АВІАЦІЙНА ТА РАКЕТНО-КОСМІЧНА ТЕХНІКА

UDC 629.7
DOI https://doi.org/10.32782/2663-5941/2024.6.1/09

Sydorchuk A.Yu.
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"

Kravchenko I.M.
SE "KYIVOBLSTANDARTMETROLOHIIA"

SPECIFIC ASPECTS OF CAMERA VIEWING ANGLE STABILIZATION DURING FPV DRONE CONTROL

The article examines the development of an automated camera fixation system for FPV drones, addressing one of the primary challenges of dynamic flights – instability of the viewing angle. Video instability caused by drone tilts significantly reduces task performance, especially in military and reconnaissance operations.

The prototype development process consisted of several stages: selecting the component base, soldering the parts according to the manufacturer's schematic, and conducting multi-stage functionality testing. The initial stage involved verifying the operability of the flight controller through software. Subsequently, the primary system components, including the camera, video transmitter, signal receiver, GPS module, and motor controller, were soldered. The final stage was the integration of servomotors for camera stabilization and comprehensive system testing under laboratory conditions.

Experimental studies revealed that the developed system ensures a stable video stream even during sharp maneuvers, significantly improving operator convenience. This is achieved through the system's rapid response to changes in the drone's position and precise adjustments of stabilization parameters. The results confirm that the automated camera fixation system enhances task performance by minimizing the impact of dynamic movements on video quality.

Future advancements in the system involve the integration of artificial intelligence algorithms for real-time object recognition and tracking. This will significantly expand the capabilities of FPV drones, enabling their use for complex tasks in military, reconnaissance, and civilian applications. Integrating features such as adaptive viewing angle adjustments and reduced energy consumption will allow longer flight durations and increased operational autonomy. Thus, the developed camera stabilization system holds significant potential for improving the functionality of modern FPV drones, making them more efficient and competitive.

Key words: *FPV drone, automated fixation, camera stabilization, prototyping, UAV.*

Formulation of the problem. Over the past few years, the development of uncrewed aerial vehicles (UAVs) has experienced significant growth. This trend is driven by the rapidly increasing demand for drones across civilian, military, and commercial sectors. Drone manufacturing is expanding daily, with the number of companies involved in their development continuing to rise. FPV (First Person View) drones exhibit the most dynamic growth among UAVs due to their real-time operational capabilities for performing complex tasks. Their popularity stems from the ability to transmit video directly from the drone, enabling rapid responses to situational changes.

According to data from Tochnyi.info [1], FPV drones are extensively utilized in the Russo-Ukrainian war for reconnaissance and combat missions. Statistics indicate that a substantial proportion of targeted objectives have been explicitly achieved through FPV drones (Fig. 1).

To ensure that a product remains competitive and meets modern demands, it is essential to implement new technological solutions continuously. One of the critical challenges is stabilizing the FPV drone's camera during dynamic maneuvers. Due to the high speeds and abrupt trajectory changes, operators often lose portions of their field of view because of camera tilt. This creates "blind spots" and reduces task performance efficiency. In military applications, such loss of information can have severe consequences.

Addressing this issue requires developing an automated camera stabilization system that ensures a fixed viewing angle regardless of the drone's spatial

