Cross Fertilization between ATM and UTM

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This short paper analyzes the ATM concepts which could be succefully transfered to the UTM world. It then identifies the limits of this UTM fertilization from the ATM. On the other way, UTM can also be a good test-bed to try new air transportation concepts which could be transfered to the ATM world.

Key Words : Ait Traffic Management, Unmanned Aircraft System Traffic Management,

1. Introduction

The ATM system started to be established at the beginning of the previous century. The main drivers of this system are the safety and the capacity. As a consequence, the airspace has been designed in order to segregate flows as much as possible in order to minimize the interactions between aircraft. Route networks have also increased the capacity of the airspace by structuring traffic into flows. The system is controlled by human (ATCo) who ensure the separation between aircraft at tactical level. In order to spread the associated workload, the airspace is partitioned inter sector, each of them being managed by a team of controllers. To protect such sectors from overload, traffic regulation are implemented to ensure that the demand is lower than capacity in sector. This regulation are insured by the mean of slot allocations, flight level settings or re-routings. To reach this goal, a collaborative decision making has been established in order to satisfy the objective of the air traffic management and the airlines operating centers.

At airport, controllers are assisted by some tools (AMAN, DMAN and SMAN) for ensuring the best throughput at runways.The connection between airports and En-Route airspace is ensured by special routes named procedures (SID-STAR). Those routes are segregated in 3D and are designed for avoiding intersection with obstacles (terrain, military areas, etc...) and minimizing noise abatement on populated areas.

A global surveillance system has been deployed (radar, gnss, etc...) for tracking the position of the civilian aircraft. Initiated by the primary radar the positioning system has evolved with the secondary radar, the Mode-S radar and finally the ADS-B. Based on this surveillance system, each aircraft in the airspace can be located with a given accuracy depending of the type of airspace (continental, oceanic, etc...)

In the nighties, new actors (UAVs) started to enter the airspace. Initially, the main driver for such new UAVs were military applications but step by step civilian applications started to emerge mainly for observation purpose. More and more UAVs are expected to fly and recently the Unmanned Aircraft System Traffic Management (UTM) has been designed. UTM is a ”traffic management” ecosystem for uncontrolled operations that is separate from, but complementary to, the Air Traffic Management (ATM) system. This system is facing the same issues as the ATM at its early stage. The main issues is linked to the separation in order to avoid collisions. Many concepts coming from ATM could be transferred to the UTM.

2. Strategic Separation

2.1. Route network Design

Since the beginning of aviation, traffic has been organized by the mean of segregated routes which ensure separation between aircraft. This separation can be done laterally or vertically. For instance, the semicircular rule which assign flight levels according to heading is a very efficient approach for segregating aircraft in the vertical dimension. Route networks have been established in airspace for increasing the associated capacity. An example of such network is given in figure 1.

Even if UTM traffic is expected to be fully segregated from aircraft traffic, there will be a strong need for UTM to be able to design route networks for UAV in order to increase the associated capacity of the system. Many researches in AI have been established for

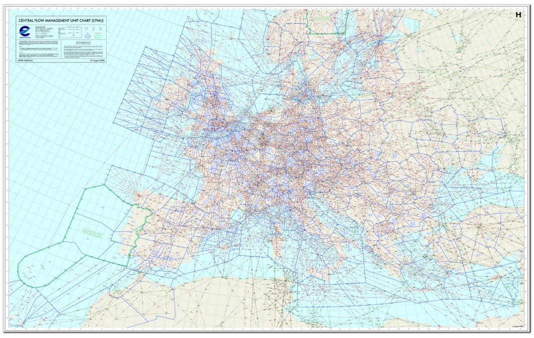

Fig. 1 European Airways Network.

bringing automation in such a design (for instance[1]) and those approaches could be efficiently adapted for UTM purposes.

For UTM, drone port are expected to be built for organizing landings and takeoffs of UAV. Here again traffic will have to be organized by the mean of dedicated routes for departure and arrival. If such route structure is not used, like for ATM, the overall capacity of the associated terminal airspace will collapse. SID-STAR have been designed for many years and have been designed at many airport. The main objective of such design is to ensure separation with obstacles (terrain, restricted areas, etc..) and with other routes. Noise abatement is also taken into account in order to minimize the noise pollution. AI approach has been also used for bringing automation[2] in such design and could also be adapted for UTM. One could also investigate the concept of "Departure or Arrival route on request" which is not possible for ATM.

3. Flow Regulation

When demand increases, one must organized traffic into flows. This concept has been used for many years for cars in order to increase the capacity at crossing. For instance, figures 2 and 3 show one car crossing in Paris at the beginning of the previous century and a current highway crossing . As it can be seen on figure, the capacity of the highways crossing is much higher. For aircraft, the situation is similar. Sometimes, even with such structure, demand may exceed capacity and in the case regulation changes the demand for not exceeding the capacity : this is the objective of the ATFM. For instance, in US, the Miles in Trail concept ensure safe and efficient crossing of aircraft by the mean of speed regulation. For UASs, the challenge will be the same and ATFM regulation will be needed in order to increase the capacity of the system. For instance,[5] proposes a UAVs flow structuring in order to ensure capacity at route crossing in cities. Many other initiatives illustrate the benefit of an ATFM system for UTM.

Fig. 2. Road Traffic at the beginning of the previous century.

