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Optimizing Air Traffic Conflict and Congestion Using Genetic Algorithm

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Abstract: The problem of air traffic congestion isn't unique to developing countries like Unites States, Russia and China. How to accommodate an ever increasing flights is a global problem and a potentially dangerous one. The projections of aircrafts in the air have tremendously increased and is expected to lead to major accidents by 2015. The aircrafts have limitations of geography and limited reach of ground radar. But an experimental system of satellite control global positioning device would enable pilots to chart their own route called Free Flight. To solve the problem we have developed a New Air Traffic Management Simulation System that is according to the ideology of the New Air Traffic Management and the concept of Free Flight. This paper analyzes the design scheme and different module functions and use of genetic algorithms to give the methods to solve the aircraft conflicts and aircraft sequence takeoff-landing phases schedule in the terminal airport.

Key words: Air traffic simulation % Air traffic % Genetic algorithm

INTRODUCTION

The most important concern in air traffic controll (ATC) are increased air traffic volume and aircraft landing delays. According to statistics, world-wide air traffic is expected to increase to unexpected levels over the coming decades, likely to reach 4.5 trillion by 2016. Existing demands on the air traffic system routinely exceed the capacity of airports leading to air-traffic-imposed ground and airborne delays of aircraft. As stated in the estimates quoted in their website Airlines for America A4A "In 2011, 103 million system delay minutes are estimated by A4A to have driven $7.7 billion in direct aircraft operating costs for scheduled U.S. passenger airlines." In USA alone, this has been estimated to cost domestic airlines as much as $3.5 billion per year. In the progressively more competitive airline industry, with its market-driven pricing and very less profit margins, such economic operating penalties are magnified and can be reduced [1].

New Air Traffic Management Simulation System (it will be called NATMSS on the next text) is an emulate system that has taken the concept of the New Air Traffic Management System and Free Flight mode, used to reform air traffic management system and to increase the technical development foreland of the advanced country. The Free Flight mode or automated Flight mode that allows the pilot to choose the flight speeds, optimizes flight speed, takeoff, ascent, cruise (level flight), descent, approach and landing phases [2].

The New Air Traffic Management System has been approved and accepted by the International Civil Aviation Organization (ICAO). After long years of research and development, the advanced countries like United States of America, Russia, Australia and China have made a substantial achievement and have launched the global satellite communication system and used for messaging, autopilot, controlling various critical issues in airline including aircraft collision, controlling aircraft in adverse weather conditions like rain or fog.

The Analysis and Design of the NATMSS(New Air Traffic Management Simulation System)

The Design Idea of the NATMSS: The research and development of the NATMSS is used mainly to solve the problem of the rapidly growing and developed air traffic flow in China. Hence there must be optimum utilization of runways and other resources to efficiently manage and coordinate the air traffic control system. The objective of NATMSS is to build an automatic network control system

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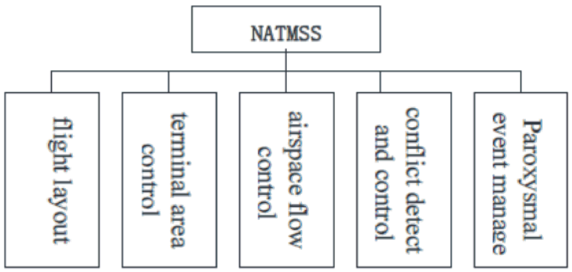

Fig. 1: System function structure

that consist of airspace and ground control management by means of joining the several part data set as a integrative 4D (3D +time) track information data set, these part data set come from the satellite communication system, the ground navigation system and the airborne orientation system. For the purpose, initially we use all the static scheduled flight plans to calculate model to form a static air traffic management data set initially, then to vary or re-compute this new data set by convulsive event, such as the atrocious weather or the airport malfunction and ensuring that the adjustment or varying recomputed value has a least total cost [3].

The Function Analyse of the NATMSS: The NATMSS is consist of five function modules which are flight layout, terminal area control, airspace flow control, conflict detection and control, paroxysmal event manage.

The NATMSS depends on the flight layout subsystem to perform its responsibility. The flight layout subsystem is consist of two function parts: the static flight plan assignment function part and the dynamic flight plan adjustment function part. The function of part one i.e static flight plan is to capture the routine manage plans such as which flights would take-off on which runway and land on a particular runway, fly route distribution among aircrafts, airspace surveillance etc, based on the flight plans existing statically in the approved plan . The dynamic flight plan adjustment function part is to change these plans dynamically and adapt to the sudden changes in the event due to the fiery weather changes or sudden flight route changes .The concept of free flight is used widely in this case [4].

