On the road identification method from images

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Abstract. The research work is devoted to the method of autonomous navigation of unmanned aerial vehicles based on video images. The main essence of the navigation method based on video images is to detect important infrastructure objects from the image, determine the features and compare them with the features located in the database. In the study, winding roads without intersections are selected as important infrastructure. Roads are determined from pre-taken images in the base, and only some features about these roads are selected and stored. The UAV takes an image of the earth's surface during its movement. Detects roads from the image, matching features related to these roads are found. The characteristics placed in the database are compared with the characteristics found at the current time. In the study, the roads in the image are identified as straight lines. For this, two different versions of the same method have been proposed. Roads from the image are defined as straight lines. As a result, the winding road is expressed as intersecting straight lines. The powers of the found paths - the number of pixels - points included in the roads are found. The ratio of these numbers to each other is considered as a feature that expresses the image. Software for solving the problem is developed and tested on images.

Keywords: UAV images, autonomous navigation, edge detection, line detection, GPS, feature.

1 Introduction

As it is known, the fields of use and application of unmanned aerial vehicles are increasing and expanding day by day. For this reason, unmanned aerial vehicles are being studied more widely. Different methods for navigating these devices are investigated and new methods are proposed. There are various methods for navigating UAVs. The most widespread of these methods, as we know, is the application of GPS technology. In the GPS navigation method, the current position and coordinates of the device are

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determined based on the signals received through the satellite. However, this method has several drawbacks. The main drawback of the method is the impossibility of applying the method in areas where there is no GPS or its use is restricted. For this reason, autonomous navigation methods without using GPS are being investigated for the navigation of UAVs [1]. There are different methods for autonomous navigation. Among these methods, the navigation method based on video images was considered in the research work. The main essence of the navigation method based on video images is as follows: the UAV receives a view of the earth's surface during its movement. Important infrastructure in this image is detected and recognized. The location of the facility is determined based on the coordinates of this infrastructure. Important infrastructure means natural objects such as rivers, mountains, power plants, well-known buildings, etc. Roads have been taken as important infrastructure to be referred to in the research work.

The result of research work is software. This software will be run in real-time on the on-board computers installed on the UAVs. For this reason, the established algorithm is required to work faster using less resources - memory.

Appropriate algorithms of fields such as artificial intelligence, computer vision, image processing, and image recognition are used to solve the problem.

The C++ programming language is used in the Code Blocks environment to describe the algorithms.

2 Problem Statement

As mentioned, the video-based navigation method for autonomous navigation of UAVs is considered in the research work. The main essence of the method is as follows: the UAV takes an image of the earth's surface during its movement. A preselected reference object is detected from this image. A reference object can include various objects. Both natural objects such as mountains, rivers, steep rocks, and important infrastructural objects such as power plants, buildings, etc. can be selected as reference objects. Roads, which are important infrastructures, are selected as objects to be referred to in the research work. Firstly, the base is created. The characteristics of all the roads that the UAV can encounter during its movement and the coordinates of the roads according to the images are placed in this database. Then, the image received by the UAV during its movement is subjected to various processing processes. The next stage after the processing process is the stage of detection of the selected infrastructure. Roads should be found from the processed image and the characteristics related to this road should be determined. The obtained characteristics are compared with the characteristics of all roads previously placed in the database. The coordinates corresponding to the characteristic in the database will be the coordinates of the road detected from the image. At this time, we can face a number of problems. One of the problems is mentioned below.

It is clear that during the UAV movement, it can capture the image of the earth's surface at different distances, at different angles and from different directions. At this time, such an issue is faced: although the road detected from the image received by the

UAV and the road located at the base are virtually the same, the characteristics obtained from these images may differ from each other. Different characteristics lead to the expression of the same roads as different roads. In this case, the detected characteristics may correspond to the characteristics of a completely different road in the base. This does not solve the problem of UAV navigation properly. Therefore, the problem of invariance due to rotation should be taken into account during image processing. An example of the same road taken from a different angle is shown in Fig. 1 and Fig. 2 is shown.

Fig. 1. UAV Image

Fig. 2. The image in the base

As we know, roads can be in the form of both straight lines and curves and detours. At the same time, these roads can be in intersecting and non-intersecting forms. It is possible to perform the identification of roads from the image in different ways. For example: Identification of roads as curves, identification of straight line segments, etc. can be other methods. Some of these methods are described in the next section. The problem set in the research work is to detect the road without intersection as straight line pieces from the image received by UAV.