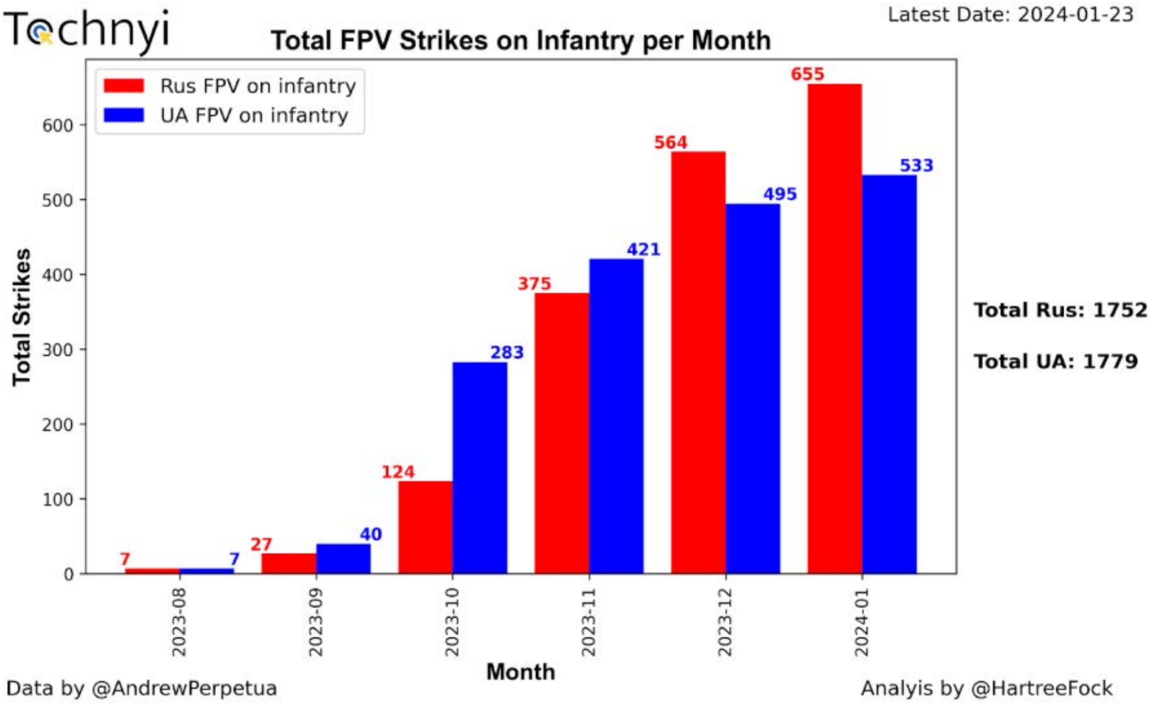

Fig. 1. Graph of the frequency dynamics of FPV drone usage in the Russion-Ukrainian war [1]

orientation. This article addresses this problem by integrating advanced solutions into developing computerized systems for FPV drones.

Analysis of recent research and publications. One of the most promising approaches in FPV drone camera stabilization is the integration of gyroscopic sensors with flight controller software. This enables adaptive systems that adjust the camera's position based on the drone's movements, ensuring stable imagery even under challenging flight conditions.

Currently, a variety of camera stabilization technologies are available. For instance, gimbal mounts (Fig. 2) are widely used in professional videography. However, their drawbacks, such as significant weight, high cost, and energy consumption, limit their application in compact FPV drones. In contrast, lighter solutions based on gyroscopic stabilizers exhibit substantial potential. Studies have explored the use of three-axis gyroscopes combined with stabilization algorithms. This approach effectively compensates for drone tilts during flight and ensures precise camera viewing angle control.

Given the rapid advancement of FPV drones and the increasing demands on their functional capabilities, the proposed approach holds significant relevance. It can be applied in civilian and military domains, particularly in monitoring, reconnaissance, and security operations. The further development of this technology could involve integrating artificial intelligence elements for real-time object tracking.

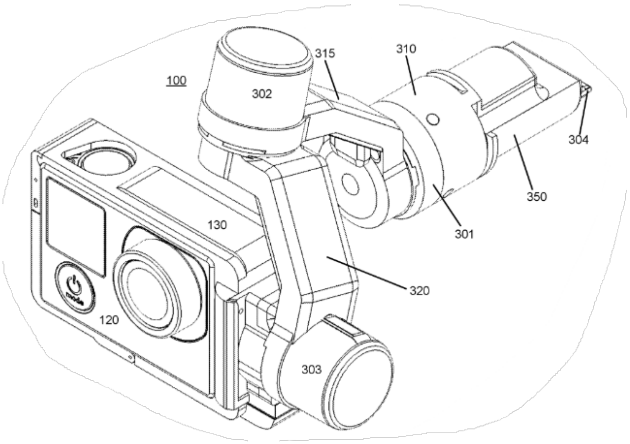

Fig. 2. Example of gimbal mount and camera attachment [2]

Moreover, recent research highlights considerable interest in incorporating machine learning algorithms for camera stabilization. This opens up automated real-time object tracking opportunities, especially critical for military and reconnaissance missions.

Task statement. The work aims to develop an automated camera fixation system for FPV drones that will ensure:

– Stability of the viewing angle regardless of the drone's orientation;

– Enhanced operator comfort when controlling the UAV;

– Improved accuracy in performing reconnaissance and combat missions.

