Traffic Surveillance in Real-time using Hidden Markov Models

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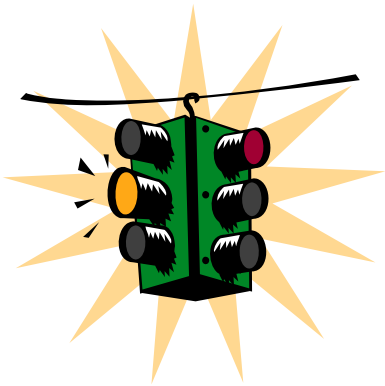
Outline of talk

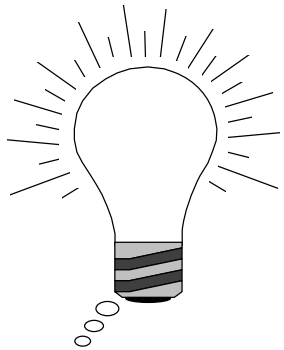
- Problem
- Idea
- Overview of system
- Low level analysis
- High level analysis
- Experiments
- Results



Motivation

- Video-based system for traffic surveillance
- Basic functionality: car detection
- Flexible
- Extendable
- Requirements:
  - Standard PC platform
  - No special hardware
  - 95% correct results

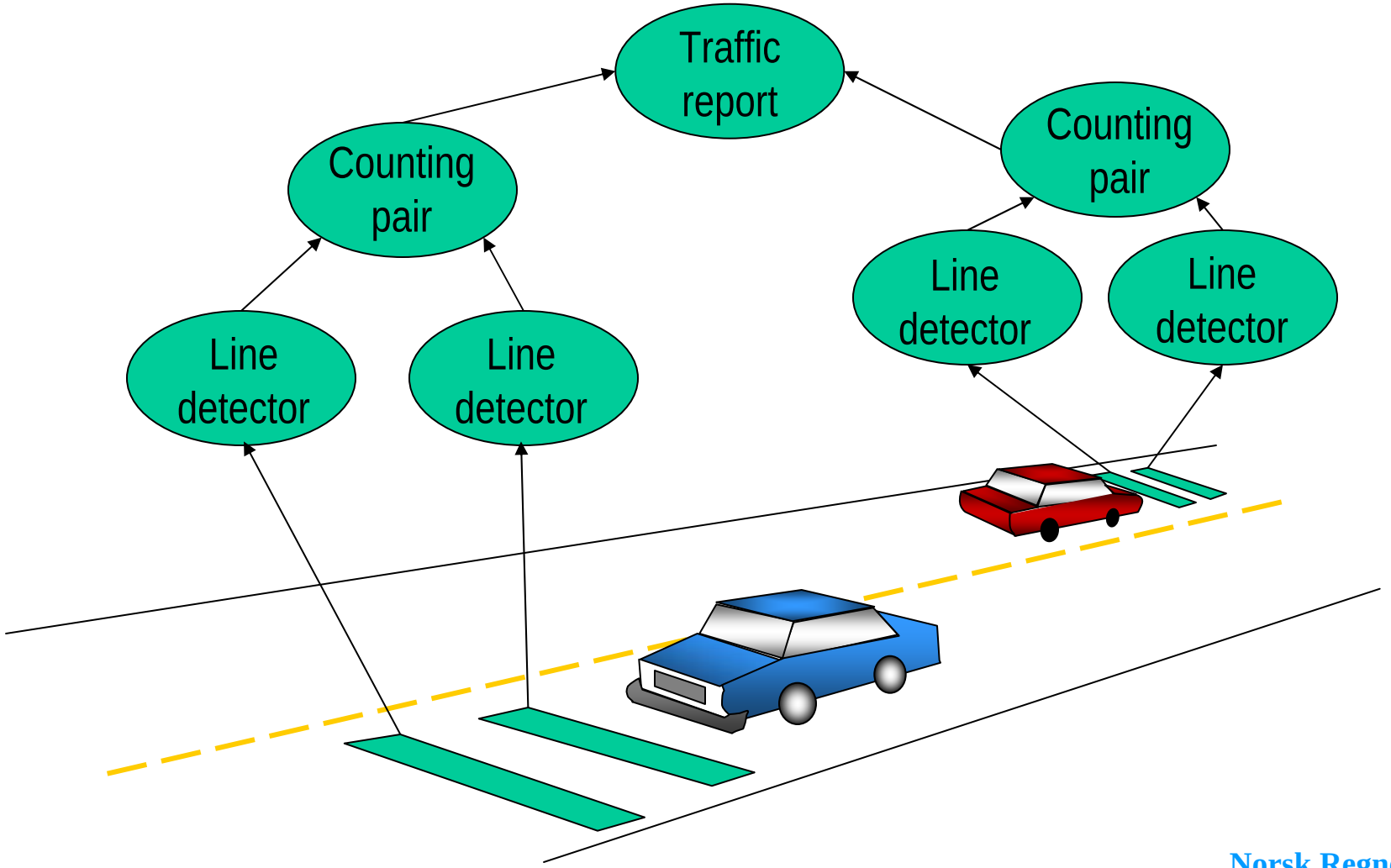
Idea



Combine low-level and high level methods

- Low level analysis
  - Extract low level features from small regions in each frame
  - Preclassify each region independently
  - ⇒ fast
- High level analysis
  - Determine events from a sequence of combinations of preclassified regions
  - ⇒ robust

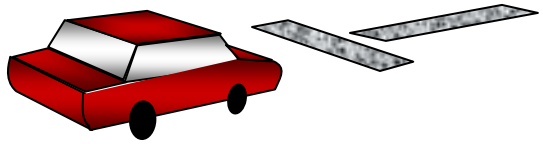
Overview of the system

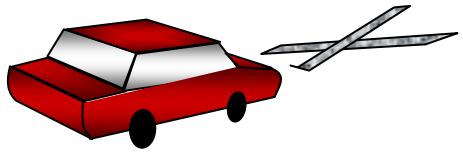


Line detector

- A line detector = a virtual sensor
- A rectangular region in the image
