Intelligent License Plate Recognition System based on Multi-Feature and Support Vector Machine
Nature of frontal and back of Malaysian car images
90% is standard license plates
10% is in special format
Definitions: Car plate recognition, plate number recognition, vision plate, automatic number plate recognition and etc. (Hofman, Y., 2004)

Most of the research has shown that classification rate was higher than detection rate. Therefore, license plate detection is a crucial research because it correlates with problem statements. Some research have been conducted world wide.

<table>
<thead>
<tr>
<th>Year</th>
<th>Designer</th>
<th>License format</th>
<th>Techniques</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>Hans. A. Herg et. al</td>
<td>Dutch</td>
<td>Histogram, Hotelling Transformation</td>
<td>98.7 %</td>
</tr>
<tr>
<td>1999</td>
<td>T.Naito et..al.</td>
<td>Japanese</td>
<td>Templat matching</td>
<td>97%</td>
</tr>
<tr>
<td>2003</td>
<td>Shen-Zen Whang and His Jian Lee</td>
<td>Taiwanese</td>
<td>Sobel, discriminant function</td>
<td>96.60%</td>
</tr>
<tr>
<td>2003</td>
<td>M.Safrz et.al</td>
<td>Arabic</td>
<td>Sobel, templat matching</td>
<td>95.24%</td>
</tr>
<tr>
<td>2004</td>
<td>Tomohiko Nukano et.al</td>
<td>Malaysian</td>
<td>NN Threshold</td>
<td>87.3%</td>
</tr>
</tbody>
</table>
LPR system lifecycle

Frame Grabber

Camera

Database

Software

Input/output device

End\Start

Image Classification

Feature Normalization

Feature Extraction

Character Segmentation

Image Capturing

Image Enhancement

Object Detection
The Framework Proposal by applying either Cluster Run Length Smoothing Algorithm or Proposed Threshold and multi-features based on MLP-BP and SVM.
Blob agglomeration

- $|H_{current} - H'| \leq (U+V) \times H_{current}$
- $|minY_{current} - Y'| \leq (U+V) \times H_{current}$
Prior LPR results (Siti Norul Huda et al., 2006)

<table>
<thead>
<tr>
<th></th>
<th>threshold</th>
<th>average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>fixed (130)</td>
<td>manual</td>
</tr>
<tr>
<td>total sample data</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>no of correct</td>
<td>803</td>
<td>919</td>
</tr>
<tr>
<td>correct percentage</td>
<td>80.3 %</td>
<td>91.9 %</td>
</tr>
<tr>
<td>segmentation error</td>
<td>121</td>
<td>10</td>
</tr>
<tr>
<td>Segmentation error percentage</td>
<td>61.4 %</td>
<td>12.3 %</td>
</tr>
<tr>
<td>classification error</td>
<td>76</td>
<td>71</td>
</tr>
<tr>
<td>Classification error percentage</td>
<td>38.6 %</td>
<td>87.7 %</td>
</tr>
</tbody>
</table>

Abdullah, S. N. H. S.; Khalid, M.; Yusof, R. & Omar, K.
License Plate Recognition Using Multi-classifier and Neural Network 2nd IEEE International Conference on Information & Communication Technologies: from Theory to Applications (ICTTA'06), 2006, 659-660. (CD Proceedings)
Prior result: Error analysis

Why?
1. Connected characters
2. Symbol or sign on LP.
3. Cannot distinguish slanting characters, fails to detect similar look characters. Ex: 3->8, B->8, 6->G or 4->A etc.
4. This problem occurs on 2 line LP.
Other issues

- Illumination often distracts determining object from the source image (Petrou and Bosdogianni, 2000).
- Improper segmentation technique contributes reduction in recognition rates (Lee et al., 2004).
- Otsu Thresholding technique applied statistical approach in calculating acceptable threshold value based on histogram projection. It only suitable in solving threshold localization process which makes it less accurate on globalization process.
- Therefore, an alternative method is required to improve the segmentation process.
Three main objectives:

1. To develop an enhance license plate detection (LPD),
2. To develop an alternative feature extraction and compare it with different classification techniques
3. To determine adaptive threshold value for image segmentation.
Hence, this research consists of three contributions:

1. **Cluster Run Length Smoothing Algorithm for Object Detection**
2. **Enhance Geometry Feature Topological Analysis for feature extraction**
3. **Determining Adaptive Threshold for Image Segmentation**
First contribution
Objective: To develop an enhanced license plate detection (LPD)

Cluster Run Length Smoothing Algorithm for Object Detection

Abdullah, S. N. H. S.; Khalid, M.; Yusof, R. & Omar, K.
Cluster Run Length Smoothing Algorithm (CRLSA) for License Plate Detection. Proceedings of the 25th International Multi-Conference on Artificial Intelligence and Applications (IASTED 2007), 2007, 323-328

Run Length Smoothing Algorithm (RLSA) has been used widely in optical character recognition (OCR) process especially in document analysis [Strouthopoulos et al. 1999].

