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COMBINATION OF HOUGH TRANSFORM AND CANNY EDGE DETECOR FOR IMPROVEMENT OF LINEAR OBECT DETECTION RESULTS

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Abstract—*Hough transform together with Canny edge detector are proposed to use for road lines detection at different weather conditions at various places. Canny operator is used for edge detection on image, then Hough transformation is applied for the detection of extended objects. Proposed testing of such combination of two methods is done on datasets of frames from the unmanned aerial vehicle benchmark. The goal of this research is to obtain comparative results of Hough transform use effectiveness at different conditions and to develop set of recommendations for the implementation of the proposed software for automatic detection of lines in the image in order to identify the roadway and improve the effectiveness of further recognition of ground moving objects. The research was implemented with the help of means of Python 3.6 language in the environment of Anaconda, Skicit image library.*

Index Terms—Image processing; Hough transform; Hough space; line detection; Canny detection.

I. INTRODUCTION

Linear object detection on video sequence is one of fundamentals for visual landmark detection aboard unmanned aerial vehicle (UAV). Linear objects can include roads, railways, rivers, elongated buildings, coastline, etc. Their stability and distinctive features make them reliable visual landmarks, appropriate for correlation extreme navigation.

Edge detection provides object contours but has such significant drawback as redundancy of information. Separation of contours which belong to linear objects is of great interest. Algorithm must operate under noisy conditions and in real-time mode.

The effectiveness of Hough transform [1] is conditioned by the quality of input data: the edges should be defined distinctly. The usage of Hough transform on the noisy images is constrained, but running it after Canny edge detection algorithm can provide preprocessing stage with the aim of noise reduction.

Methods, used for investigation images preprocessing and during basic handling, use quite resource-intensive calculations, that is why the problem of optimization is valid for such algorithms.

II. PROBLEM STATEMENT

Problem statement is formulated in the following way. Given the image (frame) it must be preprocessed (converted from the full-colored RGB image into the grayscale), detected for edges (so called image segmentation) and then problem of contours association with linear objects must be solved with consequent analyses of solution efficiency. Let's consider each step.

Edge is significant changes in the gray values in an image, which can be detected by using a discrete approximation to the gradient. The gradient is the two-dimensional equivalent of the first derivative in *x*, *y* directions and is defined as the vector

$$G[f(x,y)] = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \dfrac{\partial f}{\partial x} \\ \dfrac{\partial f}{\partial y} \end{bmatrix}.$$

Assuming the definite threshold of gradient magnitude it is possible to separate image pixels on those related to background and those related to the edge (object). Modification of the most of edge detection algorithms is Canny algorithm [2], [3], that includes noise filtering and gives adjustable parameters for optimization: signal-to-noise ratio and two thresholds (low and high) for good line localization.

Obtained binary image where zero pixels correspond to black background and ones are related to edges (contours of objects) must be further processed. Here the method of Hough transform is selected for line detection on such binary image.

A straight line is defined by the equation

$$y = mx + b. \quad (1)$$

And can be calculated for any pair of active points on the image (*x*, *y*) related previously to edge. The main idea of Hough transform method is to take into consideration the characteristics of the line in terms of its parameters, that is, parameters *m* and *b*. Thus, the parameter space for the lines will be two-dimensional and consist of two parameters – inclination angle *m* and the intersection point of line with *OY* axis, *b*. But for this type of equation, there is exist the problem for vertical lines definition. In this case the infinite values of *m* and *b* parameters are received.

If, however to present the line with the help of parameters of vector perpendicular to this line and passing through the origin of coordinates, this problem disappears [5].

III. Algorithm and Analysis of Method for Detecting Extended Objects

As has been mentioned before, classical Hough transform appears to be linear and is used for line detection.

Let's define the line through two parameters *R* and θ. Parameter *R* represents the length of indicated vector, and θ indicates the vector's angle to the coordinates axis.

