Research on Positioning Method of Irregular Table of Mechanical Process Card

Jianheng Li [1, a], * Peng Wang [1, b], Zhigang Lü [1, c], Liangliang Li [2, d]
[a]e-mail: 1161910438@163.com, Corresponding author e-mail: [b] wp_xatu@163.com, [c]e-mail: lvzhigang@xatu.edu.cn, [d]e-mail: 2977867201@qq.com

[1] School of Electronic and Information Engineering, Xi'an Technological University, Weiyang, Xi'an, Shanxi, China

[2] School of Mechatronic Engineering, Xi'an Technological University, Xi'an Technological University, Weiyang, Xi'an, Shanxi, China

Abstract—The retrieval of paper form data is large, and the storage cost is high and wasteful, and the digital reproduction of form data has become more and more common. Due to the immaturity of the early watchmaking technology of the mechanical craft card, there were problems such as dotted vertical frame lines, misplaced frame lines, and table spreads. First, a table document tilt correction algorithm based on straight line detection is used, which is convenient for better realization of table extraction and positioning and identification of effective information. Homogeneous, according to the characteristics of irregular table style, an irregular table extraction algorithm based on double histogram statistical clustering is designed to achieve precise positioning of table areas. Then, according to the sample characteristics of the cross-page table, a cross-page table splicing algorithm based on local characteristics is designed to ensure the integrity of the data. Finally, by extracting irregular table cell images and bi-histogram projection, a non-regular table cell extraction algorithm based on image statistics clustering is realized.

Keywords- Inclination correction; Histogram Statistics; table splicing; Histogram projection;

1 INTRODUCTION

With the continuous development of intelligent informatization and image processing technology, people have higher and higher requirements for work efficiency. Paper documents with various form information have been widely used in industry and life. A large number of printed paper mechanical parts historical test reports need to be digitally reproduced. The form information processing as an important carrier of test data is an important basis for building a historical test record library for mechanical parts and mechanical equipment health diagnosis management [1-2]. Due to the immaturity of early watchmaking technology, there are a large number of historical test reports of mechanical parts with dotted vertical frame lines, vertical frame lines misaligned, and table spreads. The report contains the historical iterative test information of mechanical parts, which plays a vital role in the stable operation of mechanical parts, life prediction and the construction of equipment information management system.

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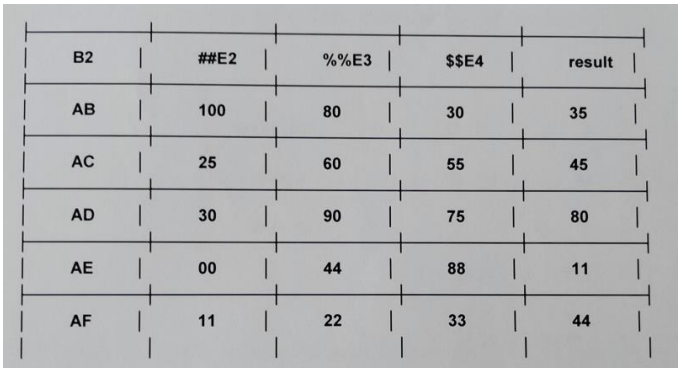
Figure 1 is a partial schematic diagram of the irregular table report sample studied in this paper. It can be clearly seen that there are obvious vertical frame lines in the table that the frame lines are dotted lines, and the frame lines are misplaced. This brings great difficulty to the digital layout reproduction analysis of the report.



B2	##E2	%%E3	$$E4	result
AB	100	80	30	35
AC	25	60	55	45
AD	30	90	75	80
AE	00	44	88	11
AF	11	22	33	44

Figure 1 Partial diagram of the irregular table studied in this paper

2 TABLE TILT CORRECTION ALGORITHM DESIGN

This paper makes corresponding improvements on the basis of the horizontal correction method based on Hough lateral line detection and fitting. Figure 2 shows the design diagram of the image tilt correction algorithm, which mainly improves the situation of wrongly detected line segments due to the direct use of Hough horizontal line detection. The horizontal straight line pre-extraction of adaptive morphological threshold is realized by using the self-defined construction level detection structure element. Then use LSD [3] to reconstruct the horizontal line, which greatly improves the detection accuracy and correction accuracy of the horizontal line.

