Detection and Classification of Vehicles

Gupte et al. 2002

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ECG 782

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Introduction

- Previously, magnetic loop detectors were used to count vehicles passing over them.
- Advantages of vision-based video monitoring:
  - Vehicle classification
  - Traffic movement
  - Additional measurements can provide cost savings for pavement maintenance

Overview of System

I. Segmentation
II. Region Tracking
III. Recovery of Vehicle Parameters
IV. Vehicle Identification
V. Vehicle Tracking
VI. Vehicle Classification

Segmentation

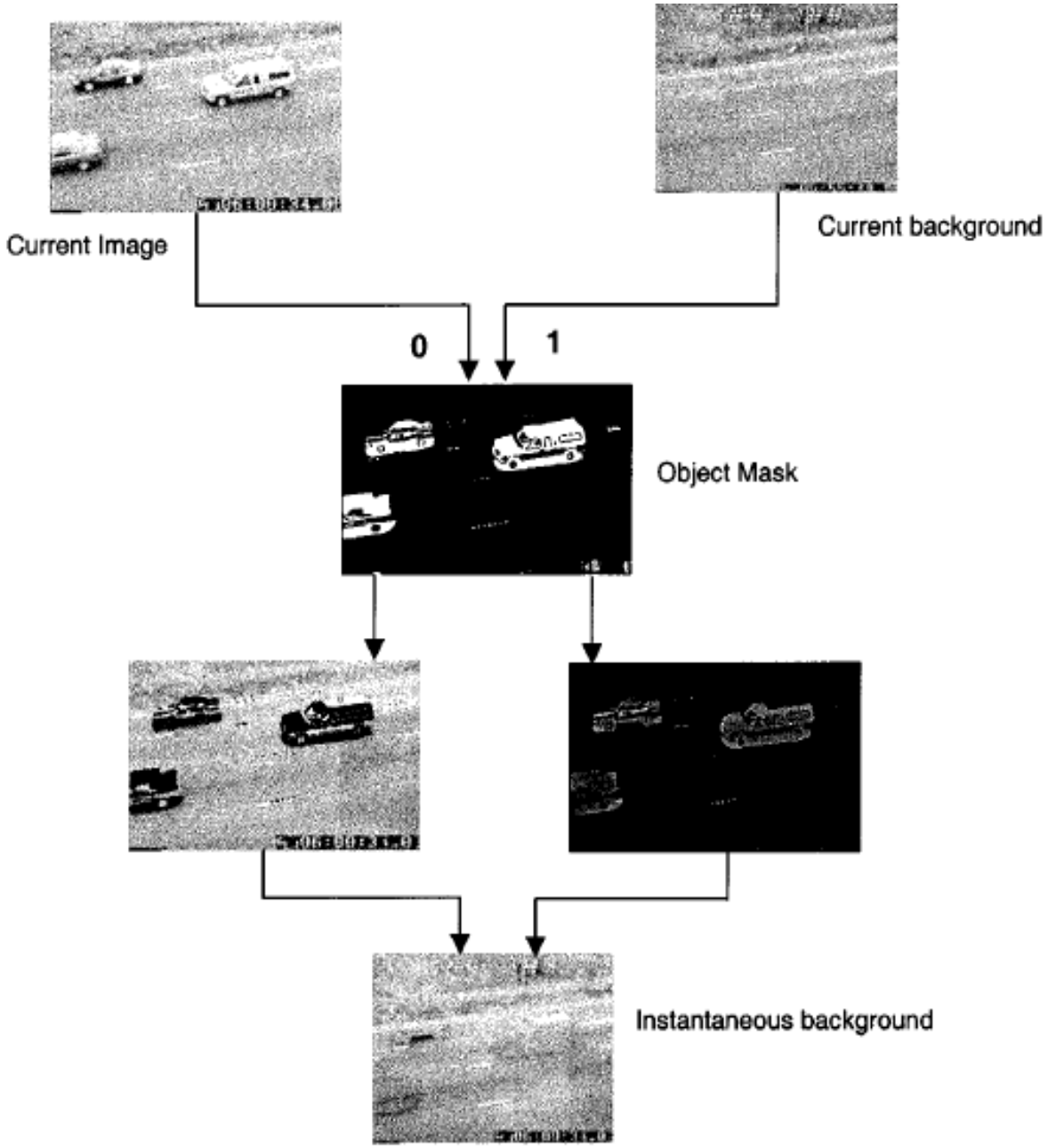
- The vehicles are separated from the background in the scene
- Segmentation technique consists of three tasks
  i. Segmentation
  ii. Background Update
  iii. Background Extraction

Segmentation (cont.)

