ROAD TRACKING FROM UAV IMAGERY USING GRADIENT INFORMATION [1],[2]

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***Abstract**: Nowadays an unmanned aerial vehicle (UAV) has many applications in a variety of fields. Detection and tracking of a road in UAV videos play an important role in traffic monitoring, ground–vehicle tracking, automatic UAV navigation etc. In this paper, an efficient road tracking framework in UAV videos is proposed. It includes the procedures of images similarity assessment and dominant direction determination. The methodology is based on using the gradient information of the sequentially captured images and corresponding correction of the motion direction of UAV.*

***Keywords**: UAV, road tracking, image similarity, dominant direction, gradient*

***ACM Classification Keywords**: ACM Classification Keywords: Image Processing and Computer Vision*

Introduction

There is currently a rapid growth in unmanned aerial vehicles application in various fields of human activity. The use of drones as part of modern navigation, video and communication equipment makes UAVs an indispensable tool for many tasks.

One of the main problems with the use of UAVs is the use of UAVs for road monitoring, traffic monitoring, tracking are objects on it, automatic navigation and others.

Road tracking is the automated or semi-automated process which uses video information captured by a camera, and special image processing methods.

The complexity of this problem is associated with the presence of the numerous factors that influence the quality and content of the images on the video shooting frames. The main factors that are constantly operating in the process of a video shooting are the evolution of the system, the turbulence

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of the atmosphere, the presence of wind, vibration side of the device, as well as external intentional and unintentional interference and distortion of the real scene.

In addition, images of the same objects in the adjacent frames of a video sequence differ both in size and perspective, and the images themselves are fluctuating due to the vibration of UAV board and other mentioned factors. Therefore, for the efficient processing of information received UAV, you must either create special approaches and methods or improve existing algorithms. At the same time it should be noted that the effectiveness of digital image analysis depends largely on the available prior information about the properties of the image characterizing features of a scene and numerical values of its major parameters. On the other hand, since the analysis results ultimately are estimated by a person, the used methods should take into account the properties and capabilities of human visual system (HVS).

It should be noted that the use of global positioning GPS systems or GLONASS and other types of navigation technology significantly simplifies the solution of the problem, but there are actual problems in recent years, in which the use of these means is inappropriate (for stealth) or impossible (in case of failure for a variety of reasons of related equipment). In such cases, the important and almost the only information to carry out the problem being solved is the video shooting of the area and online processing of video sequences. In the present study we attempted to develop methods for road tracking by control of similarity of images of various parts of the road, received by UAV.

In the literature suggested a number of approaches and methods related to the problem of search, detection, and tracking of a road and / or objects on it [1, 2 and 3]. They use a variety of features that characterize the presence of the road sections on the image or of objects on it, such as the movement [4], the background [5-6] and others [7-8]. In the paper [9] was used the fact of the similarity of neighbor video frames and corresponding similarity measure. We confine ourselves to a situation where the initial part of the road has already been found or defined, so in this study the issue of search and detection of the road in general is not considered. Instead, it is assumed that preliminarily is available a template, showing some characteristic of the road and its surroundings, and in each moment for the UAV video camera is accessible only a small part of the road contained in the current frame. Consequently, the road tracking procedure is reduced only to the use of information on road features, contained in the above-mentioned template, additionally using only electronic compass to determine the course of the flight. It is necessary to use the structural characteristics that are stable under various transformations and distortions of the image.

Description of Mathematical Models

The proposed procedure is based on repeated application of two algorithms - of the algorithms for estimating the similarity of the images and for evaluation of the dominant orientation of the images of discussed scenes. These algorithms previously proposed in [10-13], and showed the effectiveness of their using in various applications. Both algorithms are based on mathematical models, using a variety of characteristics of the image gradient field and lead to results corresponding to the perception of HVS.

Here is a brief description of these algorithms.

The basis for usage of gradient field is well known fact that HVS confidently recognizes the content of an image by the aggregate of available edges. Methods of edge detection in an image are basically based on gradient field analyze using different mathematical methods [14]. One of approaches to gradient field processing is its presentation as two-dimensional random variable and creating certain statistical models for image structure investigation [10].

