Problems of identification in information systems

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ALGORİTHMS FOR FİNDİNG NON-İNTERSECTİNG ROADS ON İMAGES

Abstract. **Research relevance** The use of GPS for UAVs to determine their current coordinates (navigation) leads to a number of problems. The development and improvement of the autonomous navigation method without the use of GPS is an actual issue, and this issue is considered in the article. **The subject** of study in the article is the issue of UAVs navigation based on video images. **The purpose** of work to develop an algorithm for autonomous navigation of UAVs that requires less resources. The following **tasks** are solved in the article: software modules are developed based on image processing algorithms; suitable model for invariant identification of curves was studied and applied. The following **results** were obtained: an algorithm was developed for the invariant identification of winding roads (curves) without intersections from different angles; developed software modules have been tested in the Republic of Azerbaijan on the basis of a map of the region called "Agsu Pass". **Conclusions:** the application of the method proposed in the article will enable rotation-invariant autonomous navigation of UAVs using less resources.

Keywords: Global Positioning System; unmanned aerial vehicle; navigation; autonomous; invariant; video; non-intersecting roads.

Introduction

The widespread use of unmanned aerial vehicles (UAVs) in modern times, both military and civilian, raises a number of issues. One such issue is the problem of locating, tracking and managing UAVs. These devices have different navigation methods. The following are some of the different navigation methods tested for UAVs.

One of the main approaches for navigating UAVs is the application of GPS technology. GPS - a global positioning system that operates continuously and transmits electromagnetic signals from position, speed and altitude meters to certain receivers. These signals allow you to determine the location of objects on the ground, the coordinates of the device with high accuracy. This technology, which is applied to the UAV, determines the location of the device and regulates its movement [1]. In [2], without human intervention, the UAV receives the current coordinates from the GPS receiver via a Bluetooth connection with the navigator computer. With this point, the optimal trajectory is drawn to the next destination. During the flight, the navigator computer provides information on which direction and how far to turn. This information is used in the control system of UAV engines.

To date, UAV navigation methods have been proposed in three main categories:

1) inertia navigation;

2) satellite navigation;

3) vision-based navigation. Visual-based navigation from these methods provides richer information about the earth's surface and objects than others [3].

It is possible to navigate the UAV with GPS when flying in the open air, at an altitude without any obstacles. However, at lower altitudes, where obstacles may be present, this approach is not appropriate. [4] proposed optical stream navigation for autonomous movement of UAVs in such zones.

Problem statement

The main disadvantage of the widely used GPS method is that the operation of the UAV is completely dependent on GPS. Where there is no GPS, there are obstacles to the movement and control of these devices. For this reason, a GPS-independent control system is required for UAVs to be able to move autonomously.

Various methods have been proposed to regulate the autonomous movement of UAVs without the use of GPS. Some of the methods are shown in the introduction. One such method is video-based navigation. The main approach in this method is to determine the location of the objects based on the objects observed by the device and their coordinates. Observed facilities include important infrastructure such as power plants and roads. UAV recognizes these objects and determines its current coordinates and location based on their coordinates. The images and coordinates of the objects to be solved must be known in advance. This data is processed and placed in the database. The image obtained by UAV is also processed. The results obtained are compared with the data in the database to determine which of these objects corresponds to the database. The location of the device is determined by the coordinates of the image object.

Problem solving

Important infrastructure as reference objects is used to determine the location of the UAV. Roads were taken as such infrastructure in the study. Thus, the UAV must take a view of the earth's surface while driving without GPS and determine its approximate location relative to the road in the image. In this study, only non-separable, non-intersecting roads were considered.

In order to solve the problem, images of all the roads that the UAV can observe must first be obtained in advance. Certain features are determined by processing these images. For winding, non-separable roads, such key features are considered to be the turning points of the roads. These features - the coordinates of the turning points are placed in the database as a factor indicating the appropriate path.

The proposed method for solving the problem is to compare the turning points of the road imagined during the flight with the turning points of the known roads. The UAV captures video of the earth's surface during movement. The obtained images are processed, ways are found. The turning points of the road are determined, compared with the coordinates placed in the database, and the appropriate one is selected.

