Using computer vision and artificial intelligence for developing multipurpose intelligent unmanned aircraft system

V Kharchenko[1], V Klobukov[1,2], O Zykov[1] and V Rjabokon[1]

[1] National Aviation University, 1 Liubomyra Huzara ave., Kyiv 03058, Ukraine

[2] E-mail: kvv@nau.edu.ua

Annotation. The paper deals with some aspects of the design and development of intelligent control systems for unmanned aerial vehicles with autonomous functioning features. Issues related to conceptual design and software implementation of Multipurpose intelligent unmanned aircraft system (MIUAS) for detecting and tracking objects using elements of computer vision and artificial intelligence are considered. The information processing system uses the application "Objects Detection and tracking" using elements of computer vision and artificial intelligence" to search forimages in the video stream according to the trained model using a neural network based on Convolutional Neural Networks (CNN) An experimental sample of a navigation and control software complex based on computer vision and artificial intelligence elements, as well as some options for the application of this system, are described. In the paper described the main elements of Multipurpose intelligent unmanned aircraft system, methods, used to detect, locate and track detected objects and described some areas where it can be used. Described application, used to control and rule unmanned aerial vehicle multicopter and aircraft types and operational modes of the system. The article can be used as a start point to develop semi-automatic intelligent unmanned aircraft system.

1. Purpose and scope of use

The development of unmanned aerial vehicles (UAVs) of various types and purposes is an extremely important and relevant direction in the development of modern aviation [1].

Increasing the autonomy and reliability of UAVs, expanding the range of their tactical, technical and operational characteristics suggests the need to develop a new generation of airborne and ground control systems that provide the ability to operate under conditions of rapid changes in the air situation, in the presence of random disturbances of the environment and other uncertainty factors based on integrated use modern intelligent technologies.

Requirements for an intelligent UAV control system are determined by its application and a given level of autonomy. In general, the functionality of modern UAV samples should provide the ability to solve the following main tasks:

- providing automatic take-off and landing modes;
- provision of autonomous flight modes along a given route or to a specified goal without a priory established route, avoiding restricted areas arising in the way of obstacles, maneuvering at low altitudes, etc.;
- organization of automatic modes of onboard processing of navigation and other useful information received during flight [2].

The generalized structure of an intelligent on-board UAV control system consists of the upper level of control and target designation, the middle level of flight control and the lower level of control of actuators and includes the following main modules:

- digital cartographic system;
- system of external sensors;
- an integrated navigation system;
- intelligent (adaptive) control and target designation system;
- intelligent (adaptive) flight control system;
- Situation analysis system;
- intelligent (adaptive) control system for actuators.

Taking into account all the above criteria, MIUAS was developed.

MIUAS is intended for solving (in manual, semi-automatic and fully automatic (without operator participation) modes) applied problems using various types of UAVs.

