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Image Feature Extraction and Selection

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Abstract

Features are the description of the image contents which could be corner, blob or edge. Scale-Invariant Feature Transform (SIFT) extraction and description patent algorithm used widely in computer vision, it is fragmented to four main stages. This paper introduces image feature extraction using SIFT and chooses the most descriptive features among them by blurring image using Gaussian function and implementing Otsu segmentation algorithm on image, then applying Scale-Invariant Feature Transform feature extraction algorithm on segmented portions. On the other hand the SIFT feature extraction algorithm preceded by gray image normalization and binary thresholding as another preprocessing step. SIFT is a strong algorithm and gives more accurate results but when system require increasing speed, it is better to select distinctive features and use them in description process. The experimental results show clearly reduction of features extracted using SIFT algorithm on segmented parts and the algorithm of feature extraction from normalized binary image gives better results for feature localization as shown in experimental images.

Keywords: SIFT, Otsu, Feature selection.

استخراج و اختيار خصائص الصورة

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الخلاصة

يمكن التعبير عن الصورة باستخدام خوارزميات لاستخراج خصائص الصورة ووصفها. خوارزميةٍ SIFT هي احدى اهم الخوارزميات المستخدمة بصورة واسعة في المعالجة الصورية وتتكون هذه الخوارزمية من اربع خطوات اساسية. هذا البحث يقدم طريقة لتقليل الخصائص المستخرجة من الصورة والحصول على الخصائص الاكثر تمييزا للصورة بطريقتين احدهما عن طريق استخراج الخصائص باستخدام خوارزمية ال SIFT لاجزاء من الصورة حيث يتم تجزئة الصورة باستخدام خوارزمية Otsu والطريقة الاخرى عن طريق تطبيق ال SIFT على الصورة بعد اجراء Linear normalization وتحويلها الى صورة ثنائية binary image. تعد خوارزمية ال SIFT خوارزمية دقيقة في استخراج النقاط بحيث تستخرج عدد كبير من النقاط وتحتاج الى وقت طويل لوصف هذه النقاط لذلك من الافضل اختيار عدد من النقاط الافضل التي ممكن ان تعبر عن الصورة. اظهرت نتائج الاختبارات بشكل واضح تقليل عدد النقاط الواصفة للصورة بطريقة تجزئة الصورة وبطريقة تحويل الصورة الى صورة ثنائية ولكن نتائج الطريقة الثانية كانت افضل في تحديد مواقع النقاط.

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1. Introduction

The term of feature detection and description is the process of defining the interested points in an image that gives the image's contents description. The main local features in any image is; (1) Edges which refer to the intensities of pixels changing abruptly, (2) Corners which refer to the pixels at the intersection of edges, and (3) Region which refer to a set of points which connected closely based on similar homogeneity criteria [1].

Analyzing pixel's neighbors that participate by some properties could localize the local features of image. Local features are less affected with environment variation, e.g. lightening alteration because the local features deal with group of pixels related spatially. Moreover the local features have been demonstrated that the performance are more robust and eminent to noise in image [2].

Presenting large number of features could increase the dimensionality, therefore increasing the processing time could also affects the accuracy. Features' selection utilized to decrease the dimensionality of a feature space and to preserve the most distinctive features [3].

This paper continues as follows: section 2 presents some related works that have similar objectives to this work. Section 3 presents a general concept of local feature extraction and Scales Invariant Feature Transform method. Section 4 presents OTSU's segmentation method. Section 5 presents linear normalization technique. Section 6 presents the proposed method for feature extraction using SIFT and selection of interested features. Section 7 presents experimental results. Section 8 presents conclusions of this work.

2. Related Works

In **2013**, Hunny Mehrotra, et.al, proposed a robust segmentation and an adaptive SURF descriptor for iris recognition. The experimental results of the proposed approach performs with enhanced accuracy and reduced processing cost [4]. In **2015**, Kalaiselvi Chinnathambi, et.al, proposed a segmentation algorithm that started with detecting the cancer cells in the region, segmenting region, extracting feature, and selecting feature. Experimental results of the proposed algorithm performed on several images and showed that the proposed algorithm able to locate and identify the tumours and other pathologies [5]. In **2017**, Yuji Nakashima, and Yoshimitsu Kuroki, proposed image segmentation algorithm automatically using Graph Cut and selected feature points on foreground region only using SIFT then selected valid corresponding points using estimated fundamental matrix, while corresponding points are eliminated. Experimental results show that the proposed method increased correct matching rate by reducing erroneous correspondents [6].

