Mapping road traffic conditions using high resolution satellite images

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Collaborators:

**Norwegian Public Roads Administration (Statens Vegvesen)
Norwegian Space Centre (Norsk Romsenter)**

Outline

► Background

► Algorithm

  ▪ Masks

  ▪ Segmentation

  ▪ Shadow prediction

  ▪ Feature extraction

  ▪ Classification

► Results

► Conclusion

Background

► Road network maintenance and development

► Annual Day Traffic (ADT)

  ▪ statistical tools developed by NR

► Today: induction loops in the road

  ▪ expensive

  ▪ limited geographical coverage

► In the future: automated counts using high resolution satellite images ?

Masks

► Road mask

- manual delineation

- automatic generation

  ◦ buffer mask from midline vectors

  ◦ rectification (manually selected reference points)

► Vegetation mask

- roadside tree canopy and vegetation between lanes
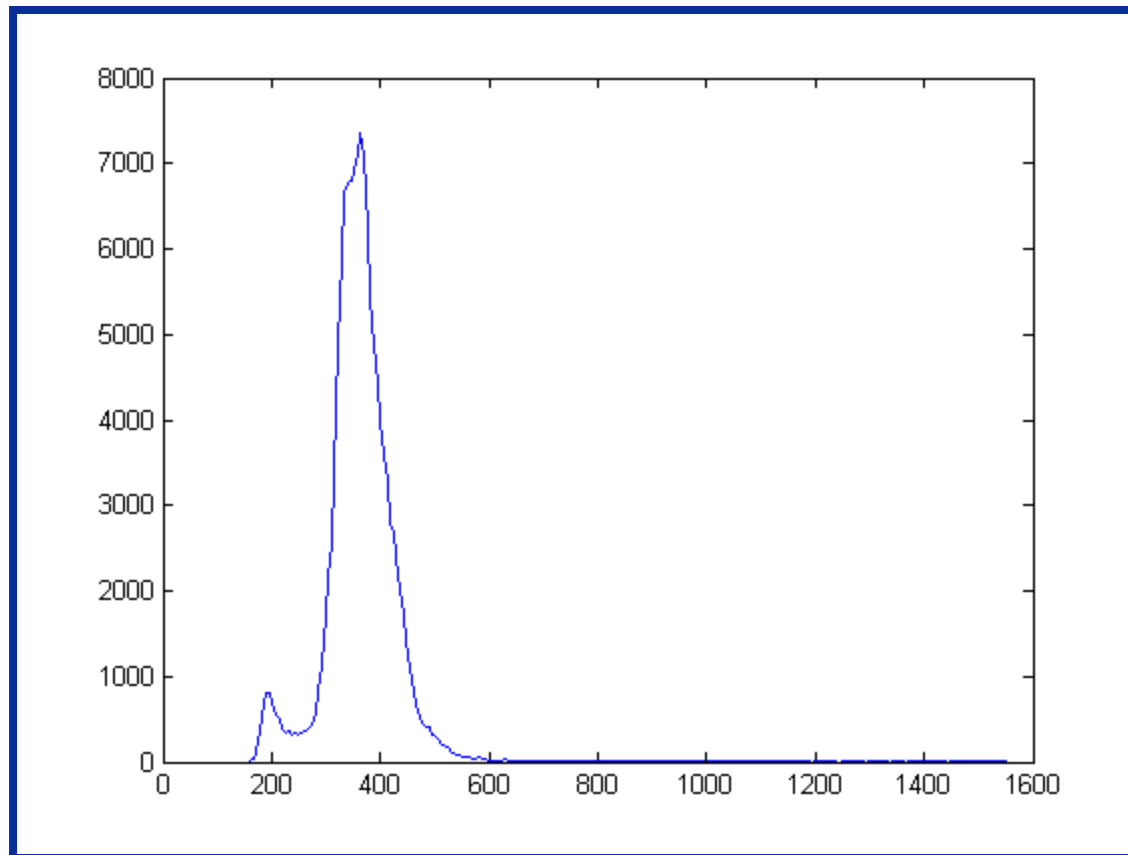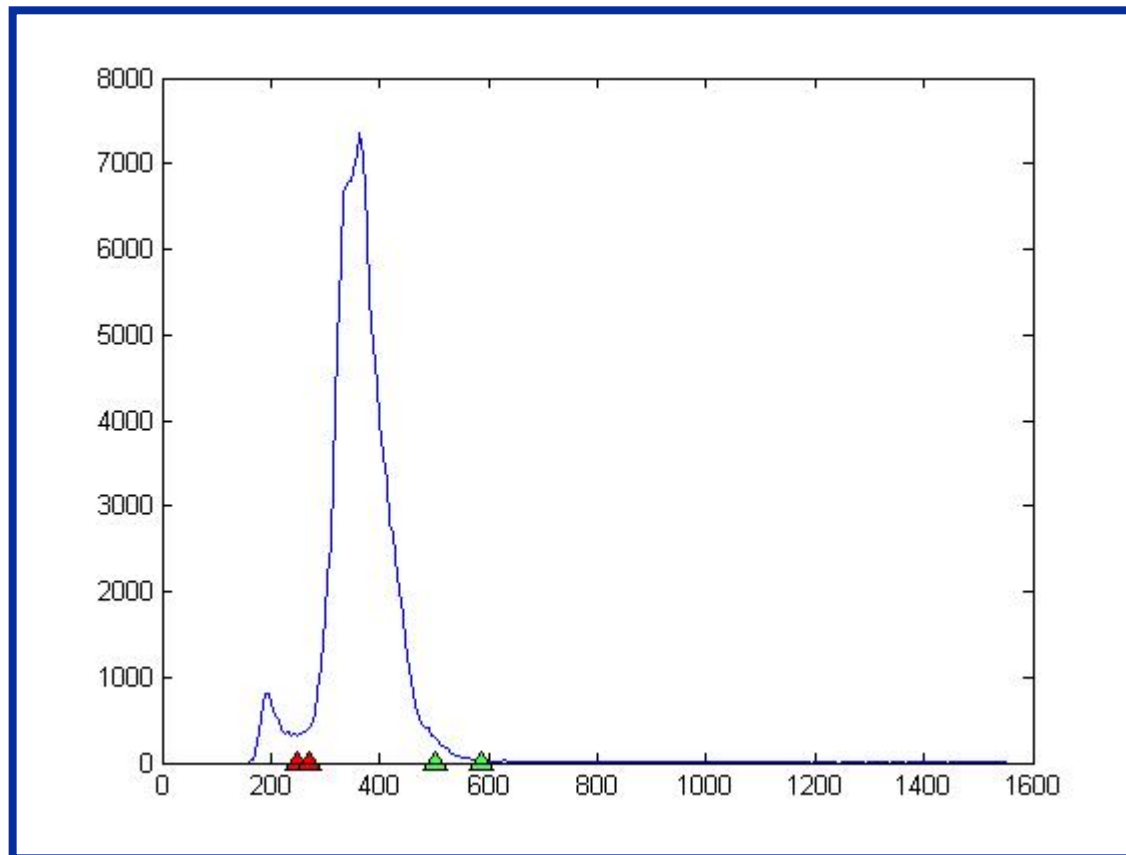
- NDVI + Otsu

