Kyrianov Artemiy, Heorhii Loutskii.

RESEARCH OF NATURAL SWARE INTELLIGENCE FROM ADAPTATION TO THE SYSTEM OF DRAIN NETWORKS

The article discusses the issue of combining drones into one network based on natural swarm intelligence. Algorithms for the behavior of a shoal of fish and a swarm of bees were considered. The technical composition of drones is analyzed and the whole algorithm of quadcopter construction is proposed with the consistent goal of improving drones and creating a network of drones.

Keywords: drone swarm intelligence, drone construction algorithm, drone network

Fig.: 11. Bibl.: 10.

Relevance

A promising area in the use of UAVs is their association in groups or in a swarm. The principle of swarm organization is observed in insects and fish. In the case of drones, after combining them into a swarm, each drone is controlled by its own automation, and the swarm behavior can be controlled by a program with AI elements or one (several) operators.

The article presents the algorithms and components of the association of free riders in groups or swarms and possible options for using such associations to solve various problems.

Formulation of the problem

Disadvantages and limitations of the use of UAV groups

Since the possibilities of concentration and multitasking are limited, engineers are developing systems to manage multiple drones as a single swarm. The main technological problem facing the developers of such systems is the difficulty of positioning the drones and tracking the position of each of them without errors and delays.

High computing capabilities are required on board the UAV for the interaction of UAVs in flight as part of a group and the preliminary processing of the collected information in real time

Necessary new types of control software:

- Integration of the UAV group management system and payload software is desirable
- Unmanned aerial vehicles in a swarm should not only not collide, but also should not interfere with each other by the air flows created by them.
- Unmanned aerial vehicles in a swarm should be able to collectively distribute "specialties" and, if necessary, redistribute assignment data to
- individual members of the swarm, for example, if one or another "specialist" fails.

Communication

Drones are controlled via the complete remote control or smartphone.

Most quadrocopters use radio channels for communication at frequencies of 2.4 or 5.8 GHz. In the first case, devices are cheaper, but their work is affected by the ubiquitous interference in the form of smartphones, Wi-Fi routers and other household appliances.

The signal transmission at a frequency of 5.8 GHz is used mainly in expensive professional quadrocopters, there are less interference, and the flight radius can be greater.

Almost all drones operate at a frequency of 2.4 GHz, while the drone acts as a Wi-Fi access point, and the remote control or smartphone from which control is connected is connected to it.

Some models can simultaneously communicate with both the remote control and the smartphone. The first one is responsible for control, and the second signal is output from the built-in

Differences between 2.4 and 5.8 GHz

The primary difference between the 2.4 GHz and 5.8 GHz wireless frequencies is the signal range. When using a frequency of 2.4 GHz, the signal is transmitted over a longer distance, compared with a frequency of 5.8 GHz. This is due to the main characteristics of the waves and occurs as a result of the fact that at a high frequency the waves decay faster. Thus, to cover the signal over long distances, you should choose a frequency of 2.4 GHz, rather than 5.8 GHz.

The second difference is the number of devices operating at these frequencies. At 2.4 GHz, the wireless signal is more susceptible to interference than using 5 GHz.

Short frequency comparison:

- The frequency of 5.8 GHz has a shorter range than the frequency of 2.4 GHz;
- The 2.4 GHz frequency is more busy than the 5.8 GHz frequency; devices at 2.4 GHz experience more interference than devices at 5.8 GHz;
- Fewer devices support the 5.8 GHz channel than the 2.4 GHz channel.

Signal delay at a frequency of 2.4 GHz from 2-3.8 ms.

The flight range of the quadrocopter depends on the power of the transmitter installed on the control panel.

Typically, the flight range is about a kilometer, since control panels using a frequency of 2.4 GHz have a guaranteed range of 900 meters.

If you fly outside the city and rise higher into the sky with distance, then the range can be up to 2 kilometers from the take-off point.

In order to fly further, one must use signal amplification or use radio control equipment with a more powerful RF part.

For longer flights, you can go in several ways

1.a. Increase in flight range due to antenna

Fig. 1. a. Parabolic reflector. b. Intermediate amplifier[10]

You can install an antenna with a large dBi or install a parabolic reflector.

