Journal of Zhejiang University Science C (Computers & Electronics)

A Credible Tilt License Plate Correction Method Based on Pairwise Parallel Lines

--Manuscript Draft--

Manuscript Number:	ZUSC-D-11-00383
Full Title:	A Credible Tilt License Plate Correction Method Based on Pairwise Parallel Lines
Article Type:	Article
Abstract:	Tilt license plate correction is an important part of the license plate recognition system. In reality, there are a lot of inclined license plates due to various reasons, such as the perspective distortion and uneven or curvy road surface. The usual rotation methods are often based only on one theory, which is difficult to use the advantages of different methods, and we do not know the rotation results are correct or not. We proposed a mutual correction method based on pairwise fitted parallel straight lines, which will provide much help in the credibility of verifying the result of line fitting method by measuring the parallelism of these two lines. If we find that this method fails, we can use another method to do tilt license plate correction or give up. The proposed method can provide reliable correction results, and utilize the advantages of different rotation algorithms. The experimental results show better results than only using one method.

A Credible Tilt License Plate Correction Method Based on Pairwise Parallel Lines

Authors:

Zhongyan Liang, Corresponding Author, leungaptiva@gmail.com

Sanyuan Zhang, syzhang@zju.edu.cn

College of Computer Science and Technology, Zhejiang University

Postal Number: 310000

Postal Address: Room 306, East Wing, Caoguangbiao Building, 38 Zheda Road, Hangzhou, Zhejiang Province, People's Republic of China

Telephone and fax numbers: +86571-87953039

Abstract

Tilt license plate correction is an important part of the license plate recognition system. In reality, there are a lot of inclined license plates due to various reasons, such as the perspective distortion and uneven or curvy road surface. The usual rotation methods are often based only on one theory, which is difficult to use the advantages of different methods, and we do not know the rotation results are correct or not. We proposed a mutual correction method based on pairwise fitted parallel straight lines, which will provide much help in the credibility of verifying the result of line fitting method by measuring the parallelism of these two lines. If we find that this method fails, we can use another method to do tilt license plate correction or give up. The proposed method can provide reliable correction results, and utilize the advantages of different rotation algorithms. The experimental results show better results than only using one method.

Keywords: tilt license plate correction, fitting straight line, PCA, Sobel

I. INTRODUCTION

With the development of science and technology, more and more cities begin using intelligent transportation systems (ITS) in the traffic management. In the ITS field, license plate recognition (LPR) system is an important component of ITS, and it is also a core component of many systems, such as vehicle logo recognition system. In the parking, traffic control, road limit line, tracing illegal vehicles, chasing criminals, etc., LPR system has a wide application prospect. The LPR system is mainly divided into the extraction of license plate location, license plate character segmentation and character recognition modules. As the situation faced by LPR system is very complex, such as changing weather conditions and different road conditions, LPR system based on video camera is also facing various challenges.

Because the road is not flat, or the license plate (LP) itself is skewed, the extracted LP by locating module may be tilted. Tilt of the LP is not conducive to the segmentation. Humans can perform the usual target recognition without too much effort. However, by computer, the task of recognizing a specific object in an image is one of the most difficult topics in the field of computer vision or digital image processing (Deb et al., 2010). Therefore, we need to do tilt LP correction before the segmentation.

II. RELATED WORK

In recent years, many scholars have proposed a lot of tilt correction algorithms for license plates.

Hough transformation based approach is used in (Wen et al., 2002; Zhang and Yin, 2008). The core idea of the method is precise positioning the LP boundaries by Hough transformation. The main advantage of this technique is that it is relatively unaffected by image noise and is capable of filling gaps in feature boundary, but its disadvantage of bigger operand and lack of robustness. (Modi and Modi, 2011)

The nearest neighborhood approach is used in (Liolios et al., 2001; Lu and Tan, 2003). This method determines the image rotation angle by analyzing the histogram of the angles between the connected components of nearest neighbors.

The orientation field based approach is proposed in (Pan et al., 2010). This method generates the estimation of the orientation field using gradients, and fully utilizes the feature information lying in an image. That makes it highly sensitive to direction feature in the image and robust to interference (Pan et al., 2010).

The projection based approach is proposed in (Postl, 1986; Bloomberg et al., 1995). This method calculates the projection profile at each angle. And the features are then extracted from each projection profile to determine the rotation angle (Li et al., 2007). The main drawback of this method is computationally expensive and low precision.

Radon transformation based approach is proposed in (Jia et al., 2008). This method is very similar to the approach based on Hough transformation. Radon transformation is an integral transformation consists of integral of image function over a straight line. It is the projection of image in the direction of certain angle. At a particular angle interval, Radon transformation is taken with some fixed step length. Skew angle is determined through the location of the maximal sum. It has an advantage of being very simple, and it is insensitive to lights and stains conditions and also suitable for the images which are highly distorted. It has the disadvantage of fixed step size (Modi and Modi, 2011).