Segmentation

Image histogram of masked panchromatic image

Segmentation

► Segmentation of dark segments:
  - strict threshold: Otsu [Imin , μ - σ]
  - loose threshold: Otsu [Imin , μ - 0.5σ]

► Segmentation of bright segments:
  - loose threshold: Otsu [μ + σ , Imax]
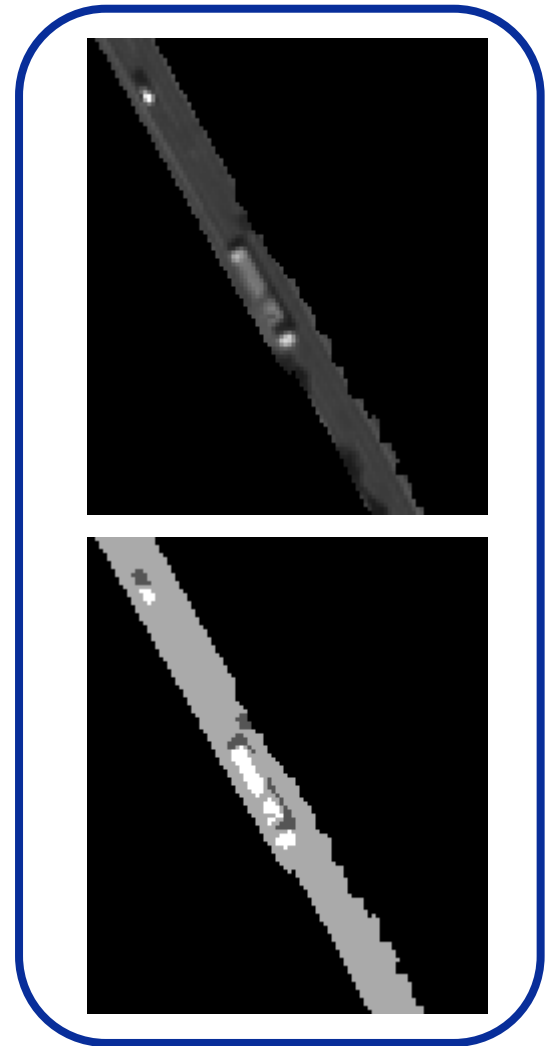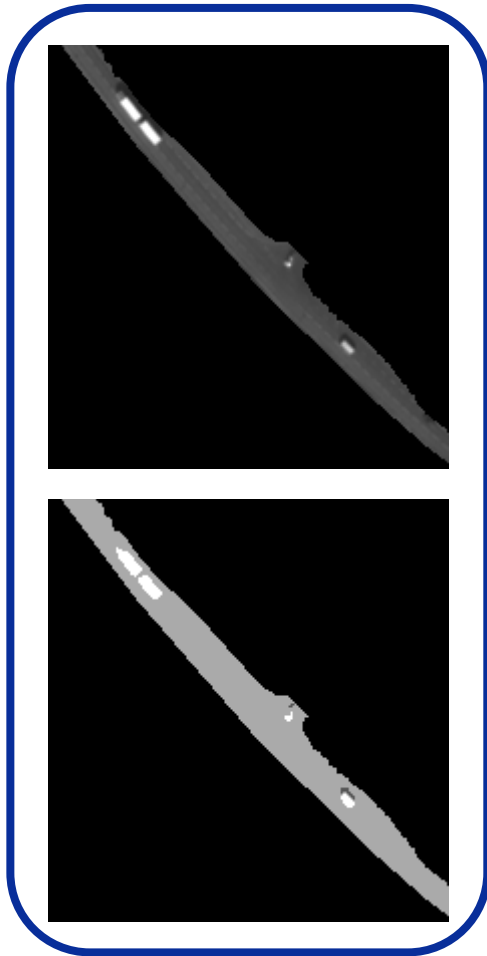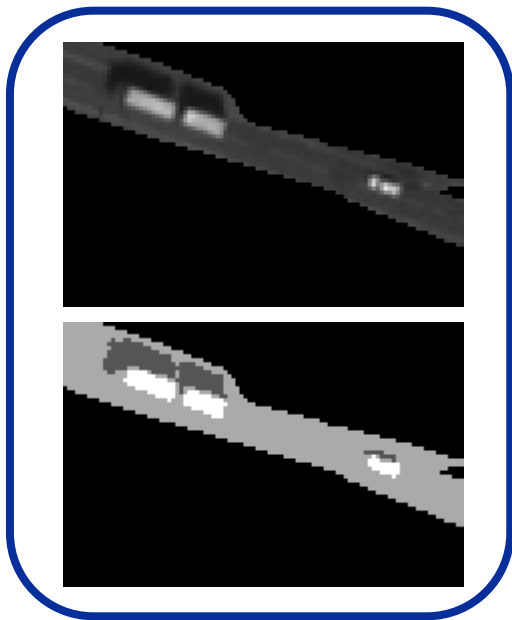 - strict threshold: μ + 3σ

Segmentation

Segmentation thresholds

Segmentation examples

Vehicle shadows

Prediction of vehicle shadows

► A dark segment that

  1) overlaps the expected shadow zone of a bright segment

  2) is close in distance to the bright segment

  is considered to be a vehicle shadow

► To predict this we need

  - a segmented image containing dark segments
  - a segmented image containing bright segments
  - a distance map to bright objects
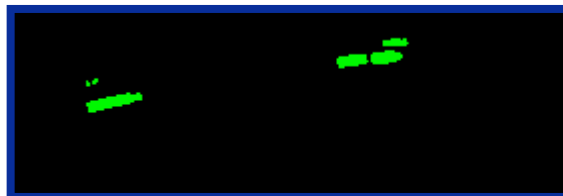 - a structure element representing the expected shadow zone