3. Scale Invariant Feature Transform (SIFT)

SIFT is a local features detection and description algorithm, it is able to provide steady point for matching image. SIFT is popular algorithm for detecting important points which are invariant to image translation, image rotation, image scaling, and image lightening variation. SIFT is patent algorithm and take dense processing cost that make it too slow [7].

SIFT composed of four main stages; (a) detect scale space, (b) localize keypoints, (c) assign orientation, and (d) describe keypoints. The first step is defined as a location and scales of the interested points using the extrema of scale space in the DoG (Difference of Gaussian) functions with various values of σ. Different scale of images created by using different value of σ in Gaussian function (σ in every scale separated by k that is constant value), then Subtract consecutive images to create DoG pyramid. DoG was used instead of Gaussian to increase the processing speed. After that the Gaussian image down sampled by 2 and create DoG to down sampled image. Gaussian function is shown in equation (1) and DoG is shown in equation (2) [8] [9].

$$G(m, n, \sigma) = \frac{1}{2\pi\sigma^2} \exp\left[-\frac{m^2+n^2}{2\sigma^2}\right] \quad (1)$$

Where G (m, n, σ) represents changing scale Gaussian,
σ represents the scale variable of the consecutive scale space,
m represents horizontal coordinates in Gaussian window,
n represents vertical coordinates in Gaussian window,
π = 3.14

$$D(x, y, \sigma) = (G(x, y, k\sigma) - G(x, y, \sigma)) * I(x, y) \quad (2)$$

Where
* represents the convolution operation,
k represents scaling factor,
G(x, y, σ) represents changing scale Gaussian function,
I(x, y) represents an input image,
D(x, y, σ) represents Difference of Gaussians have k times scale,
x represents horizontal coordinate in image (I(x, y)) with corresponding horizontal coordinate in Gaussian window (G(x, y, σ)), y represents vertical coordinate in image (I(x, y)) with corresponding vertical coordinate in Gaussian window (G(x, y, σ)).

Local extrema obtained by comparing every pixel after DoG with 26 other pixels (eight neighbor pixels at the current pixel's level and nine pixels in the upper level and nine pixels in the lower level. When the compared pixel is extrema (minimum than all 26 pixels or maximum than all 26 pixels), pixel position and scale are saved. In the keypoint localization step, low contrast points and points at edge are eliminated. Intervention point is also eliminated by using (2×2) Hessian matrix [8] [10].
The descriptors build by calculating the gradient strength and orientation strength for each neighbor of a keypoint. The neighborhood of every keypoint are characterized by creating 8 bins gradient and orientation histogram for 16×16 region of neighbors around keypoint. The region is split up into 4×4 sub regions and each sub region have 8 directions this will produce 4×4×8= 128 dimensional vector to give description for every keypoint [10][11].

The existence of large number of features will produce irrelevant or redundant features that increase the processing time and can also affect the accuracy. The aim of feature selection is to reduce feature space dimensionality and to keep the distinctive features [3].

4. OTSU's Method

Otsu approach is a successful analytical and global method for image thresholding that is based on image's gray value only. Otsu method takes the best threshold **t** by searching for criterion for maximizing *between class variance* and minimizing the *within class variance*. For each value in grey image compute the weight, the mean, and the variance, the optimal threshold will equal to the lowest sum of weighted variance. Faster approach is to select the threshold with the maximum between class variance and has the minimum within class variance [12][13].

The image points in bi-level thresholding approach are split by the threshold **t** to two classes C1 and C2 where C1 gray levels range is [0, 1, ... , t] and *C2* gray levels range is [t+1, … , L-1]. The probability distributions of gray level pg1 and pg2 for C1 and C2 classes respectively are [14]:

$$pg_1(c1) = \sum_{i=0}^{t} pro \tag{3}$$

$$pg_2(c2) = \sum_{i=t+1}^{L-1} pro \tag{4}$$

Where pro represents probabilities of intensity.

The first class mean is m1 and the second class mean is m2:

$$m1 = \sum_{i=0}^{t} i\, pro\, / pg1 \tag{5}$$

$$m_2 = \sum_{i=i+1}^{L-1} i\, pro\, / pg2 \tag{6}$$

The total mean of grey levels is denoted by m_t:

$$m_t = pg_1 \times m_1 + pg_2 \times m_2 \tag{7}$$

The variances of first and second class respectively denoted by σ1, σ2:

$$\sigma_1^2 = \sum_{i=0}^{t} (i - m1)^2\, pro\, / \, pg_1 \tag{8}$$

$$\sigma_2^2 = \sum_{i=i+1}^{L-1} (i - m2)^2\, pro\, / \, pg_2 \tag{9}$$

Within Class Variance σ_w:

$$\sigma_w^2 = pg_1 * \sigma_1 + pg_2 * \sigma_2 \quad (10)$$

Between Class Variance σ_b:

$$\sigma_b^2 = pg1\,(m1 - mt)^2 + pg2\,(m2 - mt)^2 \quad (11)$$

1. Linear Normalization

Normalization or decorrelation of data done bypass biasing distance or similarity measures, and to prepare data for classification algorithms. Limitation feature value for particular range can be done by linear techniques. Min-Max normalization technique used to map data to a particular range SMIN to SMAX but the relationship remain exist between values.

