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3D MODELLING OF UAV AND CREATING IT`S SYSTEM OF CONTROL

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Abstract. This paper presents a 3D modelling approach for developing Unmanned Aerial Vehicles (UAVs) aimed at increasing UAV availability in Ukraine. Using CAD (Computer-Aided Design) tools, particularly SolidWorks, a prototype based on the F-15 aircraft was created, followed by CNC (Computer Numerical Control) machining and the use of composite materials for a lightweight frame. For this UAV, laser guidance technology was implemented with software controlling navigation adjustments, ensuring high precision in target tracking. Laser guidance is interference-resistant, making it ideal for detecting and intercepting fast and small drones. This efficient and cost-effective design enables the rapid creation of an accurately laser-guided UAV.

Keywords: UAV, CNC, composite, flight controller, ESC (Electronic speed controller), OpenCV (Open Computer Vision).

Introduction

The war in Ukraine has demonstrated the growing role of unmanned aerial vehicles (UAVs) for both reconnaissance and strike missions. Russia actively uses various types of drones, posing a significant threat to the Ukrainian armed forces and civilians. In response, Ukraine is implementing a comprehensive set of measures to neutralize this threat, utilizing diverse methods and technologies.

One of the most effective means of countering UAVs is with other UAVs. The deployment of kamikaze drones capable of accurately targeting enemy drones even during high-speed maneuvers would provide a high level of protection on the battlefield or in civilian areas, which Russia regularly bombards with "Shahed" drones.

The production of such drones is significantly cheaper than traditional air defense systems, such as anti-aircraft missiles. Additionally, the availability of components allows for the rapid establishment of mass production, ensuring a stable supply to the arsenal.

Problem Statement

It is crucial to manufacture UAVs in a cost-effective and timely manner. The use of CAD tools significantly simplifies the creation of core components for the aircraft's body. Furthermore, 3D modelling systems make it easy and quick to adjust the dimensions of airplane parts, allowing modifications to better adapt to specific situations efficiently [1-3].

Due to limited capabilities in detecting and tracking low-visibility enemy targets in the sky, especially small drones, targeting such objects presents a challenge. Large radar systems can detect drones like the "Shahed"; however, Ukraine has a limited number of these radars. Employing radar systems together with anti-aircraft missiles like the Patriot is not always feasible due to the high cost and limited number of such systems. These complexes, which combine radar and missile launchers into a single large vehicle-based system, are not always capable of transmitting data to other systems. The enemy, using "Shaheds" as decoys, can easily detect the location of such a complex if it is activated and destroy it within minutes, for example, with "Kinzhal" missiles that can cover 300 km in under 100 seconds.

Given this, alternative methods of target detection in the air must be implemented [4-11]. One such method is laser guidance. This method involves directing a laser beam at a detected target, which serves as a guide for kamikaze drones, directing them toward the objective. This type of guidance is not only simple and practical but also cost-effective, which is especially important under current conditions. Additionally, launching such a drone leaves no visible traces in space that the enemy could detect.

Main Material Presentation

Choosing the Body Shape. To create an unmanned aerial vehicle (UAV), a sturdy and balanced body frame is required. We selected the F-15 model, known for its high-speed capability, load endurance during turns, and excellent maneuverability. Modifications will include removing unnecessary parts, such as missile mounts and special compartments for jet engines, to make the frame lighter (fig.1).

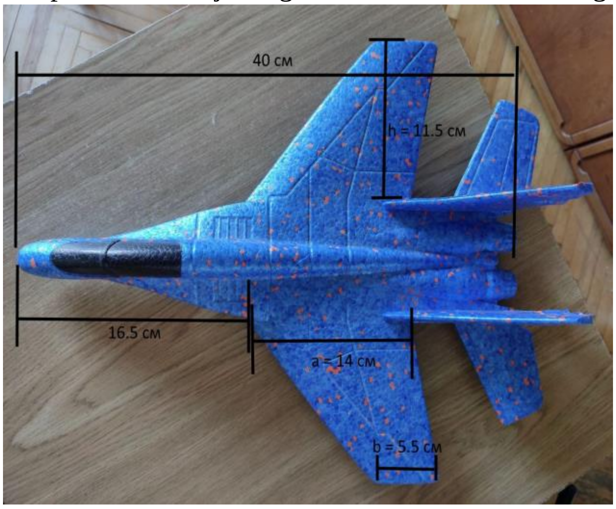

Fig.1. F-15 model.

