A COMPARATIVE STUDY OF THREE CORNER FEATURE BASED MOVING OBJECT DETECTION USING AERIAL IMAGES

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ABSTRACT

Corner feature based moving objects detection is an essential and fundamental research problem in the broader aspects of computer vision and pattern recognition research domain. Performance of various corner features based aerial types image processing specially for moving objects detection is still an unsolved issue due to up and down of performance which makes it difficult to choose the appropriate corner features for detection purpose. The core part mentioned in this research is to categorize significant corner characteristics of the objects using various corner features based detection methods in image extracted from aerial video. This research demonstrated three kinds of corner features, i.e. Moravec, Susan and Harris corners due to capability of these corner features to interpret high and low intensity various for aerial types of images. Standard datasets were used to evaluate each of the corner feature based detection. Based on comprehensive experimental analysis, Harris corner was observed performing efficiently comparing with Moravec and Susan corner based detection for both datasets considered by this research. Experimental results reveals the capacity of each corner characteristics based detection methodology in terms with the effectiveness using various performance metrics for moving object detection using aerial images.

Keywords: Moving Object Detection, Corner, Computer Vision, Image Processing

1.0 INTRODUCTION

Extraction of descriptive characteristics from real time scene for moving object detection is an unsolved research issues in research area of computer vision, image processing and pattern recognition which is not addressed properly by the previous researchers. In this context, corner characteristics feature based detection is an important feature for real time scene interpretation from frames has been a long concern which made capable to produce efficient research results for various research problems. Corner characteristics based object detection plays vital role for many problem solving tasks, i.e. classification, tracking pattern matching, recognition of objects, 3D reconstructions, motion detection, scene interpretation etc [1, 2, 19]. This research demonstrates performance of comparison among corner feature based moving object detection methodology using aerial types of images.

Corner features hold important information about frames due to having rich feature information. Hence, corner features are effective to reduce redundant amount of data to improve speed of overall operation and match image more reliably for real time processing. Due to rotational invariance and unchanged lightening condition characteristics, usage of corner features for object detection exists in many fields such as camera calibration, pattern matching, visual relation establishment, medical and satellite image processing etc [4, 9,14, 15, 16]. There are many types of corner feature based detection methods, however, these can be categorized intro three major types which are mostly mentioned by previous researchers in terms with aerial types of images for low and high intensity variation, i.e. Moravec, Susan and Harris [9, 10, 11]. Moravec corner feature based detection is based on gradient which defines interest points computed using maximum inhibition [5]. For real time good anti-interference performance, Moravec corner provided satisfactory experimental results in the existing research. Besides, Harris corner involves using Gaussian filtering which performs efficiently for anti-interference environments [6]. However, usage of Harris corner produces high complexity for aerial types of images. Proposed research aims to detect moving object by adopting Moravec, Susan and Harris corner based detection using aerial images and analyze performance using standard performance metrics.

The rest of this research paper is organized as follows. Background study section demonstrates background study of the research. A comparison of the three approaches reflects research methodology for each corner feature based detection. Validation measurements section illustrates extensive experimental results with analysis and discussion using standard datasets. Finally, conclusion section contains concluding remarks of this paper.

2.0 BACKGROUND STUDY

A larger amount of data abstraction takes place in terms with aerial types of image processing which stands for the same meaning of computer vision based complex scene interpretation. categorization and individual recognition of objects are of great importance in this whole process which mainly depends on specific types of features in the overall methodologies [7, 17]. in this context, corner feature refers two dimensional points of significant change of image intensity variation or curve maximum curvature point in the frame [2]. corner feature is considered as one of the most important distinctive characteristics which have been used as core features in detection process by previous research [8, 18]. the core aim of this research is to justify corner features based methodology and justify the comparison of performance among these methodologies using standard performance estimation parameters.

