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OPTIMIZATION AND AUTOMATION OF AIR TRAFFIC CONTROL SYSTEMS: AN OVERVIEW

MERYEME HAFIDI *
MOHAMED BENADDY **
SALAHDDINE KRIT ***

Abstract

Air passenger will nearly double to 7.8 billion according to the international air transport association 2036 forecast (1), which means that the rate of air traffic will increase exponentially leading to signicant congestion, flight delays, and pollution. To keep these numbers of aircrafts at safe distances from each other, to direct them during takeoff and landing from airports, to guide them around bad weather and ensure that traffic flows smoothly with minimal delays; there is a need of new control techniques, and optimized methods.
The optimization and automation of air traffic control have been the subject of several studies in the last decades. The objective of this paper is to review systematically current research in the literature about the automation and optimization of air traffic control systems.

Keywords:

Air traffic control;
Separation;
Optimization;
Automation.

Author correspondence:

Meryeme Hafidi,
Laboratory of Engineering Sciences and Energy, Polydisciplinary Faculty of Ouarzazate, Ibn Zohr University, Ouarzazate, Morocco.

1. Introduction

In the early days of aviation there wasn't much need to keep airplanes from hitting each other; in the 1920's as the planes became a bit more sophisticated the job of air traffic controller was born waving flags to instruct pilots when to land and take off in Croydon airport London. Then the first radio equipped air traffic control tower was established and began operations at the Cleveland Airport in the 1930's. During world war 2 the British developed radar, which would change air traffic control forever [2]. Towards the end of the Second World War the Chicago Convention on International Civil Aviation, led to the formulation of globally agreed standard practices as the fundament for international air traffic control and to the establishment of the International Civil Aviation Organization (ICAO) [3]. Through ICAO the international

* PhD student at Polydisciplinary Faculty of Ouarzazate, Ibn Zohr University, Agadir, Morocco
** Professor of computer sciences at Polydisciplinary Faculty of Ouarzazate, Ibn Zohr University, Agadir, Morocco.
*** Professor of computer sciences and Physics at Polydisciplinary Faculty of Ouarzazate, Ibn Zohr University, Agadir, Morocco.

standardization was made of standards and procedures for licensing of personnel, Air Traffic Control, rules of the air, certification of new aircraft, meteorological services, etc. The airspace of the world was divided into Flight Information Regions (FIRs). The nation within the FIR was made responsible for the Air Traffic Control (ATC) within the FIR. Around the major airports in the FIR, called Control Zones (CTRs) and Terminal Areas (TMAs) are located.The TMAs are connected by fixed airways or sectors, usually defined by the radials of Very High Frequency Omnidirectional Radio Range Beacons (VORs).Distance Measuring Equipment (DME) information is used to complement the VOR directional information [4]. Then in the 1960's Aircraft became equipped with radar beacons called transponders. This allowed the plane to send a signal to the radar, and the radar could differentiate between different aircrafts, allowing the controllers to see which plane was on their scopes.1972's direct access radar channel allowed controllers to see on their scope a data block with the plane's call sign and altitude. 1981's United States Air traffic controllers struck for stressful working conditions, since that the equipment of ATC system continued to see growth [5].

Air Traffic Control is performed in different facilities depending on the segment of the flight profiles mentioned in figure 1. Aerodrome control service is provided from the Aerodrome Control Tower (TWR) and the controllers working there are responsible for the safe and efficient conduct of flights during take-off and landing phases. They ensure the safety of airport operations by guiding the traffic in a way that only one aircraft may land or take-off on a given runway at a time. The approach control unit provides air traffic control service in TMAs to flights arriving at, or departing from one or more airports, and is closely associated with the particular characteristics of the airports. Area Control Service is provided from an Area Control Centre (ACC) or an Air Route Traffic Control Centre, in these facilities ATC provides for the en route flight phase between aircraft operating in the network of airways [6].

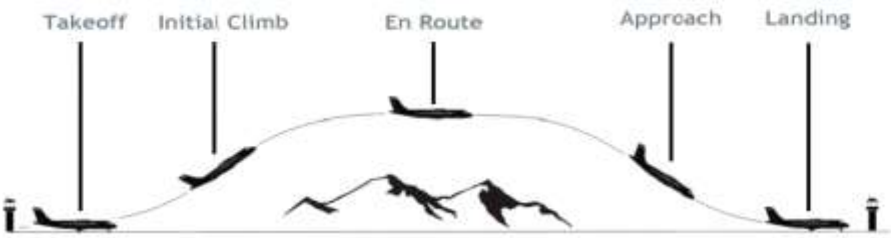

Figure 1: aircraft trajectory.

Until now different research introduced new automated tools and optimized methods to help air traffic controllers to manage the projected increase of air traffic [7]. The purpose of this paper is to review the famous state of the art of air traffic control system research according to the flight segment, and some of utilized air traffic control simulators; then the automated techniques and optimized methods used in these researches.

The remainder of the paper is organized a follows. Section II reports air traffic control system's research according to the flight segment firstly aerodrome, terminal area, and then en route. Section III describes simulators used in air traffic control research. Section IV introduces methods of optimization and automation techniques that support air traffic control system. Section V concludes the paper.

2. Air traffic control system's research according to the flight segment

According to the statistics [8] (figure 2), the aircraft fleets will increase in the next years, which will lead to the congestion of airspace; the growth of fuel consumption and the process by which aircraft are safely separated in the sky will be more complicated. The improvement of air traffic management system has been the crucial aim of research projects like single European Sky Air Traffic Management Research (SESAR) [9] in Europe and the next generation air transportation system (NEXT GEN) [10] in the United States.Therefore, various studies were established to optimize and automate the air traffic control system in the world. In the following subsections we review some of these studies according to the aircraft segment.

