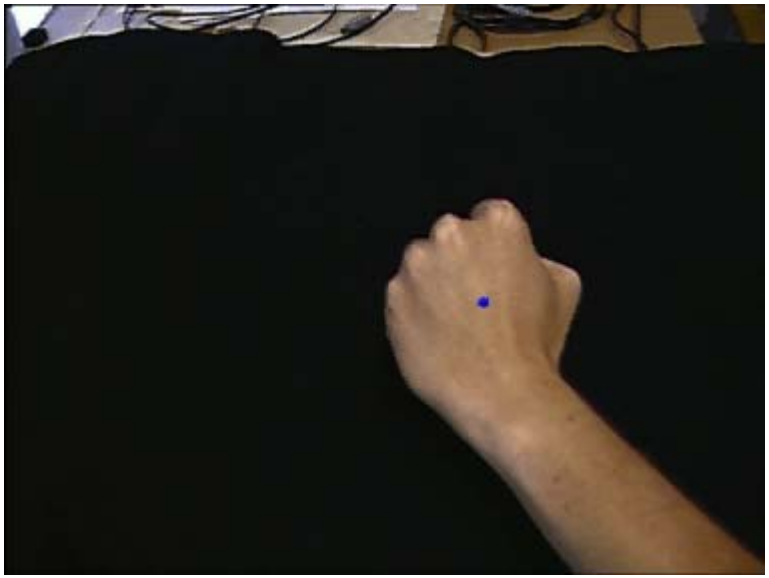
Segmentation in video

Advanced Image Processing

VGIS8 – Spring 2009

Segmentation in video

Basic idea: detect objects of interest



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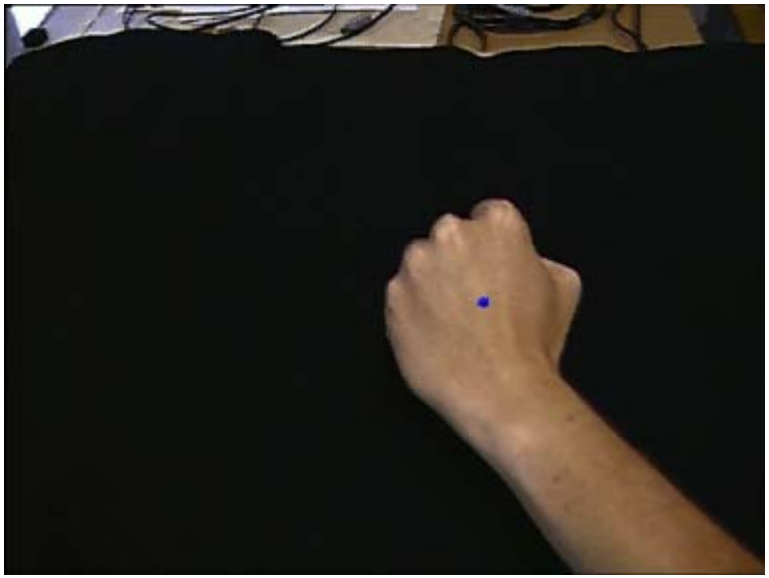
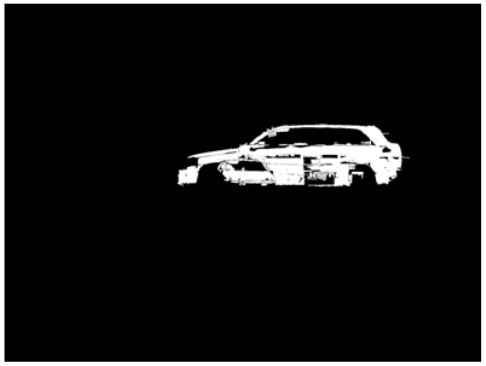
Basic idea: detect objects of interest



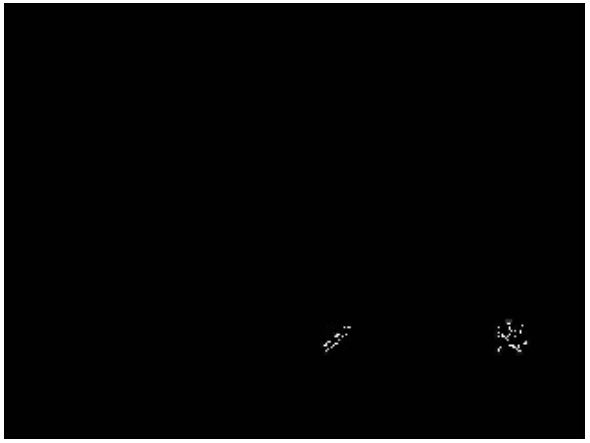
Result: binary image

General algorithm

1. Save reference image
2. Capture current image
3. Perform image subtraction
4. Thresholding
5. Filter noise



Results - General algorithm



Today's topics

- Background subtraction
- Constructing the reference image
- Updating the reference image
- Global and local thresholds
- Image differencing
- Noise filtering
- Advanced segmentation

1. Acquire reference image
2. Capture current image
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Background subtraction

1. Acquire reference image
2. Capture current image
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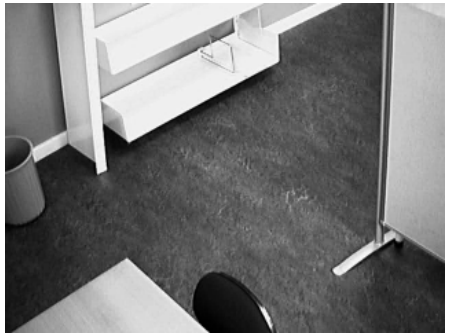
4. Thresholding
5. Filter noise

