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Segmentation Algorithm of Handwritten Adhesive Characters based on Improved Recognition Feedback

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Abstract

Handwritten mathematical characters are widely used in daily life, but handwritten characters adhere to each other, which is not conducive to character recognition. In view of the deficiency of the traditional recognition feedback algorithm for offline adhesive character segmentation, combined with the secondary point search algorithm, an adhesion segmentation algorithm based on improved recognition feedback is proposed. First of all, the minimum circumscribed rectangle of adhesive characters is cut out by connected domain analysis, the number of adhesive characters is calculated, and then the possible adhesion parts are marked by the decision method. then the segmentation region is selected according to the adhesion distribution feature screening rules, and finally the missegmentation is modified by the recognition feedback method to determine the final segmentation point. In order to verify the feasibility of this method in the segmentation of adhesive characters, this paper uses 189 adhesion symbols in the chrome character set to test. The experimental results show that this method not only improves the recognition efficiency, but also the accuracy of adhesive character segmentation can reach 88.35%.

Keywords

Adhesion Mathematical Character Segmentation; Projection Method; Recognition Feedback; Connected Domain Analysis; Marking.

1. Introduction

Mathematical formulas are widely used in life and play an important role, and the mathematical formulas of handwriting are everywhere, but at this stage, the slicing algorithm is mostly for the slicing of printed mathematical characters or the slicing of Chinese characters. For offline handwriting mathematical formulas, there are fewer slicing algorithms, and more stay on mathematical character recognition. The mathematical formula itself has a complex structure, there are semi-enclosing structures, upper and lower structures, nested structures, etc., such as $\sqrt{x}$, x/y, $\sqrt{2}/3$, etc., the changes in characters are also diverse, resulting in different positions of adhesion, which are roughly divided into horizontal adhesion, vertical adhesion, diagonal adhesion. Considering that everyone's writing habits are different, the position of the adhesion area is more complicated, the number of adhesions is not easy to determine, there may be two characters sticking, there may be multiple characters. Offline handwritten character splitting is a challenging task.

Character slicing is the separation of each number, punctuation, and English letter in a character image. Character slicing is a prerequisite for character recognition, and only the accurate slicing of characters can fully identify the image content. Common handwritten formula splitting methods include projection method and connected domain method, the principle of the two is not the same, but the function is to split the unaddressed image, and the effect of splitting the glued character is not satisfactory. The histogram projection division method proposed by Y.lu[1] is one of the earliest widely used splitting methods, which is mainly suitable for the splitting of printed Chinese characters

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and neatly written handwritten Chinese characters. R.G. Casey[2] proposed a connectivity domain analysis method based on the pixel tracking method, which completes the chinese character segmentation by tracking strokes, which cannot complete the slicing of the adhesive Chinese characters. In addition, a Chinese character splitting method based on neural network recognizers is also mentioned in the article. Guo Rongrong et al. [3] proposed the use of deep learning Faster R-CNN network to segment mathematical symbols, which can significantly improve the cleavage of sticking symbols, and the segmentation is not ideal because of its variability when dividing horizontal adhesion symbols. Luo Jia [4] proposed a fast slicing method for adhesion Of English letters, which has a good effect on the slicing of English strings, especially for the adhesion of English strings. Liu Yangxing[5] proposed an adhesion lap character slicing algorithm based on polyline splitting path, which introduced penalty weights and recognition feedback to further improve the slicing effect of printed English and Japanese, but the splitting effect of the mathematical recognition formula for handwriting was not very obvious. Wu Yue et al. [6] proposed a quadratic point-finding algorithm for the slicing of adhesion Chinese characters, which first determined the possible candidate points for the adhesion of the adhesion Chinese characters, and then combined the refined stroke feature points and the distribution of the strokes to finally determine the cleavage points, which is suitable for the slicing of non-overlapping adhesion Chinese characters.