Sun azimuth relative to image
Direction of shadow
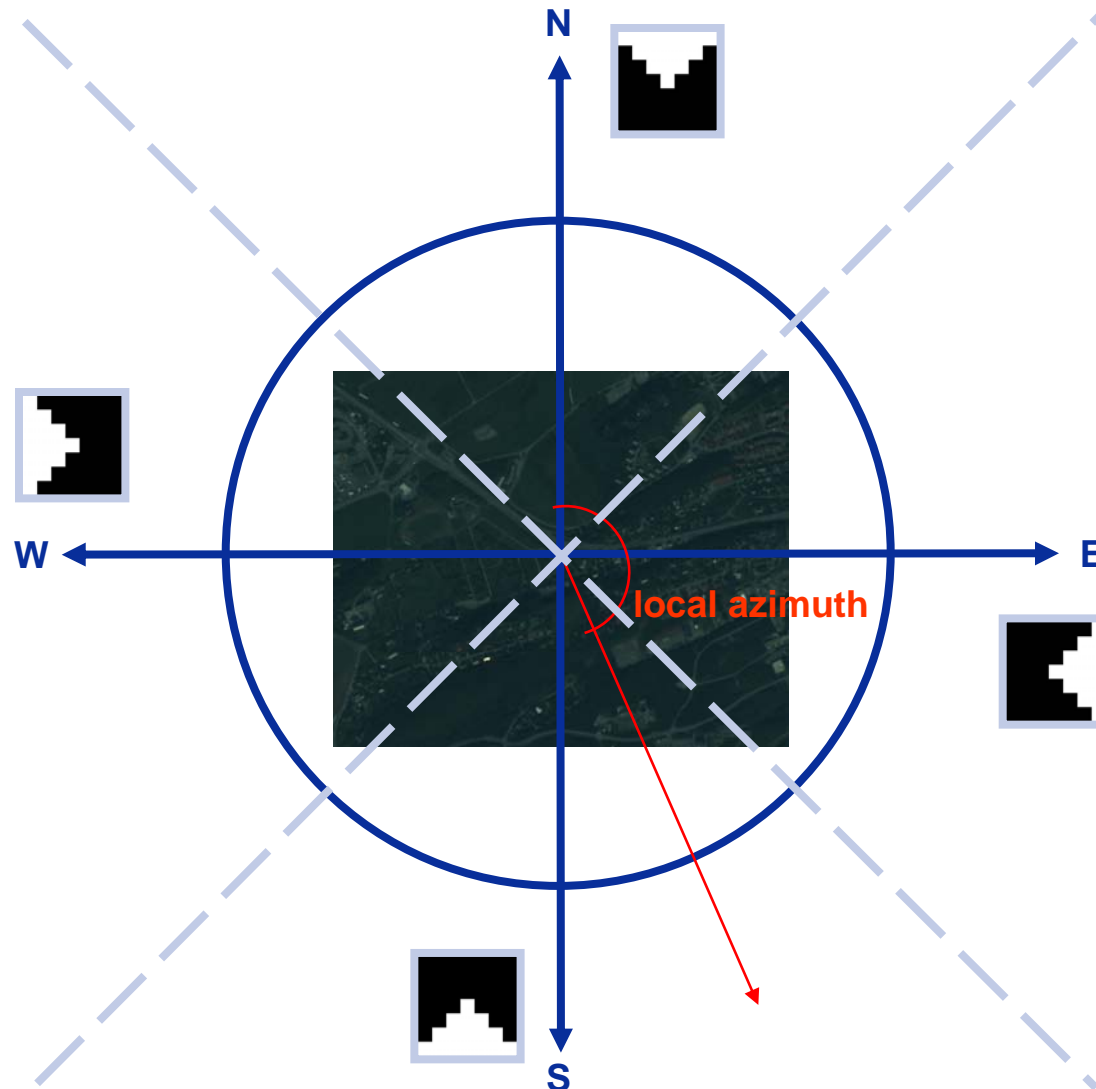
Sun elevation
Length of shadow

