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Designing of the Aero Video Intelligence on the STM32H Microcontrollers Basis

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Abstract*: The practical possibility of using the flying wing as an aero video intelligence is being considered. In this regard, an experimental sample was built with a wingspan of 1000 mm and a flight weight of up to 500 g, on that the SPRacingF3 Acro flight controller was installed on the basis of the STM32F303 microcontroller with a GPS receiver and a course video camera for FTP flights. Based on the INAV firmware, the main attention was paid to setting the flight modes NAV RTH, NAV FAILSAFE to ensure the guaranteed return of the wing to its launch zone in case of the radio communication loss with the video camera or control panel. The microOSD board has been configured for the possibility of the overlaying telemetry data on the images, that received on the monitor from the course camera. The setup and testing of the semi-automatic launch of the NAV LAUNCH flying wing was carried out, that greatly facilitated the start of the wing in windy weather and from the small areas. It has been practically shown that the flight time was about 40 minutes at an average speed of 40-45km/h with the 5x3 inch three-blade propeller on the three Sony / Murata US18650VTC5 rechargeable batteries with the capacity of 2600 mah.

Keywords*: SPRacingF3, MicroOSD, INAV, GPS receiver, FPV, STM32F, NEO-6M-0-001, ESC controller, MWOSD, Failsafe, Ardupilot.

I. INTRODUCTION

Currently, the unmanned aerial vehicles (UAVs) of the both rotary types (the quadrocopters, the hexacopters) and with the fixed wing (the flying wing, the aircraft) are increasingly being used for the video intelligence. They use the automatic flight along waypoints or the first-person flight mode - First Person View (FPV) for studying the terrain [1]. The FPV mode is based on the using of the course video camera and video transmitter. In this case, the UAV is controlled on the radio channel using the radio remote control, based on the information that the pilot receives on the additional video radio channel from the course video camera, usually at the frequency of 5.8 GHz in real time.

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The image is displayed on the devices such as the monitor, TV, video glasses, video helmets. The development of the microelectronics has highly increased the zone of the reliable radio signal reception both for controlling the flying wing and for receiving video images. With the budget transceivers help, the communication zone reaches 20 km when the flying is at the altitude from 150 m in the straight line zone [2, 3]. In addition to the course video camera, it is also installed the high-resolution recording video camera on such UAVs, that allows to view the entire flight route with HD quality in case of the video intelligence returns.

The analysis shows that the flight time of the rotary type video intelligence usually doesn't exceed 30 minutes, and that of the aircraft type – 80-90 minutes. Moreover, the first type is characterized by average flight speeds of 25-35 km/h, and for the second type – 65-75km/h with the same flight weight, battery capacity. Therefore, the aircraft type UAVs are more appropriate to use as the video intelligence for the studying of the large distances terrain than the rotor type UAVs. The emergence of very light materials and the decrease of the electronic components size led to the appearance of a low-cost aircraft type UAVs with the flight weight of 250-450 g, the developing maximum speed of 150-180 km/h with the average flight time of 60-70 min [4]. Due to the light weight, the size and the using of the special launch modes for such UAVs, the small area is required for the launch and landing, and therefore, the advantages in this regard for the quadrocopters compared with the constructive "flying wing" is reduced. Also, for the quadcopter flight in the automatic mode, it is necessary to have a larger number of the electronic components, four propulsion systems, more sophisticated software and use more settings for the stable flight. It leads to the higher cost of the rotary UAV. During the long distances flying, especially through the small settlements, where, for example, the mobile communication systems work, the strong interferences occur, especially by the video transmission [5]. Therefore, the pilot during such interferences can't navigate on the terrain and can lose control of the UAV, that leads to its accident. To do this, it is necessary to use the system of the automatic return to the starting point on the such video intelligence in case of communication loss. When the connection appears, the system should be able to return the manual control to the pilot using the remote control. The development of the experimental flying wing and its testing with the wingspan of 1000 mm, the fuselage length of 500 mm, the flight weight of not more than 500 g, that is capable to fly up to 30 km on the onboard battery and automatically return in case of radio communication loss with the pilot are considered. The flight controller with software is used for the stable flight of the flying wing, especially during the wind, for the possibility of flying in the automatic mode (the flying along waypoints, the returning to the launch point in case of communication loss with the control panel and losing video communication, the automatic altitude retention).