Through the analysis of the existing handwriting adhesion mathematical symbol splitting method, it is found that there are certain defects. Therefore, through the analysis of the slicing algorithms of the adhesion Chinese, English and mathematical characters of the predecessors, combined with the adhesion characteristics of the handwritten mathematical characters, this paper proposes a slicing algorithm that identifies and feedbacks the marking and splitting of the adhesion parts. After experimental verification, the algorithm has a good splitting effect on the adhesion number symbol of the handwritten body. The focus of this paper is to explore the precise positioning of the adhesion part of the handwriting body, which is studied as a mathematical symbol of the handwriting adhesion.

2. Basic Slicing Algorithm

2.1 Projection Splitting Algorithm

Projection method [7] is a commonly used and basic character splitting algorithm, projection algorithm is generally divided into vertical and horizontal two projection directions, the principle is to determine in turn whether the pixel value of each column (or row) is non-zero, and count the number of all black pixels in the row (or column). If the row (or column) has M black pixels, the row (or column) is black from the first column (or row) to the M column (or row). If the characters are not glued, the column (or row) is projected blank, that is, the numeric value is zero.

2.2 Connected Area Tagging Algorithm

Connected area tagging [8] is also a common image processing method, which marks the target pixels in the binaryized image so that each individual area is recognized as a separate block, and then further takes its contour, area and other characteristics. The definition of the connected area is generally divided into two types: 4 connected and 8 connected, and the connected area is a collection of pixels composed of adjacent pixels with the same pixel value. There are many kinds of connectivity analysis methods, commonly used methods are two-pass method and Seed-Filling seed filling method. This method is ideal for non-adhesive character slicing, but it is not possible to split glued characters.

2.3 Identify Feedback Algorithms

In order to improve the accuracy of the character splitting effect, a technique of splitting stickers based on recognition feedback [9] is proposed. In order to improve the cutting efficiency and avoid blind cutting, the current slicing result is identified and fed back to determine whether the slicing is correct, if it cannot be identified, it is judged that the slitting error is broken, and it is necessary to re-cut until the identification result is found. This is done repeatedly between identification and splitting. However, based on statistical methods, the amount of recognition is large, resulting in low slicing

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efficiency, and the error of the recognizer will also produce a wrong splitting path, more importantly, recognition can only be split on the character, can not identify and determine whether it is part of the split character, the reliability is not high.

The method based on recognition needs to build a recognizer to determine the split path of the character, the most important thing is the construction of the set of split paths, there are many ways to construct the set of split paths, such as the method of vertical slicing and the splitting of the connected domain mentioned above, and the method of traversing the characteristic values of the characters mentioned above, but the selection of the eigenvalues is more cumbersome, due to the different styles of handwriting, the eigenvalues are also very different, making the extracted eigenvalues more cumbersome; secondly, the method of slicing path collection construction is the dripping method of splitting, It does a good job of splitting images for simple structures, but not very well for structurally variable handwritten mathematical symbols. This method relies too much on recognizer robustness, is time-consuming, and cannot be recognized in real time [10].

3. Improved Recognition Feedback Algorithm

It has been observed that there are many kinds of stickers and sticky areas, but when the adhesions occur, they all produce specific intersections. Morphological methods are used to mark these specific crosses, but the characters themselves also have pixels that meet the conditions of cross feature points, resulting in the generation of false cut points, so it is necessary to screen the cut points, and then give weights to different cut points according to the position relationship between the cut points and the characters, and select the cut points with high weights. In order to prevent the occurrence of false splitting, this paper introduces the recognition feedback module to correct the secondary cutting point.

There are many non-adhesion mathematical symbols in the handwritten mathematical formulas that can be separated into a single connected domain using the method of connected domain analysis, and it is difficult to find the ideal cut point for the above method of sticking hyphenation. Due to the different handwriting habits of characters, there is a mis-cutting of characters, which will lead to a decrease in the recognition effect in later stages. If the image to be sliced is treated uniformly with glued characters, this will not only waste the cutting time, but also may be over-segmented. Conversely, if the image to be sliced is all treated as unaddressed, it will have an impact on the recognition characters later.