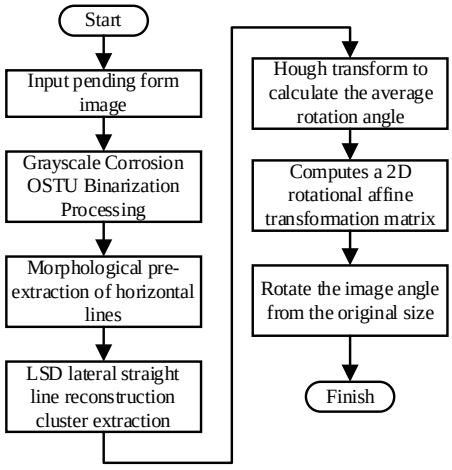


Figure 2 The design diagram of the image tilt correction algorithm

3 DESIGN OF ALGORITHM FOR RECOGNITION OF IRREGULAR TABLES

By analyzing the characteristics of irregular table styles, a table recognition method based on histogram statistics is designed to solve the problem that the vertical direction of irregular tables cannot be accurately identified. First, the minimum circumscribed rectangle detection based on vertical histogram statistics is carried out to determine the horizontal boundary; Secondly, the minimum circumscribed rectangle detection of the horizontal histogram statistics is performed to determine the vertical edge; Finally, the table area is pre-extracted using the custom border filtering rules. Perform morphological horizontal line segment extraction and LSD straight line reconstruction processing on the pre-extracted table area, and judge whether there is a horizontal straight line to ensure that the extracted area is a table area. FIG. 3 is a flowchart of an irregular table recognition algorithm. The input table image to be recognized is an image after tilt correction.

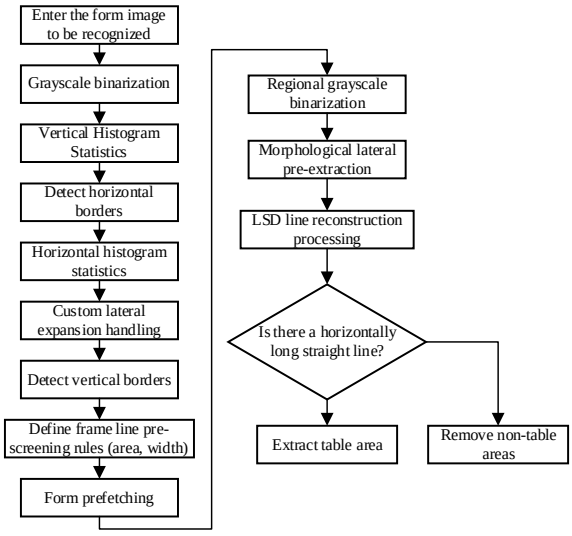
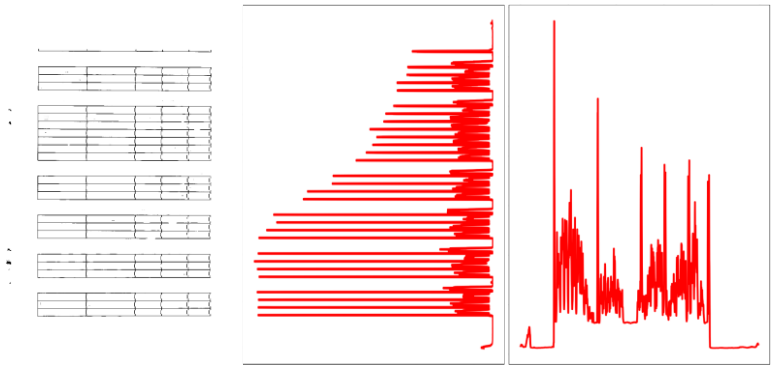


Figure 3 Flowchart of the algorithm for identifying irregular tables

The table image after tilt correction can be initially considered to be horizontal and vertical. Figure 4(a) is the irregular table sample after tilt correction, Figure 4(b) is the horizontal projection result, and Figure 4(c) is the vertical projection result. The left and right boundaries of the table area can be obtained by analyzing the longitudinal projection results; By analyzing the horizontal projection results and the characteristics of the test samples, there is a line of title information and test time information between the tables, an extra blank area of 1.5 times the line spacing, some samples have some other annotation information, and there is at least one line in the table area (A straight line is theoretically a non-table area, and this paper defines that the current table is an incomplete table across pages). Therefore, this feature can be used to determine the upper and lower regions of a separate table.



