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HARDWARE AND SOFTWARE PACKAGE FOR SEARCH, DETECTION AND FIRST AID MEANS DELIVERY IN ROUGH TERRAIN ON BASIS OF A THREE ROTOR UNMANNED AERIAL VEHICLE

Summary. The unmanned aerial vehicles are used for dangerous tasks solution. The search and detection of injured in rough terrain is one of them. Thus, vertical take-off unmanned aerial vehicles are of a special interest. A hardware and software package for the task solving is proposed in the article.

АППАРАТНО-ПРОГРАММНЫЙ КОМПЛЕКС ПОИСКА, ОБНАРУЖЕНИЯ И ДОСТАВКИ СРЕДСТВ ПЕРВОЙ НЕОБХОДИМОСТИ ПОТЕРПЕВШИМ В УСЛОВИЯХ НЕРАВНОМЕРНОГО РЕЛЬЕФА МЕСТНОСТИ НА БАЗЕ ТРИРОТОРНОГО БЕСПИЛОТНОГО ЛЕТАТЕЛЬНОГО АППАРАТА

Аннотация. Беспилотные летательные аппараты применяют для решения задач, связанных с риском для здоровья человека. К таковым можно отнести поиск и обнаружение потерпевших в условиях неравномерного рельефа местности. В связи с этим, особый интерес представляют собой беспилотные летательные аппараты вертикального взлета и посадки. В статье предложен аппаратно-программный комплекс для решения этой задачи.

1. INTRODUCTION

Ukraine is a country with Crimean and Carpathian mountains. Both of them are popular among the tourists, rock climbers and mountaineers. Such kinds of sports are closely connected with risk on human life for its extreme character. when people get into dangerous and hard-to-reach area accidents happen regularly. It is possible to use a small unmanned aerial vehicle (UAV), able to do vertical takeoff and landing, in order to simplify this problem solving. Multirotor aerial vehicles (MAV) are such as UAV. They have a series of advantages relatively to other ones. MAV have simple frame and construction, they are simple too, they are able to hover, have a small size (relatively to similar devices of earlier times) and an option of remote control. Besides, MAV is able to bear useful load, which maximal value depends on the value of thrust force, created by the rotating propellers.

2. PROBLEM CONDITION AND SOLVING METHODS

MAV are different by the number of rotating motors in the system. Thus, nowadays, MAV with even number of rotors (quadrocopters, hexacopters, octocopters etc.) are widespread [4]. A tricopter as a control object is an MAV with three rotors. An image of the object is shown in fig. 1. The tricopter has the advantages of both helicopter and quadrocopter [7]. It is able to move quickly in horizontal position and is more robust than a helicopter. The last point is specified by the tricopter's number of motors, which create thrust.

MAV must be stable in order to execute any task, whether it is hovering or maneuver. Thus, an angular stabilisation system, providing roll, pitch and yaw angles constancy, is necessary. Task of this work is to create such angular stabilisation system, which satisfies all requirements of technical task.

Fig. 1. A multirotor aerial vehicle with three propellers as control object
Рис. 1. Мультироторный летательный аппарат с тремя винтами как объект управления

A control object is the aerial vehicle, state of which is characterised by its angular position (roll, pitch and yaw) output parameters. The physical values, which influence its state, are the thrust forces, created by the rotating propellers, the overturning moments (as the result of the thrust forces influence) and reactive moments of the propellers [1]. It is necessary to say, that commutatorless motors in pairs with electronic speed controllers are used in such systems. Their weight is no more than 0.6 kg. An electronic speed controller (ESC) is a specific microcontroller, which forms switch signals for the motor's windings in the specified sequence and frequency. The ESC's output signal depends on its input signal, represented by pulse-width modulated (PWM) impulse with width range from 1000 μs (which corresponds to a complete stop of the motor) to 2000μs (maximal rotation speed). The number of motor-ESC pairs is three for the tricopter. These devices are actuators for the automatic control object. Besides, the thrust force vector is tilted by the servo, so, the servo is also one of the actuators in tricopter.

Three main types of sensors are used in MAV [3]. They are magnetometers, gyros (or angular velocity sensors) and linear accelerometers of microelectromechanical type.