In pattern interpretation research domains, many corner characteristics based detection methodology were illustrated in the existing research. In terms matching of images perspectives and their structures, corner features are hugely used especially for object detection and recognition purposes [7, 10, 11, 12, 13]. Although existing methodologies vary significantly among each other, previous approaches use region of interest point from hierarchy of object description which is extracted for various problem specifications [1, 2, 3]. This research focuses on the approaches which are correlated to the extraction of region of interesting points based on significant characteristics, i.e. Moravec, Susan and Harris corner based detection from aerial types of images. In this context, Moravec defines “points of interest” as region of interest where remarkable illumination variation occurs in every direction [8]. In addition, Moravec corner description based approaches are related to gradient measurement which defines region of interest points where comer features could be calculated though maximum threshold approximation in various aspects, i.e. illumination, types of images etc [5]. In the same context, Hams and Stephens proposed Harris corner features based detection by calculating significant correlation using derivatives [6]. Although, Harris corner based detection includes Gaussian filtering to ensure efficient preprocessing at the initial stage. However, usage of Harris corner increases complexity due to usage of high volume of parameters. Unluckily, existing research mentioned above did not provide efficient validation in the presence of noises due to the usage of derivatives operation and causes losing of important information during processing of frames. Smith and Brady proposed a method called SUSAN corner feature based detection by collecting significant part of feature neighborhoods which have almost same illumination values [4]. Given a frame, USAN area will reach a minimum number when the nucleus lies on a corner border. SUSAN corner feature based detection is one of the most efficient methods which provide illusive experimental validation in the presence of noise in lieu with the cases of rotation variance of image, but it has the disability to detect true corners and produce false corners causes low detection rate. Based on the existing research, due to capability of handling low and high intensity variation this research selected three corners features, i.e. Moravec, Susan and Harris corner feature based detection and performed comparison among these three corner feature based detection for moving object detection using aerial images.

3.0 A COMPARISON OF THE THREE APPROACHES

Let, $A_1(i,j,t)$ and $A_2(i,j,t-1)$ be two subsequent frames in the consecutive time t and $(t-1)$. Frame difference $B_f(x,y,t)$ from the above mentioned frames can be denoted by equation (1):

$$K_f(i,j,t) = round\big(A_1(i,j,t) - A_2(i,j,t-1)\big);$$

$$\text{Where} \quad \begin{Bmatrix} K_f(i,j,t) = A_1(i,j,t) & if(K_f(i,j,t) > 0) \\ K_f(i,j,t) = A_1(i,j,t) & if(K_f(i,j,t) < 0) \end{Bmatrix} \tag{1}$$

Let, $M_f(i,j,t)$ be the median filtered image achieved from $K_f(i,j,t)$.

Then, $M_f(i,j,t)$ is passed through Moravec, Susan and Harris corner feature based detection module for further processing.

Moravec corner based detection gets the feature descriptive patterns by intensity variance adopted to segment moving objects from aerial types of images [2]. Moravec corner based approach detects corner pixels by closing morphological processing and non-maximal suppression (NMS) according to the definition of "interest value" [2]. The interest values are defined by the following equations (2) to equation (5) [2].

$$v_1 = \sum_{i=l}^{l-1} (M_f(i+k) - (i+k+1, j))^2 \tag{2}$$

$$v_2 = \sum_{i=l}^{l-1} (M_f(i, j+k) - (i, j+k+1))^2 \tag{3}$$

$$v_3 = \sum_{i=l}^{l-1} (M_f(i+k, j+k) - (i+k+1, j+k+1))^2 \tag{4}$$

$$v_4 = \sum_{i=l}^{l-1} (M_f(i+k, j-k) - (i+k+1, j-k-1))^2 \tag{5}$$

Where l is the image height and width, four values are denoted using above four formulas, where

v_1 = the interest value of horizontal direction.

v_2 =interest value of vertical direction.

v_3 and v_4 =values of the two diagonal directions.

Desired pixel is chosen based on the following equation (6).

$$Moravec(i,j) = \min\{v_1, v_2, v_3, v_4\} \tag{6}$$

Difference of pixel gradient direction in lieu with efficient performance towards showing of corner pixels depends on value for equation (6). This research fixed threshold at 40. If $Moravec(i,j)$ is greater than threshold, then that pixel value is chosen as corner.