- May be positioned and combined in any way

- Analyse changes in:
  - Grey level
  - Edge magnitude
- To determine:
  - Occupied or unoccupied
- Need initialisation





Line detector — initialisation

- Estimation of initial grey level and edge magnitude of the background:

$$g_B = (1 - \alpha)\, g_B + \alpha g_i$$
$$e_B = (1 - \alpha)\, e_B + \alpha e_i$$

- Requires a longer period with no changes.
- If a change occurs during the defined interval, the initialisation starts from the beginning.
- Must avoid initialisation during
  - Heavy traffic
  - Standstill in traffic

Line detector — surveillance

- Compute grey level and edge magnitude of detector.
- Classify detector state:
  - If previous state is occupied change state to unoccupied if:

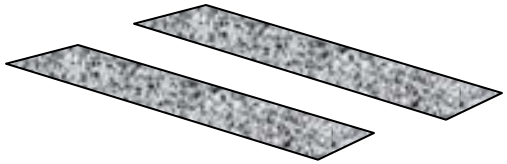
    $|e_B - e_{current}| < e_{limit}$ *and* $|g_B - g_{current}| < g_{limit}$

  - If previous state is unoccupied change state to occupied if:

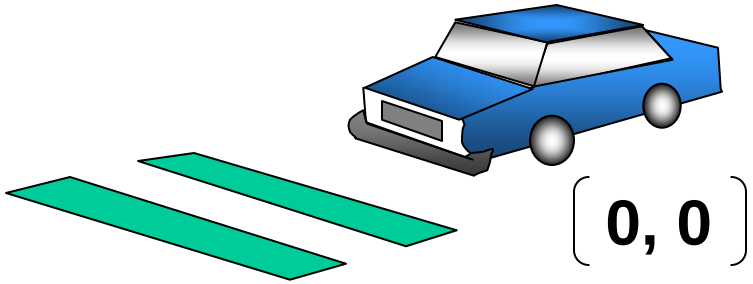
    $|e_B - e_{current}| > e_{limit}$ *and* $|g_B - g_{current}| > e_{limit}$