In order to solve the above situation of incomplete adhesion in the image to be cut, well slicing to identify the image to be cut, this paper proposes to improve the recognition feedback algorithm, the flowchart is shown in Figure 1, the method is divided into three steps: the first step is coarse slicing, due to the interference of the image to be cut, the image preprocessing needs to be preprocessed, that is, the coarse slicing contains image binarization, tilt correction, row and column slicing several steps; The second step is fine cutting, which is also the focus of the article introduction, which is the improvement part of the article's recognition feedback, including the number recognition module of the number of sticky hyphens, the module of the adhesive area marking, and the module of cross-feature point screening. The third part identifies the feedback, and the above-mentioned cut points may appear excessive cut points that need to be further modified and determined by identifying the feedback for the cut points.

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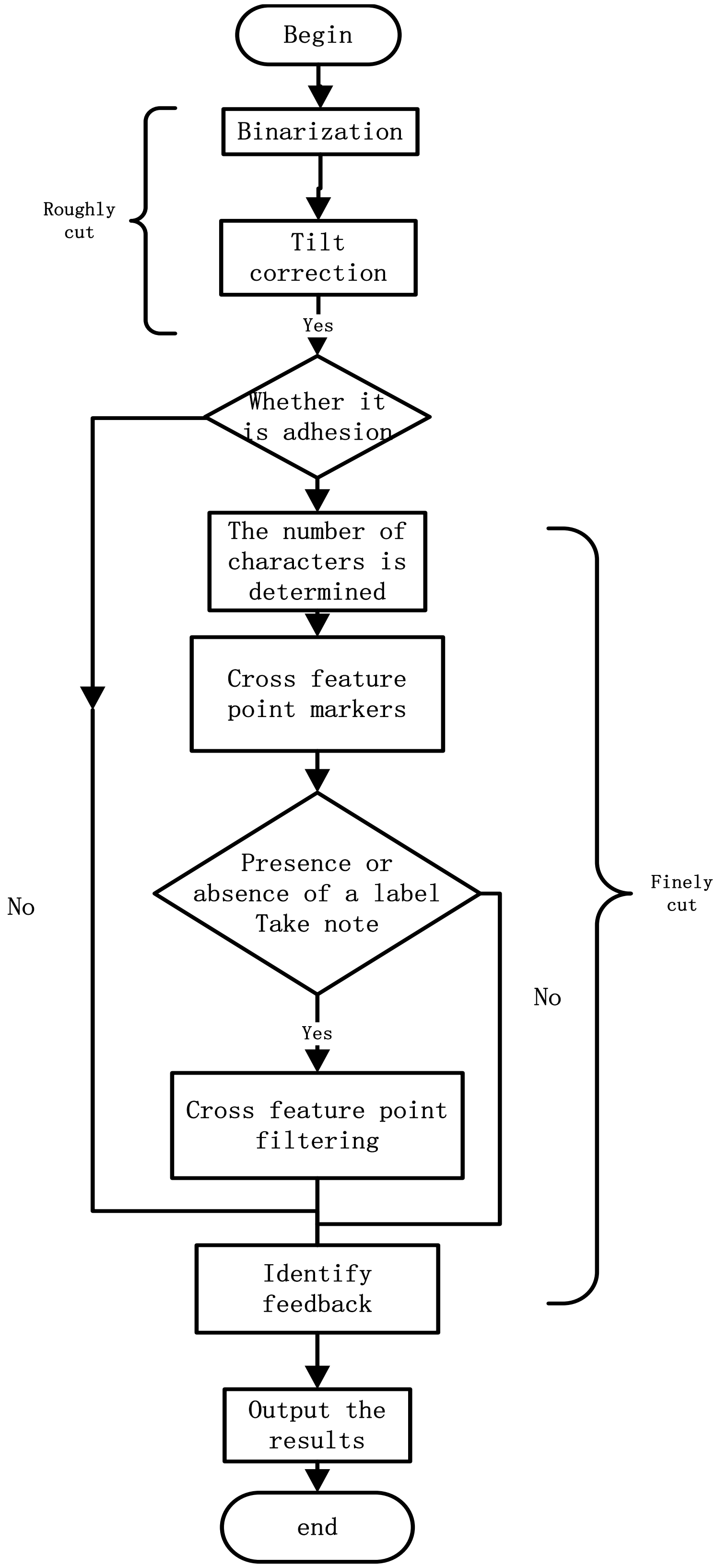