Principal Component Analysis (PCA) (Jolliffe, 1986) based approach is proposed in (Wu et al., 2008; Modi and Modi, 2011). This method uses PCA algorithm to calculate the principal component of the given input image. One can use the PCA in combination with approaches based on feature points, radon transformation, wavelet transform to produce the accurate and efficient skew correction. Major advantage of this approach is its processing time is much less compared with other methods of skew correction (Modi and Modi, 2011). However, sometimes, the extracted license plate region may be larger than the region containing the characters only. And the excess region may affect the accuracy of PCA.

The straight line fitting method is proposed in (Deb et al., 2010). This method is more accurate than other methods if the candidate points which need to be fitted are selected correctly. However, the selection of these points is the critical problem in this method.

However, these methods cannot report the confidence of the rotation results. In some cases, no correction is better than false correction. If the algorithm can report the confidence, we can decide to continue to do the tilt correction or not. To get the confidence, we do the mutual correction by pairwise fitted straight lines to improve the credibility. When the two fitted lines based method failed, we will use some features and PCA based method to estimate the rotation angle, or we can also do not do the tilt correction if the number of tilt license plates is few.

The paper is organized as follows: The proposed approach is illustrated in section III. Section IV will show some experimental results and discussions. And section V gives conclusions.

III. THE PROPOSED METHOD

The proposed method is illustrated by Figure 1.

