TECHNIQUE FOR ROAD AUTOMATED TRACKING WITH UNMANNED AERIAL VEHICLES

Samvel Hovsepyan

Abstract: *One of the most popular areas of unmanned aerial vehicles (UAV) use is the monitoring of roads and highways. UAVs are considered to be a low-cost and rapidly growing platform that can provide effective mechanisms for data collection and processing, especially in case of long distances. In this paper a new method for automated road monitoring with the help of UAV is offered. The method is suitable for determining image areas, where the heterogeneity compared with the general road structure is spotted. Also, algorithms for finding road cover from video shots and for determining the direction of the road are offered. The method is applicable for automated control of UAVs in order to find and track roads, as well as registration of various types of objects on the road. All the methods and algorithms were tested on a model and the results are shown.*

Keywords: *image processing, road tracking, road monitoring, similarity measure, UAV*

ACM Classification Keywords: *Image Processing and Computer Vision*

Introduction

Unmanned aerial vehicles (UAV) are widely being used in many fields. One of the most popular areas is the monitoring of roads and highways. The objectives of such monitoring are safety supervision, traffic and road conditions monitoring, road construction inspection, etc. For example appropriate researches had been done in the 2000s in the transport department of Ohio [Coifman 2004], and California [Frew 2004]. They used UAVs equipped with cameras and autonomous navigation systems.

Currently the UAVs are considered to be a low-cost platform that can provide effective mechanisms for data collection and processing. In particular, these data may be used in road traffic monitoring, which is important for companies that are engaged in transportation. Conventional traffic data collection methods [Zhou 2013] are based on a fixed infrastructure, which controls the local area. Therefore, control over wide areas becomes an expensive and time consuming problem. For comparison, the UAV has the following advantages: (1) low cost of monitoring over long distances; (2) by changing only the sensors it is possible to carry out different types of monitoring.

This article examines two issues related to road monitoring: (1) identification of road sections from a video stream; (2) anomalous situations detection on the road, related to obstacles occurrences, the existence of cars, their clusters, etc.

There are many approaches to solve the problems of detection and tracking of roads in the literature. Most of these methods are based on color and / or structural (geometric) properties of a road. Among them more effective and reliable methods use combination of both characteristics [Wang 2004], [Siogkas 2007]. Thus, we find more prudent use of both types of information.

In [Frew 2004], the proposed method is based on representation of color characteristics of road surface by using the Gaussian mixture models (GMM). Then, in order to determine the road pixels in each frame, the probability of pixels are checked for compliance to etalon GMM. In [Rathinam 2007] there is suggested a method, that is based on learning of color and gradient characteristics of river areas. Accordingly, to represent etalon models Gaussian and gamma distributions are used. In [Rathinam 2008], the method relies on the study of boundary structures of road. Those parts of the road, that are not being recognized automatically by using primary analysis, are being filled, if there are two sections of the road, that can bridge with straight line towards the road direction.

Most advanced tracking methods, such as the mean shift [Comaniciu 2000], particle filter [Nummiaro 2003] and optical flow [Schunck 1981] are based on the appearance of structures that were originally described. Hence, these methods are for special classes of objects, such as faces, cars or pedestrians etc, where objects have common attributes. In our case, the problem is more general, more simplified. The goal is to find any type of object on road without further specification. Also the listed algorithms require a lot of time and resources for calculations that leads to difficulties in their use in real mode.

Based on the above analysis of the literature, it seems appropriate to bring the problem to a new methodology development for road tracking and monitoring with the help of UAVs, which will meet the following requirements;

- Be fast enough for the calculations during the flight time of the UAV
- Give accurate results about the road tracking.

These goals can be divided into three separate subtasks.

- Finding road parts from an input image
- Automatically tracking of the road by a given direction
- Finding of all objects on the road.

It is assumed, that as an input method receives a video stream taken from a UAV. Video stream may come as a consecutive set of scenes or through short videos intervals, which again can be represented as a set of consecutive scenes by using already written existing application libraries. Therefore, it can be assumed, that the work is in consecutive scenes processing.

