REAL-TIME VIBRATION REDUCTION IN UAV'S IMAGE SENSORS USING EFFICIENT HOUGH TRANSFORM

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***Abstract*:** This paper explores use of Hough transform to detect and track angular changes between a series of images acquired by vision sensors attached to unmanned aerial vehicles (UAV) and are used in traffic surveillance. The small size and atmospheric conditions can lead to unstable flying and this can induce vibration to the pictures. In this research it is proposed that the vibration in the acquired images can be reduced by using the angular variation as feedback to stabilize the motion of the UAV as it captures subsequent frames.

***Keywords*:** Vibration reduction, image/vision sensor, UAV stabilization, traffic surveillance.

1. Introduction

Two main types of digital image sensors are charge-coupled device (CCD) and complementary metal-oxide semiconductor (CMOS). These devices work by converting the amount of light energy sensed on each pixel's photodiode into voltages which is converted into digital information. These technologies produce quality images with good signal-noise-ratio but they are still susceptible to vertical smear and rolling shutter effect.

The negative effects are caused by the image acquisition scheme in which the sensor sequentially scans each line of the image's frame vertically or horizontally. The effect is significant if the read-out time is slow, the image contains fast moving objects, or the UAV (unmanned aerial vehicle) flight is unstable with high frequency vibration.

In this paper, Hough transform is applied for line detection that is used to improve flight stability in real-time by providing feedback about the amount of distortion in the acquired images.

In the particular use-case of vehicle traffic surveillance [1] the image is usually comprised of straight lines from road marking, road signs, and other stationary objects in which line features can be extracted and measured for angular variation. The data from this process is then transmitted to the actuator of the UAV. In our test CMOS cameras are used because they are smaller, consume less power, and have a faster read-out speed.

2. Proposed methods

In computer vision and image processing, there are various methods for line/circle/feature detection. Hough transform (HT) has been applied in motion analysis, shape extraction and image registration [2] [3]. HT identifies lines within an image by superimposition with the Hough space defined by the following formula:

$$\mathbf{r}(\theta) = x_0 \cdot \cos\theta + y_0 \cdot \sin\theta \qquad (1)$$

Data points are determined to be a line if they contain distance, r, and angle, θ, that correlate *(see Fig. 1)*.

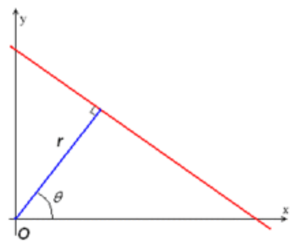

Fig. 1. Polar coordinate of Hough transforms

Fig. 2 shows the Hough transform of a simplified street image showing three distinct correlating points which are the two edges of the road and the road surface marking. The process involves running an edge detection technique (such as Canny edge detection) on an image to produce data points along the boundary of different blobs in the image. The data points are then accumulated in the Hough transform matrix and if the value of an element of the matrix is greater than desired threshold, it is then identified as a line in the image. The distance, r, and angle, θ, for each line is now obtainable.

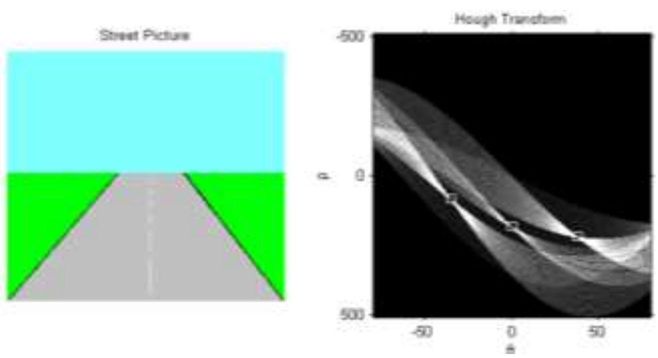

Fig. 2. Hough transform *(right)* of street picture *(left)* showing detected lines

After selecting the prominent lines from the first image, in subsequent images these lines are then continuously monitored for angular changes. Image registration is the process of overlaying a series of images taken from different viewpoints by the image sensor in order to match them to a reference (base image). The images acquired from the UAV's camera will be geometrically distorted (i.e. rotated, translated, skewed, scaled) due to the vibration. Therefore the measured angle, θ, needed for proper image registration is used as a parameter to calculate and adjust the speed of the servomotors of the UAV, consequently fine tuning its roll, pitch, and yaw *(see Figure 3)*.

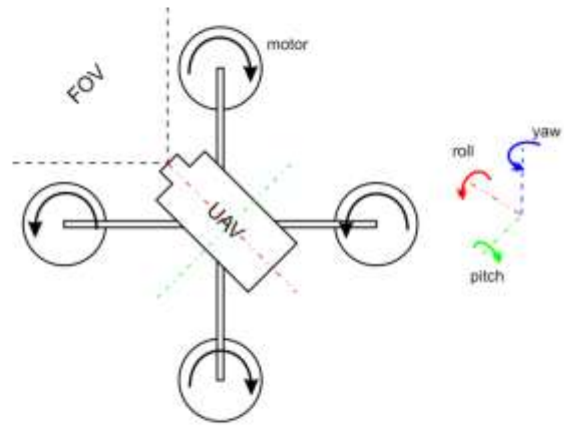

Fig. 3. A quadcopter UAV

3. Implementation and Evaluation

The proposed method for vibration reduction was implemented in MATLAB as follows:

Step 1: Convert image to grayscale
Step 2: Apply edge detection technique to highlight image intensity boundaries.
Step 3: Compute HT over a range of θ (in order to exclude horizontal line for instance)
Step 4: Select n numbers of prominent line (`houghpeaks`)
Step 5: Choose the longest line which will be continuously tracked while it remains in the scene.
Step 6: Extract only the segment of the image containing the line (to eliminate time wasted on computing the other pixels in the image)
Step 7: Continuously track the rotation in the selected segment on subsequent image
Step 8: Return the output of angular displacement
Step 9: Use the detected angular displacement as a feedback to the motors of the UAV.

At first, in order to track the rotation MATLAB's `vision.GeometricTransformEstimator` function was applied; it uses RANdom SAmpling Consensus (RANSAC) algorithm to compute similarity transformations. From Fig. 4 it can be seen that the algorithm detected matching points, and was able to recover the scale and rotation of 1.058 and 7.153 from the original deformation input of 1.1 and 6, respectively.

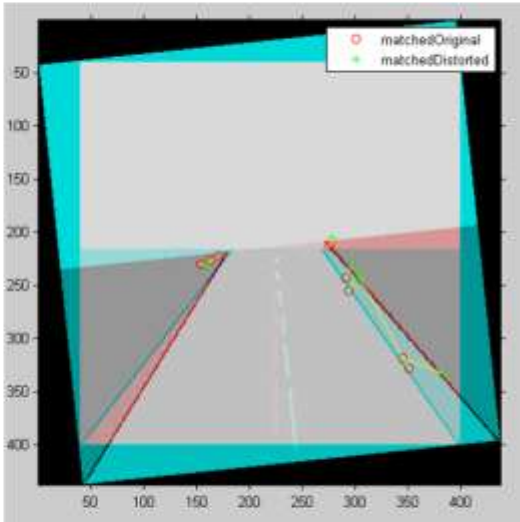

Fig. 4. Application of MATLAB image registration function

Whilst this method provided a relatively close result, it could not be applied on a smaller segment of the image as a result of limited information for matching the two images. Therefore a simpler but more efficient method for detecting the image transformations within a small segment will be necessary as it speeds up the time needed to recover the distortion angles during the UAV flight for adequate feedback.

4. Analysis of Results

After hundreds of trials the average θ (theta) error was significantly low when the angle of distortion was less than 10 degrees. The scale and theta values were generated randomly and it was noted that some angles and scales were unsolvable. Therefore the above algorithm can be improved by recomputing HT to find another prominent line in the scene if the original line is lost due to scale or rotation as the UAV moves. In addition, the above method uses random sampling to detect matching points, thus it can be improved by searching neighboring angles incrementally for the displaced line because the vibrations distortion affects image pixels in close proximity.

5. Conclusion and future work

In this paper, the use of Hough transform to reduce the image vibration in unmanned aerial vehicles to support the monitoring of road traffic by selecting the most prominent line in the scene for stability feedback during flight was proposed.

An implementation of a working prototypical system based on the proposed solution is planned. After accomplishing the set objective further research can be carried out on predicting the vibration effects in subsequent frames using the information from the current time window, and also computational parallelizing of HT [4], and finally to develop hardware that are optimized to process HT in real time [5].

6. Acknowledgements

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7. References

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