Control of User Preferred Trajectories in a constrained ATM environment

Technical specification

Introduction

The objectives expressed in the Eurocontrol ATM2000+ strategy [1] lead to the improvement of the performance of the ATM system from a user's perspective. With safety as the key parameter, improvements are sought for operational efficiency and cost effectiveness whilst minimizing the nugatory impact on the environment. The knowledge of user preferences for aircraft operation constitutes the basis. If, due to the traffic situation, the ATM system cannot accommodate the facilitate User Preferred Trajectories (UPTs), the traffic should be accommodated at minimum deviations from the UPTs. The availability of a consistent representation of predicted aircraft trajectories is paramount to achieve interoperability and consistency between the automation in the aircraft and in Flight Data Processing Systems, in particular Decision Support Tools (DSTs).

To facilitate this, the CARE Action on the Common Trajectory Prediction Initiative (CARE/TP) was initiated on March 3, 2004 [2]. A work plan consisting of 12 actions was agreed among the participants, of which 8 Actions were considered to be of high priority. The objectives of this Action Point are duly coordinated with the similar item in Action Plan 16 of the Eurocontrol-FAA R&D Committee on the development of a Common Trajectory Prediction Capability [3].

In the CARE context, Eurocontrol intends to issue a Call for Tender to improve the "Control of User Preferred Trajectories in a constrained ATM environment". This subject is directly related to the deliverables of Action Item 2 of the Work Plan addressing "TP Requirements capture", and Action Item 6: "Requirements for aircraft performance data". As a first step, a Call for Interest has been issued, to invite those organizations that have domain knowledge and/or share an interest in this subject. The development of a common view on the future path of aircraft from the perspective of both air and ground automation applications requires a duly coordinated approach to the Trajectory Prediction challenge.

From these responses and some bilateral discussions we have compiled a draft specification for work that will deliver the basis for future activities. The cooperation of several different expert domains in aircraft operation and ATC systems design is required. Although the deliverables of all four work packages are critical to an efficient, air-ground synchronized approach to the Trajectory Prediction challenge, it is realized that Intellectual Property Rights and commercial interests may complicate the exchange and sharing of information. To mitigate the potential caveats Eurocontrol has called a special meeting with the potential partners to tune the contents of the final specification for this project. The objective is to reach a good common understanding that will lead to the production of realistic deliverables in the given time frame and resources.

The Challenge

The manufacturers of flight management systems are announcing enhanced FMS performance capabilities. They claim that these can offer substantial economic and environmental benefits. Improvements in fuel efficiency of 300 to 500 kg per flight and up to 50% reduction in noise levels of the 65dbA in affected areas are promised. Other research suggests, that the use of RNAV procedures in the TMA and the simultaneous planning of flights on Continuous Descent trajectories supported by an efficient Arrivals Management Tool, create defacto altitude separation between inbound flights, leading to an intrinsic increase of safety.

Statistics prove that Air Traffic Control today, is an industry with a very high safety record. Nevertheless the Air Transport Industry and environmental constraints are putting ever increasing demands on this performance. Where today Air Traffic Control largely depends on pure human skills, it is unlikely that this approach can be maintained forever. Like in other industries before, introduction of automation to improve ATM performance will be unavoidable and the capability to accurately predict the future trajectories of aircraft is a prerequisite for advanced ATM automation.

Different stakeholders in the ATM arena have different views as to how “User Preferred Trajectories” are specified. Aircraft operators focus on the operating costs and the flight schedules, whereas ANSPs consider safety, controller workload and environmental impact as critical issues. The automation systems in the air and on the ground have largely been developed in isolation. Therefore it is not surprising that objectives and performance targets for airborne and ground based trajectory prediction and control systems are not very well synchronized. There are indications that the lack of harmonization affects the performance of the ATM system globally in a negative way. Given that in the future further automation in the air and on the ground will be required to provide the target capacity and safety levels, it is paramount to understand the various aspects of User Preferred Trajectories and to investigate possible compromises.

The work

Five work packages have been identified including one optional work package:

1. The definition and analysis of User Preferred Trajectories
2. The modeling of the aircraft performance.
3. The modeling of the aircraft intent.
4. The dissemination of the results and conclusions from WP 1-3 to the ATM community
5. *Optional*: Evaluation of FMS aircraft performance model on PAMPA platform.

