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Using Inter-Process to Expand Modeling Capabilities

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Abstract

The paper will report in the use of inter-process communications between the Eurocontrol fast-time simulation RAMS and OPGEN, the flight-planning tool developed for FAA by CSSI, Inc. The capability was developed to extend RAMS for the purpose of conducting investment analysis for the NASA AATT tools and as a proof of concept for a more fully developed capability. The paper discusses the objective in pursuing an inter-process framework for fast-time modeling and analysis as well as the specific analysis to be supported by the prototype. The paper also addresses next steps to the development of the full capability.

Objective

There are many reasons for pursuing the modeling framework we address in this paper. We will focus on the task that immediately faces us – the validation of the future operational concept. The development is part of the FAA and NASA's joint development of the National Airspace Resource Investment Model (NARIM). The goal of NARIM is to provide for modeling and analysis of current and potential operations, engineering impacts of future systems and the trading of requirements across system and procedural investment alternatives.

In human center enterprise, such as the National Airspace System, current and future concepts are based on the dissemination and use of information. The current concept is based on a paradigm where dynamic data is shared mainly for the purpose of tactical activities between the tactical controller and the flight deck. Future concepts postulate expanding the number and roles of decision points including multi-sector planners, airborne operations, and dispatch and traffic management. In fact, the transition has already begun with the efforts to improve the national traffic flow management with the exchange of information and subsequent change of procedures supported through the AOCNET.

The growth of decision points is in response to the twin and almost opposite goals of sustaining growth and increasing flexibility. It is clear that this can only be met through a proliferation of decision tools in our airspace system. But, how do we forecast the effects (whether positive or negative), validate the concepts, and support the development of these tools? This paper outlines our approach and our initial steps to realizing this capability.

Motivation Of The Framework

To understand how this capability can be achieved, we consider what is the core functionality of decision support tools. All current concepts for decision support tools are based on these three basic functions:

- Assessment of traffic situation
- Application of rules to identify mitigation
- Assignment of new paths to aircraft.

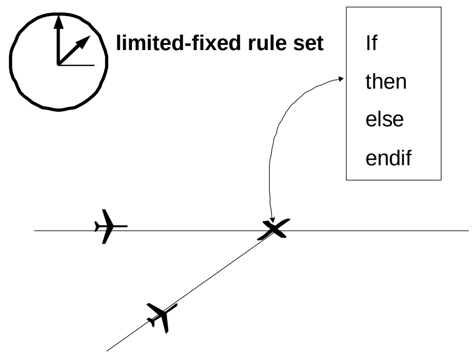
The variations in concepts can be found in

- the domain,
- focal point,
- scope/range
- and planing objective and constraint

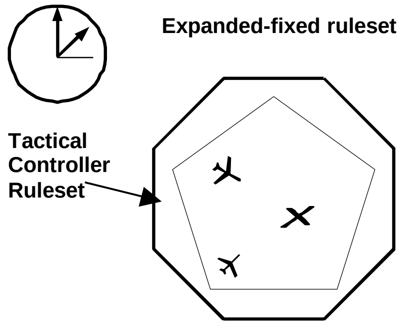
By **domain,** we can consider whether the tool supports surface or airborne movement of aircraft. **Focal point** refers to the where the assessment is taking place, i.e. is the assessment from the point of view of the flight deck, the controller, the traffic flow specialist, or the dispatcher/ AOC. **Scope and range** refers to whether it is a tactical decision or near-term strategic, i.e. is the assessment period now through the next five minute or is it in the 5 to 20 minute window, or the one hour window, etc. Finally the **object/constraint** refers to whether the rule application is for conflict resolution or flow management, does it to apply to a single vs. multi-flight solutions, is it to provide the most fuel/time efficient path or to meet some scheduled time of arrival, etc.

Based on some trigger, the tool identifies all traffic within its time window range. The traffic sample is centered on the tool's focal point. The traffic is assessed for the behavior within the scope of the operator’s/tool's ruleset and then the operator/ tool applies the “best rule” to the situation.

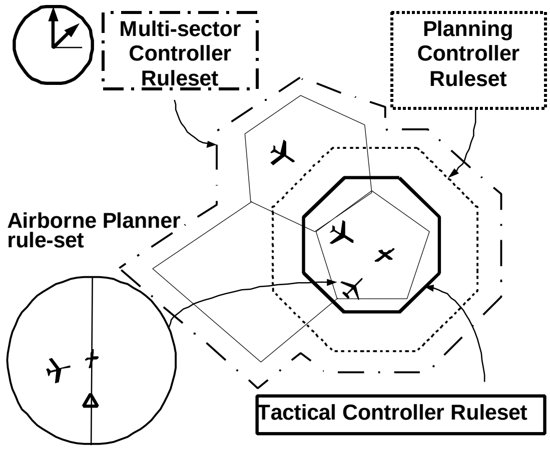
We have also described how fast-time simulations work. In fast-time simulations the traffic flow is modeled on the flight plan, the difference is that in current fast-time simulations the aircraft always perform as expected. Specific focal points are modeled and the same events that trigger decisions in the decision support tools similarly trigger decisions in the fast-time simulation.



