Computer Vision Assignment - License plate recognition
TI2716-B

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 minimal 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 write a report – in the form of a poster – that visually explains your solution. Use screenshots of intermediary results to show what happens during each step and what can go wrong.

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 list containing 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 Blackboard, recorded with the provided Philips SPC 700NC camera. It is also possible (and perhaps advisable) to generate additional recordings by yourself.

Progress and reporting

We will follow a rapid-prototyping design strategy. This means that you will generate one prototype each week and one final product in the last week. In the first week the functionality of the prototype will be limited. In the last week, all functionality should be there and your efforts should be focused on fine-tuning and doing the final evaluation.

To report on your progress you will **not** need to make a long report. Instead, we ask you to produce a poster for each of the prototypes (i.e. each week one poster). The poster will contain a visual explanation (using pictures and screenshots) of the functionality of the prototype. Make sure to include some figures that illustrate cases that are still **not** correctly identified and that need to be the focus for next week. The poster can also contain some text. Each poster will need to be submitted through Blackboard.

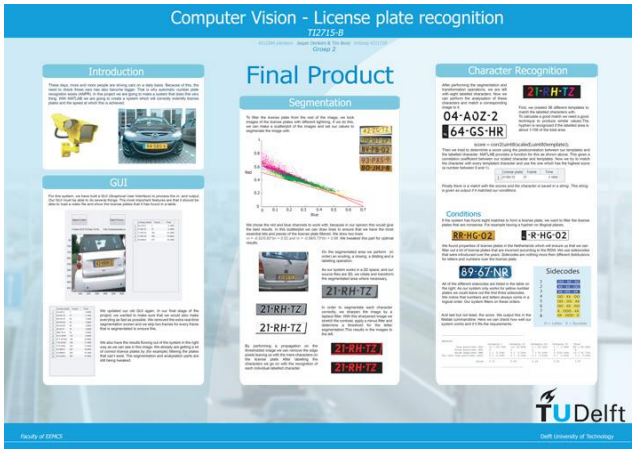

Figure 2 - Example poster

Some hints to get started

- Start by designing a GUI that can display video files and shows your results in a table.
- Make a separate function that takes a video frame as input and returns a string containing the license plate (if one is found). Keep your program structured by using several functions for the different steps of the recognition process.
- Take a look at the training videos provided on Blackboard, 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 practical assignment 4. 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.

Appendix A

The table below shows the sample output for the file Trainingsvideo.avi. See the provided sampleOutput.m how you should structure this in Matlab, and how you can compare your output with the solution.

License plate	Frame no.	Timestamp (seconds)
XL-VB-52	34	1.822
14-JDS-5	53	3.371
94-FP-BD	98	6.929
ND-NJ-64	123	9.399
30-ZRR-2	176	12.910
23-HRG-6	183	15.403
XH-SR-72	237	20.885
1-SXR-89	254	22.536
58-NF-TP	304	25.419
3-THH-64	336	27.847
36-KHJ-9	378	31.030
55-NH-JT	425	33.136
79-HGH-6	442	37.902
81-XX-RF	469	40.333
11-GBZ-1	521	44.415
JN-LF-47	565	47.849
ZD-HZ-97	609	49.385
15-JD-SF	614	52.580
23-KDF-2	672	55.908
76-JZ-GS	713	58.682
62-JLH-6	724	62.726
2-KKH-40	760	63.309
99-LB-VT	819	68.800
87-LZ-NK	846	70.321
60-RB-SK	881	74.727
1-XRP-36	933	76.404
06-LG-NB	946	79.494
15-LBS-3	998	82.657
BS-DR-28	1038	86.763
79-GZ-TR	1066	87.255
25-SZ-LP	1107	92.203
3-XGL-81	1171	96.380
79-PDD-5	1238	102.391
NS-TT-79	1265	107.006
26-JVR-6	1313	111.567
82-JZV-5	1368	114.095
XX-RH-63	1450	121.055
90-ZFD-2	1507	124.411
82-PR-SB	1574	131.032
12-ZB-LP	1631	135.360

87-XFN-4	1645	139.830
11-RL-SJ	1647	139.645
ST-BD-82	1704	142.169
PX-HB-62	1709	141.710
72-VGX-6	1717	144.704
04-BK-HL	1735	143.489
38-DD-GG	1774	148.520
75-SK-HD	1784	146.727
19-GG-SX	1818	150.387
86-ZB-NR	1804	149.781
77-TR-SH	1842	154.443
85-GJ-45	1873	156.538
NWMMX45	1914	159.548
1CMV331	1967	162.263
DS346WG	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.