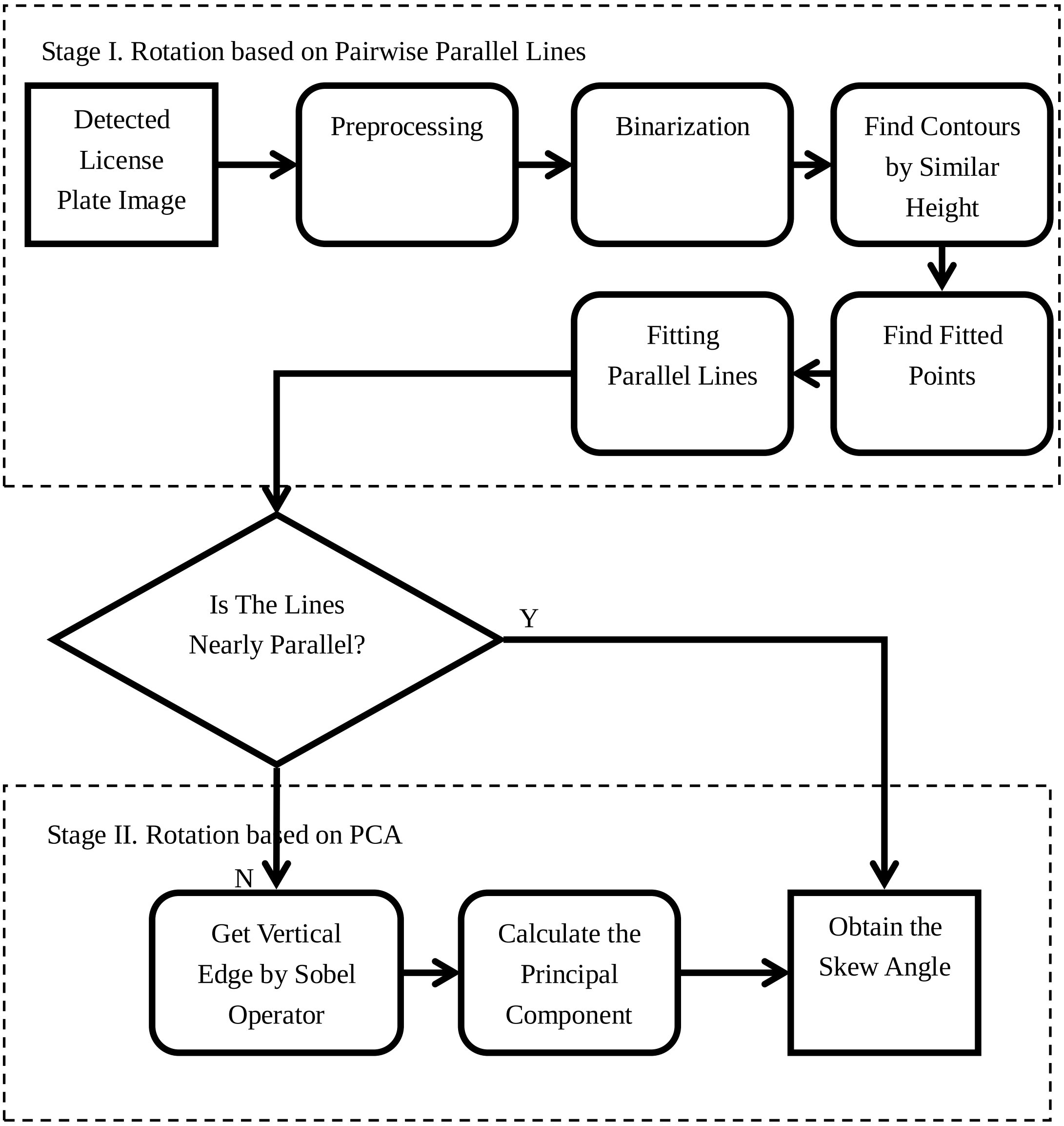

Figure 1. The Proposed Method

3.1 Pre-processing

The usage of a low-pass Wiener filter (Jain, 1989) has been proven efficiently for the elimination of noisy areas, smoothing of background texture as well as contrast enhancement between background and text areas (Gatos et al., 2006).

Wiener filter can be applied according to the following formula:

$$W(x, y) = \mu + (\sigma^2 - v^2)(I(x, y) - \mu) / \sigma^2 \quad (1)$$

Where μ is the local mean, σ^2 the variance at a $wSize \times wSize$ neighborhood around each pixel, v^2 is the average of all estimated variances for each pixel in the neighborhood, $I(x, y)$ is the source grayscale value, and the $W(x, y)$ is the destination result. In our experiments, we apply a 3 × 3 Wiener filter to a license plate image.

3.2 Find Fitted Points

1) Before finding the constrained connected contours, we need to convert the filtered image to binary image.

   By experiment, Sauvola's (Sauvola and Pietikainen, 2000) binary method can get satisfactory results. The threshold $T(x, y)$ of Sauvola's method can be calculated by following formula:

   $$T(x, y) = \mu(x, y)\cdot(1 + k\cdot(W(x, y)/R - 1)) \quad (2)$$

   Where R refers to the dynamic range of the standard deviation fixed to 128 and k instead takes a positive value between 0 and 1 (Lu and Tan, 2007).

2) Find the bounding boxes of the constrained connected contours, the height of which is within a certain range. For example, the height of these boxes is greater than one-fifth of the height of the LP.

3) Calculate the histogram of the height value of these bounding boxes.

4) Calculate the sum of histogram value of each interval, and the intervals Φ are defined as follows:

   Φ = {[0.05H, 0.2H]; [0.15H, 0.3H]; [0.25H, 0.4H]; [0.35H, 0.5H]; [0.45H, 0.6H]; [0.55H, 0.7H]; [0.65H, 0.8H]; [0.75H, H]}

   Where, H is the height of the LP. There is overlapping between two adjacent intervals to avoid the bounding box group of similar height to span two intervals.

5) Select the interval, the sum of which is the maximum sum in the histogram, as the candidate interval C_I.

6) The bounding box is selected as candidate bounding box, the height of which is in the candidate interval C_I.

7) Select the highest point and the lowest point in each candidate bounding box as the fitted points for the top fitted straight line and the bottom fitted straight line, respectively.

   The results of finding fitted points are shown in Figure 2c, which are illustrated as circles.

3.3 Fit Pairwise Parallel Lines

The least square method is a commonly used fitting method by minimizing the following formula:

$$\min \sum_i \rho(r_i) \qquad (3)$$

Where r_i is the distance between the i-th point and the line, and $\rho(r)$ is a distance function illustrated by following formula:

$$\rho(r) = r^2 / 2 \qquad (4)$$

Although, this method is simplest and fastest, the results by using this method are not good enough. To find the best M-estimator function, we test different M-estimator functions, including Fair, L1, L2 (least-square), L1 – L2, Huber's and Welsch's function (Xu and Zhang, 1996).

In our experiment, Welsch's estimator can obtain good and robust results for both tilt license plates and non-tilt license plates.

Welsch's estimator has been shown to be a robust M-estimator in (Glotsos et al., 2006), and Welsch's estimator can be given by following formula:

$$\rho(r) = \frac{C^2}{2} \cdot \left(1 - \exp\left(-\left(\frac{r}{C}\right)^2\right)\right) \qquad (5)$$

Where C is a constant and C = 2.9846.

The results of fitting a pair of parallel straight lines are shown in Figure 2c, which are illustrated by the lines.