A gyroscope and an accelerometer are installed in it, and the GPS receiver is used for automatic flight. There is no necessity to use the barometer (to maintain altitude) and the magnetometer (to ensure the straight flight in the given direction) for the flying wing in contrast to the quadrocopter. It simplifies and reduces the cost of the video intelligence on the flying wing designing. The most common flight controllers are the MultiWii (based on ATmega2560), the APM 2.x, the Pixhawk, the SPRacingF3, the OMNIBUSF4V3, the SPRacing F7 and others [6-8]. The first three of them use the Ardupilot firmware, the rest - use the cleanflight firmware (INAV, betafight). The firmwares are the softwares for the microcontrollers, that based on the mathematical models, such as the PID controllers, the Kalman filter and the complimentary filter, the dynamic Notch filter. The listed firmwares have the open source, that can be adjusted during the flight tests. The firmware customization for the specific set of the flight modes, the wing geometry, the propulsion, etc. requires the selection of the large number of the parameters in order to ensure the stable flight with minimal power consumption from the battery. The aim of the work is to study the possibility of the flying wing building - the video intelligence based on the experimental INAV firmware [9], that will allow to use the following flight modes:

- the automatic launch NAV LAUNCH, used to automate the launch of the wing from the small area;
- the automatic flight altitude retention NAV ALTHOLD [10] according to GPS data;
- the mode of the returning to the starting point when the command is sent from the NAV RTH control panel [10], for example, when video communication is lost;
- the return to take-off point in case of communication loss with the NAV FAILSAFE control panel [11].

The telemetry data should also be displayed on the course camera monitor screen (the flight speed, the altitude, the distance to the start point, the direction to the start point, the current state of the battery, etc.) for this wing.

It should include the following main components: the 2204 / kv2300 motor, the 30A ESC controller, the 5x4.5 inch propeller, the NEO6MV2 GPS receiver based on the NEO-6M-0-001 module, the microOSD, the flight controller SPRacingF3 Acro [12], the Eachine TS832 video transmitter, the Eachine 1000TVL course video camera for studying the wing's possibility to realize the performing above tasks. The management is performed by the equipment FlySky FS-i6.

The method for the solving the problem is the using and the adjustment of the INAV firmware for the flying wing as the result of the numerous test flight tests. The INAV is designed for the flight controllers based on the microcontrollers of the STM32F1, STM32F3, STM32F4 and STM32F7.

II. RESEARCH RESULTS AND ANALYSIS

The INAV configurator [13] is used to configure the flight controller operating modes. The setup is performed by setting the parameters in the tabs of the configurator and in the command mode. The Figure 1 shows the photograph of the flying wing with rectangular wing for that the firmware settings of the INAV ver.1.7.2 are shown using the budget flight controller SPRacingF3 Acro.

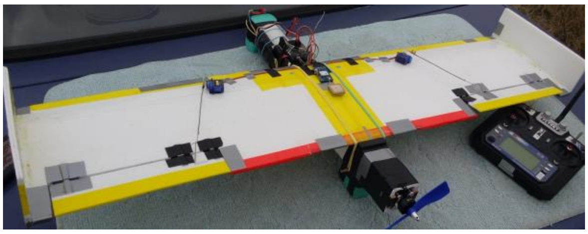

Fig. 1. The photo of the experimental flying wing

The wiring diagram of the electronic components is shown on the Figure 2. The servos of the wing elevons should be connected to the separate 5V power supply. The electrolytic capacitor of 1,500 microfarads should be installed in parallel to the servos for the reducing voltage ripples. The flight controller, control receiver, GPS receiver are connected to another 5V source integrated with the ESC motor controller.