- For each frame of the video, take the difference between the current frame and current background (*difference image*)
- Threshold the *difference image* to get a binary *object mask*.
- Object mask:
  - Pixels that correspond to foreground objects = 1
  - All others = 0

Segmentation (Background update)

- Modify *current background* in order to look similar to background of current frame
- *Instantaneous background* is needed due to foreground objects in current frame
- **CB = αIB + (1-α)CB**
- Weights affect update speed.
  - 0.1 gives best tradeoff in speed and insensitivity to changes



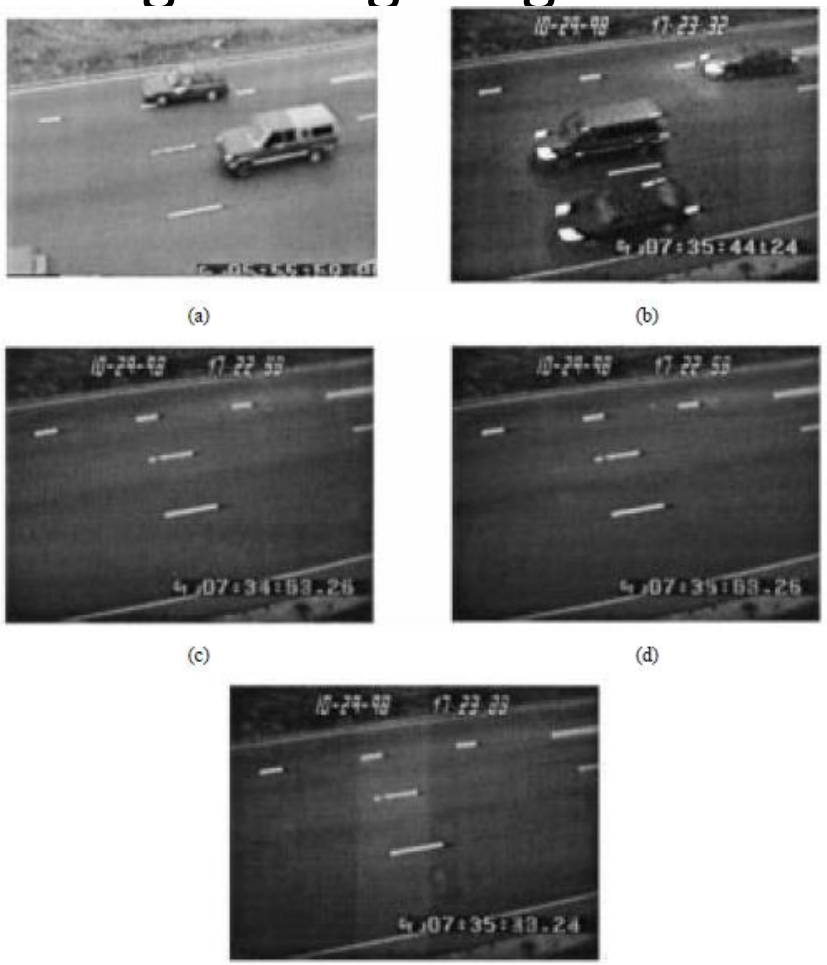
Segmentation (Background extraction)

- Dynamic Threshold Update
  - Due to dynamic background changes, a static threshold will not be able to get the binary object mask.
- Automatic Background Extraction
  - Any object that has significant motion is considered part of the foreground.
  - ***Motion mask*** is used to extract the background by subtracting images from two successive update intervals

