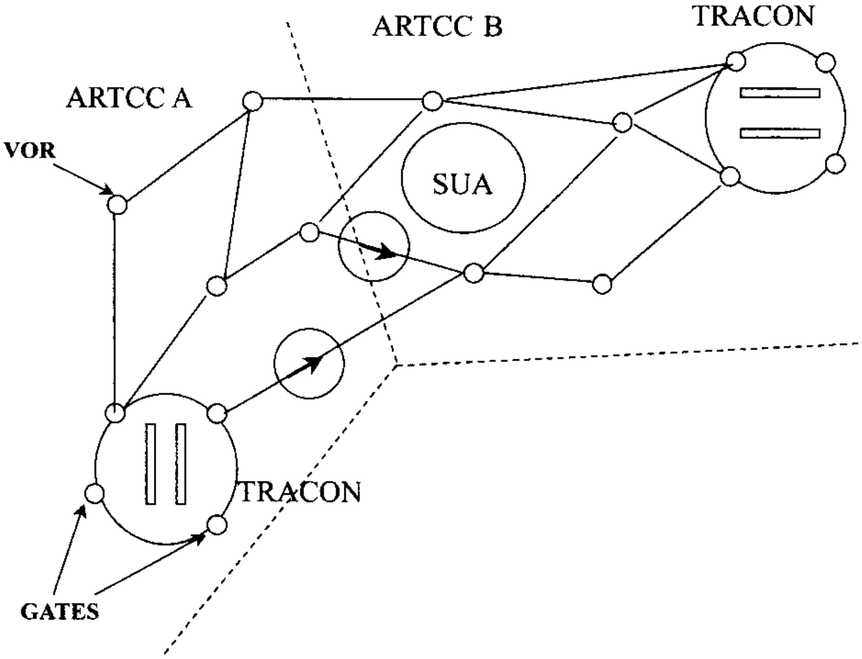

Figure 1: ATM Structure (U.S.)

the traffic in his airspace, the capacity constraints due to workload limits can be relaxed, thereby permitting a much larger number of aircraft to operate in Automated Airspace sectors.

A recent study [1] attempted to estimate the potential capacity gains of the automated airspace concept. In this study two adjacent en route sectors that are often capacity limited due to controller workload were examined. Using current traffic flows, route structures and separation criteria as a basis, the study showed that air traffic levels in the sectors could be increased to more than twice current capacity without creating an excessive number of new conflicts compared to base line traffic levels. This demonstrated that controller workload and not the availability of conflict free trajectories currently sets the limit on traffic densities and throughput in en route sectors.

2.3 Levels of delegation

As it has been outlined in HYBRIDGE deliverable D1.1 [27], the change from the current system to a complete automated airspace will be a step by step process. In [31], the notion of “level of delegation” is introduced to describe the possible successive levels of distribution of the conflict resolution process between ATC and the pilots. Three major levels of delegation have been identified.

Limited delegation. The controller is in charge of both problem and solution identification. The tasks delegated to the pilot can range from monitoring up to implementation of the solution. For each problem, the controller has the ability and responsibility to select the appropriate level of delegation depending on various factors such as traffic conditions, airspace constraints, and his practice level. Three different level of delegation can thus be identified within the limited delegation concept.

1. Identification of the clear of target. The controller provides the separation by issuing appropriate clearance. The pilot has to identify and report the clear of target. The controller is then expected to authorise resume climb or normal navigation.
2. Resume climb or normal navigation. The controller provides the separation by issuing the appropriate initial clearance. The pilot has (1) to report clear of target and (2) resume climb or navigation without explicit authorization from the controller.
3. Implementation of manoeuvre. The controller selects the type of manoeuvre to provide separation. The pilot has to (1) work out and execute the appropriate value for this type of manoeuvre, (2) report of clear of target, and (3) resume climb or normal navigation.

