Multi-Scale Image Registration Algorithm Based on Morphological Gradient

Changhui Wang[1], Jixiang Zhang[2], Qingfeng Sun[3]

[1, 2, 3]School of Electronic Engineering, Tianjin University of Technology and Education, Tianjin 300222, In China

Abstract: ***Image registration is a key step of image processing technology, which could be used for image processing including pattern recognition, image fusion, computer vision and other practical problems. In this paper, a new image registration algorithm is presented. First, morphological gradient is a method that gets the edge of image by using image edge detection and then try experimenting with combination of Harris corner detection algorithm to get the multi-scale image registration algorithm.***

Keywords: image registration; morphological gradient; corner detection.

1. Introduction

Image registration is the spatial alignment of two or more images of the same target at different time, from different view angles, or different sensor conditions [1]. With the development of science and technology, the technology of image registration plays a more important role in the image processing technology. Therefore, the technology of image registration has long attracted attention of relevant experts, home and abroad, and has been more and more widely used in the many fields.

Image registration method can be categorized into two groups: first, image registration based on pixels, which has many advantages, such as high precision. However, it is sensitive to changes in the image of grayscale and complex calculation. Then, based on the characteristics of the image registration method, which is a key of feature extraction and feature matching. Compared with the former, feature-based image registration method overcomes the shortcomings of the pixel registration, a small amount of calculation, strong adaptability and improve precision.

In a word, image registration is the key of image processing technology, the traditional matching algorithm and multi-scale morphological gradient to get image registration algorithm, more reliable, more efficient and high precision. This paper combined multi-scale morphological gradient with Harris corner detection, which led to the classical of Harris corner detection algorithm with multi-scale feature.

2. Harris Corner Detection

The Harris corner detection algorithm [2] is proposed by Chris Harris and Mike Stephens, which is a kind of feature-points extraction algorithm. The classical of Harris corner detection algorithm based on Moravec's algorithm. Its idea is this, to design the local detection of the window in the image, where measures equally in all directions with the window, and observes the average energy change of the window. When the change of value exceeded the threshold, and extracted as corner points.

We assume the gray value of pixels (x, y) is I(x, y), to shift (u, v) the image of each pixel (x, y) to get the change of gray value E(u,v), auto-correlation function is defined as:

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

Where w(u, v) is a Gaussian filter. The Taylor expansion is:

$$E(u,v) \cong [u,v] M \begin{bmatrix} u \\ v \end{bmatrix}$$

Where the 2×2 symmetric matrix M is

$$M = \begin{bmatrix} A & C \\ C & B \end{bmatrix} = e^{-\frac{x^2+y^2}{2\sigma^2}} \otimes \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix}$$

Where I_x and I_y, denote the gradient of the image along the X and Y directions, respectively.

The auto-correlation function after translation is approximated as a quadratic function, the relationship between the eigenvalues of the quadratic function and the corners, edges, and flats in the image. Three cases can be considered:

1) The edge of the image, one eigenvalue is large and the other is very small, auto-correlation function look like a ridge in general. Then a shift along the ridge direction will result in little change in M, but a shift vertical to the edge will result in a large change, which corresponds to the edge or straight line of the image.
2) The flat of the image, the two eigenvalues are small, then the auto-correlation function is flat, the matrix M in all directions will result in only a small change, corresponding to the plane area of the image.
3) The corners in the image, the two eigenvalues are large, so the auto-correlation is the peak. When the shifts in any direction will cause a large change in M, a corner can thus be detected by finding.

This paper can be used Tr(M) and Det(M) in the formulation, to avoids solving the eigenvalues (λ_1 and λ_2) of M, thus

$$Tr(M) = \lambda_1 + \lambda_2 = A + B$$
$$Det(M) = \lambda_1 \lambda_2 = AB - C^2$$

Use the following function for the Harris corner response:

$$R = Det - k\,Tr^2$$

Where, k is an empirical constant, typically between 0.04 and 0.06. Only when the R value of the pixels in the image is greater than a certain threshold, and in the surrounding eight directions for the local maximum point can be regarded as corner points. The location of the feature points in the image is determined by finding the local extremum of the local response function.