$$Norm_{(i,j)} = \left(\frac{Gray(i,j) - MinOfGray}{MaxOfGray - MinOfGray}\right)(S_{Max} - S_{Min}) + S_{Min} \quad (12)$$

Where

$Norm_{(i,j)}$ represents new normalized gray value,

S_{Max} represents the maximum value for the particular range,

S_{Min} represents the minimum value for particular range,

MinOfGray represents the minimum of the original data,

MaxOfGray represents the maximum of the original data.

When data normalization techniques are applied be aware since these techniques will move the mean, and will change the data spread [15].

6. Proposed Methods

SIFT feature detection method extracts large number of features that increases the processing time. It is important to reduce these features especially redundant features and those that are unnecessary by adding preprocessing step(s) before the process of extracting feature, therefore Otsu segmentation algorithm will be added for the first algorithm before feature extraction, and gray image normalization and binary thresholding will be preceded feature extraction for the first algorithm. Otsu method suffers to separate the noisy image histogram, therefore segmentation method in this paper preceded by Gaussian function to blur image and reduce any noise if exist and to create safe thresholding method.

Algorithm one "Features Selection Using Image Segmentation"
Input: Color Image, Sigma, k.
Output: Number of features for original image, segmented image, number of features for segmented image.

Step 1: Open colored image, convert to gray,
Step 2: Blur gray image using Gaussian function, equation (1),
Step 3: Extract features using SIFT feature detection method and calculate the number of features,
Step 4: Perform OTSU's image segmentation algorithm on blurred gray image,
Step 5: Extract features using SIFT feature detection method and calculate the number of features,
Step 6: Comparing the number of features extracted before and after segmentation.
Step 7: End.

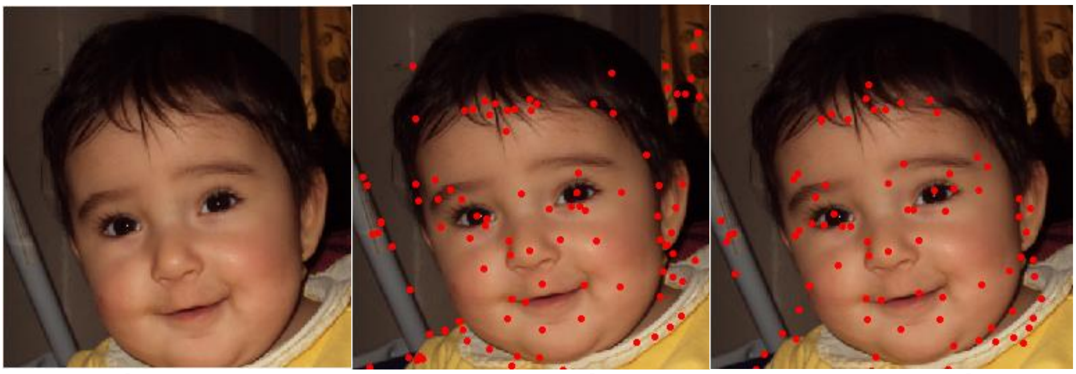
Algorithm two "Features Selection Using Image Normalization"
Input: Color Image.
Output: Number of features for original image, binary image, number of features for binary image.

Step 1: Open colord image, convert to gray,
Step2: Extract features using SIFT feature detection method and calculate number of features,
Step 3: Get maximum and minimum grey level values,
Step 4: Perform normalization equation (12),
Step 5: Define thresholding value by:
Threshold = (MaxGray - MinGray) / 2 … (13)
Step 6: Convert normalized gray image to binary image based on previous threshold,
Step 7: Extract features using SIFT feature detection method,
Step 8: Comparing the number of features extracted before and after normalization,
Step 9: End.

7. Experimental Results

Proposed algorithm written in visual basic programming language (VB2013.net) and several images have been tested, five images and their experimental results (face, house, car, apple, and tiger) displayed in Table-1 for feature reduction or selection based on Otsu image thresholding method and the results in Table-2 for feature selection based on image normalization method.