To determine road surface a method is proposed, which is based on road structural and color characteristics. It is quite fast and by effectiveness does not differ from commonly accepted models based on GMM. And for road monitoring, method tracks changes in consecutive frames and on changed parts runs a new algorithm, which is based on road structural characteristics.

Roadway Finding

In the proposed approach, finding the road surface from a given image is divided into two parts.

In the first part, based on the method, used in [Asatryan 2015], a complete image segmentation and simplification is carried out. Then, form the received segments, candidate sites on the pavement are identified based on the color characteristics of the web. Fig. 1 shows an example of an image before and after segmentation and simplification.

Fig. 1. (a)-original photo,

Fig. 1. (b) - photo after segmentation and simplification

Fig. 1. (c) - only segments of asphalt

As can be seen form Figure 1c, by performing only color analysis, the image area, which has a color and texture resembling asphalt, can be confused as a road. To avoid these kinds of incidents, another analysis, which is connected to the structure of the road, is conducted. The segment of the image, having the form of a rectangle, the longest side of which coincides with the direction of the road, and the short coincides with its width, will be considered as a road (Figure 2). Therefore, from all the candidate segments, distinguished are those, that have a rectangular appearance.

It is important to estimate the width of the road, to detect smaller objects on the road (cars, animals) in the future.

a

b

Fig. 2. Images with emphasized rectangular roads

Automated Tracking of the Road

After road section detection, operator must direct the UAV to track the road in a chosen direction of the road. The task of the UAV is not to turn off from the road, and by tracking fly along it.

For simplicity let assume that a frame of the video stream is an image I = {I(m,n)} with the dimension M×N, where m=0,1,…,M; n=0,1,…,N and I(m,n) is the color characteristic of a pixel with coordinates (m,n) in RGB color space.

Let there are successive frames of the road sections, taken by a video camera of the UAV. Let this sequence through I1, I2, …, Ik. In Fig. 3 there is an example of such a sequence of video frames, where the time interval between frames is 1 second.

To enable the examination of the road it is necessary in each frame determine the direction of the road. In this work we follow the approach proposed in [Asatryan 2010] to calculate the dominant direction of the image, by using parameters of gradient field scattering ellipse components.

Let denote horizontal and vertical components of the gradient field through G_H(m,n) and G_V(m,n) respectively.

The equation of the scattering ellipse is being given by

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

where μ_H, μ_V, σ_H, σ_V are math expectations and MSE of $G_H(m,n)$ and $G_V(m,n)$ random variables, ρ_{HV} is the correlation coefficient between them, and C is a constant. Then, the angle α of an image orientation is being defined by the formula:

$$\mathrm{tg}\alpha=\frac{2\rho_{HV}}{\sigma_H^2-\sigma_V^2+\sqrt{(\sigma_H^2-\sigma_V^2)^2+4\rho_{HV}^2}} \quad (2)$$

The components of the gradient field are measured using Sobel operator, and to calculate (1) and (2) formulas, the corresponding values of selected collections are being replaced.

The angle α which determined from the equation (2) is taken as the dominant orientation of the image.

For each frame, the dominant direction of the image is estimated and the UAV follows that direction. As the edges of the road are clearly distinguished in the image gradient magnitude, the discovered dominant direction of the image shows exactly the direction of the road.

a

b

c

d

e

f

Fig. 3. The sequence of video frames of the road.

Fig. 4. (a) The image before applying the Sobel operator and the direction of the gradient field