3 Problem Solving

In the previous part, we informed about the main essence of the method of navigation according to video images. As we know, the characteristics of the infrastructural object - road detected from the image are compared with the characteristics of other road images in the base. These characteristics vary depending on how the roads are identified from the images.

To identify any object from an image, the image should be processed firstly [2]. Image processing is done in several stages. Image processing is essential to determine the characteristics of the object that is required to be detected in the image.

Transition to gray level, edge detection algorithms are applied on the images. Various edge detection algorithms are available. Of these, Sobel and Canny algorithms are applied in the research work [3]. The results of the Sobel and Canny algorithms applied to the above Fig.1 are shown in Fig. 3 and Fig. 4. As a result of the application of algorithms, the color image is transformed into a black and white form. White pixels are non-informative pixels. As you can see from the pictures below, after edge detection, the number of required pixels is drastically reduced.

Fig. 3. The result of applying the Sobel operator

Fig. 4. The result of applying the Canny operator

3.1 Application of the B-Spline method.

After image processing, the final image consists of only informative black pixels. After processing, object detection algorithms are applied to the image. In the problem statement, we noted that the object required to be detected from the given images is the roads.

As we mentioned, the roads can be in the form of both straight lines and curves and windings, and these roads can be identified in different ways. One of these methods is identification of the road in the form of curves - splines. An identification algorithm should be chosen that satisfies the principle of invariance with respect to rotation.

B-Spline method can be applied for rotation invariant identification of curves [4]. The main parameter of the B-Spline method is the control points of the curve. The main essence of this method is that B-Spline is not an approximation method of the curve, but an interpolation method. Therefore, the curve does not pass through the specified control points, but tries to pass through. In this case, changing the location - coordinates of any of the control points does not change the shape of the entire curve, but changes only the part where that point is included.

When the paths are identified by the B-Spline method, the control points are selected as the characteristics to be compared. So, not preliminary images are placed in the base, but the characteristics of the roads in this image - control points. At the same time, the control points of the road are determined from the image received by the UAV and compared with other characteristics - control points on the market.

4 control points are marked in Fig.5. A curve constructed based on these control points is shown. As can be seen from the figure, the constructed curve does not pass through the given control points. It passes around the control points. Therefore, the result obtained during the determination of roads - curves from the image with the application of the B-Spline method may not be completely accurate.

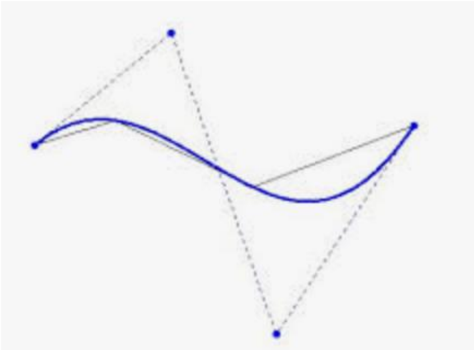

Fig. 5. B-Spline curve

3.2 Determination of straight lines from an image.

When determining roads from an image with the B-Spline method, the road is expressed by a curve. As can be seen from Fig.6, at this time the curve does not try to pass through the set control points. This may not fully represent the road. The method proposed in the research for determining roads from an image is to express the road as a broken line. For this, let's first look at detecting a straight line from an image. There are various methods for detecting straight lines from an image. The Hough Transform algorithm was applied for straight line detection in the research work [5].

Hough Transform Algorithm. This algorithm is a feature extraction technique used in image analysis, computer vision, and digital image processing. In other words, the Hough Transform technique, also known as the voting algorithm, relies on the voting procedure to ignore unnecessary pixels from the image. The algorithm was developed in 1972 by Richard Duda and Peter Hart. Initially, this algorithm was applied to determine straight lines in an image, but later it was extended to determine arbitrary shapes, mainly circles and ellipses. It is known that all images consist of dots. But each of these points is not informative. A 2-dimensional counter matrix is constructed in the Hough Transform algorithm. The parameters of the matrix vary depending on the issue. When determining straight lines, these parameters are the length of the perpendicular lowered to the straight line from the coordinate origin and the angle between this perpendicular and the abscissa axis. In curves such as circle and ellipse, the coordinates of the center and the radius are taken as parameters. When defining straight lines, straight lines are drawn through all pairs of points in the image. The parameters related to the same straight line are also the same. When the same parameters are found, the value of the matrix corresponding to that pair is increased by one unit, which is also called the voting procedure. After checking all the points, local maxima of this matrix are found. The local maxima found represent a straight line. We don't need other points. Similar calculations are performed according to the parameters of finding other figures. This algorithm can only be applied to binary images. Thus, the given photo must first be converted into a black-and-white binary image and the boundaries of the objects in the image must be determined (edge detection).