Despite its simplicity, such an antenna amplifier works, on average, gives an increase of 900 meters to flights without an amplifier.

1.b.Installation of the intermediate amplifier on the quadrocopter control panel

A conventional control panel has a transmitter power of 10mW, if an intermediate amplifier of 1-2 watts is placed between the RF part and the antenna, then the flight range from 900 meters will increase to 10 kilometers.

Sensors for quadrocopter orientation in space.

Ultrasonic sonar is well suited for automatically turning on landing lights (landing site lights) in the dark, because the lights must be turned on at a height of less than 3 m. This is the distance at which a conventional sonar module starts to work quite accurately and stably.

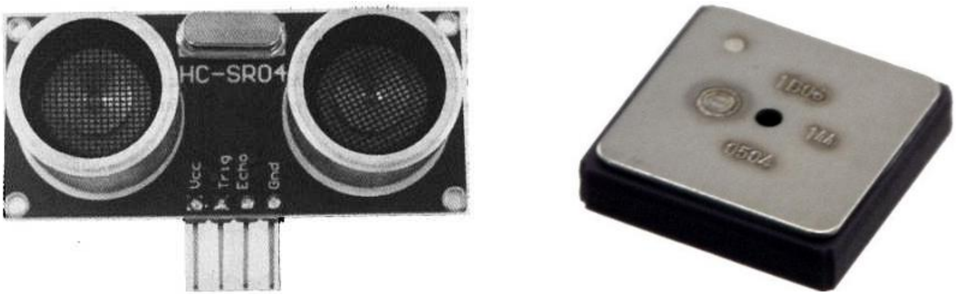

Fig. 2. a.Ultrasonic Sonar HC-SR04.

b. Atmospheric pressure strain gage device[9]

Integrated Barometer Device

The measurement of flight altitude by the barometric method is based on the dependence of atmospheric pressure on altitude. The higher the altitude, the lower the atmospheric pressure. In miniature integrated barometers, a strain gauge or piezoresonance sensor is used, as a rule (Fig. 2. b.).

The principle of operation of the integrated magnetometer (compass)

The design of the integrated magnetometer (Fig. 3.a.) is based on the anisotropic magnetoresistive effect. The sensitive element is made of permalloy film, capable of changing its resistance depending on the direction of the current flowing through it and the direction of its magnetization vector. In turn, the magnetization vector of the film is determined by the direction of the lines of force of the magnetic field in which the sensitive element is located.

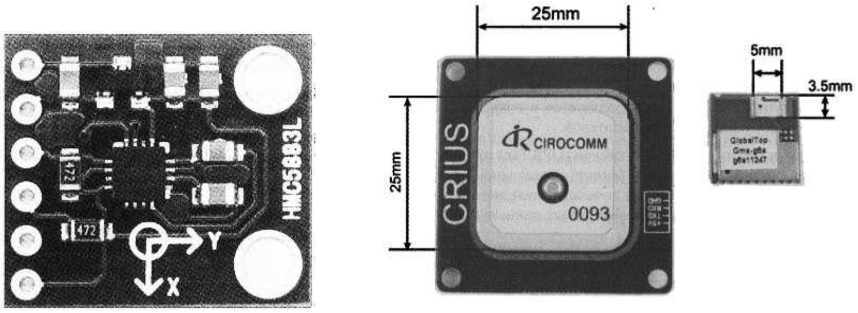

Fig. 3. a. Integrated Magnetometer Device.

b. Ordinary ceramic GPS antenna and miniature chip antenna

GPS Antennas

The antennas of portable GPS modules have a specific design. Usually this is a ceramic block with metal elements deposited on it by the electrochemical method.

The speed and accuracy of positioning depend on the location of the satellites in space relative to the receiver. The best option is to evenly distribute several satellites in the hemisphere above the receiver(Fig. 3.b.) In relation to the geometric factor, the GLONASS orbital structure is more successful than GPS NAVSTAR

FPV system

Flight Per Video or First Person View (Fig. 4. a.)

