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SYNTHESIS OF AIR TRAFFIC CONTROLLING ON THE BASE OF ARTIFICIAL GRAVITATIONAL FIELDS METHOD USING

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Abstract. *For investigation of artificial gravitational fields method was modeled the movement of two conflicting aircraft with the different angles of Ψ, was presented the area of the control states with the degrees of development.*
Keywords: attractive forces; conflict resolution; gravitational field; pendulum's radius; repulsing forces.

1. Problem statement

Air traffic will grow exponentially in the coming years.

As the number of flights will increase the number of flight delays will increase also.

The problem of conflict resolution is the result of safety flights.

Therefore, this issue is one of the most important at air traffic.

The methods of conflict detection are known exactly now and are in use. But resolution methods are not developed in proper way, some of disadvantages are present.

A conflict is defined as two or more aircraft coming within the minimum allowed distance and altitude separation of each other.

Thus today appeared a problem for the formation of aeronautical environment and air traffic management with taking in to account modern technologies development and insufficient capacity of existing scientific and methodological apparatus, in other words, the imperfection of the methods and techniques.

2. Analysis of researches and publications

As a result, the prospect of development is the formation of a new type of air navigation space, which has a fundamentally new properties virtuality, distribution, large dimension, handling and supervision, autonomy, robotic expansion if supported by the regulated level of security of all shareholders.

There is exists in the literature, an analysis of existing methods of conflict resolution, and the basic groups, such as optimization, manual, prescribied, force field and no resolution [3].

Prescribied conflict maneuvers resolution set during system design is based on a set of predefined operations.

The system gives a warning when there is a conflict, but does not perform additional calculations to avoid conflict.

Optimization approaches usually combine a kinematic model with the cost function. Optimization strategy is determined by finding the trajectories at the lowest cost. But with the introduction of a lot of parameters to the cost function there is an increase occure in the model of the controlled process.

According to the force field approach the aircrafts are considered as the charged particles and uses electrostatic equations to generate maneuvers to resolve the conflict.

Repulsive forces between the planes used to define the maneuver to avoid a collision.

This method is based on the solution of simple equations, but it can have some pathology that may require additional consideration before this method realized in other words the realization complexity of obtained maneuvers trajectories.

The model does not provide a clear conclusion or action warning on certain trial decisions by the user. This model performs detection of conflicts but is not intended for explicit consideration of conflict resolution .

Another method is probabilistic . A probabilistic approach enables a balance between the model trajectory or a set of best maneuvers.

Probabilistic method is the most general: nominal and worst-case probabilistic model subsets of trajectories.

Nominal trajectory corresponds to the case where the aircraft will follow a given (maximum likelihood) trajectory with probability equal to one, the worst case model in which the plane will follow any trajectory with equal probability.

However, the logic of probability is difficult to convey to the operators, reducing their confidence.

But the model can not be accepted in such cases as: the process has a random nature and if a set of experimental data is insufficient to obtain the characteristics of random processes.

It is so called options exist: generic algorithm that means all of the conflict resolution lies in the nature processes. Answers can be found through the exploration of the species evolution.

The same complex mechanism can be applied in the CR.

The idea is that, a random population of possible solutions in case maneuvers or routes is generated. After goes the process of fitness function applying in order to select solutions that are allowed to "breed".

To evaluate the fitness function every solution in the sample has to be simulated by using a high computer processor load.

Mutations and crossovers are applied during the breeding of the next generation of solutions. Then the fitness function is applied again and the process starts all over.

The population becomes fitter with the next iteration (or generation).

The fitness level of the fittest solution in the population can be used to decide to stop the process. This fittest sample is then used as the final solution. During this process, some random elements are present in the selection and mutation function to ensure variety of solutions.

Such method has its own disadvantages.

The first one is that process is not very clear to the crew, since the random effects might have caused the direction in which the solution evolved. About 50 generations will be involved in the process.

Such calculation is very intensive computationally and the power of FMS is not as high as at can be on the desktop computers.

