FLIGHT ALLOCATION TO EN-ROUTE CONTROLLERS IN THE TBO FRAMEWORK

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ABSTRACT

The present communication deals within the Trajectory Based Operations framework, on the problem of assigning flights to controllers in extended control areas. First, a flight centric complexity metric is used to quantify the interaction between planned flights at the pre-tactical level and an assignment problem solved through an heuristic which leads to the dimensionning of the control task force. Then, to cope with the tactical level, the flight centric complexity metric is modified to take into account trajectories' uncertainty. This allows to propose an on-line allocation scheme of flights to controllers according to their workload and to the estimated traffic complexity expected to be met by these flights.

Keywords: Air Traffic Management, Trajectory Based Operations, Flight Centric Operations, Flight Centric Complexity Metric, Flight Assignment to controllers.

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1 INTRODUCTION

The US Federal Aviation Administration's (FAA) NextGen and the European Commission's SESAR research programs (European Commission, 2024) are developing a new operational organization for air traffic control (ATC) and air traffic management (ATM) systems. The primary objective is to increase the capacity of air traffic control services through greater automation to effectively cope with the expected sustained growth in air traffic. One of the original concepts developed in this area is 4D Trajectory Based Operations (TBO). The objective of TBO is to better enable the reduction of the imbalance between capacity and demand in airspace at the strategic planning level and to promote, at the tactical level, the reduction of reactive ATC decision-making (Enea and Bronswoort, 2022). Tools are being developed to enable the management of flights throughout their operation between origin and destination airports, through the time-based management (TBM) of flights, and through the exchange of information between air and ground systems (FAA, 2025), while aircraft have acquired the ability to follow spatial trajectories on time (T+3D). The implementation of TBO is expected to improve flight efficiency, by reducing costs for airlines and environmental impact, thus, increasing airspace and airport traffic capacity, which should lead to a decrease in delays, to an improved operational predictability, thus facilitating air traffic control and influencing positively air transport safety. The TBO concept has led, at the tactical level, to the concept of flight-centered air traffic control (FCA), which proposes a new airspace configuration and renewed controller tasks (Premysl, 2019).

The implementation of flight-centric ATC leads to the elimination of the traditional division of airspace into air traffic sectors and its replacement with a subdivision based on traffic characteristics, leading to a more uniform structure over larger portions of airspace (Pütz et al., 2009), (Gil et al., 2023) composed of extended control areas (ECAs). In this situation, each controller is assigned to track and control a specific set of flights, end-to-end over an extended control area (ECA). Since in this new organization the controllers are no longer responsible for a particular sector but for a subset of flights, the problems of sizing the controller staff and of assigning flights to controllers arise differently than in the previous ATC structure (Finck et al., 2020). At the pre-tactical level, a deterministic offline assignment problem of flights to controllers has already been considered and a heuristic solution process, using a flight centric traffic complexity metric (Zombré et al., 2022), has been studied (Zombré et al., 2024), leading to the sizing of the controller staff for a given traffic. In this study, at the tactical level, an on-line assignment logic is developed where each new flight entering the system is assigned to a controller based on the estimated traffic complexity situation and workload of the controllers. To better cope with the tactical context, the flight-centric complexity metric is modified to take into account uncertainties on the trajectories to be followed in an ECA during a control service.

The paper is composed of five main sections. In Section 2, a flight centric complexity metric is considered and adapted to take into account look-ahead trajectory uncertainties. In Section 3 the pre-tactical sizing of the staff necessary to control the flights planned to cross an extended control area during a given period and a greedy solution are discussed. In section 4, an on-line decision scheme to assign flights to controllers while taking into account updated flight information, is proposed. In Section 5, the proposed approach is illustrated by a medium size example. Finally, in the conclusion, the strengths and limitations of the solution approach are discussed.

2 A FLIGHT CENTRIC TRAFFIC COMPLEXITY METRIC

2.1 Traffic notations, definitions and assumptions

The traffic of an ECA, which is the size of several traditional traffic control sectors, is considered during a given period of time $[t_0, t_F]$with $t_F = K \cdot \delta T + t_0$, where K is a large integer number and δT is the elementary time interval. I is the set of flights present in this ECA at some time during this period of time and $I_A(k)$ is the set of flights present at instant t_k in the ECA. The period of time $[t_0, t_F]$ is supposed sufficiently long so that flights are able to cross it.

