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A NEW AND IMPROVED APPROACH FOR AIR TRAFFIC FLOW PROBLEM IN THE TERMINAL AREA

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ABSTRACT

Air transport has always helped humanity and plays a major role in the globalized economic development that the world is currently experiencing; these solutions are practical and cooperative that have erased borders and brought cultures together. Despite its benefits, the increase in air traffic has caused air traffic management problems which has become one of the biggest problems we face and has emerged as an extremely complex problem. This problem involves multiple actors coming to constrain in a complex way. This study proposes innovative solutions to the modeling of conflict resolution and deals with the aircraft scheduling problem at the terminal. as is the NP-hard problem, several heuristic-based approaches are proposed. A new and improved approach Based on Grey Wolf Optimizer and Fireworks Algorithm named FWGWO is applied to solve the air traffic flow problem in the terminal area.

Keywords: *Air Traffic Management, Arrival Scheduling And Sequencing, Fireworks Algorithm, Grey Wolf Optimizer, Optimization Problems, Problem Of Sequencing Aircraft, Metaheuristic.*

1. INTRODUCTION

Air transport plays a major role in the globalized economic development that the world is currently experiencing. Many airports around the world are on the verge of saturation and the slightest incident can result in a chaotic situation that is highly penalizing for all those involved in air Transport.

For several years, authorities have been increasingly interested in the problems related to the improvement of aircraft traffic on the ground. Indeed, this has become one of the main factors limiting the capacity of airport platforms. It is now realized that that the accommodation of future traffic flows will only be possible if we directly address the problem of into account the problem of a significant improvement in ground traffic conditions.

Air Traffic Management (ATM) is concerned with organizing flight traffic to ensure safety and efficiency. Security is the main point to avoid planes from dangerous areas and also from other planes. Efficiency concerned to improve air traffic capacity while respecting as closely the planned schedules. It takes place in two stages. The traffic planning and regulation phase makes it possible to organize air flows in order to facilitate management. The other phase concerns the supervision of flights to ensure their safety, consists of monitoring traffic, and resolving air conflicts.

Basically, air traffic management also concerns air route traffic control problems (route optimization, conflict detection and resolution) as well as terminal area traffic problems (rate control, airport capacity management, and aircraft arrival sequencing and scheduling).

Several types of research have been carried out in the field of management of air traffic then more theoretical approaches appeared, led by academic researchers. Therefore, metaheuristic algorithms are often used because they allow searching for the global optimum for large-dimension problems while easily integrating constraints and being adaptable to different problems.

Metaheuristics have been applied to many ATM optimization problems [D. Delahaye and S. Puechmorel,2013]. Thus, the genetic algorithm (J. Gotteland and N. Durand, 2003) and also for its simplicity the simulated annealing algorithm (D. Delahaye, S. Chaimatanan, and M. Mongeau,2019). And the implementation and the performances of the SAA method based on the Monte-Carlo approach have been studied in-depth for a stochastic optimization problem (J. Kleywegt, A. Shapiro, T. Homem,2002). Several typical approaches used for uncertainty optimization include this programming.

In this article, we address the problem of sequencing aircraft arrivals in the terminal area, which is an NP-hard decision problem. Its complexity owes to the asymmetry of the separation values between two successive aircraft taking the same trajectory due to wake turbulence and runway occupation time. A new approach whose main objective is to find a solution that minimizes costs according to operational constraints. the new hybrid algorithm based on Grey Wolf Optimizer and Fireworks Algorithm (FWGWO) is proposed for solving The Traffic Flow Management problem in Terminal Maneuvering Area as well as minimizing contention and constraints.

The article is organized as follows: Description of the problem and a mathematical representation in Section 2. Then in section 3 an overview of the Grey Wolf Optimizer and Fireworks Algorithm. Section 4 introduces the solution approach that we use. Finally, we conclude.

2. DESCRIPTION PROBLEM

Aircraft arriving at airports must pass through the designated entry points by the surrounding airspace of that airport at a specific time, then enter the terminal following the arrival route and prepare to land on the runway after reducing speed.