The major part of the work leverages existing know how and sources of information, although it is recognized that this information may not be readily available. Work packages 1 – 3 focus on the eliciting and compiling of the basic information that will facilitate an efficient and up to date overview of the practical situation.
The terminology to be used is described in the White Paper on “Common Trajectory Prediction related terminology” [4].

WP 1. Definition and analysis of User Preferred Trajectories

Objective

The Trajectory Prediction process in air and ground ATC applications must facilitate the translation of User Preferences into Use Preferred Trajectories. The ATM environment is referred to as "unconstrained", if an Aircraft Operator can operate his aircraft in a way that meets his individual targets for the given flight without being affected by the presence of other aircraft or tactical or strategic procedures nor by ATC constraints. In contrast, the operational conditions of a "constrained" ATM environment, reflect the complexity of the real life environment. Aircraft Operators and ANSPs do not necessarily have similar optimization criteria for executing and controlling the flights. This may result in differences in the definition of "User Preferred Trajectories" when viewed from their different perspectives.

This work package delivers the high level definition of User preferred Trajectories in unconstrained and constrained ATM environments from the perspective of the Aircraft Operator and the Air Navigation service Provider. The deliverables will explain which criteria are applied in the definition process and how the characteristics of User Preferred Trajectories are defined in the various traffic conditions.

Rationale

If aircraft are operated in an unconstrained ATM environment, it is possible for the operators to achieve their individual targets. Examples may relate to minimum flight time, direct operation costs or fuel consumption. In contrast, in a practical ATM environment the progress of an individual aircraft is often affected by one or more other flights. Different stakeholders may have different views on how this is effected in an optimal way. Issues like aircraft operating costs, cockpit and controller work load, requirements for a given infrastructure or automation level, etc. will all have an impact.

Tasks

1.1. User Preferred Trajectories in unconstrained ATM environment

Define the categories of User Preferred Trajectories to meet the various objectives of Aircraft Operators in an unconstrained ATM environment. Consider light, medium and heavy aircraft categories.

1.2. User Preferred Trajectories in constrained ATM environment

Define the categories of User Preferred Trajectories to best meet the objectives of aircraft operators and ANSPs in a constrained ATM environment. Consider trajectory solutions that compensate delays of 2 and 5 minutes in an enroute environment and 1, 5 and 10 minutes in TMA environment. Consider the separate and/or combined use of speed, altitude and route deviations. Consider the potentially different solutions for light, medium and heavy categories of aircraft. Consider various practical ATC limitations caused by the dimensions of FIRs and their sectorization.

1.3. Evaluation and recommendations

Compare the UPTs in constrained and unconstrained ATM environments. Provide the estimated impact on cockpit workload, cost and impact on environment. Provide an overview of the different UPT definitions. Propose recommendations for a way forward considering the interests of the different stakeholders.

WP 2. The modeling of aircraft performance

Objective

Perform a survey and high level analysis of typical aircraft performance models for application in trajectory predictors in onboard Flight Management Systems, ground-based Flight Data Processing Systems, ATC Decision Support Tools, real-time and fast-time ATC simulators and analysis tools for environmental aspects (e.g. the Integrated noise Model, INM, etc.).

Rationale

All software that is developed to compute the behavior of aircraft does this, inter alia, using a model of the aircraft's performance. It is expected that the future ATM system will be based on automation elements that are distributed over air and ground systems. Consequently, it is paramount that a consistent view exists in FMS and ground applications of aircraft performance capabilities.

Tasks

2.1. Performance model description

Describe the typical aircraft performance models. Essential characteristics are:

- Typical applications for which the model has been developed.
- Class identification of the model [4],
- Completeness of the model (e.g. which aircraft configurations are modeled, which aircraft parameters are modeled, i.e. for in-flight (including the modeling of flight envelope), take-off & landing run, other ground movements, etc.),
- Input parameters required to drive the model (e.g. aircraft mass, speed, air temperature, configuration, airco, bank angle, pitch angle, ant-icing, a/p mode, a/t mode, throttle position, etc.)
- Type of reference data used to develop the model(e.g. need for detailed thrust, drag, lift data, integrated profiles, profile tables etc. What if the process is some of the data is not available?),
- Model generation process,
- Extent of the model data (e.g. number of polynomials and coefficients, sizes of data tables and granularity),
- Validation procedures of the model over operational flight envelope,
- Average modeling accuracy,
- Application (specific to single airframe-engine combination, ICAO class)
- Application range (Which aircraft types have been modeled in this way?)
- Maintenance of the model (aspects and consequences of model upgrades, bug fixing, distribution of the methods and coefficient data, etc.)