$$MM_i = \sim OM_{i\_1} \,\&\, OM_i$$

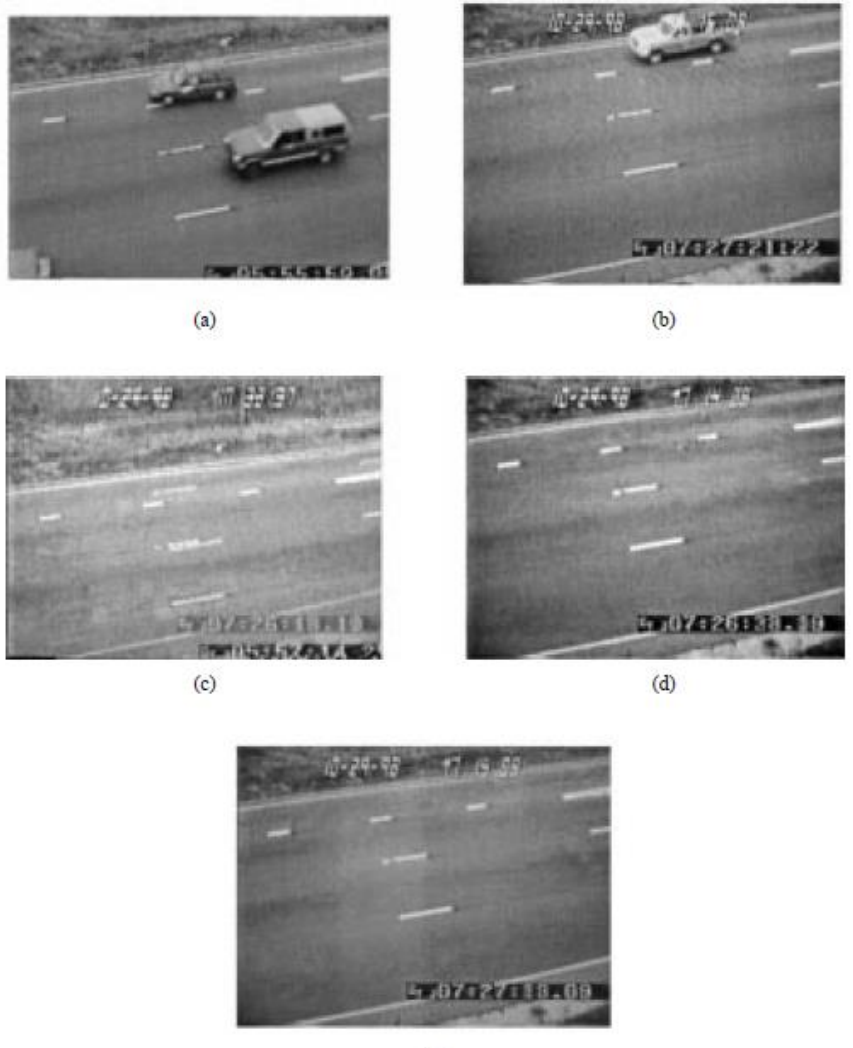
Background Subtraction Results

- Changes in lighting conditions



(a) (b) (c) (d) (e)

- Changes in camera orientation



(a) (b) (c) (d) (e)

Region Tracking

- Region extraction is performed on the output of the segmentation stage (object mask)
- During this stage, connect regions in frame i with the regions in frame *i + 1* in order to compute the velocity of the region as it moves across the image
  - A region might disappear
  - A new region might appear
  - A single region in frame i might split into multiple regions in frame i + 1
  - Multiple regions may merge
- Due to these issues, an *association graph* between previous and current frame regions is formed.
  - *Association graph* : bipartite graph where each vertex corresponds to a region.
- Previous region P_i is associated with current region C_j if there is an edge E_{ij} between vertices V_i and V_j
- Weight of edge $w(E_{ij}) = A(P_i \cap C_j)$
- Weight of graph $w(G) = \sum_{E_{ij} \in G} E_{ij}.$

Region Tracking (cont.)

- To add edges, a score *s* is computed between each P_i and C_j.
- s = $\langle s_{p\to c}, s_{c\to p} \rangle$