Let $G_H = \|G_H(m,n)\|$ and $G_V = \|G_V(m,n)\|$ be the horizontal and vertical gradients of an image I correspondingly, and $M = \|M(m,n)\|$ be the gradient magnitude, where

$$M(m,n) = \sqrt{G_H^2(m,n) + G_V^2(m,n)} \ . \qquad (1)$$

a. *Model for dominant orientation* of an image is based on usage the term of orthogonal regression, the equation of which is as follows

$$\frac{1}{1-\rho_{HV}^2}\left[\frac{(g_H-\mu_H)^2}{\sigma_H^2} - \frac{2\rho_{HV}(g_H-\mu_H)(g_V-\mu_V)}{\sigma_H\sigma_V} + \frac{(g_V-\mu_V)^2}{\sigma_V^2}\right] = C^2 , \qquad (2)$$

where $\mu_H, \mu_V, \sigma_H, \sigma_V$ mathematical expectations and MSE of random variables G_H and G_V, ρ_{HV} is the coefficient of correlation between them, C – is a constant. Dominant orientation α of an image is determined as follows

$$tg\alpha = \frac{2 * \rho_{HV}}{\sigma_H^2 - \sigma_V^2 + \sqrt{\left(\sigma_H^2 - \sigma_V^2\right)^2 + 4\rho_{HV}^2}} \ . \qquad (3)$$

Models (1)-(3) were applied in different tasks for analyzing of images with different sizes and orientations [10].

b. *Model for distribution of magnitude gradient.* Let assume that the gradient magnitude (1) is a random variable with Weibull distribution density

$$f(x;\eta,\sigma) = \frac{\eta}{\sigma}\left(\frac{x}{\sigma}\right)^{\eta-1} \exp\left[-\left(\frac{x}{\sigma}\right)^{\eta}\right], x \geq 0,$$

where $\eta > 0$ - shape parameter, $\sigma > 0$ - scale parameter.

It must be noted that the fact of using only two parameters in this model has significant advantage in certain tasks of image processing, connected with searching in big data bases. Particularly, it is proposed images similarity assessment measure in [10], which shows the proximity of images which have gradient magnitudes with Weibull distribution densities $f_1(x;\eta_1,\sigma_1)$ and $f_2(x;\eta_2,\sigma_2)$. The measure is determined by formula as follows

$$W^2 = \frac{\min(\eta_1,\eta_2)\min(\sigma_1,\sigma_2)}{\max(\eta_1,\eta_2)\max(\sigma_1,\sigma_2)},\ 0 < W^2 \leq 1,$$

where the gradients are calculated using Sobel operator and the parameters in (5) are estimated by method of moments.

Algorithm for Updating of UAV flight Course

Description of the algorithm we give on a concrete example. Fig. 1 shows an example of an image of the road, located in the forest, on which can be seen some moving vehicles on it. It is assumed that the initial small land area, containing a road, is known, hence we consider that the flight UAV begins with the video shooting of this place. A part of the road is chosen as shown in Fig. 1. The template will be compared to the current image area on similarity with him during the process of the road tracking. It is also assumed that the direction of flight is measured by an electronic compass and may be updated according to the control program, managing the flight of the UAV.

Fig. 1. Choosing the initial part of the road to be a template.

To illustrate the possibility of tracking the road on the basis of this procedure let's conduct the following experiment. We compute the similarity measure of the template to all areas of the same image size Fig. 1 which are obtained by the sliding window. Then we the resulting map of similarity binarized and compare to the binarized original image (Fig. 2).

a b

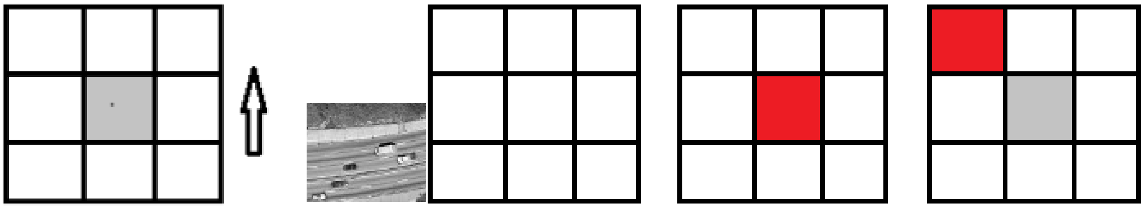
Fig. 2. Similarity map for chosen template (a) and binary pattern of the road (b).

Analysis and comparison of the images of Figures 2a and 2b indicates that the road surface is distinguished from the background significantly sharper in the first case, which illustrates the advantage of the proposed approach.

It is expected that in the course of the flight on board of the UAV is recorded a sequence of frames of video and for each frame it is making a decision about changing the direction of the UAV. This algorithm analyzes the video frames and changes direction of flight according to the following steps.

Step 1. Choosing the initial part of the road image (see. Fig. 1)

Step 2. Select ordinary frame of the video sequence, filmed in the course of the UAV flight. The image is divided into sections with approximately the same size, the amount of which is determined in advance, based on a preliminary study of the situation, flight conditions etc. (in this paper, these issues are not addressed). For definiteness, we assume it is equal to the number of 3x3 = 9 (see Fig.3a). The arrow on the image Fig.3a shows the direction of movement of UAV. In Fig. 3b marked selected template, which will be compared with the received image parts. Given the direction of motion shall be considered only six sites located in the upper part of Fig. 3a. It is assumed that the central portion corresponds to the UAV position at the moment of the frame shooting.



a b c d

Fig. 3. Description of the scheme of comparison the image parts.