Susan corner based detection methodology produces region of interest of the input frame where pixel under processing is called nucleus [3]. A corner region is justified based on intensity variation of neighborhood nucleus values. After that a mask is used with the middle at the nucleus. In the mask, the pixels with approximately the similar intensity comparing with the neighboring pixels are segmented into a group and the area consisted by the groups is called Univalue Segment Assimilating Nucleus (USAN). Based on the maximum USAN area, nucleus falls in a flat region of the frame surface. If significant groups fall to half of the maximum of the frame, then the nucleus is considered on an edge and falls to more than half of the frame, then the nucleus is considered as corner. Number of USAN map illustrates the position of frame corners depends on the following conditions [3] mentioned in equation (7).

$$c(z, \bar{z}_0) = \begin{cases} 1\, if \left| I(\bar{z}) - I(\bar{z}_0) \right| \le t \\ 0\, f \left| I(\bar{z}) - I(\bar{z}_0) \right| \le t \end{cases} \tag{7}$$

Where $I(\overline{z_0})$ refers intensity of the nucleus, $I(\overline{z})$ refers the intensity of any other pixel rather than nucleus, t is threshold which is set to 40, $c(\overline{z},\overline{z_0})$ is denoted as the output for comparison which is performed for individual pixel in the mask mentioned in equation (8) [3].

$$\alpha(\vec{z}_0) = \sum_{\vec{r} \in c(\vec{z},\vec{z}_0)} c(\vec{z},\vec{z}_0) \tag{8}$$

Next, α is compared with threshold t. Desired corner is selected based on the following condition mentioned in equation (9).

$$R(\vec{z}_0) = \begin{cases} t-\alpha(\vec{z}_0) & \alpha(\vec{z}_0) < t \\ 0 & \mathit{Otherwise} \end{cases} \tag{9}$$

This is the standard formation of SUSAN principle in terms with mathematical denotation, the smaller the USAN area, the larger the corner response [3].

The method of Harris corner detection methodology is mentioned below as [1]:

1. Designing a local detect window in the frame.
2. The window performs slight movements in all directions.
3. Investigate average illumination variation of the window.
4. The intensity variation in the value exceeds a threshold value, extracted the center value of the window for the corner.

Like other corner detection based detection, for Harris corners also this research fixed threshold value as 40. In Harris corner based detection, corner is detected through differential operator and self-correlation matrix [1].
For $M_f(i,j,t)$, changes of pixel intensity of each image after moving (r, s) is expressed as equation (10) [1].

$$H_{r,s}(i,j) = \sum_{r,s} O_{r,s}\left(r\frac{\partial f}{\partial i} + s\frac{\partial f}{\partial j} + M(r^2+s^2)\right) \tag{10}$$

Here, $O_{r,s}$ is considered as the coefficient in the position (s, t).

4.0 EXPERIMENTAL RESULTS

Proposed research used C sharp programming language is used for experimental evaluation. Visual Studio 2012 is used as compiler platform. Three corners based methods are used for comparing each method which are Moravec, Susan and Harris corner based detection. Each of the methods is evaluated in the same hardware platform which becomes useful for computation time and other performance metrics measurement. Each of the methods are raw coded which depicts more efficiency to measure the computation time. Validation measurement section is categorized into three sub sections. Dataset section illustrates about datasets, experimental results section depicts about experimental results and analysis and discussion section demonstrates analysis and discussion to evaluate overall research.

4.1 Datasets

Three specific modules are developed for three methods i.e. Moravec, Susan and Harris corner based detection. For each of the methods frame difference method and noise reduction module are also developed to provide the noise free image to the developed three modules. This research used 88 and 131 aerial frames from two datasets collected from Center for Research in Computer Vision (CRCV) from University of Central Florida [21]. Collected data sets represent a diverse pool of action features at different heights and aerial view points. Frame size in the experiment is 320 x 190.