Landing of a 390-ton aircraft on an airport runway creates wake turbulence that prevents other aircraft from landing for at least 3 minutes. However, if an Airbus A320 with 67 tons lands just behind him, he has to wait for safety reasons until this turbulence has disappeared to start descending, which is a waste of time. Thus, an airplane at a speed of 250 kt must reduce its speed in accordance with the regulations at a distance of 11 NM from the runway threshold and to 140 kt at a distance of 3 NM from the runway threshold. Considering that the aircraft's speed is equal to the speed on the ground, the effect of the wind is not taken into account.

These wake turbulences are classified into different categories, according to their intensities, directly related to the type of aircraft producing them. The International Civil Aviation Organization (ICAO) mainly defines four categories of aircraft according to the maximum takeoff weight: very high (Super Heavy SH), contains only the Airbus A380, strong (Heavy H), medium (Medium M), weak (Light L). So, the separation time depends on the type of planes that follow one another. A small aircraft that lands behind a large aircraft have to wait longer than a large plane that lands after a small one.

In our case, thus is preferable to optimize sequences of takeoff and landing and to simplify our problem. We may require data relating to the actual arrival times of aircraft as well as flight conditions (weather conditions, actual speed, aircraft weight, etc.), we assume that the initial speed of each aircraft will remain constant throughout the first phase. Then, the aircraft speed is decreased so as to meet the requirements, the plane keeps this speed constant for the rest of the trip. Finally, the aircraft plane arrives at the last phase and the speed is reduced again, to reach the final approach speed.

Each aircraft i can land within a certain time. T_i is the preferred landing time which corresponds to the time on which the aircraft would arrive on the runway. If the airplane i were alone, it would land in T_i but in the presence of other aircraft, they must either accelerate to land earlier or on the contrary slow down to arrive later in order to comply with the safety constraints. That's why we say that the final approach speed is related to wake turbulence category.

$$V = \begin{cases} 150kt \quad if \quad c = heavy \\ 130kt \quad if \quad c = Medium \\ 110kt \quad if \quad c = Small \end{cases} \qquad (1)$$

Air Traffic Control (ATC) is a sub-function of ATM responsible for monitoring and enforcing safety gaps between pairs of aircraft; Its mission is to route and control flights between airports during the different phases of flight in order to ensure safety and efficiency. There are three constraints of separations and the scheduling of aircraft in the flight phase in order to prevent delays are taken into account:

- ✓ Wake turbulence separation: suppose the minimum separation (s_{fg}) between a flight f and g.These are classified into different categories, according to their intensities and the type of aircraft. The minimum separation standards are given in the according to the International Civil Aviation Organization (ICAO) (ICAO, “Air traffic management”, Doc-4444, 2007).
- ✓ Horizontal separation constraints: Aircraft must adhere to the minimum 3 NM horizontal radar separation in the TMA
- ✓ Runway separation requirements: Calculated the different flight speeds during a landing of 2 successive planes, on the same runway. As presented in the table.

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The problem is a dynamic assignment problem, which consists of assigning each aircraft on arrival a position compatible with its operational characteristics. It is not only a question of satisfying the constraints of separation between airplanes of various types in the maneuvering area but also of eliminating all potential situations of conflict with other aircraft both on arrival and on departure from this area the main types of conflict present in the maneuvering areas are shown below:

- ✓ Link conflict detection: When 2 flights (f, g) belong to the same link then it is necessary to calculate the minimum separation between these two aircraft, S_f^g, which is obtained according to the category of wake turbulence. Thus, the separation distance of these aircraft at the time of entry and at the time of departure from the link, and compared. (J. Ma, D. Delahaye, M. Sbihi, M. Mongeau, 2016).
- ✓ The runway conflict indicator: The runway separation between two successive airplanes (f and g) must be respected. Otherwise, an indicator is defined:

$$P_{f\,g}(X) = \begin{cases} 1 \\ if\ 0 \leq T_g^r(X) - T_f^r(X) < t_{f\,g} \\ or \\ 0 \leq T_f^r(X) - T_g^r(X) < t_{g\,f} \\ 0 \text{ Otherwise} \end{cases} \quad (2)$$

where T_f^r is the time when the aircraft f arrives at the runway threshold (last node r) and $t_{f\,g}$ is the minimum runway separation between f and g. the same for T_g^r et $t_{g\,f}$.

