SIFT Feature Image Stitching Based on Improved Cuckoo Algorithm

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Abstract. Traditional image stitching method based on SIFT algorithm that the stitching time is long and the efficiency is low, and the stitching effect is not ideal. In this paper, the location of the parasitic nest in the cuckoo algorithm is mutated, and an evolutionary reduction function is proposed for the step factor and the probability of discovery. On the basis of this, an improved cuckoo algorithm is proposed, and the edge points of the image are solved by this algorithm, and the comparison between the edge points of the image and the feature points in the SIFT algorithm is made. The results show that the time of image stitching is obviously reduced and the speed and quality of the splicing are improved obviously, and it can fully meet the needs of practical application.

1. Introduction
The current image stitching [1] has become an important research direction in digital image processing, which can remove overlapping portions between two or more images, reduce data redundancy, and improve image storage efficiency. In the field of computer vision, images Splicing, especially color image stitching [2] plays an important role in the restoration and reconstruction of visual scenes. In computer graphics, it is also important in image-based rendering, while image stitching is in fine image integration, enhancement or virtual reality. Panoramic image generation, geological exploration, medical images and other aspects play an increasingly important role. Image stitching includes image preprocessing [3], image registration [4] and image fusion [5]. The most important ones are image registration and image fusion. Different image rotation and translation can be performed by image registration [6]. A series of images of parameters are transformed into the same coordinate system by transforming the model. Image fusion [7] combines the pixels between different source images into pixels on the same image, realizing a natural transition between a series of adjacent source images. The spliced image has little difference from the source image, the distortion amplitude is small, the detail is well preserved, the splicing line is not obvious, and the wide-angle image is generally suitable for human natural beauty, which makes up for the shortcomings of the panoramic camera.

In image stitching, the effect of image registration on image stitching is very important. The development of image registration is combined from the earliest regional pixels to multi-feature,
multi-frequency domain and multi-scale technology. The speed and precision of image stitching are also significantly improved. Among them, the local invariant eigen operator image registration algorithm proposed in [8] is the most typical. The operator proposes a stable matching ability for horizontal movement, rotation, scaling and affine-based scale transformation between two images in the image pair. In order to improve the speed and efficiency of image stitching, an improved cuckoo algorithm is used to find the edge points of the image, and then the edge point determined by the improved cuckoo algorithm is taken as the center, and a 5×5 neighborhood is taken. The final image registration feature points are selected by comparing the points in the neighborhood with the feature points proposed based on the SIFT features.

2. Improve the principle of image edge detection of cuckoo algorithm

According to the definition of Tsallis entropy [9], this paper deeply studies the theory of Tsallis entropy. After many experiments, CS algorithm [10] [11] is applied to color image edge detection. When CS algorithm performs color image edge detection, Tsallis entropy is used as the fitness function, and the maximum Tsallis entropy corresponding threshold is the optimal threshold in edge point detection.

2.1. Cuckoo Optimization Algorithm

The Cuckoo algorithm is a meta-heuristic search algorithm with strong optimization ability proposed by Yang and Deb in 2009. Compared with other classical group intelligence algorithms such as particle swarm optimization, artificial bee colony algorithm, genetic algorithm, and cuckoo, the cuckoo algorithm uses the Levi’s flight mode to search randomly, so it has its own unique advantages in the ability to search, and the cuckoo algorithm has the following three rules:

1. The cuckoo can only produce one egg for a certain period of time, and the eggs are randomly placed in the parasitic nest.
2. Only the selected optimal parasitic nest can be delivered.
3. The number of parasitic nests is a fixed value, so that the probability of the parasitic nest owner finding the egg is \( q_a \in [0,1] \). The position of the cuckoo changes as in formula (1):

\[
D_{i+1} = D_i + s_t \oplus R(\lambda) \quad i=1,2,...,n
\]

In the above formula, \( D_i \) represents the position of the i-th bird's nest in the t-th generation, st is the step variable, \( R(\lambda) \) is the Levi flight path, and \( R(t^\alpha) (1 < t^\alpha \leq 3) \).

2.2. Improvement of Cuckoo Optimization Algorithm

When the parasitic nest owner discovers the alien bird eggs, it is necessary to re-create a new bird nest. In order to facilitate the expansion of the diversity of the cuckoo search algorithm population and improve its search ability, prevent the local convergence of the cuckoo search algorithm and improve the global convergence ability, use the method of mutating the parasitic nest position to create a new mutated nest, and the position of this mutated nest i is as in formula (2):

\[
D_{i} = D_{i} + r_1 (D_{k} - D_{j} + \gamma) + r_2 (D_{j} - D_{k})
\]

\( D_{k} \) represents the current optimal nest position, \( D_{k} \) and \( D_{j} \) are randomly selected nests, \( k \neq j \), \( r_1 \in [-1,1] \), \( r_2 \in [0,1.5] \), and \( r_1, r_2 \) are random numbers.