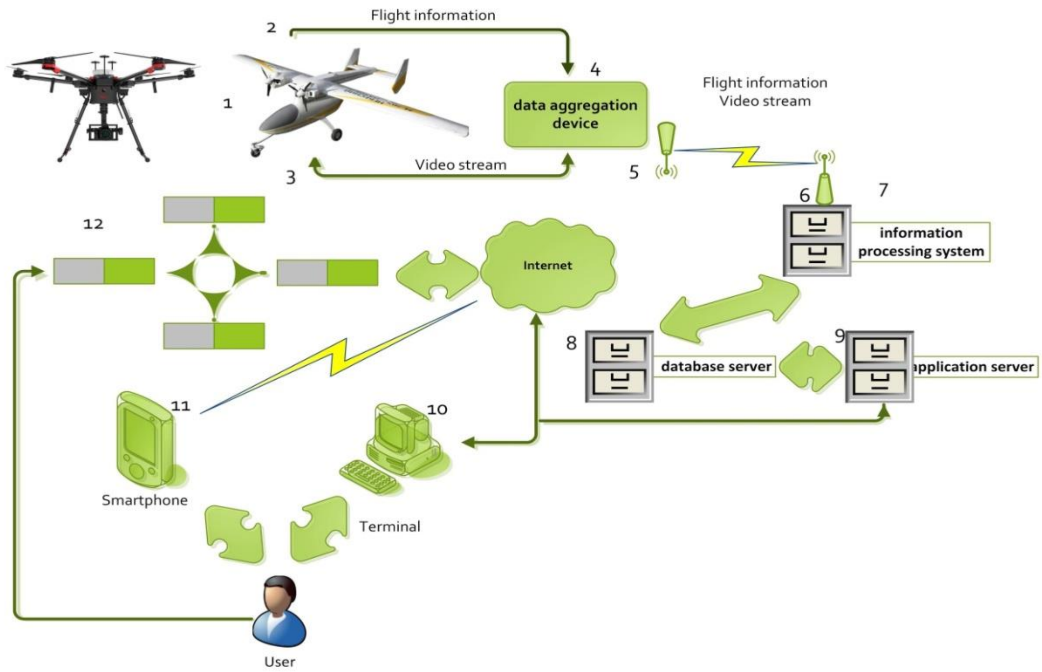

Figure 1. Block diagram of the “Objects Detection and tracking" system using elements of computer vision and artificial intelligence”

1 – UAV

2 – Flight controller (autopilot)

3 – Camcorder on gyro-stabilized controlled gimbal

4 – Data aggregation device

5 – Transceiver on the UAV side

6 – Transceiver on the side of the ground control station

7 – Information processing system with the application "Identification and tracking objects" using elements of computer vision and artificial intelligence.

8 – Database server

9 – Application server

10 –Workstation

11 – User's mobile device

12 – Additional devices that receive control signals

2. System description

The UAV (1) is controlled by the flight controller (2) and has on board video camera on a gyro-stabilized [3] controlled gimbal (3). The data aggregation device (4) receives data from the flight controller, gyro-stabilized gimbal and the video stream from the camera and transmits this information via transceivers (5, 6) to the information processing system (7). The information processing system uses the application "Objects Detection and tracking" using elements of computer vision and artificial intelligence" to search forimages in the video stream according to the trained model using a neural network based on CNN (YOLOv3) [4, 5], calculates the coordinates of detected objects and writes this information to the database (8). The user of the system can use user device (which can be a personal computer, smartphone, tablet (10, 11)) to watch in real time the process of searching for objects on video (in the form of rectangles around certain objects with captions corresponding to class of the defined object) and placement of the detected objects on the map. The user has the ability to select a specific object to track. Visual object tracking performed using fast and precise CSR-DCF algorithm [6, 7]. When the mode of tracking an object by the camera or by the UAV or both enabled, the information processing system can transmit control signals to the UAV using transceivers.

The application server (9) runs applications that use the information stored in the database for further analysis of the obtained data and to generate control signals for controlling external systems (12).

The experiments were performed with "Objects Detection and tracking" software using elements of computer vision and artificial intelligence.

3. The results of experiments using simulator

The development of the basic algorithms of the system and training of personnel is carried out on a specially created hardware and software virtualization complex, the main elements of which are an emulator for the PX4 controller and a system simulator (Figures 2,3) [8,9,10].

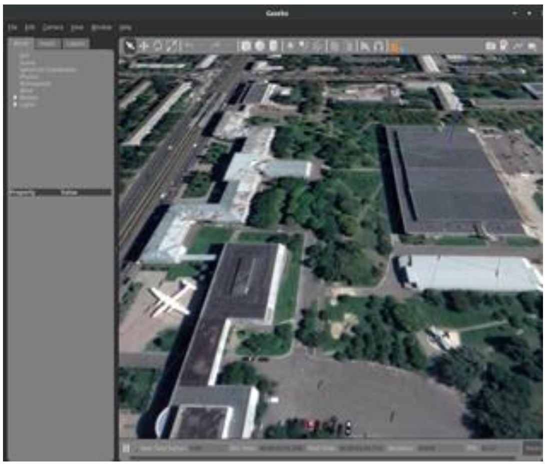

Figure 2. Virtualization of the external environment based on GAZEBO.

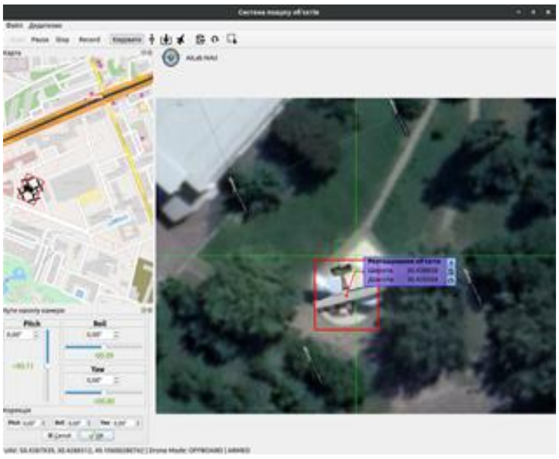

Figure 3. Testing the functions of automatic objects detection and - locating of the MIUAS system in the environment of the hardware-software virtualization complex.

4. Object detection

In MIUAS, most computer vision tasks are solved using Convolutional Neural Networks (CNN). Due to their structure, they are good at extracting features from the image. CNNs are used in classification, recognition, segmentation, etc.

Detection using CNN approximates the location of an object in an image by predicting the coordinates of its bounding box, while segmentation goes further by predicting the boundaries of objects in images.

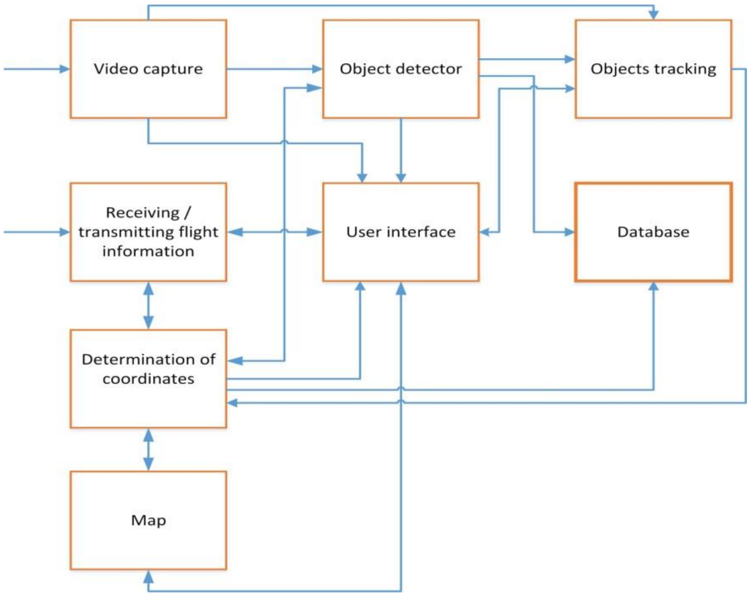

Figure 4. Block diagram of the “Objects detecting and tracking" program using elements of computer vision and artificial intelligence”.

The video capture unit receives the video stream and transmits it to the object detector. An object detector using uses a neural network based on CNN using a trained model detects the objects and their classes in each frame of the video stream.

The obtained results are transmitted to the coordinate definition unit (Figure 5) and to the user interface, where they are displayed in the form of rectangles with the names of the corresponding class.

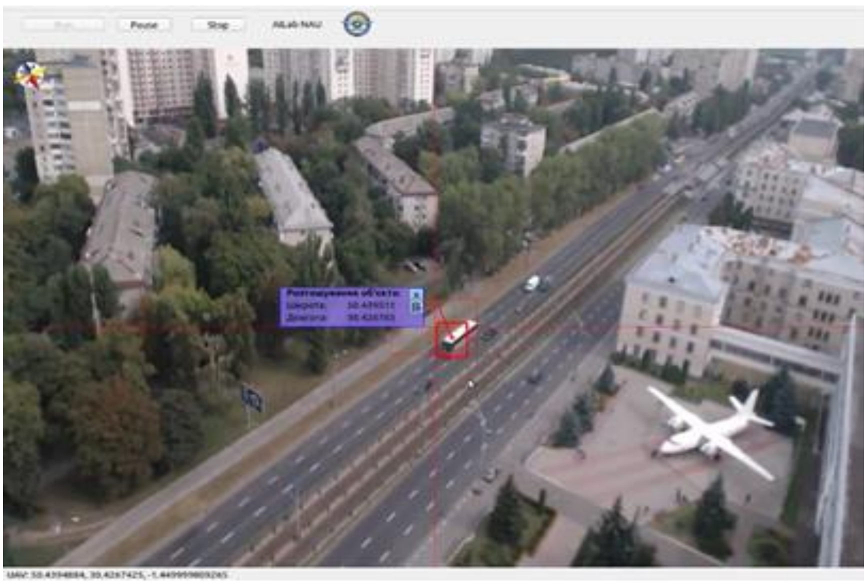

Figure 5. Flight tests of the functions of automatic detection, – locating and tracking of a moving object of the MIUAS system when working as a part of an unmanned aviation complex.

The flight information receiving / transmitting unit receives information about the position of the UAV and the video camera and transmits this information to the coordinate determination unit and to the map unit. The map block shows the current position of the UAV in the user interface (Figure 6)

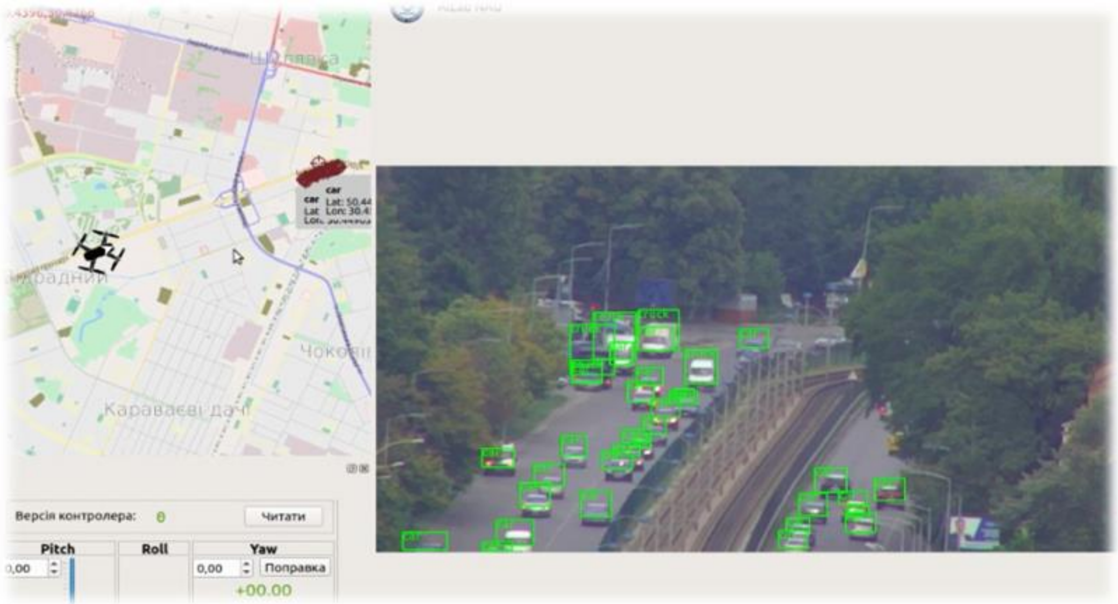

Figure 6. Implementation of the functions of automatic detection (artificial intelligence) of cars (at a distance of more than 2 km) of the MIUAS system when working as a part of an unmanned aviation complex.

The coordinate unit obtains information about the detected objects and flight information and uses the map unit to calculate the position of the detected objects using transformation matrix [11]. The calculated results are recorded in the database and displayed on the map as goals (Figure 6).

Using the user interface, the user can select one of the defined objects on the screen and enable the object tracking mode. In this case, the object tracking unit receives information about the initial position of the object in the video image from the object detector unit. The tracking unit determines the position of the tracked object in the next frames of the video stream and transmits the received information to the unit for determining the coordinates and the user interface, where a rectangle is displayed around the tracked object. The coordinate unit uses a map unit to determine the position of the monitored object and transmits this information to the user interface for display on the map and in a separate block, where it is possible to copy the current position of the monitored object in latitude and longitude to the clipboard.

In the process of tracking objects, the user can enable the mode of tracking the object with the control of the UAV or the camera gimbal, or both the UAV and the camera gimbal.

The user can control the gimbal of the camera (set the angles of the direction of the camera) and UAVs (set the height, land, set the coordinates of the next point with a map).

Currently, MIUAS is used to implement a set of scientific and applied activities aimed at conducting a number of studies and work to create a database of multispectral images of a wide class of objects (materials) (Figures 7,8).

Figure 7. Photo image of object masking elements.

