Harris Corner Detection Based on the Multi-scale Topological Feature

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***Abstract*—In order to increase the property of the corner detection, an improved method of harris corner detection based on the multi-scale topological was proposed. This method extracts the angular points on the basis of the topological structure, through which not only narrows the range of the harris corner detection but also reduces the influence of the multi-scales factor. The experiments show that the harris corner detection based on the topological structure is better than the original algorithm with certain scale invariance and noise depression capability.**

***Keyword*—technological structure; corner detection; registration**

I. INTRODUCTION

The image registration is one of the important steps in the image mosaic. With the development of the computer technology, the image registration [1] plays an important role in the area of medicine, remote sensing image, and meteorological cloud and so on. And in the process of image registration, to get the feature structure is very important. Feature space not only determines the speed and robustness of the registration algorithm, but also directly relates to the feature which is sensitivity in the image registration algorithm and which will be matched.

The point feature is one of the image characteristics, in which, the angular point feature is mainly applied. The angular point of the image has a wide range applications in computer vision, pattern recognition and image registration areas. And there have been many algorithms [2-5] taking advantage of the angular point to the image registration. But they mostly have problems below:1 The two point feature sequence requirements have less uninvolved point;2 To solve the model parameters, it is generally to arrange all point matching, and this needs large amount of calculation, such as scene consistency algorithm, clustering algorithm and so on.

In view of the above question, a method which firstly extracted multi-scale images topological characteristics was proposed in this paper, based on which the angular point was detected by using Harris corner detection technology. Finally uses the SVD image registration algorithm to image fusion. In this algorithm the topological feature multiple scales [6] will be brought in. Through this not only the interference of the scale will be avoid but also the computation time and the corner detection range will be reduced.

II. HARRIS CORNER DETECTION TECHNOLOGY AND THE MULTI-SCALE TOPOLOGICAL CHARACTERISTICS OF THE IMAGE

A. Harris corner detection technology

Differentiating operation which could reflect the changes of the gray intensity in any direction of the pixels and autocorrelation matrix to corner detection was used by Harris, through which the angular points can be effectively distinguished from the edge. And the differentiating operator is used to definition the formula of the gray strength changes, which can make the corner detection had the rotation invariant. Meanwhile Harris corner detection algorithm uses Gaussian function as detecting window to smooth filtering then to extract angular points, which to a certain extent can restrain the noise. Its gray intensity changes were expressed as:

$$E_{u,v}(x,y)=\sum_{u,v}W_{u,v}\left[f(x+u,y+v)-f(x,y)\right]^2 = \sum_{u,v}W_{u,v}\left[xX+yY+\Delta(x^2+y^2)\right]^2 \quad (1)$$

In formula the first-order derivative in x direction and y direction is respectively represents by $X=\frac{\partial f}{\partial x}; Y=\frac{\partial f}{\partial y}$.

The algorithm of harris corner detection is summarized as follows:

Step 1: To every pixel, calculate the correlation matrix M.

Step 2: Calculate the harris corner response of every pixel.

Step 3: Seek the point with maximum value in the range of w*w, if the harris corner response of the pixel is bigger than threshold value, then the pixel is the angular points.

Limiting the scope of angular point detection is necessary on the condition that the given image may be large which increased the amount of calculation in the actual extraction process. So the multi-scale topology feature of the image is imported. Firstly, the topological features of the multi-scale image were extracted, based on which the angular points were extracted by Harris corner detection.

A. . The multi-scale topological characteristics of the image

In the scale space, the overall goal structural features and the topological relationships among the elements were

precisely depict in the outline algorithm of the topological reflecting the important visual cue of the target. According to the definition of various topological features, topological characteristics can be got adopting their own mathematical model; such as the border between graphics and background, the block in the target, ridge, corner and so on. The topological feature becomes fuzzy gradually even disappears in certain rules with the increasing the scale factor and the reducing resolution. Under the small scales, it can also say in the high resolution conditions, all the architectural features, some less important characteristics of these will disappear following with the magnifying of the scale factor and the reducing of the resolution ratio. In this paper, the border was chose as the object of the study.