Also many restrictions should be applied during iterations calculation on the mutation process. By the other words the result of the restrictions is a very deterministic process, which results in the same solution as a less computationally intensive and safer old-fashioned mathematical algorithm.

3. Aim of the work

The goal of this work is systematization of existing resolution methods and introducing of synthesis air traffic controlling on the base of artificial gravitational fields using. With respect to the aeronautical environment, these principles describe the behavior of dynamic objects that would provide a solution to special problems of dynamic objects, provided a guaranteed resolution of conflicts between them and provide a given level of safety.

4. Application of artificial gravitational fields method

Existing in the nature systems are successfully functioning. It can be said that the complexity of this system is much higher that the ANS complexity.

Thus, solution to this problem must be found in the laws and properties of the natural world to integrate and self-organize, in other words synergetics.

It is an interdisciplinary science explaining the formation and self-organization of patterns and structures in open systems far from thermodynamic equilibrium [2].

According to M. Eby [1] the dynamic objects within the ANS area considered through the individual actions of each object to achieve their goals for a given level of security, and not through the plan imposed on the elements outside.

As a self-organization model ANS offers

The essence of these properties is the presence of attractive forces between heterogeneous charged particles and repulsive forces between the charged particles in uniform electric field.

As uniformly charged particles presented dynamic objects such as aircraft, unmanned aerial vehicles and their targets as airfields, intermediate route are assigned to opposite charges.

However, the proposed method of resolving conflicts between dynamic objects within the ANS is based only on the standard geometric calculations and does not contain elements that reflect the physical properties of nature.

Applying to the ANS environment with the presence of conflicting elements, the efficiency of the system can be considered stable, without the "domino principle".

The increase in conflicts due to conflict resolution is the "Domino Effect Parameter (DEP)", defined as difference of the ratio of the number of conflict alerts with no conflict resolution to the number of conflict alerts with conflict resolution and one.

Attractive and repulsive forces are constructing a gravitational field; they are a base for the realization of synergetic principle. In other words, it represents the unity of possible and desirable.

Every gravitational object is a material point with its own mass, with the full set of gravitational forces.

The full set of each object's gravitational forces have the symmetry properties.

From the position of classical mechanics the gravitational field's symmetry, every gravitational positive field exists simultaneously with negative gravitational fields.

The example of synthesis based on the artificial field's method control is presented in the form of two conflicting airplanes. Modeling was performed with the help of environment Matlab, on the field of 200 ×200 km, on the altitude of 10 000 m, with the speed of 800 km/h, for the two planes Boeing 747.

The starting and finishing positions of each dynamic object (airplanes) are the gravitational objects with the masses of the greater meanings from active elements.

The modeling was performed for different angles of Ψ, that were equal to 30°, 45° on the Fig. 1, a 90° on the Fig. 1, b 180° on the Fig. 1, c for the different masses of goals with different pendulum's radiuses.

According to which the minimum distance between the objects obtained.

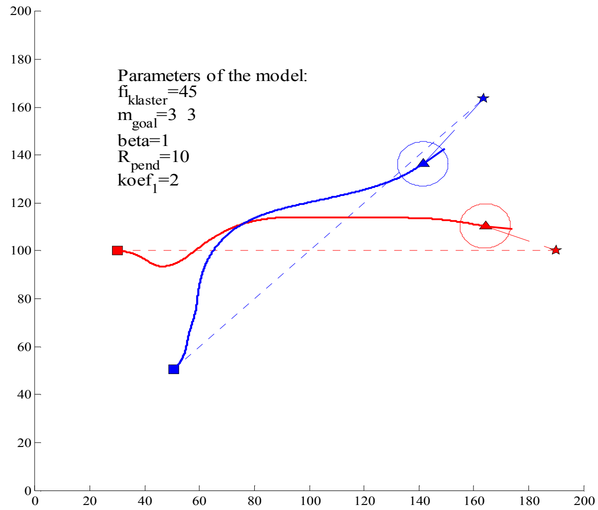
The control vector was presented as:

Rgiven=f (R_pendulum, m_goal, m_i).

