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Flamingo Search Algorithm for aircraft landing scheduling

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Abstract

Aircraft landing scheduling (ALS) is the process of organizing the arrival and departure of aircraft at an airport. This process is managed by air traffic controllers who use various tools and techniques to ensure that aircraft land and take off safely and efficiently. The goal of aircraft landing scheduling is to minimize delays and maximize the number of aircraft that can be accommodated at the airport. This is done by carefully coordinating the arrival and departure times of aircraft and the number of aircraft that can be safely accommodated. Flamingo Search is an optimization algorithm stimulated by the flamingos' behavior. A population-based metaheuristic algorithm uses a flock of flamingos to search for the optimal solution to a given problem. The algorithm works by having each flamingo in the flock search for a local optimum solution. The flamingos then communicate with each other and share their solutions. Experiments have demonstrated that our solution is significantly faster and more appropriate for real-time ALS problems compared to conventional optimization techniques, the results showed the superiority of the proposed algorithm over the rest of the algorithms by more than 90%. The suggested method can quickly identify appropriate solutions for all 8 data sets.

Keywords: Aircraft Landing Scheduling, Flamingo Search Algorithm, Genetic Algorithm, metaheuristic, Optimization.

Introduction

The International Air Transport Association (IATA) predicts that 7.8 billion people will travel in 2036, about twice as many as were counted in 2016 [1]; this rising demand for air travel puts the existing infrastructure in danger of overloading. Building additional infrastructure (runways, airports, etc.) is one option to boost capacity, but it may only sometimes be practical due to the high cost involved. The alternative is to maximize the utilization of existing infrastructure, particularly the runway, which is acknowledged as the system's primary jam for Air Traffic Management (ATM).

An essential aspect of air traffic control is aircraft landing scheduling (ALS), which chooses the most effective landing order and time for a specific group of aircraft [2]. Numerous restrictions apply to the ALS problem, such as the requirement that each aircraft land within a particular window of time and that the separation criterion between each pair of landing aircraft is guaranteed. It has been noted that ALS is an example of a classic NP-hard problem [3]. Finding the ideal solution is challenging because of ALS's large-scale and multi-constraint qualities. As a result, it consistently captures the interest of many scientific communities. The First-Come-First-Served (FCFS) method, in which the order in which planes land corresponds to the order in which they enter the radar range, is a widely employed tactic in applications.

A popular area of study in allied disciplines has been optimizing particular parameters in engineering issues. The two primary categories of optimization algorithms are deterministic and stochastic, depending on how they are found and their properties [4].

Numerous new swarm intelligence optimization algorithms, including (Cuckoo Search-CS), (Ant Colony Optimization-ACO), (Whale Optimization Algorithm-WOA), (Particle Swarm Optimization-PSO), (Grey Wolf Optimization-GWO), (Sparrow Search Algorithm-SSA), (Tunicate Swarm Algorithm-TSA), and others, have been proposed in recent years.

These algorithms share the benefits of excellent application global solid parameters, and strong global search capacity. They are frequently employed to address real-world engineering design optimization issues. FSA is a brand-new swarm intelligence optimization method that draws inspiration from flamingos' migratory and feeding habits [4].

The ALS problem can be efficiently and effectively addressed using the proposed solution known as FSA. This swarm intelligence optimization method presents a fresh perspective on achieving optimal designs across various fields of optimization studies. By employing this innovative approach, the technical challenges can be resolved with enhanced efficacy, providing a new and effective solution.

Related Work

In [5] they presented a different approach to handling the FJSSP and contrasted it with a different inquiry calculation. They describe several neighborhood structures associated with task and sequencing problems and a modification of the Climbing Discrepancy Search approach for handling this issue.

In [6] presents a discrete artificial bee colony method based on a half-and-half Pareto distribution. Every arrangement in the half-breed calculation pertains to a source of food, which is divided into two portions, the directing and planning segments.