4.2 Validation Measurements

Three validation measurements are used to evaluate three methods which are mentioned below:

1. Detection Rate (DR)
2. False Alarm Rate (FAR)
3. Computation Time

Detection Rate and False Alarm Rate are dependent on True Positive, False Positive and False Negative and Computation Time measured in milliseconds or ms for Moravec, Susan and Harris corner based detection are shown in Table 1.

TABLE (1). Measurement of Detection Rate (DR), and False Alarm Rate (FAR) and Computation by using Moravec, Susan and Harris corner based detection.

Corner Name	Datasets	Detection Rate or DR (%)	False Alarm Rate or FAR (%)	Computation Time (ms)
Moravec	Dataset 1	63.31	72.18	199.08
	Dataset 2	69.23	69.52	215.47
Susan	Dataset 1	62.62	71.51	206.74
	Dataset 2	69.57	65.88	224.70
Harris	Dataset 1	62.90	64.09	180.18
	Dataset 2	66.51	56.47	204.17

Proposed research reveals detection rate of 63.31% and 69.23% for Moravec corner features based detection using dataset 1 and dataset 2 respectively shown in Table 1. Besides, Moravec corner feature received False Alarm Rate (FAR) of 72.18% and 69.52% for both datasets. Regarding Computation Time, 199.08 ms and 215.47 ms were required for Moravec corner features. For Susan corner, Detection Rate of 62.62% and 69.57% are received for dataset 1 and dataset 2. In addition, Susan corner features received False Alarm Rate (FAR) of 71.51% and 65.88% in lieu with the Computation Time of 206.74 ms and 224.70 ms respectively for both datasets. Besides, Harris corner received Detection Rate of 62.90% and 66.51% while False Alarm Rate of 64.09% and 56.47% for both datasets. Computation Time is 180.18 ms and 204.17 ms for dataset 1 and dataset 2 respectively required by Harris corner feature based detection. The next section illustrates critical analysis and discussion for each corner feature based method.

5.0 ANALAYSIS AND DISCUSSION

5.1 Detection Rates

Maximum Detection Rate of 63.31% achieved by Moravec corner for dataset 1 whereas second Detection Rate of 62.90% achieved by Harris corner feature detection shown in figure 1. Among three corner feature based detection, Susan achieved lowest Detection Rate of 62.62%. However, due to more images in dataset 2, Detection Rate achieved by Susan corner feature detection achieved 69.57%. Moravec corner feature based detection received second highest Detection Rate of 69.23%. Besides, Harris corner based detection received lowest Detection Rate of 66.51% in dataset 2. Although Moravec corner based detection achieved higher Detection Rate with other corner based detection due to the capability of handling illumination changes, as the number of images increase in dataset 2 Susan corner based detection achieved more Detection Rate than Moravec corner based detection in dataset 1 due to capability of handling noise issue [11].

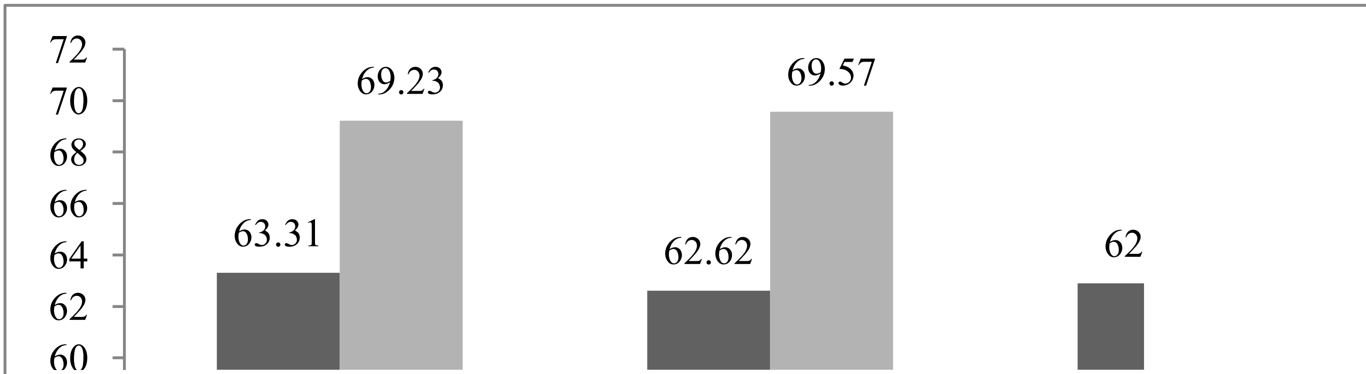

FIGURE 1. Detection Rate for Moravec, Susan and Harris corner based detection using dataset 1 and dataset 2.