The limited delegation concept can be associated to the communication and command structure identified in D1.1 as a potential near-term stepping stone towards automated airspace (see Figure 2 repeated here from D1.1 for convenience). Recall that in the figure dotted lines represent communication or data link channels whereas solid lines represent command channels.

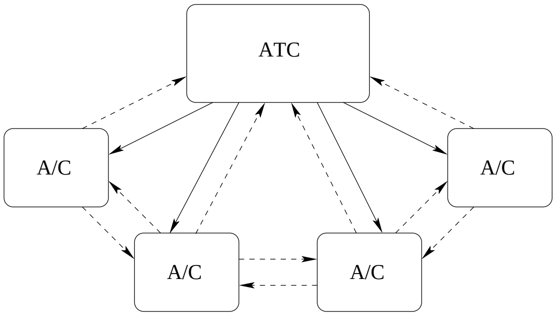

Figure 2: Near term changes.

Extended delegation. In extended delegation, although the encounter between two aircraft is identified and announced by the controller, the pilot can be in charge of altering the flight path to avoid the designated traffic. In this case, the controller identifies a conflict, then he selects the manoeuvring aircraft and lets the pilot decide which solution to use. In this context, the main role of ATC is to deliver co-ordination instructions to the aircraft, for example a sequence order in which the aircraft must solve the conflict. Co-ordination is needed to guarantee that the aircraft do not take contradictory actions that would eventually produce a new conflict. The extended delegation concept can be associated to the communication and command structure identified in D1.1 as a potential mid-term stepping stone towards automated airspace (see Figure 3 repeated here from D1.1 for convenience).

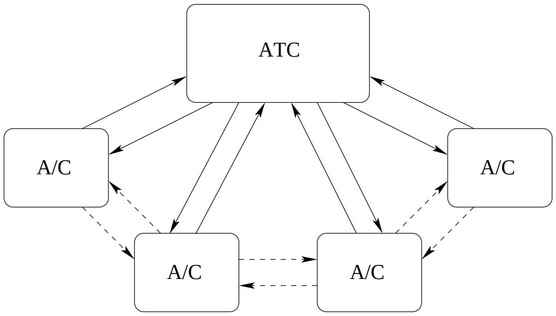

Figure 3: Mid-term changes.

Full delegation. The pilots of suitably equipped aircraft are responsible for all the tasks related to separation assurance: identification of problems and solutions, implementation and monitoring. Full delegation can take place in two types of airspace: managed airspace, in which equipped aircraft and non equipped aircraft coexist, or dedicated airspace in which only equipped aircraft are allowed (this is the case, for example, with the Free Flight concept of [9]). Full delegation can be associated to the communication and command structure identified in D1.1 as a potential mid-term stepping stone towards automated airspace (see Figure 4 repeated here from D1.1 for convenience).

In the HYBRIDGE project we are interested in advanced centralized and decentralized conflict resolution schemes (in work packages WP5 and WP6 respectively). In this report we will therefore concentrate on full delegation and investigate the issues that arise out of the cooperation of centralized and decentralized air traffic control in this context.

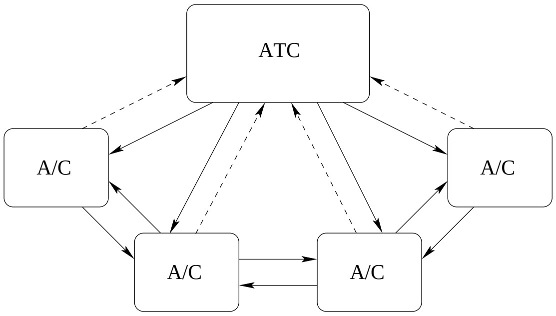

Figure 4: Long term changes.

In a context of full delegation, the role of ATC consists in providing separation for non-equipped aircraft while letting equipped aircraft self separate. The centralized ATC also have the authority and responsibility to intervene on equipped aircraft to handle non nominal situation cases, such as when a conflict is not solved in due time (principle of ATC by exception [31]).