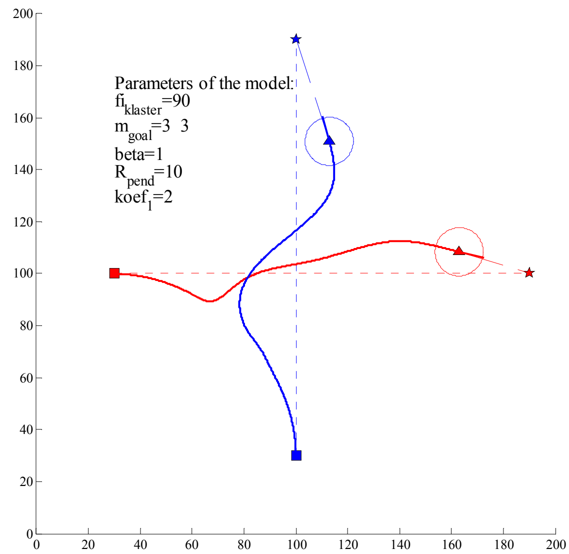
Kinematic properties of dynamic objects are determined by the energy, feasibility and parametric characteristics of the corresponding to the real objects of aeronautical space.

Thus, the movement of every object is performed corresponding to the available energy.

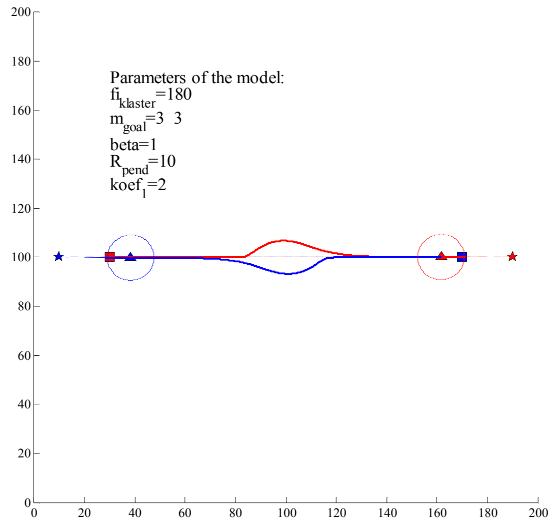
With every moment of time, the calculating of angle Ψ is taking place. After, it is transmitted as the control signal on the velocity vector's deviation.



a



b



c

Fig.1. Representing of the aircrafts movement with the mass of goal 3, radius of pendulum 10:
a — Ψ=45;
b — Ψ=90;
c — Ψ=180

The direction of elements movement is given by the angular position of Ψ of virtual measurer. The pendulum systems can be used as measurers, which are composed from the body of measurer with the mass m_i, mounted on the rigid axis that does not has a mass. The other end of the pendulum's pendant with the corresponding coordinates to coordinates of dynamic object.

At every step the calculation performed of the available direction, the movement by which provides the objective function minimization.

Also was calculated the permissible direction in accordance with the distance which was gone, from the starting point to the goal.

During this process the minimum distance between two aircraft is calculated and the limits of the protection zone are taken into consideration. It is illustrated on the Fig.2.

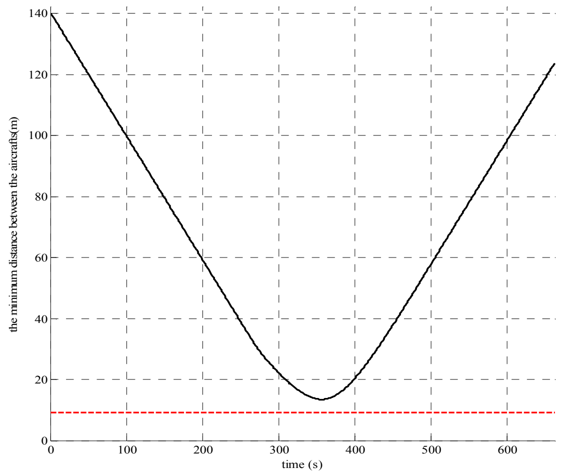


Fig. 2. Represents the changing of the distance between the aircrafts with time

There are exist such places at which controlling is impossible they are marked by red color lines (Fig. 3).