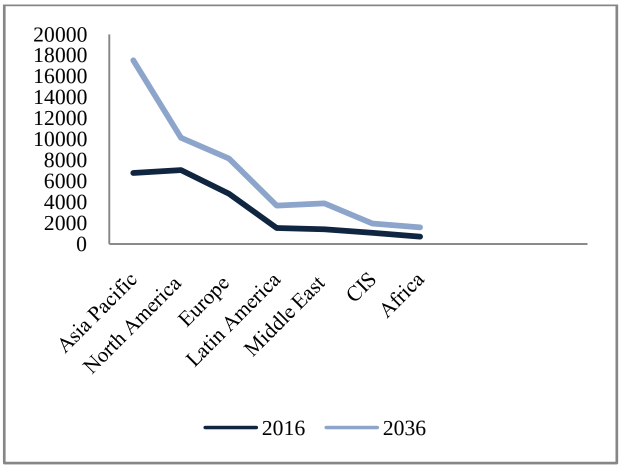

Figure 2: the biggest Size of aircraft fleets by region worldwide in 2016 and 2036 (in units).

2.1. Aerodrme's air traffic control system:

Aerodrome controllers shall issue information and clearances to aircraft under their control to achieve a safe, orderly and expeditious flow of air traffic on and in the vicinity of an aerodrome with the object of preventing collision [6]; to achieve these objectives; they must anticipate and evaluate the potential risk of a future situation. On the one hand, if a hazardous event is not anticipated, catastrophic consequences might occur, on the other hand, being too conservative can decrease the efficiency by causing unjustified delays and increased fuel consumption.

Smeltink et al. [11] introduced an approach to handle the ground movement problems for Amsterdam Schiphol Airport; in these study three variants of an algorithm for solving the taxi scheduling problem are developed and investigated. These algorithms are used for tactical taxi scheduling. The three variants are all rolling horizon algorithms where the problem is split-up into sets consisting of a small number of aircraft. To create a schedule for a whole day, the solutions to the sub-problems are combined. The sub-problems are solved using a Mixed Integer Linear Programming formulation.The first two variants use fixed time intervals to split the set of aircraft to create sub-problems. The third variant is a sliding window algorithm. As a test case a busy day at Amsterdam Airport Schiphol was used. This problem instance consists of scheduling 406 aircraft in a period of 5 hours. Using the optimization algorithm, it was possible to reduce the average delay from 20% to 2%, where the individual ideal taxi time is used as a lower bound for the obtained solution. This reduction of taxi delay makes the taxi process more efficient, and it also reduces the fuel emission levels due to taxiing. These All three variants show similar results with respect to the objective function. The first two variants, with the fixed time intervals, obtain better results With respect to the computation times than the third variant. The rolling horizon approach seems suitable for a dynamic environment like the operations at an airport, where looking far ahead in time has no point since the planning can often change completely due to delays.

Amal Srivastava [12] proposed an approach to improve departure taxi time predictions using Airport Surface Detection Equipment, Model X (ASDE-X) surveillance data which builds an adaptive taxi-out prediction model based on a historical traffic flow database generated using the (ASDE-X) data. The model relates taxi-out time and taxi-out delay to an arrangement of illustrative factors, for example, aircraft queue position, distance to the runway, arrival rates, departure rates and weather. Two forecast models are created. One treats airplane movement from the stand to the runway threshold consistently while the other models airplane time to get to the runway queue not quite the same as the holdup time experienced by the airplane in the runway queue. The models are assessed utilizing data from New York's John F Kennedy (JFK) Airport in the summer of 2010. Results demonstrate critical improvement in taxi-out forecasts when contrasted with expectations from FAA's Enhanced Traffic Management System.

Ivomar Brito Soares et al. [13] presented a Departure Management concept with a Reinforcement Learning (RL) Approach Respecting CFMU Slots applied in John F. Kennedy International Airport (KJFK) in New York City they investigated how Reinforcement Learning (RL) techniques can be used to model and learn solutions for large scale Multi-Agent Systems (MAS). The large scale MAS of interest is the context of the movement of departure flights in big airports, commonly known as the Departure Management (DMAN) problem. A particular DMAN sub problem is how to respect Central Flow Management Unit (CFMU) take-off time windows, which are time windows planned by flow management authorities to be respected for the take-off time of departure flights. A RL model to handle this problem is proposed including the Markov Decision Process (MDP) definition, the behavior of the learning agents and how the problem can be modeled using RL ranging from the simplest to the full RL problem. Several experiments are also shown that illustrate the performance of the machine learning algorithm, with a comparison on how these problems are commonly handled by airport controllers nowadays. The environment in which the agents learn is provided by the Fast Time Simulator (FTS) Air Top and the airport case study is the John F. Kennedy International Airport (KJFK) in New York City, USA, one of the busiest airports in the world RL has shown to have good potential for modelling and finding solutions for respecting assigned take of windows for departure aircraft. In a complex and busy airport such as KJFK; in a deterministic setting it managed to find solutions for almost all cases in a stochastic setting its performance rate dropped slightly but remained above 90% while the performance of the human airport controller modeled on the same tasks stars to decrease more drastically the single state setting shows the advantages of reduced fuel consumption and a reduced learning problem since there are no visited taxiing states; it has the disadvantage of increased gate delay and not being able to find a solution for all cases.