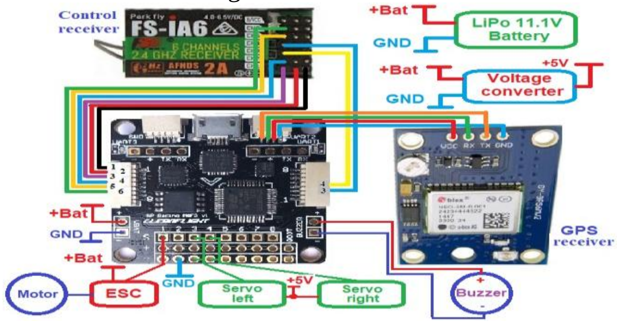

Fig. 2. The wiring diagram for the electronic components of the wing

In the Ports tab of the configurator, it is necessary to configure the flight controller to work with GPS receiver UART2 with the speed of 38400 bit/s. The Flysky FS-iA6 receiver is installed for this wing, connected to the flight controller via PWM, so only the UART2 port can be used.

Identifier	Data		Telemetry		RX	GPS	Peripherals	
UART1	MSP (on)	115200	Disabled	AUTO	Serial RX (off)	38400 (off)	Disabled	115200
UART2	MSP (off)	115200	Disabled	AUTO	Serial RX (off)	38400 (on)	Disabled	115200
UART3	MSP (off)	115200	Disabled	AUTO	Serial RX (off)	38400 (off)	Disabled	115200

Fig. 3. GPS Installing on the UART2 Port

The accelerometer is calibrated for 6 axes according to the scheme in the Setup tab, presenting in the source [14].

The parameters, that shown on the Figure 4, are set in the Configuration tab.

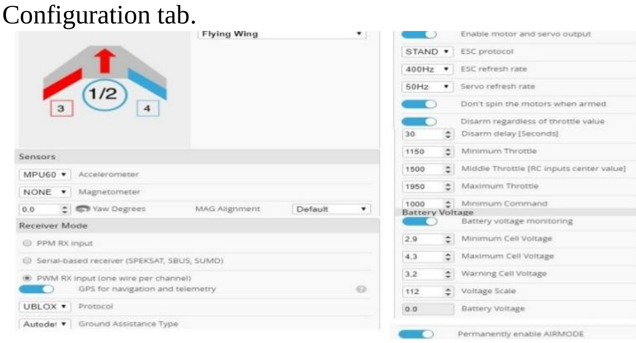

Fig. 4. The Configuration tab parameters

The Flysky FS-iA6 receiver is pre-configured for working with the failsafe parameters (Fig. 5), so that, when the control panel is turned off, it sends the 900 µs pulse to the flight controller through the throttle channel (3rd gas channel). Such receiver setup is presented in the source [15].

Fig. 5. The setup of some failsafe parameters

The parameter settings for the PID controller are performed by the sequential selection during test flights. Their values are chosen to ensure the stable flight of the wing. The latest versions of the INAV allow the automatic tuning according to the special algorithm during manual flight. However, it doesn't always provide the best tuning for the PID controller. In the tab the values of these parameters are shown.

Name	Proportional	Integral	Derivative
Basic/Acro			
Roll	30	10	10
Pitch	30	10	20
Yaw	0	0	0
GPS Navigation			
Position XY	75	5	8
Velocity XY	0	0	0
Surface	0	0	0

Fig. 6. The PID controller parameters

Some flight modes of the controller are set in the Modes tab, that can be activated from the control panel. Only two switches can be used because of used receiver is six-channel. On the first to the left of the toggle switch equipment, the ANGLE flight mode is set for any of its position. If the toggle switch is lowered down, the ANGLE mode continues to work and in addition the NAV LAUNCH (the take-off assistant) is turned on. On the three-position toggle switch the height hold mode (NAV ALTHOLD) is set to the middle position of the toggle switch and the home return mode (RTH) is the lower position (Fig. 7).

Fig. 7.The Modes tab parameters

Let's consider the setting of the NAV LAUNCH mode. This flight mode is designed to assist with the launch of the unmanned aerial vehicles. The controller detects the launch by tracking the acceleration or speed of the aircraft. After the exceeding threshold for the setting period of time, the NAV LAUNCH mode begins. During the NAV LAUNCH mode, the flight controller of the aircraft will provide the zero roll, the predetermined elevation angle and the straight line direction. By default, the NAV LAUNCH mode will complete after 5 seconds and switch to the ANGLE, HORIZON, ACRO, RTH mode.