Figure 1. Flow chart of improved recognition algorithm

3.1 Roughly Cut

For the image to be processed first pre-processing work, first of all, the image is grayscaled, binary, because the writing is not standardized formula will be tilted, so it is necessary to correct the binary image tilt, the corrected image is convenient for the projection of the later image, the corrected image is divided into connected domains, and the rough cutting result is obtained.

3.2 Finely Cut

After analyzing the image in the connected domain, the number of characters is determined first, and whether there is adhesion is determined according to the number of characters, if there is adhesion, it needs to be finely cut, and if not, it is directly into the recognition feedback link.

3.2.1 Determination of the Number of Characters

After the connected domain is split, the pictures are all single connected domains, and the method used in this article is to determine the number of characters according to the number of seeds, as follows:

First do the open operation and the closed operation of the single connected domain image to be split, as shown in Figure 2, the adhesion image to be split, and then the distance transformation process is done on the changed image, and the result is shown in Figure 3. The basic meaning of the distance transformation [11] is to calculate the distance from the non-zero pixel point in an image to the nearest zero pixel point, that is, the shortest distance L(i) from the pixel to the point where the pixel value is zero, and then according to the distance value of each pixel point, compared with the given threshold, the pixel value greater than the threshold is retained, that is, the seed of the single-connected image, if it is less than the threshold, the pixel point is rounded, according to experimental statistics, the pixel distance L(i) The maximum value is Lmax, and the threshold is taken as 0.78Lmax. By adjusting the threshold and morphological parameters so that the number of seeds is the same as the number of characters, and finally the number of connected domains in the picture is identified by the connected domain identification function, and the number of connected domains is always one more than the number of seeds, that is, the number of characters. Through the above steps, the number of characters to be cut can be calculated, and the seed image is obtained according to the above method as shown in Figure 4.

Figure 2. Adhesion image to be segmented

Figure 3. Pictures after morphological changes

Figure 4. The position of the seed to be sliced

3.2.2 Cross Feature Point Markers

Usually the handwritten mathematical symbols are composed of several relatively simple strokes, but the structure of the handwritten mathematical formulas is diverse, which is not conducive to the projection of the image, resulting in the traditional projection method can not be well divided, and even the splitting error occurs. The method of splitting the adhesion area adopted in this paper can effectively avoid the interference of the mathematical formula structure and directly mark the adhesion area. In addition to the adhesion area, the characters themselves also have a small number of cross-landmark points, and when the number of symbols to be cut into images is determined, the skeleton extraction of the sliced objects [12,13], that is, the refinement of the binary plot, reduces the difficulty of screening the later intersections. The refinement is based on the following:

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(1) Internal points need to be retained;

(2) Outliers need to be retained;

(3) Straight line endpoints need to be preserved;

(4) If A is a boundary point, after removing A, the connected component changes and needs to be retained.