With the application of this method, UAV can provide autonomous traffic on roads without GPS. However, there are a number of problems here. During the research, it was found that UAV can capture video in different forms: at different distances, at different angles, in different directions and scales. In this case, it is known that the road image of the UAV will be processed differently from the road image in the database and different features will be obtained. As a result, although both images represent the same path, they will not match or will match with another image in the database. The problem of invariance was considered to solve this problem.

Each of the roads can be identified as a curve, as the study considers only non-separable, non-intersecting and mostly curved roads. There are different methods for identifying curves: interpolation polynomials, Bezier curves, etc. However, the B-spline model was chosen to identify the curves in the study. The main reason for choosing this method is that the B-spline is resistant to operations such as rotation and scaling. Application of the B-spline method provides invariant identification of curves [5].

Application of b-spline:

$$Q(u) = \sum_{i=0}^{n} P_i N_{i,k}(u) . \quad (1)$$

In this equation u is a parameter of the function representing the curve $u = n - k + 2$;

n - the number of nodes is determined in Fig. 1;

$P_i(x_i, y_i)$ - control points;

$N_{i,k}(u)$ - basis function;

k is the number of points on each segment where the curve is divided. This number satisfies the condition $2 \le k \le n+1$.

The basis function $N_{i,k}(u)$ is the basic of the construction of the B-spline. The procedure for setting up basis functions is given in (2).

$$N_{i,k}(u) = \frac{u - t_i}{t_{i+k} - t_i} \cdot N_{i,k-1}(u) + \\ + \frac{t_{i+k+1} - u}{t_{i+k+1} - t_{i+1}} \cdot N_{i+1,k-1}(u), \quad (2)$$

$$t_i = 0, 1, 2, ..., n+k$$

As can be seen from the construction of the base functions, these functions do not depend on the control points. The B-spline model is applied to both base images and road images obtained by the UAV.

Image processing. As mentioned, the placement of pre-known images in the database means the identification and placement of certain features from these images. Comparison between images also means comparing their respective features. The image is processed to obtain these features from the images and to establish a suitable spline. The main objects - roads - should be identified from the processed images and the image should be cleaned of "dirty", non-informative data. Image processing involves a few steps. These steps are applied to the image of the so-called "Agsu Pass" in Azerbaijan, taken from the Google Earth platform Fig. 1. The sequence of these steps is shown below.

Fig. 1. Taken image of "Agsu Pass"

Converting a color image to a grayscale image. The images are usually rendered in RGB (red, green, blue) format. Due to the complexity of working with color images, these images turn into grayscale images. The transition to a grayscale image is an effective and important step in terms of speed, ease of coding, etc. in the subsequent processing stages. The procedure for converting an RGB image to a grayscale image is given below.

$$0.3 \cdot R + 0.59 \cdot G + 0.11 \cdot B . \quad (3)$$

In this formula, RGB represents the red, green, and blue color distribution in the image pixel, respectively [6]. The grayscale image of the captured image is shown in Fig. 2.

Defining the edges of objects in the image. At this stage, the Sobel Edge Detection algorithm was applied. Using this algorithm, unnecessary pixels are thrown out of the image. Defining the edges of objects in the image brings the image to the black and white format, and at the end of the step only black (or white) pixels play an informative role [7]. The result of applying the algorithm is shown in Fig. 3.

Fig. 2. Grayscale image

Clearing noise pixels from images. The number of pixels required in the black-and-white image obtained with the application of Edge Detection algorithms is slightly reduced. Based on the Connected Component Label algorithm, other additional pixels in the image are deleted, and as a result, the image consists mainly of roads [8]. The result of applying the algorithm is shown in Fig. 4.

Fig. 3. Binary image

Fig. 4. Clean image

Thinning. At the end of the processing, the image should be in black and white, consisting only of a curve. Despite the processing of the image, the curve in the final image may not be of the desired thickness. In the final stage, the curve in the image - the path should be taken as a sequence of pixels, not as a set of pixels. The construction of this sequence is done by checking the adjacent pixels of each pixel. To build this sequence for thicker curves is more difficult and impossible . For this reason, it is necessary to reduce the thickness of the curve to 1 pixel. The Zhang-suen Thinning algorithm is used as a thinning algorithm in the research [9]. The essence of this algorithm is to check the adjacent black pixels of each black pixel. As a result, the object - the curve in the image is thinned to 1 pixel, and the number of black pixels is sharply reduced. Any curve taken in Fig. 4 , the result after the thinning is shown in Fig. 6.