The activation of the NAV LAUNCH mode is performed in the following order according to the INAV firmware operation algorithm:
- the switch is set to the NAV LAUNCH position on the control panel before the arming procedure is performed (Fig. 7);
- the arming procedure is performed on the control panel;
- the throttle stick is set to the desired value, that will be worked out by the flight controller after the end of the NAV LAUNCH mode, for example, in the middle;
- the wing is sharply pushed at the angle of no more than 45 degrees (shouldn't be larger for both roll and pitch). The angle 45 degrees is set by default;
- the engines will be started with the pre-set speed according to the parameter nav_fw_launch_thr = 1700 after the time interval according to the parameter nav_fw_launch_motor_delay = 500 (500 ms);
- the startup sequence will be completed after turning off of the NAV LAUNCH mode or moving the sticks on the remote control.

There are some parameters below that setting in the command mode of the INAV configurator:
nav_fw_launch_thr=1700 (the amount of gas (in PWM units) that will be set during NAV LAUNCH mode. When using the weak motor, this value increases, for example, to 1900, otherwise the plane will not take off);
nav_fw_launch_motor_delay=500 (the delay (500 ms) between the detected start and the start of the motors. I.e. the engine will only turn on after 0.5 seconds after the push of the aircraft. In the work this value is set equal to 100-200 ms, otherwise the aircraft may not have time to rise and crash into the ground);
nav_fw_launch_spinup_time=100 (the time in ms during that the power of the motors is increased from minimum gas to nav_fw_launch_thr to avoid the large load on the ESC. This value is slightly increased to 200 ms in the research);
nav_fw_launch_timeout=5000 (the maximum run time in ms. After this time, the NAV LAUNCH mode will be turned off, and then the flight mode specified by the switch on the control panel, that is set together with the initial start mode, will be executed. The initial start mode will be turned off after 5 seconds on the command);
nav_fw_launch_climb_angle=18 (the wing climb angle for the NAV LAUNCH Mode (in degrees)).

The importance of the research is given to the setting up and testing of the failsafe mode's functionality. If it doesn't work if the control panel loses contact with the flying wing, then it will be lost.

The failsafe (safety) is the state that the flight controller should enter if the control receiver loses communication with the equipment. Any of the listed INAV firmware conditions should call the failsafe:
1) any flight channel (the pitch, the roll, the gas or the yaw) doesn't send the impulses from the control panel;
2) any channel is out of the range, that can be checked using the commands in the cli tab:
get rx_min_usec; get rx_max_usec, or on the failsafe tab (Fig. 5). According to the failsafe tab rx_min_usec = 920; rx_max_usec = 2115;
3) the FAILSAFE mode is activated using the switch on the control panel.