The function of the terminal area control subsystem is the kernel function in the whole system and is the major bottleneck to determine business flow in the Civil Aviation. In this subsystem, we calculate the total number of take-off and landing phases limits of every terminal airport in the country as the base strategy to determine the maximum flow on each fly route way which belongs to one airport to be controlled by the system and then we can get the optimum efficiency by means of adopting the genetic algorithm to realize the automatic take-off and landing phases.

Genetic Algorithm manages the complex task of scheduling arriving aircraft to the available runways in a manner that minimizes delays and satisfies safety constraints. The function of the airspace flow control subsystem is to realize the optimum flow control by means of adopting multiple dynamic tasks network compute model based on the genetic algorithm. The function of the conflict detection and control subsystem is to detect conflicts of all flying flights and disengage these flights out of the dangerous state by using the satellite orientating function data and the flying report data and the radar surveillance data and ensure that all of the flying flights are safe. The function of the paroxysmal event manage subsystem is to handle the emergency events effectively and in timely manner so that the effect of these special events on normal flights take-off and landing phases in such as snowstorm or fog should be minimal. This paroxysmal event manage subsystem will restart the dynamic flight plans adjustment function part which is belonged to the flight layout subsystem to re-compute all the effected flight plans and has a least total cost for delay cost of all the adjusted flights. In the mass, if this emulation system can be called a high efficiency system is determined by the function practicability of fly conflict detection, take-off and set-down control, fly route flow control.

The Fly Conflict Detection and Extrication Algorithm Based on Genetic Algorithm

Genetic Algorithm: Genetic Algorithm (be called GA on the next text) are probabilistic search approach based on evolutionary processes.. It can solve the question with the property of application foreground and adapts to construct every kind of complex forecast model which supports to get their answer data in the air traffic control realm. Genetic Algorithms makes use of search and evolution to produce several solutions to a given problem. It includes operators of selection, cross-over and mutation. It includes five basic factors, they are the parameter decode, race cluster initialization, adaptive functions design, inherited manipulation design, control parameters initialization and convergence functions design.. On the other hand, GA has some disadvantages such as the shortcoming in solving the question about multi-levels, absence of dynamic changeability, selecting proper fitness function. So we must design the restricted conditions and replacement rules as perfect as possible, or integrate other effective algorithm when we use it [5].

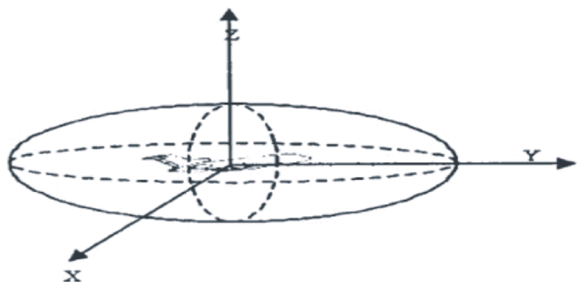

Fig. 2:

The Model and Method for Flight Conflict Detection: T The current research is about aircraft conflict detection and disengage between the safe paths of two aircrafts is basically of how to build a safe area model based on relative rules of fly alternation. We consider that a conflict will be produced when an aircraft goes into the protected safe area of another aircraft and must handle the conflict at once. The safe area is designed as an ellipsoid that sketch map is showed in Figure 2.

We set the aircraft's centre of mass as the centre point of ellipsoid, use the horizontal alternation as the semi-major axis, use the vertical alternation 'd' as the semi-minor axis. The projection of the ellipsoid is a circle on the surface of XOY with a radius equal to 10 kilo-meters and the projection is an ellipse on the surface of XOZ and YOZ with a semi-major axis equal to 10 kilo-meters and a semi-minor axis equal to 0.6 kilo-meters [6].