To achieve this objective, the following tasks were set:

– Conduct a review of current solutions in the field of FPV drone camera stabilization;

– Design a functional schematic of the stabilization system;

– Select an optimal component base for the prototype;

– Implement the prototype and conduct experimental testing.

Outline of the primary material of the study. The initial stage in developing the camera stabilization system involved selecting the component base. Identifying optimal components ensured high performance and energy efficiency. The following components were chosen for the system implementation:

1. Flight Controller JHEMCU GF30F405: Processes sensor data and generates signals to control actuators.
2. FPV Camera Runcam Phoenix 2: Delivers high-quality video streams to the operator.
3. Servomotors MG90S: Used to adjust the camera's position precisely according to controller commands.
4. Video Transmitter TBS Unify Pro: Handles the transmission of video signals from the camera to the receiver.
5. Radio Signal Receiver FrSky XM+: Provides communication between the controller and the drone.
6. GPS Module BN-220: Collects location, speed, and flight direction data.
7. Buzzer HGLRC Soter: Assists in locating the drone in case of a signal loss or crash.
8. Motor Speed Controllers Mamba F40 4-in-1 ESC: Manage the motor speeds, directly affecting the drone's maneuverability.
9. Battery Samsung 21700 Li-Ion 5000mAh: Powers all drone systems, ensuring a stable energy supply.

The next stage in prototype development involved designing the functional schematic of the system (Figure 3).

The functional schematic of the automated camera fixation system for the FPV drone was designed with an emphasis on the optimal integration of all components. The schematic development's primary objective was to ensure all elements' stability and minimize potential errors during assembly and operation. The functional schematic includes the following key components:

– The flight controller is the central unit for processing signals from gyroscopic sensors and the radio signal receiver.

– The camera transmits the video signal to the video transmitter, which sends it to the operator in real-time.

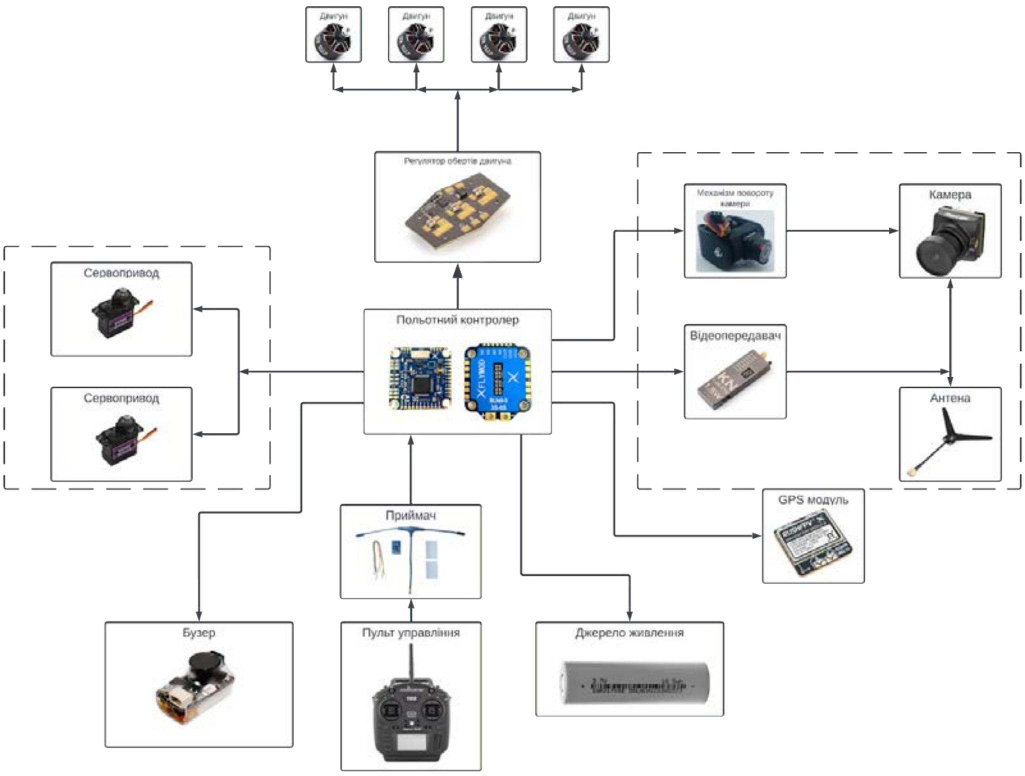

Fig. 3. Functional schematic of an FPV drone

– Servomotors receive signals from the controller and adjust the camera's position accordingly.

