Polarization Image Registration Algorithm Based on Improved SIFT Descriptor

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Abstract. With the application of polarization imaging technology more and more widely the research on how to obtain polarization information quickly and efficiently has always been the focus of people's attention. In view of the numerous edge points generated by DoG (Difference of Gaussian) in the process of feature point extraction by SIFT (Scale-invariant Feature Transform) algorithm, which leads to tedious and time-consuming operation, an improved Sobel algorithm combined with SIFT operator image registration algorithm is proposed in this paper. The concrete implementation steps are as follows: firstly, the traditional two-direction Sobel algorithm is supplemented to eight directions, and then edge points are extracted. Then SIFT algorithm is used to detect feature points. Then, the feature points belonging to edge points are eliminated by Sobel operator. This method reduces the number of matching cycles. The processing results of RGB image and polarization image with this algorithm are compared with those of traditional SIFT algorithm, and the time consumption in the registration process is reduced by 60.5% on the premise of ensuring the accuracy.

1. Introduction
Polarization imaging detection technology [1] emerged as a remote sensing detection method. The polarization image obtained by this technology can obtain the polarization intensity value, polarization degree, polarization rate and other parameters of the detected target, which greatly strengthens the information of the detected target, especially has a very significant effect on the discrimination of different material targets. In Fig. 1, (a) and (b) are respectively comparison graphs of ordinary and polarized images of two iron plates on the grassland under the same environment. It is not difficult to see from the figure that the visibility of the two plates in the polarized image is greatly improved. Due to the continuous development of the research on polarized images, how to improve the processing efficiency has become a hot issue in the research, and the optimization of image registration technology has to be considered in order to improve the efficiency.

Common image registration algorithms [2] include SIFT feature, SURF feature and Harris corner feature. Among them, SIFT algorithm has high stability for noise interference, Angle transformation, illumination mutation and other situations, and has good stability for image rotation and scale transformation. Therefore, the registration algorithm in this paper adopts the SIFT algorithm based on point feature registration.
2. Improved Sobel edge detection algorithm

Edge detection is generally divided into four steps [3]: image filtering, image enhancement, image detection and image location. Common edge detection operators [4] include Sobel operator, Robert operator, Prewitt operator, LOG (Laplace of Gaussian function) operator and canny operator.

Sobel operator is suitable for gray gradient and more noise image, edge positioning is good, the biggest advantage is the algorithm is simple and easy to implement, fast processing speed, suitable for real-time image processing. Roberts’s operator is suitable for low noise image with unsmoothness, but the edge of extraction is wide, so it can’t locate the edge accurately. The application of Prewitt operator is similar to that of Sobel, but the edge is wider and there are more discontinuous places. The LOG operator is easily disturbed by noise and cannot detect the edge direction. Canny operator noise is not too sensitive, the process is cumbersome, and the processing time is longer than other detection methods, which is not conducive to real-time image processing. Considering the real-time requirements of image processing in this study, it is decided to adopt Sobel operator as the edge detection method.

Although the Sobel operator [5] is simple and fast, has good anti-noise performance, and the detected edge has strong directivity. However, traditional Sobel operator template only considers two directions (Gx, Gy) to obtain image edges, and only horizontal and vertical image edges are detected. To solve this problem, 8-direction Sobel operator is adopted. Concrete implementation method for detecting the template extension direction of edge to edge direction 0°, 45° and 90° direction of the edge direction, 180°, 135°, 225° and 315°, 270° edge direction edge direction edge direction, a total of eight direction. The eight direction detection templates are shown in formula 1:

\[
\begin{align*}
G_0 & = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \\
G_{45} & = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \\
G_{90} & = \begin{bmatrix} -2 & -1 & 0 \\ 0 & 1 & 0 \\ -2 & -1 & 0 \end{bmatrix} \\
G_{135} & = \begin{bmatrix} 2 & 1 & 0 \\ 1 & 0 & -1 \\ 2 & 1 & 0 \end{bmatrix} \\
G_{225} & = \begin{bmatrix} -1 & 0 & -2 \\ -2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} \\
G_{315} & = \begin{bmatrix} 0 & -1 & 2 \\ -2 & 0 & -1 \\ 0 & -1 & 2 \end{bmatrix}
\end{align*}
\]  

