A SISR-Aided License Plate Recognition System

Presenter: Xing Yao

Advisor: Prof. Sina Farsiu

Biomedical Engineering Department，Duke University

Background

Issue Locate:

Super-resolution for vehicle license plates (VLP-SR) is helpful to identify the target vehicles from the low-resolution (LR) images or videos, which plays a vital role in parking lot management, traffic surveillance, finding the stolen vehicles, and so on.

Project Proposal:

To achieve the LPR in the LR condition, design a ***SISR-Aided LPR pipeline*** based on the ***Efficient Sub-Pixel Convolutional Neural Network.***

*

*Y. Zou, etc, "Semantic Super-resolution for Extremely Low-resolution Vehicle License Plate," *ICASSP 2019 - 2019 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, Brighton, United Kingdom, 2019, pp. 3772-3776, doi: 10.1109/ICASSP.2019.8682507.

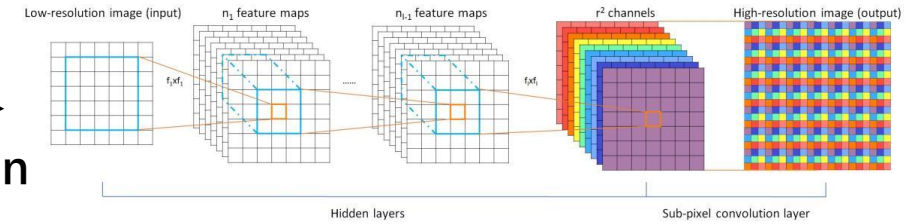
ESPCN-LPR Pipeline

LR Input

Segmentation

Tilt Correction

Efficient Sub-Pixel Convolutional Neural Network



HR Output

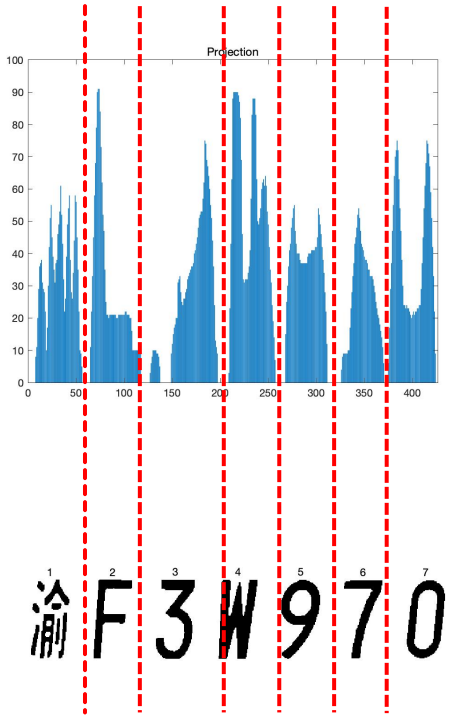
Binarization

Morphology Process

Open Operation

Remove Boundary

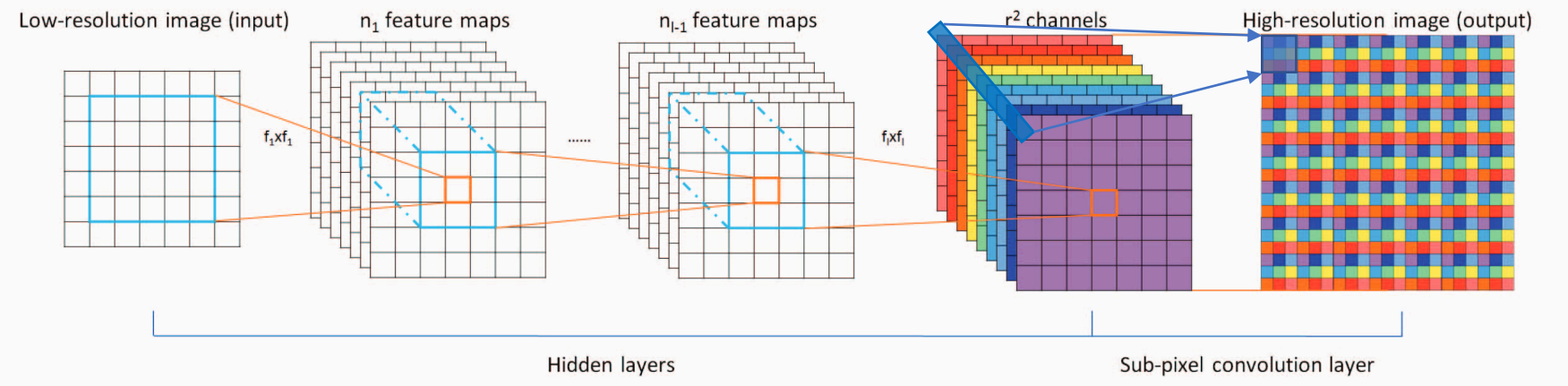
Words Split



Mask Based LPR

License Number Detection: 渝F3W970

Efficient Sub-Pixel Convolutional Neural Network*



$$f^1(\mathbf{I}^{LR}; W_1, b_1) = \phi\left(W_1 * \mathbf{I}^{LR} + b_1\right), \quad (1)$$