– The GPS module and receiver provide additional location monitoring and command transmission functionality.

– The battery maintains the Power supply, ensuring all components' stable operation.

Based on the functional schematic, the sequence for connecting components and integrating them into a unified system was determined. This approach minimizes the risk of incorrect assembly and ensures system stability, even under challenging operational conditions.

Following the development of the functional schematic, the next stage was the assembly and soldering of the FPV drone system components. During the soldering process, it is crucial to strictly adhere to the algorithm and the provided soldering schematic (Figure 4).

Figure 4 illustrates the soldering schematic for the components of the FPV drone system to the flight controller. The schematic clarifies the placement of contacts for each of the possible elements.

The soldering algorithm involves selecting the correct sequence of actions during component soldering. Before starting the process, it is essential to verify the functionality of the flight controller and ensure the absence of any damage or manufacturing defects. Testing is typically performed by simply connecting the flight controller to a computer via a Type-C cable. The Betaflight software [4] is used to confirm the operational status of the flight controller. Before connecting the flight controller to the computer, the Betaflight software must be launched. The program should immediately display a virtual drone model that reacts to the tilting of the flight controller. This response is based on data from the gyroscope integrated into the flight controller. If the controller's tilt corresponds synchronously with the virtual drone's movement on the screen and aligns with the tilt vector, it confirms the flight controller's functionality.

After the initial testing, the next step is gradually soldering components according to the schematic. The first step involves soldering the camera, a fundamental module in any FPV drone system. The drone's operation relies on transmitting images from the camera to the operator's FPV goggles. Once the corresponding contacts are connected, the process continues with the video transmitter, which is responsible for sending the video feed to the operator. The next component to solder is the GPS module. While not mandatory in the system, its functionality significantly simplifies data collection during flight, enabling tracking speed, direction, and distance traveled.

Following this, the receiver is soldered, essential for any FPV drone system. It is critical for transmitting

