Determining Flight Complexity and Relevance: Flight-Centric Filtering for Air Traffic Control

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***Abstract*—Air Traffic Controllers (ATCOs) ensure safe and efficient operations by scanning radar displays to identify flights needing clearances. They then compare flight parameters to assess the impact of potential actions on sector safety. With global air traffic expected to rise, comparing flight labels will become more time-consuming, increasing workload and response delays. To ease this cognitive burden, a flight filtering mechanism is introduced, focusing on flights with spatio-temporal proximities to a selected flight of interest. Based on data from a previous study involving five professional controllers, filter parameters and their thresholds have been selected and tuned. Results indicate that filtering by consolidated state- and intent-based interaction parameters yield the best match to controllers' judgements about relevant flights relative to a flight of interest. It is anticipated that the filter, outputting a list of relevant flights, can serve as an operational support tool by fading non-relevant flights, reducing cognitive effort in visual searches, and could aid Flight-Centric Air Traffic Control (ATC) allocation models that are based on predicting flight-centric complexity.**

***Keywords*—air traffic control, decision-making process, flight filtering, interacting flights, user strategies**

I. INTRODUCTION

The rise in global demand for air travel has made aviation operations more complex and has significantly increased the workload for human operators, posing a serious threat to safety standards [1]. The existing Air Traffic Management (ATM) system faces challenges, such as frequent delays and the need for flight reroutings, emphasizing a comprehensive reform in the Air Traffic Control (ATC) domain. Predictions indicate an upcoming shift towards collaboration between human operators and supportive tools to manage the growing demands effectively. An essential aspect of these tools is their active engagement with human input, promoting trust, reducing resistance to technology integration, mitigate skill erosion, and aligning with operational needs [2].

The Single European Sky ATM Research (SESAR) project is at the forefront of modernizing the ATM system in Europe, shifting the emphasis away from geographical borders to more effectively handle traffic demands [3]. Currently, the increasing implementation of Free Route Airspace (FRA) [4], which allows flights to plan routes freely between defined entry and exit points with enhanced flexibility, may lead to a growing demand on human operators. Although tools like trajectory prediction and conflict alerting systems have improved safety by addressing uncertainties, the decision-making process still heavily depends on the skills of human operators [5].

In managing the safe and efficient air traffic flow in their controlled upper airspace, enroute Air Traffic Controllers (ATCOs) are responsible for monitoring and managing traffic, addressing pilots' requests, and promptly identifying and resolving conflicts [6]. Scanning a radar display for upcoming events such as conflicts typically involves making pairwise comparisons of flight label information to determine what flight is best to work with [7]. After a specific flight has been selected, the ATCO needs to anticipate the impact of a clearance on surrounding traffic, again involving pairwise comparisons. Given that human operators have limited attention resources, they may struggle to focus on all relevant flights and parameters, especially during heavy traffic [8], increasing the risk of errors in issuing safe clearances. A study by Lilo *et al.* [9] showed that conflict alerts in upper airspace are often interconnected, with ATCOs sometimes creating secondary conflicts while resolving primary ones.

Research and operational practices have shown that redesigning radar display visuals, such as adding visual cues to highlight specific ATC events, reduces the cognitive effort involved in visual search while increasing ATCOs' acceptance [10], [11]. The PROSA project takes it one step further by proposing to fade flights no longer threatening the sector due to maintaining sufficient separation from other flights, which enables ATCOs to allocate their focus to only relevant flights in the airspace [12]. Faded flights may reappear on the screen if they no longer meet the spacing requirements or while ATCOs provide clearances to them or other flights. Although the solution is expected to boost sector capacity, the algorithm's role in presenting the traffic situation to ATCOs is crucial and may affect acceptance for two reasons. First, if the algorithm focuses too heavily on technical parameters and thresholds, it may produce results that do not always align with controllers' expectations [13]. Second, the algorithm can fade flights without needing any ATCO input, which could lower system understanding and impact trust.

To mitigate aforementioned potential problems, this research introduces a flight filtering concept that identifies relevant flights interacting with an ATCO's selected flight. By aligning the filter algorithm with ATCO strategies and tuning its parameters to human data, the approach aims to

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achieve high acceptance among controllers. The filter produces a list of relevant flights that interact on state- and intent-based levels, which can either be used to fade non-relevant flights on an electronic radar screen (to ease visual search during conflict resolution [14]) or be used in Flight-Centric ATC (FCA) models to determine flight allocation to the appropriate agent for flights entering the airspace [15], [16].