3.4 Verify Fitted Lines

We use θ_T and θ_B to denote the angles of the top fitted line and the bottom fitted line respectively. If θ_T and θ_B satisfy the following conditions, we believe that these two lines are approximately parallel, and the credibility of the results of fitting is high. And the skew angle is defined as the average angle of these angles.

$$\begin{cases} \theta_T \cdot \theta_B \geq 0 \\ |\theta_T - \theta_B| < \delta \\ \overline{r_T} < d \\ \overline{r_B} < d \end{cases} \qquad (6)$$

Where |·| denotes the absolute value, $\overline{r_T}$ and $\overline{r_B}$ are the average values and defined by formula 7-8, d is a threshold of distance of point to line, and δ is a small number between 0 and 0.1, which is set as 0.05 in our experiment.

$$\overline{r_T} = (r_{T1} + r_{T2} + ... + r_{Tn}) / Tn \qquad (7)$$

$$\overline{r_B} = (r_{B1} + r_{B2} + ... + r_{Bn}) / Bn \qquad (8)$$

Where r_{Ti} is the distance between the *i*-th fitted point (which consists of top point set) and the fitted straight line at the top of the LP, r_{Bi} is the distance between the *i*-th fitted point (which consists of bottom point set) and the fitted straight line at the bottom of the LP, Tn and Bn are the number of fitted points at the top and the bottom of the LP respectively.

$$\theta = (\theta_T + \theta_B) / 2 \qquad (9)$$

Where, θ is the rotation angle of the license plate.

If $\overline{r_T}$ or $\overline{r_B}$ does not satisfy formula 6, we consider that the fitted line has been influenced by some noises. We remove the point, the distance between which and the corresponding fitted line is farthest, and then re-fit the line using remaining points until the lines satisfy the formula 6 or there only are two points in the top point set or bottom point set ($Tn <= 2$ or $Bn <= 2$). In the latter case, we think the credibility of the fitted line is too low and the line fitting is unsuccessful, and we will do the rotation problem by using another method, which will be illustrated in the next section.

Figure 2. Rotate Successfully Based on Parallel Lines at Stage I. (a) Original Image (b) Results of Finding Bounding Boxes of Connected Contours by Similar Height (c) Fitted Points (shown by circles) and Parallel Lines (d) Correction Results

3.5 Features Extraction

If we obtain θ in the above section, the algorithm will be terminated, and the correction results are shown in Figure 2. Otherwise, if the fitting algorithm is unsuccessful, we will use the method based on other theories, such as PCA, to try to solve the rotation problem.

Before using the PCA method, we need to extract some useful features to help the skew angle estimation.

As the license plate characters are rich in features of the vertical edges, we use Sobel's operator [-1 0 1; -2 0 2; -1 0 1] to extract vertical edge features of the license plate characters. And then obtain the binary image by using Otsu's (Otsu, 1979) method.

To avoid the noise, we need to remove the foreground regions, the height of the bounding box of connected contours of which is less than a threshold, such as 8.

Use the foreground points in the binarized Sobel image as the selected feature points.

3.6 PCA Based Skew Angle Estimation

Principal Component Analysis can transform the measured data to a new set of variables, the principal components, which are uncorrelated. These principal components are ordered so that the first few retain most of the variation present in all of the original variables (Wu et al., 2008).

We use the *x* and *y* coordinates of the feature point as the input of PCA. That is to say, these coordinates are arranged in the form of a column vector:

$$\mathbf{x}_1^T = [x_1, x_2, ..., x_n]$$
$$\mathbf{x}_2^T = [y_1, y_2, ..., y_n] \quad (10)$$

And the data matrix can be formed as:

$$\mathbf{x} = [\mathbf{x}_1, \mathbf{x}_2] \quad (11)$$

The mean vector, $\mathbf{m_x}$, can be calculated as follows:

$$\mathbf{m}_x = \frac{1}{n}\sum_{k=1}^{n}\mathbf{x}_k \quad (12)$$

Then, we should calculate the covariance matrix, $\mathbf{C_x}$, by:

$$\mathbf{C}_x = \frac{1}{n-1}\sum_{k=1}^{n}(\mathbf{x}_k - \mathbf{m}_x)(\mathbf{x}_k - \mathbf{m}_x)^T \quad (13)$$

Where n – 1 instead of n is used to obtain an unbiased estimation of $\mathbf{C_x}$ from the samples. And because $\mathbf{C_x}$ is real and symmetric, finding a set of n orthonormal eigenvectors always is possible (Gonzalez et al., 2003).

The principal components transform is given by:

$$\mathbf{y} = \mathbf{A}(\mathbf{x} - \mathbf{m}_x) \quad (14)$$

Where, the rows of matrix **A** are the normalized eigenvectors of $\mathbf{C_x}$. Because **x** is two-dimension coordinate plane point set, the matrix A can be expressed as follows:

$$\mathbf{A} = \begin{bmatrix} e_{11} & e_{12} \\ e_{21} & e_{22} \end{bmatrix} \quad (15)$$

The skew angle θ can be calculated according to e_{11} in the matrix **A**:

$$\theta = \arccos(|e_{11}|) \quad (16)$$

The correction results are shown in Figure 2-3.