$$s_{p\to c} = \frac{A(P_i \cap C_j)}{A(P_i)}$$

$$s_{c\to p} = \frac{A(P_i \cap C_j)}{A(C_j)}$$

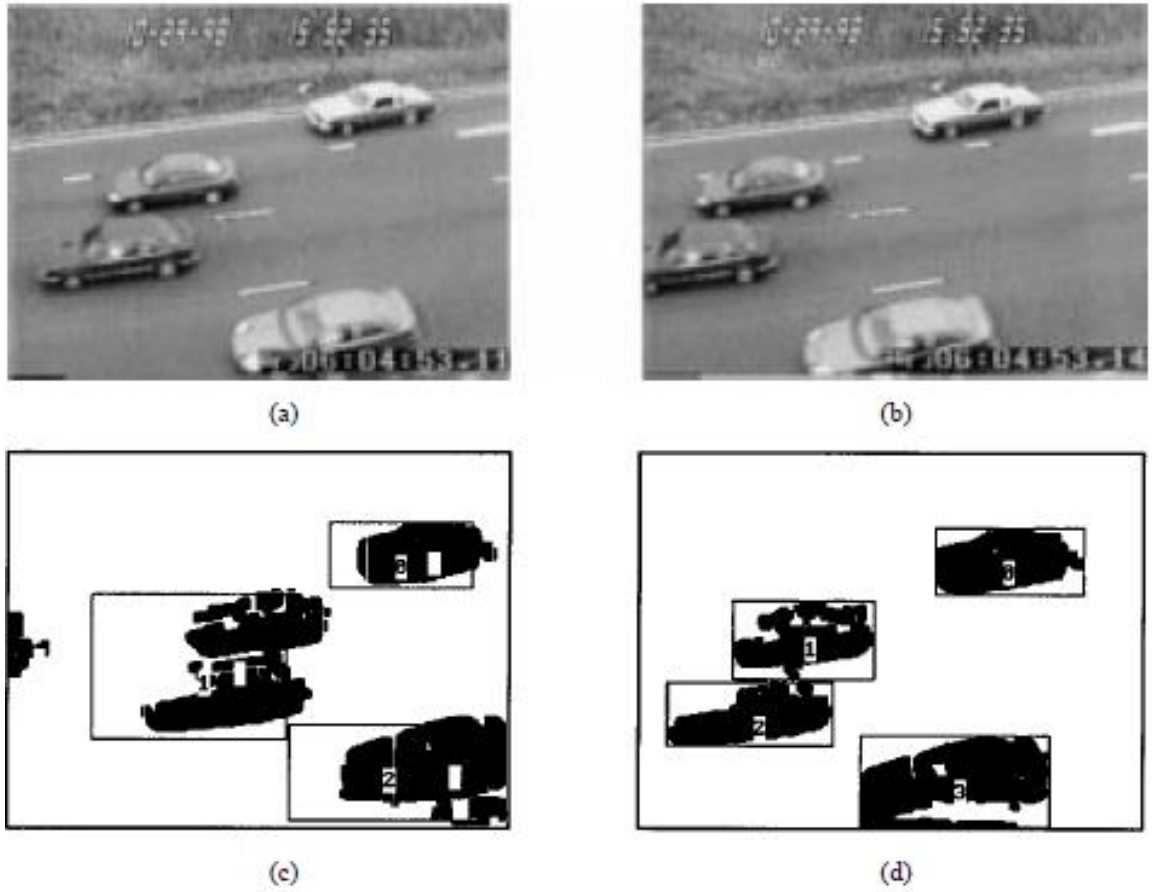
- Two-part score helps to handle region splits and merges correctly.
- Conflicts may occur while edges are added to the graph
  - In every connected component of the graph, only one vertex may have degree greater than 1.
  - for (conflict components)

    Iff (adding edge =/ conflict with constraint)