If a node n belongs to the routes of two aircraft f, g which fly over, suppose that the aircraft f crosses the node v before g .A conflict is detected when the aircraft g enters the detection zone before f has left. (J. Ma, D. Delahaye, M. Sbihi, M. Mongeau, 2016) to guarantee the minimum separation we define $R_n = 3$ with R_n, the radius of a disc centered at node n, and we assume that $v_g > v_f$.

It is possible to represent the network of taxiways of the airport platform dedicated to airplanes by a directed graph $G = (N, U)$ consisting of a set N of vertices N_t which represents the set of entry points on the runway for take-offs. N represented by a set of arcs, such that (N_p, N_q) belongs to U. U Is the set of links. Given a set of flights $F$and for each flight then we assume the following data:

- ✓ e_f is the entry point to the TMA terminal;
- ✓ t_f^0 designates the time of landing of the aircraft (estimated time of arrival at the point of entry)
- ✓ v_f^0an approach speed at TMA
- ✓ c_f : wake turbulence category

The optimization problem is established to minimize the criterion associated with the various delays. A relatively complex set of constraints is then introduced for each flight f associates an aircraft:

- ✓ we will impose the aircraft to change the entering speed of flight at a speed between a minimum value v_f^{min} and a maximum value v_f^{max}.
- ✓ Let Δ_f^v be a user-defined TMA entry speed increment. In our case we will define v_f^{min} = $0.9v_f^0$, v_f^{max}= $1.1v_f^0$ and $\Delta_f^v = 0.01v_f^0$.

$$v_f \in V_f = \begin{Bmatrix} v_f^0 + j\Delta_f^v \ j \in Z \\ and \\ v_f^{min} \leq j\ \Delta_f^v \leq v_f^{max} \end{Bmatrix} \quad (3)$$

- ✓ As well as the shift of his time of entry to the TMA:

$$T_f = \begin{Bmatrix} t_s^f + j\Delta t\ , \frac{\Delta t_{min}}{\Delta t} \leq j \leq \frac{\Delta t}{\Delta t_{max}} \\ j\epsilon Z \end{Bmatrix} \quad (4)$$

$\Delta t_{min}$and Δt_{max} is a maximum and minimum time interval of the duration of the operation to arrive at the TMA. Once the intervals and the arrival rate have been defined for each interval, we generate the arrivals; we can either delay it or speed it up. Assuming the planes show up on the radar screen 45 minutes before their scheduled arrival at the IAF and usually updates every 5 seconds. In this study, one fixes Δt_{min} and Δt_{max} is fixed between 30min and -300s, and the number of slots $\Delta t = 5\ s$.

A aircraft moves from an airport to a destination airport. Normally goes through 5 phases of flight. the take-off phase, the so-called en-route cruise phase then the descent phase including the approach phase, and finally the landing phase. As already mentioned, the speed is reduced to a constant speed during the last phase. Let u_i and v_i be decision variables, $i\epsilon I$ with I is the set of time intervals.

We introduce a decision vector $x = (u_1, \dots, u_n, v_1, \dots, v_n)$, where the decision variables would be at the level of each queue associated with the runway, beyond the threshold of the runways thus that we can guess the arrival time.

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The model (J. Ma, D. Delahaye, M. Sbihi, M. Mongeau, 2016) based on graph theory making it possible to obtain sufficiently detailed representation problems leads to the formulation of the optimization problems with the characteristics (nature of the objective function, nature of the mathematical constraints, and structure of the admissible space) suitable for solving by mathematical programming methods. The optimization problem then amounts to minimizing the following criterion associated with the sum of the various conflicts (nodes, links, runway threshold) for each flight. The function to be minimized can be written:

$$S(x) = \alpha\left(\sum_{\substack{f,g\epsilon F\\ f\neq g}} \left(\sum N_{fg}^{n}(x) + \sum L_{fg}^{l}(x) + P_{f\,g}\,(x)\right)\right) + \gamma D(x) \qquad (5)$$

Where

$$D(x) = \left|\left\{\left\{f\epsilon F \middle| t_f(x) \neq t_s^f \, or \, v_f(x) \neq v_s^f \right\}\right\}\right|$$

When the number of flights that implements the decision change, the first term of the sum counts the number of node conflicts, the second term counts the number of conflicting links and the last counts the number of runway conflicts.2.2 Final Stage.