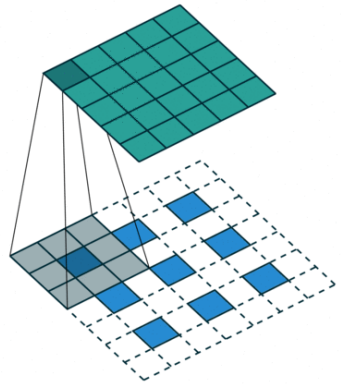
$$f^l(\mathbf{I}^{LR}; W_{1:l}, b_{1:l}) = \phi\left(W_l * f^{l-1}\left(\mathbf{I}^{LR}\right) + b_l\right), \quad (2)$$

$$\mathbf{I}^{SR} = f^L(\mathbf{I}^{LR}) = \mathcal{PS}\left(W_L * f^{L-1}(\mathbf{I}^{LR}) + b_L\right), \quad (3)$$

$$\mathcal{PS}(T)_{x,y,c} = T_{\lfloor x/r \rfloor, \lfloor y/r \rfloor, c\cdot r\cdot \mathrm{mod}(y,r)+c\cdot \mathrm{mod}(x,r)} \quad (4)$$

$$\ell(W_{1:L}, b_{1:L}) = \frac{1}{r^2 HW} \sum_{x=1}^{rH} \sum_{x=1}^{rW} \left(\mathbf{I}^{HR}_{x,y} - f^L_{x,y}(\mathbf{I}^{LR})\right)^2 \quad (5)$$

*Padding Strides Transposed：



*Shi W, Caballero J, etc. Real-time single image and video super-resolution using an efficient sub-pixel convolutional neural network. InProceedings of the IEEE conference on computer vision and pattern recognition 2016 (pp. 187

*Dumoulin V, Visin F. A guide to convolution arithmetic for deep learning[J]. arXiv preprint arXiv:1603.07285, 2016.

ESPCN Reconstruction Results

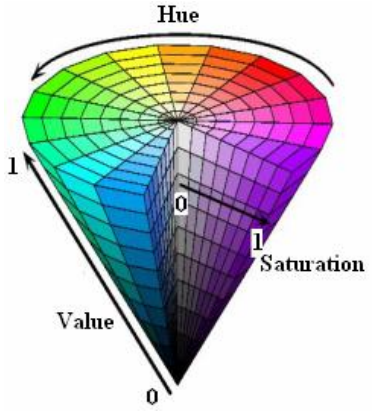
$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2$$

$$PSNR = 10 \cdot log_{10}(\frac{MAX_I^2}{MSE})$$

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + c_1)(2\sigma_{xy} + c_2)}{(\mu_x^2 + \mu_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2)}$$