The video equipment of the copter consists of the following components:

- video cameras, course and main;
- video switch;
- stabilized camera suspension;
- image overlay information module (OSD);
- video transmitter;
- omnidirectional antenna.
- power supply for video equipment.

The ground part of the video channel also consists of several components:

- video receiver;
- antennas, omnidirectional and directional;
- antenna position control system (tracker);
- video glasses and / or monitor;
- video recorder;
- power supply.

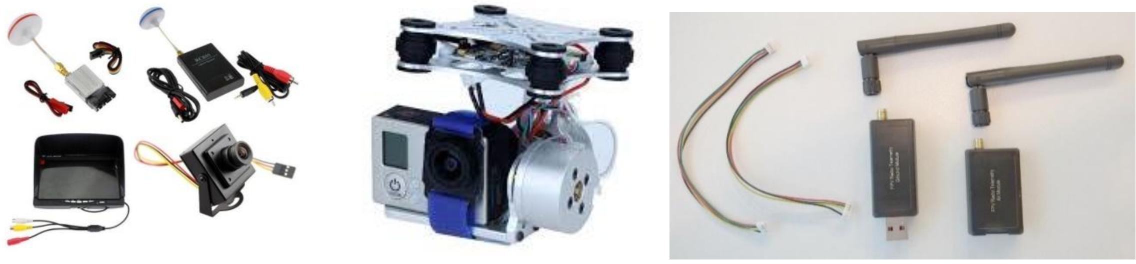

Fig. 4. a. Equipment for FPV b. Dual-axis gimbal
with its own controller and brushless drive c. 915 MHz telemetry

The delay in the FPV signal from the quadrocopter to the operator console is 100-250 ms.

Biaxial suspension

The gimbal is equipped with an independent controller with accelerometers and gyroscopes, which tracks the angular position of the camera and compensates for the slightest deviations. Recently, for the rotation of the suspension, brushless motors of a special design are used (for sui, stepper motors)

Telemetry

Telemetry is needed in order to receive on-the-fly information on speed, temperature, flight altitude, battery consumption and voltage, know the location of the drone (GPS coordinates), the distance from the start point and the level of the radio signal of the transmitter, program a flight route directly to the field from a laptop using Mission Planner, refuse the USB cable (use it except for new firmware). Configuring the PID without connecting / disconnecting the USB cable is much easier.

Algorithms behavior packs in nature[7]

Today, probabilistic algorithms based on processes occurring in living nature are an effective direction in evolutionary modeling. By projecting the laws of the world around certain areas of human activity, such as social, technical, political, we get an effective tool for solving problems in various areas of human activity.

Algorithm behavior a colony of bees.

A mathematical model of an algorithm based on the behavior of a colony of bees. The behavior of insects in wildlife consists in the fact that at first a certain number of scout bees fly out of the hive in a random direction, trying to find areas where there is nectar (Fig. 5). After some time, the bees return to the hive and in a special way tell the others where and how much they found nectar. After that, other bees go to the found sites, and the more nectar is supposed to be found in this area, the more bees fly in this direction

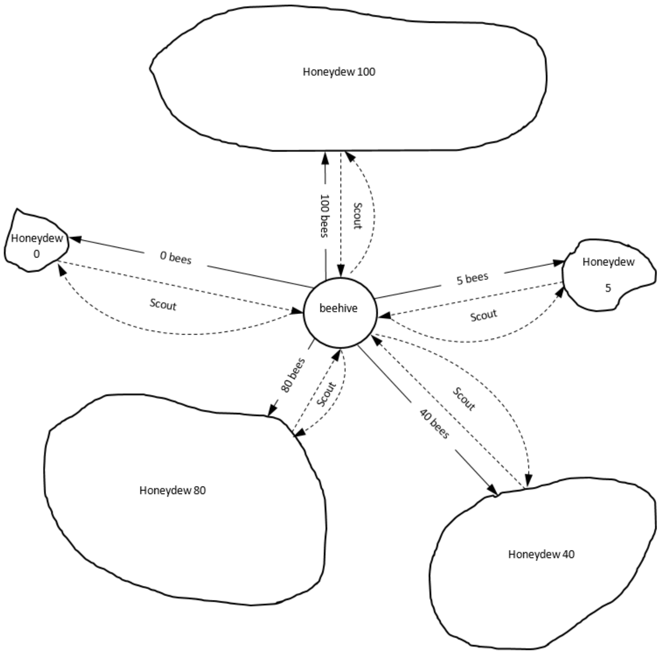

Fig. 5. Bee colony behavior pattern in wildlife [7]