3. HYBRID ALGORITHM BASED ON GREY WOLF OPTIMIZER AND FIREWORKS ALGORITHM (FWGWO ALGORITHM)

FWGWO hybrid algorithm is proposed (Yue, Z.; Zhang, S.; Xiao, W, 2020) to combine GWO mining capacity with FWA exploration capacity to achieve better overall optimization capacity. FWGWO alternately uses the FWA algorithm for exploration in the search space and the GWO algorithm for exploitation to find the global optimum without changing the general operation of the GWO and FWA algorithms. In order to balance exploration with exploitation.

An adaptive coefficient ρ is proposed to balance exploration with exploitation. When the current position is closer to the optimal solution, the coefficient p is updated to modify the search strategy. let t be the current number of iterations and $iter_{Max}$ indicates the maximum number of iterations.

$$\rho = 0.9 * (1 - \cos(\frac{\pi}{2} . \frac{t}{iter_{Max}})) \quad (6)$$

3.1 Gray Wolves Optimizer

The GWO algorithm (M. Seyedali & M.Seyed & L.Andrew,2014) is a mathematical model inspired by the behavior of gray wolves where the solutions are classified into four groups such as the classification of gray wolves during the hunting process (α, β, and ω.) Wolves that are in the foreground. They make important decisions considered the best solution (α). The second level of dominated wolves in the group is the wolves that consider second grade solution (β) and then the lowest level which is selected delta (δ). and the last on the wolf hierarchy is the ω the rest of the solutions.

The main phases of the gray wolf's hunting mechanism are described in the first-place gray wolf follows and approaches the prey, then circling and harassing the prey until it stops moving, and finally attacking it.

$\vec{D}_\alpha$ A distance between $\vec{X}_\alpha$, $\vec{X}_\beta$ and $\vec{C}_\delta$the position vectors (alpha, beta and delta respectively) and the random motion vectors $\vec{C}_1, \vec{C}_2\, \vec{C}_3$.

$$\vec{D}_\alpha = \left|\vec{C}_1 . \vec{X}_\alpha - \vec{X}\right| \;\; \&\& \;\; \vec{D}_\beta = \left|\vec{C}_2 . \vec{X}_\beta - \vec{X}\right|$$
$$\vec{D}_\Delta = \left|\vec{C}_3 . \vec{X}_\delta - \vec{X}\right| \qquad (7)$$

$$\vec{X}_1 = \vec{X}_\alpha - \vec{A}_1 . (\vec{D}_\alpha) \, \&\& \;\; \vec{X}_2 = \vec{X}_\beta - \vec{A}_2 . (\vec{D}_\beta) \;\; \&\&$$
$$\vec{X}_3 = \vec{X}_\delta - \vec{A}_3 . (\vec{D}_\delta) \quad (8)$$

$\vec{X}_1, \vec{X}_2 and\, \vec{X}_3$ are the step lengths in the direction toward alpha, beta, and delta.

$\vec{X}_{(t+1)}$ indicates the next position of the searcher before and after the update. These equations can find the main inspiration for the GWO algorithm, which is the hierarchical pyramid and the hunting mechanism.

$$\vec{X}_{(t+1)} = \frac{\vec{X}_1 + \vec{X}_2 + \vec{X}_3}{3} \qquad (9)$$

Algorithm 1: The pseudo-code of GWO

1. Initialize the wolf population $x_i = (1,2,3 \ldots\ldots n)$
2. Initialize a, A, and C
3. Calculate the fitness of each search agent
4. X_α= the best search agent
5. X_β = the sec and best search agent
6. X_δ = the third best search agent
7. **While** (t < Max number of iterations)
8. **For** each search agent
9. Update the position of the current search agent by equation (9)

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10. **End For**
11. Update a, A, and C
12. Calculate the fitness of all search agents
13. Update X_α, X_β, and X_δ
14. t = t + 1
15. **End While**
16. return Xα

3.2 Fireworks Algorithm

The FWA is a metaheuristic inspired by the behavior explosion of fireworks in the night sky [Tan and Zhu ,2010]. Every firework is considered as a possible solution in a search space. In general, the fireworks algorithm goes through the following steps: randomly generating N fireworks in the search space, which represents a feasible solution. Then assess the quality of these fireworks. Fireworks with better fitness; have a smaller search amplitude and more explosion sparks in the surrounding area

- ✓ The amplitude of a certain explosion is calculated as follows:

$$A_i = \hat{A}.\frac{f(x_i)-Y_{min}+\varepsilon}{\sum_{i=1}^{n}(f(x_i)-Y_{min})+\varepsilon} \quad (10)$$

$\hat{A}$ denotes the maximum explosion amplitude, and Y_{min} is the best value of the objective function among the n fireworks.