The Harris corner detector is a better corner point extraction algorithm, as its brightness and contrast changes are not sensitive[3], and there is a rotation invariance. However, it is sensitive to noise, for different image resolution, the corner can be easy to produce drift phenomenon. In addition, the classical Harris corner detection operator does not have scale invariance. However, the feature points in the image appear at different scales, and the content of the image in the same detection window are completely different on different scales. Generally, at larger scales, it is better to eliminate false positives and detect true corner points, but it is difficult to locate the exact location of the corners. In the smaller scale, the real corner better positioning, but the false detection rate will increase. Therefore, it is very practical to apply the multi-scale technology, which can reflect the advantages of large scale and small scale.

3. Morphological Gradient Based Multi-scale Image Registration

Mathematical morphology [4] was proposed by G. Matheron and his students J. Serra of Paris, France, in 1964, when engaged in the quantitative analysis of iron ore rock. The essence of mathematical morphological operation is an expression of the interaction between the collection of objects (or shapes) and the structure elements, so as to achieve the purpose of image analysis and recognition [5]. Mathematical morphology has been more and more widely used.

3.1 Multi-scale Morphology Related Theory

There are four basic operations of mathematical morphology: dilation, erosion, opening and closing. Dilation operation and erosion operation are the basis of morphology processing. Dilation is the operation of "lengthening" or "thickening" in binary image, whereas erosion is the operation of "shrinks" or "thins" in binary. In image processing, dilation and erosion are combined to complete a variety of morphological tasks.

In morphological processing, the dilation and erosion operations of morphology considered blow is operations of opening and closing. Opening operation makes the outline of objects smooth, and disconnects narrow discontinuous and erase thin protrusions. Closing operation also makes the contours of smooth, but the difference is that it eliminates discontinuity and connects narrow long thin gap, removes small holes, and fills the contours.

Mathematically, I is dilation by G, written as $I \oplus G$. Otherwise, I is erosion by G, written as $I \ominus G$. Dilation and erosion [6] are defined as set operation, which can be defined as follows:

$$I \oplus G = \max_{(i,j)}[I(x-i, y-j) + G(i,j)]$$

$$I \ominus G = \min_{(i,j)}[I(x+i, y+j) - G(i,j)]$$

Where, I(x, y) is an input image, G(x, y) is a structural element.

Further, the opening and closing operations are defined as follows:

$$I \circ G = (I \ominus G) \oplus G$$
$$I \cdot G = (I \oplus G) \ominus G$$

Morphological gradient [7] is obtained by subtracting, which the dilation of image is subtracted from the erosion of image. It is a measure of the local gray-scale variation in the detected image, and can be expressed as:

$$Grad[I(x)] = (I \oplus G) - (I \ominus G)$$

The value of structural element G is the key of the single-scale morphological gradient operator. If the G is large enough, the output of the gradient operator is equal to the edge height, which will also cause the gradient maximum and edge inconsistency; If the G is too small, the gradient operator will produce a smaller output, however, at this time the gradient operator has a higher resolution. In order to apply the advantages of both large and small structures, this paper proposes an operator based on multi-scale morphological gradients.

Assuming that S_i ($0 \leqslant i \leqslant n$) is a structural element and its is (2i+1) × (2i+1) pixels, the multi-scale gradient is defined as follows:

$$MG(I) = \frac{1}{n} \times \sum_{i=0}^{n}[(I \oplus S_i) - (I \ominus S_i)]$$

In this paper, we use different structural elements to detect the edge of the image, which can detect the edge of the image in every direction as far as possible.

3.2 Image Registration Based on Multi-scale Morphological Gradient

The gray scale dilation and corrosion calculation of the images to be aligned with the reference images were performed with different structural elements to obtain the morphological gradients at each scale. Image edge detection is through the mathematical method to extract the image pixels have a brightness value in the edge of space direction gradient big, line process. In reality, a lot of images to complex image, under the condition of the multi-scale edge detection is more commonly used, test results need to be stable, shall be as accurate as possible in the match. Under the condition of single scale is very difficult to do this, at the same time position is difficult to pinpoint on larger scales. Therefore, this paper proposes a multi-scale analysis to be tested.