Fast-time simulations based on link-node algorithms



Next generation fast-time simulations



Modeling framework goal

The fast-time simulation has some additional characteristics that a decision support tool relies on other capabilities to provide.

- The fast time simulation maintains a clock and advances it to model the movement of time through the day.
- The simulation keeps a complete picture of all aircraft including those in and out of the individual focal points and range
- They usually are accompanied with pre and post-processing support tools for the development of scenarios and the post-exercise analysis.
- The simulation maintains a log of all triggers, decisions and results.

The simulation is thus a "decision support" tool, timekeeper, game-master and bookkeeper.

Since fast-time simulations have so much in common with the decision support tools why aren't they used more in the development of concepts and algorithms, and in performance assessments? The answer is simple, fast-time simulations are fairly inflexible in their ability to modify their response to triggers. For most the only response flexibility is allowed for a single focal point – the controller. Most other focal points have hard-wired single responses. The traffic assessment range, i.e. the scope and range is usually limited to looking at the R or tactical controller actions, (RAMS allows D side activity). The fast time rules are usually focused on a single objective – conflict detection and resolution.

The most common responses to this dilemma has been to

1. Write a special single purpose simulation to model the focal point, scope and objectives of the individual decision support tools. These have all the inflexibility of the general simulation tools – they differ only in that their focal point is not the most "popular" point.
2. "Pay" the general simulation tool developer to include the focal point and rule base into an existing tool. "Pay" because it may be within the agency, but it does have these characteristics as a downside
   - The core simulation grows in size and complexity affecting both it execution performance and maintenance
   - In most cases, changes within the decision support tool will require the negotiation of reprogramming within the simulation to keep apace
   - The future use of this investment in the simulation tool is predicated on the continued health of the software development company if it is proprietary or the simulation project if it is an agency tool
3. Leap past these alternatives to mid-fidelity human in the loop simulation and field trials.

None of the alternatives is really attractive, but the ability to depend on the third is rapidly disappearing. As we increase the capabilities of the agents, centered at the various focal points, their interactions - especially with their difference in scope and objectives - require HITL simulations beyond a scope or funding level that can be sustained. Incremental application to real traffic in integrated field trial could well extend beyond the promised delivery time of the capabilities in our airspace. Such a field trial will also come so late in the combined development of the tools that we can only validate that we guessed right or wrong and not support through trial and error the development of this integrated capability. Consider what it would mean to evaluate the interactions of fifty aircraft with flight deck capabilities similar to that foreseen in Freer, with multi-sector, single sector, surface, decent advisor, FAST and strategic flow agents all attempting to assess and manage the situation based on their individual objectives.

The growth in software technology and distributed processing has provided another/better alternative. Rather than building the single purpose simulations or building the simulation-to-end–all-simualtions, we can, in fact, build a stripped down simulation. That is, use the features that differentiate the general simulation from a decision support tool to acts as the core functionality for simulation. Let the fast-time simulation generate the triggers and then use the decision support tools or an early representation to conduct the assessment and replan traffic. The simulation then moves the aircraft and time forward to the next assessment. If there is no external decision support tool attached to respond to the trigger, we let the internal rules set make the decision. This allows the capability to be used throughout the development of the concept and the tools, and through to integration of the tools into the airspace system.

The path to this capability involves

- Developing an inter-process capability in a general simulation so that the simulation and either the decision support tool or a representation of its capabilities can interact "real-time"
- Establishing a set of triggers and messages to allow the simulation(s) to interact with the external representation
- Either pushing via triggers or pulling data via trigger responses so that the external representation has all the traffic information within its scope or range.
- Exercising the external representation of the decision support tools to analyze traffic and develop path and sequence recommendations.
- Providing those recommendations back to the simulation for execution as part of the normal simulation process.

We have conducted proof of concept for this approach with the British CAA in the 1994 time frame by extending, through inter-process, the SIMMOD simulation. Through a series of triggers and trigger points the CAA could model strategies for dynamic runway assignments at Heathrow. Once we provided the hooks and the response mechanism, they were able to program and reprogram their own tools to evaluate multiple strategies without further interaction with the FAA SIMMOD development team.

We are currently embarking on another proof of concept to support the development of the NASA Advanced Air Transportation Technologies (AATT) tools and the validation of the Concept of Operations. Together, the FAA, NASA and Eurocontrol are developing an inter-process application. The demonstration of the dynamic linking capability includes two key components of NARIM - RAMS and OPGEN. The Eurocontrol Reorganized ATC Mathematical Simulator (RAMS) is used by NASA and the FAA to model operational concepts of the NAS. RAMS is a high fidelity tool used to model aircraft movement across the National Airspace System (NAS). The FAA has developed the Optimized Trajectory Generator (OPGEN) tool to generate a minimum fuel route that satisfies a given arrival time. Currently, OPGEN is used in the flight planning phase and data preparation for a RAMS simulation.

RAMS – OPGEN Dynamic Link Prototype

The objective of the prototype is to demonstrate the capability of inter-process communication between a fast time simulation model and an expert decision tool. The purpose is to demonstrate a capability to provide for a more robust behavior in modeling the NAS without requiring that it be incorporated into the base simulation.