(a) Input Image (b) Horizontal Statistics (c) Longitudinal Statistics

Figure 4 Horizontal and vertical statistical effect diagram

3.1 Table area prefetching

Compress the multi-resolution image data to grayscale, and perform OTSU binarization processing. Then, the horizontal and vertical histogram statistics are performed, and the horizontal and vertical boundaries are determined by the minimum circumscribed rectangle detection. By customizing the frame line pre-screening rules, the areas that meet the conditions are retained, and the table area pre-extraction is completed. The main steps are as follows:

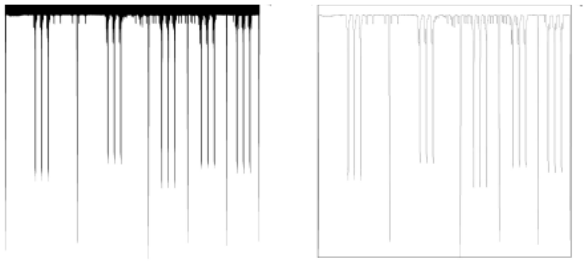
a.The grayscale OTSU binarization of the source table image;

b.Longitudinal histogram statistics;

Perform vertical histogram statistics on the table image after binarization. Figure 5(a) is the result of the table's longitudinal histogram statistical processing. As can be seen, the vertical table lines extend from top to bottom.

c.The minimum circumscribed rectangle is detected to determine the lateral boundary;

Figure 5(b) shows the result of the circumscribed rectangle after statistical processing based on the vertical histogram. By filtering out the circumscribed rectangular area with a relatively small area, the coordinates of the leftmost and right borders of the table area are determined according to the circumscribed rectangle with the largest area, that is, the left and right boundaries of the table area are determined.



(a) (b)

Figure 5. The minimum circumscribed rectangle detection diagram of the vertical histogram

d.Statistics of horizontal histogram;

After the horizontal boundary is determined, the method in steps a and b is used to conduct horizontal histogram statistics. Figure 6(a) is a graph of the statistical results of the horizontal histogram of the table. Further processing is required due to the partial gap inside the horizontal projection within the table area.

e.Custom lateral expansion processing;

The local maximum of the pixel is obtained by convolution of the image with the dilated kernel. This paper expands the highlighted part of the image by customizing the expansion kernel with a size of Size (10,20). By performing expansion processing on Fig. 6(a), the white pixel pitch in the vertical direction is reduced, which is convenient for the detection of the minimum circumscribed rectangle.

f.The detection of the minimum circumscribed rectangle determines the longitudinal boundary;

(a) (b)

Figure 6. The minimum circumscribed rectangle detection diagram of the horizontal histogram

g.table area pre-screening;

Since the detection result of the minimum circumscribed rectangle contains some non-table regions, the rectangles that do not satisfy the pre-screening rules are deleted by pre-screening the rectangles in the table pre-extraction region.

h.Table pre-extraction based on the statistics of horizontal and vertical histograms;

Through the above processing, the table area can be pre-extracted. Figure 7 is a schematic diagram of pre-extraction of some irregular table samples studied in this paper. There are some non-table areas in the pre-extraction area, and further filtering processing is performed on the extraction area.