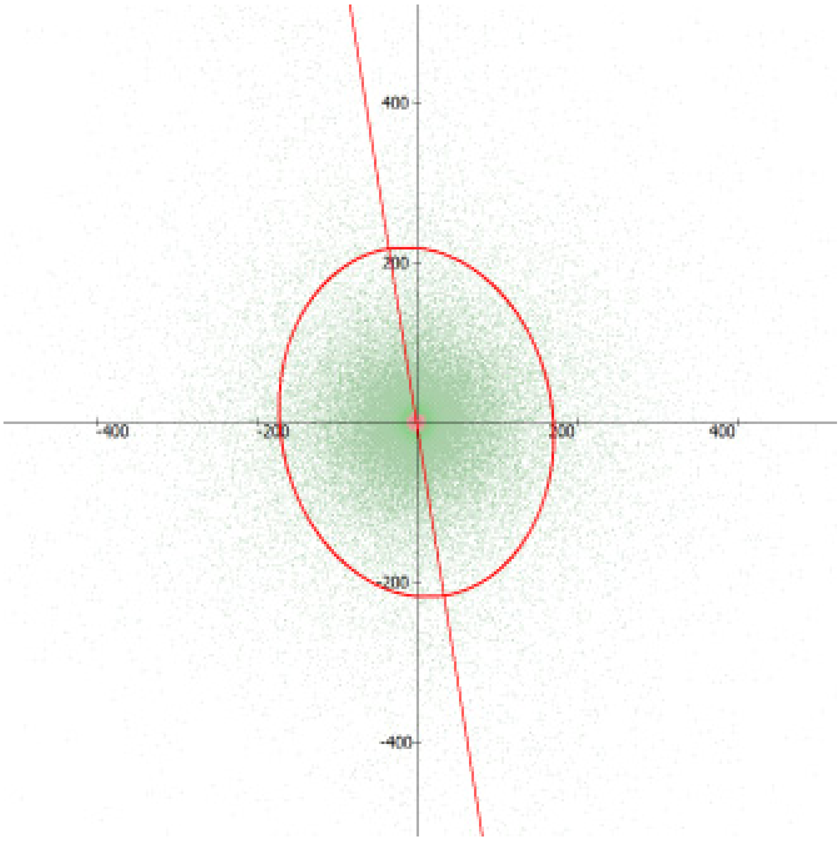

Fig. 4. (b) the Sobel operator and the direction of the gradient field.

Fig. 4. (c) The image after applying the Sobel operator and the direction of the gradient field.
Fig. 4c shows an example of a gradient magnitude image, where the distinguished outskirts of the road are clearly seen.

Finding of Different Types of Objects on the Road

The proposed method for finding various objects on the road is based on a comparison of the current road segment with the etalon section of the road, which is automatically selected from those parts, where only the roadway is present. To control the correctness of the UAV course, for each road part the similarity of successive sections of the road is estimated. The similarity of the different sections of the road is estimated using measure W^2, proposed in [Asatryan 2009].

To identify whether there is an object on the road or is it other common part of the road, based on the value W^2, it is necessary to calculate such threshold value T, so that if $W^2 \geq T$, then we are on a different section of the road, otherwise there are another objects on the road, such as cars or animals. For this, initially three different sections of the same road are selected then between them W^2 values are being calculated, and the arithmetic mean of these values is being taken for T.

Fig. 5. Image with three etalon sections of road

Results

Testing of the proposed method was carried out on a model. First a picture with a road covering, photographed from above was selected. Then all three steps of the algorithm are carried out on the picture:

- Finding the road covering of the selected image
- Automatic tracking of the road for some direction
- Finding all kinds of different objects on the road

Pic 6 shows the result of the experiment. For a given pattern, the following steps are carried out.

After the first stage, the road sections for etalons are selected. For our case we have 2 etalons of this kind, as there are two intersecting roads in the photo. Then, the direction of tracking is given. The program's objective is to find objects on the road, continuously tracking it. For the given example, the program finds such areas very well. The picture below shows the areas that have been found by the program.

