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Comparison of Different Feature Detection Techniques for Image Mosaicing

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Abstract

Image mosaicing is widely used in present computer vision applications. A considerable measure of important information is represented by the feature points in an image. Accurate extraction of these features is an essential part of image mosaicing as it can reduce misalignment errors in the final mosaic. A number of feature detection algorithms have been developed in recent years which can be used for image mosaicing. However, the computational complexity and accuracy of feature matches limits the applicability of these algorithms. In this paper, four widely used feature detection algorithms, Harris, SURF (Speeded-Up Robust Features), FAST (Features from Accelerated Segment) and FREAK (Fast Retina Key point) feature detection algorithms are compared in terms of accuracy and time complexity for mosaicing of images correctly. First, these algorithms have been applied on a single image and then, different set of images are tested for the comparison. It is concluded that the FREAK algorithm is superior to the rest of the feature detection algorithm in terms of accuracy and run time.

Keywords

Corner detection, feature detection, image matching, image mosaicing accuracy, time complexity.

1. Introduction

In recent couple of decades, real time applications in image mosaicing have been a challenging field for image processing specialists. It has wide use in the field of satellite imaging, 3-D image reproduction, therapeutic and computer vision fields. It can also be used for mosaic-based localization, motion detection and tracking, augmented reality, resolution enhancement, generating large field of view (FOV).

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The first step of image mosaicing is image registration. An extensive explanation of different registration techniques can be found in [1]. An integral part of image registration is feature detection. The two-dimensional feature points are considered as corners. Corners account for essential local features in images. The feature points in images which generate gradients of more prominent values in both the dimensions are said to be corners. A very rapid variation in pixel values is seen in corners. Extraction of corners can minimize the processing of data, without loss of information in the image. Therefore, corner detection has practical value and has an important role to play in building 2-D mosaics, image matching, scale space theory, motion tracking, image processing, stereo vision, and other fields. Generally, the algorithms which have been developed over time for detecting feature points using edge detection method are applied in both directions to find a corner [2].

In this paper, different type of feature detection algorithms have been discussed and implemented for image mosaicing. Input images are acquired and features are detected using Harris corner detection, SURF (Speeded-Up Robust Features), FAST (Features from Accelerated Segment) and FREAK (Fast Retina Key point) feature detection algorithms. These algorithms have been considered for comparison as the performance of these algorithms is better in image mosaicing as compared to the rest of the algorithms. Different set of images for mosaicing have been considered to calculate the comparison parameters for different feature detection techniques. Feature correspondences between the original images and the distorted original images are found. On the basis of this information and total execution time for each algorithm, the comparison has been made.

2. Related Work

In this section, the feature detection techniques that have been used for comparison are briefly described. The algorithm used in each of the techniques has been explained below and feature matching has been explained.

2.1 Harris corner detector algorithm

Harris corner detection algorithm detects feature points by designing a local detecting window inside the image. The small amount of shifting of window in different direction can be determined by the average variation in the pixel intensity. The corner point is the centre point of the window. Hence, on shifting the window in any of the direction, a large variation in pixel intensity is seen. When the window is shifted, no change in pixel intensity is seen in any direction if a flat region appears. But, when there is no change in pixel intensity along the edge direction, then an edge region is detected. But, when there is a significant change in pixel intensity in every direction, a corner is detected. A mathematical approach for determining whether the region found is flat, edge or corner is provided by Harris corner detection algorithm. More number of features are detected using this detection algorithm. Though, it is found to be scale variant, but it is invariant to rotation.

The change in pixel intensity for the shift [u, v] is given as below:

$$E(u,v) = \sum_{x,y} w(x,y)[I(x+u+y+v) - I(x,y)]^2$$

.... (1)

Where, w(x, y) is a window function,
I(x, y) is the intensity of the individual pixel, and
I(x + u, y + v) is the pixel intensity after shift.

The algorithm for Harris corner detection is given [3] as:

i. Autocorrelation matrix M for each pixel (x, y) in the image is calculated as follows:

$$M = \sum_{x,y} \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix} \quad (2)$$

ii. Gaussian filtering for each pixel of image is generated using matrix M and discrete two-dimensional zero mean Gaussian function:

$$Gauss = exp(-u^2 + v^2)/2\boldsymbol{\delta}^2 \quad (3)$$

iii. Calculating the corners measure (R) for each pixel (x, y)

$$R = \det(M) - k * trace(M)^2 \quad (4)$$

iv. We choose a local maximum point. The feature points whose pixel values are corresponding with the local maximum interest point are considered in Harris corner detection method.

v. The detection of corner points is done after setting the threshold value T.