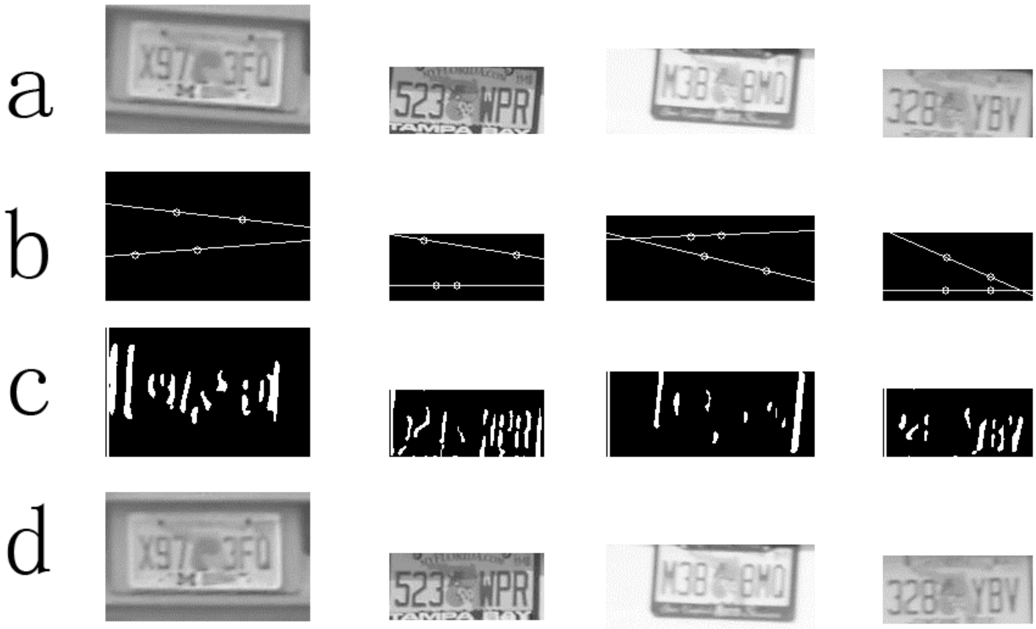

Figure 3. Rotate Results Based on PCA at Stage II. (a) Original Image (b) The Lines Fitted and Failure by Using the Method Based on Parallel Lines (c) The Vertical Edges (d) Correction Results

IV. EXPERIMENTAL RESULTS

4.1 Compare with Other Methods

The test data set we use composes of two types of license plates.

The data set 1 is used to test the correction capability for tilt license plates, and the data set 2 is used to test the error correction for non-tilt license plates. Because, in the process of license plate recognition, not only to ensure the tilt license plates can be corrected successfully, but also to ensure that the non-tilt license plates cannot be rotated incorrectly.

Before testing the algorithms, we have measured the slope k of these lines manually, which is also used as a benchmark.

Data set 1: tilt license plates ($k >= 0.03$) in a variety of environments.

Data set 2: non-tilt license plates ($k < 0.03$) in the case of sufficient sunshine.

We choose $k = 0.03$ as the dividing line, because we found that, if $k < 0.03$, the license plate is approximate horizontal. And we allow the error is 0.03.

We test our method and other four methods: one is proposed in (Modi and Modi, 2011), which is based on Harris feature and PCA method. The second one is the method based on fitting only one straight line method in (Deb et al., 2010). The third one and the fourth one is the method using the first stage and the second stage (Wu et al., 2008) of the proposed method, respectively.

The results of comparison are shown in Figure 4.

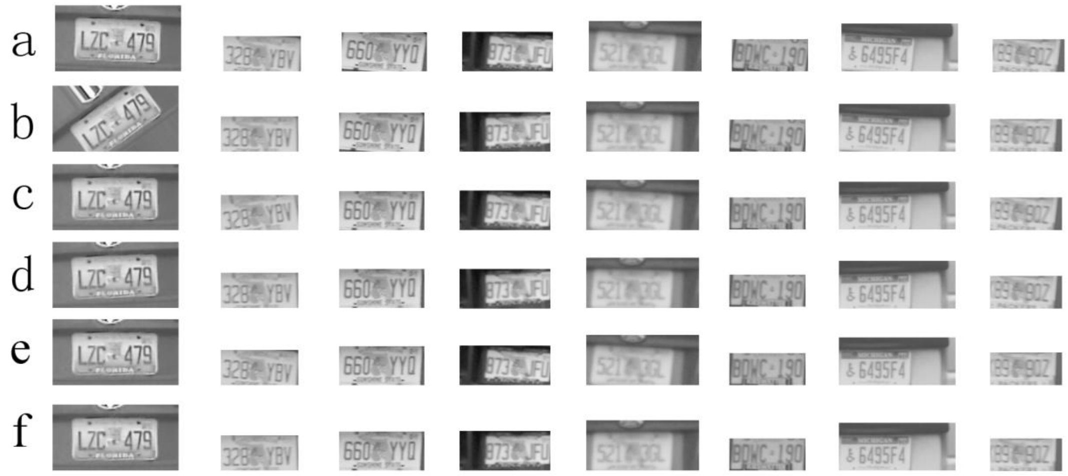

Figure 4. The Rotation Results by using Different Methods. (a) Original Image (b) Method by using Harris Feature and PCA (c) Method by using One Fitted Straight Line (d) Method by using Vertical Edges and PCA (Stage II only) (e) Method by using Two Fitted Straight Lines (Stage I only) (f) The proposed method