In this case, line equation will be presented in the following way:

$$y = -\left(\frac{\cos\theta}{\sin\theta}\right)x + \left(\frac{r}{\sin\theta}\right). \quad (2)$$

Or it can be rewritten in the following form:

$$r = x \cdot \cos\theta + y \cdot \sin\theta. \quad (3)$$

Thus, each line on the image can be presented be two parameters of its vector of normal – *r* and θ. These parameters will be unique under condition of $0 \le \theta \le \pi$ and $r \in R$ or if $0 < \theta < 2\pi$ and $r \ge 0$. By creating the accumulator array with the defined step, it is possible to put there the values of the defined parameters. This array is also called the Hough space for lines on the plane or simply accumulative space.

Infinite number of straight lines can pass through the one point. In case this point has the coordinates (x_0, y_0), then all the straight lines passing through it, will satisfy the following equation:

$$r(\theta) = x_0 \cos\theta + y_0 \sin\theta, \quad (4)$$

where *r* and θ can have arbitrary values from the above described range.

This corresponds to the sine curve in the accumulative space (r,θ) which is unique for each separate point. Sine curves of several points superimpose on one another. Their intersection points in the parameter space determine the straight line parameters (r,θ), which pass through the points defining the sine curves, which can be seen in Fig. 1. Thus, points which forms straight line, define sine curves which intersect in one point of accumulative space which in its turn sets the parameters of target line. Eventually, the task of line searching comes down to the task of searching the maximum in the parameters accumulative space.

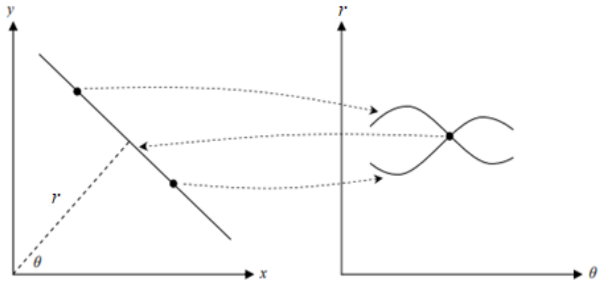


Fig. 1. Normal form parameterization

IV. Experimental Results

In the work frames from the UAVDT benchmark [4] were used which consist of 100 video sequences, which are selected from over 10 hours of videos taken with an UAV platform at a number of locations in urban areas.

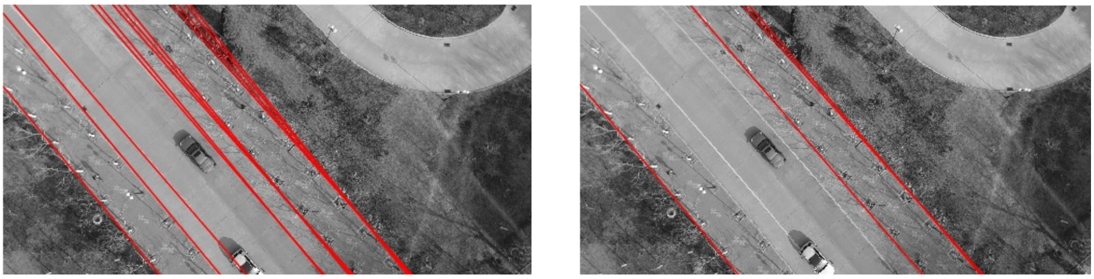
The first set of images used for evaluation have been captured at good weather conditions from high altitude (> 70 m). Different threshold for Canny edge detection, varying in the range from 0.05 to 2.6 have been applied. At the end, the highest success rate (92.3%) was obtained at low threshold being equal to 0.1 and high threshold being equal to 1.1. Putting low threshold under 0.1 gave a lot of faulty lines while setting threshold higher than 1.1 led to lines missing. The image examples are presented in Fig. 2 and Fig. 3 and in Table I.

The second set of images have been obtained at high altitude at bad weather conditions (fog, rain, white smoke, bad lightning, etc.). Applying the same thresholds range used for daylight images did not give any results. That is why, it was decided to decrease range values to 0.01. Even though the best result (46.1% of success) was achieved at values of low and high thresholds being equal to 0.05, those result gave a lot of faulty detected lines. Generally, overall success rate was almost two times lower than for daylight images. Examples can be seen in Fig. 4 and Fig. 5 and in Table II.

