CONCEPTUAL METHOD OF NAVIGATING AND CONTROLLING A DRONE

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Abstract: The main purpose of this paper is to present a conceptual method of navigating and controlling a quadcopter that aims to reach its destination, avoiding obstacles in the workspace. Another objective is to test the efficiency of the method on a simulator. Drone flight control is a major action that determines the safety and the accomplishment of the missions. The method involves setting the flight altitude by comparison with the height of the obstacle, and avoiding it, in the case of detection of an obstacle on the flight path. All drone subsystems must receive and transmit information so that the interaction between them be fully coordinated in order to increase the working capacity of the drone. In the case of a drone fleet, their interoperability is of utmost importance alongside the knowledge of the real situation in the workspace. Efficient cooperation implies that the information gathered by one of the drones to be readily known by all fleet drones, and so along with the strategic level information, the capacity of the entire military structure to have a greater degree of autonomy and mobility.

Keywords: drone; navigating and controlling method; workspace; obstacles.

1. INTRODUCTION

In the world we live, the rationale human being involves scientific knowledge, control and also the management of the action plans, so that the performances achieved to ensure the progress of the society and the individual life.

Integrating scientific research into the processes of existential action is a mean and a priority, as well, determined by the proposed goal and without which we will not be able to live better [1]. In a society dominated by technology, where humanity's demands are growing, ideas are merging and developing in an accelerating rate, which requires a balance between existing natural capacities and needs. Drones become more and more frequent in our life and as a result the field is of interest and must be treated with much responsibility and attention [2,3].

The proposed method is part of the research directions assumed by report no. 1 of 2015 of the MASIM project, respectively, from the miniaturized aerial platforms algorithms, whose concept belongs to "sense and avoid" strategies for avoiding fixed obstacles [4].

The MASIM project - "Multi-Agent Aerial System with Mobile Land Information Management Station" proposes an innovative solution for finding the necessary information to solve in real-time a situation by means of a fleet of autonomous mini-platforms, coordinated from the ground by a mobile station with command and control function.

The complexity and novelty of the MASIM system is determined by the innovative concept, the architectural structure and the complexity of the components, combined with smart management. At the same time, the testing of the research results at the integrated system level offers value to the MASIM project. [4]

## 2. DRONE NAVIGATION AND CONTROL

Drone is the popular name of unmanned multi-rotor aircraft, being considered in modern literature as the modern version of the hot air balloon. The scientific term of these complex systems is the UAV, comes from the English (Unmanned Aerial Vehicle) and defines unmanned aerial vehicles driven from a distance by human beings or capable of autonomous operation by a digital automatic pilot.

The main using areas of the drones are: military (security and safety, recognition etc.) and non-military or civil (commercial, health, agriculture, logistics, entertainment etc.). Thus, at present there are drones used for shooting, product delivery, surveillance, mapping etc.

The general architecture of a drone is presented in fig. 1 and the typical flight control loops for a multi-rotor are presented in fig. 2 [5].
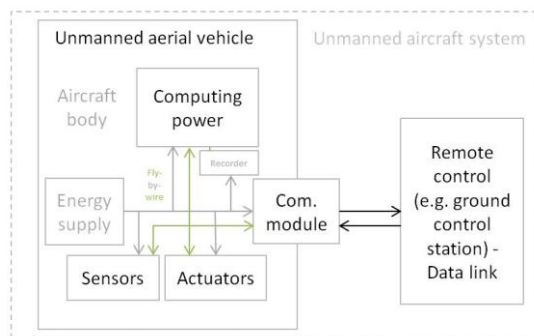
FIG. 1 General physical structure of an UAV
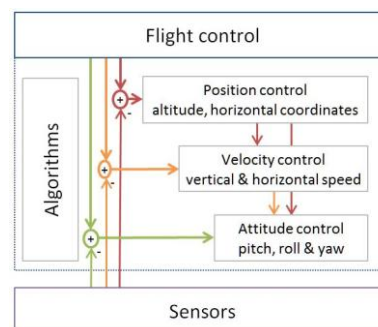
FIG. 2 Typical flight-control loops for a multi-rotor

The Federal Aviation Administration (FAA) of the US Department of Transportation announced at the end of March 2017 over 770,000 drone owners for hobby, estimating more than 1.1 million units. In the future, by 2021, this number is expected to reach 3.55 million, with an annual average growth rate of about 26.4%.

Regarding non-hobby models, the FAA has much higher expectations that the fleet would grow at an even faster rate. If in 2016 the number of drones was rather low due to strict regulations, about 42,000 units, the fleet is expected to grow at an annual average of 58.6% by 2021 (442,000 units), given that the regulations have been improved.[6]

The navigation system of a drone is divided into three main modules:
- research, detection and determination of initial parameters;
- route planning;
- movement control.