vehicle height

sun elevation

shadow length
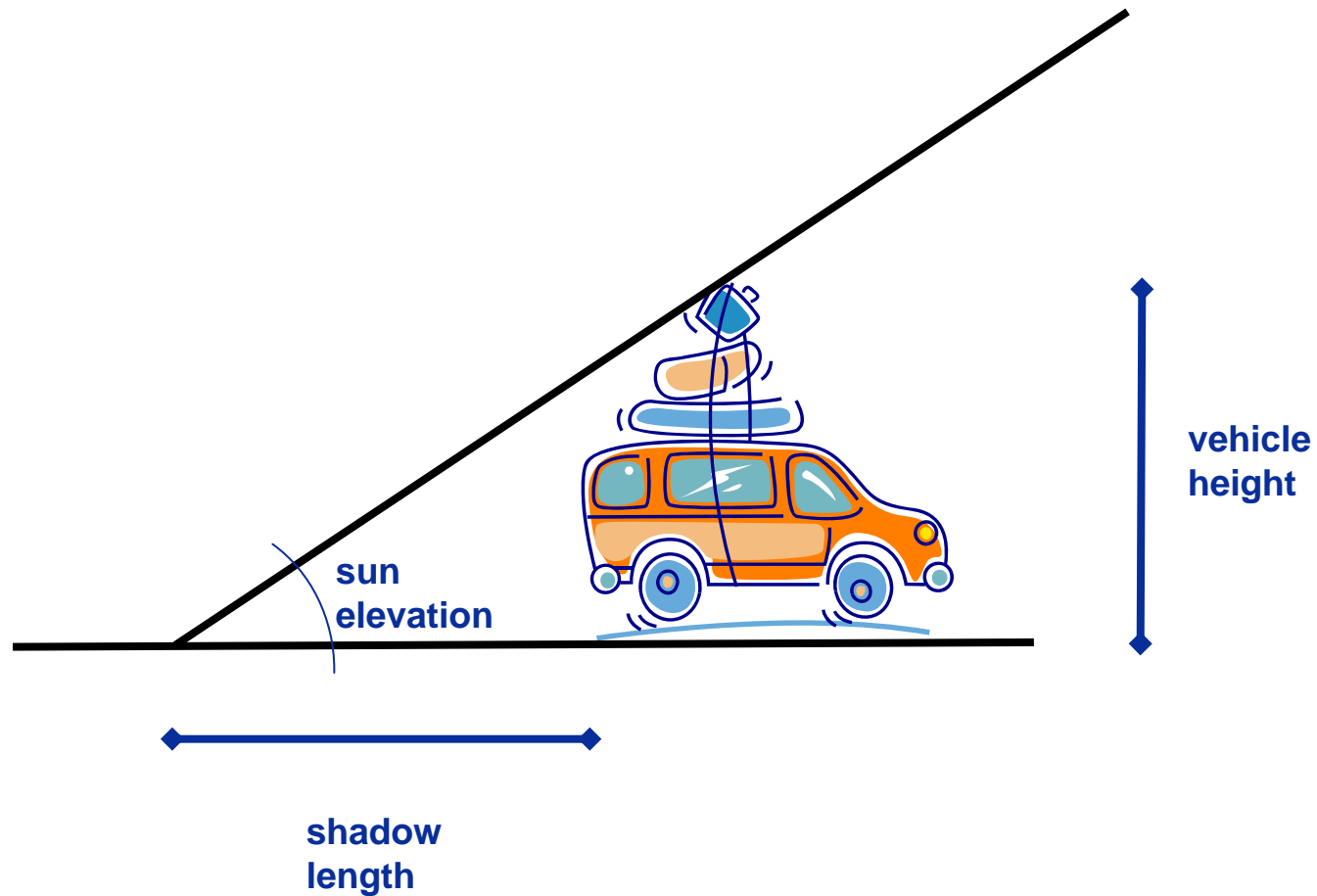
Predicting shadows 1

Dilate bright segments with expected shadow zone
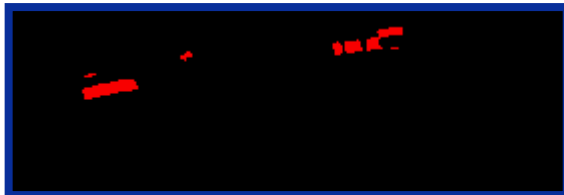