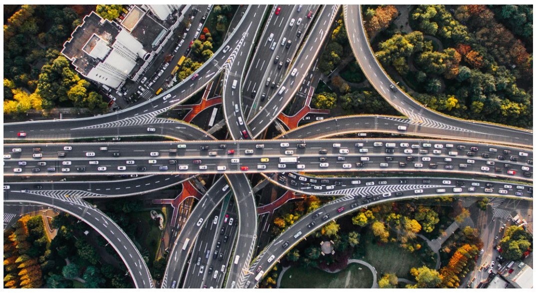

Fig. 3 Current Crossing on Highways.

4. Tactical Separation

Separation is the main issue for both ATM and UTM system. For ATM, thanks to accurate positioning methodologies (radar, GPS, ADSB), the conflicts are first detected by the controllers who extrapolate the positions of aircraft by using the associated speed vectors. When controllers are convinced that a conflict will appear, they apply conflict resolution maneuvers for insuring minimum separation between aircraft. This task is mainly done by human even if controllers are assisted by some decision support tools. It may be noticed that automation has not evolved the same way from the air segment point of view compared to the ground segment point of view. As a matter of fact, pilots are much more assisted in their tasks thanks to a high level of automation which has been deployed in cockpit for many years. First, the autopilot has released pilot workload for managing aircraft maneuvers and latter, Flight Management System (FMS) has been developed to help them in computing efficient trajectories, for instance, for fuel consumption purpose.

To illustrate this evolution, figure 4 shows the cockpit of a DC3 aircraft. For such aircraft all the task (maneuvers and navigation) were done by the pilot. In comparison, figure 5 shows the cockpit of an A340 aircraft for which maneuvers and navigation can be fully managed by the aircraft. For instance, in 1992, an A320 aircraft did a flight from Toulouse to Paris CDG without any action from the pilots (they were just monitoring what was done by the aircraft). To do that, they were assisted by the French ANSP to remove other aircraft from their. This separation task remain the hard part of the Air Traffic Management automation.

Fig. 4 Cockpit of a Dc3.

Fig. 5 Cockpit of an Airbus A340.

From the ground segment point of view, one can notice that the level of automation is still very limited. Figure 6 represents a French control center in 1950, for which controllers manipulate magnets on a control table and detected conflict by extrapolation of the speed vectors. At that time, separation norm were enlarged for taking into account localization uncertainties. Figure 7 shows the current control position of Paris CDG approach. The HMI is fully different compared to the situation in 1950, but the task of the controller is nearly the same. They extrapolate aircraft positions by the mean of the associated speed vectors and detect potential conflicts which are mainly solved by vectoring orders. The task is mainly done by humans and few automation has been inserted in the ground system.

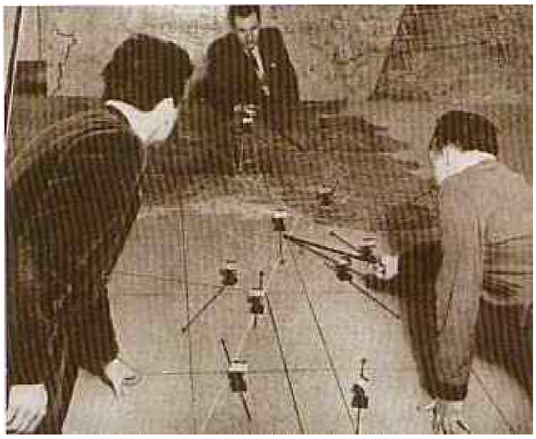

Fig. 6 En Route control room at Aix-en-Provence in 1950.

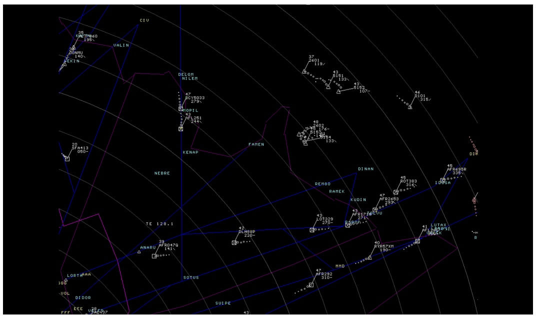

Fig. 7 Radar screen at CDG approach.

For UTM, it is expected that UAVs ensure their separations by using detect and avoid algorithm. Such algorithms share some properties with the aircraft onboard TCAS system. It is expected that the evolution and improvement of those collision avoidance algorithms will also benefit to the ATM system for which aircraft self separation is still limited.

Close to airport, the objective of the air traffic control is to sequence and merge the traffic in order to optimize the runway throughput. To reach this goal, air traffic controllers are supported by AMAN algorithm which automatically computes speed regulations to organize the traffic.

For UTM, such approach is not possible and self-organized algorithms are possible alternatives for organizing traffic for landing. Several initiatives have been already investigated, for instance, based on relative control[3] or reinforcement learning,[4] for which results show that self-organize arrival manager is a concept which could be deployed for UAV but also for arrival aircraft management.

5. Conclusion

This short paper has presented some examples of cross fertilization between ATM and UTM. As mentioned, ATM and UTM share similar issues mainly for separation between air vehicles with a big difference linked to the ground control system used for ATM. UTM will benefit from UTM for route design, separation, flow management or traffic organization. But UTM is an excellent framework for investigating new algorithms which could be later deployed for ATM, especially for automatic conflict detection and resolution which could improve the performances of the ATM system in terms of capacity.

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