Billy Josefsson et al. [14] made the news with the scheduled air traffic controllers at the remote tower center (RTC). They presented a generic optimization framework design for automation of staff planning at the RTC. Then they highlighted the problems experienced with real airport flight schedules and presented optimal shift assignments for five Swedish airports that were chosen for remote operation. The Remote Tower Service (RTS) is one of the technological and operational solutions delivered for deployment by the Single European Sky ATM Research (SESAR). This new concept fundamentally will change how operators provide Air Traffic Services, as it becomes possible to control several airports from a single remote center. In such settings an air traffic controller works at a so-called “multiple position” at the Remote Tower Center (RTC), which means that he/she can handle two or more airports from one Remote Tower Module (controller working position).

A ground traffic simulation tool has been proposed by J.B. Gotteland et al. [15] applied to Roissy Charles De Gaulle Airport; two global optimization methods are developed, using genetic algorithms at the airport, to minimize taxiing time while respecting separation and runway capabilities. Wenzhi Zhao et al. [16] introduced a new method to solve the problem of the aircraft landing congestion in the air by proposing the double direction landing on a single runway in separating time duration. A Research of taxing optimization for aircraft was proposed by Nan Li et al. [17]. An approach of tactical trajectory prediction automaton of air traffic control operator according to Takeoff weight error was provided by Mevlüt Uzun et al. [18]. The multiple runway aircraft landing problems was applied to Tunis Carthage airport by Meriem Ben Messaoud et al. [19]. Vitor Filincowsky Ribeiro et al. [20] proposed a collaborative decision making model to provide efficient departure sequencing based on the negotiation among the aircraft in a dynamic scenario modeled under the Rubinstein protocol and Collaborative decision making (CDM) principles.

2.2. Terminal area’s air traffic control system:

Approach control service shall be responsible for the control of arriving aircraft that have been released to it by the ACC and departing aircraft until such aircraft are released to the ACC. Since there is a continuous growth of traffic demand and the TMA (figure 3) are becoming the bottleneck of the entire air traffic control system.

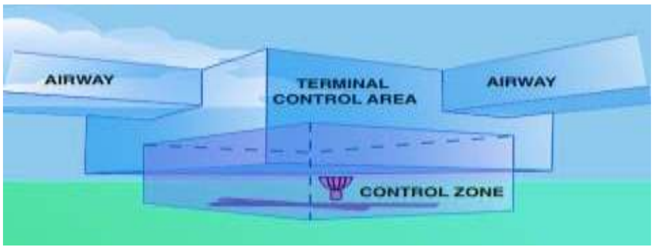

Figure 3: terminal area.

Satish C.Mohliji [21] provided a ground-based automation planning concept of traffic in terminal areas, to permit aircraft to maximize the use of avionics capabilities with flight management system (FMS) capabilities and increase the efficiency of terminal area operations during peak traffic, cause the Air Traffic Control system needs to deviate aircraft from their optimum flight paths to maintain separation, thereby limiting the use of on-board FMS capabilities. Analysis of operational data is used to identify the causes and to quantify the magnitude of deviations between the actual versus and the desired aircraft performance. Analytical results are presented, based on the comparison of operational data with the user-preferred trajectories to identify flying time variabilities in various segments of arriving flights. En route descents, terminal maneuvering areas, and the final approaches are considered in order to determine the impact of aircraft and environmental factors on flying times essential for traffic planning. Simple time estimation algorithms based on FMS defined speed schedules and prevailing winds are presented for estimating flying times during en route descents. In a multi-aircraft operation these deviations could be minimized if the FMS, aircraft provide the ATC system with information on the intended speed profiles. An automated planning and control process could meet the objective of permitting maximum use of FMS capabilities by providing the aircraft with conflict-free flight plans, and advising the ATC of timely control actions to keep the aircraft on the established flight plans.

Lucio Bianco et al. [22] proposed a multilevel optimization model of air traffic control including system planning; they examined the functions corresponding to the on-line control, that is flow control, strategic control of flights and aircraft sequencing in a terminal area, and they illustrated the optimization models and solution algorithms. Finally, relevant problems coped by recent research are mentioned and new trends are indicated. In particular, the multilevel model shows that ATC is well depicted by a control function hierarchical structure. Thus, a more correct balance between planning strategies and operational actions can be established. Moreover, in the framework, for each on-line function the corresponding optimization models and computation algorithms seem to be helpful tools to better understand the involved traffic control phenomena, to increase ATC system automation level and, therefore, to improve air traffic management.

Marcella Samà et al. [23] presented an optimal aircraft traffic flow management at a terminal control area during disturbances; to enhance the adequacy of air activity checking and control in a bustling Terminal control area, they gave a optimization-based decision support system based on a rolling horizon framework. They demonstrated the issue by an alternative graph formulation, a model of air traffic flows in the TMA, and solved via airplane rescheduling and rerouting algorithms. They compared a truncated branch and bound (BB) algorithm for airplane rescheduling with fixed highways, a tabu search (TS) scheme for combined aircraft rescheduling and rerouting, and the first in first out (FIFO) decide that they use as a surrogate for the dispatchers conduct. They evaluate different parameters of the rolling horizon framework, such as the frequency of aircraft retiming and rerouting and the time horizon of prediction the extension of the current traffic flow forecast, including roll and look-ahead periods. The roll period the move time frame is the time move between the begins of progressive activity expectations. The

Computational results for the Milano Malpensa airport demonstrate the effectiveness of the optimization procedures compared to FIFO. Overall, BB with fixed routes is the best algorithm in terms of delay minimization while TS+BB with optimized routes can better minimize travel times.

Xiaolei Yang et al. [24] modeled the ATC-Terminal control area issue as a distributed constraint optimization problem and solved it with complete and incomplete Desktop Communication Protocol (DCOP) algorithms. An objective assessment method for Area navigation (RNAV) standard terminal arrival route (STAR) adherence was proposed by Michael Stewart et al. [25]. A Computational modeling of air traffic control in the terminal area was introduced by T.J. Callantine et al. [26].