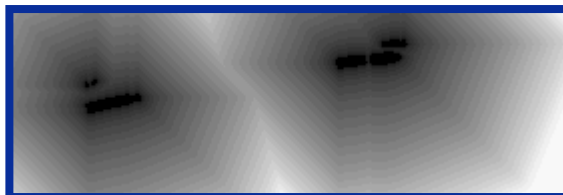**Subtract bright segments**

Predicting shadows 2

dark segments
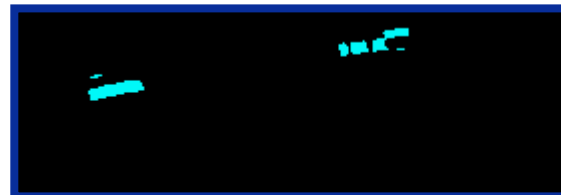

distance to bright segments

expected shadow zones

For each dark segment:

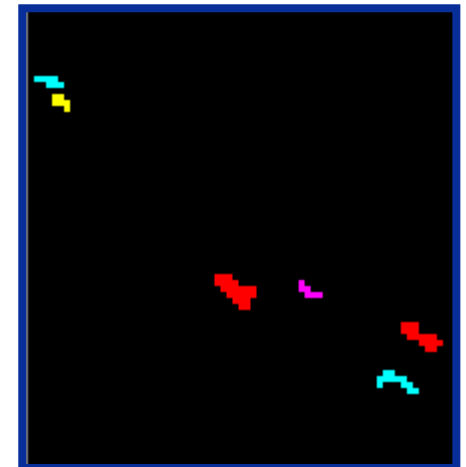**if distance to bright segment is small & it overlaps an expected shadow zone**

otherwise

vehicles

shadows

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Classification

► Maximum likelihood

- multivariate Gaussian distribution
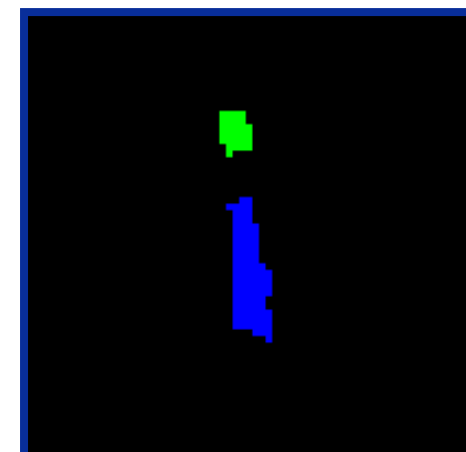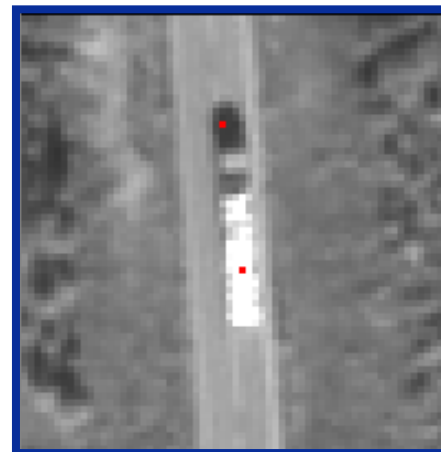- general class covariance matrices

► Six classes:

- Bright car
- Dark car
- Bright truck
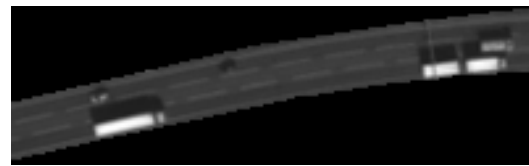- Bright vehicle fragment
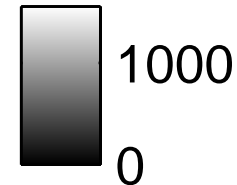- Vehicle shadow
- Road mark - arrow

Region features

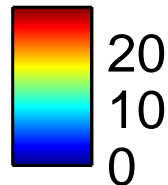| Preclassification	Main classification	Post classification
Rule based	Maximum likelihood	Rule based
►Area ►Elongation	►Intensity mean ►Gradient mean (Sobel) ►Intensity standard deviation ►Length of bounding box ►1st Hu moment ►Spatial spread ($\frac{\mu_{20} + \mu_{02}}{\mu_{00}{}^2}$)	►Distance to nearest shadow **A small bright segment close to a shadow is more likely a vehicle fragment (as opposed to a road mark)**

