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Autonomous Flight Navigation Mechanism for Air-Route Optimization

Stojanche Gjorcheski
CEO, Pinwheel Aerospace, UK
Hari Iyer
MS SE, NASA ULI Research Aide, Arizona State University, Mesa, Arizona, USA
Goce Nikolovski
Student, Ecole National De L'Aviation Civile (ENAC), France
Dragan Trajchev
Student, the University of Manchester, UK

Abstract:
Air-routes are the most critical decision factor when it comes to performance of any flight from the efficiency standpoint. With over 40 million flights scheduled every year, air travel has become an inseparable part of business, leisure, and commute. Every drop of fuel, second of time, and dollar spent, matters. In this section of travel that has paramount importance in the fast-growing world, there's definitely room for efficiency maximization. Considering a practical example, it can be quite certainly asserted that San Francisco to New York experiences a good chunk of traffic flow. This is the key area where optimization must kick in. Factors leading to great-circle wastage like waypoints, weather roughness avoidance, alongside similar attributes need operational replacement and to make the real-time use case conducive to efficient flying. This paper would talk about how and where this concept can be applied to ensure maximum throughput and minimized compromise on resource wastage. Advantages of these implementations, coupled with the existing sophisticated systems would have a profound impact on optimizing expensive dependencies to achieve flight. Leveraging the great-circle route, flight time and route planning would be optimized to attain faster air travel performance. Although such tweaks might result in some undesirable side effects, the research would encompass strategies to let the efficiency prevail.

Keywords: *Waypoints, great-circle, route optimization, airspace, air traffic control*

1. Introduction

Throughout recent aviation history, it can be easily seen that the current air traffic management system can run out of airspace pretty quickly. [6] Optimization and airspace design over the past century are not meeting the requirement of handling large volumes of air traffic and therefore causing delay reduced economic efficiency. [4] Recent studies has revealed that a modern and efficient design is needed to decrease the percentage of delays and the air traffic flow can be expedited [3]. Airlines also want a quicker and more optimized airspace so they can operate more flights, be on time and economical. [5]. To resolve this, an air traffic management model is presented in this paper for which the preliminary examination shows that it is efficient and it saves 150 miles in average for every flight. This paper also focuses on optimized flying routes which will lead to a modern airspace, and possibly alleviate the workload on air traffic controllers globally.

1.1. Air Route Optimization

1.1.1. Concept

Flight optimization can be achieved by focusing primarily on implementing the great-circle way of flying. The main advantage of doing so is that the flight path will be the most efficient, and the quickest. Instead of using the traditional mechanism for waypoint navigation, the new system would incorporate a heading-based route to be followed. *(This means, once the airplane takes off to a certain altitude, it is going to have a constant heading to the final destination)* The route would represent a parabolic path over the Earth's curvature. This would enable navigation over the shortest possible path (great circle) instead hopping through waypoints. The current waypoints would remain intact as a backup system in case of non-applicability of the new system.

1.1.2. Implementation

The shortest route would be determined upon take off, hence the heading that the aircraft would bear while exiting TRACON (Terminal RADAR Approach Control), would remain constant till the destination's TRACON is approached. This heading will be calculated based on geo-coordinates of the source and destination. The curve would mathematically represent the path that can be used to identify context of that flight to dynamically update the flight communication parameters by analyzing vicinity of current position against the preset sectors. The constant flight course enables abstraction of the GPS module, thereby ensuring the shortest path to be taken for the flight. In cases of rough weather, a traditional approach would be diversion using an ellipse-driven approach. The multiple routes need more resources to bank upon, including course, heading, and waypoint determination. It ultimately leads to increasing the flight time, and that is the most crucial component. The implementation can be demonstrated as follows:

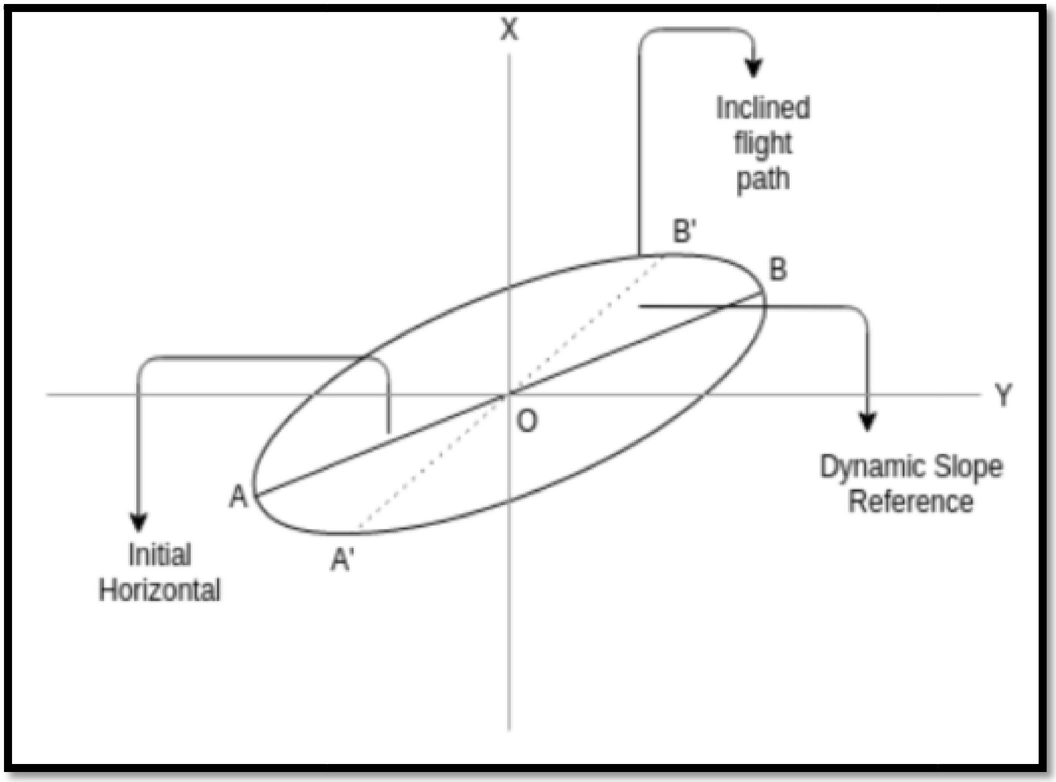

Figure 1: Flight Trajectory Model [1]

For Great Circle route distance calculation, Haversine formula can be used to determine the aerial distance between the two source and destination. The algorithm goes as follows [1]:

```
function dist (a, b, x, y) {
   // (a, b) is source, and (x, y) is destination.
   Var R = 6371000;
   a = a.toRadians();
   x = x.toRadians();
   diff_lat = (x - a).toRadians();
   diff_lon = (y - b).toRadians();
   a = pow(Math.sin(diff_lat / 2), 2) + Math.cos(a) * Math.cos(x) * pow(Math.sin(diff_lon / 2), 2);
   c = 2 * atan2(sqrt(a), sqrt(1 - a));
   d = R * c;
   return d;}
// Calculate the minimum distance path hierarchy
if (d approximately equals 20, 000) {
   // 20+ hrs duration flights.
   // Source – London – Destination:
   A = dist(src, LHR) + dist(LHR, dest);
   // Source – Hong Kong – Destination:
   B = dist(src, HKG) + dist(HKG, dest);
   // Source – North Pole – Destination:
```

```
   C = dist(src, North Pole) + dist(North Pole, dest);
   path[] = ascending_order(A, B, C);
} else {
   //Direct flights:
   path = distance(src, dest);
}
```

1.2. Waypoint Substitution Concept

Air navigation mainly operates with two main components of the route, beacons and waypoints. Waypoints are formulated using geo-coordinates of the aircraft heading and the proximity of the position from a beacon. The flight plan maps and air routes are based on a map composed of these waypoints. They are the most elementary bits of flight operations and is the most important flight parameter once airborne. A waypoint-based map would be as follows:

Figure 2: Proposed Trajectory Model
(Www. Ead. Eurocontrol. Int)