- **Face**

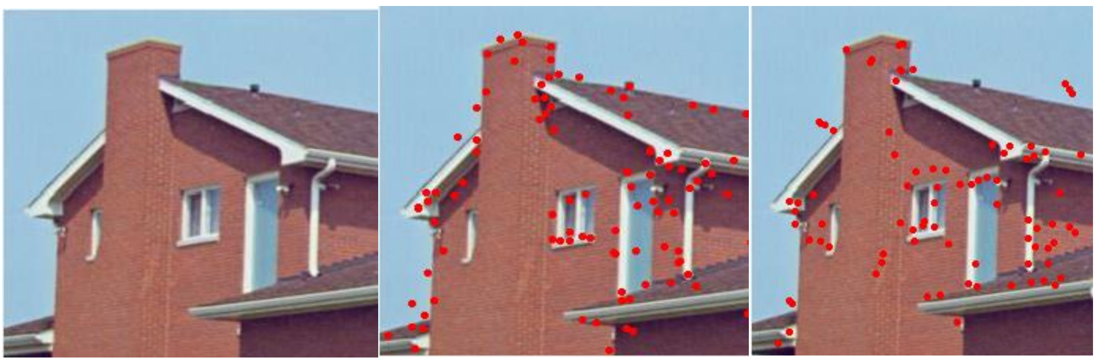


Original image *SIFT on Original image* *SIFT on segmented image*

- **Apple**

Original image *SIFT on Original image* *SIFT on segmented image*

- **House Image**



Original image *SIFT on Original image* *SIFT on segmented image*

- **Car**

Original image *SIFT on Original image* *SIFT on segmented image*

- **Tiger**

Original image *SIFT on Original image* *SIFT on segmented image*

Table 1-Extracted features after OTSU's thresholding method

Image Name	No. of original image Features	No. of segmented image Features	No. of Features difference
Face	105	83	22
Apple	48	39	9
House	108	85	23
Car	111	60	51
Tiger	253	208	45

Same images have been presented for feature selection based on normalized thresholding method:

- ***Face***

Original image *SIFT on Original image* *SIFT on normalized image*

- **Apple**

Original image *SIFT on Original image* *SIFT on normalized image*

- **House**

Original image *SIFT on Original image* *SIFT on normalized image*

- **Car**



Original image *SIFT on Original image* *SIFT on normalized image*

- **Tiger**



Original image *SIFT on Original image* *SIFT on normalized image*

Table 2-Extracted features from normalized images

Image Name	No. of original image Features	No. of segmented image Features	No. of Features difference
Face	105	76	29
Apple	48	44	4
House	108	96	12
Car	111	80	31
Tiger	253	235	18

As shown on the previous Tables-(1, 2) many features rejected when applying SIFT algorithm on segmented blurred image rather than applying it on the original image. At least one feature could affect the processing time because the number of extracted features are approximately large and the description for every feature is assigned after many processing steps on 128 region of points around keypoint.

The first algorithm includes blurring using Gaussian function, segmenting using Otsu's method and extracting feature using SIFT method. The second algorithm includes linear normalization, creating binary image, and extracting feature using SIFT method. The processing time taken in first and second algorithms approximately the same since both of them using SIFT feature extraction method that require most of the processing time. The number of the rejected keypoints in the first algorithm is more than the rejected keypoints in the second algorithm and the selected keypoints in the first algorithm is better than the selected keypoints in the second algorithm that is clearly appear in the experimental results.

The initial parameter using to write SIFT algorithm was as follows: 4 octave will be created to satisfy scale invariant characteristic (first octave represents the original image, second octave represents the original image down sampled by 2, and so on every octave down sample the previous octave by 2). Every octave have 5 levels since each level represent different scale of image which change according to consecutive increasing of σ by k (k is chosen to be $\sqrt{2}$). After the scale space stage done on 4 octave the second stage of SIFT keypoint localization is performed to obtain stable keypoints. The optimal value of σ in Gaussian function for creating image blurring window was 1.6, and the size of window was (5×5).

8. Conclusion

This paper presented one of the most important blob image's feature detection method which is SIFT. SIFT method are patent algorithm and composed of several steps, therefore it is require long time to create descriptor for every keypoint, since any image described and processed by its features. SIFT feature extraction algorithm performed on blurred and segmented image in order to reduce the number of features needed to describe image. The blurring operation is done by Gaussian function while the segmentation process is done by Otsu segmentation algorithm.

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