2.3. En route‘s air traffic control system:

En route air traffic controller tasks comprise the elimination (or reduction) of conflicts between aircraft on the route through the longitudinal or vertical spacing adjustment, changes in speed and deviation from risk areas by vectoring, among others.

There are a lot of mandatory innovation and research that are historical in the en route air traffic control system as short term conflict alert (STCA), traffic alert and collision avoidance system (TCAS),4-D trajectory control concepts and was run by European research headed by EUROCONTROL,automated en route air traffic control (AERA),user request evaluation tool (URET),verification of separation and resolution advisory (VERA), en route air traffic organizer (ERATO),program for harmonized atm research in Europe (PHARE),human machine interface (HMI), medium term conflict detection (MTCD),highly interactive problem solver (HIPS) and tactical load smoother (TLS) [27].

Alexandre d’Aspremont et al. [28] presented an Optimal Path Planning for Air Traffic Flow Management to reduce the system delay, caused by stochastic nature of weather and capacity constraints or sector saturation as notified in figure 4. By solving the optimal path planning problem in a framework that models both the weather patterns and the sector capacity constraints by a stationary Markov chain. The algorithm produces an optimal route at each network node and each weather pattern. This approach provided a set of optimal decisions for a single aircraft that starts moving towards the destination along a certain path, with the option of choosing a new path whenever new information is obtained, in order to minimize the expected delay then the model was extended for multiple aircrafts. Relative to the deterministic case, the complexity of this method grows linearly with the number of aircraft and the number of weather states, when aircraft priorities are known. Large-scale simulations on a simplified European airspace show that the algorithm scales well in practice and provides a significant improvement over purely deterministic routing techniques.

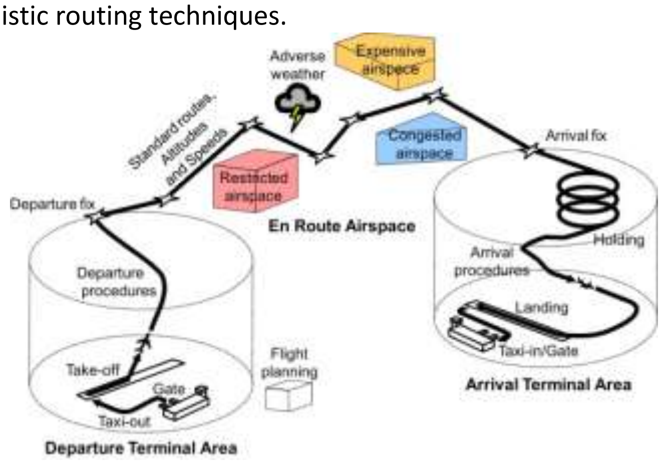

Figure 4: aircraft trajectory and Potential Causes of Flight Inefficiency.

Alessandro Gardi et al. [29] presented a 4-dimensional Trajectory Optimization Algorithm for Air Traffic Management Systems using Multi Objective Trajectory Optimization algorithms (MOTO) which are conceived for the automation-assisted replanning of 4-dimensional

Trajectories (4DT) when unforeseen perturbations arise at strategic and tactical online operational timeframes. The MOTO algorithms take into account updated weather and neighboring traffic data, as well as the related forecasts from selected sources. These MOTO algorithms allow the replanning of 4-dimensional aircraft flight Trajectories in strategic and tactical online operations, in the presence of dense air traffic, whenever airspace or air traffic reorganization is required due to tactically changing airspace conditions as well as promoting optimal rerouting around adverse weather. Simulation case studies consistently support the viability of the two proposed implementations: a fully-4D implementation for TMA based on optimal control formulation and a 2-Dimensional plus Time (2D+T) steady-state polygonal path optimization for the en route context.

Agnaldo Volpe Lovato et al. [30] provided a control concept based on the manipulation of the longitudinal speed of an aircraft during cruise flight, without changing the route. This strategy utilizes two fuzzy models arranged in series. The first one provides a metric to quantify the level of longitudinal conflict between two aircraft and the second strategy provides a systematic way to set the acceleration to be applied in each aircraft over time based on the dynamic behavior of the conflict level, The first problem comprises five flight levels, each one with two aircraft, allowing greater freedom for the acceleration or deceleration of each aircraft. The second one presents five aircraft with different levels of conflict on the same flight level, which makes the problem more restrictive regarding the availability of feasible options for the resolution of longitudinal conflict without changing the flight level. The proposition of the maximum positive and minimum negative conflicts (figure 5), together with their respective areas, provide a feasible metric to evaluate the overall performance of the control approaches based on the behavior of conflicts over time at all flight levels of an airway. In addition to the best performance in solving the conflict between two aircrafts, the proposed approach also presented better results in relation to the overall behavior of the aircraft, both improving traffic safety and airspace use. The results show that the fuzzy approach behaves consistently with the reality of air traffic, and it is able to perform well without compromising the security or violating existing rules. The proposed approach does not exclude the participation of the air traffic controller; it can be used to automatize the actions of supervision and control through support in the process of detecting and resolving conflicts in airspace.

