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A Novel approach for Object Tracking in an Independent Ground Level Vehicle

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Abstract

This is attempts to investigation into object tracking and how they can be applied to develop a visual perception system for independent vehicles. In recent years, independent robots have shifted from industry to unconstrained human environments. Unlike their industrial counterparts, the new generation of robots cannot rely on specific knowledge of a highly structured environment but must operate in unknown environments. This requires the robots to be able to understand their surroundings. Vision is clearly an intelligent choice for perception of such a dynamic environment. Therefore this attempts to develop a novel approach for object tracking in an independent ground level vehicle by combining color tracking and invariant feature tracking using kalman filter.

Keywords: *Color Tracking, Invariant Feature Tracking, Kalman Filter.*

1. Introduction

The object tracking approaches can be classified into two ways: First to detect the objects in a frame and extract their features to model the objects, and then follow the objects using their models. Second is to continuously detect objects in new frames, and match them with the list from the previous frame.

These systems often require an initial input, such as initial location of the objects or its model, which is often the output from motion detection or object detection process. In order to perform the tracking, some form of features needs to be extracted to model the objects. The features used to track object are really diverse, such as geometric features, gradient, optical flow, color, texture, wavelet, template, depth, phase in frequency domains. Selecting features partially depends on the configurations and requirements of the system, such as single camera, stereo vision or multiple cameras, and the type of input data, such as gray level, color or disparity images. Additionally, different features can be used different times or combined together to increase the robustness. In this section, we address two main approaches using color and invariant features.

The color tracking method fails to track the object that has a similar color to the background. Furthermore, when two objects which have similar colors are close to each other, the color tracking method will get lost easily. However, color tracking method can track an object which has a small size or has a uniform color. Moreover, the color tracking is simple and computationally efficient to perform in real time [1,2,3,4].

The feature tracking method, in contrast, requires enough feature points to achieve a reliable result. In other words, this method cannot track an object if its size is too small or if its color is almost uniform. However, due to the invariant feature properties, the method has a much better ability to distinct any similar color objects. The computation is more expensive than the color tracking but still can be performed in real time [5,6,7,8,9].

Therefore, this thesis proposes a method to combine the advantages of two mentioned methods to get robust tracking result. Kalman filter has been applied widely in tracking and localization in robotics. Specially, Kalman filter is an optimal method designed for linear system [10].

2. Our Approach

First, extract the interest point in incoming color frame using segmentation based on the r, g chromaticity components. This was found to be effective in accurately

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extracting objects without much of their shadows and other noise. Second, to describe the feature of the particular interest point using invariant features technique. Third to track that invariant features using the kalman filter.

2.1 Feature Descriptor

The Background subtraction method with color is used to find the interest point. The region proportion of the interested point in the frame mark the centroid and boundary region using the algorithm which is given in figure (1).

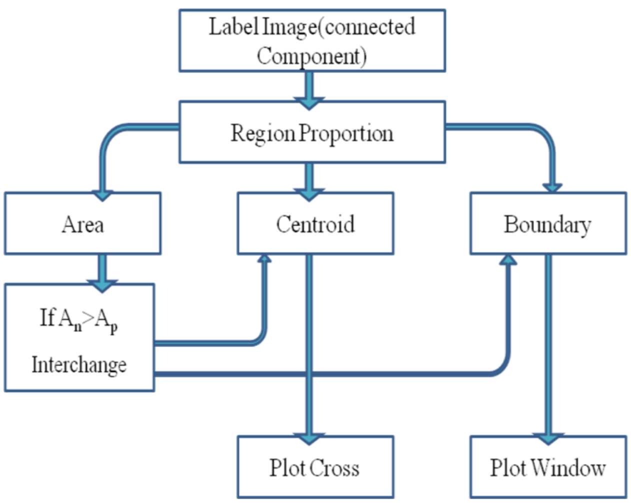

Fig. 1 Algorithm for mark centroid and boundary

In the above algorithm object's area is compare with the previous area of that object, whichever is more, that object's area is select and using their centroid and boundary, plot the cross and window. Result is shown in figure (2).

(a) (b) (c)

Fig. 2 Implementation of feature descriptor a) Original frame b) Detect interest point using BS with color c) Plot the window across interested region in blue color.

2.2 Track the Invariant feature

Kalman filter are used to track the Invariant features of the particular object. Figure (3) shows the approach to track the invariant features,

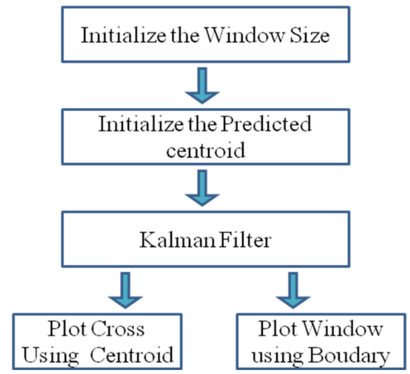

Fig. 3 Algorithm for track invariant features

In this algorithm previous centroid and boundary region are used for the parameter of the kalman filter predict the position of the centroid and boundary. Initially this parameter are based on the first frame. Result is shown in figure (4).

(a) (b)

Fig. 4 Implementation of track the invariant feature. (a) Window across interested region in Blue color. (b) Track that window using kalman filter in red color.

3. Kalman Filter

Kalman filter has been applied widely in tracking and localization in robotics. Specially, Kalman filter is an optimal method designed for linear system. Our state vector includes the coordinate (x,y) of the top left corner and two dimension (w,h) of the boundary rectangle. To implement the Kalman filter, we need a motion model. Several previous works used the simple random walk [10] or second order autoregressive process [11],

$$X_t = X_t + (X_t - X_{t-1}) + \varepsilon_t \qquad (1)$$

Where X_{t-1} is the previous state vector and X_t is the current state vector. ε_t is the random vector, representing the model uncertainty, assumed to be a random variable with the normal distributions N(0,R).

The motion model is defined as,

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$$X_t = A_t X_{t-1} + \varepsilon_t \qquad (2)$$

Where X_t is computed from Feature tracking method, so that,

$$X_t = \begin{bmatrix} \overline{X}_t \\ \overline{Y}_t \\ \overline{w}_t \\ \overline{h}_t \end{bmatrix} = \begin{bmatrix} 1 & 0 & a & 0 \\ 0 & 1 & 0 & b \\ 0 & 0 & c & 0 \\ 0 & 0 & 0 & d \end{bmatrix} \begin{bmatrix} \overline{X}_{t-1} \\ \overline{Y}_{t-1} \\ \overline{w}_{t-1} \\ \overline{h}_{t-1} \end{bmatrix} + \varepsilon_t \qquad (3)$$

From Equ. (3), the elements of matrix At can be computed as,

$$a = \frac{X_t - X_{t-1}}{w_{t-1}}, b = \frac{Y_t - Y_{t-1}}{h_{t-1}}, c = \frac{w_t}{w_{t-1}}, d = \frac{h_t}{h_{t-1}} \qquad (4)$$

The covariance matrix of the noise ε_t is defined as in

$$X_t = \lambda_x D[q(\overline{X}_t).q^*] \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 2 \end{bmatrix} \qquad (5)$$

Where $D[q(\overline{X}_t).q^*]$ is the Bhattacharyya distance between the model's color histogram q^* and the target's color histogram $q(\overline{X}_t)$ defined at $\overline{X}_t$.

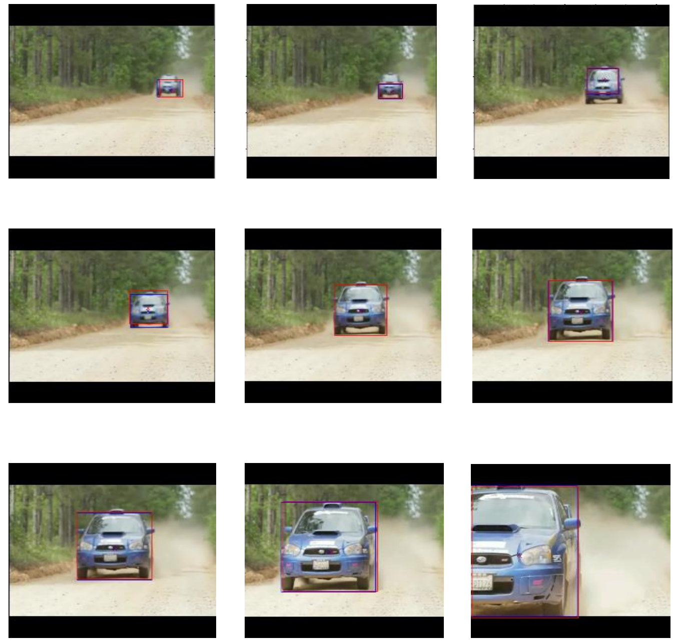
The measurement Z_t is computed from the CAMSHIFT method and the matrix Ct is defined as an identity matrix. The covariance matrix of the noise δ_t is defined as in Equ.

$$Q_t = \lambda_z D[q(Z_t).q^*] \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 2 & 0 \\ 0 & 0 & 0 & 2 \end{bmatrix} \qquad (6)$$

Where $D[q(Z_t).q^*]$ is the Bhattacharyya distance between the model's color histogram q^* and the target's color histogram $q(Z_t)$ defined at Z_t .

One implementation issue is that the feature tracking method cannot always find the object. In this situation, the motion model is set to be a normal random walk. Another issue already mentioned is that feature tracking needs to update its model after several frames because of the rapid changes in scale. The experiments show that the model should be updated after 3-5 frames.

4. Experiment Results



This experiment result using invariant feature tracking and color tracking with kalman filter to track an object in MATLAB on the computer AMD dual-core 1.333 Ghz Aspire one 725 and video frame size is 320*240.

4. Conclusions

For motion tracking, although the proposed method improves the robustness of tracking results, its speed is relatively slow when comparing with other methods. For tracking only one object, the proposed tracking method can still satisfy the real time requirement. However, it cannot perform in real time when tracking several objects at the same time. Therefore, implementation on GPU or FPGA is the key to significantly reduce the processing time.

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