The idea of multi-scale of signals was firstly put forward by Klinge [7]. He divided the image into promoter region recursively which is the prototype of the multi-scale analysis technology in order to form the tree structure. Burt [8] put this thought promotion as sub sampling and smooth to the image, so can form the pyramid structure. This is now the most common form of multi-scale analysis technology--Low-Pass Filter Pyramids. On mathematics, it states:

$$\begin{cases} R(x,y,\sigma) = G(x,y,\sigma) * I(x,y) \\ G(x,y,\sigma) = \dfrac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \end{cases} \quad (2)$$

For the first, the border under multi-scales was extracted. Because the border is composed of the part of gray dramatic changes, while in the differential geometry the direction of gradient is the direction of the most drastic changes. So the maximum along the gradient direction changes corresponding to the image border. It is:

$$\begin{cases} \partial^2 R(x,y,\sigma)/\partial v^2 = 0 \\ \partial^3 R(x,y,\sigma)/\partial v^3 < 0 \end{cases} \quad (3)$$

In the formula, gradient vector of v is $\varphi = \arctan(R_y / R_x)$, the direction operator is $\partial R/\partial v = \{\partial R/\partial x, \partial R/\partial y\} \cdot \{\cos\varphi, \sin\varphi\}$.

In order to extract meaningful border, the boundary was extracted by the algorithm in different scales. All the boundaries which were sorted by their importance in the process of the scale diminishing were tracked by their rules. At last, the more important boundary was selected and the less important was discarded. The important feature of the boundary is depended on its continuity, significant and stability. It is manifested by the sum of its energy changes from it appear to disappear. It states

$$S_i = \int_{\sigma_e}^{\sigma_d} \frac{vol_i(\sigma) - vol(\sigma)}{\mathrm{var}(vol(\sigma))} d\sigma \quad (4)$$

In the formula (4),

$$\begin{cases} \mathrm{var}(vol(\sigma)) = \sqrt{\dfrac{1}{M}\sum_{i=1}^{M}(vol_i(\sigma) - \overline{vol(\sigma)})^2}; \\ vol_i(\sigma) = l_i(\sigma) \cdot cont_i(\sigma); \overline{vol(\sigma)} = \dfrac{1}{M}\sum_{i=1}^{M} vol_i(\sigma) \end{cases}.$$

Among these the length of the boundary was represented by $l_i(\sigma)$ which determined the continuity of the boundary. The contrast between boundary and the surrounding environment is represented by $cont_i(\sigma)$, while certain scale energy is $vol_i(\sigma)$. The energy mean and variance of all boundaries are respectively represented by $\overline{vol(\sigma)}$ and $\mathrm{var}(vol(\sigma))$ under certain scale. M represents the number of border combined. The yardstick of appear and disappear of the border are respectively represented by σ_e and σ_d.

So if the longer and the more length of the border, the longer the life cycle, and the more important the border is. Sort them by their importance and take the most important border by 30%, through which the main border can keep clear. Thus the major border on the basis of which use Harris corner detection to extract the angular points can be got, thus not only the corner detection range will be narrowed, but also the scale factor influence will be reduced. Finally, the singular value decomposition [9] algorithm is used for the image registration.

