Automatic Number Plate Recognition for Angle and Perspective variations

CS 5100 - Artificial Intelligence (Fall 2023)
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Description and Applications

What is Number Plate Recognition?

A technique to read and decode alphanumeric letters on license plates using optical character recognition (OCR).

Steps:

- Capturing pictures/videos of moving vehicles
- Locating vehicle
- Locating and extracting the license plate
- Using OCR algorithms for character identification

Applications:

- Security
- Ticketless Parking
- Smart Cities
- Tolling and ITS

Problem Statement

- Challenges in accurately detecting number plates:
  1)Varying Lighting Conditions
  2)Angle and Perspective variations
  3)Different plate designs and fonts
  4)Speed of the vehicle
  5)Weather conditions
  6)Inaccurate camera quality

- These contribute to the main problem in number plate detection: Quality of image/video captured

Proposed Model

Consists of 3 main steps:

1) Vehicle Detection

2) License plate detection by unwarping images using Affine Transformation.

3) OCR

Vehicle Detection

- ➢ Used YOLOv2 model, reason:
  - Fast execution
  - Good precision and recall
- ➢ Tilted images have a very small LP size to vehicle bounding box ratio
- ➢ Leads to poor accuracy
- ➢ Solution: Resize the image

AFFINE TRANSFORMATION

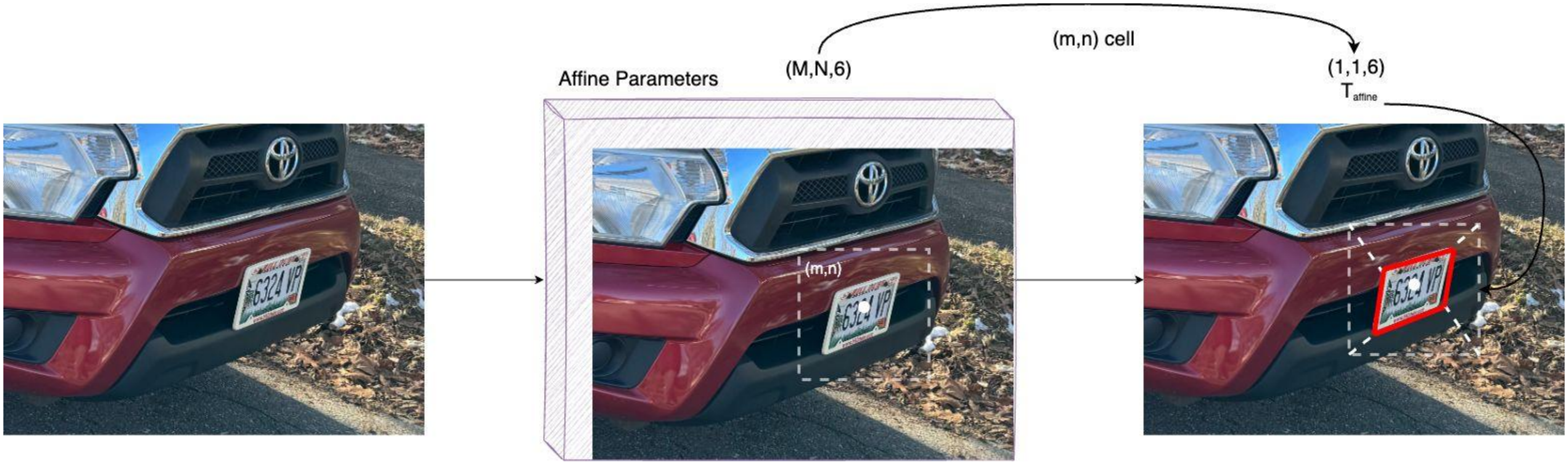
The affine transformation method is commonly employed to address geometric distortions or deformations that arise from less-ideal camera angles.

$$\begin{bmatrix} a & b \\ c & d \end{bmatrix} * \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} x' \\ y' \end{bmatrix}$$

Where, $x'=ax+by$
$y'=cx+dy$

Affine transformation functionalities are:

1. Scaling
2. Shear
3. Rotation
4. Reflection



Affine Parameters
(M,N,6)
(m,n) cell
(1,1,6)
T_{affine}
(m,n)