In fig. Figure 6 shows a model based on the behavior of a bee colony. Here B is the top of the star graph. The remaining vertices are the explored areas with the values of the objective function: vertex A - DF 100, vertex F - DF 80, vertex E - DF 40, vertex C - DF 5, vertex D - DF 0. Information about the values of the objective function in these vertices of the bee - scouts (scout agents) pass to worker bees (agents). After this, a number of agents are sent from vertex B to the remaining vertices to study their surroundings. The number of agents in each direction is proportional to the value of the objective function of each vertex of the graph.

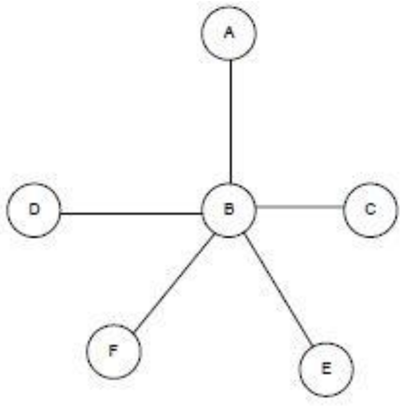

Fig. 6. Bee colony behavior model

In relation to optimization problems (problems of finding a minimum or maximum) we formalize some concepts. It is worth noting that the search is performed not at infinity, but on a predetermined interval [a, b]. Let N be the number of sections (blocks). To simplify, take the number of blocks N = const, however, the number of sections can change dynamically during the operation of the algorithm. Imagine the location of the field sections in the form of the set X = {x1, x2, ..., xi, ... xN}, and the value of the objective function in each section in the form of the set F (X) = {f (x1), number of bees to a specific block, in proportion to the value of the objective function.f (x2), ..., f (xi), ..., f (xN)}. We fix the total number of bees B = const. This will reduce our computing resources. Thus, it is always possible to precisely assign a certain

$$b_i = B * (1 - \frac{f(x_i) - \min(F(X))}{\max\,(F((X)) - \min(F(X))}) \tag{1}$$

For the maximization problem :

$$b_i = B * (\frac{f(x_i) - \min(F(X))}{\max(F(X)) - \min(F(X))} \tag{2}$$

where max (F (X)) is the maximum value from the set F (X), min (F (X)) is the minimum value from the set F (X). To create a breadth-first search in each block, it is necessary to determine the neighborhood of this block. We define a neighborhood of xi as follows :

$$[x_i - p_i, x_i + q_i] \tag{3}$$

where pi is the deviation to the left, qi is the deviation to the right. The neighborhood parameters are calculated as follows:

$$p_i = b_i * \frac{|x_i - x_i| - 1|}{(\frac{(b_i + b_{i-1})}{2})} \tag{4}$$

$$q_i = b_i * \frac{|x_i - x_{i+1}|}{(\frac{(b_i + b_{i+1})}{2})} \tag{5}$$

Since N = const, it is not advisable to expand the search segment [a, b]. Therefore, we introduce restrictions on p and q. p0 = 0, qN = 0.

Description of an algorithm based on the behavior of a bee colony. Here is the algorithm for finding the optimum of the objective function:

1. We define the segment [a, b]. We select N argument values on the initial segment

and we consider the values of the function f for each of the values of their set X. Thus, we form the sets X and F (X).

2. Assign bees in the vicinity of points xi in proportion to the values of of the function f (x) using formula (1) or (2) according to the type desired extremum. For more promising points, the number of bees in the neighborhood will be more than less promising.

3. We break the search space into areas (Fig. 7).

4. We calculate the values of the neighborhood of the i-th point by formulas (3), (4) and (5).

5. In each neighborhood of the point xi belonging to the interval (xi-pi, xi + qi), we select bi arbitrary points with a discreteness of no more than

$$\frac{(p_i+q_i)}{B} \tag{6}$$

It turns out that the set Ti = {x'1, ..., x'j, ... x'bi}, where x'j ϵ [xi-pi, xi + qi].