Suppose a photo of size *m*x*n* is given , *P[d,α]* counter array is set and all elements of this array are zero at the start. Here, *d* is the length of the perpendicular drawn from the coordinate origin to the straight line in the figure, α is the angle between this perpendicular and X axis. α and *d* are determined for the straight lines formed by each (x,y) point with all other points.

$$d = x\cos\alpha + y\sin\alpha \quad (1)$$

For each *(d, α)* pair, the value in the corresponding index of the array *P* is increased by one unit. The pair *(d, α)* in which the array *P* takes the maximum value is determined. These pairs found define the straight line in the image. Fig.6 shows examples of detecting straight lines at different angles in images. Note that each image in .bmp format has undergone the processing steps listed above. In the end, the results obtained by applying the Hough Transform algorithm on images with black-and-white binary format are given.

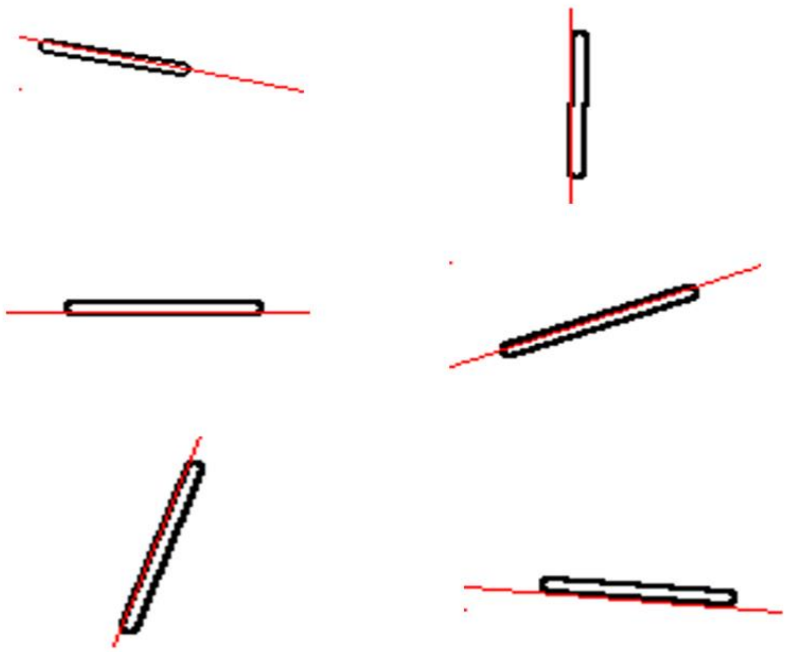

Fig. 6. Detection lines with different angle on images

In Fig.6, there is only 1 straight line in each bmp file. With the algorithm mentioned above, only one straight line can be found in an image. The straight line found is the straight line with the maximum value of the array P, that is, the maximum number of pixels.

The Hough Transform algorithm for finding straight lines from an image is performed by moving from the x,y coordinate system to the α,d polar coordinate system. Each straight line in the image replaces 1 point in the polar coordinate system. In addition to the α and d parameters of this point, let's also consider a height parameter -h (the number of points belonging to the straight line). Let h be the third coordinate axis in the three-dimensional system. At this time, depending on the number of points included in each straight line in the given image, the h value gets different results. Sometimes prices can be very close to each other. In the previous algorithm, according to the corresponding values of α and d, where the h parameter is maximum, only one straight line - the longest one - was found. By finding the local maxima of the h parameter, we can find several straight lines in the image. The method proposed in the study for determining local maximum values is as follows. First, we determine the number of straight lines we want to find from the image. 10 is accepted as such number in the research work. Known P[d,α] values are considered. Each P[d,α] value is compared with P[d, α-1], P[d, α+1] values. The proximity value of P[d, α], which is greater than both values, is calculated with other local maximum values found. If this value is smaller than a certain Δ value, the found P[d, α] is written instead of the smallest value among the 10 other P[d, α] values stored before it. This price has been accepted as the local maximum price and saved as one of the 10 straight lines. The process is repeated for every 11th local maximum value found. A part of the program code written in C++ is given in Fig.7.

```
for (int i=1;i<d;i++)
  {
    for (int j=0;j<alfa;j++)
     {

       if ((P[i][j]>P[i-1][j])&&(P[i][j]>P[i+1][j]))
         {

           if (P[i][j]>minmax[2])
             {
               int k=0;
               while (k<k0)
                 {
                   if((abs(i-maks[k][0])+abs(j-maks[k][1]))<delta)
                     {
                       if( maks[k][2]<P[i][j])
                         {
                           maks[k][2]=P[i][j];
                           maks[k][0]=i;
                           maks[k][1]=j;
```

Fig. 7. A part of C++ program.