Loss Function

- **Aim:** Estimate *8* feature-map parameters
- **Feature-map elements-**
  - 2 representing object/not object probability (m_1, m_2)
  - 6 representing affine transformation parameters (m_3 to m_8)

- **2 parts of loss function:**

1. Probability of presence of the object at any point (x, y) - Determined by logloss function

   $f_{prob}(h, w) = logloss(I_{obj}, m_1) + logloss(1 - I_{obj}, m_2)$, where

   $$I_{obj} = \begin{cases} 1, & \text{if (h, w) has object,} \\ 0, & otherwise \end{cases}$$

2. Error between the affine transformed points of a square with (h, w) as the center w.r.t normalised actual LP corner points

   $\mathbf{f_{affine}(h, w) = \Sigma_{i = 1 \text{ to } 4} |T_{hw}(q_i) - \text{Original image points}|}$,

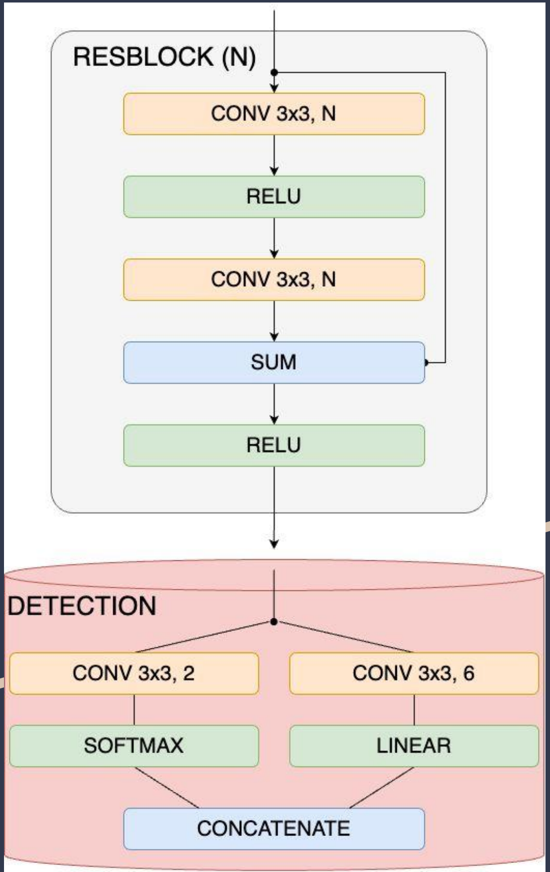
   where, q_i be the center points of unit square vertices centered at origin, and,

   $$T_{hw}(q) = \begin{bmatrix} \max(m_3, 0) & m_4 \\ m_5 & \max(m_6, 0) \end{bmatrix} . q + \begin{bmatrix} m_7 \\ m_8 \end{bmatrix}$$

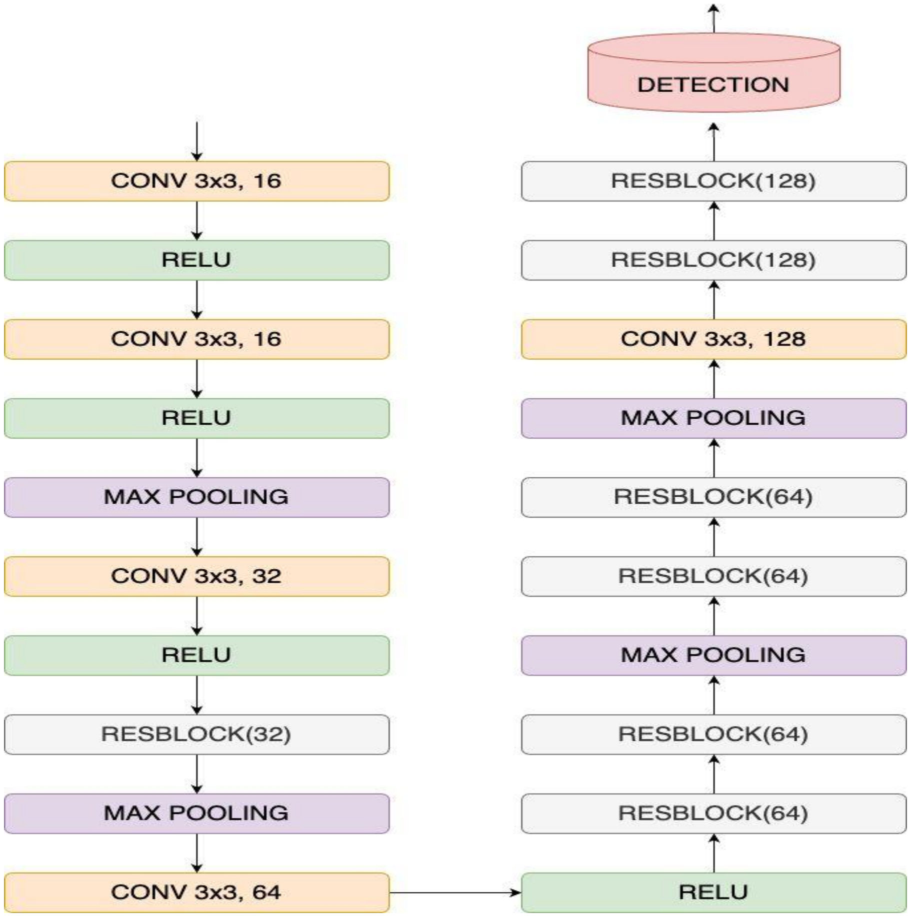
- **Final loss** $= \Sigma_{h = 1 \text{ to } H} \Sigma_{w = 1 \text{ to } W} [f_{prob}(h, w) + I_{obj}(h, w) . f_{affine}(h, w)]$,

