Application of an Improved Hough Transform and Image Correction Algorithm in ACC

Biao Chen, Bangfeng Ding and Jiangtao Wang∗
School of Software Engineering, East China Normal University, 3663 Zhongshan North Road, Shanghai, China
Email: jtwang@sei.ecnu.edu.cn

Abstract. Numerous studies have shown that ACC (Augmentative and Alternative Communication), as a tool in language and communication training for children with autism, has effectively improved and played a positive role. ACC’s Picture Exchange System (PECS) provides an important support for the correction and feature recognition of language and training teaching cards. When designing the picture exchange function of ACC, this paper proposes a modified Hough transform and image correction algorithm suitable for teaching cards to solve the problems of large data calculation, time-consuming calculation, large space occupation and false peaks caused by traditional Hough transform algorithm in detecting straight lines, which also optimizes the interactive experience of the teaching scene. Finally, we design two experiments to compare and analyse the classic Hough transform, random Hough transform and improved Hough transform. Experimental results show that the improved Hough transform algorithm has superior performance in terms of execution efficiency and accuracy of line detection.

Keywords. ACC; Hough transform; line detection.

1. Introduction
Social communication disorder is one of the core obstacles for children with autism spectrum disorder (ASD), which seriously affects their interpersonal communication. As an effective means to improve the symptoms of children with autism spectrum disorder (ASD), ACC has two main functions. One is to help children with autism expand their willingness to communicate. The other is to communicate with them as an auxiliary tool. This system is a way to help children with autism improve their self-will expression [1].

In the picture exchange function of ACC, we need to correct and identify the pictures on the teaching card. Among them, the methods of image correction and recognition mainly include classic Hough transform and Radon change.

Hough transform maps the points in the original image space to the parameter space, and performs simple cumulative statistics to obtain the number of reference points, and finally selects the peak value [2]. Radon transform is a smooth transition from the detection of straight lines in a flat image to the detection of bright and dark points.

Hough transform has strong anti-noise ability and high robustness. The advantage of Radon over Hough transform is that the transform is not affected by the image format and can detect non-binary images.

In the teaching scene, the course puts forward requirements for the rapid identification of teaching cards, that is, the real-time requirements of teaching card identification. However, the card tilt
phenomenon is more common in teaching scenes, and the tilt of the picture will directly affect the recognition effect and recognition speed of the card content, which will hinder the autistic children from expressing their willingness smoothly.

Therefore, when designing the picture correction and recognition function of ACC, we considered that the teaching cards mainly existed in a two-dimensional plane, mainly using the classic Hough transform method, and taking into account the real-time requirements of the teaching site. In fact, because the Hough transform needs to calculate the entire picture, there are shortcomings such as large amount of calculation and slow speed, which will affect the real-time experience. Therefore, we hope to propose an improved Hough transform algorithm to reduce the classic, the space complexity and time complexity of Hough transform.

2. Basic Principles of Hough Transform
Hough transform is a feature extraction technology, first proposed by Paul Hough. Hough transform can be used to detect straight lines in a two-dimensional planar image, and it can further detect basic features of the image. The most prominent and obvious basic feature of a two-dimensional planar image is a straight line, so the general outline of an image can be organically formed by straight lines [3]. Therefore, the feature detection for the image can be converted into the detection of straight lines in the image.

The basic principle of the Hough transform to detect a straight line is to transform the points in the image space to the parameter space, and then accumulate the points in the parameter space to find a peak point, then this peak corresponds to a straight line in the image space (slope k and constant b, etc.). In this way, the detection problem of a given straight line in the original image is converted into a peak problem in the parameter space, that is, the overall detection characteristic is detected into a local characteristic. The schematic diagram of the sine curve of the Hough transform is shown in figure 1.

![Figure 1. The image of Hough transform in line detection.](image)

Hough transform has the following steps to detect a straight line in an image. The overall process is shown in figure 2.

Step 1. Detect edge contours of a given image in space;
Step 2. After the edge detection in step 1, binarize the original image and look for non-zero coordinates in the binarized image. This point is the key data point.
Step 3. Hough transform the key points found in step 2.
Step 4. Set a threshold and find the point in the parameter space whose value is greater than the threshold. These point pairs are collinear in the corresponding Cartesian space.
Step 5. Finally, complete the straight line detection.