Notice that in some cases full delegation implies that the controller is moved from an anticipative role to a reactive one. This raises the question of a possible loss of situation awareness and possible increase of mental workload. The higher the level of delegation the lower the workload of ATC is expected to be. However, a trade off exists with respect to the predictability of trajectories and situation awareness of the controller. Indeed, on the one hand very limited delegation would maintain a high level of predictability of aircraft behaviour, with a counterpart of limited gain in controller workload. On the other hand, more extended delegation leaves more autonomy to the pilots to manage the solution, with a risk of a possible reduction of predictability of the controller. As a consequence one of the requirements to delegation is that it has to be spatially delimited [31] and traffic should be organized to reduce as much as possible the interactions between equipped, self separating aircraft and non-equipped aircraft.

In the case of managed airspace, a simple and effective organization of the sector would consist in creating distinct regions or air corridors: some dedicated to unequipped aircraft and others dedicated to aircraft that self separate. In this organization of the sector ATC provides separation assurance to non equipped aircraft and redirect the equipped aircraft in the region dedicated to them. Care, however, must be exercised since in general it is not possible to redirect an arbitrary number of aircraft in the dedicated region. This issue is discussed in Section 3.

3 Considerations in hierarchical conflict resolution

In a full delegation context, centralized and decentralized schemes have to jointly ensure the safety of the system and increase its efficiency. A major obstacle in the process is the need to quantify safety and efficiency. This is needed to allow one to quantify and compare the performance of different designs. In this section we outline concepts of airspace stability from the literature that can be used to quantify safety in the interaction between centralized and decentralized schemes. We also discuss concepts of airspace complexity that have been proposed for quantifying controller workload and are therefore related to the efficiency of the system.

3.1 Airspace stability

The stability of a set of aircraft under decentralized conflict detection and resolution rules is related to the "domino effect", whereby the resolution of a conflict between two aircraft causes subsequent conflicts. The system is stable if the conflict resolution process succeeds in solving all conflicts (whether they are direct or created via domino effect) and the effort spent in the conflict resolution procedure by any aircraft remains bounded.

It is likely that decentralised control schemes will be able to provide stability guarantees for certain initial configurations of aircraft. If a region of the sector is dedicated to a system of aircraft that separate themselves autonomously then a role of centralized ATC is to monitor a suitable indicator of stability of the system and intervene whenever the stability of the system is at risk. The intervention can take many qualitatively different forms:

1. The centralized controller ensures that traffic patterns with which the decentralized controller has difficulty dealing do not arise. For example, ATC only allows an aircraft to enter a sector if certain stability criteria are met.

2. The centralized controller imposes bounds on parameters of the decentralized controllers (e.g. the size of an alert zone around each aircraft [29]) to prevent dangerous situations from arising. Using an analogy from ground transportation, think of the different speed limits imposed on highways, city arterials, around schools, etc.

3. The decentralized controllers select trajectories for each aircraft. The centralized controller receives these trajectories as requests and acts as a broker: it gives clearance to a subset of trajectories that meet the safety constraints and rejects the rest. It then runs a centralized optimization algorithm to suggest alternate trajectories to the aircraft whose requests were denied.

From the centralized controller point of view, the different types of intervention require different levels of knowledge about the workings of the decentralized schemes and different levels of sophistication of the centralized decision making algorithms. Schemes 1 and 2 require considerable knowledge about the capabilities of the decentralized algorithm. Scheme 3 is the least dependent on the details of the decentralized algorithms, but requires the most sophisticated centralized decision making tools. If powerful centralized algorithms necessary for scheme 3 are developed, however, they can also be used with limited and extended delegation concepts, as stepping stones towards full delegation.