If we define the position of the aircraft as the center point of coordinates system, thus the boundary of the ellipsoid can be denoted as expression as below:

$$\frac{x^2+y^2}{S^2}+\frac{z^2}{d^2}=1 \tag{1}$$

According to the aviation standards, we consider that the conflict must be created and exist when the distance between any two aircrafts is less than the minimum safe alternation between the aircrafts. If we designate the barycentric coordinates of the two aircrafts Ai and Aj as (xi, yi, zi) and (xj, yj, zi), then the vector of the relative position of the two aircrafts can be expressed as ()x,)y,)z) .Hence we can deduce the distance of the two aircrafts from their geometric relation, the result expression is showed below:

$$\sqrt{\Delta x^2+\Delta y^2+\Delta z^2} \tag{2}$$

The length of the relative position of aircraft Ai in the safe area of aircraft Aj is expressed as below

$$\sqrt{\frac{s^2 d^2.(\Delta x^2+\Delta y^2+\Delta z^2)}{s^2.\ \Delta z^2+d^2.\ (\Delta x^2+\Delta y^2)}} \tag{3}$$

The distance of the two aircrafts called ' rij' can be expressed as below:

$$r_{ij}\sqrt{\Delta x^2+\Delta y^2+\Delta z^2}-\sqrt{\frac{s^2 d^2.(\Delta x^2+\Delta y^2+\Delta z^2)}{s^2.\ \Delta z^2+d^2.\ (\Delta x^2+\Delta y^2)}} \tag{4}$$

So the condition when the is conflict produced between two aircrafts is r ij<= 0.

The Design of Genetic Algorithm for Solving the Fly Conflict: The primary key to determine the performance of genetic algorithm is to decide the initial value to the two parameters of this algorithm which called the cross-probability (named Pc) and the aberrance probability (named Pm) also called mutation probability [7]. The selection of Pc and Pm plays a crucial in determining the performance of genetic algorithm. If the value of Pc is too large, it will make the new individual gene to be created too fast and will increase the possibility of destroying the genetic pattern. On the other hand, if the value of Pc is too small it will make the work of searching to became slow more and more, at last to be stopped. If the value of Pm is too small it will make the new individual gene to be created too slow. But if the value of Pm is too big it will make the genetic algorithm to be retrogressed to a common random searching algorithm.Thus, it is very difficult to get the optimal values of Pc and Pm to suit each problem [8].

A new self-adaptive genetic algorithm named AGA determines that the parameters Pc and Pm can automatically change following the adaptation in the new algorithm AGA. The detail operations of AGA are that to increase the values of Pc and Pm when all race cluster of genes become as same and get to local optimization and to decrease the values of Pc and Pm when all race cluster of genes become dispersed. At the same time, set Pc and Pm to lower values for the individual gene which has the higher adaptive value than the average of whole race cluster of genes to make sure these genes go into the next generation and set values of Pc and Pm to high for the individual gene which adaptive value is lower than the average level to make these genes to be eliminated The values of Pc and Pm are set by according to the expressed as below when use the AGA to solve the problem of fly conflict [9].

$$P_c = \begin{cases} P_{c1} - \dfrac{(P_{c1} - P_{e2})(f' - f_{avg})}{f_{\max} - f_{avg}} \\ P_{c1} \end{cases}$$
$$P_m = \begin{cases} P_{m1} - \dfrac{(P_{m1} - P_{m2})(f_{\max} - f)}{f_{\max} - f_{avg}} \\ P_{m1} \end{cases} \quad (5)$$

Some parameters in the expression:

fmax ---- max adapt value in race cluster
favg ----- average adapt value in a general of race cluster
f ----- the bigger adapt value of crossed two individuals
f ----- the adapt value of the individual to be mutated

The detail operation of AGA is listed below:

- Step 1, designate a concrete space area to solve the conflict and to be extricated or disengaged .
- Step 2, create some air routes randomly according to the rules of AGA in the space area.
- Step 3, use the fitness function and constraints to evaluate every air route which is newlycreated. The purpose of using aim fitness function is to make sure to keep the least windage or difference between the new route and the original route. The constraints make sure that each new route has a safe alternation to the any other one [10].
- Step 4, take the actions of selection, crossing and mutating. Repeat step 3 and 4 until we have get the usable result data, at this time we can use the result data to solve the current fly conflict.