(5) The purpose of skeleton extraction is to facilitate the marking of later feature points, there are many methods of skeleton extraction known to exist, the method adopted in this article is a fast parallel algorithm [14], the algorithm of each iteration process is to discard the target pixels that meet specific conditions, so that the target becomes thinner and thinner, as the target continues to iterate, until the result after the last iteration, in this round of operation, no new target pixels meet the following algorithm end conditions:

1) As shown in Figure 5, the number of target pixels around the center pixel P1 and between 2 and 6, that is, $2\leq B(P1)\leq 6$;

2) In the 8 neighborhood pixels of the central image P1, in the clockwise direction, the adjacent pixels appear 0→1 times at a time, that is, A(P) = 1;

3) P2*P4*P6=0 and P4*P6*P8=0. According to the above algorithm, the final output result is the result of handwriting refinement. After the skeleton is extracted, continue its morphological operation to determine the cross feature point, the cross feature point is defined as follows: Definition: K is 3X3 of the full 1 convolutional kernel, ie:

$$K = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

N8(p) is the convolution kernel K that convolutes the image, assigned to the central pixel p.

(1) P is the intersection point and N8(p) = 3, and the P point is a three-connected point;

(2) P is the intersection point and N8(p) = 4, and the P point is the four connected points;

P9 (i-1,j-1)	**P2 (i-1,j)**	**P3 (i-1,j+1)**
P8 (i,j-1)	**P1 (i,j)**	**P4 (i,j+1)**
P7 (i+1,j-1)	**P6 (i+1,j)**	**P5 (i+1,j+1)**

Figure 5. Schematic diagram of the distribution of front scenic spots

According to the above conditions to determine the intersection feature points in the image to be cut, you can obtain the characteristic points that meet the conditions, but some of these points are the intersection points contained in the letter itself, such as the handwritten letter "t" has a feature point, the handwritten letter "A" has two feature points, a part belongs to the adhesive region, and the same adhesive region contains multiple cross feature points, as shown in Figure 6, the same adhesive region contains multiple feature points. Due to the misidentification of the feature points containing the

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character itself, it is necessary to filter the cross feature points first to obtain effective tangent points, which not only reduces the slicing time but also improves the slicing effect to avoid excessive splitting, and the cross feature points extracted from Figure 6 are shown in Figure 7.

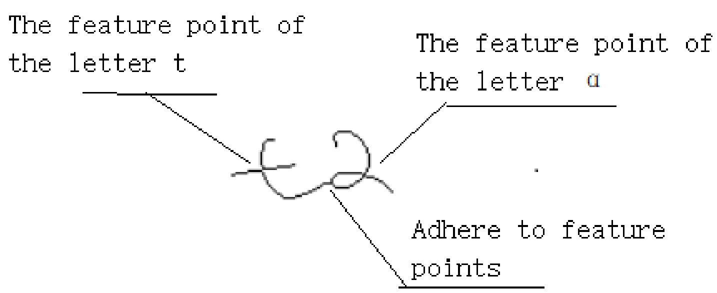

Figure 6. Adhesion character feature point

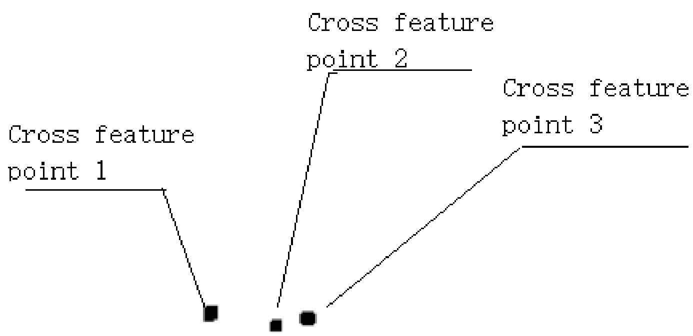

Figure 7. Extract adhesion region

3.2.3 Cross Feature Point Filtering

From the above methods, more cross-feature points are obtained, which increases the cutting time and easily causes the problem of excessive splitting, so it is proposed to effectively screen the cut points, and the main screening process is as follows:

Step 1: Take the upper left corner of the image to be sliced as the origin, establish the image coordinate system, extract the position coordinates of the crossed feature points, calculate the Euclidean distance from each other based on the calculated feature point coordinates, if the distance is less than the threshold, the two points are taken as the same cross feature point, and the area between the two is also regarded as part of the adhesion area;

$$\sqrt{|M1.y - M2.y|^2 + |M1.x - M2.x|^2} \leq \gamma \tag{1}$$

Among them: M1, M2 are the feature points, y and x are the coordinates of the two points, γ is the threshold, and the threshold size is determined according to the size of the characters of the statistical picture.