In [7] The multi-objective integrated process planning and scheduling (IPPS) issue with different process planning flexibilities is optimized using an efficient evolutionary algorithm in this study. Process, sequence, and machine-related flexibilities fall under three categories. The simultaneous consideration of three objectives—makespan, overall machine workload, and maximum machine workload—is also made. The effectiveness of the suggested method is examined through two trials. The experiment's findings demonstrate that the suggested algorithm can solve multi-objective IPPS problems with a range of process planning flexibilities efficiently and produce satisfactory results.

In [8] this paper demonstrated an improved (Cuckoo Search-CS) to determine FJSSP and compared it to the first CS algorithm connected to the HU dataset. The improvement was accomplished using two methodologies, the first considering a frequently used Levy flight and the second in light of current-based neighbor age.

This study introduced an enhanced AFSA method in [9] to resolve the Flexible Job Shop Scheduling Problem (FJSSP). The enhancement is based on the Variable Neighborhood Descent (VND) method, which various neighborhood structures apply to the original AFSA to enhance its performance. On a few FJSSP benchmark instances, the updated algorithm (AFSA-VND) has been evaluated to assess its performance.

A brand-new Camel Herd algorithm for swarm intelligence is presented in [10]. FJSSP utilizes the suggested CHA to solve it to limit makespan. The proposed algorithm provides a good variation arrangement through the camel system given neighbors that depend on the crowd's leader with the highest moisture content in the desert.

This work [11] offers a thorough and critical assessment emphasizing dynamic parameter setting methods. The study discusses several parameter-setting strategies used with swarm intelligence systems. By compiling all available parameter-setting methods into a single document and organizing them according to taxonomy, this review makes it easier to choose the best way for each algorithm. In this review, suggestions for selecting a parameter-setting strategy are given.

Flamingo Search Method (FSA), developed in [4] is a new swarm intelligence algorithm for optimization motivated by flamingo migration and feeding patterns. According to the simulation findings, in terms of stability, the approach is competitive with existing algorithms, speed of convergence, and search accuracy. Additionally, nine test functions were chosen, with a dimensionality of 2. The migratory trajectory of the flamingo population was shown using FSA to locate and discover their optimum.

In [12] this paper focuses on the optimization model of urban emergency resource scheduling, which builds the emergency resource distribution system framework using the deep reinforcement learning algorithm and optimizes the system using the Deep Q Network path planning algorithm to achieve the goal of improving and optimizing the effective scheduling of emergency resources in the city. The deep learning technique benefits the emergency resource scheduling optimization system, according to simulated trials.

This research [13], published in 2019, compares existing methods to determine which, if any, MHST can effectively aid Automated Test Data Generation (ATDG) when carrying out dynamic-functional testing in APA. The study considers several up-to-date MHST, spanning the years 2000 to 2018. These MHST combine local and worldwide search algorithms. Based on the study's findings, a combination of Cuckoo Search, Tabu Search, and lévy flight is a viable MHST to apply because it achieves better results in terms of both the number of iterations and the input space.

This study suggested a Particle Swarm Optimizer-based Hyper Heuristic (HH PSO) solve UCTP effectively in [14]. Higher-level methods like PSO are used to pick low-level heuristics (LLH) sequences, which are then utilized to build an optimal solution. Solution generation in the suggested way is split into two stages (initial and improvement). A new least-cost-heuristic (LLH), called "least possible rooms remaining" has been proposed for planning events. The proposed method is tested on data from the 2002 and 2007 editions of the international timetabling competition (ITC). According to the findings, the suggested LLH can be solved if its importance is raised to the top of the list

Description of Problem

When an aircraft enters an airport's radar range, air traffic control must grant permission to land, set a time of landing, and designate the proper runway, if more than one is available. The landing time necessity falls between the earliest and latest landing times, which are the times the aircraft might land if it flew at its top speed (which is not inexpensive for airplanes) [15].

To meet operational constraints while optimizing a given criterion for a group of airplanes close to the terminal area of an airport, the ALP includes mapping each plane to a time of landing. When an airport has a number of the runway, controllers must choose which runway will be used for landing; this choice is based on several variables, including the layout of the airport and the direction of incoming aircraft [15].