Each flight i of the set I of considered flights, is described by a sequence of positions $P_i(k) = (x_i(k), y_i(k), z_i(k))$ at time $t_k = t_0 + k \cdot \delta T$ with $k \in [\, k_s^i, k_F^i \,]$ with $0 \leq k_s^i < k_F^i \leq K$ where the flight i crosses the extended traffic control area during the interval $[t_{k_S^i}\ , t_{k_F^i}\,]$. Here, $x_i(k)$, $y_i(k)$and $z_i(k)$ are coordinates in the Earth-centered, Earth-fixed coordinate (ECEF) system of the position of the aircraft assigned to the i^{th} flight at time t_k. Other Earth coordinate systems such as longitude, latitude, flight altitude can also be used and in both cases, a calculation of the transition from flight level to flight altitude may be necessary. It is assumed that a flight enters and exits the ECA only once during the control period. The successive positions of flight i at times t_k are extracted from its 4D flight plan and can be updated during the flight operation by the on-board Flight Management System. These positions constitute a time discretized 4D flight trajectory to be transmitted to ATM.

2.2 Criticality of separation between two aircraft

Criticality of the current separation between two aircrafts is considered given by two functions of the separation x, either horizontal or vertical, between these aircraft. These functions are expected to take the zero value when the corresponding separation is well above minimum separation standards and increases more and more when separation is decreasing well below these minimum separation standards. Recently, in (Zombré et al, 2022) a criticality function for the horizontal separation between aircraft has been proposed:

$$H(x) = -\lambda \cdot \ln(x) \text{ if } 0 < x < 1 \text{ and } H(x) = 0 \text{ if } x > 1 \qquad (1)$$

A horizontal threshold distance D_c and a vertical threshold distance $Z_c$are introduced below which are considered respectively that the horizontal separation and the vertical separation between two aircrafts is small and introduces some criticality. The following normalized distances δ_{ij}^H and δ_{ij}^V are introduced:

$$\delta_{ij}^H(k) = d_{ij}(k)/D_c \quad \text{and} \quad \delta_{ij}^V(k) = z_{ij}(k)/Z_c \qquad (2)$$

where $d_{ij}(k)$ and $z_{ij}(k)$ are respectively the horizontal distance and the vertical separation between aircrafts i and j at instant k.
The criticality level of the current horizontal and vertical separations between aircrafts i and j at time t_k are given respectively by:

For $k \in [k_s^i, k_F^i] \cap [k_s^j, k_F^j]$:

$$Cr_{ij}^H\,(k) = -\lambda_H \cdot ln\,(\delta_{ij}^H(k)) \text{ for } \delta_{ij}^H(k) < 1 \text{ and } Cr_{ij}^H\,(k) = 0 \text{ for } \delta_{ij}^H(k) \geq 1 \qquad (3.1)$$

$$Cr_{ij}^V\,(k) = -\lambda_V \cdot ln\,(\delta_{ij}^V(k)) \text{ for } \delta_{ij}^V(k) < 1 \text{ and } Cr_{ij}^V\,(k) = 0 \text{ for } \delta_{ij}^V(k) \geq 1 \qquad (3.2)$$

where $\lambda_H$and λ_V are scaling factors whose value can be set by considering the horizontal and vertical separations at which a conflict between two aircrafts i and j is declared and by choosing a criticality level accordingly. Taking 100 as maximum value for the criticality level, it corresponds to minimum separations $\delta_{min}^H$and δ_{min}^V, see Figure 1. Then:

$$\lambda_H = -100/ln\,(\delta_{min}^H) \quad \text{and} \quad \lambda_V = -100/ln\,(\delta_{min}^V) \qquad (3.3)$$

When one of two aircrafts i or j is not in the extended control area, the criticality level of their separation is taken equal to zero:

$$\text{For } k \notin [k_s^i, k_F^i] \cap [k_s^j, k_F^j]\text{: } Cr_{ij}^H(k) = 0 \text{ and } Cr_{ij}^V(k) = 0 \qquad (4)$$