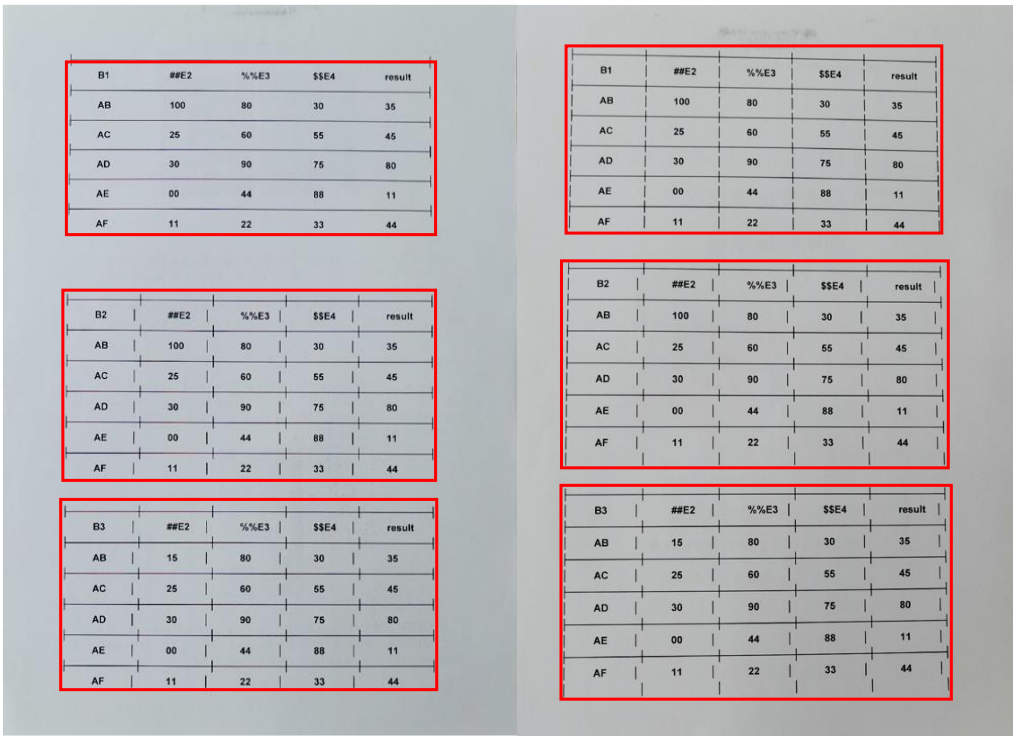


Figure 7 Table pre-extraction output result diagram

3.2 Filtering Prefetched Table Regions

Gray-scale binarization is performed on the pre-extracted table area, and then horizontal line segment pre-extraction based on morphology is performed. Perform straight line reconstruction processing through the LSD algorithm to determine whether there is a horizontally long straight line. If it does not exist, remove the non-form area, and complete the extraction of the form area, including the complete form and incomplete form, as well as the title of the form and the test time information; Finally, the straight line coordinates are obtained by sorting the vertical coordinates of the straight line, and processing the extreme value clustering mean value. For the table area that has been extracted, the table title and test time information are extracted by pre-

extracting the upper boundary of the area and the coordinates of the first straight line, which facilitates the classification and management of subsequent tables.

4 ALGORITHM DESIGN OF INCOMPLETE CROSS-PAGE TABLE MOSAIC

This section mainly introduces the contextual processing of incomplete and incomplete tables. Incomplete and incomplete forms contain redundant information. It is necessary to remove redundant information, retain valid form information, and judge the integrity of the form to determine whether to perform cross-page splicing. Design cross-page splicing rules for complete splicing of incomplete tables as follows:

In this paper, the incomplete state of the i top page is set to T_i, and the incomplete state of the bottom page is B_i. For the convenience of judgment, the incomplete state is set to 1, and the state that requires cross-page splicing is 1. Otherwise, the state is 0. According to the above, the incomplete state matrix can be obtained for: $\begin{bmatrix} 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \end{bmatrix}^T$.

The incomplete state matrix is mainly used to judge the context information of the incomplete and incomplete table splicing of the current page. According to the incomplete state matrix, the cross-page splicing rules of this paper can be obtained:

Rule 1: Use the top table of the next page to supplement the bottom table of the previous page when splicing (the current page number is greater than 2 and is complete, which is the collection of tables on the current page); Rule 2: Follow the width of the bottom table of the previous page and the top table of the next page during splicing; Rule 3: The number of spliced images is greater than or equal to 2, and N pages can be spliced continuously across pages (N is a positive integer) under the premise that memory allows. According to rule 1, rule 2, and rule 3, the splicing problem of cross-page tables is realized in turn, and the splicing of cross-page tables is realized according to the incomplete state matrix. Figure 8 shows the process of implementing cross-page splicing.

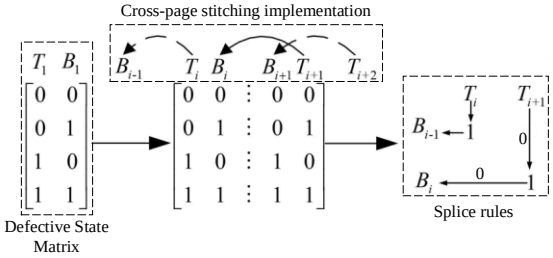


Figure 8 Schematic diagram of cross-page splicing implementation process

5 ALGORITHM DESIGN OF IRREGULAR TABLE STRUCTURE RECOGNITION

After the cross-page splicing process, the cross-page problem existing in the upper and lower pages of the table is solved. This section mainly introduces the identification of the table structure after the integrity detection and judgment, and obtains the corresponding table unit image, which is convenient for subsequent digital identification.