The First-Come First-Served (FCFS) rule, wherein aircraft land in the order of the planned times of arrival at the runway, and air traffic supervisors enforce the minimum standards for separation, is the method employed by controllers most frequently to sequence aircraft. This FCFS heuristic ensures aircraft equity and is simple to use. Take into account the significant spacing needed in some situations where a big plane is followed by a light airplane to see why it is seldom ideal in terms of runway throughput, especially in crowded airports [15].

Airport disruptions result from any departure (early or late) from the target time. As a result, any deviation before or after an aircraft's target time has a penalty cost. Therefore, the goal is to reduce the overall cost of fines like [15]

• There should be a security pause between any two landings on the same runway;

• A security gap must separate two subsequent landings on different runways;

• A time window [Earliest landing time, Latest landing time] is set aside for each aircraft to land.

Formulation as JSSP

One of the most challenging issues on a real shop floor is the JSSP [16 -18]. In general, it involves placing an order for a group of jobs to be completed by a group of equipment, such as:

• Each job is made up of a predetermined series of automatic actions;

• Some machines must process each job in a specific order that isn't always the same;

• A machine may process only one job at a time.

consider 10 airplanes (N=10) and 2 runways (R=2) during the rest of this section to further clarify our theory. Fig. 1 displays the time frames and goal timings for the aircraft.

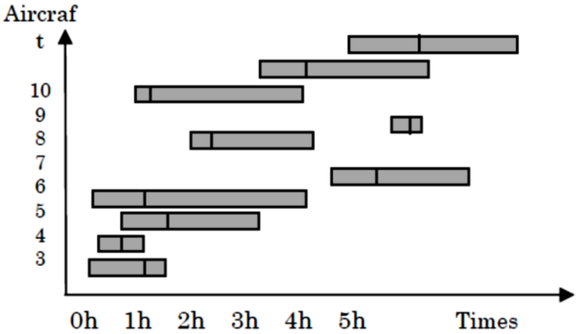

Figure 1. Shows the target timings and aircraft time windows

Each rectangle on the graph corresponds to an aircraft's earliest landing time (ei), latest landing time (li), and target time (tai), as described in Fig. 2.

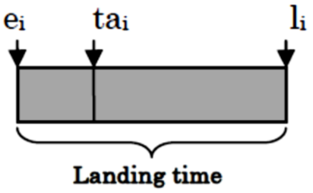

Figure 2. Aircraft's earliest landing time.

The definition of the Jobs and their constituent parts come first. First, as indicated in Fig. 3 below, it divide the aircraft into subsets:

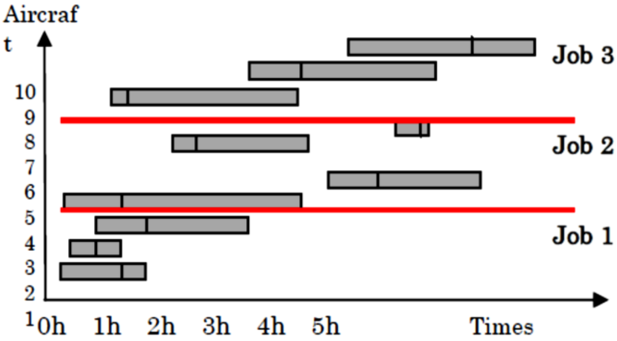

Figure 3. Aircrafts are randomly divided into sets.

The jobs are constructed at this step as follows:

• The 1st duty J1 is related to the aircraft landing: {1, 2, 3}

• The 2nd duty J2 is related to the aircraft landing: {4, 5, 6, 7}

• The landing of the following aircraft is the third job J3: {8, 9, 10}.

Here, we treat the airplane landing as an operation (landing) of a job1 (aircraft1 on a machine, and the runways as machines (runway).

Second, the order between the operations of each job is established by assuming that there is an order between two airplanes when their time windows are apart, which accounts for the appearance of incomplete order at the level of job operations. A JSSP will therefore consist of three jobs, J1, J2, and J3, each of which is made up of 3 operations, 4 operations, and 3 operations, respectively.