2.2 SURF Algorithm

SURF is a quick and robust algorithm which was developed by Bay [4] for nearby, closeness invariant representation and correlation. The SURF methodology can be partitioned into three fundamental steps.

i. The first step is to choose key feature points such as edges, corners, blobs, and T-intersections at distinctive regions in the image.

ii. Second step is to use feature vector to depict the surrounding neighbourhood of each feature point. This descriptor must be a unique one. At the same time, it ought to be robust to error identification, noise, photometric and geometric deformations.

iii. Finally, the descriptor feature vectors are coordinated among the different accessible images. A Fast-Hessian Detector is used for finding feature points taking into consideration the close estimation of the Hessian lattice of a given picture point. Before the shaping of feature point descriptor is done from the wavelet responses in a certain surrounding to the point, an introduction task needs to be done. This can be done by using the responses to Haar wavelets. This is the reason why a circular region is developed around the detected feature points when SURF algorithm is used.

The fundamental point of interest of the SURF methodology is its fast computation, which empowers numerous ongoing applications, such as, image mosaicing, tracking and object recognition. It has speeded-up the SIFT's location transform as well as has counteracted nature of the recognized feature points from degrading. The principle focus is laid on speeding-up the matching step.

2.3 FAST Algorithm

The FAST strategy was presented by Rosten Drummond [5] for recognizing interest points in an image. The purpose of FAST algorithm was to add such an interest point indicator in the list of other interest point detector that can be utilized continuously in real time frame rate applications.

In this algorithm, a machine learning approach is used which is adaptive in processing. Here, only a few points inside the range are identified and processed whereas the points that fall outside the scope of interest are rejected.

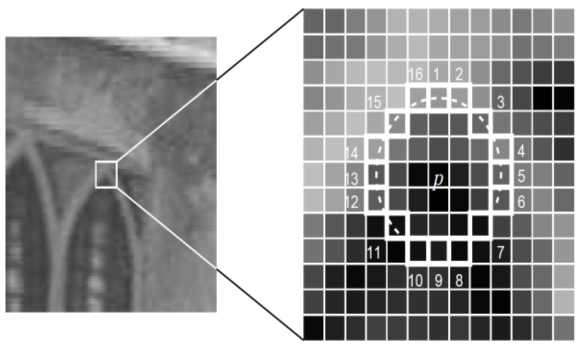

Figure 1: Interest point detection (a) Interest point under test and (b) Closer view of the interest point with 16 pixels on the circle

The algorithm is explained below:

i. A pixel "p" is selected in the image. The intensity of this pixel is assumed to be I_P. This is the pixel under test, i.e., it needs to be confirmed whether it is an interest point or not as shown in Figure 1 [5].
ii. A threshold intensity value T is set (its value is assumed to be around 20% of the pixel under test).
iii. A circle of 16 pixels surrounding the pixel p is considered whose pixel intensity is assumed to be I_p. This is a Bresenham circle of radii 3.
iv. For the pixel to be distinguished as an interest point, "N" adjacent pixels out of the 16 need to be either above or beneath I_P by the threshold value T. For the present case N=12.
v. The algorithm can be made fast by comparing the intensity of pixels 1, 5, 9 and 13 of the circle with I_P first. As apparent from the Figure 1, no less than three of the above mentioned four pixels ought to fulfil the rule in step iv to detect a feature point.
vi. If at least three of the pixels are above Ip + T or beneath Ip - T, then for each of the 16 pixels it is checked that 12 contiguous pixels fall under the criterion.
vii. The process is repeated for all the pixels in the image.

There are a couple of disadvantages of the algorithm. To start with, the algorithm does not work extremely well in all cases. When N<12, then the number of interest points identified are very high. Second, the order in which the 16 pixels are queried decides the speed or the time complexity of the algorithm.

2.4 FREAK Descriptor

FREAK is a binary descriptor that improves the sampling pattern and method of pair selection over a non-overlapping concentric circular rings used by BRISK (Binary Robust Invariant Scalable Keypoints) as shown in Figure 2.

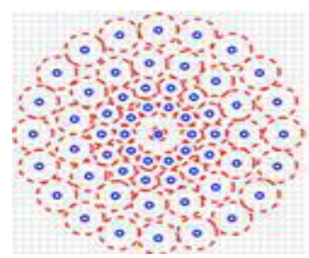

Figure 2: BRISK sampling pattern

At the locations around the feature point, 43 weighted Gaussians are evaluated using FREAK but the pattern formed by these Gaussians is biologically inspired by the retinal pattern in the eye as shown in Figure 3 [6]. There is overlapping of the pixels that are being averaged and hence, they are much more concentrated near the key point than at the farther side. This results in a more accurate depiction of the key point.