Normally RLSA is only applied after horizontal or vertical projection to recognize the block segmentation and the transformation are only concerned on two dimensional image (black – white) [Gatos & Papamarkos, 2001]

Strouthopoulos, C.; Papamarkos, N. & Chamzas, C.
PLA using RLSA and a neural network
*Engineering Applications of Artificial Intelligence, 1999*, 12, 119-138

Gatos, B. & Papamarkos, N.
Applying fast segmentation techniques at a binary image represented by a set of non-overlapping blocks
### TABLE I
PREVIOUS RESULTS USING DIFFERENT APPROACHES IN OBJECT DETECTION PHASE.

<table>
<thead>
<tr>
<th>Techniques</th>
<th>Accuracy</th>
<th>Designed by</th>
<th>License Background color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clustering</td>
<td>89.63% - 97.78%</td>
<td>[5]</td>
<td>black</td>
</tr>
<tr>
<td>Square or contour</td>
<td>nil</td>
<td>[23]</td>
<td>yellow</td>
</tr>
<tr>
<td>Morphology</td>
<td>98.38%</td>
<td>[1]</td>
<td>yellow</td>
</tr>
<tr>
<td>Hough Transform</td>
<td>92.40%</td>
<td>[2]</td>
<td>yellow</td>
</tr>
<tr>
<td>Radon Transform</td>
<td>96.20%</td>
<td>[22]</td>
<td>yellow</td>
</tr>
</tbody>
</table>

[1] Han, P.; Han, W.; Wang, D. & Zhai, Y. Car License Plate feature extraction and recognition based on multistage classifier. *International conference on Machine Learning and Cybernetics*, 2003, 1, 128-13
Proposed Method: Cluster Run Length Smoothing Algorithm

Cluster Run Length Smoothing Algorithm (CRLSA)

Modified Clustering Technique (MCT)

1. Cluster blobs
2. Sort clusters' members
3. Check cluster
4. Set winner cluster index(es)

Checking Technique (CT)

1a. Run RGB Convolution Process
1b. Check RLSA1
1c. Run Threshold Value One (TV1) Process

Pass

Fail

Check RLSA2
The proposed technique where:

- The CT sub-module comprises three main processes:
  
  (a) Run RGB Convolution (RGBC) and Check the First Run Length Smoothing Algorithm (RLSA1),
  
  (b) Run Threshold Value One (TV1) and Check the Second RLSA (RLSA2),
  
  (c) Get winner cluster indexes.
### TABLE III
**Experiment results of different LPD techniques.**

<table>
<thead>
<tr>
<th>Malaysian license plate</th>
<th>CLUSTERING</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>standard</td>
<td>Special</td>
<td>standard</td>
<td>Special</td>
<td>standard</td>
</tr>
<tr>
<td>Non detect</td>
<td>72</td>
<td>8</td>
<td>44</td>
<td>3</td>
<td>916</td>
</tr>
<tr>
<td>Detect</td>
<td>1163</td>
<td>12</td>
<td>1191</td>
<td>17</td>
<td>319</td>
</tr>
<tr>
<td>Total image</td>
<td>1235</td>
<td>20</td>
<td>1235</td>
<td>20</td>
<td>1235</td>
</tr>
<tr>
<td>Detect %</td>
<td>0.941700405</td>
<td>0.6</td>
<td>0.96437247</td>
<td>0.85</td>
<td>0.258299595</td>
</tr>
<tr>
<td>Non detect %</td>
<td>0.058299595</td>
<td>0.4</td>
<td>0.03562753</td>
<td>0.15</td>
<td>0.741700405</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Malaysian license plate</th>
<th>MORPHOLOGICAL</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>standard</td>
<td>Special</td>
<td>standard</td>
<td>Special</td>
<td>standard</td>
</tr>
<tr>
<td>Non detect</td>
<td>571</td>
<td>3</td>
<td>232</td>
<td>5</td>
<td>340</td>
</tr>
<tr>
<td>Detect</td>
<td>692</td>
<td>17</td>
<td>1050</td>
<td>15</td>
<td>956</td>
</tr>
<tr>
<td>Total image</td>
<td>1263</td>
<td>20</td>
<td>1282</td>
<td>20</td>
<td>1296</td>
</tr>
<tr>
<td>Detect %</td>
<td>0.547901821</td>
<td>0.85</td>
<td>0.819032761</td>
<td>0.75</td>
<td>0.737654321</td>
</tr>
<tr>
<td>Non detect %</td>
<td>0.452098179</td>
<td>0.15</td>
<td>0.180967239</td>
<td>0.25</td>
<td>0.262345679</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Malaysian license plate</th>
<th>HOUGH TRANSFORM</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>standard</td>
<td>Special</td>
<td>standard</td>
<td>Special</td>
<td></td>
</tr>
<tr>
<td>Non detect</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detect</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total image</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detect %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non detect %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Malaysian license plate</th>
<th>RADON TRANSFORM</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>standard</td>
<td>Special</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non detect</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detect</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total image</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detect %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non detect %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Comparisons of license plate detection techniques