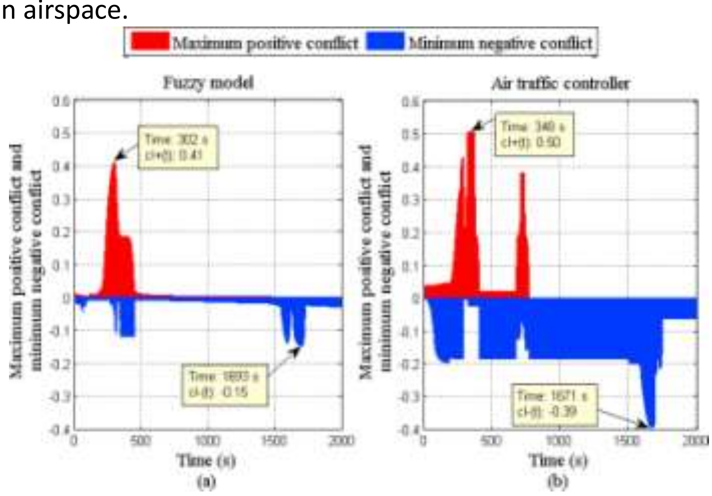

Figure 5: the results of the fuzzy model and air traffic controller Positive and negative areas of conflict levels.

3. Simulators used in air traffic control research

Nowadays There is a variety of multi-aircraft simulators used for air traffic control research purposes we can notify: NLR's Air Traffic Control Research Simulator (NARSIM)), Pseudo Aircraft System (PAS), Target Generation Facility (TGF; ATC Interactive for the future of air traffic control), Future Atm Concepts Evaluation Tool (FACET) (2) and Multi-aircraft Control System (MACS).

NARSIM NLR's Air Traffic Control Research Simulator: is an air traffic research simulator. Its aim is to evaluate new operational procedures, new controller assistance tools, and new human/machine interfaces. There are six air traffic consoles and up to 12 pseudo pilot positions, each of which can control up to 15 aircraft. The air traffic consoles and pseudo pilots are connected by a voice communication net. The computers driving each station are connected to the main NARSIM computer. The NARSIM software simulates most important aspects of a real air traffic control system, including realistic radar information. It has the capability to use currently recorded radar data, computer-generated data, pseudo pilot generated data, or combinations of the three.NARSIM has been developed by National Aerospace Laboratory NLR and is integrated with Tower Research Simulator (TRS) NLR's: NARSIM has already been used for diverse national research projects, such as Development of new display and control concepts for the future Schiphol ATC system, improvement of Short Term Conflict Alert (STCA) concepts; development of controller assistance tools for the handling of arrivals on dependent converging runways under low-visibility conditions; evaluation of new digital datalink concepts and consequences to the pilot's situational awareness (lack of "party-line" information) (3).

Pseudo Aircraft System (PAS): is a computerized flight dynamic and piloting system designed to provide a high fidelity, multi-aircraft, real-time simulation environment to support air traffic control research. PAS is comprised of three major software components that run on a network of computer workstations. Simulation: It provides the computer link between the PAS network and the Air Traffic Control system. The Simulation Manager also contains the kinematic models of the individual aircraft comprising the simulated traffic scenario. PAS Pilot Manager (figure 6): Executive control over a set of Pilot Stations and communication services for the components of the PAS network. Pilot runs on a set of workstations that serve as both input devices and data display devices for operators called pseudo pilots. Each pseudo pilot controls a number of aircraft by issuing commands in response to verbal instructions from air traffic controllers, much as an actual pilot controls his aircraft (4).

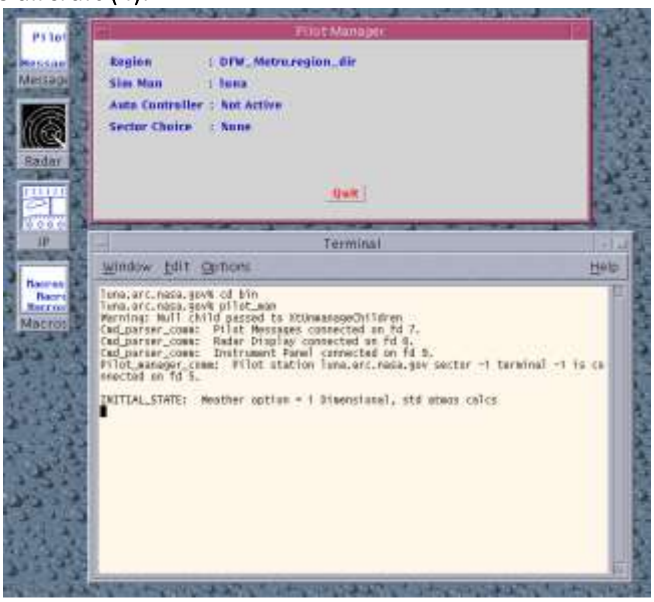

Figure 6: Screenshot of the Pilot Manager.

Future Atm Concepts Evaluation Tool (FACET): is a flexible software tool that is capable of quickly generating and analyzing thousands of aircraft trajectories. It provides researchers with a simulation environment for preliminary testing (figure 7) of advanced ATM concepts.Using aircraft performance profiles, airspace models, weather data and flight schedules, the tool models trajectories for the climb, cruise, and descent phases of flight for each type of aircraft. An advanced graphical interface displays traffic patterns in two and three dimensions, under various current and projected conditions for specific airspace regions or over the entire continental United States. The system is able to simulate a full day's dynamic national airspace system (NAS) operations, model system uncertainty, measure the impact of different decision-makers in the NAS, and provide analysis of the results in graphical form, including sector, airport, fix, and airway usage statistics (5).