(1)

Figure 2 shows the results of two kinds of edge detection on Lena images. Scale the processing image to prevent the overflow of the grayscale value. The gray gradient values in eight directions are obtained by this method to make the image edges smoother. Where, figure (a) is the image to be processed. Figure (b) is the image processed by traditional Sobel algorithm. Figure (c) is the image processed by eight-direction Sobel algorithm. The traditional Sobel algorithm can extract images with lower sharpness and more discontinuous edges. The edge extracted by the improved Sobel algorithm is clearer and smoother, especially the details of the decorations on Lena hats are more detailed and the detection results are more accurate.
3. Improved feature extraction algorithm with SIFT

Feature extraction [6] is a crucial step before image registration. Only when the edge features are extracted, can the image be accurately positioned, so that the two images can be processed for registration. The improvement of edge detection method in the previous section makes the location of edge points clearer and more accurate. This section will introduce the traditional SIFT feature extraction algorithm, improve it with Sobel algorithm, and process the polarization images taken to verify the correctness of this algorithm research.

3.1. SIFT registration principle

SIFT algorithm [7] is a computer vision algorithm used to detect and describe the regional features of images. It can obtain the information of extreme points and their position, scale and rotation invariants in the spatial scale. This algorithm was proposed by David Lowe in 1999 and supplemented in 2004. The algorithm is characterized by large amount of information, high operation rate and high stability. It is divided into four stages: extreme value detection in scale space, location of key points, determination of direction of key points, and description of key points.

Since SIFT algorithm finds key points in different scale spaces, it needs scaling transformation to obtain different scale spaces, and gaussian convolution kernel is the only available linear kernel. Gaussian blur the gaussian blur template is calculated by the gaussian function, which is convolved with the original image to blur the image so as to reduce the noise in the image. Equation 2 is the calculation formula of gaussian template.

\[
G(x, y, \sigma) = \frac{1}{2\pi\sigma^2} e^{-\frac{(x-m)^2+(y-n)^2}{2\sigma^2}}
\]  

(2)

The scale space \(L(x, y, \sigma)\) of an image is represented by the convolution of the gaussian function \(G(x, y, \sigma)\) of a scale transformation with the original image \(I(x, y)\). The equation is as follows:

\[
L(x, y, \sigma) = G(x, y, \sigma) * I(x, y)
\]  

(3)

In the above two formulas, \((x, y)\) represents the coordinate of the element on the template, namely the scale coordinate. The size of two-dimensional template is \(m \times n\). \(\sigma\) is the scale factor. Different scales correspond to different features of the image. The larger \(\sigma\) the scale is, the lower the resolution will be. The smaller \(\sigma\) the image is, the higher the resolution is, corresponding to the detailed features of the image.

In order to ensure the stability of the key points obtained, the difference operation of adjacent scale space is required, namely gaussian difference operation. As shown in equation 4:

\[
D(x, y, \sigma) = (G(x, y, k\sigma) - G(x, y, \sigma)) * I(x, y)
\]

\[
= L(x, y, k\sigma) - L(x, y, \sigma)
\]  

(4)

The key points are composed of local extremum points in gaussian difference scale space and are compared between adjacent images in each gaussian difference scale space in the same group. In order
to find the extreme point of gaussian difference function, every pixel point should be compared with all its neighboring points to determine whether the neighboring points of its image domain and scale domain are larger or smaller.

Gaussian difference operator can generate strong edge response when detecting feature points. In order to enhance the stability of matching, Taylor series curve fitting and lyson matrix are first used to remove the corresponding points of unstable edges, but some edge points are still not removed. This is the main content of this paper. That is, pseudo points in feature points extracted by SIFT algorithm are removed.

3.2. Improved registration principle of SIFT algorithm

Although in the last section is introduced to remove pseudo point due to gaussian difference operator method, but does not get rid of a pseudo point all the retained portion of the pseudo point will continue to take part in the late of feature points matching calculation, time cost is larger, so the Sobel operator is used to remove the edge points in the SIFT feature points, in order to reduce the algorithm redundancy. The algorithm consists of the following four steps:

1) The improved Sobel operator is used to detect the edge of the image to be processed, and the set of feature points is obtained.
2) The traditional SIFT operator is used to detect the image to be processed and the set of feature points is obtained.
3) Calculate the neighborhood coordinates and get the set.
4) The set is compared with the set, and the feature points with the same coordinate are removed, so as to finally obtain the SIFT feature points.