Illustration of features

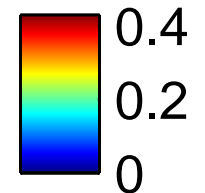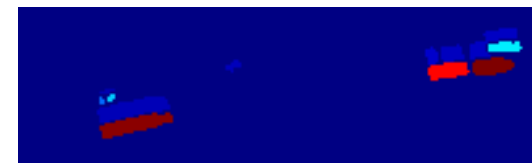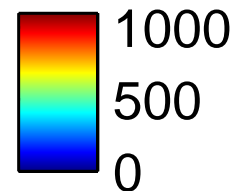masked panchromatic image

1000

0

length

20
10
0

spatial spread

0.4
0.2
0

mean intensity

1000
500
0

intensity standard deviation

200
100
0

1st Hu moment

40
20
0

mean gradient

2500
1500
500
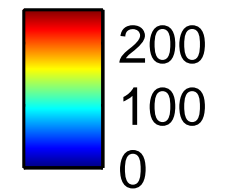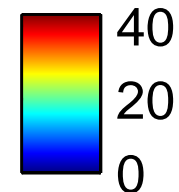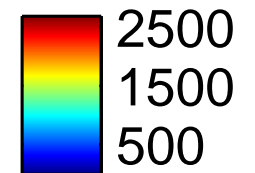
Classification results

► Classification rate: 70,6%

► Classification rate not including reject segments: 88,7%

► Two-class (car/no car) classification rate: 81,0%

Given label / True label	Bright vehicle	Dark vehicle	Vehicle shadow	Road mark	SUM
Bright vehicle	96	0	0	11	107
Dark vehicle	0	59	7	0	66
Vehicle shadow	0	10	62	0	72
Road marking	0	0	0	2	2
Reject	11	20	22	10	63
SUM	107	89	91	23	310

Validation

► Counts from road stations:

- # of cars passing per hour
- average speed
- extract sub image that cover a road segment in the vicinity of the station
- estimate # of vehicles that "should" appear in the image (based on # of vehicles per hour + speed + length of road)

► Manual counts:

- two persons have independently counted vehicles in the images

► Automatic counts in image:

- using the described methods

Validation results

| Location	Length of road segment (m)	Time of image acquisition (UTC)	Manual count in image	Predicted # of vehicles in image (from in-road counts 10-11 UTC)	Predicted # of vehicles in image (from in-road counts 11-12 UTC)	Number of objects classified as vehicles
Sennalandet	19 718	10:35	12	10	9	-
Kristiansund # 1	1 055	10:56	22	25	25	17
Kristiansund # 2	5 775	10:56	32	27	28	22
Østerdalen north	31 779	10:39	44	51	40	80
Eiker	7 836	10:42	57	57	67	39
Sollihøgda # 1	7 819	10:32	63	58	61	64
Sollihøgda # 2	6 139	10:32	30	38	41	26