The goal now is to establish the order of jobs on the set of machines M, where M stands for "set of runways" in our example. This process entails deciding on a landing time for each operation and allocating a runway while keeping the time limits in mind.

Flamingo Search Algorithm

The major food sources for flamingos, which are gregarious migratory birds, include algae, tiny shrimp, clams, worms, and insect larvae. As they move, they consume by touching the water's bottom with their curled beaks and sweeping them around their bodies, flamingos also have a characteristic feeding technique [19]. They achieve this they cocked their long necks downward and twisted over their heads.

Foraging and migration are the two primary behavioral traits of flamingos. Most flamingo populations live in regions with plenty of food. Flamingo populations move after a period of active foraging when the amount of food in the region is insufficient to support the population [20]. The following [4] illustrate the primary FSA model optimization concepts.

1. In order to convey their position and the presence of food nearby, flamingos sing to one another.

2. The flamingo population is unaware of where the majority of food is located During this search range. Instead, they just alter each flamingo's position, which is influenced by its migration and foraging patterns, in order to locate additional food sources outside the recognized ones in the search region.

3. Position-changing regulations are based on flamingo behavior. Foraging activity and migratory behavior are primarily the two primary modes of behavior.

Beak scanning and foot mobility, two behavioral traits that have an impact on flamingos' foraging activity, can be used to categorize foraging behavior. The fundamental steps of FSA are outlined in this subsection [4].

Step 1: Initialize the population, set *Popu* as the population size, *MaxIter* as the most iterations allowed, and *FMP* as the percentage of migratory flamingos in the first section.

Step 2: *MagPro =rand[0,1]*Popu*(1-FMP)* represents the quantity of foraging flamingos in the ith iteration of flamingo population renewal. *MagPro0=FMP*Popu* is the number of migratory flamingos in the first iteration. In the second iteration, the number of migratory flamingos is *MagProi =Popu- MagPro0- MagPro.* Individual flamingos' fitness values are determined, and the population of flamingos is arranged in accordance with their fitness values. Former flamingos *FMP* and *MagProi* with low fitness and high fitness, respectively, are considered migratory flamingos, while the others are foraging flamingos.

Step 3: Foraging flamingos and migrating flamingos are updated in accordance with (3) and (2), respectively (2).

Step 4: Scan the area for flamingos that are not permitted.

Step 5: Continue to Step 6 if achieved the maximum number of iterations; otherwise, return to Step2.

Step 6: optimal solution and optimal value are output.

Algorithm1. FS Algorithm

```
Input: population of flamingo size, Popu;
Max number of iterations, MaxIter ;
The fraction of migratory flamingos make up the first component., FMP;
Output: fitness with optimal value, FitOpt; The optimal solution, sbest ;
    Calculated values of fitness and discovery of the current best individual, sbest ;
    $i \leftarrow 1$.
    while ($i \le MaxIter$)do
        $Rand = random[0,1]$.
        $MagPro = Rand \times Popu \times (1-FMP)$.
        $MagPro0 = FMP$.
        $MagProi = Popu-MagPro0-MagPror$.
        for $i$=1 to $FMP$
            for $j$ =1 to $n$ //n is the size of dimension
                Used (3) Update the location of Flamingo's;
            end for
        end for
        for $g$= 1 + $MagPro0$ to $MagPro0$ + $MagPror$
            for $j$= 1 to $n$
                Used (2) Update the location  of Flamingo's;
            end for
        end for
        for k= MagPro0 + MagPror + 1 to Popu
            for j= 1 to n
                Used (3) Update the Flamingo's location;
            end for
        end for
        for n= 1 to Popu // detection of boundary;
            for j 1 to d
                if $x_{nj}^{i}$ > ub then
                    $x_{nj}^{i}$ = ub
                end if
                if $x_{nj}^{i}$ < lb then
                    $x_{nj}^{i}$ ←lb
                end if
            end for
        end for
        Calculated the values of fitness and discovery of the current best of individuals, sbest;
        t← t +1
    end while
    return FitOpt and sbest
```

FSA for ALS Problem

Based on the limited knowledge supplied, the FSA algorithm mimics flamingos to attempt to identify the best solution in the search area (i.e., the position where food is most abundant). There are two tasks to finish the ALS. A landing sequence is first provided, and then the time of landing for a group of the airplane is determined. Based on the landing sequence, the landing timings are calculated. A 3rd list is used to indicate the assignment of runways to aircraft in addition to the two lists used to show the landing sequence and landing timings. An example of the code for 10 airplane and 3 runways are shown in Fig. 4.