This however relies on the concept of following waypoints. The red line on the picture describes the flight plan filed from the origin to the destination airport, and it shows all the waypoints that the airplane will follow and fly over. However, the blue line shows the great circle route and how direct the flight will be if it flies that way. Visually infer the great circle route to be much faster and economical than the traditional waypoint to waypoint approach. Once the aircraft takes off, it needs to follow the departure procedure as long as it is within the TRACON unless ATC (Air Traffic Control) gives it clearance to do otherwise. After exiting TRACON, the heading should turn towards the destination airport. It would thus utilize the great circle route. The straight line of flying would be the shortest by distance and time which would be proved in the forthcoming sections.

Flying the great circle route, the pilot is expected to report to ATC as a when the aircraft enters every sector. This would not pose an issue to the traditional approach of flight, and it would decrease ATC's workload. This is due to the reason that the straight route does not need heading changing as frequently as opposed to the waypoint approach. In the following sector map [2], the traditional system of following waypoints is mentioned for when the aircraft enters the sector. The blue lines show how the great circle would not be an issue with sector transitioning. On the contrary, it can be seen that the great circle route is much more efficient from the distance, time, and ATC workload standpoints. Utilizing the optimized flight path, the heading of the aircraft remains constant for the most of it. Thus, ATC neither needs to update aircraft headings, nor needs to assign shortcuts for reducing flight time because the aircraft would already be flying the most optimal route.

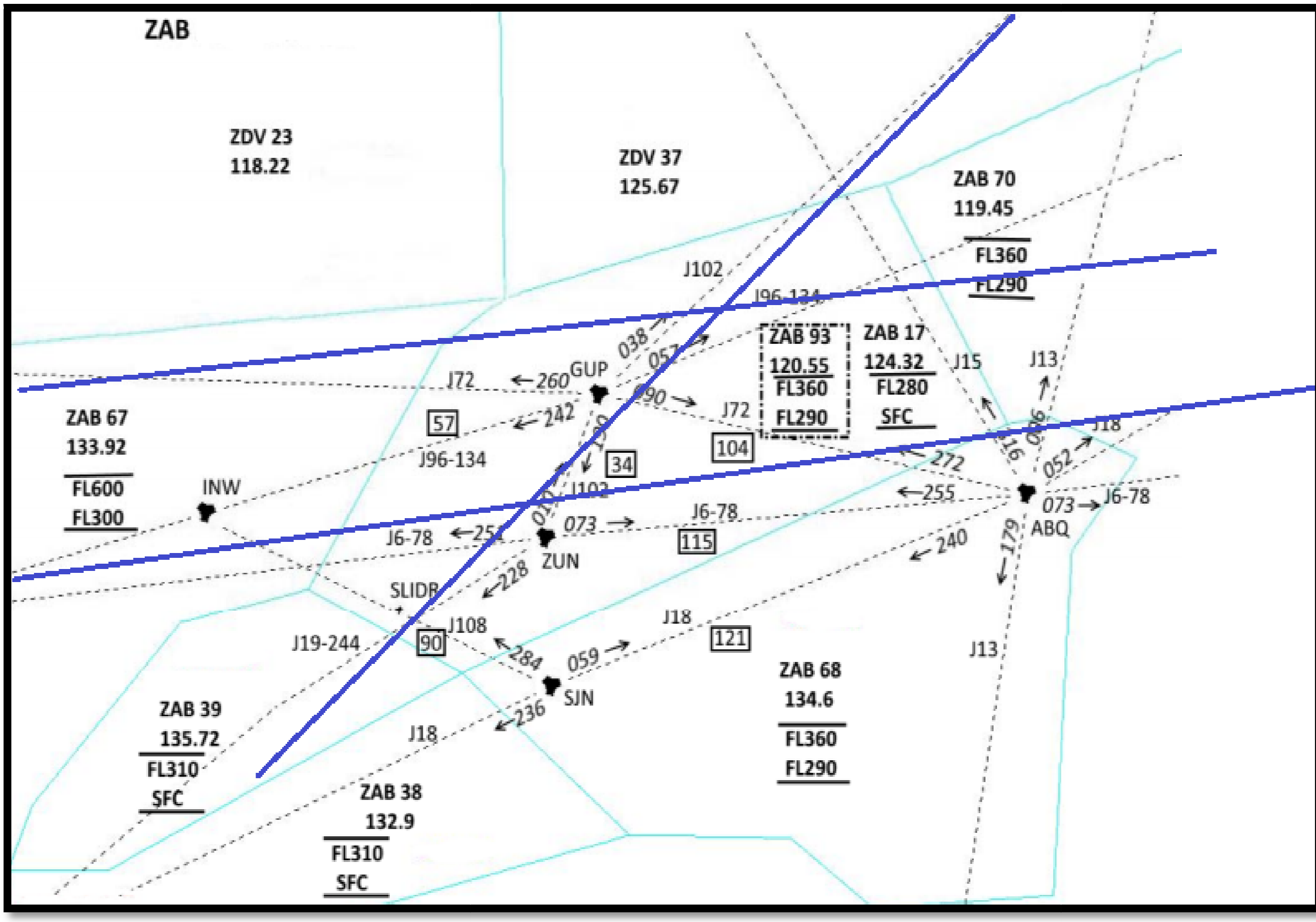

Figure 3: Albuquerque Enroute Center Sector 93 [2]

1.3. Overlapping Routes and Possible Deviation

Once the mechanism is applied in the cockpit of the airplane the flight strip will show up in the Air Traffic Control system. The way this will work is very similar of the today's system. Once the route is accepted by the system, ATC could see the route beforehand, be able to plot it on the radar screen and see the possible actions that need to be taken like vertical separation.

This mechanism as any other solution has its own shortcomings and times when it is not fully applicable. The possible deviations for our mechanism would be in a time where there is weather along the route, restricted airspace or any kind of obstacle that prevent the airplane to follow the given heading over the earth's surface. In this case, the airplanes will be routed accordingly and after the obstacles are passed, the direct heading would be given back. This following situation is more of a solution for a situation rather than deviation. If there are few airplanes meeting at a same point, same time and same altitude, they would be vertically separated by the Air Traffic Controller in charge of them. The chances of this happening are less than 5% in any time at any point on the globe. Arranging a certain flow is another side of this mechanism. As stated before, the direct heading would be from TRACON to TRACON. This means that the flow for entering/exiting a TRACON will be done at a certain point at the edge of the TRACON. Our belief is this will reduce the holding patterns and airplanes holding on the ground because all the process will be expedited and there will be more time and space available for airplane go in. Being this said, the overall workload of the Air Traffic Control would be reduced. In a situation where there will be simply too many airplanes to fit in the arrival flow in order to meet the safe distance, this could be solved with speed restrictions and every airplane to enter the TRACON at a certain time, and with doing that the overall flow would stay efficient, in order, and safe.

2. Data Collection and Results

Our data was collected based on two categories for which we applied our mechanism. The categories we used are:

- Short-Medium Haul Flights
- Long-Ultra Long-Haul Flights

In order to have an ideal representation we combined these two categories taking the average out of it. The data represented in based on a one calendar year. In this data we used the average price for jet fuel and the average number of flights per year. In order our mechanism to be applied we found the average number of miles flown by a given flight on year's level.