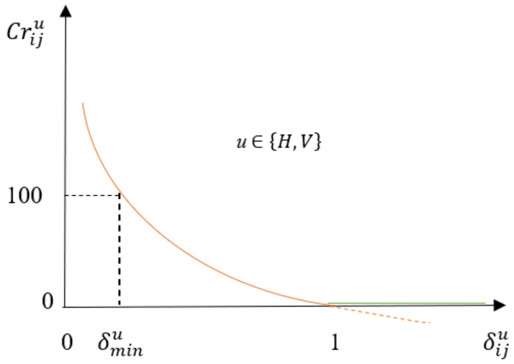

Figure 1: Separation criticality functions

2.3 Criticality with uncertainty

In the case where the uncertainty of the position of aircraft along their current planned trajectory is considered, a correction must be made in the computation of criticality. Assuming that the position uncertainty along the three directions is approximated by a Gaussian distribution with mean values equal to the nominal coordinates we can consider an ellipsoid with main axes equal to the corresponding standard deviations. Then the uncertainty about the distance between two aircrafts can be approximated along the trajectory by Gaussian distributions in the horizontal plane and the vertical axis. The standard deviations of the horizontal distance and of the vertical separation can be obtained from a neural network specially trained (Schimpf et al., 2023) to produce these estimates based on the relative nominal positions and speeds of two aircraft and the standard deviations characterizing the uncertainty of their positions. References such as (McNally and Gong, 2004) discuss the estimation of these standard deviations along a planned flight trajectory. Figure 2 displays such a situation for the horizontal plane (left) and the vertical plane (right):

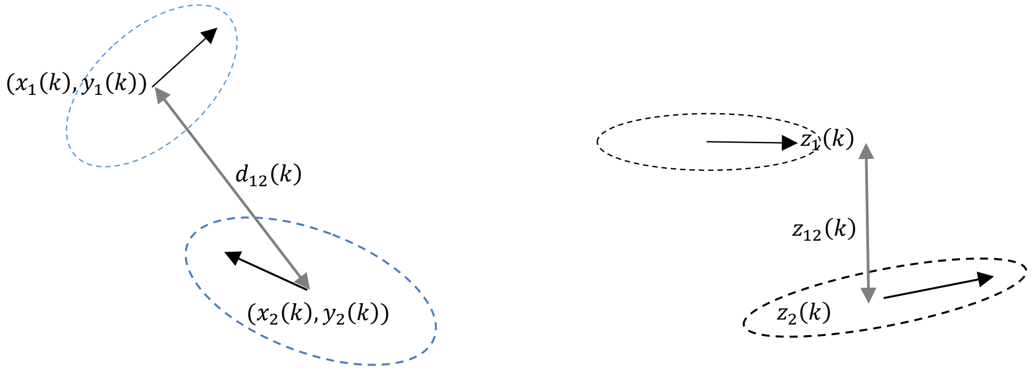

Figure 2 Uncertainty in horizontal and vertical relative positions of two aircrafts

Considering that along the aircrafts trajectories, $\delta_{ij}^H(k)$ and $\delta_{ij}^H(k)$ are Gaussian variables, the corresponding criticity levels $Cr_{ij}^H(k)$ and $Cr_{ij}^V(k)$ take random values with skewed distributions as sketched in Figure 3. There, $\sigma_{ij}^u(k)$ is the horizontal standard deviation for $u = H$ and the vertical standard deviation for $u=V$. What is proposed here taking into consideration the uncertainty about the relative position of two aircrafts along their planned trajectory, is to compute the criticality levels with a separation taken equal to its nominal value diminished of a value proportional to its current standard deviation: $\delta_{ij}^{u}(k) - \rho^{u} \cdot \sigma_{ij}^{u}(k)$ where ρ is a positive parameter taken such as:

$$\rho^{u} < \delta_{ij}^{u}/\sigma_{ij}^{u} \qquad \forall\, i, j, i \neq j \qquad \text{for } u \in \{H, V\} \tag{5}$$