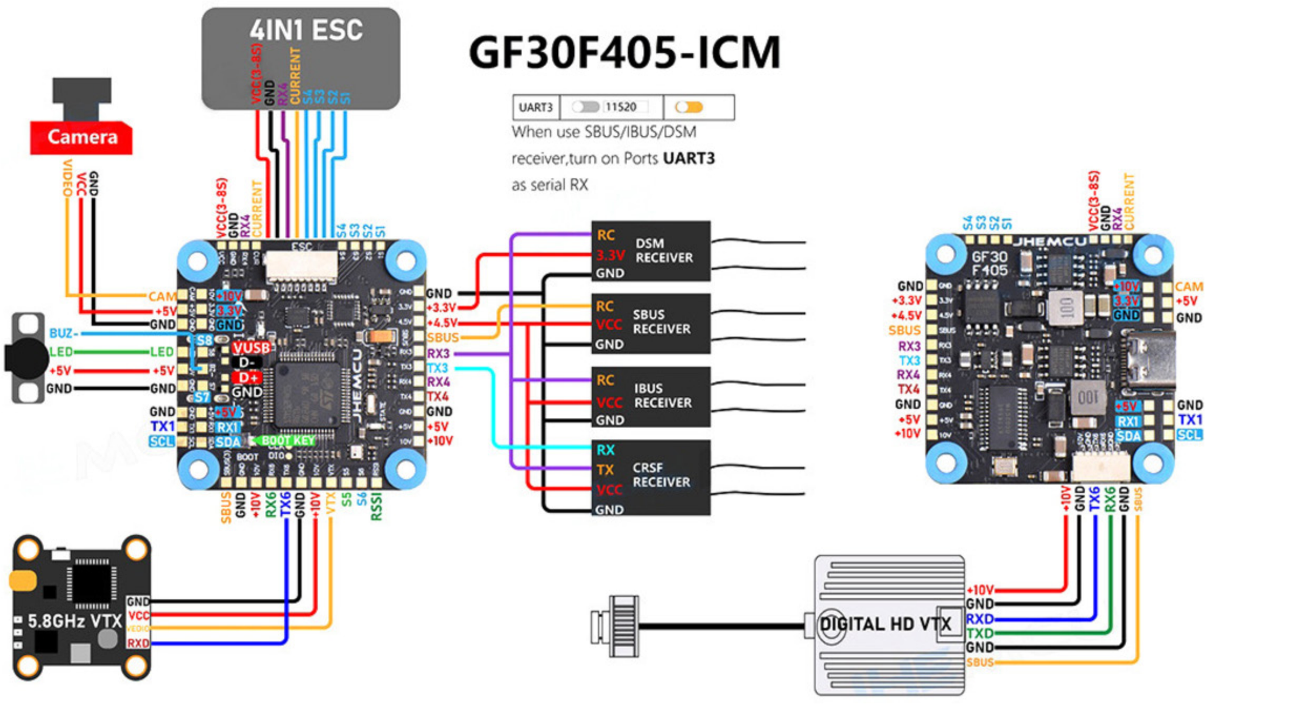

Fig. 4. Connection schematic of the JHEMCU GF30F405 ICM F405 flight controller [3]

control signals from the remote controller to the UAV. Its functions include maintaining a stable connection at a specified frequency and avoiding interference such as electronic countermeasures (ECM). The next step involves soldering the buzzer or locator beacon. The buzzer is essential for locating the drone in case of a crash or signal loss. The final element to solder is the motor speed controller, a key module that manages the rotation speed of the drone's motors. This component ensures proper motor rotation direction, directly affecting the drone's maneuverability and speed. The system also includes servomotors used for camera stabilization and payload release systems. Most listed components are mandatory, but additional modules can be integrated depending on the operator's needs and tasks. The soldering algorithm involves sequential testing of the flight controller's functionality, connecting system components according to the manufacturer's schematic, and integrating them into a unified functional system. The process begins by verifying the flight controller's functionality with software tools, followed by step-by-step soldering of modules, such as the camera, video transmitter, GPS module, signal receiver, buzzer, and motor speed controllers. A critical step is the proper configuration of the system to ensure stable component operation and effective task execution.

The system operates on continuous data analysis from gyroscopic sensors and automatically adjusts the camera's position. The main stages of operation are as follows:

1. Collecting data on angular velocities and the drone's tilt.
2. Processing the data by the flight controller and determining the necessary adjustments.
3. Transmitting signals to the servomotors to adjust the camera's position.
4. Continuously updating data to ensure smooth operation.

A series of experiments were conducted under both laboratory and field conditions to evaluate the system's effectiveness. The primary evaluation criteria were:

– Stabilization accuracy during abrupt maneuvers.
– Energy efficiency of the system.
– Video stream quality during dynamic flights.

The results demonstrated that the system maintains a stable viewing angle regardless of the drone's movement, significantly enhancing operator comfort and task performance efficiency.

Conclusions. The developed automated camera fixation system for FPV drones has proven its effectiveness in stabilizing the viewing angle during flights under challenging conditions. Experimental studies confirmed that the proposed solution significantly reduces the impact of dynamic maneuvers on image quality, ensuring a stable video stream for the operator. This greatly enhances the ease of drone control and improves the accuracy of task execution.

The system has broad application prospects, particularly in military and reconnaissance missions, where operational efficiency and precise data transmission are critical. Further development could include:

– Integration of artificial intelligence for real-time object tracking.
– Optimization of energy consumption to increase flight duration.
– Development of additional features, such as adaptive viewing angle adjustments based on selected flight scenarios.

Thus, the proposed automation system represents a promising platform for modernizing FPV drones and enhancing their competitiveness in contemporary environments.