Airplane	1	2	3	4	5	6	7	8	9	10
Runway 1	3	1	4	5	6	7	8	5	9	10
Runway 2	3	2	3	2	2	3	2	1	2	1
Runway 3	100	115	140	150	300	320	400	552	650	580

Figure 4. Example of the code for 10 airplanes and 3 runways.

Any local search's quality of the ultimate solution is significantly influenced by the initial solution, and early excellent schedules can grow into superior schedules. The starting population can, however, be generated at random, although it's typically challenging to provide many workable solutions quickly and at a low cost.

The landing timings of aircraft are calculated for each produced solution based on the assigned runways and the landing sequence while taking into account the security gaps and aircrew landing windows, see Eq. 1.

$$tj = \max(taj, \max_{i\in 0}(ti + Sij)) \text{ ……….1}$$

separation time (*Sij*). This choice will result in a well-balanced distribution of aircraft on runways.

- |*tai* - *taj*|: The aircraft that are closed in terms of target time are given preference over the others so they can land. as near as possible to their target time of landing in order to minimize the cost penalty.

assuming the flamingo symbolizes the plane to be landed, the location with enough food is the proper runway, and the jet's radar is the flamingos' beaks scanning the area.

Based on the limited knowledge supplied, the FSA algorithm mimics flamingos to attempt to identify the best solution in the search area (i.e., the position where food is most abundant). Consequently, given that (*xbj*)is the flamingo with the greatest amount of food in the (*jth*) dimension

The likelihood of their being plentiful food increases with proximity to the site where there is the greatest concentration of flamingos. Assuming that the (*ith*) flamingo is located at position (*xij*) in the (*jth*) dimension in the population of flamingos, and taking into account the variety of each flamingo's natural preferences as well as the impact of the environment's suddenness on the behavior of flamingo's foraging.

When flamingos forage, their claws travel in the direction of the areas where there is a high concentration of food while they examine the area with their beaks.

The distance traveled can be calculated as (*ξ1 * xbj*), where (*ξ1*) is an ether -1 or 1, which is primarily used to grow the search range of flamingos foraging and measure individual differences in choice. This is predicated on the assumption that (*xbj*) is the area where people have the maximum food availability.

The flamingo’s population moves to the next position where food is more plentiful when there is a food shortage in the current foraging area.

Results and Discussion

The output of the algorithm FSA is shown in this section together with the output of the algorithms GA and ACGA. The data collected for 25 benchmark cases [21] are summarized in Table 1. The first three fields in Table 1 represent reset benchmark instances. The fourth field displays the optimal results of the algorithms for the benchmark and all the following fields (N = no. of airplanes, R = no. of runways).

Table 1. Computational results

Benchmarks	N	R	Optimal Values	ACGA Values	GA Values	FSA Values
1	10	1	700	700	820	700
		2	90	90	90	90
		3	0	0	0	0
2	15	1	1480	1720	1720	1501
		2	210	210	220	210
		3	0	0	10	0
3	20	1	820	850	1750	850
		2	60	60	570	60
		3	0	0	320	0
4	20	1	2520	4480	6580	2633
		2	640	680	1770	680
		3	130	130	600	130
		4	0	0	330	0
5	30	1	3100	4800	5800	3100
		2	650	720	1650	650
		3	170	240	560	170
		4	0	0	440	0
6	30	1	24442	24442	*	24442
		2	554	554	*	554
		3	0	0	*	0
7	44	1	1550	1550	*	1550
		2	0	200	*	0
8	50	1	1950	3240	*	1960
		2	135	160	*	135
		3	0	0	*	0

As it is clear from the results table, the FSA algorithm outperformed the rest of the comparison algorithms, especially in the data set with a large number of frames with more runways (4, 5, 6, 7, and 8) and was closer to the optimal solution than the rest of the algorithms.

the Flamingo Search Algorithm demonstrates strong potential for improving aircraft landing scheduling.