Step 2: Observe the characteristics of the adhesion image to see that the adhesion area mostly occurs at the edge of the letter, that is, the weight of the adhesive area is positively correlated with the center of the seed of the two images and can be simulated by normal sub-simulation [7,14,15].The weight W1 relationship is shown in Equation (2):

$$W_1=\begin{cases} r_1*\dfrac{1}{\sqrt{2\pi\sigma}}exp\left(-\left(\dfrac{(x-u)^2}{2\sigma}\right)\right) & \text{Horizontal adhesion} \\ r_1*\dfrac{1}{\sqrt{2\pi\sigma}}exp\left(-\left(\dfrac{(y-u)^2}{2\sigma}\right)\right) & \text{Vertical adhesion} \\ r_1*\dfrac{1}{\sqrt{2\pi\sigma}}exp\left(-\left(\dfrac{(x-u)^2}{2\sigma}\right)\right) \text{ or } r_1*\dfrac{1}{\sqrt{2\pi\sigma}}exp\left(-\left(\dfrac{(y-u)^2}{2\sigma}\right)\right) & \text{Diagonal adhesion} \end{cases} \tag{2}$$

Where r1 is the constant; u is the center position of the seed of the two images; σ is the constant, the value can be 1 or 2; x is the position of the seed center abscissa, and y is the abscissa position of the seed center.

Step 3: Perform the projection of the split picture and find that the cleavage points are mostly distributed near the valley points [14], as shown in Figure 8, by the differential method [16].

The method finds the position of the projection of the trough, and assigns weight to the corresponding cross feature by calculating the distance between the trough point and the cross feature, and the weight w2 relationship is shown in Equation (3):

$$W_2=\begin{cases} r_2*\left(1/(u-u_1)\right) & \text{Horizontal adhesion} \\ r_2*\left(1/(v-v_1)\right) & \text{Vertical adhesion} \\ r_2*\left(1/(u-u_1)\right) \text{ or } r_2*\left(1/(v-v_1)\right) & \text{Diagonal adhesion} \end{cases} \tag{3}$$

Where r2 is constant; v and u are the abscissa and ordinate coordinates of the marker point in the image coordinate system, respectively; u1 and v1 are the abscissa and ordinate coordinates of the valley point in the image coordinate system, respectively.

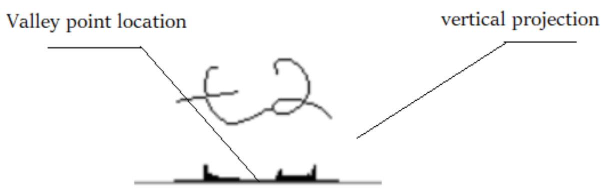

Figure 8. Vertical projection of adhesive image

Step 4: Consider two or three steps, where the sum of r_1, r_2 is 1. Normalize the two weights separately, and then find the sum of the two, and take a few cleavage points with higher weights.

3.3 Identify Feedback

Through the above process, the number of character recognition and the number of cleavage points are obtained, whether the difference between the number of character recognition and the number of

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cleavage points is 1, if it is 1, it means that there is no excessive splitting, if the number of cleavage points is the same or greater than the number of recognized characters, there is a possibility of excessive splitting, and it is necessary to mistakenly split and merge.