After generated a shower of sparks including explosion sparks and Gaussian sparks. N solutions including sparks and fireworks must be selected for the next generation, the distance-based strategy is used. Noted that the best spark is always kept for the next generation. Then, the other individuals are selected as:

$$P(x_i) = \frac{R(x_i)}{\sum_{j\in k} R(x_f)} \quad (11)$$

Where $R(x_i) = \sum_{j\in k} d(x_i, x_j) = \sum_{j\in k}\|x_i - x_j\|$ The distance between i^{th} solution and all of the other solutions. K represents all of the solution's location and j∈ K means the position j belongs to set K.

The pseudo-code of FWGWO Algorithm is given as follows:

Algorithm 2: FWGWO Algorithm

1. Initialize the wolf population $x_i = (1,2,3 \ldots ..n)$
2. Initialize a, A, k, t and C
3. Calculate the fitness of each search agent
4. X_α= the best search agent
5. X_β = the sec and best search agent
6. X_δ = the third best search agent
7. **While** (t < Max number of iterations)
8. **For** each search agent
9. Update the position of the current search agent by equation (9)
10. **End for**
11. Update A, and C
12. Calculate the fitness of all search agents
13. Update X_α, X_β, and X_δ
14. **If** Xα changed then
15. Update the adaptive balance coefficient (p) (6)
16. **End if**
17. if k >= T and rand() > p then
18. **For** each search agent x_i do
19. Generate explosion sparks
20. **End for**
21. Generate m Gaussian spark for the search agents
22. Select new search agents equation (11)
23. t = t + 1
24. k = 0
25. **End if**
26. k = k + 1 t = t + 1
27. **End while**
28. return X_α

4. SOLUTION APPROACH

We will present a local method of conflict resolution. Among the global optimization methods, the FW algorithm has the particularity of requiring little information on the evaluation function and of being able to simultaneously detect several optima premises close to the optimum. The Gray Wolf Optimizer (GWO) is a meta-heuristic algorithm inspired by the hierarchy of gray wolves (Canis lupus) for solving NP-difficult problems, based on the alternate repetition of the intensification phase. The GWO algorithm is used for the exploitation in order to find the global optimum neighborhood of the current solution, As well as the FWA algorithm is used for the diversification phase in order to explore new regions of the research space.

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The FWGWO algorithm explores in a search space by several FWA use. Then, the algorithm exploits in the optimization phases, small regions for an efficient search for the optimum with the rapid increase of p. In order to avoid that only GWO is executed at the end of the algorithm, the value of p increases in [0, 0.9]. In specific cases, the FWGWO algorithm will jump to the next iteration of the FWA algorithm without going through the exploitation part to escape the current local optimal space and to miss the global optimal solution. To avoid these cases, the FWGWO algorithm exploits the current region with at least T iterations of the GWO algorithm before moving on to the next FWA algorithm we define T=10. Let's k a variable to count how many GWO iterations have occurred. k is initialized at the start of FWGWO and increases after each GWO iteration. If k > T and r > p, FWA will be used to execute the iteration. At the last of these iterations, k will be set to 0.

The approach that we propose addresses the problem of conflicts and sequencing of aircraft which consists of evaluating all the airplanes of an individual for the resolution period. Thus, evaluated all movements of aircraft for each generation. The conflict optimization always starts from the best solution found in the previous optimization phase, until a stop condition is met.

For our problem, the FWGWO algorithm consists of successively changing the aircraft runways so as to converge a solution with minimal congestion and minimize computing time. the algorithm consists in generating a neighboring solution by obtaining a new state. We start with the random choice of the flight then we search for the list of sequence positions that can be used by the chosen flight without exceeding the maximum time limit. Then, we evaluate the objective function of the new state. This function must reach all states of the search space (or almost all). This ensures good exploration of solutions.