If the failsafe mode happens when the flight controller is in the disarming mode (doesn't ready for flight or doesn't armed), this will prevent it from the switching to the arming (ready for the flight-armed). If failsafe mode occurs in the arming, the INAV firmware enforces the security policy that is configured in the failsafe_procedure command.
The available command options.
The DROP is turning off the motors and disarm (the UAV will crash and be damaged).
The SET-THR (Land) is enter the pre-set roll / pitch / yaw angle when the aircraft lowering and set the predetermined value for the throttle (gas) for the failsafe_throttle parameter during the predefined time specified by the failsafe_off_delay parameter (20 sec by the default, Fig. 5). It is intended to make the UAV's landing relatively safe. In this case, the gyroscope and the accelerometer are used.
The RTH (the returning to the starting point) is the INAV firmware allows the UAV to automatically move back to its original position and land or circle within the radius of 50 m above the landing site for the aircraft. The GPS receiver is used for this.
The NONE is doing nothing. This is intended for the fully automated flight, for example, on the waypoints that are outside of the radio range from the control panel. This parameter is very unsafe during manual control of the UAV.
The parameters are set in the CLI and Failsafe tabs. The Figure 5 shows that the RTH is set when the failsafe is triggered.
When setting up the wing testing, the following features of the INAV firmware were taken into account:
1) the failsafe will disarm the flight controller for the DROP, the SET-THR procedures after the failsafe_off_delay parameter and for RTH when the nav_disarm_on_landing command is set to ON (by default, it will not happen when the landing and disarming on the RTH).
The transition of the flight controller to the arming state will be blocked. If the signal from the receiver is restored for 30 seconds, and the ARM switch is in the OFF state on the remote control, then it's possible to make the arming of the flight controller again. However, it is better to reconnect the UAV to the power source;
2) before running of the failsafe function, it is checked whether the gas position has been below the min_throttle parameter for the number of the seconds that are set in the failsafe_throttle_low_delay parameter. If so, then the failsafe function should start. If you set failsafe_throttle_low_delay to zero, then the failsafe will not work. It must be done, when the starting gliders with the long unworking engine, when planning.
The min_throttle parameter is set in the Configuration tab and by defaults to 1150, and the failsafe_throttle_low_delay parameter is set in the Failsafe tab and by defaults to 100 (10 seconds);
3) if the UAV lands in the RTH failsafe mode, but doesn't disarm, the failsafe function can turn on the motors again, causing the UAV to take off. Therefore, the nav_disarm_on_landing parameter should be set to ON;
4) if the GPS receiver becomes unavailable upon returning home, an emergency landing will be performed after the short wait time similar to the SET-THR. If any sensor used during the flight is declared unavailable, the failsafe will trigger and the emergency landing will be performed;
5) the failsafe SET-THR procedure controls the descent in the failsafe_throttle parameter by the fixed throttle value. The proper gas test requires preliminary test. If the plane is planning, it can be set to 1000, at what the propeller will not rotate. If the plane performed acrobatic stunts, the motor should level it. Therefore, the motor must rotate for some time to align. It was indicated above that the motor rotation time is determined by the failsafe_off_delay parameter;
6) in case of the signal restoration from the remote control, the current positions of the sticks will be immediately determined. If the remote control power was turned off, and it was turned on after the while, then for switching of the control mode, just move the stick a little to the right, left. After that, the UAV will exit the failsafe and will again be controlled from the remote control.
The microOSD [16] is used in the work to obtain the telemetric data from UAVs. For its firmware, the Arduino IDE programming environment and the MWOS software suite [17] are used here. It will allow to impose the telemetry data on the image of the course camera. For microOSD firmware, the USB to TTL converter is used, that connects to the USB output of the computer and to the UART input of the microOSD board, based on the CH340 chip. The Figure 8 shows the connection of such converter to microOSD and its firmware with the manual generation of the DTR signal by briefly button pressing at the time of the firmware download from the Arduino IDE begins.

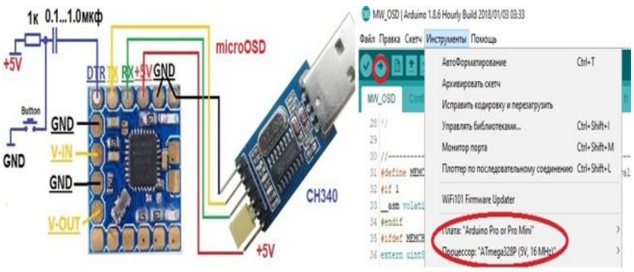

Fig. 8. The connecting of the converter to the microOSD and its firmware

The software was downloaded from the site https://github.com/ShikOfTheRa/scarab-osd/archive/v1.6. for firmware with the followed unpacking. The MW_OSD.ino file was loaded from the C: \ scarab-osd-1.6 \ scarab-osd-1.6 \ MW_OSD directory into the Arduino IDE software environment (Fig. 8) and the Arduino Pro or the Pro Mini board was selected. The following lines are recommended in the Config.h firmware section: #define CLEANFLIGHT; #define FIXEDWING.
After that, the compilation and the firmware download into microOSD is performed. At the moment the "download" inscription appeared at the bottom of the Arduino IDE window, the button, that shown on the Figure 8, was briefly pressed. After that, the programmer transferred the compiled file to the microOSD.
The firmware configurator was launched from the directory C:\scarab-osd-1.6\scarab-osd-1.6\MW_OSD_GUI\application.windows32\MW_OSD_GUI.exe. The Figure 9a shows the photo of the monitor screen with the OSD configured.