Step 3. Each part of the resulting partition of the image is compared by similarity with selected one, and find out the part with a maximum value of the similarity measure. Two situations are possible: a site with a maximum value of the similarity measure is coincide (Situation 1, Fig 3c.) or not (Situation 2, Fig 3d) with a central part. Case 1 indicates that the UAV is located above the road; therefore the direction of motion may be determined according to the dominant direction of the central part. In Case 2 the direction of movement must be corrected by the direction of the site with the maximum value of the similarity measure.

Step 4. Go to Step 2 for the processing of the next video frame.

Fig. 4 illustrates the procedure described above on the same example. The top three parts which lie in the frame captured by the UAV are highlighted in red. The second row shows the images of these areas (with the numbers 1, 2 and 3), and the third row shows the values of the measures of similarity of these images with the template (located on the lower left corner of the image). As can be seen, the maximum similarity is observed with a central portion (W02 = 0.71), hence we observe the above-described Situation 1. Therefore, the direction of the central portion of the image is equal to 1700, and the command may generate compensation of the motion direction of flight of the UAV.

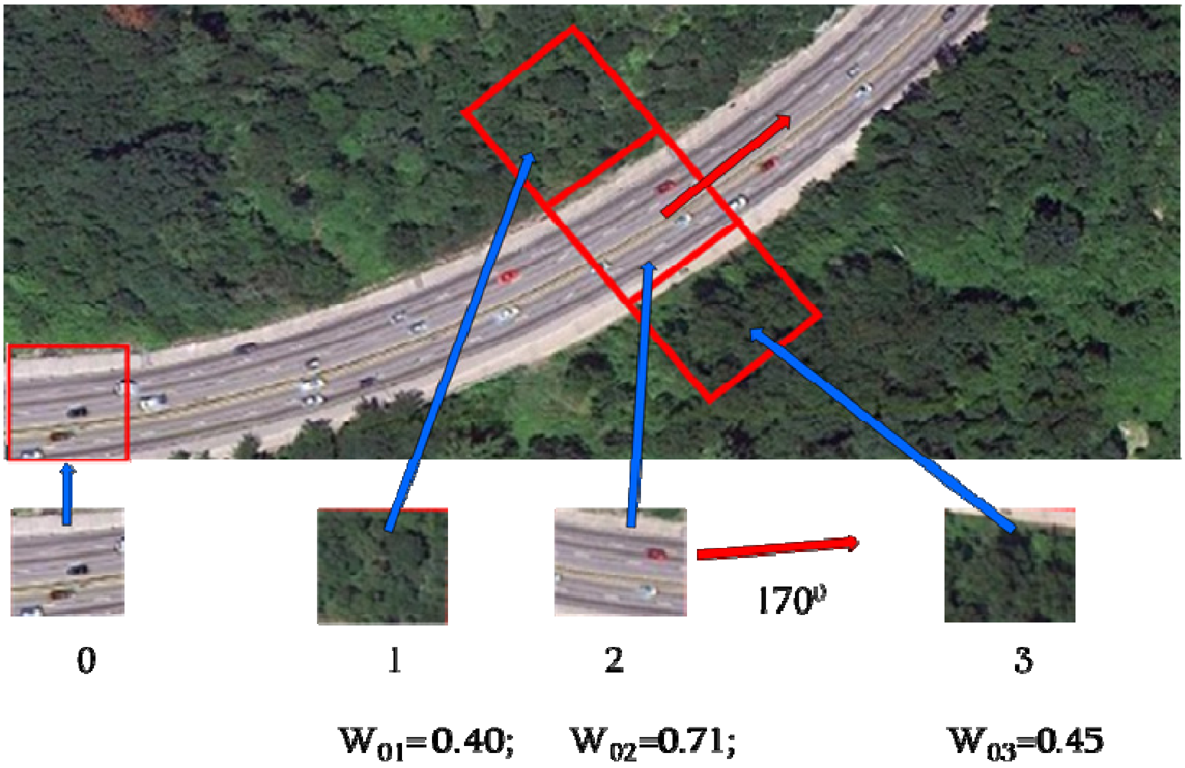


Fig. 4. Illustration of application of proposed procedure for road tracking.

Conclusion

The problem of road tracking by UAV imagery, using only the information delivered with video sequence and by electronic compass to determine the flight course, is considered. The possibility of reducing the problem to multiple applications of procedures of estimating similarity of images of different sizes and of determining the dominant direction of an image in each frame of a video sequence is analyzed. A corresponding motion control algorithm for UAV is proposed.

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