According to the characteristics of the test report studied in this paper, a table structure recognition method based on double histogram statistics is designed. In order to solve the problem that the horizontal frame line of the table is complete, and the vertical frame line has dislocation and discontinuous irregular table structure identification. Figure 9 shows the algorithm flow of the irregular table structure recognition targeted in this paper.

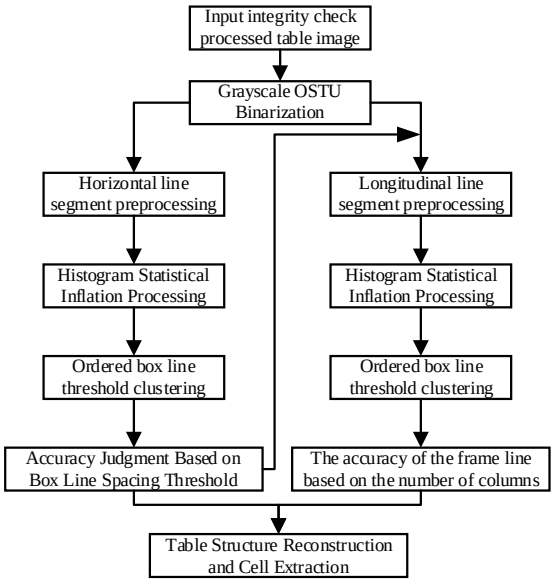


Figure 9 Flow chart of the algorithm for identifying irregular table structure

The OSTU [4-5] binarization with adaptive threshold is used for preprocessing to construct the corresponding horizontal straight line detection structural element, Size (width/4,1). Select MORPH_RECT for straight line approximation output detection, where width is the pixel width of the current input table. Secondly, perform horizontal projection statistics on the detected horizontal straight line and do expansion processing in a small range, Guarantee the continuity of the line segment, and record the current horizontal statistical value as H_{sheet}, the maximum statistical value is: H_{sheet_M}, and the filtering rules are:

$$H_{sheet} > 0.75 \times H_{sheet\_M} \tag{1}$$

Denote the statistical value that meets the condition as a valid horizontal frame line as: $H=\{H_{sheet}(i)\},(i=0,1,2...)$,

Sort the valid sets in order, and extract them according to the threshold value of formula (2) to obtain a set of horizontal frame lines H_{Lines} , of which $h\_thresh=20$ represents that the difference between the lines is at least 20 pixels.

$$H_{Lines}=\{H_{sheet}(i+1)\text{-}H_{sheet}(i)>h\_thresh\} \tag{2}$$

Compute the set H_{Lines} line-spacing mean $\bar{H}$:

$$\bar{H}=(\sum_{i-1}\{H_{Lines}(i+1)-H_{Lines}(i)\})/(i-1) \tag{3}$$

Based on the average line spacing of $\bar{H}$, the self-adaptive extraction of the vertical frame line is carried out. This part uses the construction of longitudinal morphological detection structural elements to pre-extract the vertical straight line. When splicing images that span N pages continuously, the image height is large, which makes the detection of small vertical line segments extremely difficult. In this paper, the vertical detection structural element is constructed on the basis of the mean value of horizontal frame line spacing: Size (1, $\bar{H}/4$), and MORPH_RECT is selected for linear approximation output detection, which can realize the threshold adaptation of morphological detection of longitudinal line segments. In this paper, the set of wave peaks (local maxima) in the vertical statistics of vertical detection records is constructed based on the mean value of horizontal frame line spacing as V_{sheet} . According to formula (4), the wave peaks with similar lateral coordinates are filtered out to ensure that there is only one wave peak in the local lateral coordinate range. Among them, V_{sheet_j} is the horizontal coordinate corresponding to the j-th peak value, and $v\_thresh=20$ represents that the horizontal distance between the two peak values is at least 20 pixels.

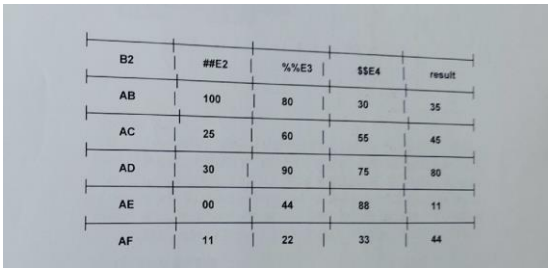
$$V_{Peak}=\{j,V_{sheet\_j+1}\text{-}V_{sheet\_j}>v\_thresh\} \tag{4}$$

Next, process the two-dimensional wave peak set V_{Peak} , sort it in order. Since the test reports studied in this paper are all 5 columns, the first 6 corresponding horizontal coordinates in the V_{Peak} set with the largest wave peak value are taken as the vertical effective frame line equation. Finally, superimpose the extracted horizontal straight line equation and the vertical straight line equation to obtain the positioning area of the table unit.