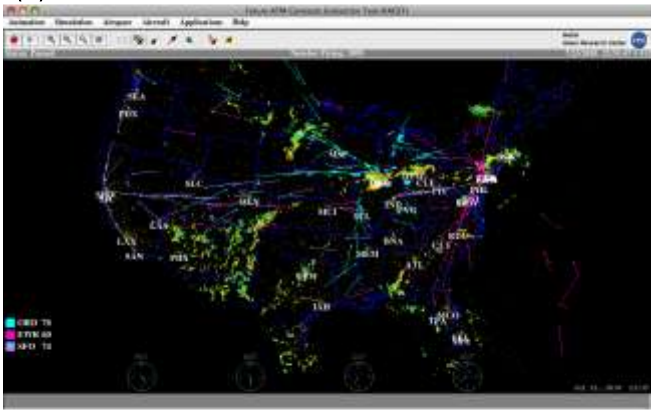

Figure 7: Future atm concepts evaluation tool (FACET).

The Target Generation Facility (TGF): is a Dynamic Real-Time Air Traffic Simulation capability designed to generate realistic Aircraft trajectories and associated digital radar messages for aircraft in a simulated airspace environment. Up to 600 targets (400 piloted) can be generated in one or more concurrent simulation environments. Multiple Terminal, En route, and Oceanic airspaces may be simulated individually or simultaneously. The TGF capability is fully integrated. Simultaneous simulations in various environments and in different laboratories at the William J. Hughes Technical Center can be supported and can run concurrently. Primarily, TGF is used to generate real time, interactive traffic in support of human in the loop simulations. Realistic traffic flows and voice communications are created in real time by pilots operating the simulated TGF 'aircraft' in response to air traffic control instructions. All major Air Traffic laboratories of the Technical Center are supported including the En route Display System Replacement (DSR) Laboratories, the Scientific and Technological Advanced Research Terminal Laboratories, En route Integration and Interoperability Facility (IIF) and the Research Development and Human Factors Laboratory (RDHFL) (6).

Multi Aircraft Control System (MACS) simulation platform developed in the Airspace Operations Laboratory (AOL) at NASA Ames Research Center. MACS are a comprehensive research tool that has been improved to increase the overall realism and flexibility of controller and pilot in the loop air traffic simulations. The research focus in the AOL is on verification of air traffic operations in rich air/ground environments that can include multiple oceanic, en route, and terminal airspace sectors (7).

4. Methods of optimization and automation techniques that support air traffic control

The air traffic control system (8) incorporates various and advanced technologies and techniques for Automation we can mention: Open system LAN-based architecture as notified in Handbook for Networked Local Area Networks in Aircraft (9); commercial processors (10); standard communication protocols (IEEE- 802.3, TCP/IP, UDP/IP) (11); color raster displays (12); advanced software languages (ADA, C++), commercial databases (Postgrad, SQL); data mining (13) and standard database access languages (4GL) .

Data mining (14) is a process used by companies to turn raw data into useful information. By using software to search patterns in large batches of data, businesses can take in more about their customers and develop more e powerful marketing strategies as well as increase sales and decrease costs. Data mining depends on effective data collection and warehousing as well as computer processing.

Commercial databases (15) are simply accumulations of information presented electronically. Databases range in measure from simple books made accessible, to several billion records in the larger news databases. The retail database industry is obscure. Costs are highly variable and hard to determine in advance. Products with the same name may contain different information.

Databases are habitually combined into larger collections of databases, (also called databases,) often several times. An individual magazine or database may exist within several databases and several collections.

A fourth generation (programming) language (4GL) is a grouping of programming languages that attempt to get closer than 3GLs to human language, form of thinking and conceptualization. 4GLs are designed to reduce the overall time, effort and cost of software development. The main domains and families of 4GLs are: database queries, report generators, data manipulation, analysis and reporting, screen painters and generators, Graphical User Interface, creators, mathematical optimization, web development and general-purpose languages.

Studies to improve air traffic control systems utilize several optimization methods to solve the issues encountered in this field. We can notify Mixed Integer-linear programming (16); Multi-agent system (MAS) (17); Routing Algorithm; Genetic algorithms (18); FIFO; Branch-and-Bound; Tabu search (19); Reinforcement learning (RL).

Mixed Integer-linear Programs are linear programs in which some variables are required to take integer values, and arise naturally in many applications. The integer variables may come from the nature of the products (e.g., a machine may, or may not, be rented). Mixed integer-linear programs are solved using the same technology as integer programs (or vice-versa). For instance, a branch-and-bound algorithm can exploit the linear relaxation, and its branching procedure is applied only to integer variables.

Multi-Agent System (MAS) is defined as, a multi-agent system which coupled network of problem-solving entities (agents) that work together to find answers to problems that are beyond the individual capabilities or knowledge of each entity (agent). The fact that the agents within a MAS work together implies that a sort of cooperation among individual agents is to be involved. However, the concept of cooperation in MAS is at best unclear and at worst highly inconsistent, so that the terminology, possible classifications, etc., are even more problematic then in the case of agents what makes any attempt to present MAS a hard problem. A typology of cooperation from Figure 8 is the basis for MAS classification.

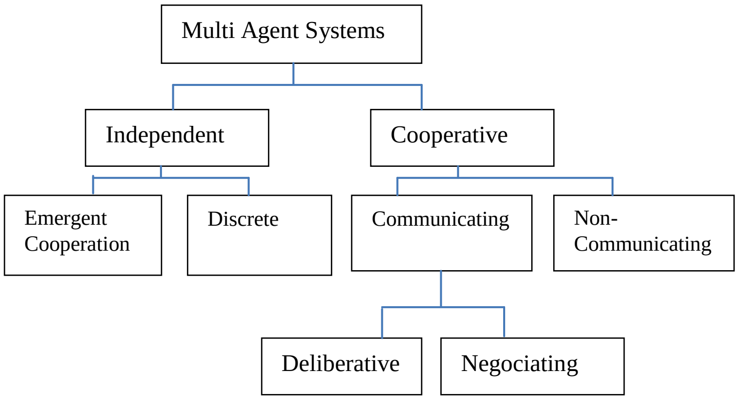

Figure 8: MAS Cooperation Topology

Routing Algorithm (20) is a set of step-by-step operations used to direct Internet traffic efficiently. When a packet of data leaves its source; there are many different paths it can take to its destination. The routing algorithm is used to determine mathematically the best path to take.