Choosing the Tail Type. Instead of a dual tail, we opted for a V-tail configuration, reducing the number of servomotors from four to two, simplifying the setup and lowering structural complexity. This design also makes transport easier thanks to the monolithic tail construction. The V-tail requires a more complex control system, as it combines the functions of horizontal and vertical stabilizers. However, for our model, which will not exceed speeds of 300 km/h, this drawback is not significant. The compact and lightweight design minimizes stability concerns.

Theoretical Model Design. In creating the model, maintaining the correct wing loading—the weight-to-lift surface area ratio, including both the wing and stabilizer – is important. If this value is too high, the model becomes difficult to control at low speeds. Let`s calculate wing area. Wing trapezoid area:

$$S = 0{,}5(a+b)*h, \quad (1)$$

where a = 14*3 = 42 cm, b = 5.5*3 = 16.5 cm, h = 11.5*3 = 34.5 cm – geometric dimensions of the wing.

Thus, S = 0.5*(42 + 16.5)*34.5 = 1009.125 cm^2 , or approximately 11 dm^2. The area of both wings is therefore 11* 2 = 22 dm^2. Suppose UAV weighs about 2.4 kg, this results in a wing loading of around 115 g/dm^2, which is acceptable for medium-sized UAVs.

3D Modeling in CAD SolidWorks. Using 3D modeling in SolidWorks allows quick visualization, analysis, and testing of different design options without requiring physical prototypes. This approach saves time and resources, enabling faster design iterations and early detection of issues. 3D model of UAV is shown on figure 2. After creating the model, an analysis of the effect of air flows was carried out (fig.3).

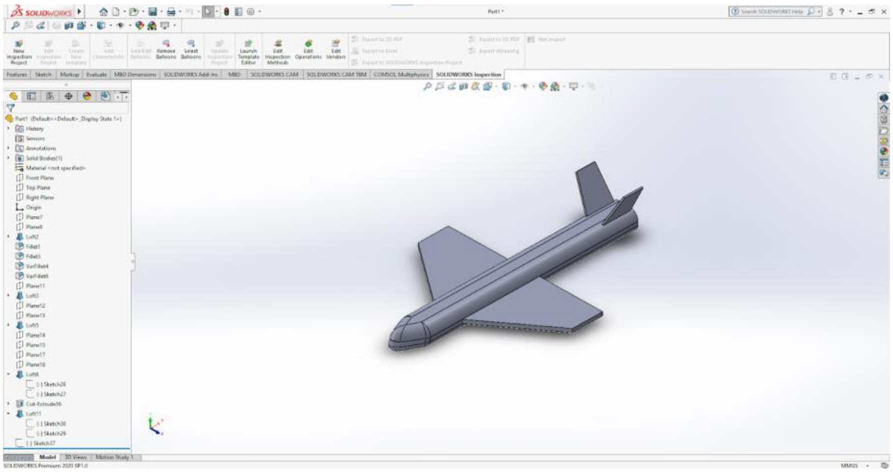

Fig. 2. 3D model of plane.