It appears that scheme 2 is the most difficult to quantify for the decentralized conflict resolution algorithms that have been proposed in the literature. In the next two subsections we outline how schemes of type 1 can be formulated for two decentralised resolution schemes, the scheme proposed by [7, 19] and the approach currently under development in work package WP6 of the HYBRIDGE project. In Section 4 we outline the problem formulation for the decision making algorithms for a scheme of type 3 that we propose to develop under workpackage WP5 of HYBRIDGE.

3.2 Stability in the resolution scheme of [7, 19]

In [7, 19], it is pointed out that most of the work on decentralized conflict resolution focuses on problems involving a finite, usually small number of aircraft. Such a stand point is useful when designing efficient conflict detection and resolution systems. However, it does not take into account aircraft flows, since interactions occurring within a set of aircraft have a finite duration. In [7, 19] stability of the traffic is then proved for a possibly infinite number of aircraft under a certain stationary encounter geometry and decentralized conflict resolution scheme. The characteristics of the traffic and the decentralized scheme considered in [7, 19] are as follows.

1. Two flows of regularly spaced aircraft with the same desired heading are intersecting;
2. the conflict resolution maneuver is a heading change, each aircraft performs only one heading change and then holds the heading;
3. each aircraft in making the heading change for conflict avoidance consider all aircraft that maneuvered earlier but does not account for the aircraft which have not maneuvered yet;
4. The amplitude of the conflict avoidance maneuver is as small as possible.

The information shared in such decentralized scheme is the position and heading of other aircraft and which are the aircraft that have already maneuvered at a certain time.

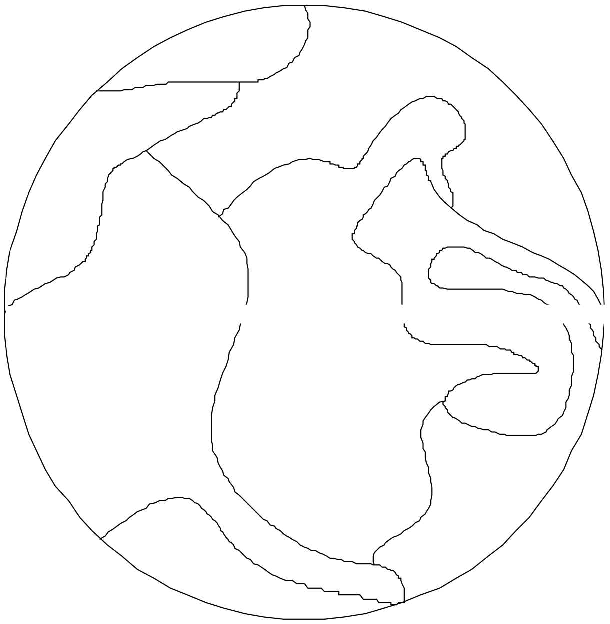

Figure 5: Division of the workspace in sectors

3.3 Stability in the approach of Work Package WP6

A hierarchical approach to free flight is the division of the airspace into separate areas named sectors in which aircraft plan their trajectories according to decentralized decision making rules. The planning goals for each aircraft include conflict avoidance, i.e. maintenance of a predefined separation minimum with the other aircraft in the sector and destination convergence, either to the final destination (whenever it lies within the boundaries of the specific sector) or to an exit point of the sector.

A natural question that arises is what mechanism should control a possible transition of an aircraft from one sector to another. The arrival or departure of a new agent in a sector can affect the performance characteristics of the overall system, and in particular, its stability properties. Given the fact that the motion of each aircraft is a part of the continuous world and the transitions from one sector to another a part of the discrete world, sufficient conditions for the stability of the decentralized scheme would have to be formulated in the context of stability of hybrid systems (see, for example, [3, 30, 20, 4]).

Having these sufficient conditions in hand, the problem stated above (i.e. what mechanism should control a possible transition of an aircraft from one sector to another) can be tackled with the introduction of a centralized supervisor, which represents the upper level behaviour in a hierarchical control scheme Figure 6.

