License plate recognition system based on principal component analysis and one-against-one multi-class support vector machine

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Abstract. The license plate number which identifies the original registered place of the vehicle, as well as the usage of each vehicle which belongs to a private entity, a government vehicle, and a commercial vehicle, is identified in this work. Vehicle plate detection by a camera that mounted on parking gate. Detection process starts with collecting data using the camera. This work consists two important parts, namely image processing and classification system, respectively. In the image processing, the plate image capture by the camera is extracted to the feature space which will use as the input to the classification system. The classification system is then will identify the extracted input to the plat recognition identification. The Fast Fourier Transform (FFT) and Support Vector Machine (SVM) are applied as feature extraction technique and classification methods, respectively. The results of the training and testing phase are 80% and 66%, respectively.

Keyword: Plate number, Fast Fourier Transform (FFT), Support Vector Machines (SVMs)

1. Introduction

Number Plates have been used for years as a way for an authority to identify and differentiate vehicles on the road. Every vehicle has a given unique number plate given by a governing body. In Indonesia, this number plate can be used to identify the original registered place of said vehicle, as well as the usage of each vehicle. The background color of the number plate indicates whether the vehicle belongs to a private entity, a government vehicle, and a commercial vehicle. Each feature on an Indonesian number plate is dictated by law [1].

Indonesian license plate consists of two rows that shows various information of a given vehicle. The first row from left to right consists of a region code, identification number, and an area letter. The second row consists of the month and year expiry. The region code usually consists of 1-2 letters that correspond to the region in which said vehicle was registered. The identification number consists of 1-4 numbers given by the police department. The area code usually consists of up to 3 letters that may further identify which specific are said vehicle are registered from. The month and year of expiry on the second row both consist of two number indicating the month and year of expiry [2].

These number plate features can be used to assist authorities to identify various information of a vehicle. An identification system using computer vision as well as machine learning could help authorities identify and decipher information on a number plate. Such systems has been developed using various method of image recognition and intelligent system.
Aris Budianto, Teguh Bharata Adji, and Rudy Hartanto in their work on license plate recognition used Connected Component and Support Vector Machine to identify if a license plate is detected on a video stream. Their work can identify whether or not a license plate is present on a video stream with an overall accuracy of 78% [3]. Silviana Utari, Tjut Awaliyah, and Irma Anggraeni from Pakuan University used Principal Component Analysis and Support Vector Machine to detect various character on images of license plate. Their work detected multiple characters from the images with an overall accuracy of 77.46% to 77.77% according to the type of plate [4].

In this paper, support vector machines one agains one multiclass classification (SVMs), which is a relatively new machine learning technique, are introduced and proposed for licence plat number recognition system. SVM is simple and very powerful method. This is due to optimization and generalization solution [5]. The proposed SVMs-based licence plat recognition system used Fast Fourier Transform (FFT) as input. The effectiveness of the proposed system is evaluated experimentally based on support vector machine. The results show that the proposed technique has produced the good level of accuracy.

2. Proposed System

The proposed system consist of two main parts in detecting various characters on images of license plate, namely image processing and classifier, respectively. Image processing is a process of manipulated image in such a way that certain features can be extracted and made ready for classifying. The second part is a classifier in which said image into, after those necessary features has been extracted can be identified or classified into. These steps are necessary in order for a system being able to identify.

The image processing proposed in this work is applied blob detection to detect areas of interest and segment it them into bounding boxes in which said image would be cropped into [6]. Next, a gaussian filter would be added to the cropped image to reduce noise[7]. The cropped image then would go trough edge detection using Canny method. Fast Fourier Transform is then applied to turn the image into matrix in frequency domain. Principal Component Analysis is then applied in order to extract the FFT matrix resulted from the previous matrix into its four selected components. Meanwhile the classifier used in this work is Support Vector Machine.