II. BACKGROUND

A. *ATCO Decision-Making Process*

Enroute ATCOs construct a mental picture of the airspace by integrating static information, such as sector boundaries and waypoint locations, with dynamically updated flight positions. This mental picture enables ATCOs to anticipate future flight positions and proactively prevent potential conflicts [17]. They employ a subjective look-ahead time strategy to predict future flight positions based on current flight parameters, assigned routes, and planned clearances. ATCOs assume control of incoming flights and issue clearances that maintain safe separation standards. They seamlessly transfer control of outgoing flights to adjacent ATCOs while maintaining an expansive view of the airspace to prevent conflicts in neighboring sectors.

Rantanen and Nunes [7] explored the flight characteristics that ATCOs prioritize for conflict detection in enroute airspace. Initially, ATCOs focus on verifying altitudes to guarantee adequate vertical separation between flights. Flights maintaining sufficient vertical separations necessitate minimal cognitive effort for safety evaluations. Subsequently, ATCOs carefully examine flight pairs operating at the same altitudes by assessing their positions and headings to determine their convergence and evaluate horizontal separations. Moreover, ATCOs also consider the speed of converging flights to determine which flight will reach the convergence point first by utilizing speed-distance computations. However, incorporating the speed parameter into the mental picture proves cognitively demanding and is therefore assigned a lower priority, contrary to altitudes and headings. The promptness of conflict detection is notably affected by both the conflict angle and its duration. Conflicts characterized by small conflict angles and short conflict times are detected more rapidly than conflicts with large conflict angles and extended conflict times [18].

The subjective look-ahead time, a crucial element in predicting future flight positions adopted by ATCOs, significantly influences conflict detection accuracy. The choice of resolution maneuvers varies among ATCOs and heavily depends on the spatial, temporal, and technical parameters of flights within the sector [19]. Typically, minimal heading changes are advised for flights separated by a considerable distance, indicating sufficient time for resolution. In contrast, closer flights, determined by positional proximity, often necessitate altitude changes, indicating the need for more immediate action to maintain separation standards.

Rantanen and Wickens [20] examined the cognitive factors influencing the selection of resolution maneuvers among ATCOs. Achieving sufficient vertical separation involves minimal mental effort, making altitude adjustments a popular conflict resolution strategy among ATCOs. However, it increases workload as ATCOs need to consider potential conflicts arising from overlapping altitudes during the transition, requiring additional monitoring and coordination. Conversely, a lateral maneuver via heading change is visually straightforward, maintaining a constant altitude without considering climb or descent rates. This maneuver diverts the flight from its intended route, necessitating rerouting unless cleared by ATCOs to skip intermediate waypoints. Speed adjustments are less favored than altitude and heading changes, especially at higher altitudes, due to their slower profiles and narrowness, primarily used for resolving overtaking conflicts [21]. The preferred resolution maneuver minimizes disruption in the sector, and ATCOs issue it accordingly.

Effectively resolving conflicts with minimal workload involves maneuvering a flight behind another or employing step climbs or descents to different flight levels (FLs) [22]. For efficiency, ATCOs may prioritize higher altitudes for extended periods or direct trajectories towards the sector exit (COPX), aiming to optimize traffic flow through the sector. They utilize a prospective memory approach, briefly storing critical flight information and issuing clearances at opportune moments to meet operational demands. However, this approach becomes vulnerable under high workload conditions due to its cognitive demands and the potential for overlooking conflicts [23]. Failure to resolve conflicts or missed alerts can limit available resolution maneuvers, leading to deviations from planned flight paths or altitudes and accumulations of errors [24]. Importantly, clearances issued by ATCOs to meet operational demands, such as clearing flights towards their transfer flight level or directly clearing towards sector exit, must always adhere to established separation standards between flight pairs within the sector.

B. *Decision-Aiding Tools*

Current tools integrated into ATC workspaces primarily operate at the lowest level of automation, assisting ATCOs in information acquisition and analysis. These tools help ATCOs identify potential threats within their sector by examining current traffic. For instance, radar displays incorporate a Short-Term Conflict Alert (STCA) tool that warns ATCOs of imminent safety violations within a two-minute look-ahead time, assuming flights maintain ground tracks.

To mitigate potential STCAs and minimize the need for last-minute maneuvers, ATCOs at Maastricht Upper Area Control (MUAC) utilize the Verification and Resolution Advisory (VERA) tool [25]. VERA takes radar data to forecast future flight positions (by state-based extrapolations), distance at, and time to the closest point of approach (CPA) values for selected flight pairs by ATCOs. This tool assists ATCOs in monitoring a flight pair over an extended period and assessing if current flight headings result in conflicts. Although VERA is a useful tool for detecting conflicts between selected flight pairs, it does not provide assistance in determining and previewing the impact of a clearance on surrounding traffic.

