Academic Projects on Air Traffic Management

Air Traffic Management Research Institute
Nanyang Technological University
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Conflict Resolution Aid for Future Air Traffic Control: Effects of Aid Reliability on Controllers’ Workload

Conflict resolution aid (CRA) is used to study the relationships between the workload, performance, and situation awareness (SA) of the air traffic controllers (ATCOs). Situation scenarios with reliable, unreliable and manual conditions were designed with conflict resolutions. There was a positive effect of reliability on participants’ performance, where most conflicts were resolved under reliable, unreliable, and manual conditions (in decreasing order). The availability of CRA improved the level of SA as there were more correct answers to the SA questions with a shorter response time.

Effects of Automation Reliability in Different Traffic Density Environments on Air Traffic Controllers’ Conflict Resolution Performance

The reliability of CRA significantly increased the percentage of resolved conflict, thereby improving the performance of the participants, who responded to the SA questions faster under automated conditions compared to manual conditions. The ground-based CRA concept proved to be of huge potential in resolving en-route airspace capacity issues in the future. A steady shift towards more automated operations can happen with additional development in research and operations.

Effects of Time Pressure on Conflict Resolution Performance Using Conflict Resolution Aid in Future Air Traffic Control

The effects that secondary conflicts and consequential time pressure levels have on ATCOs’ performance to handle the increased traffic capacity were investigated. The performance was analysed in terms of Percentage of Resolved Conflict, Conflict Resolution Time and Number of Error Count. An unreliable CRA resulted in poorer ATCO performance and low SA, with high level of time pressure producing the worst results. The secondary conflict involving look-ahead time differences under two unreliable conditions had a significant impact on ATCOs in resolving of conflicts.

Vision of Future Air Traffic Control

Various factors such as weather, airfield configuration, wake vortex, and noise affect the capacity of the entire air traffic system and put pressure on ATCOs. Current technological and decision making aids help ATCOs execute their functions but face limitations in fulfilling future demands such as meeting exact separation minima and optimal utilisation of airport resources. Furthermore, current and future ongoing advancements and their efficacies for fulfilling future requirements were also discussed.
Improved Gate Allocation Mechanism for Better Runway Optimisation

The airport runway throughput, a sub-functional group in airport operations, is often identified as a bottleneck. Current gate allocation practices are examined for their correlations and effectiveness in contributing to improving runway throughput. An improved gate allocation model for runway optimisation, built on linear programming techniques, was proposed. Parameters obtained from real-life historical data were inputted into the General Algebraic Modelling System (GAMS) to establish a baseline for comparison of effectiveness.

Load Balancing Algorithms for Multiple Runway Airports

The existing load balancing strategies were analysed and an improved load balancing algorithm for multiple runways under mixed-mode operations was proposed. A mixed-integer formulation was used to schedule a set of aircrafts that consisted of arriving and departing flights to minimise the overall cost. The load-balancing algorithm will be implemented by using the current Changi dual parallel runway configuration data as a test bed. The model was solved using GAMS over several simulated instances of up to 90 flight movements per hour.

Network Flow Models for Air Traffic Flow Management

Air traffic flow management takes into account the safety and efficiency of the entire air traffic network while simultaneously striving to strike a balance between demand and capacity. The proposed network flow models seek to minimise the cost of delay of aircrafts in a small network of departures. A simulation model has been developed based on a small-scale network of aircrafts using Microsoft Excel Solver.
Modelling and Sequencing of Air Traffic using Genetic Algorithm

The aim was to develop an existing Genetic Algorithm (GA) to optimise the sequence of aircraft departing and arriving at Changi Airport T2. Previously, GA simulated 20 aircraft scenarios with position shift constraints. The results showed a lack of responsiveness to dynamic situations. An in-depth analysis of the different situations that could result in delays was then conducted. This was performed using a random generator to first simulate the unplanned nature of flight cancellations and delays. This was followed by incorporating various situations. It was found that the modified GA model was able to execute the appropriate shifts to provide the optimal timings.

Modelling and Analysis of Arrival Management Systems in Air Traffic Management

Due to the different sizes of aircraft, the minimum separation distance between consecutive takeoffs is different. Optimising the use of runways by reducing the separation distance between planes and allowing more planes to take off in the same amount of time can solve aircraft takeoff bottleneck problems. A mathematical model based on first-come-first-serve was used to model the aircraft-sequencing problem. Further modifications were made to optimise the aircraft takeoff movement. The results of using the modified model turned out to be a better solution when compared to the first-come-first-serve approach only.