There may be a result of missection by splitting the image to be sliced by the above segmentation point, and several slicing results need to be identified compared with the given rejection recognition threshold, if it is above the threshold, it is an independent character, if it is below the threshold, the split part is merged according to certain rules, and then recognized. The rules for false-slicing and merging[5] are as follows:

The oversharded part is combined with the adjacent part for identification, and the recognition accuracy rate is returned, and the recognition return value is n1; then each part is identified, and the recognition return value is m1 and m2;

$Nexp = \alpha * m1 + \beta * m2$ is calculated. where $\alpha + \beta = 1$, α and β are pre-set constants based on the quality of the characters. When n1 >max(Nexp, T), the two parts can be merged into one character for recognition, if not satisfied, the two are not the same independent character, can not be merged. If the two cannot be merged this requires merging the part with other adjacent parts, repeat the above three steps again. The tangent points are modified according to the combined slicing results to obtain the final cleavage points. The slicing effect is shown in Figure 9, and it can be seen from the above slicing results that the slicing results reach the desired goal.

Figure 9. Adhesion image segmentation result

Through Figure 9, we can see that the tangent points are very accurate to the adhesion area of the adhesion image, but the size of the cleavage points causes the letter lines to break after the split, because the subsequent recognition is more identification using feature extraction, which will not have a greater impact.

4. Experimental Results and Analysis

The data in this article is a database in CROHME. Using the improved recognition feedback algorithm proposed in this paper to split the mathematical symbols of the writing body, Figures 10 to 12 are the final splitting results of the handwritten mathematical symbols, and it can be seen through experiments that the algorithm can effectively split the mathematical symbols of the writing body, especially for the positioning of the adhesion area, which reduces the difficulty of splitting.

(1) Original icon (2) Split result icon

Figure 10. Results of vertical adhesion segmentation

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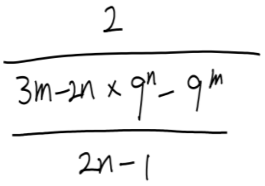
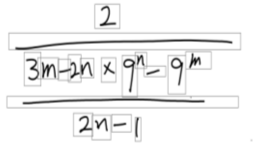
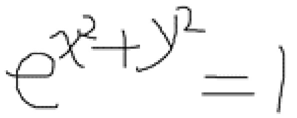


(1) Original icon

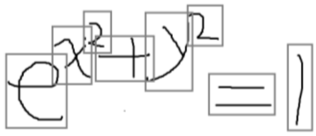


(2) Split result icon

Figure 11. Results of horizontal adhesion segmentation



(1) Original icon



(2) Split result icon

Figure 12. Results of diagonal adhesion segmentation

In this paper, 557 non-sticking hyphens and 189 sticky hyphens are extracted from the database, and the data are sliced by the traditional projection method and the recognition feedback method proposed in this paper, and the slicing statistical results are shown in Table 1. Two definitions have been introduced for the evaluation of adhesion results, as follows:

Definition 1: The number of stickers refers to the total number of samples in the measured samples for vertical adhesions, horizontal adhesions, and diagonal adhesions.

Definition 2: Sticking and splitting accuracy refers to the total number of stickers to the sticker ratio after the stickers are correctly split in the sample.

Table 1. Statistics of the results of mathematical character segmentation

	Unbonded character recognition	Adhesive character recognition
Number of characters	557	189
Recognition accuracy of connected domain cutting method(%)	93.87	82.54
Recognition accuracy of projection slicing method(%)	93.57	81.37
Recognition accuracy of recognition feedback method(%)	93.90	86.45
Improve the recognition accuracy of recognition feedback(%)	93.93	88.35

According to the statistics of the slicing results, the improved recognition feedback slicing algorithm proposed in this paper is 6% higher than that of the traditional slicing method, and the accuracy rate of 88.35% is increased.