More advanced decision-aiding tools directly provide resolution advisories to resolve traffic conflicts. Such tools often do not involve the ATCO in the decision-making process on how a specific advisory was selected, leading to several reported human performance issues, such as ‘out-of-the-loop’ situation awareness, transient workload peaks, complacency and skill erosion [26], [27]. To mitigate these problems, transparency and additional machine explanations are required to help fostering acceptance, understanding and trust [28]. Previous research done within SESAR’s MAHALO project showed that acceptance of resolution advisories was more affected by matching them to human preferences and strategies rather than transparency [29], underlining the need for a human-centered approach in the design and *tuning* of decision-aiding tools.

III. FLIGHT-CENTRIC FILTERING CONCEPT

From previous sections, it is clear that the acceptance of a decision-support tool is largely determined by how much it is compatible to the ATCOs’ way(s) of working and how much it engages the ATCO in the work itself. In this section, a filtering concept is introduced that is geared towards determining relevant flights relative to a selected flight of interest, thereby aiming to support (and not replace) the ATCO’s decision-making process. This section details the design and tuning of the flight-centric filter algorithm.

A. *Filtering Process*

Enroute ATCOs scan radar displays to identify flights requiring clearances. Selecting a flight and providing a clearance can be motivated by multiple reasons, such as resolving conflicts, guiding flights to their transfer flight levels, and optimizing flight trajectories towards the sector exit for efficiency purposes. When a flight has been selected, the ATCO needs to judge the impact of a clearance on the safety of surrounding traffic, representing at its core a conflict detection task.

Based on findings from literature and field studies described in the previous section, a typical ATCO’s conflict detection strategy can be captured in a flowchart as shown in Figure 1.

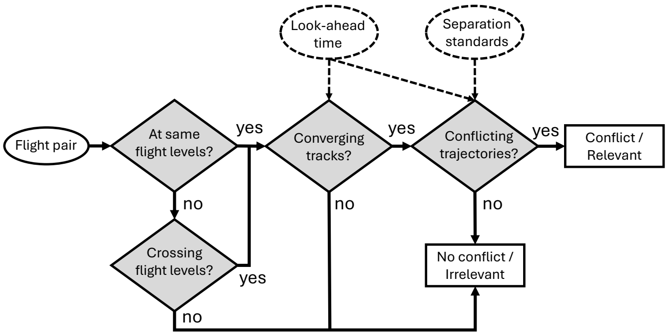


Figure 1. Flowchart for ATCO conflict detection. The dashed items may be ATCO dependent.

Modelling the filtering mechanism after the flowchart in Figure 1 would make it compatible with an ATCO’s strategy for determining relevant flights. Filtering for relevant flights (relative to a selected flight) essentially follows a step-wise process involving the following checks:

1) **Altitude Overlap:** ATCOs initially focus on flight levels displayed on the radar because of their less demanding cognitive efforts to ensure safety. Ensuring sufficient vertical separations is essential, and once maintained, examining flight headings becomes unnecessary. Therefore, only flights whose flight levels overlap with the selected flight’s current (cleared), target and transfer (exit) flight levels are considered relevant.
2) **Spatial Overlap:** Flights having overlapping flight levels are further examined based on their heading to ensure horizontal separations. This step involves determining if their trajectories are parallel, converging, or diverging from the selected flight. Additionally, flights likely to share a common waypoint or cross paths with the selected flight are critical and require closer examination.
3) **Temporal Overlap:** The subset of flights possessing overlapping flight levels and spatial proximity undergoes further refinement through additional temporal considerations. By utilizing speed-distance calculations, the filter pinpoints the time and closest distance at which flights will reach the potential interaction points, indicating their immediate threat level. Estimated Times Over (ETO) waypoints or spatial intersections further assist ATCOs in focusing on the most critical interacting flights to a selected flight of interest.

Flights satisfying all three criteria are identified as potential interacting flights relative to the selected flight of interest, while the remaining flights are deemed irrelevant.

Altitude characteristics such as current, cleared, and transfer flight levels are commonly portrayed in the flight labels (and are thus available from data links), while horizontal locations are represented as radar blips, accompanied by a speed vector. The look-ahead time, adjusted to predict future positions, is significantly influenced by the current traffic scenario and preferred clearances to solve potential conflicts. For example, during heavy traffic, ATCOs may prefer safer solutions with a shorter look-ahead time, whereas during low-traffic conditions, a longer look-ahead time [30]. Since the look-ahead time adopted by ATCOs is highly subjective, a gold standard is difficult to select. As such, the flight filtering concept proposes two look-ahead times, using state-based and intent-based extrapolation, to determine relevant flights regarding spatial and temporal overlaps.

In state-based extrapolation, flights are projected forward from their current positions, headings and speeds to determine the CPA position with other flights without considering their intended flight plan [31], see Figure 2 and Table I. State-based projection is somewhat a ‘reactive’ approach signifying accuracy for a shorter time scale. However, introducing trajectory-based operations in future ATM systems will diminish uncertainties regarding future flight positions, resulting in enhanced ATCO decision-making by considering flight intent.