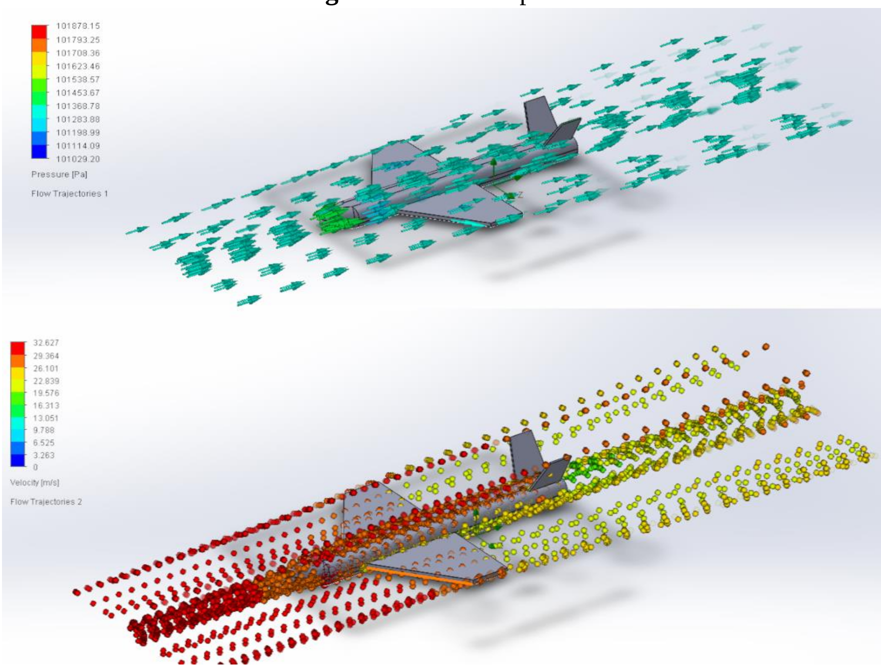

Fig.3. 3D Simulation of air flows.

Application of CNC in UAV Design Process. CNC (Computer Numerical Control) is an essential tool in the process of manufacturing parts and complex structures, such as the fuselages for Unmanned Aerial Vehicles (UAVs). Its application allows for precise, automated production of parts with high repeatability and minimal errors. CNC can be used for manufacturing various parts of the fuselage, such as the body, wings, tail, and other components.

Precise Manufacturing of the Fuselage. Using 3D models developed in CAD (SolidWorks), CNC programs are created to ensure precise cutting of materials for the production of all parts of the UAV fuselage. This allows for the production of parts with the required geometric parameters and minimizes the likelihood of errors during manufacturing.

*Manufacturing of Complex Component*s. CNC allows for the manufacturing of components with high precision, such as mechanisms for controlling the movement of the tail or mounting elements. Manufacturing such parts manually can be time-consuming and not always precise, so automating this process significantly simplifies the work and improves quality.

Speed and Cost-Effectiveness. Due to the automation of the process, CNC reduces the time required to manufacture each part and decreases material costs, as the process can be optimized to minimize waste.

Material Selection: Composites and Other Materials. Selecting lightweight and durable materials for the UAV body is essential. In our case, we use composites, specifically Airex foam for the core, which is light and adheres well to outer layers, and Kevlar, carbon fiber, or fiberglass for the outer layer. Kevlar is strong but expensive and challenging to shape, carbon fiber is both strong and light but costly, and fiberglass offers a balance of affordability and strength, making it suitable for our model.

UAV Body Construction Process. The process of building the body using Airex and Kevlar with epoxy adhesive includes:

1. Core Preparation: cutting Airex parts to the required shape using CNC or manually, then sanding to improve adhesion.

2. Kevlar Preparation: cutting Kevlar slightly larger than the Airex parts, then applying epoxy to ensure even coating.

3. Layering and Vacuuming: assembling the layers of Airex and Kevlar on a mold, removing air bubbles, vacuum-sealing, and curing for 5–15 hours.

4. Finishing Touches: after curing, trimming excess material, smoothing surfaces, and, if desired, painting or varnishing.

This process produces a lightweight, durable UAV body ready for operational use (fig.4).

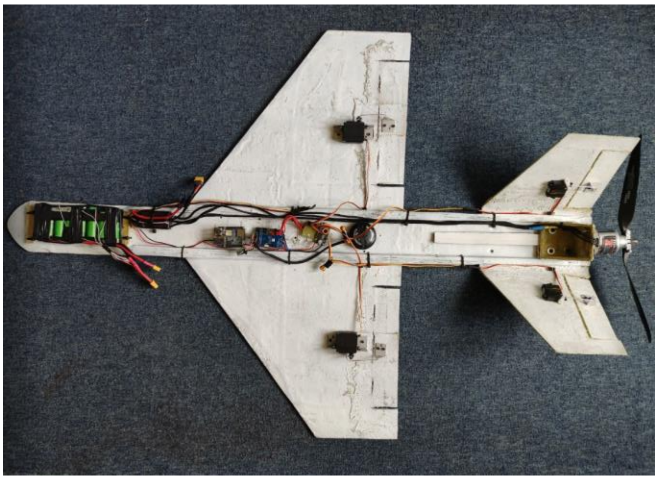

Fig.4. Fuselage with control system.