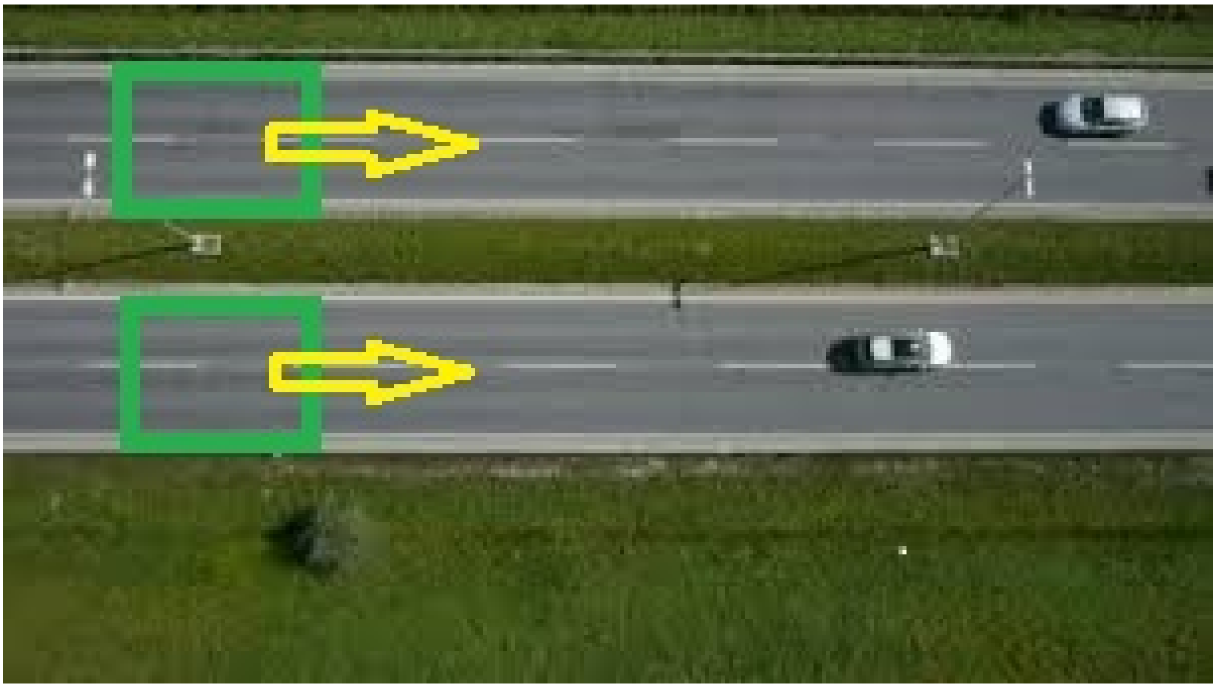

Fig. 6. By green squares the etalon pieces of the road are labeled and the direction of tracking is set.

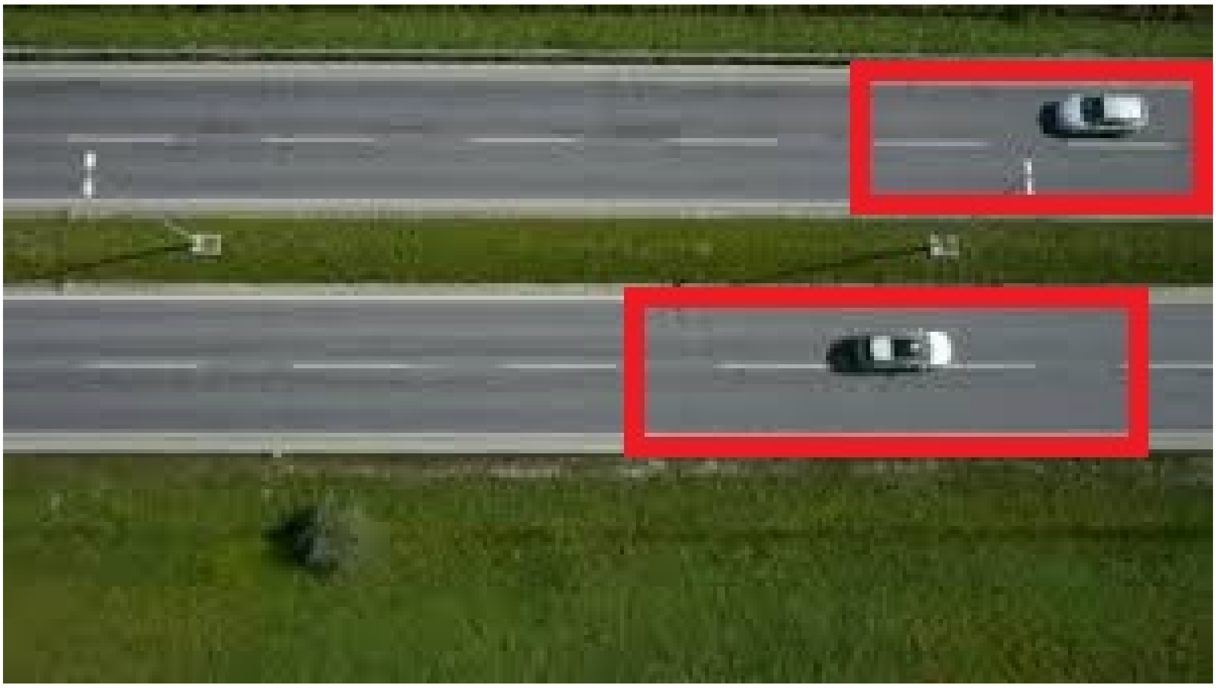

Fig. 7. The result of the algorithm.