3.3. Experimental results and analysis

In order to verify the effectiveness of the algorithm in this study, feature registration experiments were conducted on two sets of RGB images of the same scene from different angles. First, the experimental images were preprocessed, and then the two registration algorithms were applied to the same group of images. The Fig.3 shows the effect of different registration methods. Where, figure (a) and figure (c) are the registration renderings of the SIFT algorithm improved on the experimental images. Figure (b) and figure (d) are the traditional SIFT algorithm registration renderings of the experimental images.

![Figure 3. Shows the registration effect comparison between the improved SIFT algorithm and the traditional SIFT algorithm](image)

It can be clearly seen from the figure that the location of feature points detected by the improved algorithm is more accurate, and the number of useless edge points detected is also greatly reduced, and the error rate is also reduced in the registration process. Then, on the premise of ensuring the registration accuracy, the algorithm proposed in this paper also improves the registration speed compared with the
traditional SIFT algorithm through experiments. The accuracy and time statistical pairs of feature point matching of the above two groups of experimental images were obtained by using two methods, as shown in Table 1 and Table 2. In order to facilitate the labeling, the left and right images in the (a) group were labeled as (a) left, (a) right, and the other images were labeled in the same way.

Table 1. The accuracy and time statistics of feature point matching of the improved SIFT algorithm

| Number of Feature Points | Feature Points | Correct Matching Point | Matching Accuracy/ % | Time/s |
|--------------------------|----------------|------------------------|----------------------|--------|
| (a) left                 | 144            | 96                     | 87.5                 | 2.02   |
| (a) right                | 117            |                        |                      |        |
| (c) left                 | 1103           | 134                    | 88.1                 | 11.24  |
| (c) right                | 1271           |                        |                      |        |

Table 2. Traditional SIFT algorithm feature point matching accuracy and time statistics

| Number of Feature Points | Feature Points | Correct Matching Point | Matching Accuracy/ % | Time/s |
|--------------------------|----------------|------------------------|----------------------|--------|
| (b) left                 | 345            | 131                    | 83.21                | 4.77   |
| (d) right                | 301            |                        |                      |        |
| (b) left                 | 2298           | 489                    | 79.75                | 30.66  |
| (d) right                | 2587           |                        |                      |        |

As can be seen from the table, the improved SIFT algorithm has improved the registration rate and processing speed of feature point matching. Under the premise of ensuring the registration rate, the algorithm proposed in this paper reduces the time consumption of the feature registration process by 60.5% compared with the traditional.

SIFT algorithm. In order to prove that this algorithm can be used for the registration of polarized images, four polarized images of the same scene from different angles were selected for verification. The images used in the experiment, shown as Fig.4, were all urban images taken by the polarizing camera used in the project 973 of the laboratory. (a) is the reference image, (b), (c) and (d) are the image to be registered, and (e), (f) and (g) are the corresponding registration images processed by the algorithm in this study.

Figure 4. Three groups of registration results

It can be seen from the image that the improved algorithm also has a good effect on the polarization image processing, and the processing speed is also significantly improved under the premise of ensuring the accuracy. The feasibility of the algorithm is further verified.
4. Summary

Aiming at the slow matching speed of SIFT algorithm, this paper proposes a fast image registration method combining Sobel algorithm and SIFT operator. This method firstly aims at the problem that traditional Sobel algorithm can only extract the edge points in two directions, and then it is improved to detect the edge points in eight directions. Then, aiming at the problem that too many edge points in the feature points detected by the traditional SIFT algorithm affect the processing speed, the improved Sobel and SIFT algorithm are combined to eliminate redundant edge points and further improve the processing speed. Experiments on RGB image and polarization image show that the improved algorithm has a significant improvement in processing speed. Although the accuracy of the improved Sobel operator edge detection has been improved, since the edge contour of Sobel operator is fuzzy, how to accurately locate the edge contour is the next problem to be solved.

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