Diverse routing algorithms utilize different methods to determine the best path. For example, a distance vector algorithm calculates a diagram of all available routes by having each point (called a node) determine the "cost" of travelling to each immediate neighbor. This data is collected for each node to create a distance table; which is used to determine the best path to from any one node to another.

Genetic Algorithm (GA) (21) is a method for solving both compelled and unconstrained optimization issues based on a natural selection process that mimics biological evolution. The algorithm repeatedly modifies a population of individual solutions. At each progression, the genetic algorithm randomly selects individuals from the current population and uses them as parents to produce the children for the next generation. Over progressive generations, the population "evolves" toward an optimal solution. You can apply the genetic algorithm to solve problems that are not well suited for standard optimization algorithms, including problems in which the objective function is discontinuous, non-differentiable, stochastic, or highly nonlinear.

FIFO first in first out (22): is a cost flow assumption regularly used to remove costs from the Inventory account when a thing in inventory had been purchased at varying costs. Under FIFO, the oldest cost of an item in inventory will be removed first when one of those items is sold. This oldest cost will then be reported on the income statement as part of the cost of goods sold. FIFO additionally implies that the more recent costs of an item will remain in the Inventory account and will be reported on the balance sheet.

Reinforcement learning (RL) (23) is an area of machine learning inspired by behaviorist psychology, concerned with how software agents ought to take actions in an environment so as to maximize some notion of cumulative reward. The problem, because of its generality, is studied in many other disciplines, for example, game theory, control theory, operations research, information theory, simulation-based optimization, systems, swarm intelligence, statistics.

5. Conclusion

In this paper, a state of the art of air traffic control system researches in the Aerodrome, TMA, and FIR is presented different air traffic control simulators are notified and described. Then we provided some of the optimization and automation tools utilized in traffic control studies.

Longer term innovative research activities are currently ongoing within the SESAR project and NextGen operational concepts, humans will maintain a central decision role, eventually assisted by decision support tools. Aiming at relaxing the constraint on the central role of humans and opening up new possibilities related to the introduction of high degrees of automation, possibly up to full automation.

To summarize research in air traffic control system facilitated the human manual work, but no one can deny that this field is more in need of scientific investigations to fulfill the dreamed automated air traffic control.

References

[1] http://www.iata.org/pressroom/pr/Pages/2017-10-24-01.aspx. [Accessed 01 12 2017].
[2] www.actforlibraries.org. [Accessed 01 12 2017].
[3] https://www.icao.int/secretariat/TechnicalCooperation/Pages/history.aspx. [Accessed 01 12 2017].
[4] F. Abbink, "Integrated Free Flight and 4-D Gate-To-Gate Air Traffic Management, Possibilities, Promises And Problems", in The 9th European Aerospace Congress "Visions and Limits of Long-term", Berlin, 14-15 May, 1996.
[5] http://www.history.com/this-day-in-history/reagan-fires-11359-air-traffic-controllers. [Accessed 01 12 2017].
[6] ICAO, Doc 4444 Pans Atm Air Traffic Management Procedures For Air Navigation Services, the 16th edition, 2016.
[7] «https://www.icao.int/Newsroom/Pages/traffic-growth-and-airline-profitability-were-highlights-of-air-transport-in-2016.aspx,». [Accessed 01 12 2017].
[8] https://www.statista.com/statistics/269919/growth-rates-for-passenger-and-cargo-air-traffic/. [Accessed 01 12 2017].
[9] «http://www.eurocontrol.int/sesar2020,». [Accessed 01 12 2017].
[10] «https://www.faa.gov/nextgen/,». [Accessed 01 12 2017].
[11] M. J. S. P. R. d. W. a. R. D. v. d. M. J. W. Smeltink, "An Optimisation Model For Airport Taxi Scheduling"in Proceedings Of The Informs Annual Meeting, Denver ,Usa, 2004.