Modelling and Analysis of Departure Management Systems in Air Traffic Management

The problem of runway congestion in air traffic management was being examined, particularly the aircraft take-off problem. The work seeks to optimise the use of runways by rearranging the sequence of take-offs. Due to the size of different aircrafts, the minimum separation distance between consecutive take-offs could vary. Hence, rearranging the sequence of take-offs could reduce the separation distance between planes and allow more planes to take off in the same amount of time. The results of using the suggested approach were then compared to the current approach of first-come-first serve. The results reflected that the suggested approach provided a better solution than the current approach. There was also an attempt to improve the approach by exploring a smaller number of feasible solutions before attaining the optimal.
Airborne Separation Assurance
To ensure optimal use of finite airspace, the use of the Automatic Dependent Surveillance-Broadcast for aircraft separation was explored. Self-separation allowed pilots to fly more direct paths to their destinations, thereby reducing flight time and fuel consumption. This shift of responsibility implied a lighter workload for Air Traffic Controllers (ATCOs) but the complexities and intricacies of the role in flight guidance may not be as straightforward in practice. Various assessments of implementing self-separation and supporting structures to manage the complexities were examined.

Air Traffic Scheduling Policies during Landing or Takeoff
The gate allocation procedure in Changi Airport was investigated to minimise the aircraft turnaround time. A simulation model depicting the gate allocation procedure showed that the aircraft turnaround time was increased due to the long waiting time of flights and the under-utilisation of airport gates. The suggested solution integrates the gate allocation procedure for paired airlines thereby maximising the gate utilisation rate and minimising waiting time. The modified simulation model yielded zero waiting time for all regular sized aircrafts, which minimised the aircraft turnaround time.

Air Traffic Growth in ASEAN Region and its Impact on Changi Airport
To forecast the air traffic growth in ASEAN countries, two forecasting methods were employed onto international and domestic air passenger traffic, and air cargo traffic. The two methodologies were split between statistical method of curve estimation and time-series smoothing techniques, comprising various moving averages and exponential smoothing techniques. The selection of the different subcategories within the methodologies was based on residual analysis. Upon actualisation of the ASEAN countries' air traffic forecast, an in-depth situation analysis was conducted to observe the effect it would have on the current and future growth of Changi Airport.
Continuous Descent Operations in High Throughput and Constant Wind Environment
The flight of a Boeing 747-400 operating under Continuous Descent Operation procedures with a constant wind velocity was simulated. The Constant Flight Path Angle and Constant Rate of Descent modes yielded 64 combinations descent profiles, simulated under 2 headwind and 2 tailwind conditions, with speeds of 25 knots and 50 knots. The simulations showed that a pure constant Flight Path Angle descent was the most fuel-efficient but the introduction of constant rate of descent segments at low altitudes caused small negative impact on fuel consumption.

Functional Airspace Block of South East Asia
Feasibility studies have shown that a Functional Airspace Block (FAB) can improve safety, cost efficiency, and capacity. FAB can also reduce delays and environmental impact. Successful examples of Functional Airspace Block Europe Central (FABEC) were used as reference. An attempt was made to apply its concepts to South East Asia where air traffic was projected to grow. The benefits and pitfalls of FABs’ implementation to Functional Airspace Block of South East Asia (FABSEA) were also identified. In addition, potential challenges for FABSEA based on adopted principles by FABs in the EU were also highlighted.

Model Simulation for Increased Airport Capacity via Traffic Load Balancing Approach
Studies have shown how flight scheduling affects Changi Airport’s runway throughput with the use of a fast time simulation software, AirTOp. Through a model, the best routes for arrivals into Singapore from the different entry fixes were determined. An idealised index for assessing the runway capacity was also established along with an optimal ratio between arrival and departure. This index was validated with actual flight status data.

New Surveillance Systems in Air Traffic Control
A review of the technologies and operations that are used in current Air Traffic Control (ATC) surveillance systems was made. The automatic dependent surveillance – broadcast (ADS-B) technology was investigated. Factors being examined include broadcasts position, altitude, and vector of the aircraft. In addition, some preliminary conclusions of the potential operational benefits in adopting this new technology were also identified.
Optimising Precision Final Approach

The pilot has the means to measure the deviation of the desired descending profile, usually using the Instrument Landing System (ILS) in Precision Approach. It utilises radio signals and commonly high intensity lighting arrays to provide pilots with precise landing guidance. To improve accuracy and precision in approach guidance, augmentation systems become an integral part of ILS. Efficient usage of the frequency band would help to increase its availability, as well as to facilitate an easier integration with navigational satellites. Various precision approach methods will be introduced in terms of the system constitution and working principles were discussed.