In intent-based projections, flight positions are extrapolated along their intended trajectory and planned altitude and speed

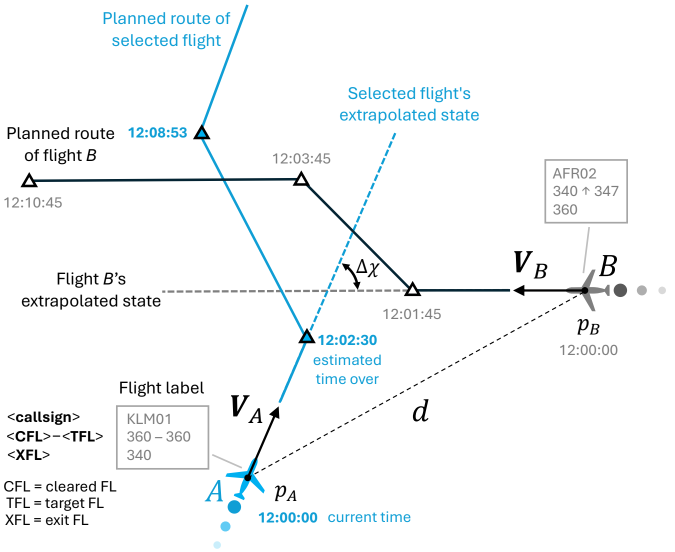


Figure 2. The geometry of state- and intent-based predictions. The cyan flight and lines correspond to the flight of interest (FoI) selected by the ATCO. Definitions of some parameters are listed in Table I.

TABLE I. COMMON, STATE- AND INTENT-BASED FLIGHT FILTER PARAMETERS.

Common filter parameter	
ΔFL	Vertical overlap between the FoI and another flight. The overlap includes cleared (current), target (autopilot setting) and sector exit flight levels of both flights.
State-based parameters	
d	Current horizontal distance between two flights.
ΔT	Prediction look-ahead time.
d_{cpa}	Minimum horizontal distance calculated between two flights at their CPA when extrapolated along their current positions, headings and (ground)speeds over look-ahead time ΔT.
t_{cpa}	Time required for flights to reach their CPA from state extrapolation over look-ahead time ΔT.
$\Delta\chi$	The convergence angle formed between the straight paths of two flights from state extrapolation over look-ahead time ΔT.
Intent-based parameter	
Crossing distance / d_{cpa}	The CPA distance between two flights at overlapping route segments in time and space. Alternatively, if both flight routes are not intersecting, then the minimum distance between two flight segments along their flight paths are taken.

profiles while using a geometrical approach to assess spatial and temporal overlaps, see Figure 2 and Table I. The path between two waypoints is considered a line segment for spatial overlaps (i.e., crossing tracks) and the estimated arrival time at the waypoints for the temporal overlaps. When a spatial and temporal overlap between route segments exists, the CPA can be calculated for that segment by predicting the state of the flight pairs at the start of the critical route segment. The intent-based projection is more of a 'proactive' detection strategy, motivating ATCOs to issue a global conflict-free trajectory solution for the selected flight of interest by considering the selected flight's and other flights' entire trajectories.

In both state- and intent-based projections, deeming a flight to be flight relevant also depends on whether (and how much) separation standards will be violated. Similar to look-ahead times, acceptable separation standards can also vary between ATCOs. In general, ATCOs in en-route airspaces adopt varying safety margins on top of the 5 NM minimum separation to account for trajectory uncertainty. ATCO separation standards may vary between 5 and 10 nautical miles, depending on the traffic situation [29], [31].

B. *Parameter Thresholds*

Thresholds for the filtering parameters will determine what and how many flights are deemed relevant to a flight of interest. Given that thresholds may be ATCO and situation dependent, similar to conflict resolution strategies [29], an individual-sensitive approach may result in higher acceptance. While tuning parameter thresholds to individual ATCOs to accommodate personal preferences is important, previous studies have shown a high level of consensus among professional controllers [31]. By that, our study explored the possibility of deriving a set of fixed thresholds by analyzing data from multiple ATCOs in varying traffic situations.

The data used to derive parameter thresholds came from a previous study where ATCOs judged flight-centric complexity of a predetermined flight of interest [31]. In a set of 36 static traffic scenarios, five professional MUAC controllers working in the Brussels West sector indicated what other flights in the sector were deemed relevant to the FoI, see Figure 3. Here, relevance was defined by the perceived interaction of the FoI with other flights throughout their trajectories, ranging from their current positions to reaching their sector exits and transfer flight levels (indicated in the labels).