III. THE SPECIFIC STEPS OF OPTIMIZATION ALGORITHM

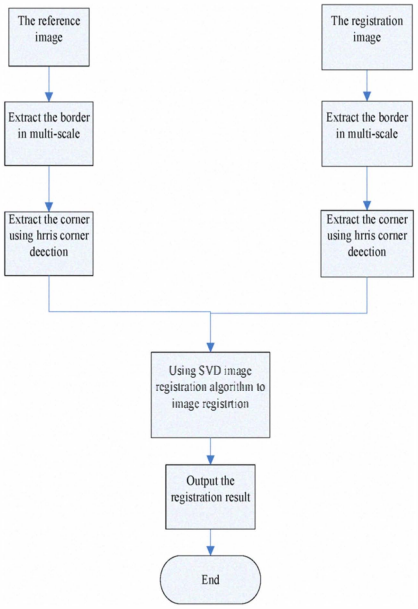
A. *The specific steps*

Step 1: Extract the border in different scales. Assume that $I(x,y)$ represents one image, make $I(x,y)$ and scale factor for σ Gaussian filter for convolution computation. Then calculate the second derivative of the image which has been smoothed. It is given by $\nabla^2[G(x,y,\sigma) * I(x,y)]$.Because the second derivative is linear operation, $\nabla^2[G(x,y,\sigma)] * I(x,y)$ is equal to $\nabla^2[G(x,y,\sigma) * I(x,y)]$. It is firstly to calculate the derivative and then to the convolution.

Step 2: Sort the different scale borders by its energy, and take the border before the 30% as the extraction results.

Step 3: Take the second step obtain image boundary along with images together to Harris corner detection function. Calculate each pixel correlation matrix of the extracted boundary. Then corner response was calculated. Among the $w * w$ range to search the maximum, if the corner is greater than the given threshold corner, shall be regarded as corner. Put its coordinate into a zeros array, marking it with one; Repeat until extract all the borders.

A. *The procedures of optimization algorithm*



IV. THE ANALYSIS OF SIMULATION EXPERIMENT

In order to verify the efficiency of the method, the image of different scales and the image with noise were chosen to do experiment. The table (1) is the result of comparing the improved algorithm with the original algorithm. The Fig. 1 and Fig. 2 show the result got by the two algorithms on the condition that these images are all cut .In the graph, the feature points are marked by red dot.

For further the effectiveness of the algorithm, the result of the algorithm in this paper was compared with the algorithm in another paper [10] and the same data was used. The result is given by the table (2). From the simulation experiments the improved algorithm which was compared with the traditional algorithm and other algorithm, the precision of matching was increased to some extent, and had a certain scale invariance and noise depression capability.

Figure 1. The angular point extracted on topological feature

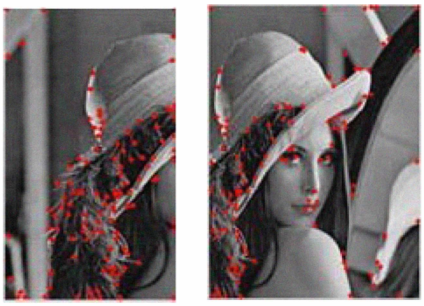


Figure 2. the angular point extracted on the whole image

TABLE I. THE RESULT OF COMPARING THE IMPROVED ALGORITHM WITH THE ORIGINAL ALGORITHM

The way image processed	Algorithm contrast	Couples of corner points	Couples of matched corne points	Registration rate%
Narrow two times	The original algorithm	83	72	0.867
	The improved algorithm	73	70	0.959
Amplification two times	The original algorithm	143	107	0.748
	The improved algorithm	134	121	0.903
Rotating 30 degrees	The original algorithm	143	112	0.783
	The improved algorithm	134	118	0.881
Join noise	The original algorithm	143	109	0.762
	The improved algorithm	134	112	0.835

TABLE II. THE RESULT OF COMPARING THE ALGORITHM IN THIS PAPER WITH THE ALGORITHM IN ANOTHER PAPER

Image	Algorithm	Couples of points	Couples of points	Couples of right matching point	Couples of error matching point	Couples of mismatching points
Original	the algorithm in another paper	65	55	50	5	10
	the algorithm in this paper	65	59	54	5	6
Noise	the algorithm in another paper	46	38	34	4	8
	the algorithm in this paper	46	42	37	5	4

V. CONCLUSION

Through the experiments, the edge of the multi-scale image which was firstly extracted achieved a good effect. After the image edge detection under multi-scales, the harris corner detection only needs to extract the edge rather than the whole image. Such not only the range of the harris corner detection can be narrowed by this method but also the influence of the multi-scales influence of the multi-scale factor will be reduced, through which the algorithm has certain scale invariance and noise suppression capability. This improves the efficiency of the corner registration and will play an important role in the image fusion later.

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