A neighbor solution is by altering one flight which was drawn randomly. However, the probability to select a particular flight is increased when heavy congestion is detected. To this end, we take the list of all aircraft and calculate the sum of the congestion encountered during the flight path for each aircraft, which we will call individual congestion. Then we go through the list of airplanes by adding up their individual congestion. The values of these successive sums are then brought back between 0 and 1. The choice is then made by randomly drawing a number between 0 and 1 and the drawn value makes it possible to determine the flight path. The flight that is more likely to be selected is the flight whose interval between 0 and 1 is larger for this aircraft.

In this section, we present results related to the aircraft arrival scheduling problem, we have implemented scenarios based on real and artificial data. We used and adapted, in our experiments, real data taken based on the current state of the European traffic network. These data specify the category, the type, the speed of the aircraft, the altitude, as well as the hours of entry and exit of aircraft in the TMA.

We have defined the values to specify the optimization problem and the solving algorithm. We assume $\Delta t = 5\ s$,we fix Δt_{min} and Δt_{max} between 1800s and -300s and speed step $\Delta_f^v = 0.01 v_f^0$ we give a $v_f^{min} = 0.9 v_f^0$, $v_f^{max} = 1.1 v_f^0$. We have chosen to set the parameters to specify the resolution algorithm, we give the size of the population 20, and the maximum number of iterations (max_iter= 500). And let the maximum explosion amplitude 40, and the number of sparks Gaussians is 5 (a=0.04 and b=0.8 and a decrease from 2 to 0).

Each line of the table presents the flight program for a particular day. the first 2 columns respectively designate the type of movement (arrivals-departures) and a column which corresponds to the total. As well as the last indicates the Traffic of each flight program.

Table 1: Number of flight schedule for a day

	Arrivals	Departure	Traffic	Total
1	554	563		1116
2	252	253	55%	505
3	194	196	35%	390

The airport has 4 independent parallel runways, that is to say, the operation of one runway does not participate in the operation of the other runway. In actual operations, the two runways 26L and 27R are used only for landings, while the other two runways 26R and 27L are used for departures. It consists of three terminals and a complex network of traffic lanes with a capacity value of 11 for terminal 1, the capacity of terminal 2 is 91 and for terminal 3 a capacity value of 57.

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Table 2: Comparison Between The Algorithms Proposed With 20 Aircraft

ALGORITHM	Total Arrival Delay	Best	Worst	Mean	CPU (Time)
FCFS	4578				
ACS-ASS	2915	2702	3308	3146.91	738.59
BRGA	2765				
RHC-ACS	2702	2702	3266	2823.38	160.62
RHC-ILS	2702	2702	3165	2850.16	182.5

The table 2 shows a test that is already done on the 20 aircraft is extracted from Hu and Paolo (2008). It presents the results obtained on the arrival sequences after execution by FCFS and RHC-ILS and other algorithms. The data (type of aircraft, arrival sequences) are taken from the mentioned articles (Z. Zhan et al., 2010) and (U.Benlic, 2016) we noted that FCFS recorded a total arrival delay of 4578 while the others have incurred a delay of 2915, 2765, 2702 and 2702 respectively. Then, the results of the table show that the RHC-ACS algorithm (S Zhan et al. (2010)) is the most suitable to solve the problem.

Similar to the results of table 2 which shows the test which is already done on the 20 planes but this time on 30 planes. The experiments show that the best solution is 3721. The minimum value for CPU-Time is for the RHC-ILS algorithm with a value of 24.02Unlike the ACS-ASS algorithm which finds itself with a value of 3634.53.

Table 3: Comparisons Between Proposed Algorithms With 30 Aircraft

ALGORITHM	Total Arrival Delay	Best	Worst	Mean	CPU (Time)
FCFS	8027				
ACS-ASS	3866	3721	4221	3874.76	3634.53
RHC-GA	3763				
RHC-ACS	3721	3721	4075	3730.3	222.18
RHC-ILS	3721	3721	3721	3721	24.02

5. CONCLUSION

This research has focused on the problem of resolving conflicts in the sequencing of aircraft in the en route and arrival flight phases. Conflict resolution and plane sequencing are very complex combinatorial problems. Several studies have employed analytical techniques to address these issues. Although analytical methods are interesting, they can only solve a very limited number of specific problems. We present in this article a mathematical formulation of the problem whose goal is to minimize conflicts and constraints.