With the connected component label approach, the set of black pixels that represent the curve is brought to the pixel sequence. Properties - turning points are determined in a certain method from the sequence of obtained pixels.

Each of these steps is applied to known images and the image obtained by the UAV. The characteristics of the known images are placed in the database, and the characteristics of the image obtained by the UAV are compared with those in the database. The corresponding one from the known images is determined. The current position of the UAV is determined based on the coordinates and position of this road.

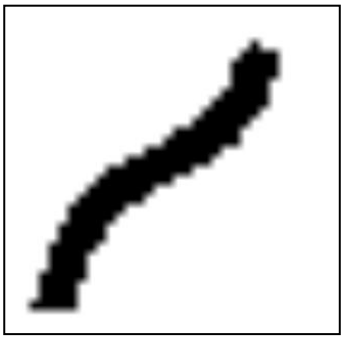

Fig. 5. Any curve taken

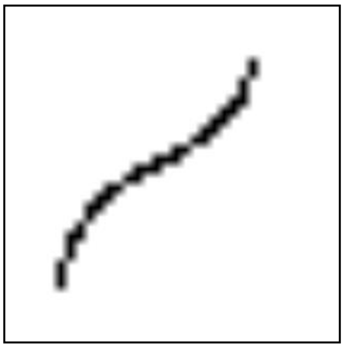

Fig. 6. The curve after the thinning

Aspects (opportunities) of practical application

The proposed method can be used as a navigation method for UAVs. The main essence of this method is that navigation is based on images. The main advantages of the method:

1. Having the ability to navigate the device without depending on GPS,

2. It requires quite a few resources during navigation.

The main limitations and disadvantages when applying the method are as follows:

1. The recognition process will not work in unfavorable weather conditions such as fog, rain, or any obstruction that restricts vision.

2. The proposed method can be applied only for winding roads without intersections.

Discussion of the results

To date, several navigation methods for UAVs have been reported in the literature. Most of these methods rely on the use of GPS. However, in environments where the use of GPS is restricted or there are external interferences to GPS, problems may arise when applying those methods. In such cases, it is more efficient to use the navigation method based on video images. There are also video-based navigation methods in the literature.

The advantage of the video-based navigation method proposed in the article over other video-based methods is that it requires less resources. Carrying out extensive processing on the images has significantly reduced the number of points that play a role in the end. This has led to the requirement of less time and memory.

Conclusions

The article develops a method of navigating objects encountered in video images to ensure the autonomous movement of the UAV without the use of GPS. Non-separable, non-intersecting highways are taken as reference objects to determine the location of the UAV. This method was tested in the Republic of Azerbaijan on the basis of a picture taken of the region called "Agsu Pass". The proposed method can be used to ensure the autonomous movement and control of UAV in places where there are restrictions on the use of GPS. The application of the method is possible both in military zones and in other areas.

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Алгоритми пошуку непересічних доріг на зображеннях

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Анотація. Дослідження присвячене розгляду питань забезпечення автономного руху безпілотних літальних апаратів. **Актуальність дослідження.** Використання GPS для БПЛА для визначення їх поточних координат (навігація) призводить до ряду проблем. Розробка та вдосконалення методу автономної навігації без використання GPS є актуальною проблемою, і це питання розглядається в статті. **Предметом дослідження** в статті є питання навігації БПЛА на основі відеозображень. **Метою роботи** є розробка алгоритму автономної навігації БПЛА, що вимагає менших ресурсів. У статті вирішуються **наступні завдання**: розроблено програмні модулі на основі алгоритмів обробки зображень; вивчена та застосована відповідна модель інваріантної ідентифікації кривих. Отримано **наступні результати**. Розроблено алгоритм інваріантної ідентифікації звивистих доріг (кривих) без перетинів з різних кутів. Алгоритм Zhang-Suen Thinning був застосований для зменшення товщини кривих на зображеннях до 1 пікселя. Розроблені програмні модулі пройшли випробування в Азербайджанській Республіці на основі карти регіону під назвою «Агсуський перевал». **Висновки:** застосування запропонованого в статті методу дозволить здійснювати ротаційно-інваріантну автономну навігацію БПЛА з меншими ресурсами.

Ключові слова: глобальна система позиціонування; безпілотний літальний апарат; навігація; автономний; незмінний; відео; дороги, що не перетинаються.