Role of Secondary Surveillance Transponder in Today’s Context and in the Future

With the increase in air travel and the limited availability of aerodrome capacity, technology will have to be improved to ensure air safety and efficiency. The applications of various Secondary Surveillance Radar (SSR) Transponders onboard the aircraft were analysed. Possible solutions of providing redundancy or creating a fail-safe environment were looked into such that should the SSR transponder malfunction, there will be secondary backups or other means to prevent a service disruption.

Simulation Models for Air Traffic Flow Management

Simulation of an aircraft landing had been done to minimise the landing cost rate, which is the multiplication of the total deviation cost of actual landing with the target landing time. The most optimal landing time was found for a set of planes that possesses realistic and predetermined time window periods using a Mixed Integer zero-one approach. The simulation also highlighted that separation time limits need to be strictly adhered.

Surface Management Issues for Taxiing Aircraft

A probable solution for efficient surface management is to improve on the existing taxiing routes for arrival and departure aircrafts at Changi Airport. A proposed optimisation model was chosen and experimented to investigate its feasibility. However, further detailed feasibility studies will have to be conducted for Changi Airport to be able to reap the full benefits of the optimisation model.
**Development of Global Real Time Numerical Optimiser**

Human Cognition Inspired Particle Swarm Optimisation (HCIPSO) is adopted to deal with rotation variance properties of the search space. Four learning strategies, namely self-regulating inertia weight, the self-perception on the global search direction, the rotation update strategy, and social direction guidance for the least performing particles were investigated. The strategies managed to achieve better convergence characteristics and provide better solutions for various search spaces.

**Simulation of Wind Shear**

To understand the mechanism of wind shear due to microbursts, numerical methods were used to simulate microbursts and microbursts with crosswinds of varying strength. Large Eddy Simulation (LES) provides high fidelity for the large eddies, while modelling the smallest eddies to reduce computation cost and time. After an initial downdraft impact, the microbursts displayed localised high vorticity regions while microbursts with crosswinds displayed vorticity that are spread evenly across the entire domain.

**Infectious Disease Propagation in an Airport Network**

Simulations were done to show the propagation of Ebola disease. A modified Susceptible/Exposed/Infected/Resistant (SEIR) model demonstrated the relationships between each variable of an infectious disease in transmission and the dynamics of transmission in different affected geographic locations. Global air travel data was obtained to form a complex air traffic network to assist in this simulation. The simulated results showed that Singapore has a chance of exposure to Ebola disease even though the odds are very small. Different transmission variables gave different results and durations in disease propagation.

**The Impact of the Carbon Footprint on the Aviation Industry**

There is a need to quantify the current and future impact of aviation emissions on local air quality in light of growing sustainability concerns and current aviation trends. Traffic growth rates from Airbus were used to make a simple 5-year forecast and to examine the potential growth in emissions. A 5-year forecast for Changi Airport showed that HC, CO, NOx, and CO₂ emissions would increase by 34.2%, 36.1%, 30.5%, and 32.6% respectively.
Design and Development of Joined-wing Aircraft
Investigation on joined wing designs was done to determine the optimal configuration in terms of aerodynamic performance. Both Computational Fluid Dynamics (CFD) simulations and wind tunnel testing on actual models were used to determine the lift and drag coefficients. Although it was noted that there was no additional increase in drag at stall angles contrary to flow separation theory, the value of lift coefficient was generally found to be greater than most 2D airfoils at the tested Reynolds number.

Elastic Mechanisms for Clapping-and-Flinging X Wings
Flapping wing flight offers many potential applications for micro air vehicles (MAV) that require high agility to maneuver through tight spaces. However, flapping wing flight is costly. Large amounts of energy are expended to replicate the wings. An energy-storing thoracic mechanism found in insects has inspired man to imitate it with compliant hinges for flapping wing micro air vehicle (FWMAV). Flapping wing flight imitates their wings in a clap and fling manner. A compliant mechanism was designed to assist the clap motion as well as to reduce the energy required for imitation of the wing motion. Design and fabrication of both fling assisted and clap assisted compliant mechanism FWMAV were then compared for energy performance.

Effect of Carbon Spar Reinforcement on Flapping Wings: Kinematics and Thrust Generation
Flapping Wing Micro Air Vehicles have garnered much attention in the aviation industry due to its capability in performing flight at low Reynolds number and having a higher efficiency compared to fixed wing flights. Much research has been done in mimicking the thoraxes of insects with regards to its actuating mechanism. Little focus was placed on the wing component. In view of the complexity of unsteady flight, an investigation was done on the effects of varying reinforcement orientation and size on the flight performance of the FWMAV.