Computer Vision Assignment - License plate recognition
CSE2225 Image Processing
Due Date: Wednesday – 8th of January, @ 23:59.

Summary of assignment
Design and implement a system to automatically recognize the number/letter combination from license plates in a video sequence. The system needs to meet certain minimum requirements with regards to the number of correctly identified license plates and the speed at which the recognition is achieved. This will be tested using a sequence of test videos that we will provide.

Also prepare a poster – that visually explains your solution. Use screenshots of intermediary results to show what happens during each step, what can go wrong and the evaluation of each step.

Detailed description of assignment
The input to the system consists of a video sequence of motor vehicles under various conditions (i.e. different angles, types of lighting, speeds, types of plates, etc). The video sequence can be subdivided into video segments from four different categories (Category I through IV). Each category the system will need to meet increasingly difficult requirements, ranging from easy (Category I) to difficult (Category IV). A decent performance on categories I and II is required to pass the project, while categories III and IV are optional. However, a decent performance on categories III and IV is required for an exceptional grade. A rough description of the categories is as follows:

- Category I (Easy): stationary camera and cars, yellow plates and one plate at a time
- Category II (Medium): moving camera or cars, yellow plates and one plate at a time
- Category III (Difficult): yellow plates, two plates at a time
- Category IV (Extreme): plates of various colors

These categories and the requirements for each category are specified in detail below.

The system will output a CSV file containing a list of three columns:

1) license plate number
2) frame number of one frame in which the license plate was recognized
3) a timestamp specifying the time between the start of the video sequence and the recognition of the plate.

See Appendix A for an example.

For each line in the output list, a true positive (TP) is counted if:

a. the first column contains the correct number/letter combination
b. the second column is within the range of frames in which the plate was actually present

A line in the output list is a false positive (FP) if it does not meet criterion (a) of the definition of a true positive. A false negative (FN) is counted if a license plate in the test video is not among the true positive detections.

See Appendix B for a more detailed explanation and some examples.

Specification for all categories
For all categories, a license plate should be recognized if:
*) the size of the plate is more than 100 pixels in width
*) the lighting conditions are such that a human can decipher the plate at 20 meters
*) the plate is completely visible and non-occluded for at least consecutive 24 frames (equivalent of 2 seconds)
*) the in-plane rotation of the plate is maximally ±40 degrees (see fig. 1b)
*) the out-of-plane rotation of the plate is maximally ±15 degrees (see fig. 1c)

(a) original plate (b) in-plane rotation (c) out-of-plane rotation

Figure 1 – Different types of rotation

Specification for Category I
*) the video sequence is obtained with a fixed camera
*) the car to which the license plate is attached is stationary for at least 24 frames (equivalent of 2 seconds)
*) the license plate is Dutch, yellow and contains a single line of characters
*) there is a maximum of one plate present in the same frame

Specification for Category II
*) the position of the bounding box around the plate does not differ by more than 10% of the frame size between two consecutive frames
*) the license plate is Dutch, yellow and contains a single line of characters
*) there is a maximum of one plate present in the same frame

Specification for Category III
*) the position of the bounding box around the plate does not differ by more than 10% of the frame size between two consecutive frames
*) the license plate is Dutch, yellow and contains a single line of characters
*) there is a maximum of two plates present in the same frame

Specification for Category IV
*) the position of the bounding box around the plate does not differ by more than 10% of the frame size between two consecutive frames
*) the license plate is European, of any color and contains a single line of characters
*) there is a maximum of one plate present in the same frame

Performance requirements and testing

The system will be tested with a video sequence of approximately 180 seconds. This sequence will contain video segments of 60 cars, each with a unique license plate (30 for Category I and 10 for each of the other categories). Your score for one or more categories is calculated by the following formula:

$$score = \frac{TP}{FP + FN + TP}$$

A sufficient grade can only be obtained if the following requirements are met:

I) The score for category I is at least 0.5.
II) The score for category II is at least 0.5.
III) The average score of category I and II is at least 0.6.

Additionally, the time required for the system to analyze a video should not exceed that video's duration plus 33% (e.g. when analyzing a 3 minute video, all output must be printed less than 4 minutes after the start of the video).

Categories III and IV are optional, but either can be used as a 'stermodule' when successfully completed. To achieve this you are also required to achieve a score of at least 0.6 for category III or IV, in addition to the default requirements.

To design the system some pre-recorded video will be available on BightSpace, recorded with the provided Philips SPC 700NC camera. It is also possible (and perhaps advisable) to generate additional recordings by yourself.