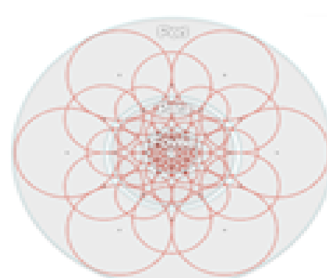

Figure 3: Freak Sampling Pattern

A cascade is used in the actual FREAK algorithm for comparing these pairs which puts forward the most important 64 bits for speeding up the matching process.

The steps of the algorithm are as follows:

i. For obtaining the local areas of interest from the images, the FAST key point detector is applied separately on all the image inputs.
ii. Then, the descriptors, i.e., feature vector for all of these key points that are present in the reference images are obtained using the FREAK key point descriptor, which describes each key point with a 64 bit descriptor.

2.5 Feature Matching

All the features that have been detected are matched so as to confirm that features are from the corresponding locations from completely different images. As the arrangement of feature points may not be accurate, an exact coordination needs to be done by the means of progressive incremental motion refinement, but that is tedious and may degrade the performance [7].

When feature tracking is done over larger image arrangements, it may result in larger variation in their appearances. In such cases, the comparison between the appearances must be done with the help of an affine, projective or other motion model. The descriptors of differential invariants are lethargic to moderations in arrangement by configuration, and hence, fails to perform as expected.

3. Comparison of Feature Detection Algorithms for Image Mosaicing

Two main parameters used for comparison of different feature detection algorithms in image mosaicing are: Accuracy [8] and Time complexity (run time). Even when an image is distorted, the best feature points of an image should remain almost the same. So, when feature matching is done between the original image and the distorted image, the more is the number of matching features out of the number of extracted features, the more is the accuracy. So, it can be said that accuracy is a relative term that also depends on the number of extracted features. Hence, accuracy is defined as the percentage of matched features to the extracted features.

The steps for comparison are as follows:

i. An input image (original image) is read and is saved with a variable name.
ii. The original image is distorted and saved with another variable name. This can be done by either resizing the image or by rotating the image or by changing pixel intensity of the image. The distortion should be same for each of the four algorithms.
iii. Detection of feature points is done using different algorithms separately and out of these, N strongest features are detected in each case which is followed by extraction of features.
iv. Feature matching is done for the extracted features in each case.
v. Accuracy (%) is given as

$$\frac{1}{n}\sum_{i=1}^{n}\frac{I_m}{I_{ex}}*100$$

(5)

Where,
I_m = Total no. of matched features
I_{ex} = Total no. of extracted features from original
image
n = Total no. of images used

vi. Lesser the computational time, better is the performance of the algorithm. This can be calculated by using the run and time option provided in MATLAB. On clicking the run and time option, profiler window opens up that includes all the timing data for each line executed in the code and the total execution time. So, the total execution time and time for only extraction can be obtained.

4. Results and Discussions

Initially, the comparison algorithm is implemented on a single image and then the number of images is increased. The results obtained from comparing different feature detection algorithms on the basis of accuracy and time complexity are presented in Table 1. From the table, it is clear that the performance of FREAK algorithm is better than the other three algorithms.

Figure 4 shows the graph plotted for comparison of different feature detection algorithms on the basis of accuracy and Figure 5 shows the graph plotted on the basis of time complexity. A closer view of the graph plotted in Figure 5 is shown Figure 6. From Figure 4, it can be found that FREAK has the best accuracy among all the feature detectors. It should be noted that accuracy is a relative term which can vary from image to image. Figure 5 and Figure 6, represent that FREAK has the optimum speed as compared to other algorithms. It can be observed that the other algorithms, that is, Harris and FAST also have high computational speed From both the graphs, it can be concluded that FREAK has the highest accuracy with an optimum speed. FAST also has a good accuracy and speed but both are less as compared to FREAK. SURF has mediocre accuracy but is slowest as compared to other algorithms. Harris has a poor accuracy but has good computational speed because of the simple algorithm implied.

Table 1: Comparison of Different Feature Detection Algorithms

No. of Images	Algorithm	Run Time (sec)	Extracted Features		Matched Features		Accuracy (%)
			Original image	Distorted image	Original image	Distorted image	
1	FREAK	0.002	45	109	35	35	77.7
	FAST	0.003	136	148	73	73	53.6
	SURF	0.057	38	70	14	14	26.3
	Harris	0.008	48	140	8	8	16.7
4	FREAK	0.003	288	508	154	154	49.35
	FAST	0.004	556	591	241	241	42.51
	SURF	0.215	369	520	131	131	36.07
	Harris	0.024	249	895	30	30	15.73

