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The Math Model of Drone Behavior in the Hive, Providing Algorithmic Architecture

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ABSTRACT

Nowadays, drones play a significant role not only in civil ventures, but also in the military sphere. Planning the trajectories of the hives of the drones is not a trivial task and requires deep research. In this research, the author considers different strategies of biological creatures and then extrapolated on the drones. The author's research demonstrates the math model of the drones behavior in the hive, provides algorithmic architecture. The author describes in the detail the layers of the system for management of the drones and their responsibilities and architecture. The author also provides a software algorithm which demonstrates effective grouping of the drones (creating a swarm) which is later on used in the movement of the swarm.

KEYWORDS

Artificial intelligence, Bee, Drone intelligence algorithm, Drone, Hive intelligence algorithm, Hive, Swarm intelligence algorithms, Swarm

INTRODUCTION

Nowadays there are many types of drones on the market. One can purchase not just a ready to use drone but also different types of the component parts used in drones' modeling. The types of the drones also vary a lot: from the smallest ones (usually used for gaming, video streaming or military purposes) to the big ones used for transporting different kind of cargo and even people (such as Ehang-184). It's possible to purchase even the controllers and the software which can already implement the basic operations necessary for the drone, such as different kind of movements, etc. So, a developer having the SDK can work on more complex topics such as managing the hive of drones, applying AI, etc.

A developer will have to implement many different functionalities and apply lots of technologies working on such the projects.

For example, below are listed some modules which will be necessary to develop for such the work:

Computer vision, which is usually based on OpenCV or similar frameworks.

Voice recognition system which is based on transforming of voice into text and then a bot system which would be able to properly process the text and select the proper action from the TODO list. There are lots of different frameworks and libraries for this purpose, for example Microsoft bot. Some advanced system are based on different kind of neural networks and different kind of frameworks like TensorFlow, etc.

The module responsible for different type of calculation of the flight path and trajectories, which would depend not on the most short path but first of all on the physical abilities of a drone, taking into consideration the angle of rotation a drone can take, the speed, the weight of the drone, the type

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of the drone (cargo, taxi, etc.), etc. As an example: it's not the proper path when we consider a taxi drone carrying people and the path of the flight has a rotation of 90 degrees and high speed.

- The module for checking the positions and the status of the other objects (not only the drones) in the area and a predictable system which could send urgent signals to the drones to avoid their collision.

During the research and the work of the author, the author developed multi-layered architecture and software for management of the hive of drones.

The system manages not only the drones but the whole drone's traffic over some territory. This could be compared with management of the regular road traffic.

The author developed several architectures for such the task, one of them is related to management of the hive and not related to the drone's traffic management. Such the system could be used in the military sphere. Another system manages the traffic and the drones and it could be applied in civil life.

In this article we will consider the first type of the system, for managing the hive of the drones.

Inertia-Weighted Particle Swarm Algorithm

In the mid 90s of the last century, J. Kennedy and R. Eberhart developed and proved a new method for optimizing zero-order nonlinear functions, based on an evolutionary algorithm that simulates the behavior of individuals in a pack (Eberhart R. & C., Kennedy J., 1995). Other researchers have developed other versions of this algorithm.

A swarm of drones/bees is a set of $\{P_{i,j}=1, L\}$ of L drones / bees with predetermined connections between them. Each drone/bee P_j and the whole swarm as a whole is characterized by a number of parameters that determine their state at a particular point in time:

$x=(x_1,\ldots,x_n)^T$ – the position of the drone/bee in the space of internal parameters
$V = (V_1,.., V_n)^T$ – drone/bee speed
$p = (p_1,\ldots, p_n)^T$ – the best local position
$g = (g_1,\ldots, g_n)^T$ –global solution

Vector V characterizes the change in the position of the drone/bee per unit of time equal to one iteration of time.

At the initial stage of the algorithm, the vectors x and V are independent random variables uniformly distributed in the tolerance bar B_T. At each iteration of the algorithm, the direction and length of the velocity vector of each dron / bee are adjusted in accordance with the information about the found drones/bees P_j local optima p in accordance with the formula:

$$V'_i = \omega V_i + \alpha_1 \bullet rnd \bullet (p_i - x_i) + \alpha_2 \bullet rnd \bullet (g_i - x_i)$$

where

V'_i – the component of the drone/bee velocity vector in the next step;
V_i – the component of the drone / bee velocity vector in the previous step;
ω – inertia coefficient;
α_1, α_2 - constant acceleration;
rnd – random variable uniformly distributed on the interval [-1, 1];

After the initialization, an iterative process is started. At each iteration of the algorithm, the drone / bee position changes according to the formula: