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Abstract. The paper considers the problem of positioning unmanned aerial vehicles (UAVs) without using satellite navigation systems. The application of positioning occurs through the visual channel of flight control by means of an on-Board video camera on the basis of the terrain plan or satellite photos. The aim of the work is to improve the accuracy of the positioning method in accordance with several flight control positions, predetermined landmarks and closed route flight (both open or obstructed ways), for implementation in control computer systems or mobile applications. The obtained results will improve the effectiveness of UAV technology in applications for environmental monitoring, construction monitoring, agriculture, maritime industry, forestry, law enforcement, urban and municipal economy.

Keywords: unmanned aerial vehicle, geoinformation system, environmental monitoring, pixel polygon, object on the ground, flight route, control points.

1. Introduction
The use of unmanned aerial vehicles (UAVs) in the purposes of geodesy, topography, visual monitoring of the terrain requires the use of the most practical methods for measuring distances, the location of UAVs and local objects.

The use of JPS trackers, special devices for determining coordinates, course and speed largely solves the problems of positioning and target designation of UAVs, however, solving practical problems requires measurements on the ground not only of the UAVs themselves, but of local objects.

The study of the work consists in determining the geometric dimensions of local objects, for example, the size of flooded areas due to floods, or the area under crops. More often, all available maps require continuous correction due to changes in annual magnetic declination, distortion of map projections and other factors. These tasks are solved in connection with pronounced local objects - boiler pipes, dominant heights on the terrain, detached buildings, and other objects [1].

Determination of the positions of local objects is clear and accessible, the size of the UAV itself is best determined by eye, through a video surveillance camera. However, this method can hardly be called accurate. This stems from the skills of measuring distances by eye, distortion of images obtained from the camera and the need to scale the picture from the video.
The second factor in the applicability of UAVs with visual control of the terrain is the limited visibility from surveillance cameras. However, with an increase in the measured distance, the measurement error also increases, therefore, the UAV position must be refined for several objects.

The application of methods for estimating the area of a pixel polygon of a screenshot of a video image from a drone camera to a known size of a local object, a pre-calibrated video camera is to be considered. This can be called a modified method of goniometric positioning.

2. Measuring the distance to the visible horizon

To determine the distances to the observed objects, we will use the goniometric scale shown in Figure 1.

As you know the circumference:

\[ l = 2\pi r, \]  \hspace{1cm} (1)

where \( r \) is the radius.

We place the observer in the centre of the observer's circle, divide the circumference into 6000 parts [1]:

\[ 0.001 \ g. \ d. = \frac{2\pi r}{6000} \approx 0,001r, \]  \hspace{1cm} (2)

considering that \( r = D_t \) also known as a distance to the target, then 1 division on the scale is \( 0.001 \ D_t \), a small division is 0.5, knowing the size of the target, we can determine the distance!

Observing several local objects relatively certain, as landmarks, it is possible to determine the distance between the location of objects and their position on the ground. If you have a plan of the terrain or a satellite image in advance, you can scale the image to the observed landmarks, providing the tasks of visual control of the terrain, or geodetic measurements.

3. Angular positioning of the quadcopter

The quadcopter is equipped with a high-speed high-resolution video camera. The use of a quadrocopter is carried out on a terrain with a known terrain plan or satellite image.

The position of local objects is fixed by the operator on the goniometric scale presented by me in Figure 2.

Figure 1. Determination of distance on a goniometric scale - an image of a person is placed in two thousandth divisions, if a person's height is approximately 1.8 meters, then the distance to a person will be \( D = \frac{1.8 \times 1000}{2} = 900 \) meters.
The goniometric scale positioning system includes the following elements:
- a quadrocopter with a video camera on which a transparent film with an applied goniometric scale is placed.
- quadrocopter control panel with a pilot’s monitor.
- a channel for controlling a quadrocopter by visual reactions of the pilot, including: a block for capturing measuring marks on a goniometric scale; block for calculating corrections (distance to visually captured target); position display unit for two (or more measured distances by points).
- in the feedback channel, the speed values set from the operator’s console are recorded (along three axes) and are entered into the position display unit, for subsequent display on the computer screen of the set position of the apparatus, which is compared with the current one according to the video captured from the video, to control the drift of the apparatus.

The block diagram of the adaptive control is shown in Figure 3.
Combining the goniometer scales with images of local objects, the pilot calculates the distance from the quadcopter to the object by capturing measuring marks, according to the size of local objects previously marked by waypoints.

According to the formula (2), in the block for calculating corrections, the distances to objects are calculated at the intersections of the lines of sight, which are determined by the point of flight, as well as between the objects themselves.

The unit for displaying the position of the vehicle puts the flight point on the base of the flight map (topographic electronic map, or the terrain plan, including a satellite image of the terrain), on which the video of the flight is also displayed.

Feedback, control systems, captures signals from the control panel joysticks (pre-set values of flight speeds along three axes). The corrected value of the velocities is taken into account when constructing a point of the position of the apparatus, by compensating for the drift of the apparatus.

Video recording on any of the media allows you to control the flight along a pre-developed route relative to the control points of the route.
Figure 4. Example: the height of the chimney of the Yuzhnaya boiler house in Novorossiysk is 20 meters \cite{4}, given that the projection is strictly not vertical ($\cos 45^\circ \approx 0.7$), the distance to the chimney will be $D_t = \frac{20 \cdot 1000}{5 \cdot g.d. \cdot 0.7} = \text{meters}$

The proposed method for measuring distances and positioning requires a certain training of the pilot, as well as studying and working out the flight route. If it is necessary to estimate the cultivated area, then when planning the flight, it is necessary to study the route points and the characteristic sizes of these objects.

Distance measurement must be performed using two or three characteristic points on the ground. When measuring at three points, you can already get geodetic accuracy. If you build a route along a closed curve, then a measurement is obtained using the closed path technology. Placing a video camera on a quadrocopter assumes the absence of optical visibility of the aircraft itself from the location of the drone pilot.

4. Estimation of distances by pixel polygons

Formula (1.2) allows, on the basis of the ratio of the scale of the observed object with known dimensions, to find the distance, if the observing device is calibrated according to the optical characteristics of the video camera.

We assume that the size of the image in the screenshot of the video broadcast from the drone in pixels is calibrated 1: 1000, 1 mm in the screenshot corresponds to the real size of 1 meter, then the distance to the object will be 1 km.

We will implement the method in the MatlabR2014 package using the functions of the MATLAB language \cite{5}, which is shown in Figure 5.
Figure 5. Result of calculating the sizes of pixel polygons linked in the screenshot component

Calculation result:
>> polygonC
RESULT =
   1       98885
   2           2
   3           5
   4           3
   5           7
   6           2
   7           1
      5217          8
      5218          1
      5219          1
      5220          95
      5221         15
      5222          5

Application of methods for estimating the area of a pixel polygon of a screenshot component of a video image from a drone camera to a known size of a local object, a pre-calibrated video camera allows modifying the method of goniometric positioning [6].

The parameters of the scale of the area of the pixel polygon and the area of the observed net object correspond to the scale of the transformation, if the obtained ratio is multiplied by the calibration factor, then the distance to the local observed object will be obtained.

The disadvantage of this method is the need for a preliminary assessment of the flight route and, accordingly, the study of the actual size of the area of local objects. Filtering methods allow you to get more accurate estimates of the position of the drone [7].

5. Conclusion
UAVs of "peaceful" use fly at altitudes usually at altitudes of 100-500 meters, no more than 1000 meters. Even with JPS or GLONASS trackers, you have to fly in real terrain, taking into account the height of the suspension
lines and the height of power transmission towers, buildings, terrain [8]. Flight conditions are monitored using video received from the UAV.

Methods for ensuring UAV flight using video from onboard are relevant from the practical sense of the usage of unmanned aerial vehicles.

The second urgent task is to compensate for the UAV flight conditions, with the adaptation of the pilot's high-speed reactions according to the flight conditions.

The use of positioning on the observed local objects allows you to fix objects that have reappeared on the ground and are not marked by JPS or GLONASS navigation methods. For example, the results of avalanches or mudflows, other natural or man-made objects on which markers are not installed using satellite navigation systems. These are the tasks of operational reflection of the situation on the ground using UAVs [9].

The process of displaying the route of movement with fixing marks on the video recorded during the flight can be automated using the method of angular positioning by measured distances. With the determination of a larger number of points, the flight accuracy parameters are only refined.

The use of angular positioning with distance measurement on local objects requires some training of the pilot and knowledge of the basics of geodesy.

The implementation of the results of the work makes it possible to increase the applicability of the UAV technology in environmental monitoring, construction, agriculture and forestry, law enforcement, urban and municipal economy.

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