Hough transform is essentially a voting mechanism. Each point in the parameter space is a ballot box. Once the point is the intersection of some two straight lines, a vote is cast into the ballot box. If the number of votes in the ballot box reaches a preset threshold, it is considered that there are enough points in the original image space to be located on a straight line determined by the parameter points. This method based on voting mechanism has strong anti-noise ability and high robustness.

After the classic Hough transform was proposed, it showed good detection results for straight line detection, but there were still many problems. The classic Hough transform calculates all the discrete points in the image one by one when transforming the points in the image space to the parameter space, so the points outside the straight line in the original image are also calculated and stored, which increases
It takes time and space to calculate the transform. In addition, the peak value of the Hough transform is difficult to determine in the parameter space, and false peaks may appear, so the detected straight line may be wrong. Below we will refer to the idea of random Hough transform [4], make improvements to Hough transform, and combine perspective transform for image correction [5].

![Hough transform overall flowchart](image)

**Figure 2.** Hough transform overall flowchart.

3. **Improved Hough Transform Algorithm**

In order to solve the shortcomings of large amount of calculation, high resource occupation and slow speed of Hough transform, we proposed an improved Hough transform image correction and field correction method suitable for field teaching based on the classic Hough transform algorithm and the design rules of teaching cards.

First, pick a random point in the image. If this point is on a certain straight line, then there must be points that can form a straight line with it. Then, a point set G is set for the selected points. Select a point \( g_i \) from the point set, and set a region of interest with \( g_i \) as the center and \( l \) as the radius, that is, the shortest length of a straight line that can be detected. When looking for the next point with the center \( g_i \) as the starting point, the interval is adopted, that is, with \( g_i \) as the center of the circle and \( d \) as the length of the interval. Local points can be formed with \( g_i \) by using the Hough transform. This can greatly reduce the time and space complexity of the Hough transform, and achieve the purpose of fast detection. The algorithm steps are described as follows:

- **Step 1.** Randomly select a point \( g_i \) from the image, and set the region of interest \( S \) with \( g_i \) as the center and \( I \) as the radius.
- **Step 2.** Set the interval step \( d \), sample the points with the point \( g_i \) as the center and the step \( d \) as the radius, and place them in the point set \( S \).
Step 3. Randomly select a point \( p_i \) from the point set \( S \), and use the Hough transform to detect the possibility of a straight line. If it exists, select the \( p_i \) point. If it does not exist, continue to repeat step 3 until all point calculations are completed and delete all points in point set \( S \), then repeat step 1.

Step 4. Recalculate all selected points by Hough transform. If the voting result is greater than the set threshold, a straight line is considered to exist and a straight line equation is obtained. Then take points along the straight line to the two ends, and check whether these points are on a straight line, until a deviation point appears, that is, the point does not exist on the straight line.

Step 5. Calculate the detected straight line length. If the length is longer than the shortest length \( L_{\text{min}} \), it means that the straight line is not misjudged, and a straight line is extracted.

The pseudocode of the improved algorithm is described below:

**Algorithm** The pseudocode of the improved Hough transform algorithm

```
Input: Point set \( G \)
1: Randomly select a point \( g_i \) in the point set
2: Create a region \( S \) of interest with point \( g_i \) as the center and \( l \) as the radius
3: Sampling points with \( g_i \) as the center and step \( d \) as the radius, and then put them into the candidate point set \( S \)
4: select a point \( p_i \) from set \( S \)
5: while all points in \( S \) are used do
6: Hough transform and find extreme points
7: \( \text{len} = \text{normal}(\text{lines}(p_i).\text{point1} - \text{lines}(p_i).\text{point2}) \)
8: if \( \text{len} > \max_{\text{len}} \) then
9: \( \max_{\text{len}} = \text{len} \)
10: \( \text{xy}_{\text{long}} = \text{xy} \)
11: end if
12: end while
Output: Result (Candidate line)
```

This improved algorithm adopts the strategy of interval picking points, avoids occupying a huge space, and performs Hough transform on the local, reducing the amount of program calculation.

4. Improved Image Correction Algorithm

When tilt-correcting an image, a designated calibration point can be used to change a tilted rectangle into a non-slanted rectangle. In this section, the improved Hough transform algorithm is used to detect the straight lines in the image, and the four intersections of the detected straight lines are used as calibration points. Then calculate the perspective parameter vector based on the four points. Finally, the original image of the parameter vector is corrected to obtain the front view. The main steps of the algorithm are:

Step 1. According to the improved Hough transform algorithm, four straight lines in the image are detected.

Step 2. According to the principle of straight line intersection, calculate the coordinates of the intersection point as the calibration point.