Its optimization capabilities, adaptability to dynamic situations, and consideration of multiple objectives make it a promising approach for enhancing operational efficiency, safety, and environmental sustainability. However, further research and real-world testing are essential to address challenges and ensure the algorithm's practical implementation in complex air traffic management systems.

Conclusion

The Flamingo Search Algorithm presents a novel and promising approach to aircraft landing scheduling. Its inspiration from the flocking behavior of flamingos offers a unique perspective for optimizing landing sequences while considering multiple factors and adapting to changing conditions. With further development and validation, this algorithm has the potential to revolutionize aircraft landing operations, leading to improved efficiency, safety, and environmental sustainability in the aviation industry. The static aircraft landing problem's multiple runway situation, when the data are known in advance, has been covered in this study. The single-runway Aircraft Landing Scheduling Problem was taken into consideration, and the ALS was stated as a JSSP.
The ALS problem may be quickly and successfully solved with the suggested solution, FSA. This innovative swarm intelligence optimization method may completely offer a new solution for optimum design in several optimization issue study fields. These technical challenges can be solved more effectively with this new approach.

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Authors' Declaration

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours. Furthermore, any Figures and images, that are not ours, have been included with the necessary permission for re-publication, which is attached to the manuscript.
- No animal studies are present in the manuscript.
- No human studies are present in the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee at University of Mustansiriyah.

Authors' Contribution Statement

Z. O. A. contributed to the article by the conception, design, analysis, interpretation, and drafting of the MS manuscript. N. T. M. shared in the conception, analysis, interpretation, revision, and proofreading. S. M. A. participated in the conception, revision, and proofreading.

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[2]كلية العلوم السياسية، الجامعة المستنصرية بغداد، العراق.

الخلاصة

جدولة هبوط الطائرات (ALS) هي عملية تنظيم وصول ومغادرة الطائرات في المطار. تتم إدارة هذه العملية من قبل مراقبي الحركة الجوية الذين يستخدمون أدوات وتقيات مختلفة لضمان هبوط الطائرة وإقلاعها بأمان وكفاءة. الهدف من جدولة هبوط الطائرات هو تقليل التأخير وزيادة عدد الطائرات التي يمكن استيعابها في المطار. يتم ذلك من خلال التنسيق الدقيق لمواعيد وصول ومغادرة الطائرات، بالإضافة إلى عدد الطائرات التي يمكن استيعابها بأمان. بحث الفلامنغو هي خوارزمية تحسين مستوحاة من سلوك طيور النحام. إنها خوارزمية metaheuristic تعتمد على السكان وتستخدم سربًا من طيور النحام للبحث عن الحل الأمثل لمشكلة معينة. تعمل الخوارزمية من خلال جعل كل فلامنغو في القطيع يبحث عن الحل الأمثل المحلي. ثم تتواصل طيور النحام مع بعضها البعض وتتبادل الحلول. بالمقارنة مع تقنيات التحسين التقليدية، أظهرت التجارب أن الحل الذي قدمه أسرع بشكل ملحوظ وأكثر ملاءمة لمشاكل جدولة هبوط الطائرات في الوقت الفعلي فلقد اظهرت النتائج تفوق الخوارزمية المقترحة على بقية الخوارزميات بنسبة تجاوزت ٩٠ %. يمكن للطريقة المقترحة تحديد الحلول المناسبة بسرعة لجميع مجموعات البيانات الـ 8.

الكلمات المفتاحية: جدولة هبوط الطائرات، خوارزمية بحث فلامنغو، الخوارزمية الجينية، الأدلة العليا، التحسين.