![Flow Chart Indonesian Lisence Plate Recognition System](image)

2.1. Image Processing

The blob detection technique used is Maximally Stable External Region (MSER). MSER detects area of interest on the image by thresholding gray level of an image and grouping them [8]. The area with high intensity then would be marked as area of interest. Bounding boxes then would be put on those areas. The bounding box information then will be used to crop the image to only include those area of interest.
Next, a Gaussian filter is then applied into the cropped image. A gaussian filter would reduce the noise on an image by smoothing said image. Gaussian filter took account the neighboring pixels and outputs a weighted average for said pixel. It then compares it to the value of the central pixel [7]. The Gaussian filter formulated as follow [9]:

\[
G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}
\]

(1)

where \( x \) is the distance from the origin in the horizontal axis, \( y \) is the distance from the origin in the vertical axis, and \( \sigma \) is the standard deviation of the Gaussian distribution. After the filter is applied, the cropped image then would go through canny edge detection method where using the gradient of the image, an edge can be detected. Canny edge detection uses first-order directional Gaussian derivative to find an edge on a 2D image [9].

Fast Fourier Transform (FFT) then applied to said image to turn the image from a spatial domain into a frequency domain. FFT works by using a Discrete Fourier Transform algorithm but it requires number of points \( N \) is a power of two [10].

\[
F(k, l) = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} f(i,j) e^{-2\pi i (k/\tilde{N} + l/\tilde{M})}
\]

(2)

The output will be various frequency in matrix that that can be extracted by Principle Component Analysis (PCA). Principal Component Analysis proposed uses orthogonal transformation to convert the frequency matrix into four of its principal components that is linearly uncorrelated [11]. Those principal components output is then applied as input the classifier to identify.

2.2. Classifier

The classifier proposed is SVM or Support Vector Machine which is a linear model used for classification. SVM was originally a binary classification technique but was modified to be able to handle multiclass problems. SVM multiclass type proposed is a one-against-one type to handle the multiclass nature of differentiating alpha-numerical characters [9].

SVM is a machine learning technique, which is based on statistical theory. SVM maps non-linearly training data into higher-dimensional space through the kernel function. There are three important aspects of SVM, discrimination hyperplane, optimization via Lagrange multipliers and kernel function. The first two aspects are derived from linear separable form of classification (with no possibility of misclassification), whereas the third aspect deals with non-separable data classification, which may introduce any misclassification data[12].
In this case the SVM training always seeks a global optimizes solution and avoids over-fitting, so it has ability to deal with a large number of features. Thus, in the linear separable case, there exists a separating hyperplane whose function is;

\[ w \cdot x + b = 0 \quad w \in \mathbb{R}^N, b \in \mathbb{R} \quad (3) \]

For optimized linear division a hyperplane is constructed to separate the two classes [10]. which implies

\[ y_i(w \cdot x + b = 0) \geq 1, i = 1, \ldots, N \quad (4) \]

By minimizing \( ||w|| \) subject to this constrain, the SVM approach tries to find a unique separating hyperplane. Here \( ||w|| \) is the Euclidean norm of \( w \), and the distance between the hyperplane and the nearest data points of each class is \( 1/||w|| \). By introducing Lagrange multiplier \( \alpha_i \), the SVM training procedure amounts to solving a convex quadratic problem (QP). The solution is a unique globally optimization result, which has following properties

\[ w = \sum_i^{N} \alpha_i y_i x_i \quad (5) \]

provided \( \alpha_i \) is not equal to zero, \( x_i \) is called the support vectors. When SVM is trained, a decision can be obtained by comparing each new example \( x \) with only the support vector \( \{x_i\}, i \in SV \);

\[ y = \text{sign} \left( \sum_{i \in SV} \alpha_i y_i \left( x \cdot x_i^T \right) + b \right) \quad (6) \]

In many practical situations, the non-linear separable case is often considered incorporation to linear separable case. Fig. 3 shows non-linear separable data with introduced miss-classification data

![SVM with Linear separable data.](image)

In the case of a non-linear separable problem, SVM performs a non-linear mapping of the input vector \( x \) from the input space into a higher dimensional feature space, where the mapping data is determined by kernel function. Four typical kernel functions often used in data classification are listed in Table 1.