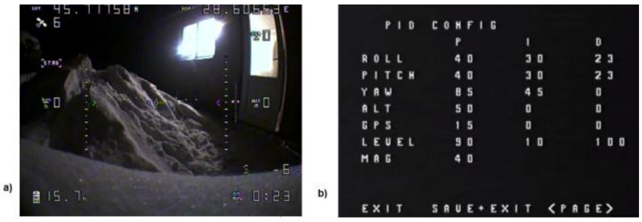

Fig. 9. The OSD configured screen photo

Using the OSD, it's possible to display not only the telemetry parameters, but also change the parameters of the flight controller, for example, the parameters of the PID controller. It is necessary to move the left stick to the center and to the right, the right stick up on the control panel for doing that (Fig. 9b). The displayed parameters are changed by manipulating the sticks and the next pages with other parameters are navigated.

The Figure 10 shows the connection of the course video camera, the video transmitter and the microOSD to the SPRacingF3 Acro flight controller via the UART1 port. The microOSD board disconnected from the flight controller, when connected to the computer for the setup through the INAV configurator. It is important to note, that the flight controller and the microOSD + camera + video transmitter must be connected to the different 5V power sources (for example, to the power source of servos, Fig. 2).

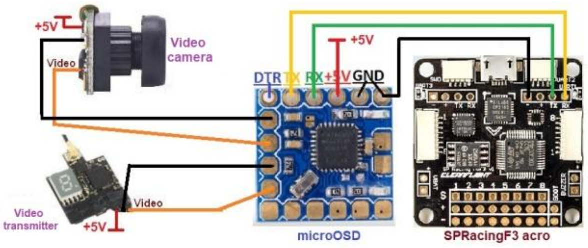

Fig. 10. The OSD connection to the flight controller

III. CONCLUSION

Based on test flight tests:

1. It is possible to use only the GPS receiver to ensure the functioning of the altitude hold modes, to return to the launch point by command from the remote control, to return to the launch point, if the contact with the remote control loses for the flying wing. The barometer and the magnetometer are also required for the quadrocopter, when performing these modes.
2. It is noted, that the flying wing can continue the relatively long flight along the given route until the communication is restored in the event of the communication loss with satellites. The quadrocopter turns off the motors and performs the hard landing in case of communication loss after the short period of time (1-2 sec).
3. It has been established, that the pilot completely loses the orientation on the terrain in case of video communication loss with the flying wing, when the flying along the course video camera. The switching of the flight controller to the NAV RTH mode reliably returns the wing to the launch zone, that allows to switch back to the manual control from the remote control, when video connection establishing.
4. The possibility of the semi-automatic wing launch in the NAV LAUNCH mode is shown. It greatly facilitates the start of the wing and allows to launch it from the small areas.
5. It is shown, that the use of the INAV firmware greatly simplifies the aircraft control, especially in windy weather. It is enough to start in the NAV LAUNCH mode, switch to the NAV ALTHOLD altitude hold mode and steer to the right or left to hold the course along the camera. The engine is turned off from the remote to complete the landing control and the wing lands in automatic mode.
6. The possibility of the using the microOSD in conjunction with the flight controller SPRacing Acro to superimpose the telemetry parameters on the image of the course camera was established.
7. The possibility of using the INAV latest version firmware to use the automatic flight mode for the waypoints is shown. It is enough to set these points on the INAV configurator map and save them in the memory of the flight controller for that performing.
8. It was established that the flight time is about 40 minutes at the average speed of 40-45km/h with the 3-blade propeller of 5x3 inches on the three Sony/Murata US18650VTC5 rechargeable batteries with capacity of 2600 mah.

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