Each of the 36 scenarios displayed a distinct radar snapshot from 23 March 2022. The snapshots were selected such they encompassed a wide range of flight characteristics in terms of altitude overlap, spatial and temporal proximity, and routing complexity, without special events (e.g. separation losses and emergencies). Additionally, the initial state and intent characteristics of FoI also varied across scenarios. For example, in one scenario the FoI did not need to change flight level, was on a direct route to the exit waypoint, and was located far-away from other flights, while in another scenario the FoI needed to climb 4,000 ft, followed a route, and needed to pass a dense part of the sector. The FoI was always positioned outside the sector to consider it as an incoming flight.

Given that all 36 traffic scenarios were static, filter parameter values of the FoI relative to the relevant flights could be calculated using standard CPA and 2D distance calculations. For simplicity, the altitude overlap was retrieved as a boolean instead of the exact value of the overlap. In general, the parameter values at which the number of included flights decreases significantly can be set as a threshold to classify flight as relevant for that particular parameter. Figure 4 shows the total number of included flights against the parameter values used for threshold determination. Unlike distance-at-CPA and time-to-CPA, current distance exhibited an uneven distribution of included flights. To account for this unevenness and establish appropriate thresholds, the values for these

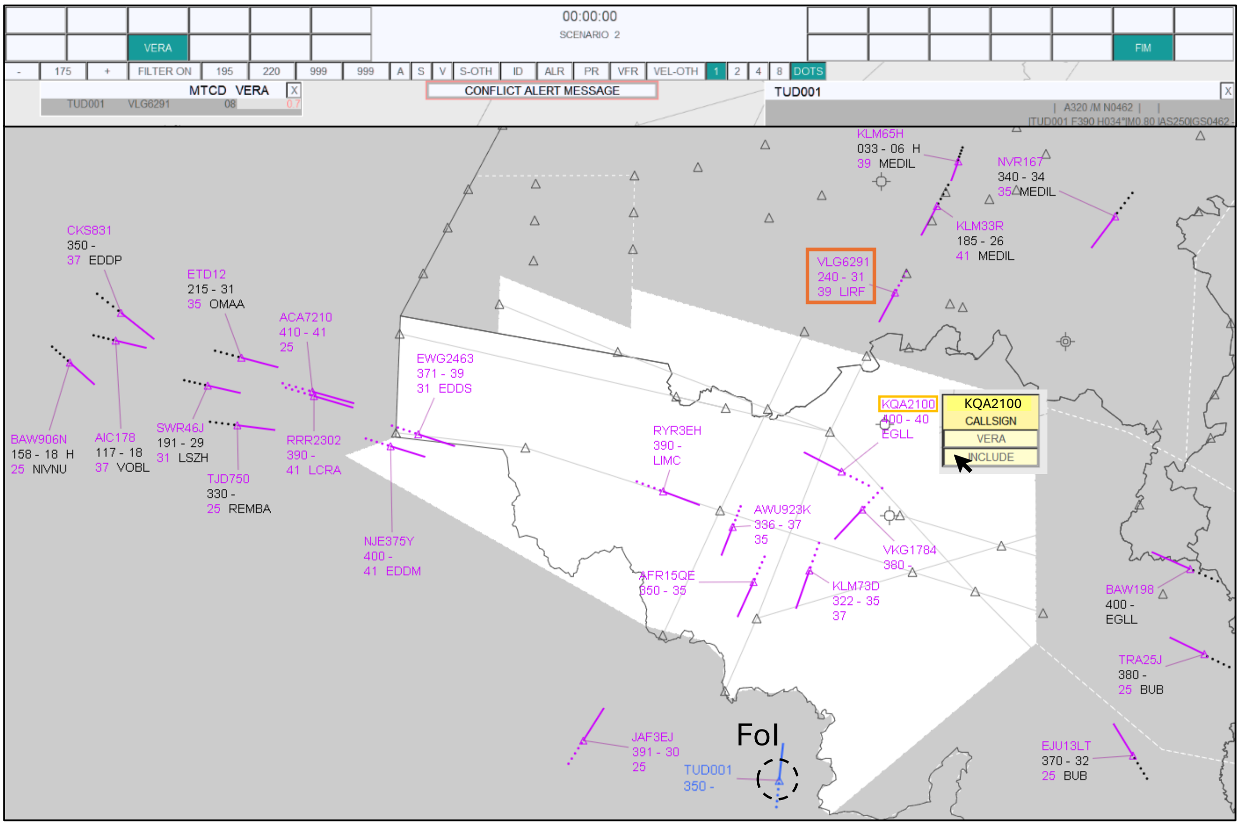


Figure 3. Simulator interface (mimicking MUAC's plan view display) showing a Brussels scenario with the FoI in blue. Clicking on the label's callsign item would activate a menu that allowed ATCOs to mark a flight as relevant to the FoI, after which a border would appear around flight label. Colors have been inverted for print clarity. See [31] for more details.

parameters were grouped. The flights included by multiple ATCOs within each bin were then summed to identify the bin containing the most included flights before a 'sudden' drop was witnessed in the next adjacent bin. This is somewhat similar to the 'elbow' method found in clustering algorithms to determine the optimal number of clusters.