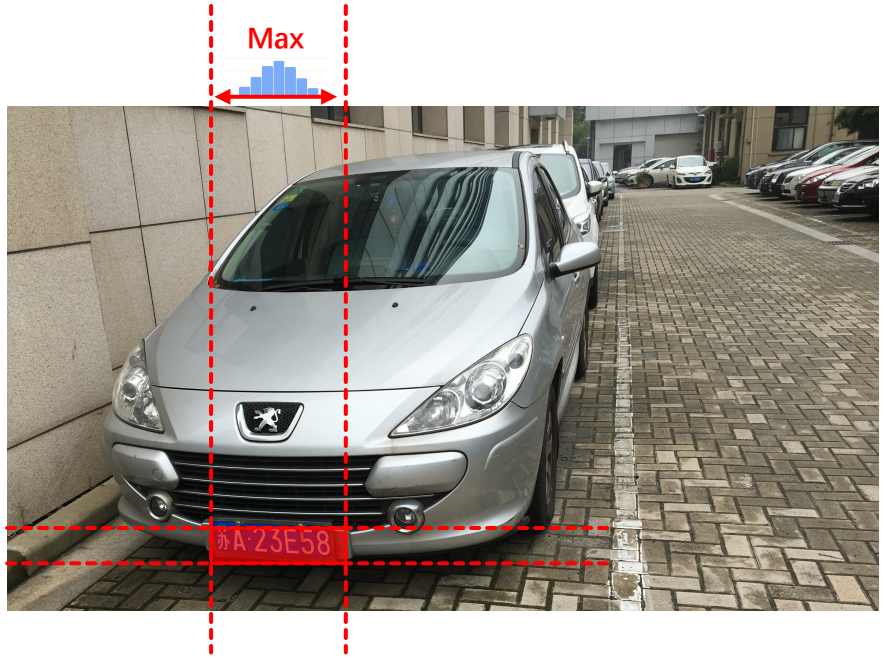
	PSNR	MSE	SSIM
Dgrade1	22.47	1102.91	0.81
ESPCN1	26.69	417.16	0.93
Dgrade2	30.20	185.95	0.93
ESPCN2	35.24	58.35	0.98
Dgrade3	27.61	337.58	0.83
ESPCN3	30.60	169.78	0.92
Dgrade4	20.35	1796.30	0.83
ESPCN4	24.45	699.96	0.94
Dgrade5	21.56	1360.10	0.82
ESPCN5	26.23	464.69	0.94
Dgrade6	21.24	1466.75	0.85
ESPCN6	27.10	383.00	0.95

License Plate Segmentation*



Blue:

$$\begin{cases} H \in [0.5, 0.667] \\ S \in [0.4, 1.000] \\ V \in [0.3, 1.000] \end{cases}$$