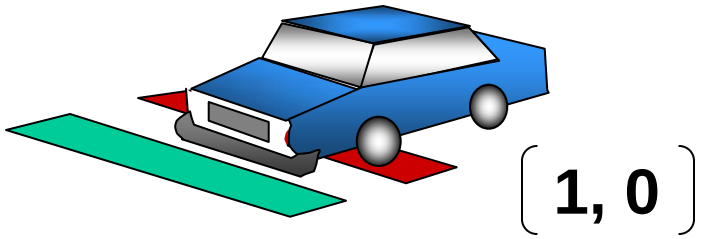
- Assumption: A change occurs as vehicles pass the detector.
- Background estimates are updated when a detector is classified as unoccupied.

Counting pair



- Detectors are organized in counting pairs
  - More robust than only one detector
  - Able to determine direction
- Each line detector in a pair is classified independently.
- This gives a sequence of pairs of observations.



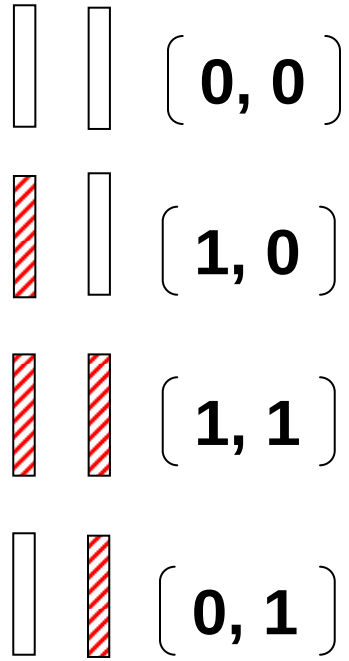


High level analysis with HMMs

- The counting pair results in a sequence of 0's and 1's.
- We will use a hidden Markov model to determine the underlying sequence of events.
  - Observations: $Y=Y_1,\ldots, Y_n$
  - States in the hidden process: $C= C_1,\ldots, C_n$
  - The number of states
  - The transition probabilities
  - The observation probabilities
  - The initial probabilities

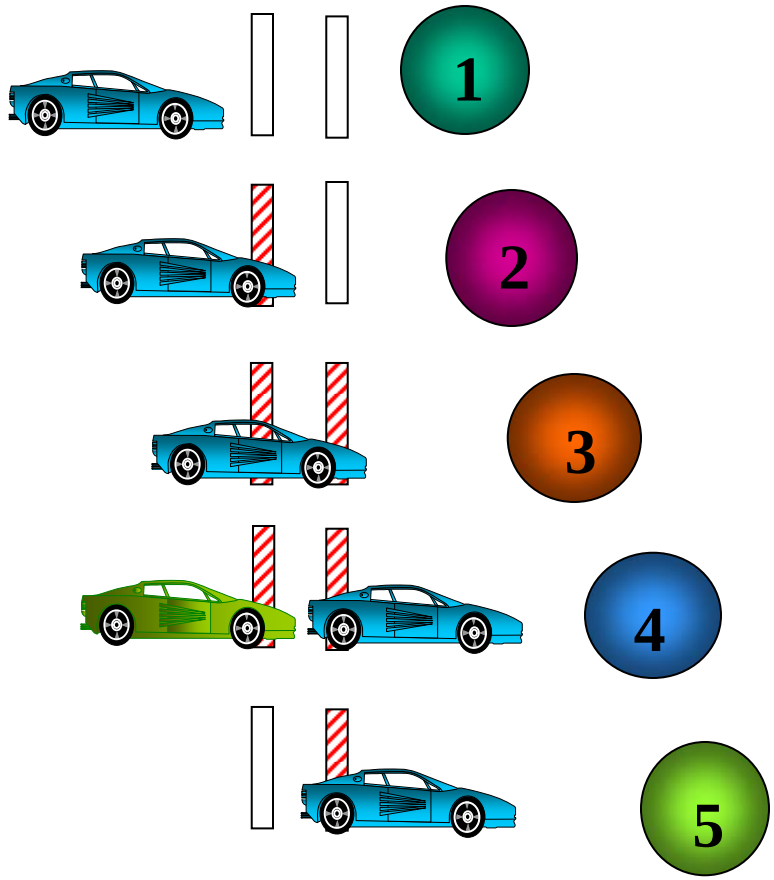
The observations

- No detectors occupied.
- Only the first detector occupied.
- Both detectors are occupied
- Only the second detector is occupied.