[12] A. Srivastava, "Data, Improving Departure Taxi Time Predictions Using Asde-X Surveillance",Digital Avionics Systems Conference (DASC), 2011 IEEE/AIAA 30th, Seattle, Wa, Usa, 2011.
[13] Y.-M. d. H. J. Ivomar Brito Soares, "Departure Management With a Reinforcement Learning Approach: Respecting Cfmu Slots", chez Intelligent Transportation Systems (ITSC), IEEE 18th International Conference on, Las Palmas, Spain, 2015.
[14] T. P. P. Billy Josefsson, "Center, Scheduling Air Traffic Controllers at The Remote Tower", chez Digital Avionics Systems Conference (DASC), IEEE/AIAA 36th, st. Petersburg, USA, 2017.
[15] N. D. J.B. Gotteland, "Genetic algorithms applied to airport ground traffic optimization", Canberra, Australia,2003.
[16] Y. W. G. Wenzhi Zhao,"The Air Traffic Congestion Analysis for Landing."Nanjing, Jiangsu, China.
[17] Q. Z. h. X. Nan Li, "Research Of Taxing Optimization for Aircraft" Changchun, China, 2012.
[18] B. B. K. Mevlüt Uzun, "Takeoff Weight Error Recovery for Tactical Trajectory Prediction Automaton Of Air Traffic Control Operator" St. Petersburg, FL, USA, 2017.
[19] K. G. H. Meriem Ben Messaoud, "The Multiple Runway Aircraft Landing Problem: A Case Study for Tunis Carthage Airport." Banff, AB, Canada, 2017.
[20] L. W. M . Vitor Filincowsky Ribeiro,"Collaborative Decision Making In Departure Sequencing With An Adapted Rubinstein Protocol" 2015.
[21] S. C. Mohleji, "Air Traffic Control Automation Concepts To Optimize Flight Management System Utilization", Aviation Administration Sponsorship, 1988.
[22] M. B. Lucio Bianco,"Air Traffic Management: Optimization Models And Algorithms",journal of advanced transportation, Volume 26, Issue 2, p. Pages 131–167, 1992.
[23] A. D. D.. P. Marcella Sama, "Air Traffic Optimization Models for Aircraft Delay" chez Springer-Verlag , Berlin Heidelberg , 2015.
[24] X. Z. Y. Xiaolei Yang, "Distributed Air Traffic Flow Management at Terminal Control Area", Chengdu, China, 2017.
[25] B. M. Michael Stewart, "Objective Assessment Method For Rnav Star Adherence," St. Petersburg, FL, USA, 2017.
[26] T. Callantine, "Computational Modeling Of Air Traffic Control: Terminal Area Case Study," Waikoloa, HI, USA, 2006.
[27] R. Ehrmanntraut, "Full Automation Of Air Traffic Management In High Complexity Airspace", 2010.
[28] D. S. A. N. L. E. G. a. V. D. Alexandre d'Aspremont, "Optimal Path Planning For Air Traffic Flow,Management Under Stochastic Weather Andcapacity Constraints",Research, Innovation and Vision for the Future, International Conference , Ho Chi Minh City, Vietnam, 2006.
[29] R. S. M. K. Alessandro Gardi, "Multi-Objective 4d Trajectory Optimization For Online Strategic And Tactical Air Traffic Management," Sustainable Aviation, School of Aerospace, Mechanical and Manufacturing EngineeringRMIT UniversityMelbourneAustralia, THALES,Australia MelbourneAustralia, 2016.
[30] C. H. F. M. E. R. K. Agnaldo Volpe Lovato, "A Fuzzy Modeling Approach To Optimize Control And Decision Making In Conflict Management In Air Traffic Control",elsevier, pp. Programa de Engenharia Industrial (Graduate Program in Industrial Engineering), Escola Politécnica (Polytechnic Institute), Universidade Federal da Bahia, Brazil, 2017.
[31] C. S. S. L. D. S. Peng Wei, "Workload Evaluation Of Sectorized Air Traffic Control And Stream Management", Purdue University, West Lafayette, Indiana, 2012.
[32] https://www.skybrary.aero/index.php/NLR%27s_Air_Traffic_Control_Research_Simulator_(NARSIM). [Accessed 01 12 2017].
[33] https://www.aviationsystemsdivision.arc.nasa.gov/research/foundations/pas.shtml#pilot_manager. [Accessed 01 12 2017].
[34] https://www.aviationsystemsdivision.arc.nasa.gov/research/modeling/facet.shtml. [Accessed 01 12 2017].
[35] https://www.faa.gov/about/office_org/headquarters_offices/ang/offices/tc/about/campus/faa_host/labs/tgf/. [Accessed 01 12 2017].
[36] T. Prevot, "Exploring The Many Perspectives Of Distributed Air Traffic Management:The Multi Aircraft Control System Macs" San Jose State University,NASA Ames Research Center,Moffett Field, CA 94035, USA, 2002.
[37] indracompany.com, "Air Traffic Control Automation System Supplying Atm Systems Around The World For More Than 90 Years".
[38] "Networked, Handbook for Air Traffic Organization," Library of Congress Catalog Card Number 82-600545, 1982.
[39] "Airport and Air Traffic Control System," Library of Congress Catalog Card Number 82-600545, 1982.
[40] H. G. f. S. mbH, "Protocol API,TCP/IP,Packet Interface,V2.2" www.hilscher.com.
[41] L. Reynolds, "Colour For Air Traffic Control Displays" 1994.
[42] F. Rehm, F. Klawonn, G. Ruß et R. Kruse, "Modern Data Visualization for Air Traffic Management," 2007.
[43] "https://www.investopedia.com/terms/d/datamining.asp,". [Accedded 05 12 2017].
[44] "http://spireproject.com/database.htm". [Accessed 09 12 2017].
[45] J. omer, "Comparison of Mixed-Integer Linear Models for Fuel Optimal Air Conflict Resolution With Recovery".
[46] F. D. Hojjat Emami, "An Overview On Conflict Detection And Resolution Methods In Air Traffic Management Using Multi Agent Systems" Shiraz, Fars, Iran, 2012.
[47] R. G. R. John R. McDonnell et D. B. Fogel."Genetic Algorithms for Automatic Regrouping of Air Traffic Control Sectors," 1995.

[48] J. Z. Yan Zhang,"An Improved Tabu Search Algorithm Application To Intelligent Airline Network Optimization", Shenzhen, China, 2009.

[49] https://www.computerhope.com/jargon/r/routing-algorithm.htm. [Accessed 04 12 2017].

[50] https://www.mathworks.com/discovery/genetic-algorithm.html. [Accessed 06 12 2017].

[51] https://www.accountingcoach.com/blog/what-is-fifo. [Accessed 08 12 2017].

[52] Van Otterlo, M.Wiering, (2012). "Reinforcement Learning And Markov Decision Processes". Reinforcement Learning. Springer Berlin Heidelberg: 3–42.