The behaviour of the system can be adequately modelled as a deterministic hybrid system. Switching occurs whenever a sector transition is about to take place. The centralized unit plays the role of a passive observer in between switching instants. Whenever an aircraft

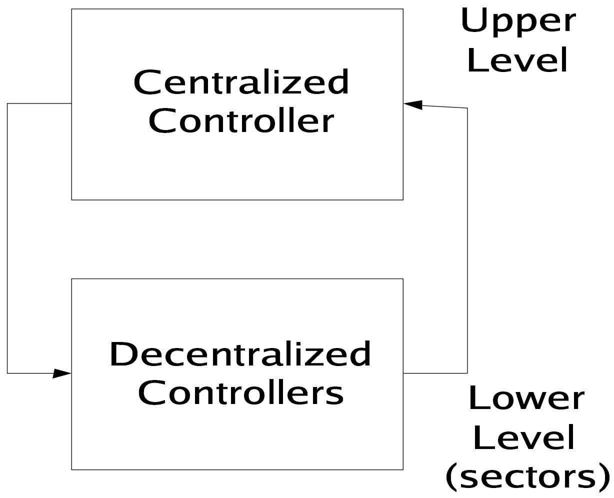

Figure 6: Hierarical ATM scheme

wants to enter/leave a specific sector the centralized supervisor issues an affirmative or forbidding instruction to the cockpit. That depends on whether the arrival of the aircraft at its target sector and its departure from its current sector satisfy the stability conditions of the decentralized system. In case of a forbidding instruction the aircraft either stays on the boundary of its sector and waits until an affirmative instruction is given by the supervisor or requests to be transferred to another (third) sector.

Work under work package WP6 [6, 18] has led to a decentralized motion planning algorithm which guarantees collision avoidance and destination convergence in an environment with multiple moving agents. In this work, only a fixed number of agents was taken into account. These algorithms could be used in the lower level of the hierarchical controller. The current goal is to find specific constraints on the parameters of the decentralized controllers that can be used by a centralized controller to decide whether a requested sector transition satisfies the sufficient conditions for the stability of the overall system. Similar comments extend to other methods for decentralized conflict resolution based on potential field path planning, for example [15].

3.4 Airspace complexity

The sector capacity for a given sector is the maximum number of aircraft that are allowed to be in the sector during a certain period of time. In practice, when an air traffic control sector is said to be overloaded, this means that the number of aircraft which have crossed the boundary during the last period has reached the sector capacity. When an operational sector is observed during several days it can be noticed that sometimes the controller in charge of this sector accepts more aircraft than the nominal capacity, while at other times the controller refuses some aircraft even if the nominal capacity has not been reached.

This suggests that the feeling of the controller about the complexity of the traffic for which he is in charge cannot be summarized using only the number of aircraft in the sector. This feeling which can be called "workload" is much more complex and is related to many factors, some of which are quantitative while others are qualitative.

With full delegation, where the majority of the workload for separation assurance is delegated to aircraft, the centralized ATC would retain more strategic tasks, such as managing the evolution of traffic densities and the possibility of future congestion. It follows from the above discussion, that in order to evaluate these quantities, a prediction of the number of aircraft that will coexist in the sector is not sufficient and more useful measures are needed. This type of measure differs from the measure associated to stability of the traffic. It may even be unrelated to the specific conflict resolution schemes, since it is used to quantify general characteristics of the traffic.

References [5, 12] discuss several metrics that have been proposed to measure the complexity of the airspace. Most of these metrics are controller oriented, in the sense that they are based on the "perceived complexity" of the airspace from the point of view of the controller. The parameters of this metrics were adjusted by showing several situations to the air traffic controllers and trying to get their feeling about the complexity of each situation. The authors of [5, 12] point out the need to establish an intrinsic measure of disorder of the traffic. As an example, consider the situation in which a regular flow of aircraft pass trough a sector with the situation in which aircrafts are randomly positioned in the sector with random headings. The second situation is intrinsically more complex than the first. In [12] a weighted sum of convergence velocities and sensitivity of conflict on the resolution maneuver is proposed as an instantaneous intrinsic measure of traffic disorder. The sensitivity to conflicts is linked to the number of predicted tight crossing angles and reflects the fact that a face to face convergence between aircrafts is much less sensitive to heading changes.