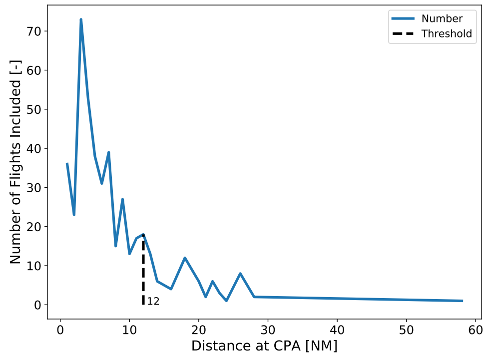
Figures 4a and 4b show multiple decreasing points, and the thresholds are set to appropriate values based on existing literature. Studies show that ATCOs prioritize flights with predicted distance at CPA under ten nautical miles [29], [31] and aim to resolve conflicts 7 to 12 minutes before violating separation minima [19]. While the distance parameter had a decreasing trend for the sum of included flights after binning the parameter values, no clear trends were visible in the crossing angle parameter. As such, crossing angle was discarded as a filtering parameter. Finally, we decided that the intent-based filter parameter utilizes the same distance at CPA threshold as the state parameter to identify relevant flights. For flights deviating from their route, an artificial trajectory can be generated to project its flight path until the time-to-CPA threshold based on current flight parameters, accounting for flight intent.

IV. FILTERING PERFORMANCE

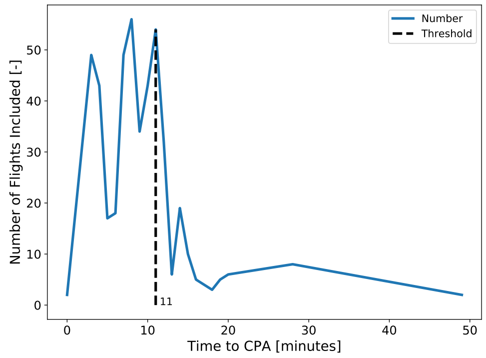
Having established the thresholds for the filtering parameters, this section discloses the performance of the proposed state- and intent-based filters in how well their outputs match the ATCOs' indicated relevant flights. The evaluation of the filtering performance involved comparing the state-based filter (extrapolating the state over a fixed ΔT) against the intent-based filter parameter that checked for spatial and temporal overlaps over entire trajectories.

Additionally, a consolidated filter was introduced that combined the state and intent information in a sort of parallel process, as shown in Figure 5. The consolidated filter aims to capture relevant flights that would not have been detected by either the state or intent filter alone. Obviously, in this parallel setup, the same flight could be detected twice. To mitigate that, duplicates need to be removed from the final list of relevant flights.

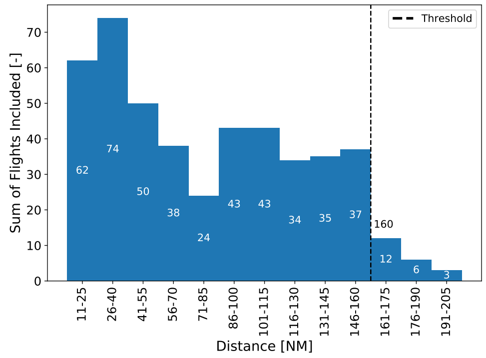
As an example, Figure 6 portrays the filter results in one scenario for one ATCO. In the top left picture, the traffic scenario is displayed containing the FoI and the flights that the ATCO deemed relevant to the FoI. The top right picture shows the results of the state-based filter, which missed three relevant flights, resulting in a 66.7% success percentage. The intent filter (bottom right) only missed one flight (88.9% success), but also marked an new flight as relevant that was not selected by this particular ATCO (but was sometimes picked by another ATCO). Finally, the consolidated filter (bottom left) matched the ATCO's judgement and marked an additional flight as



(a) Distance-at-CPA threshold: $d_{cpa} = 12$ NM



(b) Time-to-CPA threshold: $t_{cpa} = \Delta T = 11$ min



(c) Distance threshold: $d = 160$ NM

Figure 4. The number of flights perceived to interact with the introduced flight against the state parameter values.

relevant, thereby overachieving its purpose for this particular ATCO.

To combine the filter results across all scenarios and all five ATCOs, it was chosen to put the results in confusion matrices (see Figure 7). A confusion matrix is a convenient and graphical way to evaluate classification model performance by comparing predicted and actual classifications. The actual label indicates whether the flight is included as relevant, along with its consensus among ATCOs, while the predicted labels show if the filter highlights the same flight(s) relative to the FoI. Using these matrices, several metrics can be derived to evaluate the filter performance, as shown in Table II.