An example of the presence of several straight lines on an image file and the detection of these straight lines is shown in Fig. 8.

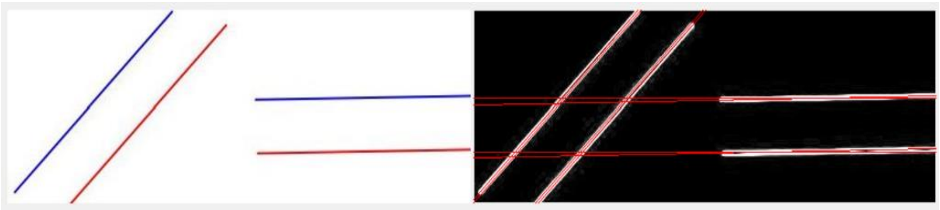

Fig. 8. An example of detecting multiple straight lines on an image.

In the article, the Hough Transform algorithm is applied in 2 different ways to find straight lines. One of them, as mentioned above, is the equation of the straight lines formed by each black dot (pixel) with each other black dot in the black-and-white format image. (d, α) pairs are calculated. The value of the corresponding P[d, α] is increased. A straight line corresponding to the pair (d, α) where the maximum value is obtained in the array P is found.

In another proposed method for finding straight lines based on the Hough Transform algorithm, 180 straight lines are drawn from each black point. Here is an angle of 180. The value of angle α varies between (0.180). A d value is calculated for each α. The corresponding x, y coordinates are stored.

Let's apply this method on Fig. 9 given below. Also, let's apply the Canny operator to this image to determine the edges. The result of the Canny operator is shown below in Fig. 10, and the result of the algorithm for finding straight lines from the given image is shown in Fig. 11.

Fig. 9. Any image

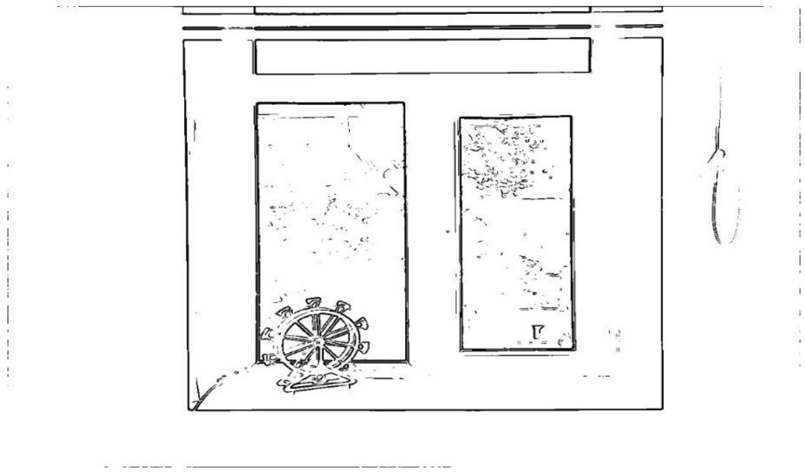

Fig. 10. The result of applying the Canny operator

Fig. 11. Lines on image

3.3 Comparing UAV images with base images.

The task is to compare the path in the image taken during the UAV movement with the ones in the base and choose the appropriate one. It is known that it is not efficient to store the entire image in the database and compare it with the image taken by the UAV at the current time. Therefore, images are not stored in the database. Certain characteristics and features are selected from these images and saved. The images taken by the UAV are also processed to find those features and compare them with the ones in the base. The ratio of straight lines to each other is taken as such a feature in the article. Thus, straight lines in an image are found and their ratio is calculated. These proportions are stored in the database as a feature. The same calculations are made for the image received at the present time, the features are selected. These characteristics are compared with those in the base. The appropriate one is selected in the base. The coordinates of all roads placed in the database are known in advance. Thus, the UAV can determine its location based on the coordinates of the road placed in the base.

4 Conclusion

In the research work, a navigation method based on video images is proposed as an autonomous navigation method. A new method for determining roads from images is proposed - the intersecting straight lines method. Two different versions of the same algorithm have been developed for finding straight lines. Image processing operations are applied to the "Agsu Pass" road located on the territory of Azerbaijan, taken using the Google Earth platform. Approximation of non-intersecting roads with the intersecting straight lines saves computational resources - both memory and computation time. The method can be applied in autonomous navigation of UAV in conditions where visibility is not limited.

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