- Availability (Intellectual Property rights, restrictions for use, costs, legal issues for use in operational systems, etc.)
- Current user base.

2.2. Key performance indicators for aircraft performance models

Define a matrix of key performance indicators for the use of these models in the different ATM applications. This list of applications should include Flight Planning tools, Air Traffic Flow Management functions, Flight Data Processing Systems, “basic” Decision Support Tools, e.g., Medium Term Conflict Detection, “advanced” Decision Support Tools, e.g., Conflict Resolution Assistant (CORA), advanced and very advanced Arrivals Management (AMAN), on-board Flight management Systems, ATC simulators and environmental analysis tools.

2.2. Mapping of KPIs for aircraft performance models

Map the various aircraft performance models against the matrix of key performance indicators.

2.3. Evaluation and recommendations

Summarize the above findings in a list of recommendations to better harmonize the generation, maintenance and use of aircraft performance models in ATM automation functions.

WP 3. The modeling of the aircraft intent

Definition of aircraft intent

The understanding of the definition of “intent” in the context of trajectory prediction is defined in Ref [4]. From the perspective of the Trajectory Prediction process, intent information describes the planned operation of the aircraft. In effect this information is input into the trajectory prediction process. This notion is significantly different from the understanding in other circles, where it is assumed that intent refers to a sequence of 4D points. From this perspective, intent information would be related to the output of the trajectory prediction process.

Objective

Perform a survey and high level analysis of various ways in which aircraft intent information is described for trajectory predictors in FMS, Flight Data Processing Systems, ATC Decision Support Tools, real-time and fast-time ATC simulators and analysis tools for environmental aspects.

Rationale

In this context, the aircraft intent describes the way the aircraft is operated to effect the target trajectory. In a Trajectory Predictor this information is compiled in the Flight Script [Ref. 4]. There are different methodologies to model this information in the Flight Script, each with its advantages and disadvantages. Achieving consistency in the way intent information is modeled in air and ground applications is paramount for achieving consistency in predicted trajectories.

Tasks

3.1. Methodology for trajectory intent description

Describe the methodologies used for modeling the aircraft intent in the various TP applications in the air and on the ground. Typical examples include the "segment-based" approach as used in the CITRAC method developed by CENA, or the "profile-based" approach as applied in the CINTIA method of Eurocontrol. The description must include the level of detail that can be specified, e.g. ARINC 422 leg terminators, fixed rates, parameter limits, parameters used to define start/end conditions of flight phases or segments, etc.

3.2. Key performance indicators for trajectory intent description methodologies

Define a matrix of key performance indicators related to intent modeling approaches for the different ATM applications.

3.3. Mapping of KPIs for intent description methodologies

Map the methodologies against the matrix of key performance indicators.

3.4. Qualification of trajectory intent methodologies

A given methodology to model the aircraft intent is directly related to the methods and algorithms applied in the Trajectory Engine that computes the trajectory. In this work package a qualified evaluation is produced of on the expected performance that can be achieved when using the various trajectory intent description methodologies and the consequences for the design and performance of the associated Trajectory Engine. Issues to be considered include:

- input requirements,
- estimated processing effort to build the Flight Script data from flight plan information and supporting databases (e.g. adaptation data, aircraft performance models, etc.)
- estimated processing effort for trajectory calculation by the Trajectory Engine,
- expected accuracy that can be obtained.

3.5. Evaluation and recommendations

Summarize the above findings in a list of recommendations to better harmonize the modeling of aircraft intent both in air and ground based Trajectory Predictors. Consider various combinations of use of static databases and real-time communication through air-ground datalink. Identify the datalink performance requirements in terms of response time and communication capacity.

WP 4 Dissemination of the results and conclusions

In order to disseminate the findings of the Work Packages 1-3 to the ATM community, the consortium is requested to organize a workshop at which the conclusions are presented to the ATM community. The workshop will be an efficient means to discuss the recommendations of the studies with the stakeholders. The deliverable of this workshop will consist of a summary report to the stakeholders for further action.

The workshop will be organized and chaired by the consortium. Eurocontrol will provide the necessary support facilities at Eurocontrol HQ in Brussels.