    add edge

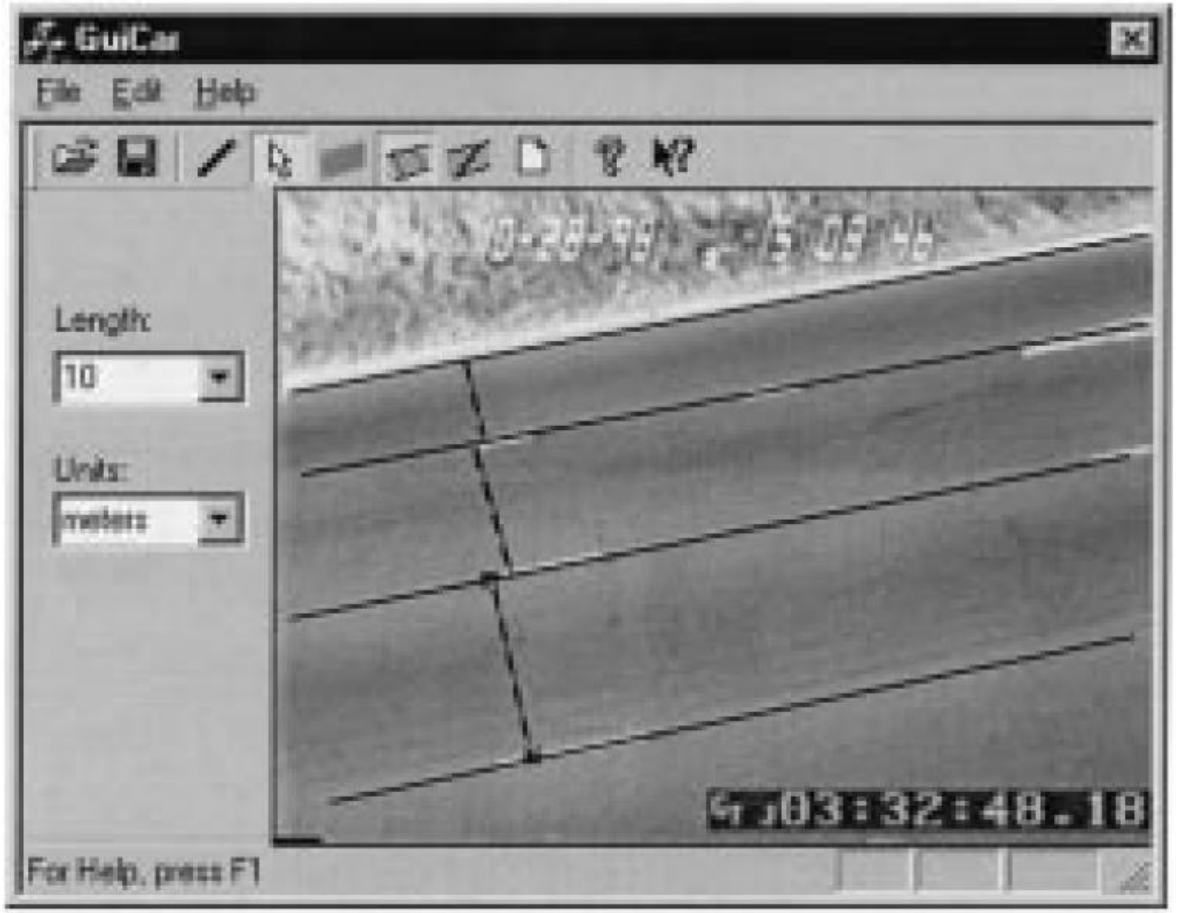
    Else

    ignore edge



Recovery of Vehicle Parameters

- Accurate camera calibration is necessary in estimating the location, length, width and velocity of the regions from the image.
- Due to the difficulties of obtaining calibration parameters from the scene, Gupte et al developed a camera calibration tool for specific traffic scenes.
- The tool allowed them to point to locations on the image, and then compute parameters
- User can define traffic lanes in the video, and direction of traffic.



Vehicle Identification

- Stage groups vehicle regions together to form vehicles.
- *Orphan regions : new regions that do not belong to any vehicle*
- Vehicle is modeled as a rectangle (dimensions dependent on regions)
- Thresholds are made for the min and max sizes of vehicles based on common vehicle sizes
- A new vehicle is created when an orphan region of ample size is tracked over a sequence of 3 frames

Vehicle Tracking

- Vehicle tracking stage updates the location, velocity and dimensions of each vehicle based on the association graph
- Location and dimensions = the bounding box of all its connected regions
- Velocity = weighted average of the velocities $w_i = \frac{A(P_i \cap v)}{A(v)}$
- Velocity is used to predict location of vehicle in next frame

Vehicle Tracking (cont.)