  where, H - height of image; W - width of image

License Plate Detection



Network Architecture



Dataset and Training Details

Dataset	# images
Open ALPR (EU)	104
Open ALPR (BR)	108
AOLP	611
UFPR-ALPR	60

Training - 40% (353 images)

Validation - 40% (353 images)

Testing - 20% (177 images)

- Data augmentation steps
  - Scaling
  - Rotation
  - Translation
  - Colorspace
  - Aspect Ratio
- Performed OCR to extract number plate using YOLO model.
- Ran 10,000 iterations, took 12 hours.
- Machine specs
  - Macbook Pro M3 Pro Chip
  - 11-core CPU
  - 14-core GPU
  - 18GB Unified Memory

Evaluation Functions

$$\text{Extraction Rate} = \left(\frac{\text{Number of Successfully Extracted License Plates}}{\text{Total Number of Input Images}}\right) \star 100\%$$

$$\text{Recognition Rate} = \left(\frac{\text{Number of Correctly Recognized Characters}}{\text{Total Number of Characters Processed}}\right) \star 100\%$$

Results

Dataset	Recognition Rate (Ours)
ALPR (EU)	94.65%
ALPR (BR)	82.91%
AOLP	94.78%
UFPR	74.66%

Dataset	Extraction Rate
ALPR (EU)	99.08%
ALPR (BR)	97.39%
AOLP	98.19%
UFPR	98.79%

Results

Comparing our results on AOLP dataset based on recognition rate

Papers	Recognition Rate
Hiu Li etal. [4]	95.57%
Ibtissam Slimani [5]	96.11%
Ours	**94.78%**

Comparing our results on UFPR dataset based on recognition rate

Papers	Recognition Rate
Sighthound [1]	62.50%
Open ALPR [2]	54.72%
Ours	**74.66%**

Comparing our results on AOLP dataset based on extraction rate

Papers	Extraction Rate
Yuan etal. [6]	91.27%
Ibtissam Slimani [5]	96.72%
Ours	**98.19%**

Results

Future Work

- After detecting the license plate and unwarping it,
    - Add GAN model to increase the image quality.
    - Current model has high extraction rate.
    - Limitations of current model - miss detects the characters due to low image quality.
    - Eg - Considers I as 1

- Can extend the work for detecting motorcycle LP as it encounters challenges such as changes in aspect rate and layout.

References

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2) OpenALPR Cloud API, http://www.openalpr.com/cloud-api.html.

3) Silva, S.M., Jung, C.R.: "Real-time brazilian license plate detection and recognition using deep convolutional neural networks." In: 2017 30th SIBGRAPI Conference on Graphics, Patterns and Images (SIBGRAPI). pp. 55–62 (Oct 2017). https://doi.org/10.1109/SIBGRAPI.2017.14

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