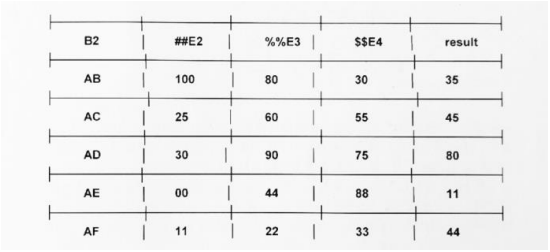
6 EXPERIMENTAL TESTING AND ANALYSIS OF RESULTS

In order to verify the validity and effect of the method in this paper, the non-regular table is used for testing. On a computer with AMD Ryzen7 5800X 8-Core Processor and 32GB of

memory, the table positioning algorithm proposed in this paper is experimentally verified by using C++. As shown in Figure 10(a), the input irregular table is not corrected in the direction of the table, and the vertical frame line is dashed and the frame line is misplaced. Figure 10(b) is the binarized image processed by the table inclination correction algorithm in this paper. It can be seen that the handwriting in the image is clearly displayed and the correction effect is good.



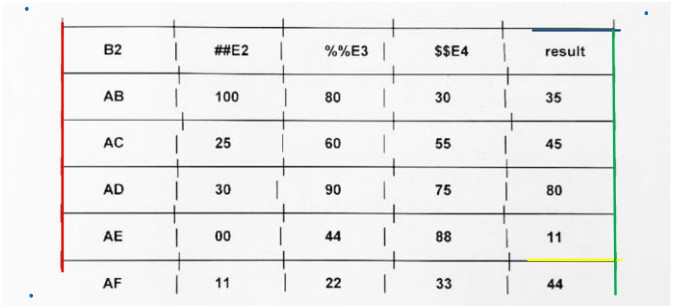
(a) Input Image



(b) Image after correction

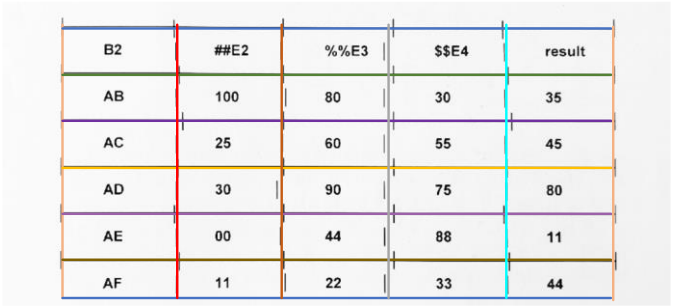
Figure 10. Irregular table of input

Use the rectified irregular table images for comparison of different table algorithms. Figure 11(a) shows the result of identifying the table by the traditional algorithm. Due to the misalignment of the right frame line, the vertical straight line was not successfully detected, so the irregular table could not be correctly identified. Figure 11(b) is the result of table positioning after processing by the algorithm in this paper. It can be seen that the algorithm in this paper can correctly identify the complete table with high accuracy. The vertical frame line is dashed and the frame line is misplaced and other problems have not affected the recognition results of this algorithm. There is a certain dislocation of the vertical line coordinates. This dislocation is caused by the dislocation of the table frame line and the Hough extraction of the straight line.



B2	##E2	%%E3	$$E4	result
AB	100	80	30	35
AC	25	60	55	45
AD	30	90	75	80
AE	00	44	88	11
AF	11	22	33	44

(a) Traditional Algorithm Results



B2	##E2	%%E3	$$E4	result
AB	100	80	30	35
AC	25	60	55	45
AD	30	90	75	80
AE	00	44	88	11
AF	11	22	33	44

(b) The results of the algorithm in this paper

Figure 11 Table location results of different algorithms

7 CONCLUSIONS

The algorithm researched in this paper has realized the batch identification management of the historical test report of mechanical parts. Through the experimental analysis of irregular tables, the algorithm in this paper has the advantages of high recognition accuracy and fast recognition speed, and has realized the accurate and effective processing of irregular tables.

However, this method also has shortcomings. For tables with inconsistent orientations on the same sheet of paper, it cannot be corrected correctly, and the accuracy rate is low. Later, consider differentiating the tables in different directions and process them independently.

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