Step 3. According to the four calibration points obtained, solve the perspective transformation parameter equations, and obtain the result as the corrected parameter vector.

Step 4. Apply the parameter vector obtained in Step 3 to the entire image, and correct the image to get the front view.

5. Experiments and Analysis

This experiment uses a processor version of Intel (R) Core (TM) i7-7700HQ, clocked at 2.80GHZ, memory size is 8GB, with Win10 system, development language is python, development environment PyCharm2019.1.
In this section, the experimental analysis compares the effects of classical Hough transform, random Hough transform, and the improved Hough transform proposed in this paper on image correction.

5.1. Experiment 1
Select 300 pictures of the teaching sample to examine the execution speed of the three algorithms, as shown in table 1. As can be seen from the table, the detection speed of the classic Hough transform is undoubtedly the slowest. The detection speed of the random Hough transform algorithm is improved by a grade. Compared with the random Hough algorithm, the algorithm proposed in this paper has a certain improvement in detection speed, which speeds up the straight line detection of the image.

Table 1. The execution speed of the three algorithms.

| Algorithm                  | Total time | Average time |
|----------------------------|------------|--------------|
| Classic Hough transform    | 180.070    | 0.6002       |
| Random Hough Transform     | 153.240    | 0.5108       |
| Improved Hough transform   | 119.400    | 0.3980       |

5.2. Experiment 2
300 teaching sample pictures were selected, and the three algorithms were compared in terms of the effect of line detection. In order to examine the accuracy of the algorithm's straight line detection, this section is measured by the total number of straight lines in the original image, the straight line detection number, the straight line miss detection, the straight line fault detection, the straight line detection accuracy rate, and the straight line detection error rate. Among them:

The straight line detection accuracy rate = (the straight line detection number - the straight line fault detection)/the total number of straight lines in the original image × 100%.

The straight line detection error rate = (the straight line miss detection + the straight line fault detection)/the total number of straight lines in the original image × 100%.

The straight line detection correct rate and straight line detection error rate of the above three algorithms for straight line detection of 300 teaching sample pictures are shown in table 2.

Table 2. Comparison of the effects of three methods on line detection.

| Parameter index                        | Classic Hough transform | Random Hough Transform | Improved Hough transform |
|----------------------------------------|-------------------------|------------------------|--------------------------|
| Total number of straight lines in the original image | 1200 | 1200 | 1200 |
| Straight line detection number         | 1330 | 1157 | 1093 |
| Straight line miss detection           | 432  | 546  | 122  |
| Straight line fault detection          | 562  | 204  | 28   |
| Straight line detection accuracy rate  | 61.5 | 54.50 | 89.83 |
| Straight line detection error rate     | 82.83 | 62.50 | 12.50 |

According to the statistical data in table 2, compared with the random Hough transform, the classical Hough transform performs better in the number of missed straight lines, which is slightly higher than the algorithm in this paper. Although the classic Hough transform is more prominent in missed detections, it is not inferior to the number of false detections, which is also very high. The improved algorithm proposed in this paper has superior performance, which is obviously better than random Hough transform and classic classical Hough transform. In terms of accuracy and error rate, it can be seen that this method performs well, and it has a lot of improvement over random Hough algorithm. The
accuracy rate is 89.83%. While the error rate is only 12.5%, the comparative histogram is shown in figure 3.

![Figure 3. The comparative histogram.](image)

6. Conclusion
Therefore, the improved algorithm proposed in this paper not only speeds up the straight line detection of the image, but also performs well in the accuracy and error rate of straight line detection, which satisfies the needs of card image detection in ACC teaching scenes.

Acknowledgments
This work is supported by National Trusted Embedded Software Engineering Technology Research Center (East China Normal University).

References
[1] Liu Y N and Liu J J 2017 Application of assisted communication system in communication training for autistic children Chinese Rehabilitation Theory and Practice 23 (4) 410-414.
[2] Ballard D H 1981 Generalizing the Hough transform to detect arbitrary shapes Pattern recognition 13 (2) 111-122.
[3] Feng F R and Ji J R 2001 Fast Hough transform algorithm Chinese Journal of Computers 24 (10) 1102-1109.
[4] Matas J, Galambos C and Kittler J 2000 Robust detection of lines using the progressive probabilistic hough transform Computer Vision and Image Understanding 78 (1) 119-137.
[5] Zheng C and Wei ZZ 2016 Object tracking by transitive learning using perspective transformation The International Society for Optical Engineering 10157.