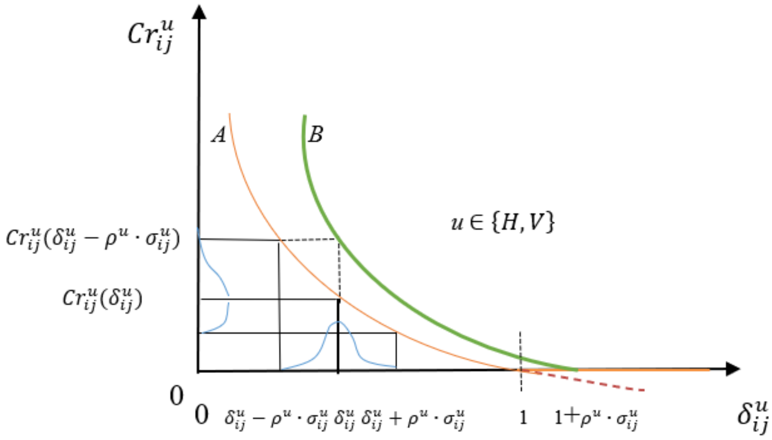

Figure 3: Separation criticality functions

This leads to compute safe criticality levels for $u \in \{H, V\}$ according to:

$$Cr_{ij}^{u}(k) = -\lambda_{u} \cdot ln\,(\delta_{ij}^{u}(k) - \rho \cdot \sigma_{ij}^{u}(k)) \text{ for } \delta_{ij}^{u}(k) < 1 + \rho \cdot \sigma_{ij}^{u}(k) \tag{6.1}$$

and

$$Cr_{ij}^{u}(k) = 0 \text{ for } \delta_{ij}^{u}(k) \geq 1 + \rho \cdot \sigma_{ij}^{u}(k) \tag{6.2}$$

and in Figure 3, the criticality curve A is replaced by the safe criticality curve B where it is clear that taking into account the uncertainty of the aircrafts along their planned trajectory increases the level of criticality of close aircrafts, where two flights i and j are considered “close” at time t_k according to the above defined criticality, if $Cr_{ij}(k)$ as computed in 3.1 or 3.2 is strictly positive.

2.4 Global criticability

As illustrated in Figure 4, the global criticality level of the relative situation of aircrafts i and j at time t_k , which takes into account its horizontal and vertical criticalities, can be taken as:

$$Cr_{ij}(k) = \min\{\, Cr_{ij}^{H}(k), Cr_{ij}^{V}(k)\} \qquad k \in [0, K] \tag{7}$$

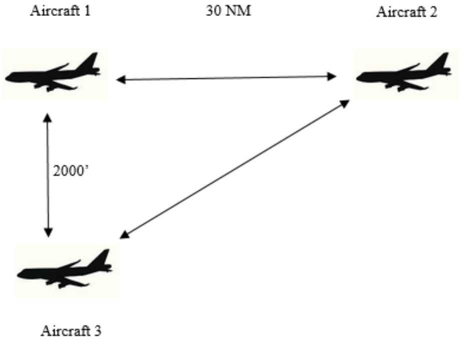

Figure 4. Criticality of separation between aircrafts

In (Zombré, 2024), intrinsic traffic complexity is built up from the accumulation, at different levels, of criticality occurrences. This allows to formally introduce air traffic complexity measures attached to the instant position of an aircraft, to a whole flight or to portions of it in the considered ECA.
The complexity of traffic $I_A(k)$ around the aircraft of flight i at time t_k which is at position $P_i(k)$ is then given by:

$$C_i(P_i(k)) = \sum_{j\in I_A(k)} Cr_{ij}(k) \tag{8}$$

It is supposed that the pre-tactical flight traffic program released by the ATFM is conflict free and such that separation between flights is such that:

$$C_i(P_i(k)) \leq C_{max}^{inst} \;\; k \in [\; k_S^i, k_F^i \;], i \in [0, 1, \cdots, m] \tag{9}$$

where C_{max}^{inst} is a local maximum traffic complexity level of a flight with respect to the others and which is at most equal to the maximum instantaneous level of complexity a controller can cope with.
The complexity of the surrounding traffic for flight i during the time period $[k_S^i, k_F^i]$ is given by:

$$CF_i = \sum_{k=k_S^i}^{k=k_F^i} \sum_{j\in I_A(k)} Cr_{ij}(k) \tag{10}$$

3 DIMENSIONNING OF THE CONTROLLER STAFF FOR A GIVEN TRAFFIC

Within the Flight Centric approach of ATC applied extended areas, controllers are in charge over a large portion of their trajectories of a set of flights, insuring their separation, detecting and resolving conflicts between them and cooperating for the resolution of conflicts with aircrafts controlled by other controllers. First problem to be considered is the problem of sizing the controller staff necessary to cope safely with the planned air traffic. It is assumed that the introduced flight centric complexity index provides an effective measure of the workload generated by the monitoring of the corresponding section of the flight. The problem under study at the pre-tactical level is the one of determining the number of controllers necessary to monitor efficiently m given flights over an extended control area during a specified time window. The primary objective, for economic reasons, is to minimize this number N_c, with necessarily $N_c \geq m/n_{max}$, where n_{max} is the allowed maximum number of aircrafts that can be managed by an air traffic controller.
Some considerations to be taken include:

- The interaction between controllers must be limited so that their workload is not increased by additional coordination tasks.
- It appears that flights interacting tightly should be treated by the same controller.
- The workload of a controller dedicated to de-confliction is composed of the one dedicated to monitoring interactions between the aircraft for which the controller is directly responsible and the one dedicated to monitoring interactions with flights monitored by other controllers.
- The workload assigned to a controller must be limited to a maximum value.

The second consideration seems to lead to the definition of flight clusters to be controlled by the same control post. The complexity index proposed in this study provides a surrogate c_{ij} to the estimation of the level of interaction between two flights i and j during the considered time period and hence to the corresponding share of workload:

$$c_{ij} = c_{ji} = \sum_{k=k_S^i}^{k=k_F^i} Cr_{ij}(k) = \sum_{k=k_S^j}^{k=k_F^j} Cr_{ij}(k) \quad i,j \in I \tag{11}$$

The total complexity around a flight i is given by:

$$C_i = \sum_{j=1, j\neq i}^{m} c_{ij} \tag{12}$$

It is supposed that ATFM pre-defined trajectories for the m flights do not present clear collision situations even if traffic conflicts are still predicted. To ensure that any present flight can be coped with, it is assumed that:

$$C_i \leq c_{max} \quad i=1 \text{ to } m \tag{13}$$

with c_{max} representing the maximum acceptable cumulated traffic complexity faced by a controller in the considered period. It is considered that this represents a measure of its workload. Writing I_l the set of flights under control of controller l, his workload is given by:

$$W_l = \sum_{i\in I_l} C_i \tag{14}$$

This results in a special capacitated clustering problem (Negreiros and Palhano, 2006) whose computational complexity makes it untractable to compute exact solutions for real-size problems (Garey and Johnson, 1979). Then, a greedy heuristic process is proposed to obtain via a reduced computational load, a feasible solution with an acceptable performance. For that, the adopted guiding idea is to assign to the same controller flights which interact strongly between each other according to equation (11) up to its capacity, expressed by c_{max} and n_{max}, so that it is expected that flights assigned to the other controllers will interact weakly with its own controlled flights. Here N_c is the number of necessary controller positions to manage all the flights given c_{max}. The algorithm below gives the steps of the proposed greedy heuristic.

Dimensioning heuristic:

```
Initialization:   $F = \{1,\cdots,m\},\ N_c = 0$
Iteration on the flights:
While $F \neq \emptyset$ do
    Iteration on the controllers:
        $l=N_c+1$
        $I_l = \left\{i^* = \underset{i\in F}{argmax} \sum_{j\in F} C_{ij}\right\}$
        $n_l = 1,\ W_l = \sum_{j\in F} C_{i^*j} \quad F = F - \{i^*\}$
        Iteration on workload of controller l
        While $W_l < c_{\max}$ do
            $j^* = \underset{j\in F}{argmax}\, V_j$ with $W_l + V_{j^*} \leq C_{max}$ where $V_j = \sum_{i\in I_l} C_{ij}$
                $W_l = W_l + V_{j^*}$ , $I_l = I_l \cup \{j^*\}$,
                $F = F - \{j^*\}$, $n_l = n_l + 1$
                If $n_l = n_{max}$ exit from inner while loop
        End While n
        $N_c = l$
    End While F
```

While constraint (13) is satisfied, the proposed heuristic will always provide a feasible solution. The solution of this problem brings two results: on the one hand, the dimensioning of the control task force necessary to manage the considered air traffic (N_c) and on the other hand, a first definition of the flight groups, $I_1, I_2, \ldots, I_{N_c}$, to be assigned to the pairs of controllers. Here the workload of at least N_c-1 pairs of controllers will be close to c_{max}, resulting in a balanced workload. Of course, the calculated staff size can be increased with additional reserves to cope with traffic uncertainties or perturbations.