Final reporting:

To report on your work, you will **not** need to make a long report. Instead, we ask you to produce a poster for the final prototypes. The poster will contain a visual explanation (using pictures and screenshots) of the functionality of the prototype. ***Please also include how you evaluated each stage of the project (the plate localization, the character segmentation, and the recognition rate).*** Make sure to include some figures that illustrate cases that are still **not** correctly identified and that need to be the focus if you have more time to work on the project. The poster should also contain summary explanation text. The final poster will need to be submitted through Brightspace by the deadline of the project.

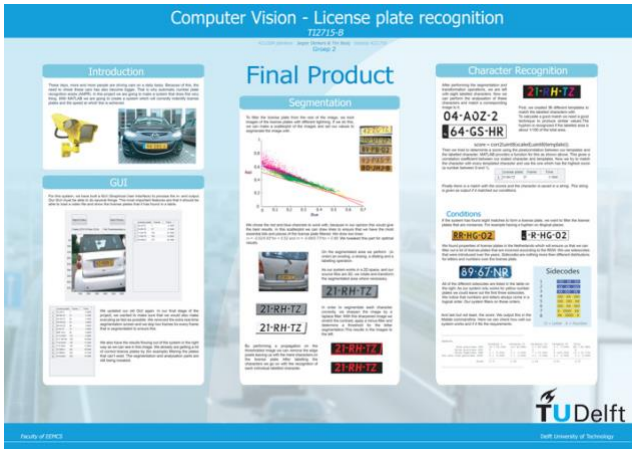

Figure 2 - Example poster

Mid-way reporting (optional):

To report on your work, you will **not** need to make a long report. Instead, we ask you to produce a poster for the current prototypes. The poster will contain a visual explanation (using pictures and screenshots) of the functionality of the prototype.
Please also include how you evaluated each stage of the project (the plate localization, the character segmentation, and the recognition rate).
Make sure to include some figures that illustrate cases that are still **not** correctly identified and what is your plan to fix those cases.
The purpose of this report is to make sure that you are on the right track in tackling the problem, and to guide you if there are better paths to follow.

Some hints to get started

- You are provided with a set of python functions that will help guide you to the pipeline needed to finish the project
    - Main.py
    - CaptureFrame_Process.py
    - Localization.py
    - Recognize.py
    - Evaluation.py ***(do not edit or modify).***

  Using those functions are optional (***except for evaluation.py***), you are free to create your own as long as you deliver the same final output. The details, description and functionality of them is in the beginning of each file.
- You are free to use any IDE to debug and design your code.
- The functions provided are commented with specifying clearly what is the input and the output for that function.
- Take a look at the training videos provided on BrightSpace, which will illustrate the several categories.
- Analyze multiple frames of the training video to find out exactly which colors are present in a number plate. Hint: take a look at color lab. Then try to extract the license plate from a number of new frames.
- You could also use edge detection, or some other techniques described in the practical exercises to extract a license plate from a frame.

Important Rules:

- You are **not allowed** to use any library to do the recognition of the plates. You can implement your own recognition technique. To be more specific, you are not allowed to use a ready-made (lib.) function that directly implements a recognition method. You can definitely use functions from numpy or opencv to build up your function (e.g. imread, gaussian blur, fft or ifft , etc. , *in general any function used in any of the labs is definitely allowed to use.*). For any function used, you have to know how it works; by that we **do not** mean the exact implementation of a specific library, we mean ***the steps and theory behind how an algorithm works***.
- You are provided with 2 folders:
    - SameSizeLetters
    - SameSizeNumbers

  Those are examples of character templates that you can use as an inspiration for your recognition technique. (i.e. template matching). Feel free to change the templates with more suitable ones if you feel that is necessary.
- You have to understand in details how any function used in your code works. (e.g.

```
regionprops(label_img, [
    'BoundingBox',
    'Centroid',
    'Orientation',
    'MajorAxisLength',
    'MinorAxisLength'
```

```
])
```

- The final output of the training video and the test video will be evaluated using the “Evaluation.py” function provided. Make sure that you call it correctly in your code after you are done processing the input video. ***Failing to do so will fail you the full grade of the project.***
- During the final interview session, you will be provided with a new test video that will be used to evaluate your work. Your code should process the code, give the final CSV output file and the run the evaluation.py function on it.
- During the final interview session, you will be asked theoretical questions about the project and what motivated your choices in solving the license plate problem

Appendix A

The table below shows the sample output for the file Trainingsvideo.avi. See the provided sampleOutput.csv to know how you should structure your python program's output file, and how you can compare your output with the solution.