The last set of images have been obtained at night at medium altitude (30 m – 70 m). Experimental results showed that optimal threshold values for images of this weather conditions lie in range from 0.5 to 1.0 for low and high thresholds respectively. The overall performance was better then for frames obtained at fog. However, investigation showed that at low altitude light colored cars together with flashing of lantern have huge impact on the results and at such situation, additional image preprocessing should be performed. The worst results were obtained for frames at night light raining weather. Examples can be seen in Fig. 6 and Fig. 7 and in Table III.

(a) (b)

Fig. 2. (a) Input Image; (b) Input image after conversion to grayscale



(a) (b)

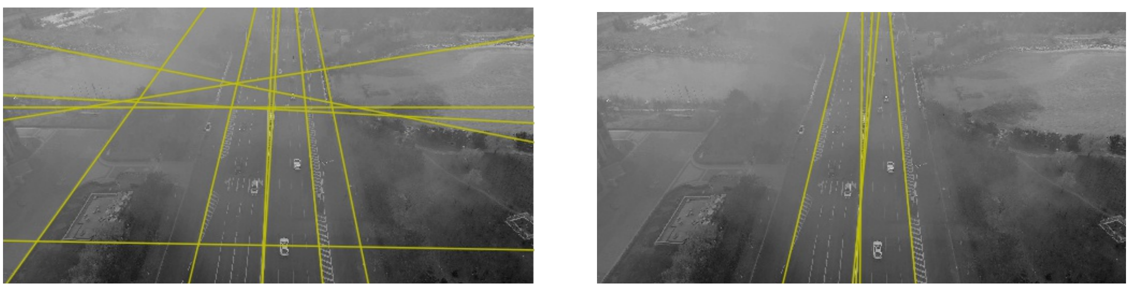
Fig 3. Results of applying Hough Transformation after Canny Edge detection with: (a) low threshold = 0.1, high threshold = 1.1; (b) low threshold = 0.6, high threshold = 2.1

TABLE I. RESULTS EVALUATION FOR BIRD VIEW PICTURES AT DAY LIGHT

Canny edge detector		**Number of**			**Efficiency, %**
Low threshold	***High threshold***	***Detected Lines***	***Correct Lines***	***Faulty Lines***	
0.1	1.1	22	12	10	92.3
0.6	1.1	8	7	1	53.8
0.6	2.1	2	2	0	15.3

(a) (b)

Fig. 4. (a) Input Image; (b) Input image after conversion to grayscale

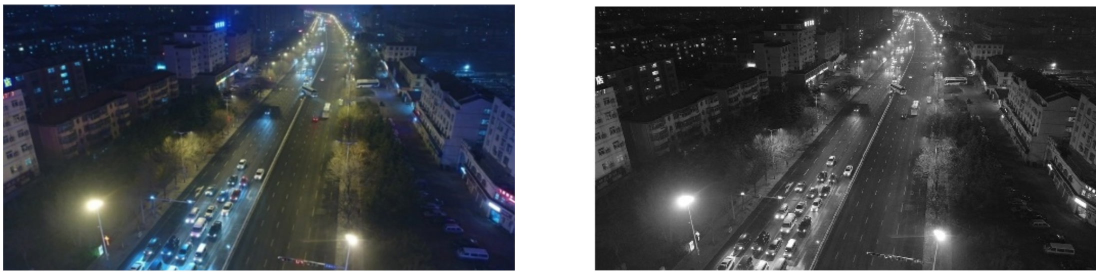


(a) (b)

Fig. 5. Results of applying Hough Transformation after Canny Edge detection with: (a) low threshold = 0.05, high threshold = 0.05; (b) low threshold = 0.05, high threshold = 0.3

TABLE II. RESULTS EVALUATION FOR FRONT VIEW PICTURES AT BAD WEATHER

Canny edge detector		**Number of**			**Efficiency, %**
Low threshold	***High threshold***	***Detected Lines***	***Correct Lines***	***Faulty Lines***	
0.05	0.05	11	6	5	46.1
0.05	0.55	2	2	0	15.3
0.05	0.3	5	3	2	23