Literature [12] shows that because the cuckoo algorithm uses Levi's flight mode for search optimization, its search not only randomly jumps from one region to another but also the step size and direction are random, so the fixed step factor \( s_r \) and Discovery probability \( q_a \) is advantageous in the early search for the global optimal solution. However, in the later period, after repeated iterations by the cuckoo algorithm, it has approached the global optimal solution. At this time, the larger jump of
the Levi flight mode will lead to the neglect of the local optimal information, and the fixed step factor and discovery probability affects the speed and accuracy of the search. Therefore, as the number of iterations increases, dynamically adjusting the non-decreasing step factor and the discovery probability will significantly improve the global optimal search ability of the cuckoo algorithm.

After many experiments, this paper proposes a set of nonlinear decreasing functions for the step factor and the discovery probability, such as formula (3) and formula (4):

\[ q_i = q_{\text{min}} + (q_{\text{max}} - q_{\text{min}}) \times (1 - \frac{i}{S})^3 \]  

\[ s_{r,i} = s_{r_{\text{min}}} + (s_{r_{\text{max}}} - s_{r_{\text{min}}}) \exp\left(\frac{1}{(1 + \frac{i}{S})^3}\right) \]  

In the above formula, \( q_i, q_{\text{min}}, \) and \( q_{\text{max}} \) represent the discovery probability, the minimum discovery probability, and the maximum discovery probability, respectively, \( i, S \) represent the current and total number of iterations, \( s_{r,i} \) represents the current step factor, \( s_{r_{\text{min}}} \) represents the minimum step factor, and \( s_{r_{\text{max}}} \) represents the longest step factor.

In this paper, the cuckoo algorithm is used to detect the edge of the color image, and the cuckoo algorithm is improved. The condition of the end loop is changed to the value of the first N fitness function is greater than the set threshold. At this time, the cuckoo algorithm is used in color image edge detection. Instead of converge to a global optimal solution, N local optimal solutions are obtained. These N local optimal solutions actually correspond to N image edge points.

Based on the obtained N color image edge points, the cuckoo algorithm continues to search for points with similar fitness function values in the obtained N local edge point neighborhoods, and cyclically searches, and finally all the obtained points constitute the color image edges.

3. Improved SIFT algorithm proposed in this paper

The literature [13] shows that in the feature points extracted by the SIFT algorithm, the non-edge region feature points are prone to false matching due to low contrast and relatively weak gradient information, while the SIFT algorithm extracts more feature points. The time effect of the entire SIFT-based image stitching algorithm is relatively large. Therefore, in the SIFT algorithm, the feature points in the edge region can be mainly considered.

(1) The feature point set A1 of the image is obtained by the SIFT algorithm.
(2) Find the image edge point set A2 by the improved cuckoo algorithm.
(3) Centering on each point of the A2 point set, take the point within the neighborhood 5×5 as the neighborhood point set A3.
(4) Compare the points of the A1 point set with the points of the A2 and A3 point sets. If there are the same points, the same points are eliminated.
(5) The point after the set A1-A2-A3 is the feature point sought.
(6) Image feature matching is performed with this feature point.

4. Experimental results and analysis

This experiment uses Windows7 as the system platform, CPU frequency is 3.1GHZ, quad core, internal memory capacity is 4GB, graphics memory capacity is Direct X 2GB, and multiple color images are used in the experiment, its size is 640*480, and Vs2010+ Opencv2.4.8 is the experimental platform. In this experiment, the standard SIFT algorithm is used, the literature [14] is abbreviated as BSIFT, the literature [15] is abbreviated as HSIFT, and the improved algorithm proposed in this paper is abbreviated as ISIFT. The experiment includes three aspects: the number of feature points before and after the improvement of the algorithm and the extraction time ratio of the feature points, the total
number of feature point matching pairs and the number of incorrect matching pairs, match accuracy and match time ratio.

In the experiment of the number of feature points and the extraction time ratio before and after the algorithm is improved, the partial maps used are shown in Fig.1a, Fig.1b and Fig.1c:

![Fig. 1a](image1a.png) ![Fig. 1b](image1b.png) ![Fig. 1c](image1c.png)

**Fig. 1** The original images in the comparison experiment of extracting feature points

In this experiment, the SIFT algorithm and the improved SIFT algorithm are used to extract the feature points respectively. The experimental results are shown in Table 1:

| Image Feature Points | Run Time (/ms) | Time ratio before and after the algorithm is improved |
|----------------------|----------------|-------------------------------------------------------|
| Fig.1a before improvement | 1182            | 3339                                                 | 59.75% |
| Fig.1a after improvement | 595             | 1995                                                 |       |
| Fig.1b before improvement | 1057            | 2981                                                 | 63.03% |
| Fig.1b after improvement | 536             | 1879                                                 |       |
| Fig.1c before improvement | 1102            | 3129                                                 | 55.03% |
| Fig.1c after improvement | 523             | 1722                                                 |       |