Electronic scheme. A USB camera is mounted on the nose of the aircraft body. It records video and transmits this data via a USB cable, which connects it to a microcomputer. In our case, this microcomputer is the NanoPi Neo Plus 2, which receives the signal. The camera data is transmitted through the UART protocol from our computer, specifically from the Tx1 pin to the Rx1 pin of the flight controller. The NanoPi Neo Plus 2 receives its power from this same controller. It is connected to a GPS module with a compass, which transmits information about the UAV's position in space to the controller. These components are connected to the Matek F-405 Wing V2 using UART and I2C protocols, respectively. That is, the Rx and Tx pins of this module communicate through the Tx3 and Rx3 pins of the controller, while the SDA and SCL pins send and receive data through the DA1 and CL1 pins, respectively. This GPS and compass also receive power from the Matek F-405 Wing V2.

The servomotors are connected through the S1-S5 pins. Through these pins, the servos receive commands to turn to a specific angle and, accordingly, to move the aileron, changing the UAV's direction. These motors receive power from a voltage converter through the 5V pins. This converter supplies 5V to its output pins, providing electricity to the connected components. It draws power directly from the battery, with wires soldered to its input pins and forming a connector that plugs into the battery’s connector.

The main motor is powered by the ESC. This component has a built-in converter to 5V, so no additional voltage reduction is needed. It connects directly to the battery through a connector. A detailed view of the electronic circuit is shown on figure 5.

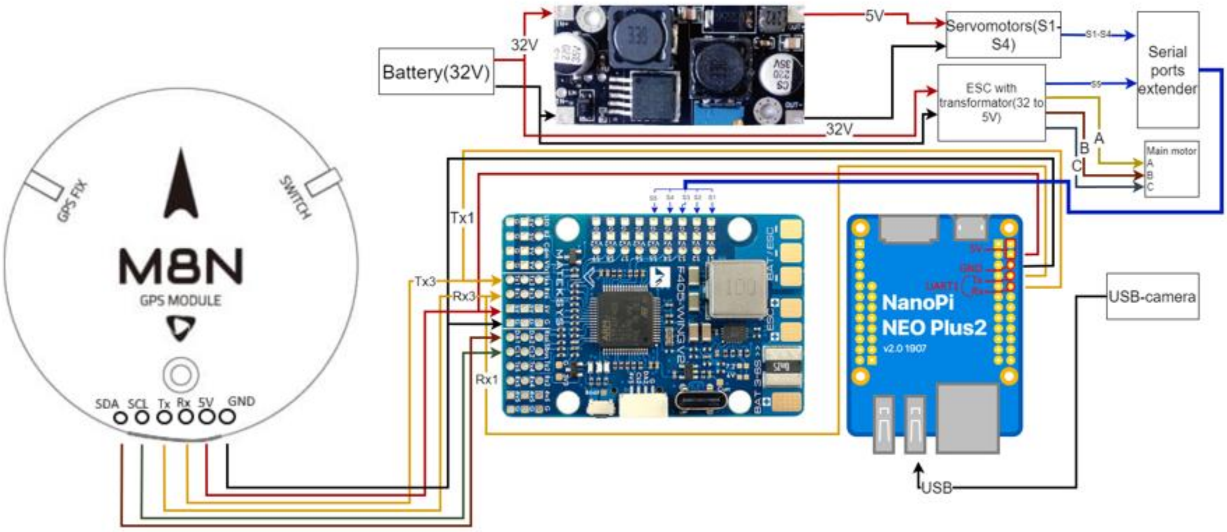

Fig. 5. Electronic scheme of control system

Justification for Using the Selected Guidance Type. Laser guidance for creating a UAV drone interceptor offers promising advantages over alternative methods like FPV (First Person View) and coordinate-based guidance. Laser guidance ensures high precision and resistance to interference by maintaining direct visual contact with the target, making it ideal for intercepting small, fast-moving drones that are challenging for other systems. It's also immune to electronic warfare interference, making it reliable in complex environments.