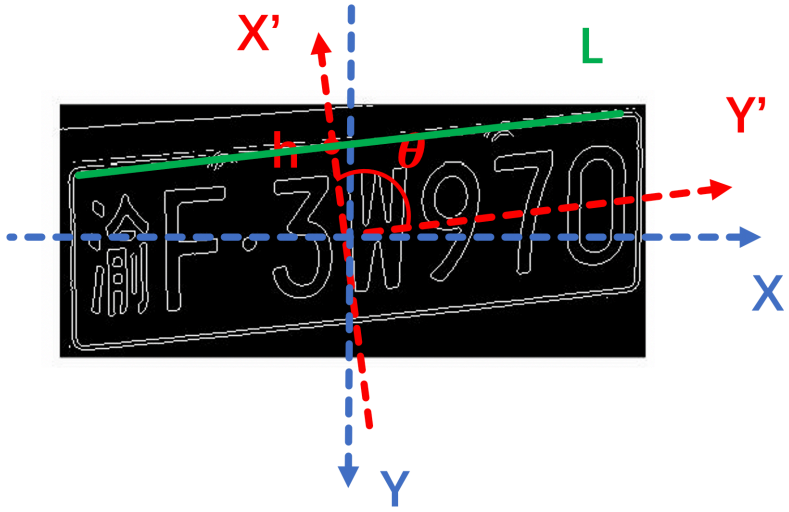


LP Segmentation Results, r = 10

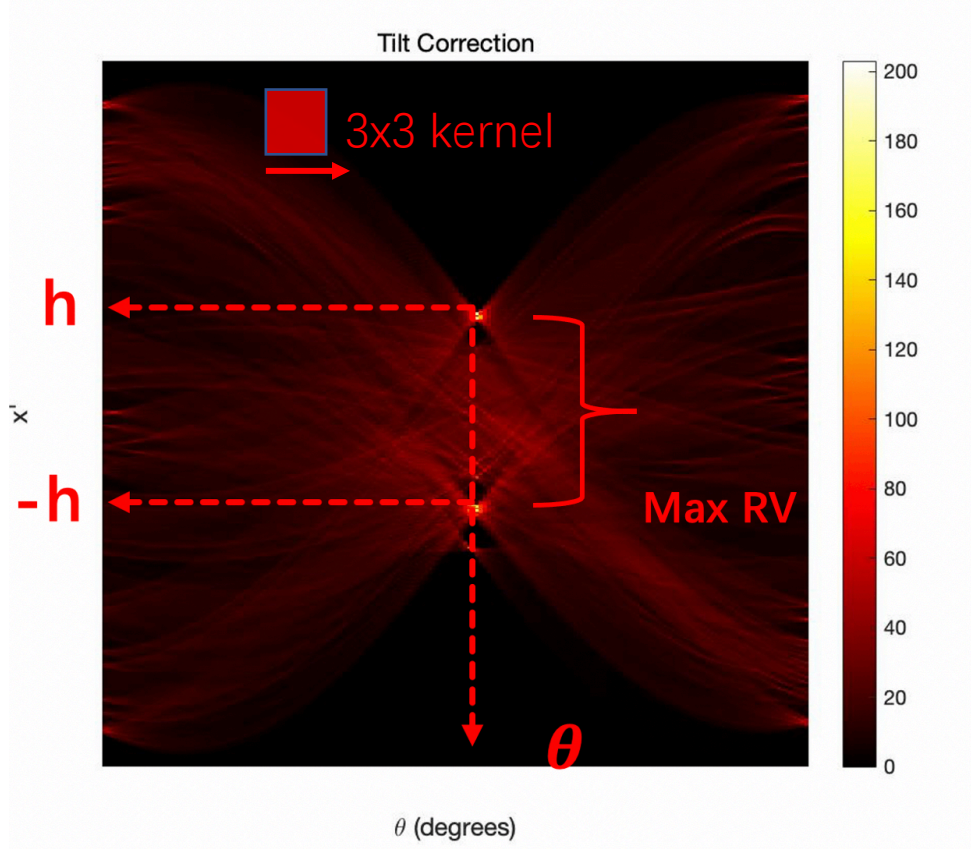
*Luo L, Sun H, Zhou W, Luo L. An efficient method of license plate location. In2009 First International Conference on Information Science and Engineering 2009 Dec 26 (pp. 770-773). IEEE.

Tilt Correction

Radon Transform*: Determine the inclination angle of the straight line by calculating the maximum projection value



$$RV = \int_L f(x,y)\,ds$$

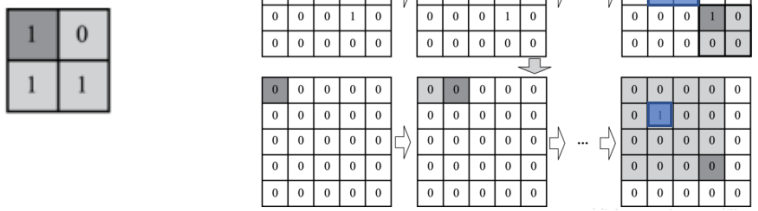


$$90° - \theta$$

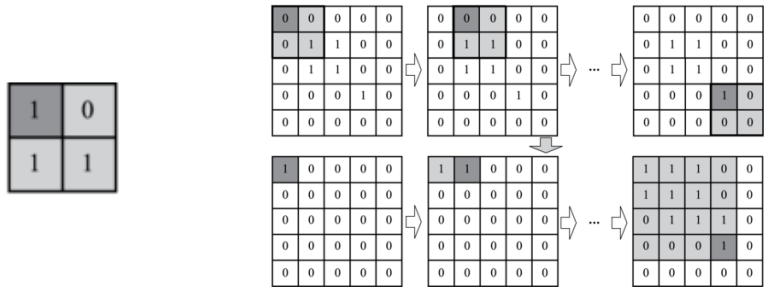
* Chen Y, Li Y, Zhang H, Tong L, Cao Y, Xue Z. Automatic power line extraction from high resolution remote sensing imagery based on an improved radon transform. Pattern Recognition. 2016 Jan 1;49:174-86.