6. If for the set Ti there exists a member x'j such that, then in the set X we make a replacement.$f(\grave{x}_j) < f(x_i)x_i = \grave{x}_j$

7. If the stopping conditions of the algorithm are not met, then go to step 2. Otherwise, to point 8. The stopping conditions may be:

♦ achieving a given number of iterations;

♦ development of a set algorithm running time;

♦ achieving an acceptable value of the objective function.

8. The end of the algorithm.

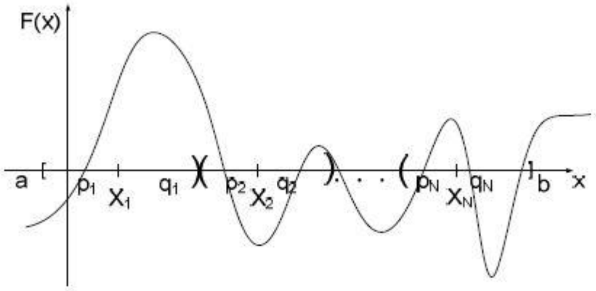

Fig. 7. Partitioning Search Space[7]

Note that a distinctive feature of the developed algorithm is the ability to dynamically divide the search space into regions, which reduces the time of the algorithm. This algorithm illustrates the divide and conquer search strategy, i.e. the complex optimization tasks are subdivided into subtasks. The main advantage is the fact that, thanks to the search along the entire length of the segment, the probability of getting into the local optimum is sharply reduced, and due to parallelization, the time is reduced. At each iteration, it is equal to the search time in the most promising block. Conclusion. This algorithm allows you to parallelize the process of placing elements, effectively manage the search, and obtain optimal and quasi-optimal solutions. A computational experiment was conducted. A series of tests and experiments made it possible to clarify theoretical estimates of the time complexity of design algorithms and their behavior for schemes of various structures. In the best case, the time complexity of the algorithm is ≈O (n · log (n)), in the worst case - O (n3).

Algorithm behavior of schools of fish[8]

Since the middle of the last century, studies have been conducted on the simulation of the biological mechanisms of nature, in particular, related to the process of evolution. Only by the 80s, practical testing of these methods began in connection with the need for effective methods for optimizing n-ary functions that have high computational complexity, multi-extremity, etc. Speaking of terminology, it is worth mentioning that these algorithms belong to the class of stochastic search engines. In many sources, one can also find definitions such as behavioral, intellectual, metaheuristic or population.

Idea of the algorithm

This algorithm was proposed in 2008 by Filo (B. Filho) and Neto (L. Neto). As in all population algorithms, the following parameters are set as input parameters: fitness function (a function for which it is necessary to find extrema), the field of study of this function, and the parameters of the algorithmwhich will be described later. In the current FSS (Fish School Search) algorithm, the search area is an aquarium in which fish (agents) swim. As you know, in the process of finding food, fish swim in a joint, so in this case the ultimate goal is to shift all agents to the extremum region of the function. In general terms, the scheme of the algorithm is as follows:

1. Initialization of the population (uniform distribution of fish in the aquarium).
2. Migration of agents to a food source (analogy: the larger the step the agents took in the direction of the extremum of the function, the more food they received).
3. Completion of the search.

Detailed description of the algorithm

The Agent Migration stage is performed iteratively, and in each of the iterations there are two groups of operators:

1. Swimming operators providing agents for migration within the aquarium.
2. Feeding operators, recording the success of the study of various areas of the aquarium.

The process of executing the algorithm, as mentioned above, depends on the input parameters specified by the user. They are characteristic of the entire aquarium as a whole. Note: all of the following explanations of the algorithm are designed to solve the problem of conditional maximization of a function, but this should not cause doubts about the inoperability of this method when searching for minimum values of a function.