The main metrics for inspecting the filter's performance are

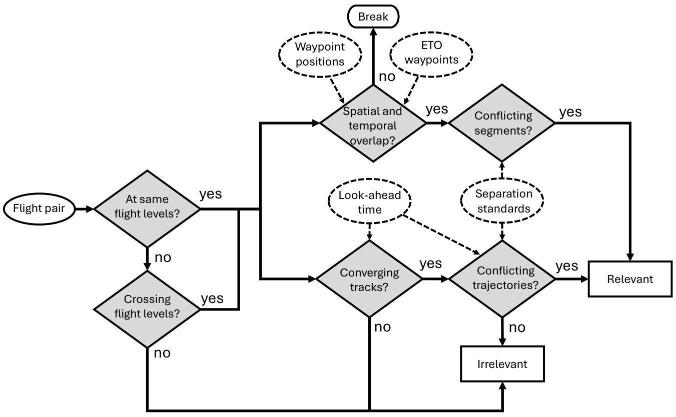


Figure 5. Consolidated filter flowchart, combining intent (top part) and state (lower part) information to detect relevant flights.

accuracy, precision, recall, and F1-score. Accuracy measures how often the filter correctly predicted relevant and irrelevant flights. All filters are similar in accuracy by being roughly 87% accurate, but this is not very useful given the unbalanced relevant and irrelevant flights (i.e., there are many more irrelevant flights than relevant).

Precision measures how often the filters correctly predicted relevant flights from all predicted relevant flights and is most useful when the cost of a false positive (i.e., incorrectly predict a relevant flight) is high. Recall measures how often the filters correctly predicted relevant flights (true positives) from all actual relevant flight and is most useful when the cost of false negatives is high. In that case, you typically are interested in finding all relevant flights, even if this results in some irrelevant flights being considered as relevant (false positives). The F1-score calculates the harmonic mean between precision and recall to provide a balanced in predictive performance.

The state-based filter results in the highest precision and lowest recall compared to the other filters. This filter seems to emphasize potentially critical and more imminent interactions between flights, but risks overlooking later-stage interactions. Conversely, the intent-based filter highlights most interactions throughout the FoI's entire trajectory. This more conservative approach seems to ensure comprehensive coverage, but may include flights deemed irrelevant by ATCOs, resulting in high recall but lower precision. The consolidated filter, merging state- and intent-based predictions, resulted in a better balance between precision and recall compared to the state and intent filters.

Based on all performance results of the filters, in conjunction with the interpretation of the filter's operational relevance, the filter with the highest recall is considered more meaningful. We believe that it is more important for a filter to detect all relevant flights, even if this sometimes results in false positives. In this regard, the consolidated filter is most favourable as it combines predicting both short- and long-term flight interactions. Given that human input data is used, we hope that using such flight filtering in operational settings fosters high acceptance. Finally, although filter performance