In this demonstration, Eurocontrol's RAMS model will query the OPGEN program for a new flight trajectory for an aircraft. The response will be a new optimized trajectory for the flight to mitigate the effects of delays imposed during the course of the RAMS simulation. There is no requirement within the RAMS model to provide any business objective for the trajectory. The simulation only queries for and reads back a trajectory. The business/weather/congestion objective is carried within the expert system and is subject to the will/whim of the simulation user. We use the external tool to exploit the modeling of trajectories within the simulation to meet any objective.

Currently, flights in RAMS fly very consistent profiles based on a standard matrix of aircraft performance data. All deviations are short-term responses to conflicts and tend to be the "most" efficient path to meet the conflict constraints. With the interprocess capabilities, decisions support tools can be modeled with major deviations possible based on changing objectives – avoid future congestion, fly to minimum fuel, re-route to meet AOC fleet objectives, etc.

To show this capability we have developed a Decision Tool that incorporates RAMS and OPGEN. RAMS has been modified to read externally generated flight profiles during the course of the simulation. Triggering events have been included into the RAMS rule base, in our example through the rules associated with the entry of a flight into the planning window (time-based) for the Planning or D-side controller. The bridging decision tool looks at parameters previously set by the operator to determine if a new optimized profile is to be generated. If there is to be a new trajectory, OPGEN the FAA's flight planning tool developed by CSSI, Inc. will be executed to develop a new trajectory with the flights objective being set by the decision tool.

Case Study

The prototype consists of RAMS 2.3 modified to support the reading and writing of ASCII files and functionality to replace and existing flight profile with an update read from the ASCII file. [The final prototype, delivered in December will use the more robust remote process calls(RPC)]. OPGEN has been modified to include a new flight objective file based on the initial flight profiles. This file contains a series of constraints for the re-optimization including the point beyond which optimization can first occur and a final point for the optimization. Before the initial point and beyond the final listed point, the trajectory matches the initial profile. The parameter file also includes a desired arrival time for each flight to be optimized and the weight of the flight at the initial optimization point. The bridging program, the Decision Tool has been set up to manage the operator's objective in running the interactive process. The Decision Tool determines from a set of parameters and from the current state of the simulation whether a re-optimization for the flight will occur. Parameter values include whether the flight has been previously re-optimized, the level of delay to tolerate before replanning, and time parameters for setting time envelopes for optimization.

The process runs as follows. A flight enters a sector's Planning Controller window. RAMS uses an external function call to the Decision Tool to initiated a possible flight replanning. The Decision Tool uses the state of the simulation and, especially, the state of the flight to determine if a call is to be made to OPGEN to develop a new flight trajectory. The Decision Tool will re-optimize if the tool knows about the flight from the tool's initiation file. If this flight had not been established as a flight eligible for replanning prior to the initiation of the simulation, control returns to RAMS and the current profile executed. If the flight is an eligible flight, the Decision Tool will replan if:

- The flight has not already been optimized (shows the ability to turn optimization off and on based on prior external history),
- The flight is within the portion of its profile eligible for optimization,
- The flight has exceeded its delay threshold, and
- The clock time is within the time envelope for optimization (a flight with excess delay in its initial flight legs may be beyond a time objective for meaningfully meeting schedule)

If the flight is to be replanned, OPGEN is called and a new flight profile is developed. The flight profile will attempt to meet a previously set desire arrival time subject to the aircraft's performance constraints and the requirement to fly any portion of the profile that remains beyond the final optimization point. This profile is written to an ASCII file to be read into RAMS. Control then returns to the Decision Tool and then to RAMS. RAMS reads and replaces the flight profile with the newly generate profile and continues execution.

The FAA and NASA will use the capability to do initial modeling of the effects of new operational concepts and decision support tools for the NAS. We will extend the simple base case to consider several scenarios. The first will be the impact of airborne strategic tools on the NAS to help more finely develop and test the operational requirements. A second application will be to look a fleet level replans and rules for implementation. As the capability matures, an increasingly robust external state space will be developed so that increasingly more tactical rule changes can be evaluated.

The ability to manipulate trajectories within the simulation through external processes provides for an almost unlimited source of concept parameters and interactions to investigate. If the airspace grid of points is increased, deviations from path, aberrant behaviors by navigation systems, dynamic movements can all be modeled and the effects examined. The first upgrade to the capability provides an external dynamic weather program to the modeling system. This capability is currently under development and will also be available by the end of the month. Demonstrations of both capabilities are available upon request and scheduling constraints.

Conclusion

The need for a more dynamic modeling environment, capable of modeling more than the current concept, is required to validate our future operational concepts. Both the Europeans and the FAA have identified this need. We are hoping to collaborate through the FAA/Eurocontrol RE&D mechanism on next steps to move the capability forward. Through this R&D cooperation we hope to agree on inter-process mechanisms and messaging to support this larger modeling environment. This agreement will provide the critical user mass to ensure that current and future simulation tools will adhere to these basic standards assuring continued flexible use and the ability to reuse our expert systems across a variety of simulation environments.

Acknowledgments

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