The fitness function is expressed in below. The n is the number of aircrafts in the sector. The Si is the difference between the real distance of route in extrication or disengaged area and the distance of original route.

$$y = \sum_{i=1}^{n} S_i \quad (6)$$

The constraint here is the least distance between the aircraft Ai and Aj. It is expressed as rij > 0.The NATMSS will exam if has the fly conflict between the flight path produced by AGA and other aircraft. If the conflict is existed that we set the adapt value equal to 0 to the chromosome of the individual gene, otherwise, for each aircraft i to calculate the difference named di between the real distance of route and the distance of original route. At last we can determine the value by using the expression below.

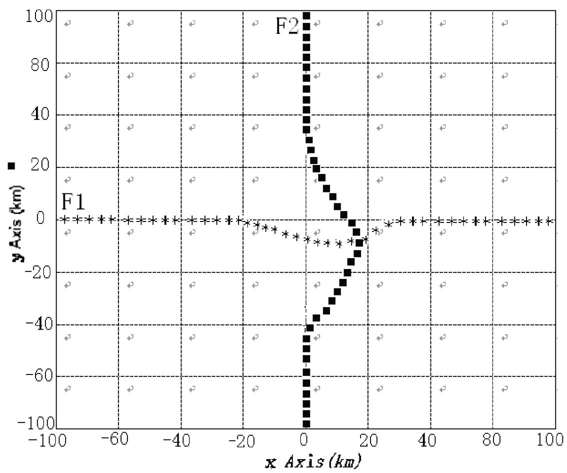

Fig. 3: Conflict extrication map

$$f = e^{\frac{\sum_{i=1}^{n} S_i}{k}} \quad (7)$$

Constant k must be set compatibly to keep the high efficiency of the exponent function in the expression. We hope the point on the new route at where the conflict is solved should be more closer to the original route, so we has add a punish function f to the adapt value which is created just now. Expression f is showed below, parameter d is the summation of all the distance of the extrication point to the out point of the original route for n numbers aircrafts.

$$f = \begin{cases} f - 0.05, & 0 < d' < 10 \\ f - 0.10, & 10 < d' < 20 \\ f - 0.20, & d' > 20 \end{cases} \quad (8)$$

Next figure is the sketch map of conflict extrication (chart)

Scheduled Flight Sort Algorithm Based on Genetic Algorithm: Most of the airports in our country are modern with multi- runways currently, hence to arrange the takeoff and landing on the multi-runways for aircrafts perfectly is a typical problem of a nonlinear, optimized and combined. It is suitable to be solved by genetic algorithm.

Design of Individual Gene and Race Cluster: Supposing that there are n numbers of scheduled flights flying on an airport with m numbers of runways, sequence Ai(i=1,2,...n) delegate the scheduled flights that have known the information such as flight-type, take-off and landing time, total passenger number etc. If define the chromosome named A[k] (k=l, 2, m) for sorting all the scheduled flights (A1, A2,..An) which has the take-off order of time sequence on the multi-runways 1 to m, the A[k] is a gene just at the position number k on the hereditary coordinate, also this gene is the flight Ai in the all scheduled flights, at last the gene is the only initial state which corresponds to the time state of a fight stepping into or out off. Now we can set the initial state by selecting the number of original chromosome equal m, then form a waiting sequence of take-off flights on one of multi-runways . Finally, we form the all initial states of the whole throng named A[1], A[2], A[m]. and the other states of chromosome are created symmetrically from the scheduled flights sequence A1, A2, ...An.

Adapt Function of Arrangement of Scheduled Flights: The adapt function F working for arranging the scheduled flights is listed below. Parameter ái is rights add factor and ái is always bigger than 0. Parameter m is the total of all adapt functions. Parameter Fi is each adapt sub-function.

$$\min F = \sum_{i=1}^{m} a_i F_i(A_{[i]}) \tag{9}$$

Restricted Conditions: Define the collection A={l 2 ...n} as the data set of the scheduled flights, Ain is a variable that denotes the sub-collection of landing flights, Aout is a variable that denotes the sub-collection of take-off flights, thus Ain A and Aout A.

Define L is the length of runway, Vi-min(i=1,2,...n) is minimum speed of flight i, Vi-max (i=1,2,... n) is maximum speed of flight i, hi is the real arrived time of flight i, Ehi is the earliest arrived time of flight i, Lhi is the latest arrived time of flight i, Yij is a dualistic parameter denoting the time order of two flights i and j, if flight i arrived before flight j that Yij equal 1, otherwise equal 0.