4 TACTICAL FLIGHT ALLOCATION TO CONTROLLERS

At the pre-tactical level, the planned 4D trajectories of the flights have already been de-conflicted, see for instance (Monteiro et al. 2023), so that complexity levels may be rather small when air traffic over the extended area during a given time window is not heavy. However, at the tactical level with traffic perturbations such as departure delays and trajectory deviations, the traffic complexity level of the considered extended control area may be rather different and the assignment of flights to controllers may need a profound revision.

The following procedures characterize the proposed tactical solution:

- The assignment of a flight to a controller is performed when the aircraft enters the ECA.
- 4D trajectories of aircraft present or to enter in the ECA are updated as frequently as possible and communicated to ATM.
- Criticality levels between each entering aircraft (flight index i) and the other aircraft present or to enter in the ECA are computed starting at the entry time $t_{k_S^i}$ according to equation (11).
- Flight sets I_l assigned to a controller by the pre-tactical study are maintained until the arrival of a new flight i in the ECA. This flight is deleted from I_{l^i} where l^i is the controller assigned to flight i by the pre-tactical assignment procedure.
- At time $t_{k_S^i}$, the estimated workload of each controller is recomputed without considering the last entering flight i, it is written: W_l^i. The estimated workload of the controllers is then equal to the sum of their workload until time $t_{k_S^i}$, $W_l^{i-}$and their workload from time $t_{k_S^i}$ to time t_F, W_l^{i+}, which is computed with updated criticalities at time $t_{k_S^i}$for the period $[t_{k_S^i}, t_F]$:

$$W_l^i = W_l^{i-} + W_l^{i+} \qquad l = 1 \; to \; N_c \tag{15}$$

with

$$W_l^{i-} = W_l^{i'} + \sum_{k=k_S^{i'}}^{k=k_S^i} \sum_{r \in I_l} \sum_{s=1, s \neq r}^{m} Cr_{rs}^{i'}(k) \text{ and } W_l^{i+} = \sum_{k=k_S^i}^{k=K} \sum_{r \in I_l} \sum_{s=1, s \neq r}^{m} Cr_{rs}^{i}(k) \tag{16}$$

In equation (16), i' is the index of the last flight arrived into the ECA before flight i, the $Cr_{rs}^{i'}(k)$ and $Cr_{rs}^{i}(k)$ are safe criticalities updated at time $t_{k_S^{i'}}$ and $t_{k_S^i}$. The complexity attached to flight i in relation to the flights assigned to controller l and written V_i^l, is such that:

$$V_i^l = \sum_{k=k_S^i}^{k=K} \sum_{r \in I_l} Cr_{ir}^{i}(k) \qquad l = 1 \;\; to \; m \tag{17}$$

A greedy solution approach to assign flight i to a controller l^*will be to choose the controller whose controlled flights have the higher interaction with flight i while the resulting increase in workload is acceptable:

$$l^* = \underset{l \in \{1, \cdots, N_c\}}{\arg max} \, V_i^l \text{ with } W_l^i + V_i^l \leq c_{max} \tag{18}$$

Then, when flight i enters the ECA at time $t_{k_S^i}$, it is assigned to controller l^* and $I_{l^*}$is updated. When all controllers are saturated, an additional controller must be introduced and flight i must be assigned to him.

5 ILLUSTRATION OF THE PROPOSED APPROACH

The proposed heuristics are illustrated through a small to medium dimensional case with seventy-five flights over an extended enroute area crossed in an hour. Following the Trajectory Based Operations concept, these flights are grouped into fifteen 3D trajectories, so that the proposed heuristics here assign all the flights following the same 3D trajectory to a same pair of controllers. The corresponding interaction levels between the flows of flights of different 3D trajectories (C_{ij}) computed at the pre-tactical level, are given in Table 1. Here c_{max} and n_{max} are respectively taken as 350 and 20.