1. initialize_randomly_all_fish

In this algorithm, fish swim in an aquarium, the dimension of which is equal to the arity of the fitness function, and having boundaries that coincide with the search area of the maximum function. After entering the algorithm parameters, the aquarium is filled with fish, that is, each instance is assigned random coordinates (swimStatePos [0]), evenly distributed within the boundaries of the aquarium, and a weight equal to half of the maximum ($weight\ =\ weightScale\ /\ 2$) is set.

```
populationSize - population size (number of fish in the
school);
iterationCount - the number of iterations in the “Agent
Migration” stage;
lowerBoundPoint - upper bound of the search;
higherBoundPoint - lower bound of the search;
individStepStart— sets the initial radius of the food
search around agents;
individStepFinal - sets the final radius of the food search
around agents;
weightScale - maximum agent weight.
With their help, the ratio “accuracy - runtime” of the
algorithm is regulated. As for the agents themselves, they
are characterized by two values:
swimStatePos - agent position at different stages of
swimming;
weight - the current weight of the agent.
Below is the pseudo-code of this algorithm:
initialize_randomly_all_fish;
while (stop_criterion is not met)
{
for (each_fish)
{
individual_movement;
evaluate_fitness_function;
}
feeding_operator;
for (each_fish)
instinctive_movement;
calculate_barycentre;
for (each_fish) do
{
volitive_movement;
evaluate_fitness_function;
}
update_individidual_step;
}
```

Fig.8 Code of this algorithm

2. stop_criterion

In the general case, the stopping criterion may be the achievement of a certain accuracy of the results, the execution time of the program, the amount of memory used, and so on. In the current implementation of the algorithm, this is the number of iterations that the user sets before the execution of the algorithm (iterationCount).

3. individual_movement

At this stage of swimming, fish are given the chance to make individual movements, which are limited by the parameter "individual swimming step" (individStep): $swimStatePos\ [1]\ =\ swimStatePos\ [0]\ +\ rand\ (-1;\ 1) * indivitStep$ (7)

If, as a result, this movement takes the agent (fish) out of the search area or leads to a point with the worst value of the fitness function, then it is considered that its position remains the same.

4. feeding_operator

Now you need to consolidate the success in the individual stage of swimming. For this, the characteristic "weight" is used. It is equal to the change in the fitness function for a given agent before and after the individual stage, normalized by the maximum change in function among the population:

$$weight += \mathit{\Delta fi}\ /\ max\mathit{\Delta f} \tag{8}$$

Generally speaking, this is a distinctive feature of this algorithm, since it is not necessary to memorize the best agents in previous iterations. The weight value lies in the range [1; weightScale] and is adjusted if necessary.

5. instinctive_movement

After this, the fish make the next stage of swimming - instinctively collective. For the entire school of fish, the value “total migration step” is calculated:

$$m = \frac{\sum_{i=1}^{populationSize}((swimStatePos_i[1]-swimStatePos_i[0])*\Delta f_i}{\sum_{i=1}^{populationSize}\Delta f_i} \tag{9}$$

From a practical point of view, this means that each agent is affected by the entire population as a whole, while the influence of an individual agent is proportional to its success in the individual swimming stage. After that, the entire population is shifted by the calculated value m:

$$swimStatePos\ [2]\ =\ swimStatePos\ [1]\ +\ m \tag{10}$$

6. calculate_barycentre

Before the next swimming operation, it is necessary to perform intermediate steps, namely: to calculate the center of gravity of the entire joint:

$$m = \frac{\sum_{i=1}^{populationSize}(swimStatePos_i[2]-weight_i)}{\sum_{i=1}^{populationSize}weight_i} \tag{11}$$

7. volitive_movement At this stage, the collective-volitional stage of swimming is performed. First of all, you need to find out how the weight of the population has changed compared to the previous iteration. If it has increased, then the population has approached the region of the maximum of the function, therefore, it is necessary to narrow the circle of its search - thereby intensifying properties are manifested. And vice versa: if the weight of the jamb has decreased, then the agents are looking for the maximum in the wrong place, so it is necessary to change the direction of the trajectory to the opposite and show diversification properties.