4.1.1 Accuracy

If the tangent value of the skew angle estimated satisfies the following formula, the estimated skew angle is considered to be correct. Otherwise, it is considered to be incorrect.

$$|\tan(\theta) - k_0| < 0.03 \quad (17)$$

Where, k_0 is the reference slope measured manually.

And the accuracy of the tested methods is shown in Table 1 and Figure 5.

Table 1 Accuracy of Different Methods

	Harris & PCA	Fitting One Line	Stage I only	Stage II only	Proposed
Set 1	36.99%	85.62%	88.36%	60.27%	92.47%
Set 2	40.00%	98.18%	98.18%	65.45%	98.18%

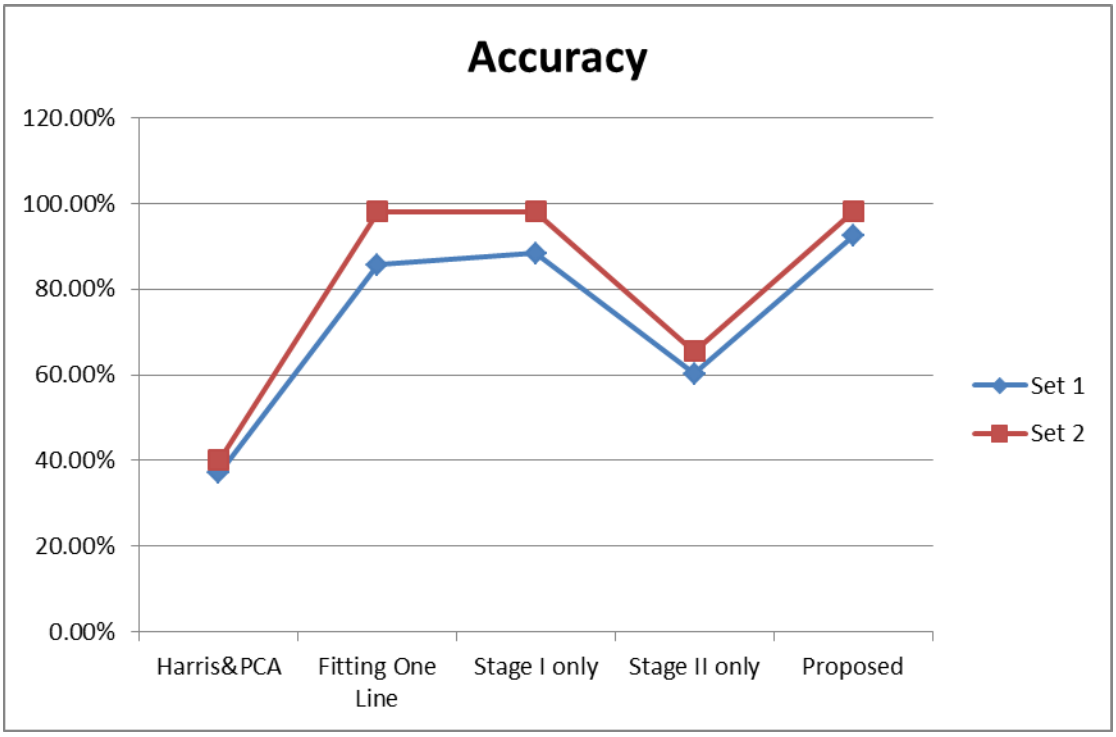

Figure 5. Accuracy of Different Methods

4.1.2 Robustness

The robustness is measured by the error standard deviation (ESD), which can be calculated as follows:

$\sigma = \text{stdDev}(|\tan(\theta) - k_0|)$ (18)

Where, stdDev is a function to calculate the standard deviation.

Smaller value of σ means the algorithm is better robustness, and the estimated skew angle is closer to the reference one.

The result of ESD is shown in Table 2 and Figure 6.