Table 1. Interaction levels between planned flights flows

Trajectories	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	$\sum_{j\in F} c_{ij}$	Flights flows
1	5	30	5	0	0	0	0	5	20	0	0	5	0	30	5	105	5
2	30	8	20	0	0	20	10	5	0	20	10	10	0	30	30	193	8
3	5	20	4	0	0	40	20	5	0	20	10	5	0	20	0	149	4
4	0	0	0	3	40	10	5	0	0	0	0	0	0	5	5	68	3
5	0	0	0	40	5	10	5	0	0	0	0	0	0	10	5	75	5
6	0	20	40	10	10	6	40	0	0	20	10	10	0	0	0	166	6
7	0	10	20	5	5	40	7	0	0	10	10	20	0	0	0	127	7
8	5	5	5	0	0	0	0	5	0	20	20	10	0	40	5	115	5
9	20	0	0	0	0	0	0	0	2	5	5	5	30	0	0	67	2
10	0	20	20	0	0	20	10	20	5	6	40	5	0	0	10	156	6
11	0	10	10	0	0	10	10	20	5	40	4	10	0	20	5	144	4
12	5	10	5	0	0	10	20	10	5	5	10	5	5	30	20	140	5
13	0	0	0	0	0	0	0	0	30	0	0	5	3	8	0	38	3
14	30	30	20	5	10	0	0	40	0	0	20	30	8	0	20	213	8
15	5	30	0	5	5	0	0	5	0	10	5	20	0	20	4	109	4

The heuristic computes a number of necessary controllers $N_c = 6$, with a pre-assignment of flights given by $I_1 = \{14, 8\}$, $I_2 = \{2, 1, 13\}$, $I_3 = \{6, 3\}$, $I_4 = \{10, 11\}$, $I_5 = \{12, 9, 7\}$, $I_6 = \{15, 4, 5\}$, corresponding to a number of flights controlled by each pair of controllers given by: $n_1 = 13, n_2 = 16, n_3 = 10, n_4 = 10, n_5 = 14, n_6 = 12$ and with the respective expected workloads: $W_1 = 328, W_2 = 336, W_3 = 315\ , W_4 = 300\ , W_5 = 334, W_6 = 252$.
Regarding online assignment, initial simulations show that flight delays tend to challenge the tactical assignment of flights to aircraft and that, beyond a certain threshold of uncertainty about aircraft separations, its increase leads to a significant augmentation of the number of controllers needed to properly monitor traffic. An intensive simulation study should provide significant quantitative results, enabling the establishment of practical rules for assigning flights to controllers.

6 CONCLUSION

This communication discussed the assignment of flights to controllers in the Flight Trajectory Operations framework. A new flight centric complexity metric of air traffic has been used to characterize traffic complexity around each flight and quantify the worload associated with the monitoring of flights in extended control areas. At the pre-tactical level, the assignment problem of air traffic controllers to flights has been introduced with the objective of dimensioning the control staff necessary to cope efficiently with the planned traffic over extended control areas during given periods of time. At this pre-tactical level of decision, it is known that the real traffic which will follow may be rather different than the planned one, so it was deemed sufficient to make use of a greedy type heuristic solution approach to solve this problem, instead of an exact, surely extremely time consumming solution approach.

At the tactical level, the controllers face the real traffic which differs from the planned one as a consequence of random occurrences (weather conditions, airport operations delays, new on-board guidance directives). This is traduced for the flight trajectories either in delays or horizontal and vertical deviations. The proposed tactical decision-making process for assigning flights to controllers addresses both types of disruptions. The online and adaptive nature of the decision-making process allows for the best possible consideration of arrival delays, the effects of which will be felt throughout the trajectory while the adoption of a complexity metric penalized by the level of uncertainty on separations should limit the effect of trajectory deviations on the quality of the online-calculated assignment solution.

This study contributes to the definition of the organization of the ATC service in the TBO perspective. It still needs to be fully validated before being integrated with the other components of the new ATC system.

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