Table 2. Time statistics of mathematical character segmentation

	Recognition feedback algorithm	Improved recognition feedback algorithm
Average segmentation time of a single adhesive character (ms)	21.91	18.63
Average time for double-adhesive character segmentation (ms)	35.64	27.56

5. Conclusion

The premise of a higher OCR recognition accuracy is to accurately slice the symbols. Aiming at the splitting problem of handwritten mathematical symbols, this paper proposes an improved recognition feedback algorithm according to the geometric characteristics of handwritten mathematical symbols, first using the traditional projection algorithm and the connectivity domain analysis algorithm to roughly cut the handwritten body symbols, then performing the secondary point finding method on the adhesion area of the mathematical symbols, combining the character width and projection valley point position to filter the marker points, and finally using the recognition feedback method to further modify and determine the tangent points. For images with fractions and root numbers, there is no splitting due to incorrect character discrimination. So the later work is to find a more accurate method of character number discrimination.

References

[1] Yi Lu. Machine printed character segmentation -; An overview[J]. Pattern Recognition,1995,28(1).

[2] R. G. Casey and E. Lecolinet, "A survey of methods and strategies in character segmentation," in IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 18, no. 7, pp. 690-706, July 1996, doi: 10.1109/34.506792.

[3] Guo Rongrong, Li Tao, Wei Qi. Segmentation of Touching Symbols in Mathematical Expressions Based on Deep Learning [J]. Computer and Digital Engineering, 2019,547 (10): 2579-2584.

[4] Luo Jia. Study on a Fast Segmentation Algorithm of Adhesion English String [J]. Computer Technology and Development, 2014 24 (08): 59-62.

[5] Liu Yangxing. Non-linear partitioning path based approach for touching and kerned character segmentation [J]. Computer Application Research, 2011, 28(10): 3998-4001.

[6] Wu Yue, Zhao Yuming, Zhu Yun. The Segmentation of Handwritten Chinese Characters by Bi-extracting Points [J]. Computer Engineering and applications, 2004 (08): 31-34.

[7] T. T. Zin, S. Thant, Y. Htet and P. Tin, "Handwritten Characters Segmentation using Projection Approach," 2020 IEEE 2nd Global Conference on Life Sciences and Technologies (LifeTech), 2020, pp.107-108, doi: 10.1109/LifeTech48969.2020.1570625477.

[8] NAGY G. Twenty years of document image analysis in PAMI[J]. IEEE Trans on Pattern Analysis and Machine Intelligence, 2000, 22(1) : 38-62.

[9] Y. Xu and J. Xue, "A Segmentation-driven Handwritten Uighur Word Recognition Algorithm Based on Feedback Structure," 2019 IEEE 10th International Conference on Software Engineering and Service Science (ICSESS), 2019, pp. 419-423, doi: 10.1109/ICSESS47205.2019.9040846.

[10] Zhang Zhenhui, Liu Sai. Design and Realization on Character Segmentation Algorithm for Women Writings [J]. China Science and Technology Information, 2010(12): 119-120.

[11] Lu Bin, Fan Xiaoming. Research on 3D Point Cloud Skeleton Extraction based on Improved Adaptive K-means Clustering[J/OL]. Acta Automatica Sinica: 1-13[2021-05-31].

[12] Zhang Dengpan, Li Guoxuan, Wang Liyang. Fingertips Recognition Based on Kinect Skeleton Information Depth Data [J]. Computer Measurement and Control, 2019pi 27 (03): 24-29.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202204_8(4).0098

[13] Chang Qinghe,Wu Minhua,Luo Liming. HANDWRITTEN CHINESE CHARACTER SKELETON EXTRACTION BASED ON IMPROVED ZS THINNING ALGORITHM [J].Computer Applications and Software,2020,37(07):107-113+164.

[14] Hong Tao,Liang Weijian,Lu Yufeng.Adaptive Location, Merged characters segmentation reconstruction and recognition of labels based on adaptive location [J].Journal of Image and Graphics, 2014, 19(06): 886-895.

[15] ZhangXin,Aiskar·Aimdula,Kamili·Muyiding. Regional localization and segmentation of connected characters between lines in offline handwritten Uyghur texts[J].Laser Journal,2014,35(11):4-10.

[16] Zhou Cheng. Car Position Locating Method Based on Image Processing [J].Computer System Applications, 2011,20(08):219-221.