The images, where the road is clearly allocated, the algorithm always gives quite good results.

Conclusion

A new method for automated road monitoring with the help of UAV is offered. The method is suitable for determining image areas, where the heterogeneity compared with the general picture is spotted. An algorithm for finding the road cover in pictures, as well as the algorithm for finding the direction of the road from the image is offered.

The methodology is applicable to the processing of automatic control of unmanned aerial vehicles in order to find and track roads, as well as registration of various types of objects on the road.

Bibliography

[Coifman 2004] B. Coifman, M. McCord, M. Mishalani, and K. Redmill, "Surface transportation surveillance from unmanned aerial vehicles," in *Proc. 83rd Annu. Meet. Transp. Res. Board*, 2004, pp. 1–9.

[Frew 2004] E. Frew *et al.*, "Vision-based road-following using a small autonomous aircraft," in *Proc. IEEE Aerosp. Conf.*, Mar. 2004, vol. 5, pp. 3006–3015.

[Zhou 2013] H. Zhou, D. Creighton, L. Wei, D. Y. Gao, and S. Nahavandi, "Video driven traffic modeling," in *Proc. IEEE/ASME Int. Conf. Adv. Intell. Mechatronics*, Jul. 2013, pp. 506–511.

[Wang 2004] Y. He, H. Wang, and B. Zhang, "Color-based road detection in urban traffic scenes," *IEEE Trans. Intell. Transp. Syst.*, vol. 5, no. 4, pp. 309–318, Dec. 2004.

[Siogkas 2007] G. K. Siogkas and E. S. Dermatas, "Random-walker monocular road detection in adverse conditions using automated spatiotemporal seed selection," *IEEE Trans. Intell. Transp. Syst.*, vol. 14, no. 2, pp. 527–538, Jun. 2013.

[Rathinam 2007] S. Rathinam *et al.*, "Autonomous searching and tracking of a river using an UAV," in *Proc. IEEE Am. Control Conf.*, Jul. 2007, pp. 359–364.

[Rathinam 2008] S. Rathinam, Z. Kim, and R. Sengupta, "Vision-based monitoring of locally linear structures using an unmanned aerial vehicle 1," *J. Infrastructure Syst.*, vol. 14, no. 1, pp. 52–63, Mar. 2008.

[Comaniciu 2000] D. Comaniciu, V. Ramesh, and P. Meer, "Real-time tracking of non-rigid objects using mean shift," in *Proc. IEEE Comput. Vis. Pattern Recog.*, 2000, pp. 142–149.

[Nummiaro 2003] K. Nummiaro, E. Koller-Meier, and L. Van Gool, "An adaptive colorbased particle filter," *Image Vis. Comput.*, vol. 21, no. 1, pp. 99–110, Jan. 2003.

[Schunck 1981] B. G. Schunck, "Determining optical flow," *Artif. Intell.*, vol. 17, no. 1, pp. 185–203, Aug. 1981.

[Asatryan 2015] D. Asatryan, S. Hovsepyan, "Vision Based Technique for Smoke and Fire Detection in Monitored Forest Terrain", Computer Science and Information Technologies, vol. 10, no. 1, pp. 129–132, Sep 2015.

[Asatryan 2010] D. Asatryan, K. Egiazarian, V. Kurkchiyan “Orientation estimation with applications to image analysis and registration” Information Theories and Applications, Vol. 17, Number 4, 2010 pp 303-311

[Asatryan 2009] D. Asatryan and K. Egiazarian. “Quality Assessment Measure Based on Image Structural Properties.”

International Workshop on Local and Non-Local Approximation in Image Processing, Finland, Helsinki, pp. 70-73, 2009.

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