Morphology Process*

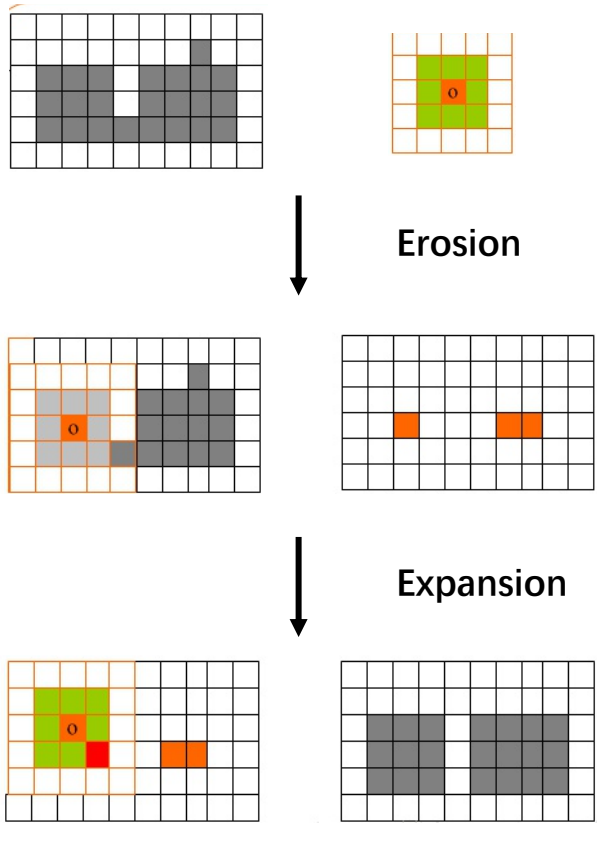
Erosion: $A \ominus B = \{X, Y \mid (B)_{x,y} \subseteq A\}$



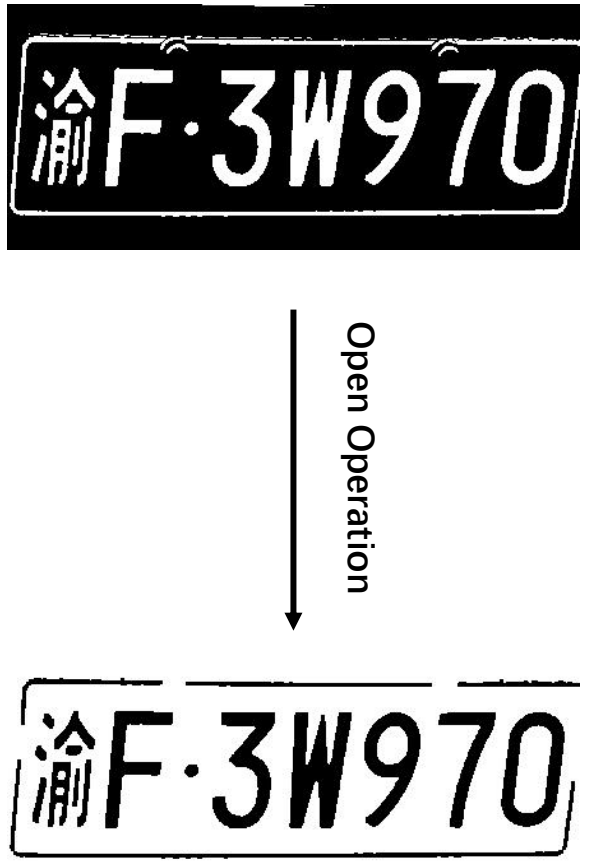
Expansion: $A \oplus B = \{X, Y \mid (B)_{x,y} \cap A \neq \phi\}$



Open Operation:



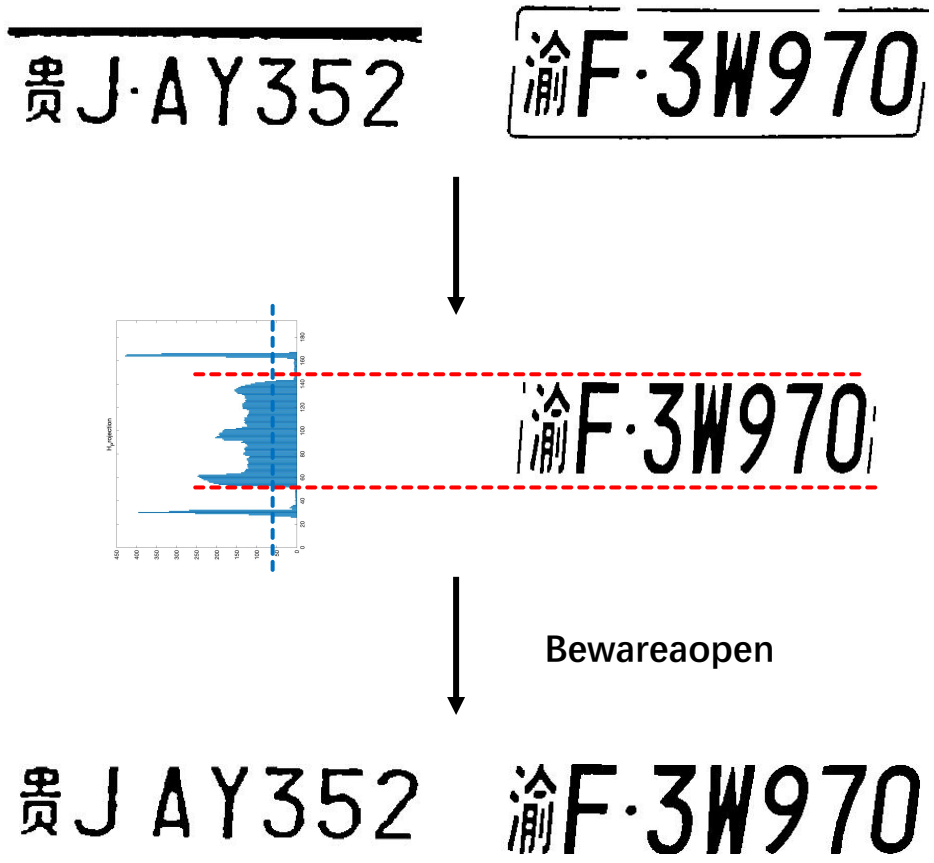
Performance:



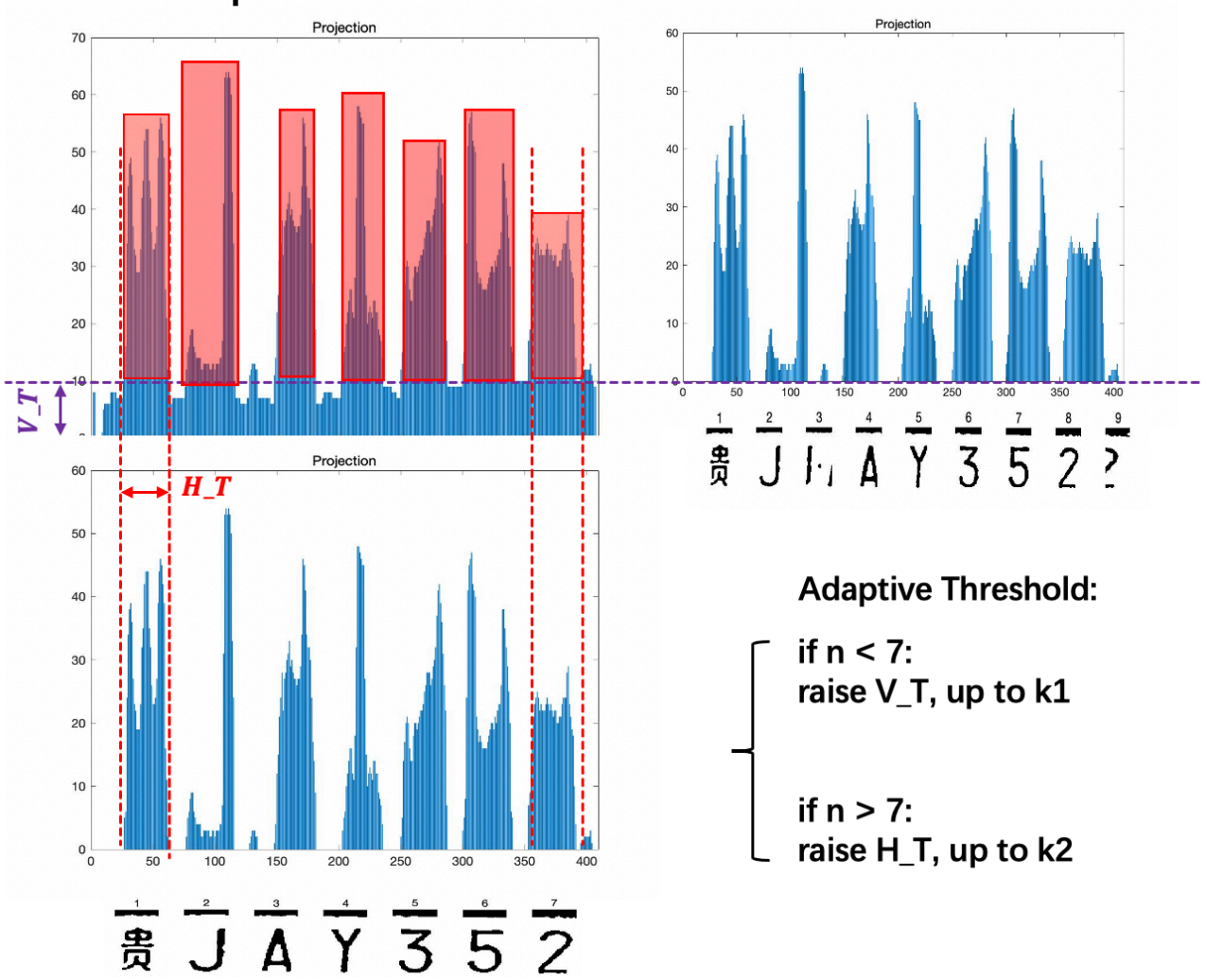
*X. Zhai, F. Benssali and S. Ramalingam, "License plate localisation based on morphological operations," *2010 11th International Conference on Control Automation Robotics & Vision*, Singapore, 2010, pp. 1128-1132, doi: 10.1109/ICARCV.2010.5707933.