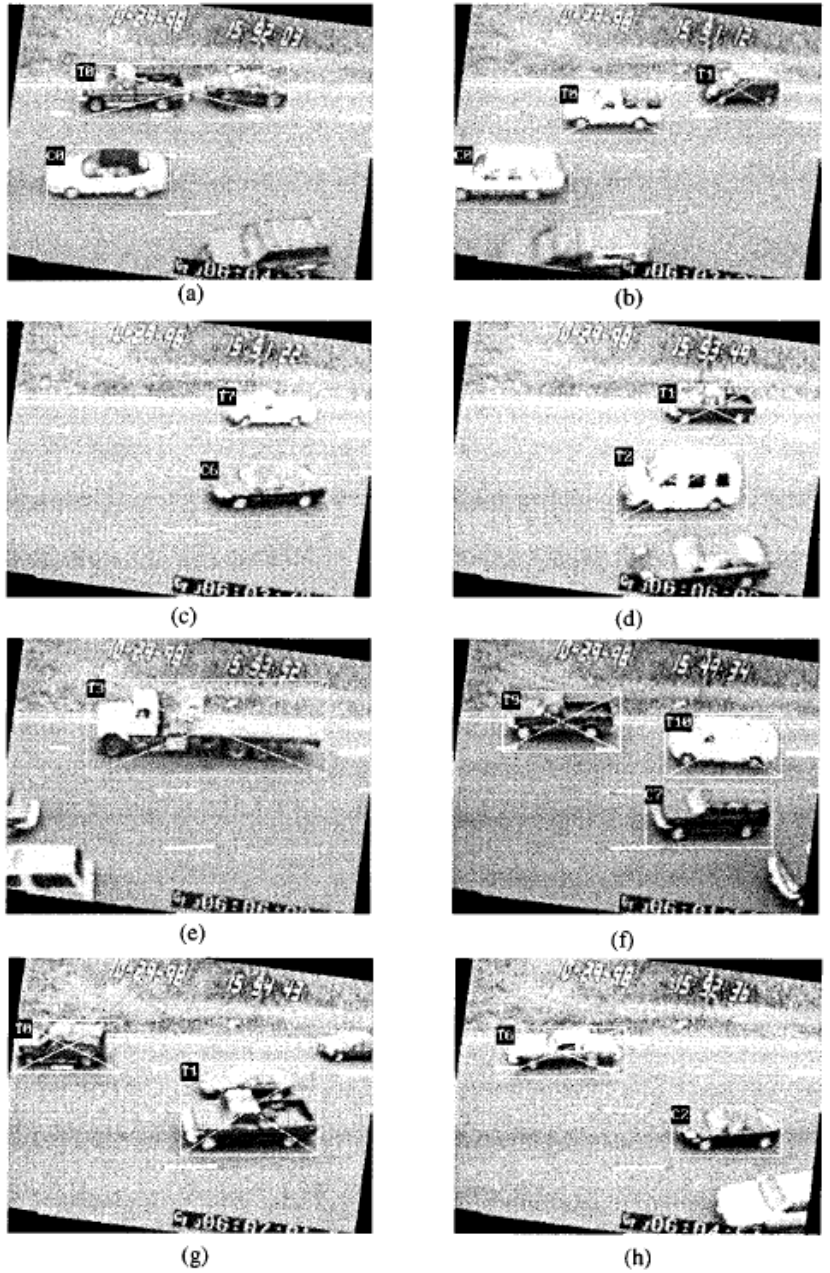
- A region can be in one of five possible states.
  - Update
    - $P_i = C_j$ → vehicle that owned P_i now owns C_j
  - Merge
    - Regions P_i … P_k merge into single region C_j → area of overlap is computed for each vehicle, if above min threshold, C_j is assigned.
  - Split
    - P_i splits into regions C_j … C_k → area of overlap is computed for each vehicle with Regions C_j … C_k, if greater than a min value, the region is assigned to that vehicle.
  - Disappear
    - A region in P is not matched by any region in C → region is removed from all vehicles that owned it.
  - Appear
    - A region in C does not match any region in P. → A new vehicle is created.

Vehicle Classification

- Vehicle dimensions are used to classify vehicles into two categories
  - Cars
  - Noncars (vans, SUVs, pickup trucks, tractor-trailers, semis and buses)
- Vehicle's category is determined by its length and height
- Calculated the mean and variance of a sample of 50 cars and 50 trucks.
  - From samples, computed a discriminant function to classify vehicles

Results

- 90% of vehicles were correctly detected and tracked (20 minute highway scene)
- 70% of those vehicles were correctly classified.
- Errors due to occlusions and/or poor segmentation.
- Due to failures in updating the background, noise can be added or subtracted from the detected vehicles.
- Due to segmentation being intensity-based, vehicles with similar intensities to the road are missed.



Thank you for your time.

Questions?

References

- S. Gupte, O. Masoud, R.P.K. Martin, N.P. Papanikolopoulos, "Detection and classification of vehicles", in IEEE Transactions on Intelligent Transportation Systems, vol. 3, no. 1, pp. 37-47, March 2002.