5.2 False Alarm Rate

False Alarm Rate or FAR refers the percentage of falsely detected object by this research for both datasets shown in figure 2. Lowest FAR of 64.09% received by Harris corner feature while Moravec achieved FAR of 72.18% which is highest among three corner feature based detections. Besides, Harris corner feature based detection received lowest FAR of 56.47% for dataset 2 while Susan received second lowest FAR of 65.88%. In addition, highest FAR of 69.52% was achieved by Moravec corner. Harris corner features based detection received lowest FAR comparing with other features based detection due to usage of Gaussian filtering which performs efficiently for anti-interference environments.

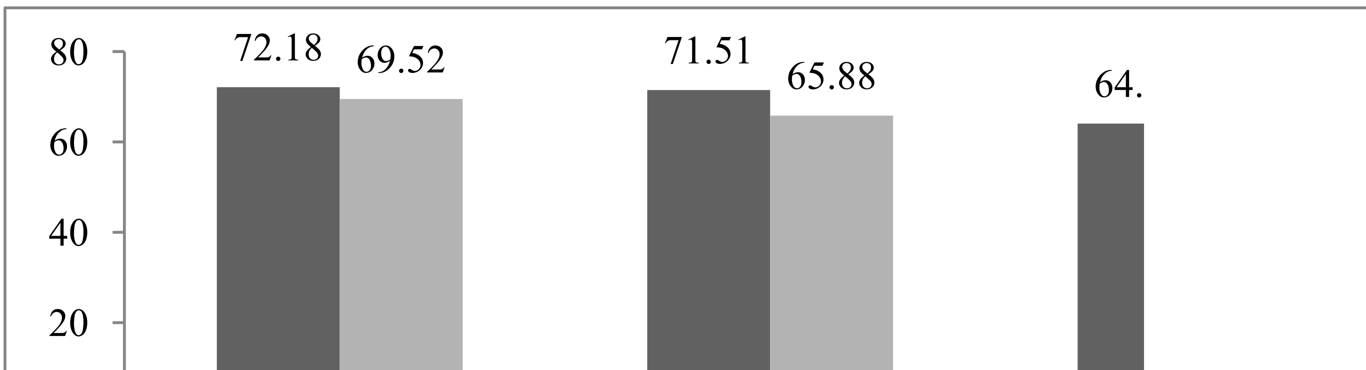

FIGURE 2. False Alarm Rate for Moravec, Susan and Harris corner based detection using dataset 1 and dataset 2

5.3 Computation Time

Lowest Computation Time of 180.18 ms required by Harris corner feature based detection while second lowest CT of 199.08 ms is required by Moravec corner for dataset 1. Susan corner features based detection required highest CT of 206.74 ms among corner features based detection. Similarly, Harris corner feature based detection performed again most efficiently in terms with CT for dataset 2 also with the CT of 204.17 ms shown in figure 3. Like mentioned in dataset 1, Moravec corner feature based detection received second lowest CT of 215.47 ms and Susan corner feature based detection received highest CT of 224.7 ms for dataset 2. Based on the critical observation mentioned above, proposed research illustrates the fact that Harris corner based detection performed significantly efficient for both datasets considered by this research in terms with two standard parameters like False Alarm Rate and Computation Time due to affine invariant and partial rotational invariance [21]. Although, Moravec and Susan corner feature based detection received higher Detection Rate in some cases, Harris corner feature based moving object detection using aerial types of images are recommended due to low False Alarm Rate and Computation Time.