There are numerous experiments that have clearly indicated that the error of measuring the distance between the drone and the obstacle depends on the size, shape, physical structure of the obstacle material, the ability to reflect light, the degree of finishing of the outer surface/roughness or environmental parameters.

Flight controller is one of the most important part of the drone, being basically the element that reads all the sensor data, organizes and conducts the flight, continuously calculating according to an algorithm and passing the best commands to the other components so that the drone can successfully complete its mission. Remote sensors are indispensable components of a drone to fulfil the mission and the safety requirements.

Distance sensor orientation is made in several directions, respectively vertically downwards as the drone flight involves, on the one hand, altitude to eliminate impact with the ground, but also horizontally, on the other hand, for the detection of the fixed obstacles situated on the flight route, to avoid them.

The workspace is framed into a three-dimensional axe system comprising three elements: the starting position of the drone, the fixed obstacle (elementary geometric object) and the end position of the drone (finishing point).

In our case study, we will neglect air friction and all environmental factors, and the flight will be considered horizontally parallel with the ground after the drone reached the necessary altitude.

The drone will be considered as a point that has to move from the starting position to the final position. The dimensions are virtually reduced to its mass centre. Its mission does not end to the final position and the drone has to return to the starting position. The back route is not the subject of the present study.

The fixed obstacle can have a multitude of shapes, whether convex or concave. In this paper we will study the parallelepiped rectangular obstacle, with a convex body, whose dimensions are comparable to each other.

3. THE CONTROL ALGORITHM

The logic scheme of the flight algorithm of the drone moving into the three-dimensional workspace is shown in fig. 3.

The algorithm compares the zB value of the destination point with the L3 value of the obstacle, ie the altitude of the target point with the obstacle height.

If the zB > L3 the drone rises to the zB altitude and flies in a right line parallel to the ground to the point B (target).

If zB ≤ L3 the conceptual navigation scheme of fig. 4 will be used because there is an obstacle on the drone route. In this case, the control algorithm of a plane flight is reported to a two-dimensional reference system and the drone route can be seen in fig. 5.
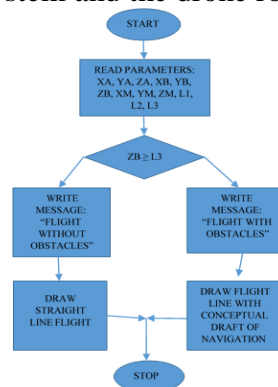

FIG. 3 Schematic block diagram of the drone flight

Navigation and control conceptual scheme in case of an existing obstacle has the following graphic representation [7,8]:
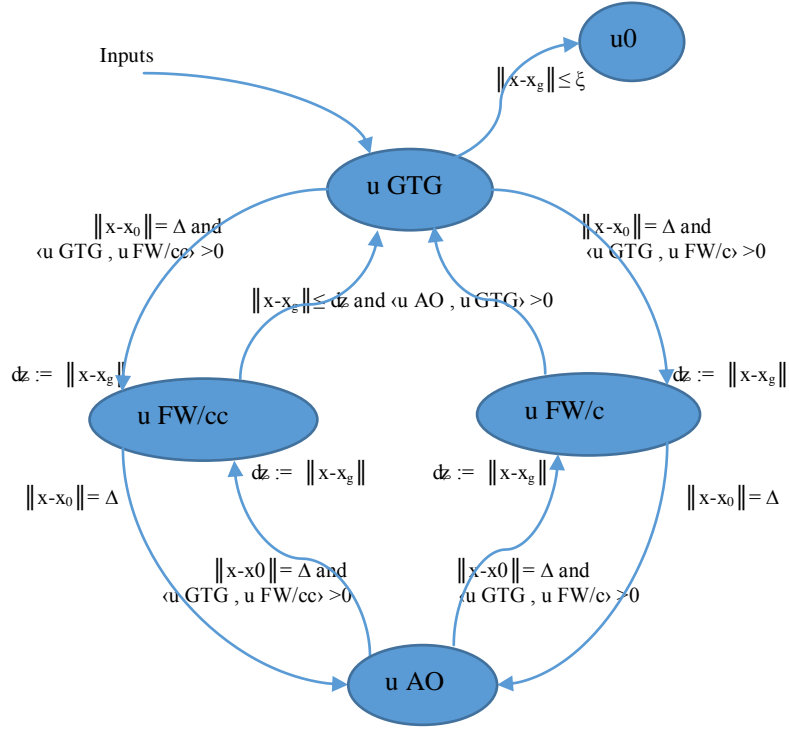

FIG. 4 Navigation and control conceptual scheme in case of an existing obstacle

where: u GTG is the vector from the starting point of the drone to the goal, u AO is the vector to avoid obstacle, u FW/c is the vector follow wall in clockwise direction, u FW/cc is the vector follow wall in counter clockwise direction, uo is the vector STOP when the drone arrives to the goal (u = 0), x0 = initial position, xg= position of the goal, d_z is the distance to the goal.