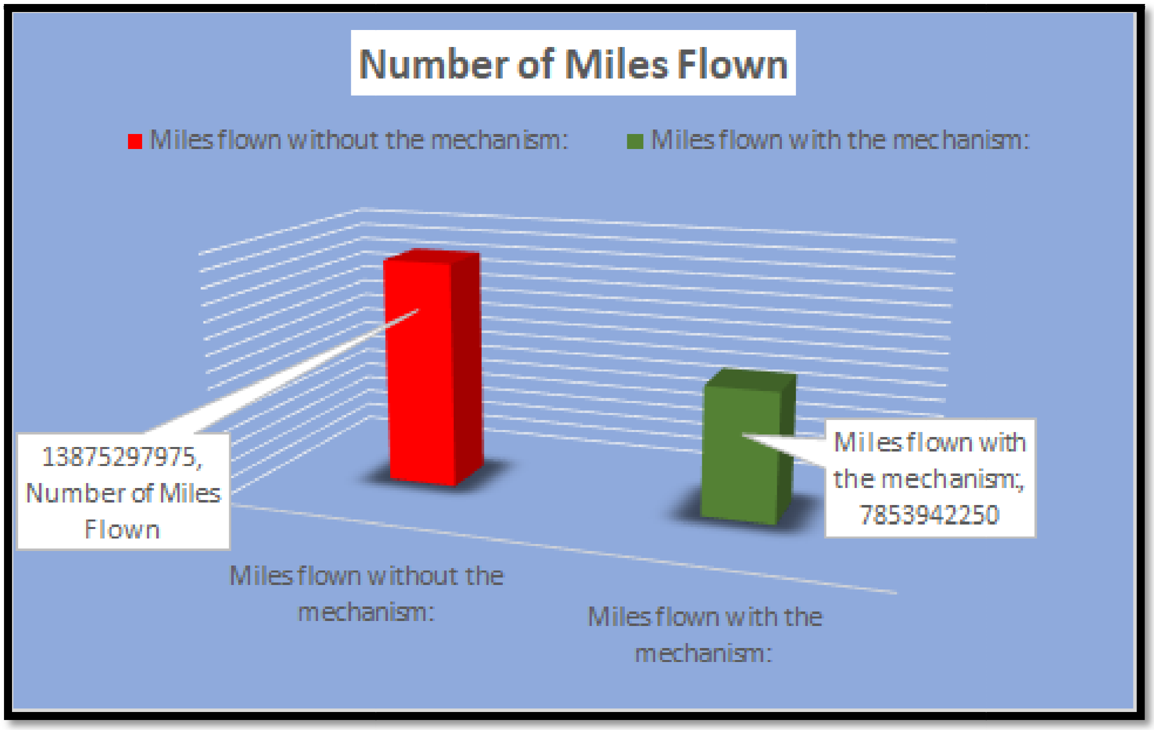

Figure 4: Flight Mileage Savings Using Proposed Model

Flight miles using current system turns out to be 13875 297 975. With the proposed solution, the number of miles flown is 7 853 942 250 miles. This represents 43.6 % efficiency.