WP 5 ***Optional WP***: Evaluation of FMS performance model on PAMPA platform

Given that consistency among aircraft performance models used in air and ground applications is paramount, it is of interest to compare and assess the detailed output of the different performance models against the aircraft manufacturer's reference data. To that effect Eurocontrol has placed a contract to develop the Aircraft Performance Evaluation Platform, PAMPA [6]. The final delivery of the platform is scheduled for December 2004. The platform has an Applications Program Interface for the Eurocontrol BADA, CFMU and GAME, the NASA-CTAS model and CENA models. The technical description of the API can be downloaded from Reference 6.

This optional work package comprises the following tasks:

5.1 PAMPA interface development

Development of an interface of a typical aircraft performance model used in new generation FMSs to the PAMPA platform. The wrapping software may encapsulate the internal algorithms and coefficient sets of the model.

5.2 Performance model evaluation

The evaluation of this model against the performance models already interfaced to the PAMPA platform.

5.3. Evaluation and recommendations.

The deliverables of optional work package 5 consists of a document that reports on

- The technical issues encountered when implementing the interface.
- A summary of the evaluation results.
- Conclusions and recommendations.

Deliverables.

The deliverables of the work packages consist of a document per task that reports on the specified issues.

Intellectual Property Rights and Commercial Interests

Eurocontrol is aware of the sensitivity of the requested deliverables with respect to Intellectual property Rights and commercial interests.
For the execution of the work it is essential for the members of the consortium to have access to these data. The consortium is requested for each task to indicate the following:

- Which information do they have access to to perform the work.
- Which part of this information will be made available to the Eurocontrol TP experts at a confidential level, i.e. "information presented, but no notes taken"
- Which part of this information will be delivered in the form of documents with restricted distribution? Please indicate which restrictions will apply.
- Which information will be delivered for public dissemination?

Administrative aspects

To comply with the collaborative principle of CARE, responses to this call for tender should come from a consortium of at least 3 organisations from 2 different countries with one clearly identified as the leader.

Award criteria

The offers will be evaluated in accordance with the following award criteria:

- Compliance with the technical requirements of this specification.
- Consortium's understanding of the problem
- Technical merit of the proposal
- Limits on Intellectual Property Rights
- Trust in the consortium's knowledge
- Trust in the consortium's availability
- Work distribution.
- Delivery dates.
- Cost of the work packages.
- Financial guarantees.

Points of Contact

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Acronyms

AP16	FAA-Eurocontrol R&D Committee – Action Plan 16
ATC	Air Traffic Control
ATM	Air Traffic Management
ANSP	Air Traffic/Navigation Service Provider

CARE	Co-operative Actions of R&D in Eurocontrol
CfT	Call for Tender
DST	Decision Support Tool
EHQ	Eurocontrol Headquarters
FAA	Federal Aviation Authority
FDPS	Flight Data Processing System
FMS	Flight Management System
PAMPA	Platform for Aircraft Modelling Performance Analysis
RNAV	Area Navigation
TP	Trajectory Predictor
UPT	User Preferred Trajectory

References

[1] Eurocontrol ATM 2000+ strategy
http://www.eurocontrol.int/dgs/publications/atm2000plus_strategy/main1.html

[2] Reference to CARE/TP
http://www.eurocontrol.int/care/TP/index.html

[3] Eurocontrol-FAA R&D Committee Action Plan 16
http://www.eurocontrol.int/faa-euro/start.html
Draft Terms of Reference and Work Plan are available from the Eurocontrol One Sky Online portal, accessible from http://www.eurocontrol.int, "One Sky Online". Select "Common Trajectory Prediction Initiative".

[4] White Paper on "Common Trajectory Prediction related terminology",RDCOM-AP16 Core Team, available from the Eurocontrol One Sky Online portal, accessible from http://www.eurocontrol.int, "One Sky Online". Select "Common Trajectory Prediction Initiative". Library-Action Points- Action Point 1.

[5] EATCHIP Operational Requirements Doc. For Trajectory Prediction V0.95. available from the Eurocontrol One Sky Online portal, accessible from http://www.eurocontrol.int, "One Sky Online". Select "Common Trajectory Prediction Initiative". Library-Action Points- Action Point 2.

[6] PAMPA project – Aircraft Performance Evaluation platform
Documents and software downloads related to the PAMPA project are available from the Eurocontrol One Sky Online portal, accessible from http://www.eurocontrol.int, "One Sky Online". Select "Common Trajectory Prediction Initiative". Library-Action Points- Action point 5.