We have proposed a new hybrid algorithm based on the Gray Wolf Optimizer and the Fireworks algorithm (FWGWO) which is divided into two steps: the first part explores a search space by several FWA uses used to generate an optimal trajectory. In the second operational part, the algorithm is then used in the hybrid method by combining it with the Gray Wolf Optimizer algorithm and improving the choice of parameters.

REFERENCES:

[1] D.Delahaye, S. Chaimatanan, and M. Mongeau, "Simulated annealing: From basics to applications," in Hanbook of Metaheuristics, pp. 1–35, Springer, 2019.

[2] N. Durand, D. Gianazza, J.-B. Gotteland, and J.M. Alliot, Metaheuristics for Air Traffic Management. John Wiley & Sons, 2015

[3] A. J. Kleywegt, A. Shapiro, T. Homem-de M, The sample average approximation method for stochastic discrete optimization /SIAM Journal on Optimization 12 (2) (2002) 479-502.

[4] Xiao-Bing Hu, Wen-Hua Chen, Genetic algorithm based on receding horizon control for arrival sequencing and scheduling/ Engineering Applications of Artificial Intelligence, vol:18,n°5,2005,Pages633-642, https://doi.org/10.1016/j.engappai.2004.11.012

[5] J.E.Beasley, M. Krishnamoorthy, Y. M. Sharaiha, D. Abramson, Displacement problem and dynamically scheduling aircraft landings Journal of the operational research society 55 (1) (2004) 54-64.

[6] J. Ma, D.Delahaye, M. Sbihi, P.Scala, M.A Mujica Mota, Integrated optimization of terminal maneuvering area and airport at the macroscopic level/Transportation Research Part C:EmergingTechnologies,V:98,2019,Pages338-357; https://doi.org/10.1016/j.trc.2018.12.006

[7] Ma, Ji; D.Daniel; S, Mohammed; M, Marcel. Merging Flows in Terminal Moneuvering Area using Time Decomposition Approach. ICRAT 2016, 7th International Conference on Research in Air Transportation, Philadelphie, PA, United States, Jun 2016. ⟨hal-01343823⟩

[8] J.E. Beasley, M. Krishnamoorthy, Y.M. Sharaiha and D. Abramson, "Scheduling aircraft landings - the static case" Transportation Science, vol.34, 2000, pp180-197

[9] Tan, Ying & Zhu, Yuanchun. (2010). Fireworks Algorithm for Optimization. 355-364. 10.1007/978-3-642-13495-1_44.

[10] Z-H.Zhan, Jun Zhang, Yun Li, Ou Liu, Kwok, S. K., Ip, W. H., & Kaynak, O. An Efficient Ant Colony System Based on Receding Horizon Control for the Aircraft Arrival Sequencing and Scheduling Problem/ IEEE Transactions on IntelligentTransportationSystems,11(2),399/41.

[11] Yue, Z.; Zhang, S.; Xiao, W. A Novel Hybrid Algorithm Based on Grey Wolf Optimizer and Fireworks Algorithm. Sensors 2020, 20, 2147. https://doi.org/10.3390/s20072147

[12] Una. B, Al. E.I. Brownlee, Ed.Burke,"Heuristic search for the coupled runway sequencing and taxiway routing problem", Transportation Research Part C: Emerging Technologies, Vol:71,2016,Pages:333-355, https://doi.org/10.1016/j.trc.2016.08.004

[13] X.-B. Hu and E. Di Paolo, "Binary representation-based genetic algorithm for aircraft arrival sequencing and scheduling," IEEE Transactions on Intelligent Transportation Systems, (vol. 9, n 2), pp. 301–310, 2008

[14] Mirjalili, Seyedali & Mirjalili, Seyed & Lewis, Andrew. (2014). Grey Wolf Optimizer. Advances in Engineering Software.Vol:69;p46-61 https://doi.org/10.1016/j.advengsoft.2013.12.007

[15] Bertsimas, D. & F, Michael. Air traffic flow management at airports: A unified optimization approach/Proceedings of the 10th USA/Europe Air Traffic Management Research and Development Seminar, ATM 2013.

[16] W. Yang and L. Ke "An improved fireworks algorithm for the capacitated vehicle routing problem[J]" Frontiers of Computer Science vol. 13 no. 3 pp. 552-564 2019.