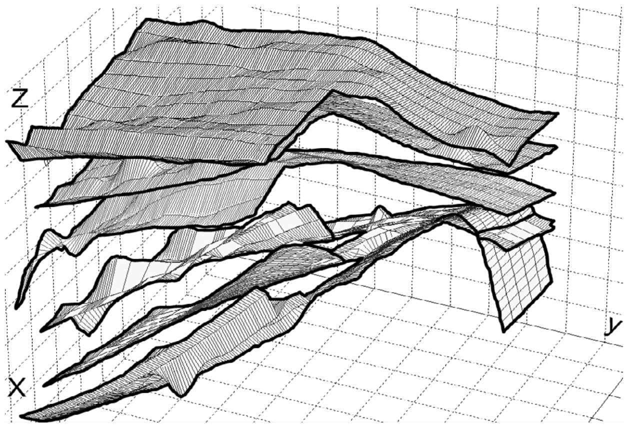


Fig.3. The area of controlling states:
X — the mass of goal;
Y — minimum distance between the aircraft;
Z — the pendulum's radius

So those are not taking in to account when the values are chosen.

The given radius can be taken and with the help of degrees of development, the meanings of goal's mass and pendulum's radius can be chosen, in correspondence with the required angles of Ψ.

The values of goals mass and pendulums radius can be taken in the limits which are presented, an example is introduced on the Fig. 4, where Radius of protected area zone is constant

$$R\_pendulum = [R_{min}, R_{max}]$$

and

$$m\_goal = [m_{min}, m_{max}].$$

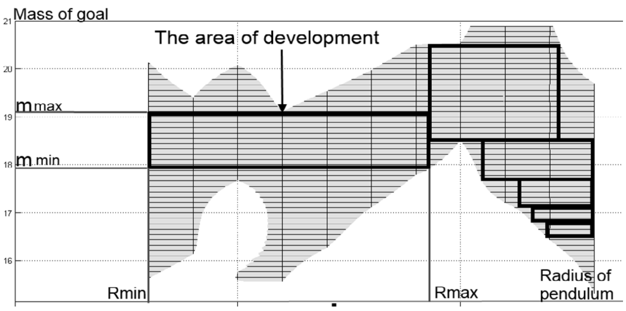


Fig. 4. The level of development, for the Ψ=45, given radius 15

5. Conclusions

The problem of two conflicting airplanes was solved with the help of artificial gravitational fields methods. The modeled controlling system is can be easily used for the conflicts resolution, by the adjusting of necessary parameters with the help of calculated levels of development for the different klaster's angles. The conflicting problem is solved for the different situations. During this work was described the behavior of dynamic objects that would provide a solution to special problems of dynamic objects.

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В.І. Чепіженко[1], Н.О. Соломіна[2]. Синтез управління повітряним рухом на основі використання методу штучних гравітаційних полів
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Для дослідження методу штучних гравітаційних полів змодульовано рух двох конфліктуючих літаків з різними кутами Ψ. Наведено область керованих станів з різними ступенями розвиненості.

Ключові слова: вирішення конфлікту; гравітаційне поле; радіус маятника; сили що притягуються, сили що відштовхуються.

В.И. Чепиженко[1], Н.А. Соломина[2]. Синтез управления воздушным движением на основе использования искусственных гравитационных полей
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Для исследования метода искусственных гравитационных полей промоделировано движение двух конфликтующих самолетов с различными углами Ψ. Представлена область управляемых состояний с различными степенями развитости.

Ключевые слова: гравитационное поле; отталкивающиеся силы; притягивающиеся силы; радиус маятника; разрешение конфликта.

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