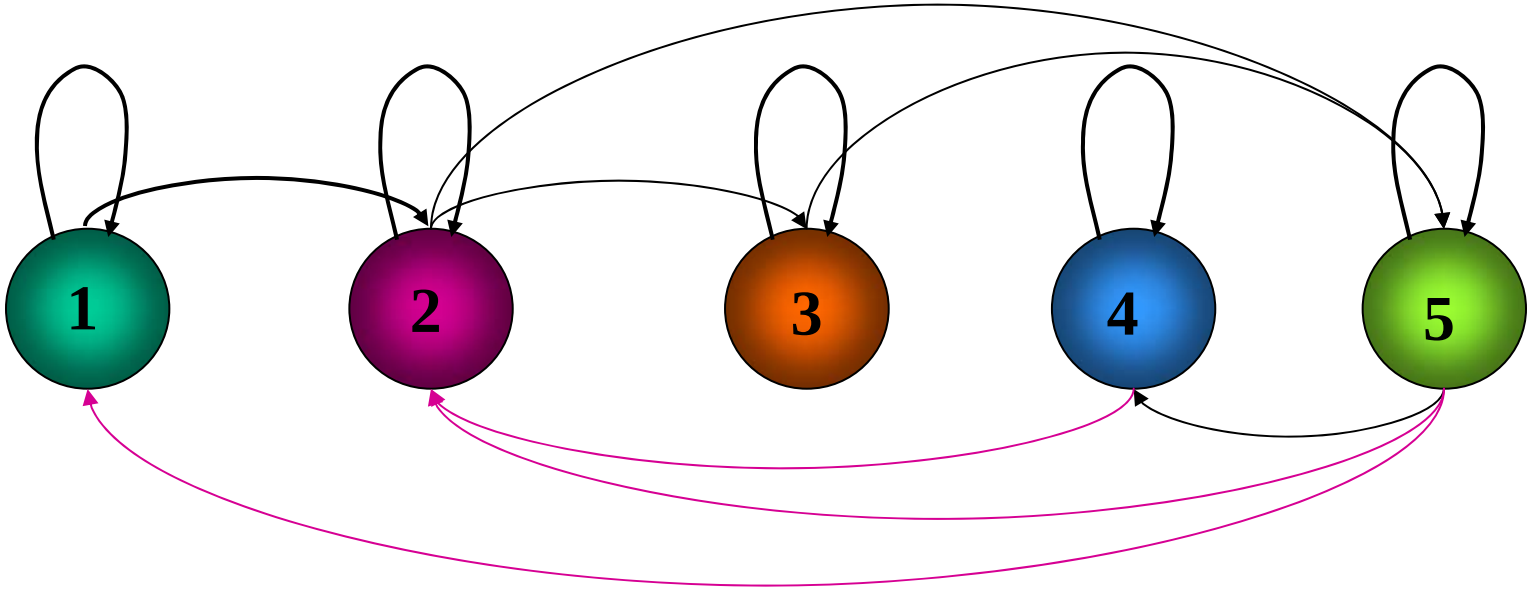


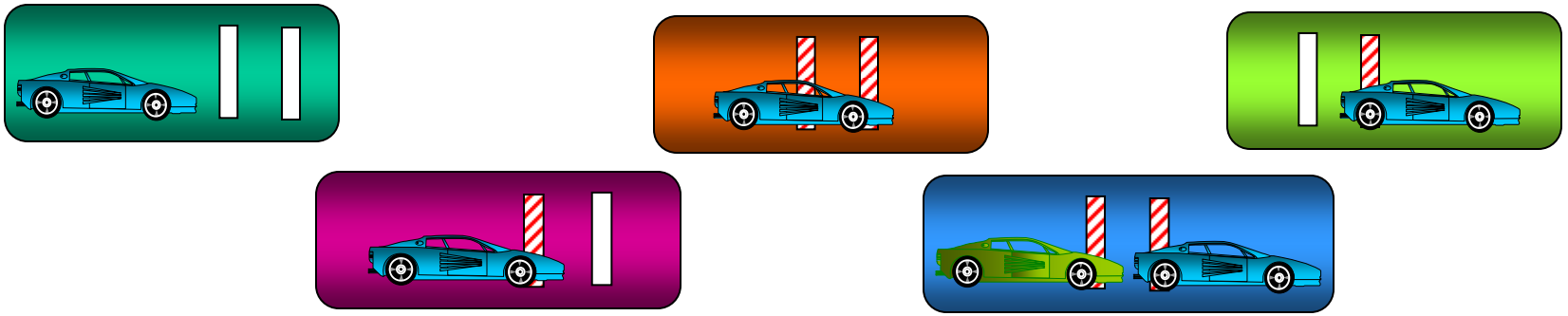
The states

1. No vehicle on any detector.
2. Vehicle only on first detector
3. One vehicle covering both detectors.
4. One vehicle on the first, and another on the second detector.
5. Vehicle only on the second detector.



The state transitions





Problem statement

- A vehicle has passed a pair of detectors if there is:

  a large probability of transition from one of the states corresponding to a vehicle leaving the region (4 or 5) to one of the states corresponding to an empty detector or a new car entering the region (1 or 2).

- This corresponds to the transitions:

  $4 \Rightarrow 2, \qquad 5 \Rightarrow 2, \qquad 5 \Rightarrow 1$

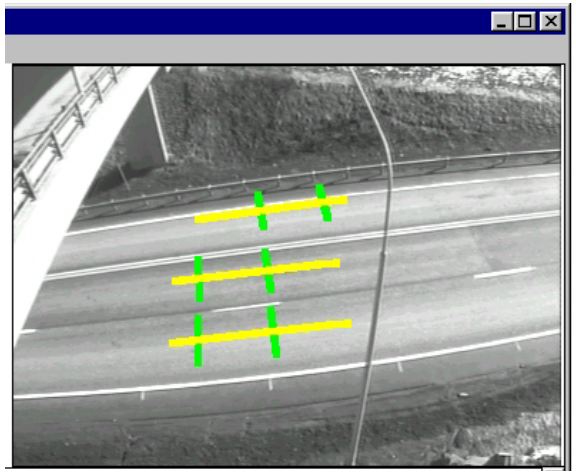
- Hence, we compute the probability of these transitions (using Kitagawa's method):

$$P(C_{t-1} = i, C_t = j \mid Y_1, \ldots, Y_n)$$

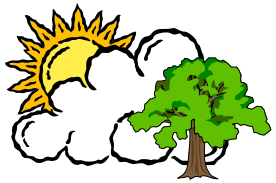
Experiments

- Video camera on a 12 m high pole.
- CCD camera, using the G-component of the RGB signal.
- Standard PC with video input and frame grabber.

- A road stretch with fast moving traffic.
- In ground loop detectors for evaluation of results.
- Day and night for about 200 days.
- Data from 3 periods analysed.

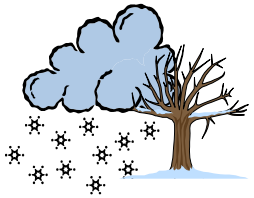


Results



17 hours daylight

10 hours daylight



8 hours daylight

- Summer (July).
  - 7 days
  - Weather: sunny, overcast, rain.
  - Deviation: 1.7%
- Autumn (October).
  - 7 days
  - Weather: clear, low sun, overcast, rain.
  - Deviation: 1.9%
- Winter (January & February).
  - 2+2 days.
  - Weather: clear (low sun), snow covered road face, fog, rain, snow.
  - Deviation: 2.2%

Comments…

- Shadows
- Reflections
- Heavy traffic
- Changing light conditions

Concluding remarks

- Combines low and high level methods.
- Fast on a standard platform.
- Stable and robust.
- Good results.
- Flexible basis.