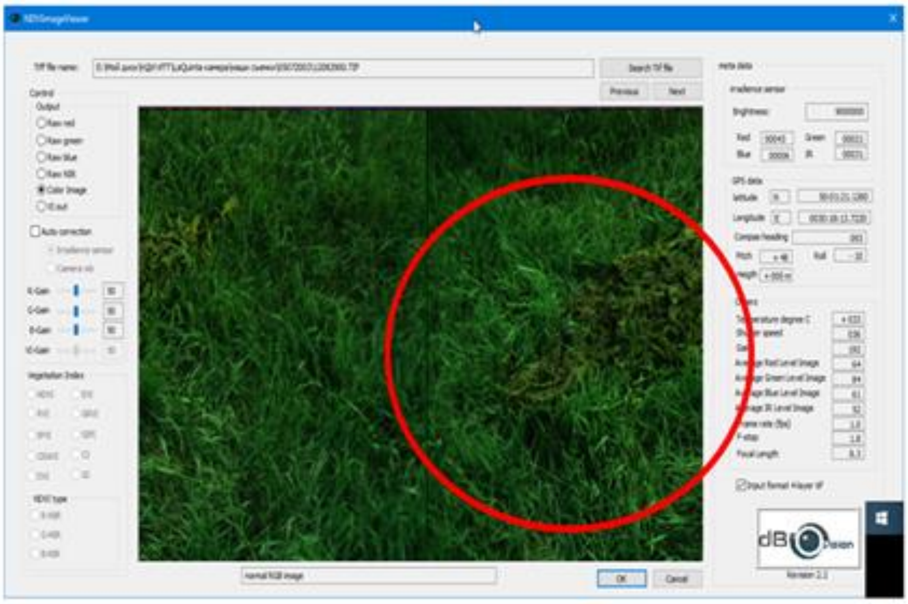

Figure 8. Image of object masking elements taken with an RGB camera.

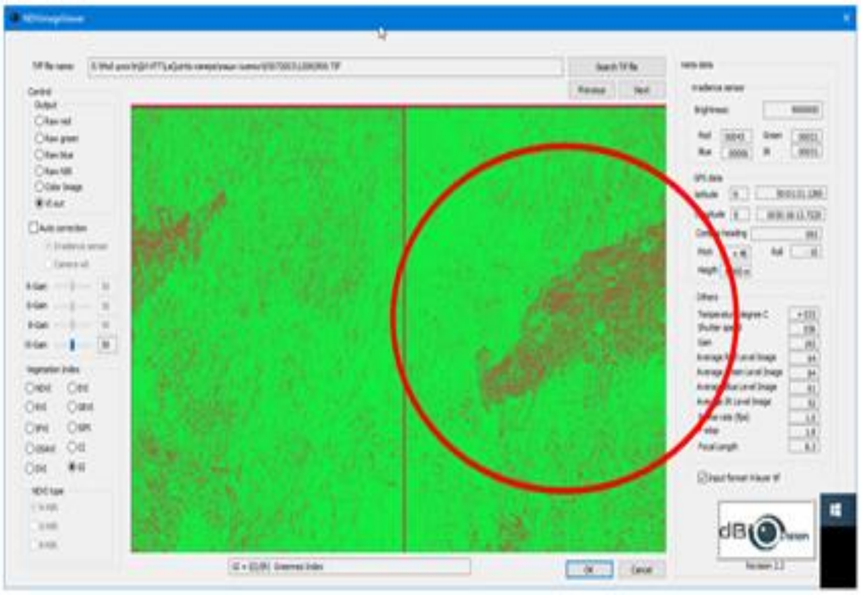

Figure 9. Image of the object's masking elements captured with a multispectral camera and post-processed using machine learning and artificial intelligence algorithms.

It is also used to develop specialized adaptive algorithms for processing and analysis of multispectral data based on technologies of computer vision, machine learning and artificial intelligence (Figure 9). The system can be used to locate, record and analyze zones of different vegetation indexes using NVDI [12].

Other areas where the system can be used include road traffic density monitoring and forecasting and controlling, deforestation monitoring, coastline monitoring and other.

Conclusions

The developed MIUAS made it possible to carry out a large-scale series of experimental studies on modeling an autonomous UAV, developing intelligent control technologies based on the use of computer vision and artificial intelligence technologies, checking the adequacy of various options for the mathematical description of a controlled object, as well as synthesizing and debugging knowledge that regulates strategies for appropriate behavior when solving required applied problems under a priory incompletely defined conditions in the presence of external disturbances of a random nature.

The results of computer modeling in practice confirmed the effectiveness of the proposed approach, clearly proving that an intelligent control system based on the use of computer vision and artificial intelligence technologies provides a high level of adaptability, reliability and quality of UAV functioning in various modes of operation.

The use of MIUAS based on AI technologies makes it possible to reach a fundamentally new qualitative level of UAV application for the following tasks: remote sensing of the earth, precision farming, multispectral aerial photography, monitoring of distributed objects in real time. Potential users of MIUAS are private and public companies, law enforcement and special structures of Ukraine.

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