Boundary Remove, Words Split*

Remove Boundary:



Words Split:



Adaptive Threshold:

- if n < 7:
  raise V_T, up to k1
- if n > 7:
  raise H_T, up to k2

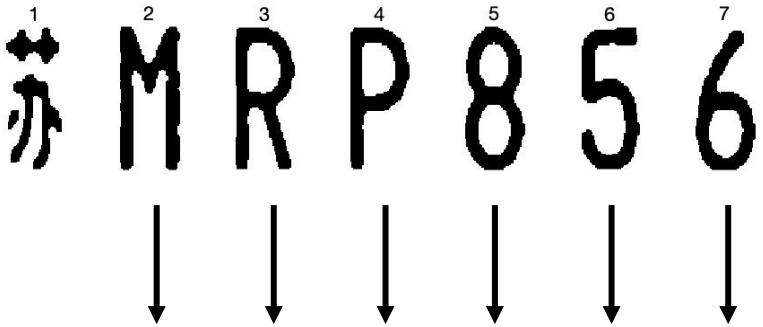
*Jagannathan J, Sherajdheen A, Deepak RM, Krishnan N. License plate character segmentation using horizontal and vertical projection with dynamic thresholding. In2013 IEEE International Conference ON Emerging Trends in Computing, Communication and Nanotechnology (ICECCN) 2013 Mar 25 (pp. 700-705). IEEE.

Characters Recognition, Results

Normalized Cross-Correlation*:

$$\gamma = \frac{\sum_{x,y}(f(x,y) - \bar{f}_{u,v})(t(x-u,y-v) - \bar{t})}{\sqrt{\sum_{x,y}(f(x,y) - \bar{f}_{u,v})^2 \sum_{x,y}(t(x-u,y-v) - \bar{t})^2}}$$

Detected Words



Masks:

Detection Accuracy for 50 LPs

	Words*	Whole
Accuracy	0.87	0.55

License Number Detection: 苏MRP856

License Number Detection: 鲁Q782AP

License Number Detection: 豫A668LA

License Number Detection: 豫A7630

License Number Detection: 苏MRH669

License Number Detection: 贵NMV8G2

*Annaby MH, Fouda YM, Rushdi MA. Improved normalized cross-correlation for defect detection in printed-circuit boards. IEEE Transactions on Semiconductor Manufacturing. 2019 Apr 12;32(2):199-211.

*Wang Y, Ban X, Chen J, Hu B, Yang X. License plate recognition based on SIFT feature. Optik. 2015 Nov 1;126(21):2895-901.

Thanks!