As an open issue, [5] also discuss the possible use of probability distributions for determining airspace complexity. It is suggested that, if on the basis of a stochastic model of air traffic one can calculate the probability distribution of future conflicts in time and space, then the entropy of this distribution can be considered as a measure of complexity of the airspace. This measure is based on the assumption that a given traffic situation has high complexity precisely when conflicts are close in time and space. A high value of entropy would indicate a nearly uniform distribution of the conflicts in time and space which corresponds to a low complexity. The computation of conflict probability distributions in WP3 could be ideally suited for this task.

4 Outline of the approach in Work Package 5

4.1 Problem formulation

The main emphasis of the work in WP5 is the problem of conflict resolution at the ATC level. The main considerations are

- The use of all available information.
- The availability of computational power.

The available information includes the use of models of the evolution of the wind and weather. Computational power permits the use of stochastic models to take into account uncertainty, for example in the evolution of the wind and the behaviour of aircraft following planned trajectories.

The behaviour of aircraft strongly influences the efficiency of conflict resolution algorithms. For this reason a Model Predictive Approach will be considered. In this framework models of the behaviour of aircraft following their flight plans will be used to predict their future positions. At the ATC level, the flight plan of each aircraft consists of a sequence of way points time, each time stamped with an expected time of arrival (or, equivalently, a velocity to be used until the next way point). Models that take this into account are discussed, for example, in [24] and in deliverable D1.3 of HYBRIDGE [11].

Let us consider a set of aircraft, $1, \dots, N$ and let $\alpha(t) = \{\alpha_1(t), \dots, \alpha_N(t)\}$ denote their state[1] at time t. Without loss of generality we will denote the current time by $t = 0$ and perform predictions over a horizon T into the future. Let also $\Omega = \{\Omega_1, \dots, \Omega_N\}$ denote the set of flight plans of the N aircraft, with $\Omega_i = \{O_i^j, T_i^j\}_{j=1}^{M_i}$, $O_i^j \in \mathbb{R}^3$ being a way point and $T_i^j \in \mathbb{R}_+$ being the expected time of arrival at that way point.

Given this data, the model of the aircraft behaviour can be used to:

- Calculate the probability of conflict, $P(\alpha, \Omega)$, over the horizon T. Following [13, 28], we will define the probability of conflict as the probability that any two aircraft will enter a conflict zone[2], $\mathcal{C}$, at some time over the horizon, i.e.

$$P(\alpha, \Omega) = P\{\exists i, j \in \{1, \dots, N\},\ \exists t \in [0, T]\ :\ (\alpha_i - \alpha_j) \in \mathcal{C}\}.$$

- Define a cost function associated to a modification of the current flight plan. For aircraft i we can define a cost function $J(\alpha_i, \Omega_i, \bar{\Omega}_i)$ which represents the cost of a

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[1] With the model of [11], for example, the state, $\alpha_i(t)$, of aircraft i consists of its $X - Y - Z$ position, its speed, its heading angle and its mass. With the model of [24], on the other hand, the state of each aircraft is just its $X - Y - Z$ position.

[2] For example, come closer than a given safety distance.

change form the current flight plan Ω_i to a new flight plan $\bar{\Omega}_i$. The cost function can be expressed in terms of length of the trajectory to the desired destination, expected delay or economic factors as fuel consumption or the cost of a conflict or of a collision (see for example [2, 16]).