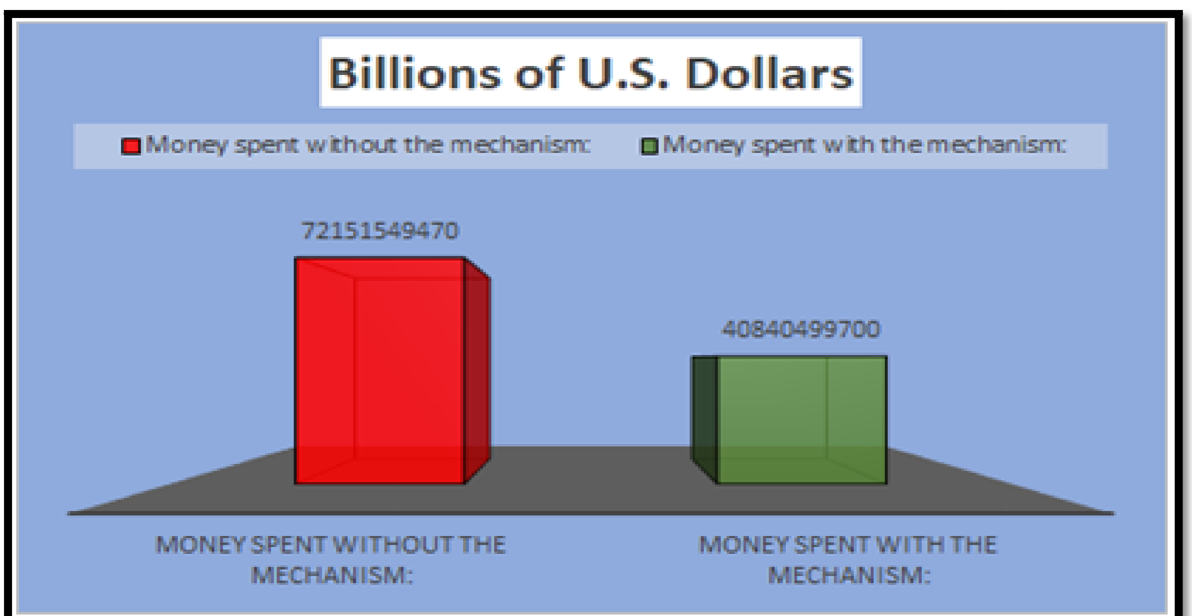

Figure 5: Fuel Economy Saving Using the Proposed Model

The amount of money spent for fuel without the mechanism is 72 151 549 470 US Dollars. The amount of money spent on fuel after the mechanism is applied is 40 840 499 700 US Dollars which is 43.6% efficiency.

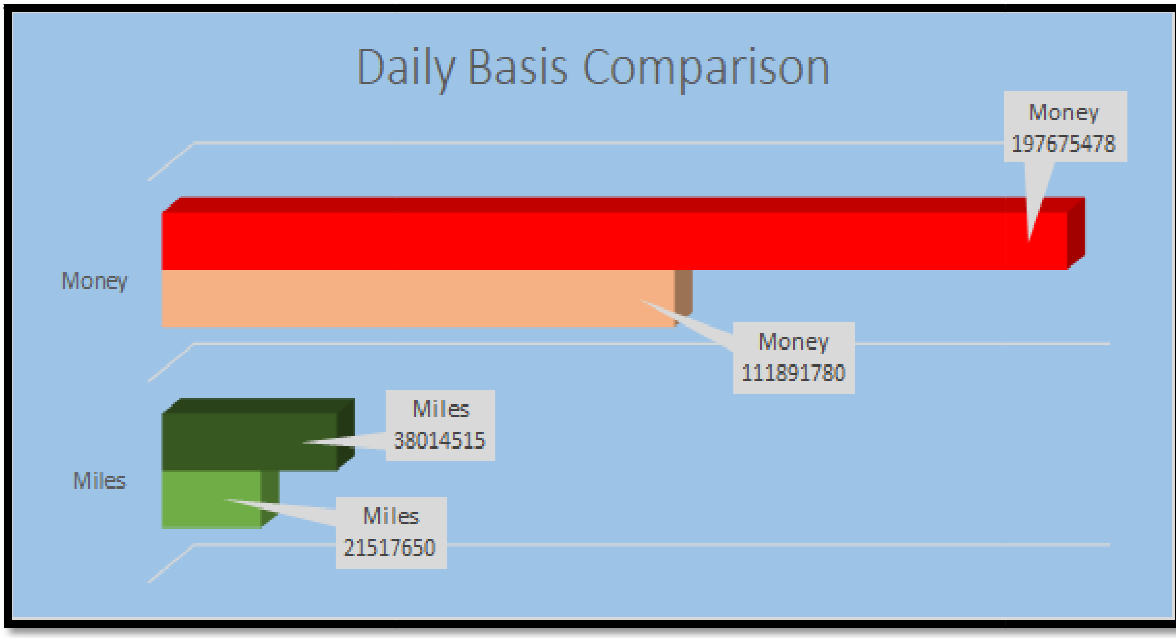

Figure 6: Daily Basis Comparison of Miles Vs Money

In words this means that during an average day in there would be 16 496 865 less miles flown and there would be 85 783 698 US Dollars savings for fuel which is 43.6 % savings in both fuel and miles. This directly impacts the time spent in air.

3. Conclusion

This mechanism for point-to-point flying, as explained, would pave the way for huge savings from the airtime, flight miles, and fuel economy standpoints. Enhanced air traffic flow is a major need of the day and with the introduction of this mechanism, the aviation industry is just a step closer to achieve the maximum possible efficiency in flight. This proposal is introducing a whole new model of traffic routing that potentially increases the efficiency of the existing system by 43.6%. That being said, with the proposed changes in Air Traffic Control system, the workload of Air Traffic Control will decrease proportional to the operational flight bottlenecks, hence opens new avenues for airlines to cater to increasing flying demand.

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