The gyros [6], placed along three axis of the MAV bound coordinate system, measure the vehicle's angular velocities round the corresponding axis. It is possible to use one three-axis gyro instead. The gyro's signals are integrated in order to obtain the angles in each moment of time. The most widespread for its simplicity is the method of rectangles. But the constant integration has a

disadvantage of the gyro's systematic errors accumulation. This is the reason, for which the calculated values of the angles are, in fact not corresponding to the real ones after some time. Thus, it is necessary to correct them in order to get rid of the systematic error. This means, that the calculated values of the angles must be zeroed once in some period of time. The accelerometers are used for this operation. Their axis of sensitivity coincide with the bound coordinate system's. A three-axis accelerometer can be used instead.

If MAV does not move (it is hovering, for example), then a three-axis accelerometer will measure the projections of the gravity acceleration on the axis of the bound coordinate system. The measured vector can be used in order to correct the values of roll, pitch and yaw angles, calculated by the gyro's signals integration. But, if MAV moves in space, it gets his own acceleration, which would influence on the accelerometers' signals. The sensors would measure the MAV's total acceleration. Besides, it is possible to correct only roll and pitch values in such way.

In order to correct the value of yaw angle, a magnetometer is used. This sensor is, in fact, a digital compass and is sensitive to the direction of the magnetic force lines. The output signal of the magnetometer is a vector, the direction of which coincides with the northern direction in the bound coordinate system. Thus, the signals of the magnetometer can be used to correct the errors of yaw and pitch angles calculation. The main disadvantage of the sensor is its low accuracy. In ideal conditions it equals nearly 5 degrees and more than that in real situations, near power supply wires and motors.

A GPS [2] unit is also used in order to correct the vehicle's drift along the inertial coordinate system axis and to define its position in Earth coordinate system. A barometer is used as an altimeter. Thus, GPS unit and magnetometer provide the correction of an inertial strapdown system.
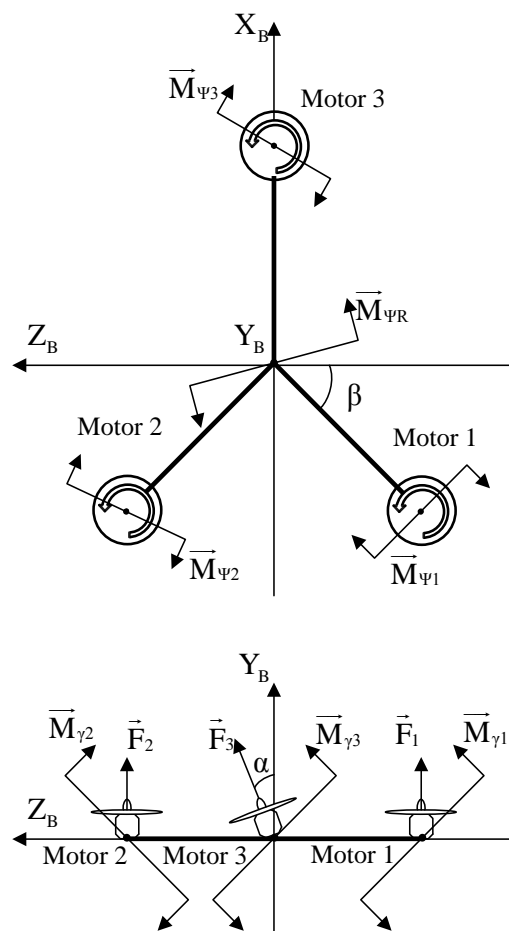