Table 2 ESD of Different Methods

	Harris & PCA	Fitting One Line	Stage I only	Stage II only	Proposed
Set 1	0.07597	0.02781	0.02833	0.02892	0.02441
Set 2	0.13714	0.00675	0.0071	0.02531	0.0071

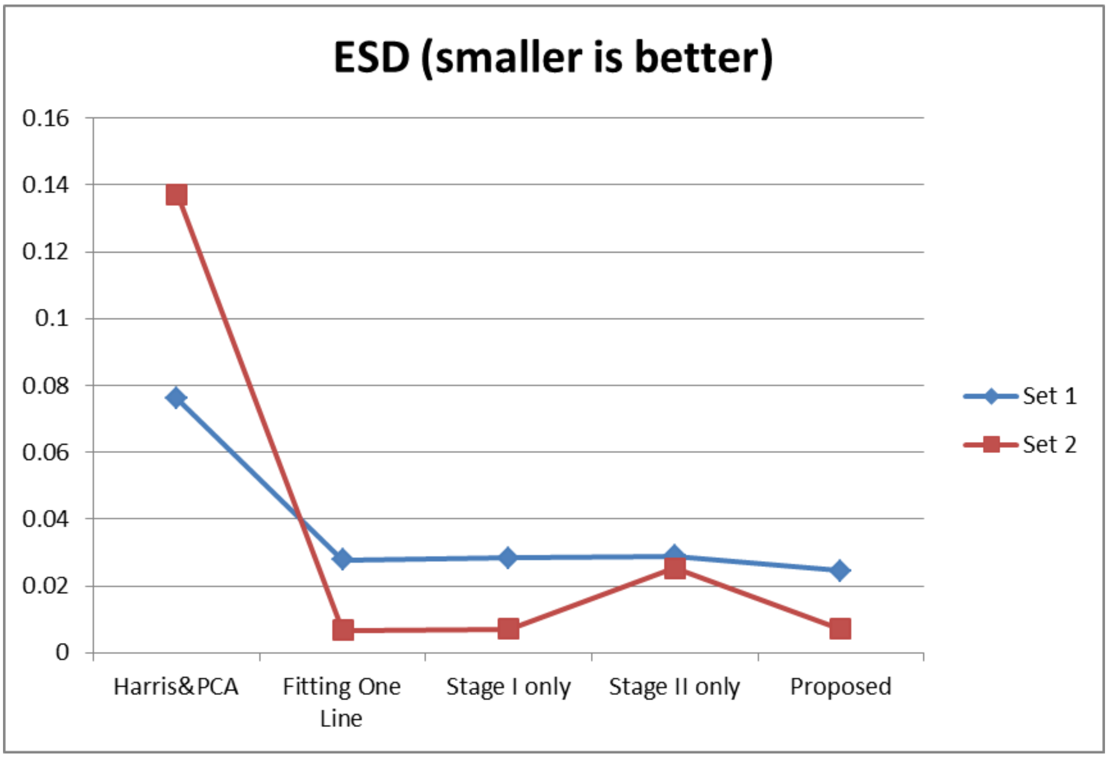

Figure 6. ESD of Different Methods

4.2 Credibility

Most of the method cannot report the confidence of the correction results, and we do not know the correction results are correct or not. However, our method can tell you the correction is successful or failure by using pairwise parallel lines, so we can choose a suitable method to continue to do the correction on the uncorrected license plates or to terminate the tilt correction process.

The confidence of the credibility is shown in Table 3. And it can be calculated by following formula:

$$\text{Confidence of the Credibility} = \frac{\text{Real Correct Correction Results}}{\text{Reported Correct Correction Results}} \times 100\% \qquad (19)$$

Table 3 Confidence of the Credibility

	Set 1	Set 2
Total	146	56

Reported Correct Correction Results	134	55
Real Correct Correction Results	129	55
Confidence of the Credibility (%)	96.27	100

4.3 Discussions

Comparing with other methods, our approach can maximize accuracy and reduce error rates in different circumstances. In Table 3, we can see that the clearer the license plates, the higher the confidence of the credibility. For a clear license plate, the method based on line fitting is more accurate, but for a blurred license plate with little noise, the method based on PCA is superior. That is because for the clear license plate, the accuracy of fitting lines is higher than the method based on PCA. And for the blurred license plate with little noise, searching for feature points is easier than finding the points which can be used for fitting a straight line. The PCA-based methods are susceptible to ambient noise.

For different applications, we can use different strategies. If there are few inclined license plates, we can only do the first stage method. By testing set 2, we can see that the accuracy and error of stage 1 are the same as the proposed method. Because the credibility of PCA-based method is unknown, no correction may be better than correction in the case of few inclined license plates. In the case of most inclined license plates, we need to do the second stage and select a suitable correction method.

V. CONCLUSIONS

Usually, we can only use one method to do the tilt correction, because we do not know whether the results of correction are correct or not. To overcome the main drawback of correction method, we proposed a tilt correction method for license plates based on pairwise parallel lines with credibility and PCA with vertical edge features to do accurate license plate correction. By using parallel lines, we can know the credibility of the fitting results, and then we can decide to continue to do the correction by other methods or not. The proposed method makes full use of the advantages of different algorithms. The experimental results show that whether the image is clear or blur our approach can obtain acceptable results, and have good noise immunity.