The restricted conditions is showed below:

Ehi#hi#Lhi	(i=1,2.....n)	(11)
Ehi=L/Vi-max	(I=1,2....n)	(12)
Lhi=L/Vi-min	(I=1,2....n)	(13)
Yij=1	(i, j=1,2,...n; i>j)	(14)
Yij={0,1}	(i, j=1,2....n; I#j)	(15)

Genetic Arithmetic Operators:

- C Select: Save or delete strategy, eliminate the sort gene has a low adaptability.

Table I: Emulation Sort Result by Using ga

	Sort by time order				Sort by GA			
Flight Num	Run ways	Takeoff time	Delay (S)	Sum of delay (S)	Run ways	Takeoff Time	Delay (S)	Sum of delay (S)
Flight-1	0	10:01:08	0	0	0	10:01:08	0	0
Flight-2	2	10:03:42	110	110	1	10:03:12	80	80
Flight-3	1	10:05:12	0	110	2	10:04:23	0	80
Flight-4	0	10:06:05	0	110	0	10:05:45	0	80
Flight-5	2	10:08:33	40	150	1	10:07:29	20	100
Flight-6	1	10:10:56	28	178	2	10:09:17	15	115
Flight-7	2	10:12:24	56	234	1	10:11:38	45	160
Flight-8	0	10:13:19	0	234	0	10:12:58	0	160
Flight-9	1	10:14:28	22	256	2	10:13:35	30	190
Flight-10	0	10:16:45	10	266	1	10:15:48	10	200
Flight-11	2	10:17:05	0	266	0	10:16:56	0	200
Flight-12	0	10:19:28	0	266	1	10:18:28	15	215

- C Cross: Adopt the sequence cross of multiple points. Reverse all genes in the hereditary coordinate of the chromosome to create new chromosome generation.
- C Mutation: Adopt the shift operation of multiple points and converse action of single point in the whole space created by flight sorting chromosome. Converse action means set gene n to the position 1 and make followed genes 1, 2, n-l move backward.

Table1 lists out the emulation result data from a airport which has 3 runways and manage 10 flight at one moment by using genetic algorithm.

CONCLUSIONS

Genetic algorithm can solve the fly conflict and airport terminal arrangement efficiently and economize the fuel oil by commanding the aircraft to fly along the direct air line and the lowest waiting cost or hold time. Looking at the engineering and adopting the GA can get optimum emulation results when passed through a iterative loop and it will be the most available and effective tools to proofing to manage and level in air traffic control.

REFERENCES

1. Xiao Bng Hu and Ezequiel D.I. Palo, 2007. An efficient genetic algorithm with uniform crossover for air traffic control. Department of Informatics, University of Sussex, Falmer, Brightton.
2. Hang Guo, 2012. Application of Genetic algorithm in the New Air Traffic Management Simulation System, lecturer, Computer Science and Engineer Dept of CAUC, Tianjin City, China.
3. Zhao Yifei, May, 2010. Air Traffic Congestion assessment method based on evidence, IEEE Conference Publications.

4. Howe, B., 2003. Potential air traffic congestion solution: slot allocation by auction method, IEEE Conference, Syst. Eng. & Operations Res. Dept., George Mason Univ., Fairfax, VA, USA.
5. De Armon, J., 2005. Advanced congestion management: benefits of what-if modeling of compound flow-control actions Digital Avoinics System Conference, 2 MITRE Corp., McLean, VA, USA.
6. Tatyana Aleksandrovna Skalozubova and Valentina Olegovna Reshetova, 2013. Leaves of Common Nettle (Urtica dioica L.) As a Source of Ascorbic Acid (Vitamin C), World Applied Sciences Journal, 28(2): 250-253.
7. Rassoulinejad-Mousavi, S.M., M. Jamil and M. Layeghi, 2013. Experimental Study of a Combined Three Bucket H-Rotor with Savonius Wind Turbine, World Applied Sciences Journal, 28(2): 205-211.
8. Vladimir G. Andronov, 2013. Approximation of Physical Models of Space Scanner Systems World Applied Sciences Journal, 28(4): 528-531.
9. Naseer Ahmed, 2013. Ultrasonically Assisted Turning: Effects on Surface Roughness World Applied Sciences Journal, 27(2): 201-206.
10. Tatyana Nikolayevna Vitsenets, 2014. Concept and Forming Factors of Migration Processes Middle-East Journal of Scientific Research, 19(5): 620-624.