Behaviour of a the drone flight towards a goal is represented by a schema of a hybrid automaton with many guard conditions.

The flight stages include several commands:
- stage 1: go to goal,
- stage 2: navigating avoiding obstacle,
- stage 3: follow wall in clockwise or counter clockwise direction,
- stage 4: continue to the goal after avoiding obstacle,
- stage 5: repeat stage 2, 3 and 4 in case that another obstacle appears.

Around the obstacle we consider a line at Δ distance away from the obstacle, at which the drone need to change its trajectory and navigate avoiding obstacle.

The movement parameters are:

$$u_{GTG} = K_{GTG} (x_{goal} - x),$$
$$u_{AO} = K_{AO} (x - x_{obst}),$$
$$u_{FW} = \alpha R_{(\pm\pi/2)} u_{AO},$$
$$R(\theta) = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} \text{ - rotation matrix.}$$

The drone trajectory meets Δ line and now the automaton schema starts working.

These two formula of inner product represents control laws to avoid obstacle clockwise or counter clockwise:

$$\langle u_{GTG} , u_{FW}^{C} \rangle = \left\| u_{GTG} \right\| \left\| u_{FW}^{C} \right\| \cos(\theta_{GTG,FW})$$
$$\langle u_{GTG} , u_{FW}^{CC} \rangle = \left\| u_{GTG} \right\| \left\| u_{FW}^{CC} \right\| \cos(\theta_{GTG,FW}).$$

The point where the drone meets the Δ line is represented in the next figure.
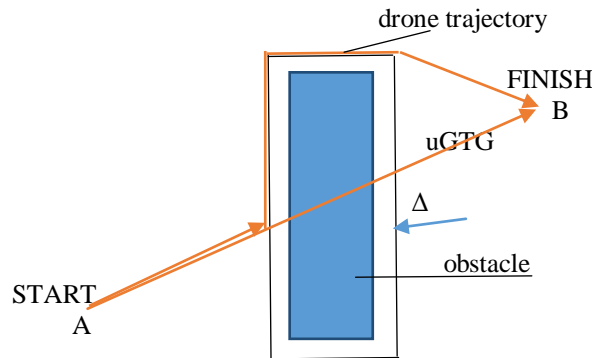

FIG. 5 Drone trajectory

The main term of this equation is the angle θ between the two vectors u_{GTG} and u_{FW}, which determines the clockwise or counter clockwise direction in which the drone flight will follow wall to avoid the obstacle.

Going closer to the goal determines the return to the automaton and restarting the stages of the schema.

When the two conditions are satisfied:

$$\left\| x - x_g \right\| \le d_z \text{ and } \langle u_{AO} , u_{GTG} \rangle > 0$$

the drone will switch back from follow wall to go to goal, where d_z is the distance to the goal.

In case of encountering another obstacle the drone will start the whole process again.

4. SIMULATION RESULTS AND CONCLUSIONS

However to get a better result, an experimental method is preferable and we will use a simulation environment in which to test and view the results of various inputs and controllers.

In our case we will use DroneKit-Python, which is an open-source project and communicates with vehicle autopilots using the MAVLink protocol. The kit version 2.9.0 offers the opportunities which we need to test the proposed conceptual method [9].

In the MASIM project, communication between the aerial vectors and the base (or between them) is done by radio transmission, MavLink protocol. Transmission of feeds (video, sensors etc.) is done through an industrial power WI-FI network, in which base and drones are access points. [3]

On Quick Start the application and then we launches the simulator. Vehicle state information is exposed through vehicle attributes which can be read and observed (and in some cases written) and vehicle settings which can be read, written, iterated and observed using parameters (a special attribute). The proposed method is a simple one and the results legitimize its use.

This paper illustrates a simple way of navigating and controlling a drone. The drones will definitely be more and more present in our everyday life and will occupy an important place taking into account the current trends.

Our research will continue aiming a better understanding of the phenomenon, as well as an increasing progress in this area. The current application also presents ample opportunities for future research in a wide array of connected fields, of which several possibilities, such as virtualisation, terrestrial robot cooperation and complex decision systems [10,11], are already being investigated.

That is why, in the near future, we will model and simulate cases where the fixed obstacle will be: a cylinder, an ellipsoid, a pyramid or a rigid in suspension. We can say very sincerely that we, the research team, have found a model and its algorithm for a drone flight from the start point to a final target avoiding a fixed rectangular parallelepiped obstacle.

These things must be presented and communicated in order to be known hoping that they will be appreciated and developed in the future, so that the results can provide a real breakthrough to the problems faced in this field nowadays.

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