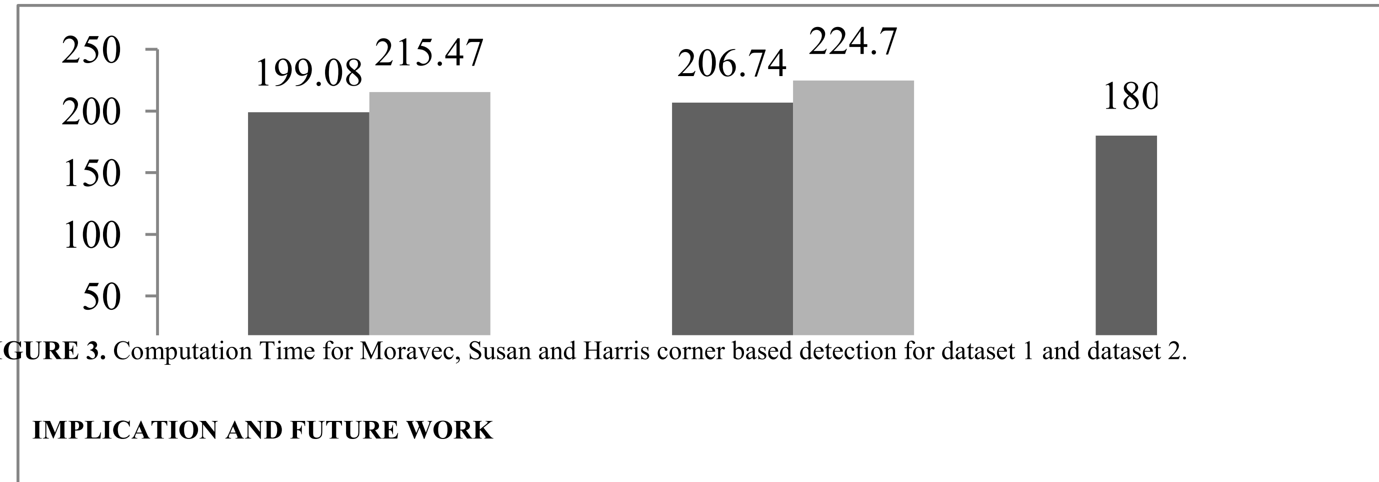

FIGURE 3. Computation Time for Moravec, Susan and Harris corner based detection for dataset 1 and dataset 2.

6.0 IMPLICATION AND FUTURE WORK

Moving object detection is still an unsolved research issue in the area of computer vision and pattern recognition research domain in terms with reliable detection rate, false alarm rate and computation time. Aerial images have many challenges for processing, i.e. lack of features due to unstable camera position, altitude variation, brightness issues, structural and unstructured shape of objects. These challenges cause huge amount of processing time during overall detection methodology. Expected outcomes of the proposed research are aimed to use in the later phases of detection methodology, i.e. motion modeling, segmentation, efficient feature extractions. In addition, proposed investigation is expected to use to decide the types corner features will be suitable for overall detection procedures especially for aerial types of images.

7.0 CONCLUSION

The main aim of this research is to illustrate comparison among corner based detection for moving object detection using aerial types of images. Three corner features are selected for overall detection performance evaluation which is Moravec, Susan and Harris corner due to capability of handling low and high intensity variation especially aerial types of images. Three performance parameters are used to evaluate overall performance for detection which is Detection Rate, False Alarm Rate and Computation Time. Two datasets are used for experimental validation purpose. Evaluation with Detection Rate indicates that Susan corner based detection demonstrates higher performance than other two corner based detection as the number of input aerial images increases in dataset 2. Evaluation with False Alarm Rate depicts that Harris corners based detection received lowest False Alarm Rate than other corners based detection for both dataset 1 and dataset 2. Evaluation with Computation Time illustrates that Harris corner based detection required lowest Computation Time than other corner based detection for both datasets. Experimentation of three corners based detection was performed with the same computational environment to ensure the justification of the same hardware performance measurement and reliability of the demonstrated research. Proposed research is expected to be beneficial to choose appropriate corner feature for moving object detection problem in computer vision, image processing and pattern recognition research field.

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