(a) (b)

Fig. 6. (a) Input Image; (b) Input image after conversion to grayscale

(a) (b)

Fig. 7. Results of applying Hough Transformation after Canny Edge detection with: (a) low threshold =0.8; high threshold = 0.8; (b) low threshold = 0.95; high threshold = 1.25

TABLE III. RESULTS EVALUATION FOR SIDE VIEW PICTURES AT NIGHT LIGHT

Canny edge detector		**Number of**			**Efficiency, %**
Low threshold	***High threshold***	***Detected Lines***	***Correct Lines***	***Faulty Lines***	
0.8	0.8	7	6	1	54.5
0.95	1.25	1	1	0	9.09

V. CONCLUSIONS

Here the use of Hough transform together with Canny edge detector for road lines detection at different weather conditions is discussed. In the work frames from the UAV benchmark were used. As the result, comparative values of Hough transform use at different conditions were obtained.

The best success rate (92.3%) of proposed algorithm was obtained at daylight at good weather conditions. The results also showed that for day light the altitude of flight does not have great influence on performance.

However, the situation changes for frames obtained at fog or rain. In that case, with the altitude increase, the overall performance success decreases by 32.4%. For better performance at such conditions, it is recommended to do at low altitude (10m -30m) and to decrease the applied threshold values to be not higher than 0.6.

During the night light, it was observer that light colored cars together with flashing of lanterns have great influence on algorithm performance results. So, it is recommended to use additional image preprocessing in order to overcome this limitation. The worst results were obtained for frames at night light raining weather.

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М. П. Мухіна, В. Ю. Деркач, А. П. Примак. Комбінація перетворення Хафа та детектора країв Кенні для підвищення результатів знаходження лінійних об'єктів

Перетворення Хафа разом з детектором країв Кенні пропонується використовувати для виявлення дорожніх ліній при різних погодних умовах в різних місцях. Оператор Кенні використовується для виявлення країв на зображенні, потім застосовується перетворення Хафа для виявлення протяжних об'єктів. Пропоноване тестування такої комбінації двох методів виконується на наборах даних кадрів з еталонного тесту безпілотного літального апарату. Метою даного дослідження є отримання порівняльних результатів ефективності використання перетворення Хафа в різних умовах і розробка набору рекомендацій щодо впровадження пропонованого програмного забезпечення для автоматичного виявлення ліній на зображенні з метою ідентифікації проїжджої частини і підвищення ефективності подальше розпізнавання наземних рухомих об'єктів. Дослідження проводилося за допомогою засобів мови Python 3.6 в середовищі Anaconda, бібліотеки зображень Skicit.

Ключові слова: обробка зображень; перетворення Хафа; простір Хафа; виявлення лінії; детектор Кенні.

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М. П. Мухина, В. Ю. Деркач, А. П. Примак. Комбинация преобразования Хафа и детектора краев Кенни для повышения результатов нахождения линейных объектов
Преобразование Хафа вместе с детектором краев Кенни предлагается использовать для обнаружения дорожных линий при различных погодных условиях в разных местах. Оператор Кенни используется для обнаружения краев на изображении, затем применяется преобразование Хафа для обнаружения протяженных объектов. Предлагаемое тестирование такой комбинации двух методов выполняется на наборах данных кадров из эталонного теста беспилотного летательного аппарата. Целью данного исследования является получение сравнительных результатов эффективности использования преобразования Хафа в различных условиях и разработка набора рекомендаций по внедрению предлагаемого программного обеспечения для автоматического обнаружения линий на изображении с целью идентификации проезжей части и повышения эффективности дальнейшее распознавание наземных движущихся объектов. Исследование проводилось с помощью средств языка Python 3.6 в среде Anaconda, библиотеки изображений Skicit.
Ключевые слова: обработка изображений; преобразования Хафа; пространство Хафа; выявление линии; детектор Кенни.

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