Table 1. Comparison of the number and time of extraction of feature points before and after the algorithm is improved

It can be seen from Table 1 that the improved SIFT algorithm not only reduces the number of feature points, but also significantly reduces the running time, which greatly reduces the data redundancy. To improve the effectiveness of algorithm matching, choose Fig.1a, Fig.1b and Fig. 1b, Fig.1c are used as the first group and the second group respectively, and Fig. 2a , Fig.2b are used as the third group. The image matching logarithm comparison of the three groups is performed by SIFT algorithm and improved SIFT algorithm (ISIFT). The experiment was carried out 10 times in total, and Table 2 is the average data of 10 experiments.

![Fig.2 a](image2a.png) ![Fig.2 b](image2b.png) ![Fig.2 c](image2c.png)

**Fig.2** Material map for image matching and stitching
Table 2. Comparison of the results before and after the feature matching logarithm

| Number of groups | Number of matching pairs (before/after improvement) | Number of incorrect match pairs |
|------------------|------------------------------------------------------|--------------------------------|
| First group      | 213/16                                               | 16                             |
|                  | 107/3                                                | 3                              |
| Second Group     | 195/16                                               | 16                             |
|                  | 103/5                                                | 5                              |
| The third group  | 201/17                                               | 17                             |
|                  | 99/4                                                 | 4                              |

The experimental data in Table 2 shows that the image feature point matching is performed by the improved algorithm (ISIFT) proposed in this paper, compared with the image feature point matching using the ISIFT algorithm.

From the total number of matching pairs and the number of mismatches, both are significantly reduced, so the improved SIFT algorithm (ISIFT) can reduce the number of redundant feature points and reduce the number of mismatched pairs in non-edge areas. In order to further prove the advantages of the ISIFT algorithm proposed in the paper in image feature matching accuracy and matching time, this paper compares the accuracy and time of the four algorithms on the first three sets of graphs, and selects four experimental results. The experimental data is shown in Table 3.

Table 3. Comparison of matching accuracy and matching time for four algorithms on three sets of Graphs

| Experiment algorithm | Accuracy and time of matching | Experiment 1 | Experiment 2 | Experiment 3 | Experiment 4 |
|----------------------|-------------------------------|--------------|--------------|--------------|--------------|
| SIFT                 | Matching accuracy %          | 81.23        | 73.42        | 80.85        | 81.24        |
|                      | Matching time /S             | 6.26         | 5.49         | 7.13         | 6.61         |
| BSIFT                | Matching accuracy %          | 86.42        | 78.98        | 85.54        | 85.3         |
|                      | Matching time /S             | 4.24         | 4.87         | 5.63         | 4.78         |
| HSIFT                | Matching accuracy %          | 92.34        | 86.26        | 90.13        | 92.63        |
|                      | Matching time /S             | 3.91         | 4.10         | 4.39         | 4.23         |
| ISIFT                | Matching accuracy %          | 95.34        | 94.93        | 96.29        | 97.1         |
|                      | Matching time /S             | 3.78         | 4.16         | 4.15         | 4.02         |

From the previous four experiments, the ISIFT algorithm proposed in this paper is the highest in matching accuracy and matching time, while the matching accuracy and matching time of HSIFT algorithm is better than BSIFT and SIFT, and BSIFT is better than SIFT. In order to prove the experimental effect of the algorithm image stitching proposed in this paper, the experiment uses the ISIFT algorithm proposed in Fig.2 to carry out the image stitching experiment. The stitching result is shown in Fig. 3. It is quite satisfactory, so the improved SIFT algorithm proposed in this paper is effective both in terms of matching accuracy, matching time and stitching effect, and can be used in practice.
5. Conclusion
In order to improve the speed and accuracy of image stitching, this paper improves the traditional cuckoo algorithm and proposes an improved cuckoo algorithm.

Centering on the edge points obtained by the improved cuckoo algorithm, each field takes $5 \times 5$, and the points in this neighborhood are compared with the traditional SIFT feature points and the final reduced image registration feature points are selected.

Image registration with these streamlined image feature points,

Finally, the image is spliced. Compared with the image splicing experiment based on the standard SIFT algorithm, BSIFF algorithm and HSIFF algorithm, the experimental results show that the SIFT image splicing algorithm based on the improved cuckoo algorithm is effective in the subjective effect of image splicing. The accuracy of image stitching is significantly improved, and the time for image stitching is also significantly reduced.

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