Acknowledgements

This work is supported by the National 973 Program (No.2009CB320804), Program for production-university-academe of Guangdong province joint with ministry of education (No.2010B090400193).

References

Bloomberg, D.S., G.E. Kopec, L. Dasari, 1995. Measuring Document Image Skew and Orientation *Proc. SPIE* **2422**: 302-316. [doi: 10.1117/12.205832].

Deb, K., A. Vavilin, J. Kim, K. Jo, 2010. Vehicle License Plate Tilt Correction Based on the Straight Line Fitting Method *International Journal of Control, Automation, and Systems* **8**(5): 975-984. [doi: 10.1007/s12555-010-0506-z].

Gatos, B., I. Pratikakis, S.J. Perantonis, 2006. Adaptive Degraded Document Image Binarization *Pattern Recognition* **39**: 317-327. [doi: 10.1016/j.patcog.2005.09.010].

Glotsos, D., J. Tohka, J. Soukka, J. T., 2006. Robust Estimation of Bioaffinity Assay Fluorescence Signals *IEEE Transactions on Information Technology in Biomedicine* **10**(4): 733-739.

Gonzalez, R.C., R.E. Woods, S.L. Eddins, 2003. Digital Image Processing Using MATLAB., Prentice Hall

Jain, A., 1989. Fundamentals of Digital Image Processing. Englewood Cliffs, NJ, Prentice-Hall

Jia, X., W. Li, H. Wang, 2008. Novel Approach for vehicle license plate tilt correction based on Radon transform *Computer Engineering and Applications* **44**(3): 245-248. [doi: 10.3778/j.issn.1002-8331.2008.03.077].

Jolliffe, I.T., 1986. Principal Component Analysis *Springer Verlag*.

Li, S., Q. Shen, J. Sun, 2007. Skew detection using wavelet decomposition and projection profile analysis *Pattern Recogn Lett* **28**: 555-562. [doi: 10.1016/j.patrec.2006.10.002].

Liolios, N., N. Fakotkis, G. Kokkinakis, 2001. Improved Document Skew Detection Based on Text Line Connected Component Clustering. Image Processing, 2001. Proceedings. 2001 International Conference on. IEEE. Thessaloniki, p.1098-1101. [doi: 10.1109/ICIP.2001.959241].

Lu, S., C.L. Tan, 2007. Binarization of Badly Illuminated Document Images through Shading Estimation and Compensation. Ninth International Conference on Document Analysis and

Recognition ICDAR 2007. IEEE, p.312-316. [doi: 10.1109/ICDAR.2007.4378723].

Lu, Y., C.L. Tan, 2003. A nearest-neighbor chain based approach to skew estimation in document images *Pattern Recogn Lett* **24**: 2315-2323. [doi: 10.1016/S0167-8655(03)00057-6].

Modi, N.D., C.K. Modi, 2011. Skew Correction for Vehicle License Plates using Principal Component of Harris. IEEE. Katra, Jammu, p.339-343. [doi: 10.1109/CSNT.2011.77].

Otsu, N., 1979. A Thresholding Selection Method from Gray-scale Histogram *IEEE Trans Syst Man Cybern* **9**(1): 62-66.

Pan, R., X. Ma, L. Wang, 2010. An Efficient Method for Skew Correction of License Plate. 2010 Second International Workshop on Education Technology and Computer Science. IEEE, p.90-93. [doi: 10.1109/ETCS.2010.14].

Postl, W., 1986. Detection of linear oblique structures and skew scan in digitized documents. Proc. 8th International Conf. on Pattern Recognition, Paris, France, p. 687-689.

Sauvola, J., M. Pietikainen, 2000. Adaptive document image binarization *Pattern Recognition* **33**(2): 225-236. [doi: 10.1016/S0031-3203(99)00055-2].

Wen, C.Y., C.C. Yu, Z.D. Hun, 2002. A 3D transformation to improve the legibility of license plate numbers *Journal of Forensic Sciences* **47**(3): 578-585.

Wu, G., S. Cheng, M. Ao, H. Lei, 2008. Slant Correction of Vehicle License Plate Based on Feature Point and Principal Component Analysis. Computer Science and Software Engineering, 2008 International Conference on. IEEE. Wuhan, Hubei, p.487-490. [doi: 10.1109/CSSE.2008.1648].

Xu, G., Z. Zhang, 1996. Epipolar geometry in stereo, motion, and object recognition: a unified approach., Kluwer Academic Publishers.p.95-102

Zhang, Z.H., S.H. Yin, 2008. Hough Transform and its Application in Vehicle License Plate Tilt Correction *Computer and Information Science* **1**: 116-120. [doi: 10.5539/cis.v1n3P116].