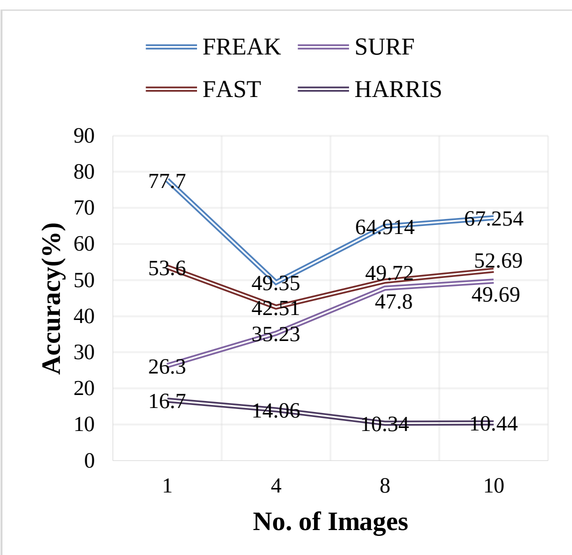

Figure 4: Accuracy versus no. of images used plot

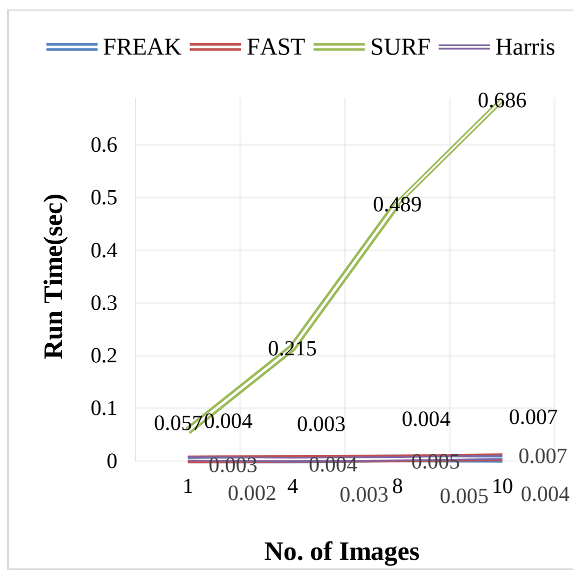

Figure 5: Time complexity versus no. of images used plot

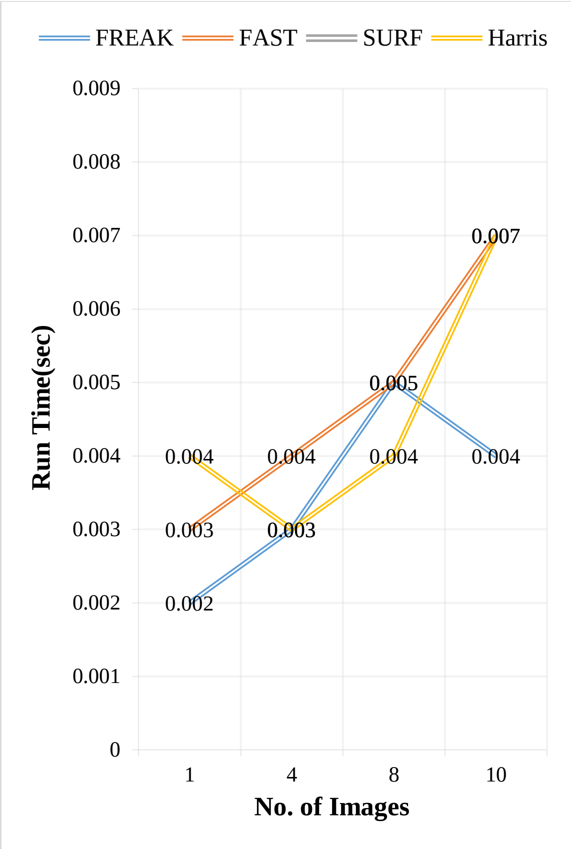

Figure 6: Closer view of time complexity versus no. of images used

5. Conclusion and Future Work

In this paper the performance of Harris, SURF, FAST and FREAK feature detection algorithms for image mosaicing has been compared. Feature detection is an essential step for the generation of good quality image mosaic. Computational complexity and accuracy of feature matches limits the use of various algorithms. In this work, popularly used feature detection algorithms have been considered and compared for their applicability in image mosaicing. Firstly, a set of distorted images are generated from the acquired original images taking into consideration that the amount of distortion should be same for each image. Then, the comparison is done between each of the original image and the distorted image. It has been incorporated over different set of images. After that the algorithm with better performance can be used for image mosaicing.

Presently, feature detection algorithms have been compared quantitatively for their application in image mosaicing. As a part of future work these algorithms will be tested and compared for their performance visually on different set of images to generate good quality image mosaics.

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