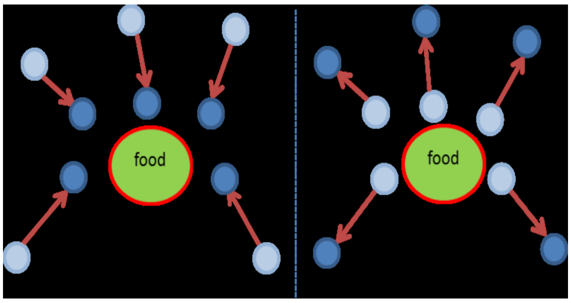

Fig. 9. Stage of collective volitional swimming[8]

The value of collStep in the following formula is responsible for the step of volitional bias. It is recommended to use a value 2 times larger than an individual search step. The dist operator calculates the distance between two points in Euclidean space:

$$\mathrm{swimStatePos}[3] = \mathrm{swimStatePos}[2] \pm \mathrm{collStep} * \mathrm{rand}(0;1) * \\ * \frac{swimStatePos[2] - barycentre}{dist(swimStatePos[2]; barycentre)} \tag{12}$$

Note: variables responsible for the position of agents are considered as mathematical n-dimensional points. However, to perform operations such as adding / subtracting two points, adding / subtracting a point and a number, multiplying / dividing a point and a number, and also comparing points, it is convenient to consider variables as radius vectors with the origin at the point (0; 0)

8. update_individidual_step The last statement in an iteration is to linearly decrease the individual search step for the next iteration. This action is already a modification of the standard FSS algorithm to increase search efficiency and is performed according to the following formula:

$$individStep -= \frac{individStepStart - individStepFinal}{iterationCount} \tag{13}$$

From a practical point of view, this is explained by the fact that the more iterations have already been completed, the closer the agents are to the maximum of the function, and therefore it makes sense to limit the search area to the next iteration.

Project implementation

To start a full-scale implementation of the drone network, you need to create a single drone to check the technical and software compatibility.

Frame selection

The main parameter according to which the frame is selected is its size. The size is considered to be the distance between the diagonally located engines.

Engines

Collectorless motors have become widespread due to their high efficiency. These motors contain three windings, alternating which creates the required torque.

The main disadvantage is the large mass. Among the advantages over collector motors are reliability due to the lack of brush contact and gearbox, as well as traction. Quadcopters equipped with engines of this type can lift, in addition to the quadcopter, attachments.(Fig. 9. b.)

Fig. 10. a The frame is made of plastic,
but my rigid characteristics b. Collectorless motors

Rechargeable batteries

The battery weight should be small for greater maneuverability of the quadcopter. Also, motors in peak modes are able to consume high currents, about 100 A. Optimal characteristics have lithium-polymer batteries.

When choosing a battery for a quadcopter, it is important to consider three of its characteristics:

- capacity
- Discharge rating
- High-voltage

Depends on the number of "cans" or battery cells. The voltage of one cell of the lithium-polymer battery is about 3.7. Accordingly, the more cells, the greater the voltage. In commercial sale the batteries are marked: 1S, 2S, 3S and 4S. 1S denotes a voltage equal to 3.7V, 2S - 7.4 V, 3S - 11.1 V, 4S - 14.8 V.

A 3S battery with a capacity of 5200 mA was selected

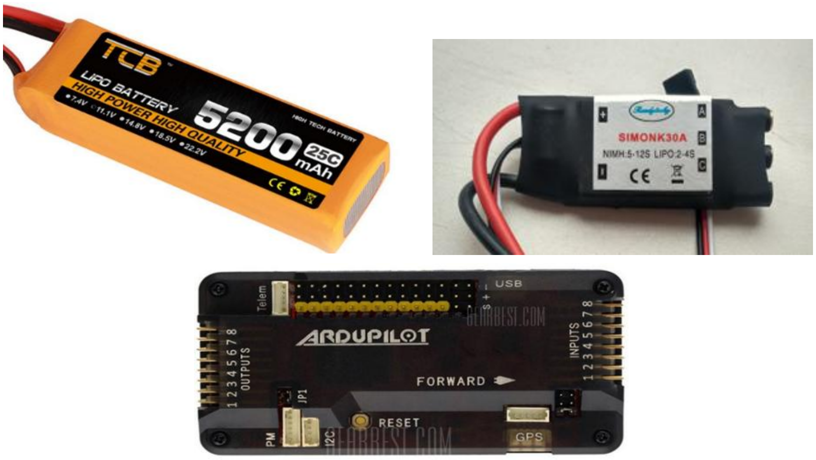

Fig. 11. a. Rechargeable batteri, b. Speed regulator Simonk 30 A speed controller is a programmable controller, c. APM2.8

The discharge rating indicates how much the maximum discharge current exceeds the capacitance.