Challenges

► Different lighting conditions

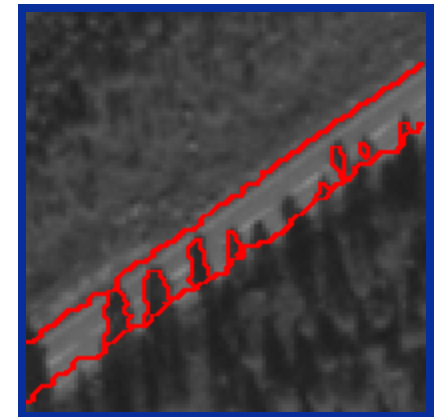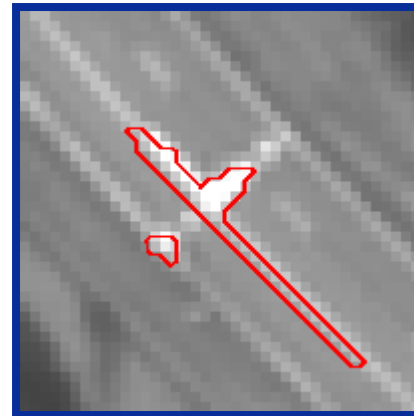► The hypothesis about the image histogram does not hold anymore
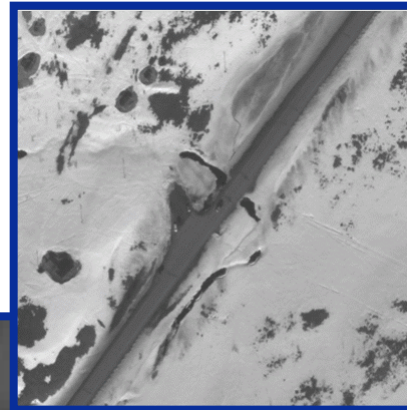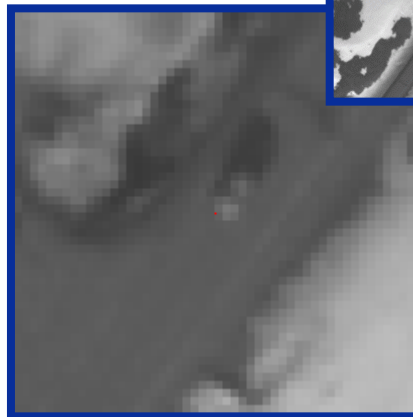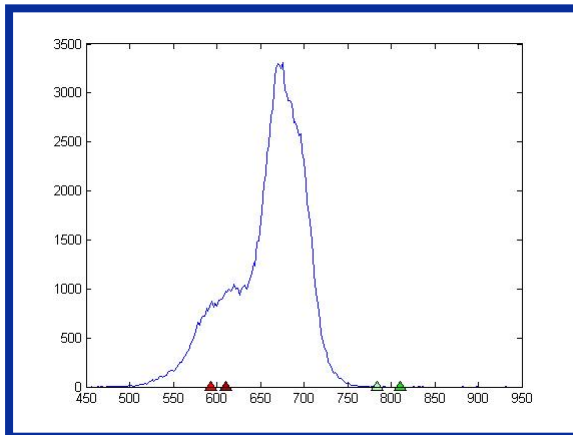
Challenges
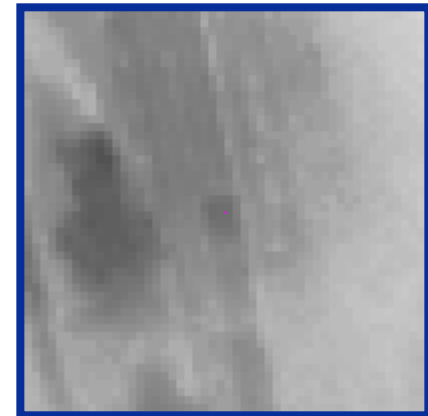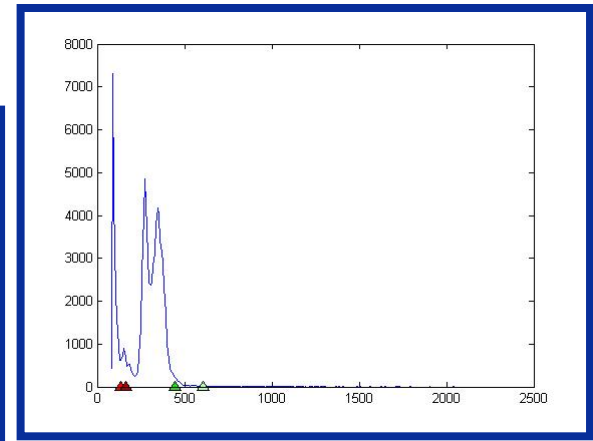
Reject segments

► Heteregeneous group of segments that do not belong to any of the classes, e.g.:

- tree shadows

- other types of road marks

- part of bridges, signs, roundabouts, etc.

Conclusion

► The majority of vehicles that are correctly segmented are also correctly classified

► The segmentation routine should be improved in order to find even vehicles with low contrast

► Additional features and context based information should be examined in order to reject non-vehicle segments

The SatTrafikk project

- ► Started in 2006 with the ESA (European Space Agency) project Road Traffic Snapshot, Institute of Transport Economics (Transportøkonomisk Institutt) also involved

- ► SatTrafikk: 2007 - ?

- ► Main utility: estimate Annual Day Traffic,

  used by **Norwegian Public Roads Administration**,

  especially useful for (country side) high ways where in-road

  counts are expensive

- ► Software developed by NR

- ► Funding: **Norwegian Space Centre**

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Thank you for the attention!