| Kernel       | \( K(x, x_i) \)                               |
|--------------|---------------------------------------------|
| Linear       | \( x^T x_i \)                               |
| Polynomial   | \( (x^T x_i + 1)^d \)                       |
| Gaussian     | \( \exp(-||x-x_i||^2/2\sigma^2) \)           |
| RBF          |                                             |

The choice of the kernel function depends on the data. The different kernel function can be selected to obtain an optimal classification result. The choice of the degree in polynomial kernel and choice of \( \sigma \) in the Gaussian RBF kernel also depends on the data[13].
2.3 Multi-class Classification SVM

SVMs were originally designed for binary classification. However, it can be extended to multi-class classification. The extension of the SVMs to solve the problem containing more than two classes is important. There are also some advantages applying Multi-class classification SVMs, not only improve the error rate in the learning and testing set process but also faster adaptation and classification times. There have been many methods proposed to solve multi-classification problem, one of the methods that used in this work is one-against-one. This method is based on the binary classification problem. Multi-class classification one-against-one constructs $k(k-2)/2$ classifiers where each one is trained on the data from a combination of two classifications. For the training data from the $i$th and $j$th classes, that will solve using binary classification. For testing data the following strategy can be used; if binary classification says, $x$ is in the class $i$th, then vote for class $i$ is add by one. Otherwise, the $j$th increased by one. The decision goes to the largest vote, this method called ‘Max win’. In the case two classes have same vote, the decision will go to the smallest index [14].

3. Experimental Result

A. Experiment setup
The experiment performed with multiple different license plate images taken from a camera. Both the image processing and classifier would be run through MATLAB. Both the training and testing images are obtained by taking pictures of real license plate with a camera.

B. Image Processing
A license plate image with the size of 300x300 pixel is passed into a MSER detector to detect areas of interest on the image. The MSER detector uses an area threshold of 255 to 600 pixels and geometric properties of the area to predict such area of interest.

![MSER regions](image1.png)

![After Removing Non-Test Regions Based On Geometric Properties](image2.png)

Bounding boxes around the MSER regions, then would be added to mark the cropping area.

![Bounding boxes](image3.png)

A Gaussian filter with a sigma value of 2 then added to reduce noise. The image then would go through edge detection using canny and be passed through FFT so that the said image transformed into a matrix in frequency domain instead of a special one. Next, PCA then would be applied to break down the frequency domain matrix into 4 of its principal components in which it is linearly un-correlated.
C. Multi-class Classification

Due to the alphanumerical nature of license plate character to be detected, the classifier needs to differentiate 36 different characters even though SVM is originally designed as a binary classifier. The one-against-one and one-against-all method is used to circumvent this problem. Due to the high computational requirements needed to run the one-against-all method, the one-against-one method is used in this experiment.

D. Training and Classification performance

The SVM-based binary classification is applied to perform speaker identification system. Polynomial kernel with a degree of 36 and a penalty term C of $10^7$ are used in this experiment. Moreover, the proposed system is used to classify 36 characters, which consist of 26-letters and 10-numbers. The training data consists of 504 character images and the testing data consist of 5 license plate image.

The training time required 31 minutes to fully complete. In the training phase, Licences plate recognition system achieved a classification rate of 80% of the training accuracy. Testing phase is carried out using 5 other license plate image in order to evaluate the effectiveness of the proposed system. The test result of the licences plate achieved an average accuracy 66%.

3.1. A part

| No. | Plate   | Result |
|-----|---------|--------|
| 1   | ![Plate1](image1) | B 10 QD 08·20 | 80% |
| 2   | ![Plate2](image2) | B 1116 SJD 12·20 | 62.5% |
| 3   | ![Plate3](image3) | B 5073 T 01·24 | 50% |
| 4   | ![Plate4](image4) | B 1434 VML 01·24 | 75% |
4. Conclusion

The automatic plat number classification system has been proposed and developed in this paper. This technique develops image processing and classification system. The Fast Fourier Technique (FFT and Support Vector Machine (SVM) are applied in this system. The accuracy of the SVM based plate number identification system has good result which has the training and testing phases are 80% and 66%, respectively. It was also clear, from our computer simulation results, that the proposed method has good result of plate number identification.

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