Fig. 2. A multirotor aerial vehicle kinematic diagram
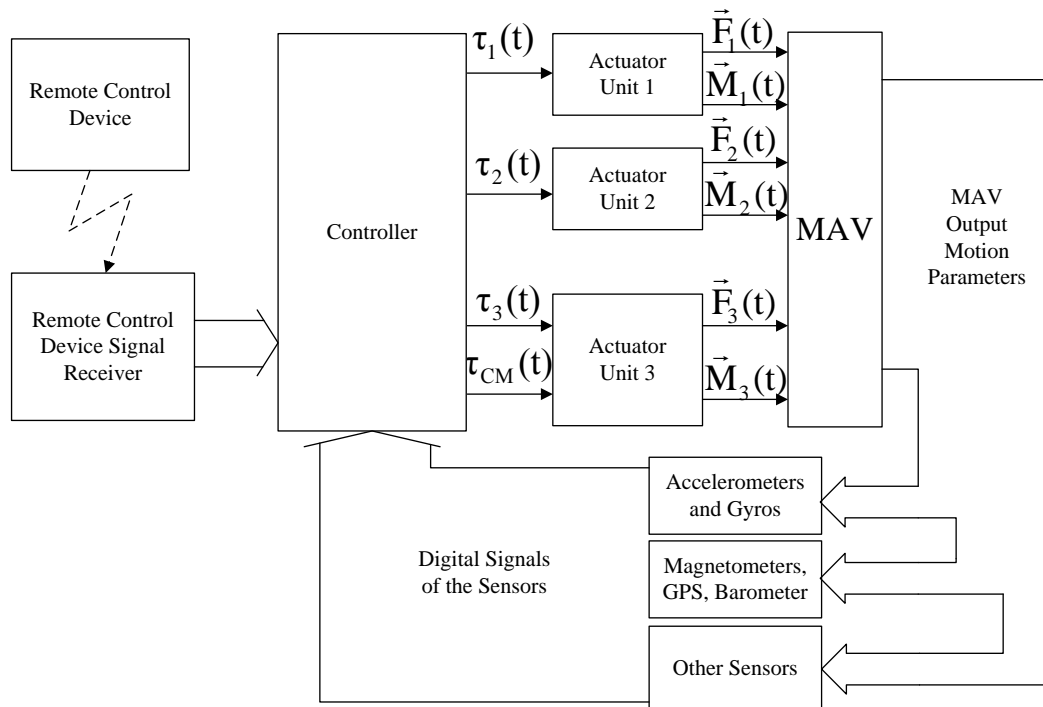Рис. 2. Кинематическая схема мультироторного летательного аппарата

Fig. 3. Functional diagram of multirotor aerial vehicle angular stabilisation system
Рис. 3. Функциональная схема системы угловой стабилизации мультироторного летательного аппарата

Here:

MAV – is a multirotor aerial vehicle;

Actuators Unit 1, 2 – two ESC-motor pairs, placed according to the kinematic diagram;

Actuators Unit 3 – an ESC-motor pair, which motor is placed on the shaft of the servo;

Accelerometers – three linear accelerometers, which axes coincide with the axes of the bound coordinate system respectively;

Gyros – angular velocities sensors, which axes coincide with the axes of the bound coordinate system;

Magnetometers – three magnetometers, which sensitivity axes coincide with the axes of the bound coordinate system;

GPS, Barometer – a GPS sensor and a barometer;

$\tau_{1,2,3,CM}(t)$ – PWM control signals for actuator units 1-3;

$\vec{F}_{1,2,3}(t)$ – thrust force vectors of the corresponding motors;

$\vec{M}_{1,2,3}(t)$ – torques, inducted by the corresponding actuator units.

The controller is, in fact, a printed board with integrated accelerometers, gyros, magnetometers, GPS and barometer, connected, at the same time, by I^2C interface. Gyros and accelerometers are physically realised in an inertial measuring unit chip with in-built temperature sensor and self-control option.

Video equipment represents the MAV's effective load. So-called GIMBAL-systems are used to stabilize the camera's angles around to axes. The telecommunication allows to get the picture from the camera online. This approach allows to find a person in trouble in mountainous terrain.

MAV's flight controllers programming is done on-land by means of the special software. Both text and GUI-programs can be used. A well-known and widespread project according to this is MultiWii. Another famous project that can be applied for this system also is OpenPilot project [7]. It aims to create an Open Source Auto Pilot controller for unmanned aerial platforms. This project has been done

by flying robots that have been used for search and rescue missions. This project does not involve commercial developments. In aviation people's life often depends on the quality of the aerial vehicle. That is why non-commercial project, which does not depend on the third person involvement and financial provision, but only depends on the enthusiasm and professionalism of the developers, usage for such purpose can be more effective than any commercial one.

3. CONCLUSIONS

As a matter of fact, it is often hard to risk one's life in order to save somebody else. In the age of the scientific progress and intensive hardware and software development it is an obligation of the engineers to suggest a hardware and software package for the purpose in question.

The first aid means delivery within the limited period of time can save somebody's life. A hardware and software package for search, detection and first aid means delivery in rough terrain on basis of a three rotor unmanned aerial vehicle was developed. One of its main components is the aerial vehicle itself. Its autopilot is the matter of great importance for the system's fast work and response.

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