A key benefit of laser guidance is autonomy. Unlike FPV, which requires constant operator control, laser guidance can work autonomously, freeing the operator to focus on other tasks or use another UAV. This autonomy makes laser guidance suitable for use in hazardous or remote areas. Additionally, laser guidance can operate effectively over long distances, providing greater flexibility compared to the limited range of FPV. This allows UAV interceptors to engage hostile drones before they pose a threat. Laser guidance technology is also cost-effective and straightforward, speeding up development and making interceptors more accessible to a wider range of users.

Coordinate-based guidance may work for stationary targets, but it lacks the accuracy and reliability of laser guidance when targeting drones. Coordinate guidance also depends on precise target location data, which may be difficult to acquire in dynamic conditions.

Programming of laser-targeting system. The primary library used in the program is OpenCV for Java, an optimal choice for laser-guided UAVs. OpenCV (Open Source Computer Vision Library) is an open-source computer vision library for image and video processing. It offers functions and algorithms for image operations, including filtering, contour detection, and object tracking, which improve image quality and accuracy for further processing.

In the UAV laser guidance system, OpenCV enables light point positioning on images, which is crucial for target identification, navigation, and control. Algorithms for contour detection and color analysis help pinpoint the light point coordinates on the image.

The Java program recognizes the laser spot contour from video captured by the camera and sends information about the spot's deviation from the video center to the Pixhawk flight controller. It uses

OpenCV for image processing and MAVLink for communication with Pixhawk. Key components are distributed across classes, each with specific functionalities.

The *DroneMainApp* class serves as the program's entry point, creating a *DroneMainApp* instance, which initializes *VideoGrabber* and runs the main video processing loop. *VideoGrabber* handles video capture and analysis, continuously reading frames and calculating the laser spot's deviation, which is passed to PixhawkConnector. *PixhawkConnector* communicates with the Pixhawk via serial port, sending control signals to servos that adjust the drone's position and periodically sending "heartbeat" signals to maintain the connection. *AppProperties* loads configuration settings from Tracking.properties using a Singleton pattern, ensuring a single instance across the program. Settings include Pixhawk's serial port information and other parameters. *OpenCVTest* is a test class for verifying OpenCV video processing functionality. It also displays the camera image and processing results through a graphical interface.

Conclusions

As a result of this thesis, a UAV was designed using 3D modeling tools, and a control system with laser guidance was created. The lightweight, sturdy frame, described step-by-step in Chapter 2, achieves efficient and simple fuselage production, which is critical for UAV development, especially under current conditions. The aircraft control system is reliable and kept as simple as possible despite the overall project complexity. The program accurately identifies the laser spot contour in various screen sections and environments, then sends this data to the flight controller, which quickly and correctly calculates the aircraft's direction.

This type of UAV does not exist on the Ukrainian market. The UAV developed in this thesis has many international counterparts. Western-made systems are often superior, but considering local conditions, time constraints, and production efficiency, this UAV surpasses all foreign models.

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3D ПРОЕКТУВАННЯ БПЛА ТА СТВОРЕННЯ СИСТЕМИ ЙОГО УПРАВЛІННЯ

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Анотація. Ця стаття представляє підхід до 3D-моделювання для розробки безпілотних літальних апаратів (БПЛА), спрямований на підвищення доступності БПЛА в Україні. За допомогою САПР (систем автоматизованого проєктування), зокрема SolidWorks, був створений прототип, заснований на літаку F-15, після чого були виконані обробка на верстаті з ЧПК (числовим програмним керуванням) та використані композитні матеріали для легкого каркасу. Для цього БПЛА була реалізована технологія лазерного наведення з програмним забезпеченням, що контролює корекції в навігації, що забезпечує високу точність при відстеженні цілі. Лазерне наведення стійке до перешкод, що робить його ідеальним для виявлення та перехоплення швидких і малорозмірних дронів. Цей ефективний та економічний дизайн забезпечує швидке створення точного наведеного по лазеру БПЛА.

Ключові слова: БПЛА, ЧПК, композит, контролер польоту, ESC (електронний контролер швидкості), OpenCV (бібліотека комп'ютерного зору).