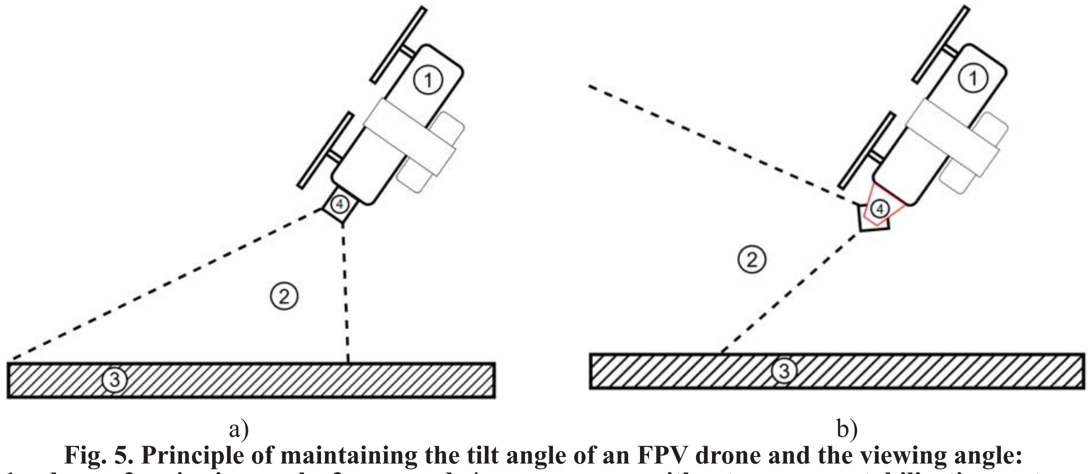

Fig. 5. Principle of maintaining the tilt angle of an FPV drone and the viewing angle: 1 – drone, 2 – viewing angle, 3 – ground, 4 – camera; a – without a camera stabilization system; b – with a camera stabilization system

Bibliography:

1. Tochnyi Info [Electronic resource] – Access mode: https://tochnyi.info/2024/01/update-on-fpv-drone-warfare-27-01-2024-2/
2. Camera System Using Stabilizing Gimbal [Electronic resource] – Access mode: https://patents.google.com/patent/US11480291B2/en?q=(camera+rotation+system)&oq=camera+rotation+system
3. Flymod [Electronic resource] – Access mode: https://flymod.net/item/fc_jhemcu_gf30f405_icm
4. BetaFlight [Electronic resource] – Access mode: https://betaflight.com

Сидорчук А.Ю., Кравченко І.М. ОСОБЛИВОСТІ ФІКСАЦІЇ КУТА ОГЛЯДУ КАМЕРИ ПРИ КЕРУВАННІ FPV ДРОНОМ

У статті розглянуто розробку системи автоматизованої фіксації камери для FPV-дронів, що дозволяє вирішити одну з основних проблем динамічних польотів – нестабільність кута огляду. Нестабільність відеозображення, викликана нахилами дрона, суттєво знижує ефективність виконання завдань, особливо у військових та розвідувальних операціях.

Створення прототипу включало кілька етапів: вибір елементної бази, пайка компонентів відповідно до схеми виробника та багатоступеневе тестування працездатності системи. Першим етапом була перевірка працездатності польотного контролера за допомогою програмного забезпечення. Далі проводилася пайка основних компонентів системи, включаючи камеру, відеопередавач, приймач сигналу, GPS-модуль та регулятор обертів. Завершальним етапом стала інтеграція сервоприводів, які забезпечують стабілізацію камери, і фінальне тестування всієї системи у лабораторних умовах.

Експериментальні дослідження показали, що розроблена система забезпечує стабільний відеопотік навіть під час виконання різких маневрів, що значно підвищує зручність для оператора. Це досягається завдяки швидкій реакції системи на зміни положення дрона та точному налаштуванню параметрів стабілізації. Результати підтверджують, що автоматизована фіксація камери дозволяє ефективніше виконувати завдання, мінімізуючи вплив динамічних рухів на якість зображення.

Подальший розвиток системи передбачає інтеграцію алгоритмів штучного інтелекту для автоматичного розпізнавання та відстеження об'єктів у реальному часі. Це значно розширить можливості FPV-дронів, дозволяючи їм використовуватися для складних завдань у військовій, розвідувальній та цивільній сферах. Інтеграція таких функцій, як адаптивна зміна кута огляду та зниження енергоспоживання, дозволить забезпечити триваліший час польоту та більшу автономність роботи. Таким чином, розроблена система стабілізації камери має великий потенціал для вдосконалення функціональності сучасних FPV-дронів, роблячи їх ефективнішими та більш конкурентоспроможними.

Ключові слова: *FPV-дрон, автоматизована фіксація, стабілізація камери, прототипування, БПЛА.*