Conflict resolution can then be posed as an optimization problem. The control variables are the flight plans of the aircraft which are cleared or modified by ATC. The objective is to minimize the cost of the resolution for each aircraft. The problem can be posed as follows

$$\text{find} \quad \hat{\Omega} = \arg\min_{\Omega} \left[J_1(\alpha_1, \Omega_1, \bar{\Omega}_1), \ldots, J_N(\alpha_N, \Omega_N, \bar{\Omega}_N) \right] \quad \text{subject to} \quad \Omega \in \mathcal{O}$$

This problem is a standard multiobjective constrained optimization form [14, 21]. The set $\mathcal{O}$ represents the feasible set of flight plans. It reflects both global constraints (e.g. a safety constraint of the form $P\{\bar{\alpha}, \Omega\} < \bar{c}$ where $\bar{c}$ is a given threshold) and local constraints (e.g. the fact that the angle between two successive segments of the same flight plan cannot be bigger than a certain maximum).

In WP5 we assume that the resolution maneuvers obtained from the conflict resolution procedure are passed as advisories to human operators to implement. Because the adoption of a realistic model of human reactions goes beyond the scope of WP5, the models used in the MPC formulation will assume that the operators respond perfectly and istantaneously to the advisories issued by the conflict resolution algorithms. All together this is equal to the situation that the human air traffic controller is replaced by a machine.

4.2 Solution strategies

The safety constraints based on the probability of conflict are nonconvex and nonlinear. Moreover, the probability of conflict $P(\alpha, \Omega)$ can be a very complicated function of Ω, in particular if one wants to take into account characteristics of the wind as correlation of the wind field in space and time ([11, 13]). These facts make the constrained optimization problem difficult.

In order to face the optimization problem the following considerations can be made.

- Difficult constraints can be taken into account via a penalty approach. In this approach the constrained optimization problem is converted into an unconstrained optimization problem in which a very high cost is assigned to variables that violate the constraints. The approach permits to handle difficult constraints in quite a straightforward way.

- Assuming availability of computational power allows extensive use of the model as a simulator. Using a simulation based optimization strategy gives the possibility to modify and add new features to the model without having to change the solution strategy or having to care about the complexity of the model (however, simplified models are useful in order to reduce simulation time).

In the reminder of this section we outline two optimization approaches that have been considered.

- *Stochastic Approximation*

  If an unbiased estimate of the gradient of the optimization criterion can be constructed by using simulation data, then one can apply a Robbins-Monro type iterative stochastic optimization procedure. The procedure converges with probability 1 to a constrained local minimum. The classical RM stochastic optimization procedure can be extended to optimization problems with penalty functions (see e.g. [17]).
  If obtaining an unbiased estimate of the gradient through simulations is impossible, one can resort to the procedure of [25, 26]. This is a stochastic optimization procedure based on an estimate of the gradient that is asymptotically (with the number of iterations of the optimization process) unbiased. This estimate of the gradient is constructed on the basis of unbiased estimates of the optimization criterion and randomized small perturbations to the current value of the optimization variables. In the case of conflict resolution one can obtain Monte-Carlo estimates of the probability of conflict through simulations and apply the optimization procedure of [25, 26] to solve the conflict.

- *Simulated Annealing*

  This approach addresses directly the objective of global optimization. The core of simulated annealing is the construction of a Markov chain such that the stationary distribution of the state of the chain is concentrated around optimal points. As it has been shown in [22, 23], the chain can be constructed on the basis of simulations. This approach has been used mainly in a Bayesian setting in order to compute characteristics of posterior distribution that are hard to calculate analytically. However, the procedure can be extended to more general problems.
  This approach seems promising for the conflict resolution problem. Typically the conflict resolution have several possible solutions that are nearly optimal, therefore a global optimization procedure is more suitable. Moreover, constraints of the type IF - THEN can be easily implemented in this approach, this feature is useful for certain requirements as for example a desired sequencing of arrivals.

Further details will be reported in the next deliverable of Work Package 5.

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