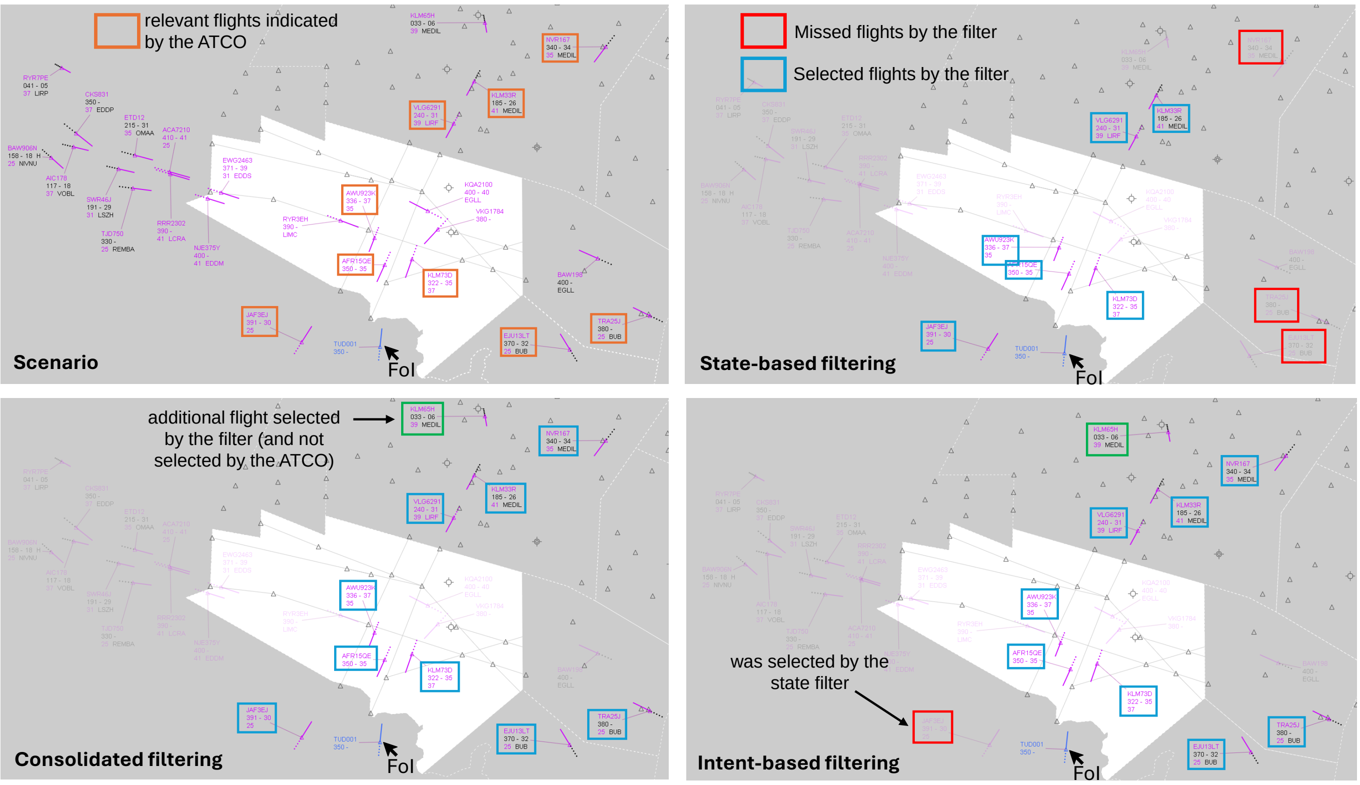


Figure 6. Filter results in one scenario for one ATCO.

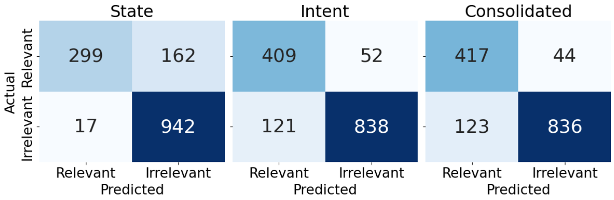


Figure 7. Confusion matrices per flight filter.

values are within acceptable ranges (between 80-90%), more data would be needed to substantiate these promising results.

TABLE II. FLIGHT FILTERS - PERFORMANCE

Filtering	Accuracy	Precision	Recall	F1
State	87.39	94.62	64.86	76.96
Intent	87.82	77.17	88.72	82.54
Consolidated	88.24	77.22	90.46	83.32

V. CONCLUSION AND FUTURE WORK

This research presents a flight filtering concept aimed at identifying relevant flights interacting with a selected flight of interest. Two filters, state-based and intent-based, were introduced to assess flight relevance by extrapolating flights over varying look-ahead times. Additionally, a consolidated filter, combining state and intent parameters, was proposed and showed to outperform the state and intent filters in detecting all flights deemed relevant by multiple ATCOs. Given the availability of state and intent information in ADS-B messages and radar data, implementing the proposed filters in current and future ATC systems would be feasible.

In this study, however, the filters do not yet consider real-world uncertainties like atmospheric conditions, pilot delays, or trajectory uncertainties. The filters' robustness can be improved by incorporating these uncertainties in future research. Additionally, the filters' performance should be evaluated with increased sample sizes in conjunction with various airspaces and sectors (with varying traffic conditions) to verify its generalizability.

While the consolidated filter successfully identified relevant flights that interact with the selected flight, its practical performance in operational settings has not been evaluated. The filter should be tested as an operational tool in managing dynamic traffic scenarios by fading irrelevant flights, thereby enhancing decision-making abilities through reduced visual search effort [14]. Moreover, updating the filtered results based on preferred clearances could alter the number of interactions with other flights, allowing ATCOs to evaluate and implement new strategies.

Finally, the filters are expected to be compatible with novel ATC operational concepts, such as FCA [15], [16], that focus on allocating individual flights to different controllers to more evenly distribute the workload among controllers. The success of such allocation hinges on robustly predicting the interactions between individual flights. Ideally, flights that have (many) interactions are best allocated to the same controller so as to minimize coordination efforts between controllers.

MUAC's ARGOS automation project takes it one step further by attempting to allocate 'basic, routine' flights to a digital ATCO while the human ATCO remains in charge of all 'non-basic, complex' flights [32], [33]. In both concepts, the consolidated filter can serve as a way to assess the complexity of (new) flights entering the airspace by using the number of relevant flights (i.e., filter output) as a proxy for quantifying flight-centric complexity.

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