Combined with multi-scale morphological gradient and the Harris corner detection, get a kind of multi-scale image registration algorithm based on morphological gradient. The detailed steps are as follows:

1) The gray scale dilation and corrosion calculation of the images to be aligned with the reference images were performed with different structural elements to obtain the morphological gradients at each scale.
2) The morphological gradients at different scales are averaged and further obtained the edge images of the gradient images.
3) In order to avoid the influence of k value selection, this paper adopt modified Harris corner response function:

$$R = (I_x^2 * I_y^2 - I_{xy}^2)/(I_x^2 + I_y^2 + eps)$$

Extracted feature points from the gradient image that obtained in the second step.

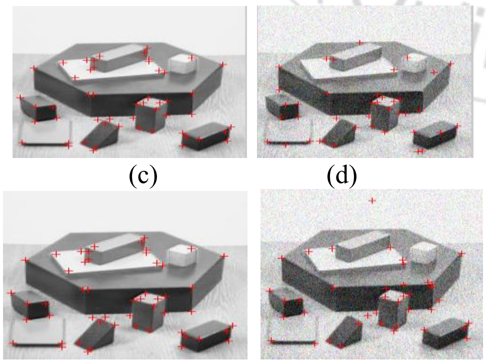
4) Executed the matching point, according to the correlation rule.
5) Random sample and consensus (RANSAC) [8] was used to eliminate the error matching points, and solved the estimated parameters.
6) Select the appropriate image transformation relationship for the two images.

4. Simulation Results and Analysis

In this paper, the Blocks and Lena map are used to analyze the proposed algorithm. Figure 1 shows the original image, where (a) and (b). Figure 2 adopts the proposed algorithm to extract the corner from blocks diagram in the different situations, (c), (e) are the results of the corner detection in different scales. Observation shows that the position and the number of the corner probably same for different scales. It is improves the shortcoming that the tradition Harris corner detection does not have the scale invariance; (d), (f) are better than those of the original algorithm when Gaussian noise (δ=0.01) is added at different scales. At different scale (scale=1, 2), figure 3 Image (g), (h) shows the gradient images at different scale. Figure 4 Image (i), (j) shows the corner images at different scale. Figure 5 Image (k), (l) shows the RANSAC matching images at different scale. Figure 6 shows the matching result of the lena image after rotating and scaled at different scales. Obviously, there is no mismatch in (m), (n), which there is good stability. Then, the matching point pair has high repeatability at different scales.

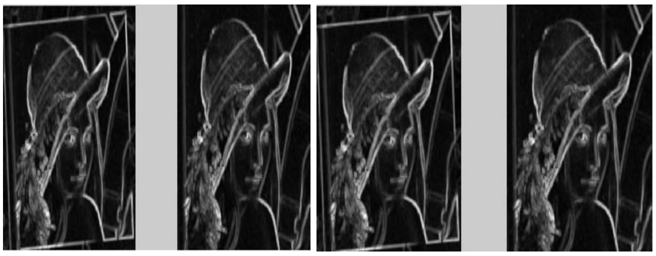
(a) (b)

Figure 1: The original image



(c) (d) (e) (f)

Figure 2: Image (c), (e) shows the corners at different scales(scale =1,2) without adding noise, where(d), (f) add Gaussian noise(δ=0.01) corresponding to (c), (e) when detect corners.



(g) (h)

Figure 3: Image (g), (h) shows the gradient images at different scale (scale = 1,2).

(i) (j)

Figure 4: Image (i), (j) shows the corner images at different scale(scale = 1,2).

(k) (l)

Figure 5: Image (k), (l) shows the RANSAC matching images at different scale(scale = 1,2).

(m) (n)

Figure 6: The match results of the images in different scale (scale = 1, 2).

5. Conclusion

In this paper, to maintain its original advantage, combined with the application of multi-scale morphological gradient in edge extraction, proposed an image registration algorithm based on multi-scale morphological gradient. The research proved that the method has higher accuracy of registration at different scales, higher computing speed and stronger ability of anti-noise increase apparently.

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Author Profile

Changhui Wang received the B.S. degrees from Huanghe Science and Technology College in 2015. Now studying at Department of Electronic Engineering, Tianjin University of Technology and Education.

Jixiang Zhang doctor of engineering, professor, master tutor. The main research direction: sound, image processing and transmission, communication and information systems. Participated in a number of national and provincial and ministerial projects, published more than 20 papers.

Qingfeng Sun received the M.S. degrees from Tianjin University of Technology and Education.