- Cluster
- CRLSA
- Square/Contour
- Morphology
- Hough Transform
- Radon Transform

Results

Accuracy

0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

Datasets
- Special
- Standard
Benefits:
- Even though the original image of the back or frontal car is having fusion problems such as illumination, blur, rotated, skewed, CRLSA can still successfully detect the locations of the license plate.
- CRLSA is able to detect the precise location of the license plate even though the license plates’ characters are connected or too close to each other.

Limitations:
- Processing time. RGB convolution with an edge detector is time consuming.
- Memory allocation. Quite often memory leaks when using RGB convolution because it requires high storage.

Future Works:
- Instead of using RGB Convolution using individual pixels, why not apply feature vectors.
- Introduce new algorithm for adaptive thresholding.
Second contribution
Objective 2: To develop an alternative feature extraction and compare it with different classification techniques

Enhance Geometry Feature Topological Analysis for feature extraction
Third contribution
Objective 3: To determine adaptive threshold value for image segmentation.

Determining Adaptive Threshold for Image Segmentation
State of the art

- Thresholding is a straightforward technique in transforming a gray scale image into a binary image that can facilitate the segmentation process. If $I$ is the input image, the value of the output image $\phi$, at position $(x, y)$, given a threshold $\Omega$, is:

$$
\phi(x, y) = \begin{cases} 
1 & \text{if } I(x, y) \geq \Omega, \\
0 & \text{else } I(x, y) < \Omega.
\end{cases}
$$
Other methods for calculating the threshold namely the method of local entropy, proposed by Shanon [10] and Otsu[11].

Otsu Thresholding is a favourite optimization thresholding method (Siah, 2000; Shapiro et al., 2006; Kahraman et al., 2003). It adopts primitive mean, \( \mu \), (Equation 2.8a) and variance, \( \sigma^2 \), (Equation 2.8b) calculations from histogram distributions, \( \rho_i \), of an image, \( \rho \) where \( i \) is from 0 until \( g \) of gray level values.

\[
\mu \equiv \frac{\sum_{i=0}^{g} i \rho_i}{\sum_{i=0}^{g} \rho_i} \quad \text{(2.8a)}
\]

\[
\sigma^2_i = \frac{\sum_{i=0}^{g} (i - \mu)^2 \rho_i}{\sum_{i=0}^{g} \rho_i} \quad \text{(2.8b)}
\]

[10] Yan, C.; Sang, N. & Zhang, T. Local entropy-based transition region extraction and thresholding *Pattern Recognition Letters*, **2003**, 24, 2935 - 2941

The proposed threshold (PT) consists of three steps:
(1) Identify the type of image according to its histogram,
(2) Calculation of blob distributions for various threshold values
(3) Selection of thresholds.
Identify the type of image according to its histogram.
2 Calculation of blob distributions for various threshold values

(a) Total of objects versus threshold value for ‘ADG676’ image
(b) Total of objects versus threshold value for ‘ACP92’ image
(c) Total of objects versus threshold value for ‘ACN65’ image

Figure 4.14 Graphs of the total of objects, $\Omega_{0,1,...,k-1}$, versus the threshold value, $(0,1,...,k-1)$, are the range of 10 from 0 to 255 for (a) ‘ADG676’, (b) ‘ACP92’, and (b) ‘ACN65’ image.
### 3 Selection of thresholds

\[
\Omega_{\text{Select}(0,1,...,q-1)} = \begin{cases} 
\Omega_{\text{Peak}(0,1,...,p-1)} : (\Omega(q-1) = 130) & \text{if medium} \\
\Omega_{\text{Peak}(0,1,...,p-1)} & \text{else (fair ∪ dark)}
\end{cases}
\]
Examples on screen shot LPR using Heuristic Threshold
Advantages:

- The proposed framework has significantly increased the LPD and LPS accuracy rate and it can give an alternative way to the LPR system.
- The proposed threshold gives an alternative solution to obtain better threshold value(s) based on rule of thumb.
- The proposed threshold equally treats all global and local maximum values of the probability density. Unlike Otsu, which only selects the global maximum value as the best threshold value which might not necessarily be true.

Disadvantages

- The proposed framework is prone to detect unnecessary blobs and signs together with the license plate characters.
- Still not robust enough for real time applications due to overall LPR processing time because it suggests a selection of threshold values.
Future works

- Apply two dimensional blob distributions and apply mean and standard deviations to select only one threshold values.
- Apply local entropy to select the best peaks of the blob distributions.