Speed regulators

When choosing a speed controller must take into account: the maximum current consumed by the engine, as well as the battery voltage. Simonk 30A regulators were selected.(Fig.10 .b.)

Sensors

A set of feedback sensors is required for the correct operation of the quadcopter control system. The following sensors are used In the designed control system:

- gyroscope

- accelerometer
- GPS receiver

The data obtained by the gyroscope determine the orientation of the quadcopter in space. The output of the sensor is the angles: roll, pitch and yaw.

The accelerometer forms the acceleration along each of the Cartesian axes in the basic coordinate system. Further accelerations are projected on the axis of the normal coordinate system using data obtained from the gyroscope.

Advanced functionality and the presence of built-in sensors are in the controller APM2.8 (Fig.c)

The GPS receiver obtains the coordinates of the quadcopter in space in an absolute coordinate system.

Later, when the quadcopter takes off, the starting coordinate is fixed and further calculation is performed relative to it.

Conclusions

Advantages of using a quadrocopters group reduction of the total cost of quadrocopters, istribution of payload on several boards (possibility to save on total cost of payload),reduction of losses from accidents, improving the positioning accuracy of each quadrocopters due to mutual positioning, improving the results obtained due to different angles of view of different quadrocopters, accelerate the result in a number of applications.

References

1. Курейчик В.М. Genetic algorithms and their application. - Taganrog: TRTU, 2002 - P. 242. - UDC 681.3.001.63

2. Bastos, F., Carmelo JA, Lima Neto, Fernando B. de, Lins, Anthony JCC, Nascimento, Antônio IS, Lima, Marília P: "A Novel Search Algorithm based on Fish School Behavior". In: 2008 IEEE International Conference on Systems, Man, and Cybernetics - SMC 2008, 2008, Singapore.

3. Karpenko AP Population algorithms of global search optimization. Overview of new and little-known algorithms. // Сайт Is.ifmo.ru. January 9 (http://is.ifmo.ru/works/2012/karpenko-population-algorithms.pdf)

4. Bastos, F., Carmelo JA Fish School Search.// Website Cs.fit.edu. January 9 (http://cs.fit.edu/~rmenezes/Teaching/Entries/2011/8/22_OLD____CSE5801Swarm_Intelligence_files/ 01930261.pdf)

5. Bioinspired methods in optimization / Gladkov LA, Kureychik VV, Kureychik VM, Sorokoletov PV - Bioinspired methods in optimization. - M .: ФИЗМАТЛИТ, 2009. - 384 с.

6. The Bees Algorithm - A Novel Tool for Complex Optimization Problems /

DT Pham, A. Ghanbarzadeh, E. Koç, S. Otri, S. Rahim, M. Zaidi - Manufacturing Engineering Center, Cardiff University, Cardiff CF24 3AA, UK.

7. Ant partitioning algorithm / OB Lebedev. Evolutionary adaptation on the basis of a colony of bees / VV Курейчик, E.E. Полупанова.

8. Kureychik VV, Kureychik VM, Rodzin SI The concept of evolutionary calculations inspired by natural systems // Izvestiya YuFU. Technical sciences. - 2009.– № 4 (93). - P. 16-24.

9. https://robotclass.ru/articles/barometer-test-bmp085-bmp180-ms5611/

10. http://quad-copter.ru/dalnii-polet.html

AUTHORS

Kyrianov Artemii - Master, Department of Computer Engineering, National Technical University of Ukraine "Kyiv Polytechnic Igor Sikorsky Institute ".

Heorhii Loutskii (supervisor) - Professor, Doctor of Technical Sciences Chairman of the Dissertation Academic Council, National Technical University of Ukraine "Kyiv Polytechnic Institute named after Igor Sikorsky".