License plate	Frame no.	Timestamp (seconds)
5-KKL-63	34	1.822
PX-FD-96	53	3.371
07-HT-XD	98	6.929
88-SLV-9	123	9.399
4-TSX-79	176	12.910
47-RS-HJ	183	15.403
94-RV-BL	237	20.885
8-VXZ-62	254	22.536
88-BB-TS	304	25.419
87-VB-TR	336	27.847
XL-LH-20	378	31.030
91-SZ-GH	425	33.136
60-LX-XP	442	37.902
20-DL-PN	469	40.333
06-KDT-6	521	44.415
10-PPD-2	565	47.849
99-TH-PZ	609	49.385
87-SK-TJ	614	52.580
58-NFH-5	672	55.908
73-SV-NF	713	58.682
49-HT-RK	724	62.726
3-KGD-65	760	63.309
TF-TB-20	819	68.800
28-NHH-7	846	70.321
04-HH-DP	881	74.727
15-TR-NV	933	76.404
10-PFJ-8	946	79.494
RN-HH-98	998	82.657
58-TG-NK	1038	86.763
BS-DJ-49	1066	87.255
41-JS-SB	1107	92.203
46-LS-KV	1171	96.380
46-LJG-1	1238	102.391
HL-FP-34	1265	107.006
51-LR-BN	1313	111.567
19-DG-SF	1368	114.095
16-PTG-8	1450	121.055
15-TP-SH	1507	124.411

RZ-ZN-62	1574	131.032
61-XXZ-9	1631	135.360
79-NK-JK	1645	139.830
59-KTJ-5	1647	139.645
96-ZND-7	1704	142.169
18-VL-PK	1709	141.710
SV-FZ-63	1717	144.704
23-JJ-JJ	1735	143.489
08-JKJ-2	1774	148.520
39-TF-DR	1784	146.727
RF-GD-58	1818	150.387
38-NZ-JT	1804	149.781
EH3201BP	1842	154.443
B102AMT	1873	156.538
RECM2111	1914	159.548
096-BZN	1967	162.263
VFD88	1990	166.259

Appendix B

Every number plate that is present in the video will be judged as either one of the following:

- True positive (TP)
- False positive (FP)
- True positive and false positive (TP+FP)
- False negative (FN)

This final result is based on the results of all frames in which the number plate in question was visible. The result of a single frame will be one of the following:

- **True positive (TP)**
  The number plate given as output corresponds with the number plate of the car.
- **False positive(FP)**
  The number plate given as output does not correspond with the number plate of the car.
- **False negative (FN)**
  No number plate was given as output.

The final result of a number plate will only be a FN if no number plate was given as output for every frame in which the number plate was present. The final result will be TP when at least one frame was judged as a TP and it will be FP when at least one frame was judged as a FP. When the condition for a TP and a FP are both true, the final result with be TP+FP, counting as a true positive and a false positive. See the following examples:

Correct number plate	Frame number	Detected number plate	Intermediary verdict	Final verdict
TB-GH-65	56		FN	TP+FP
	57	TT-GH-88	FP	
	58		FN	
	59	TB-GH-65	TP	
	59	TB-GH-65	TP	

The final verdict is TP+FP, because at least one frame was judged as a TP and at least one frame was judged as a FP.

The following only applies to category III. When more than one number plate is present in a number of frames, the final verdict of this interval of frames will be one of the final verdicts described above for each number plate. When two number plates are present in a number of frames, all possible final results are:

- 2 TP
- 2 TP and 1 FP
- 2 TP and 2 FP
- 1 TP and 2 FP
- 1 TP and 1 FP
- 1 TP and 1 FN
- 2 FP
- 1 FP and 1 FN
- 2 FN

Note that it is not determined to which of the two number plates a FP 'belongs'. The FP will be assigned to the first possible plate, unless one of the other plates is still counted as a FN. In that case, the FP is assigned to this plate. This makes it impossible to get the result of 1 TP, 1 FP and 1 FN for a case where 2 number plates are visible.

Examples:

Correct number plates	**Frame number**	**Detected number plates**	**Intermediary verdict**	**Final verdict**
GH-45-MN TX-GB-66	60	GH-45-MN TX-BB-68	TP FP	TP FP
	61		FN	
	62		FN	
	63	GH-45-MN	TP	
	64		FN	
66-HBL-7 8-GKB-91	65		FN	TP FN
	66		FN	
	67	8-GKB-91	TP	
	68	8-GKB-91	TP	
KM-HG-85 FG-45-RH	69	FG-45-RH	TP	2 TP 2 FP
	70	FG-56-RH	FP	
	71	FG-45-BT	FP	
	72	KM-HG-85	TP	
5-KBN-78 TH-23-HB	73		FN	2 TP FP
	74	5-KBN-78	TP	
	75	TH-23-HB	TP	
	76		FN	
	77	TH-23-GG	FP	
	78		FN	
PL-23-BN VB-ZW-56	79	PL-23-MM	FP	TP 2 FP
	80	FL-88-BN	FP	
	81	FL-23-BN	FP	
	82	PL-23-BN	TP	

The number of frames in which a number plate is visible has been decreased to make the above table more concise.