- First frame as reference image

$r(x,y)$: 

$f(x,y)$: 

- Pixel-wise subtraction

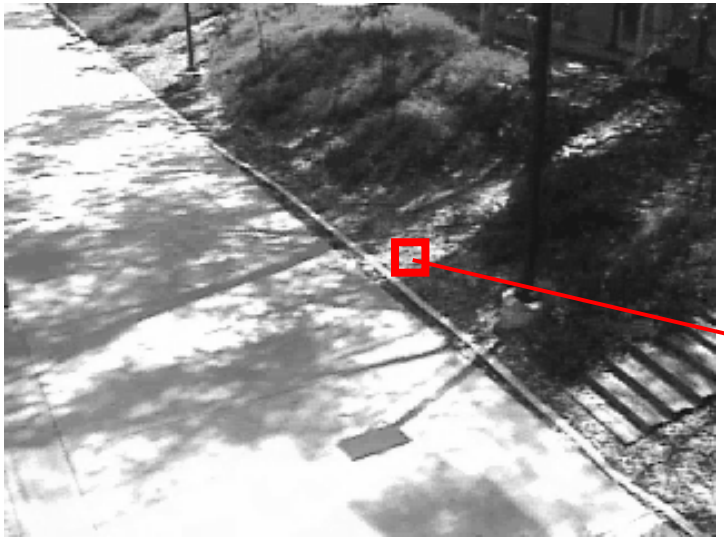
$$g(x,y) = f(x,y) - r(x,y)$$

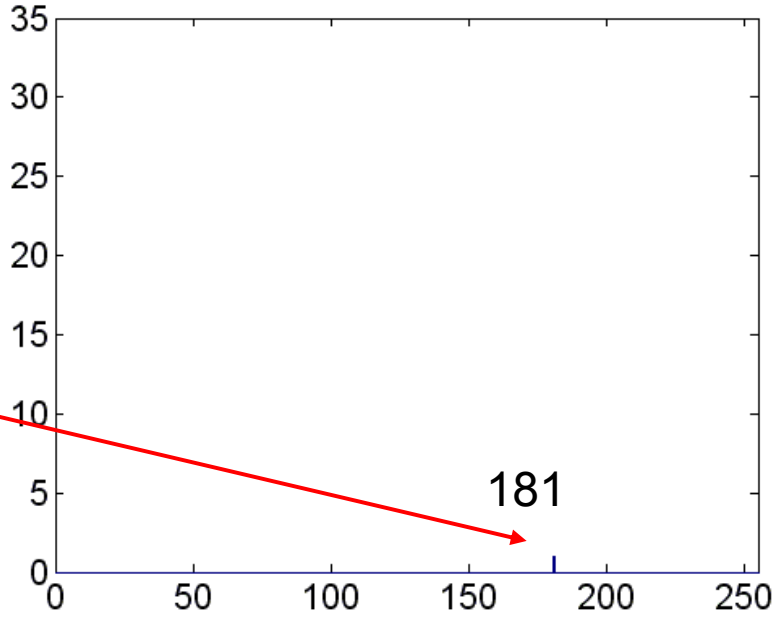
- Apply absolute value

$$g(x,y) = |f(x,y) - r(x,y)|$$

Constructing the reference image

- With non-stable background
  - e.g. camera noise, changes in light, small motion from wind gusts
- Then learn the background





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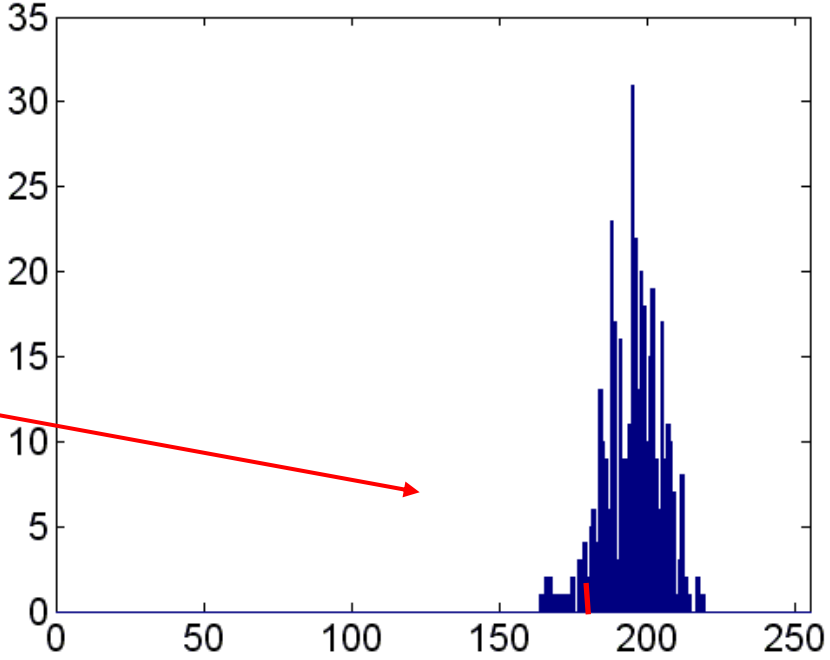
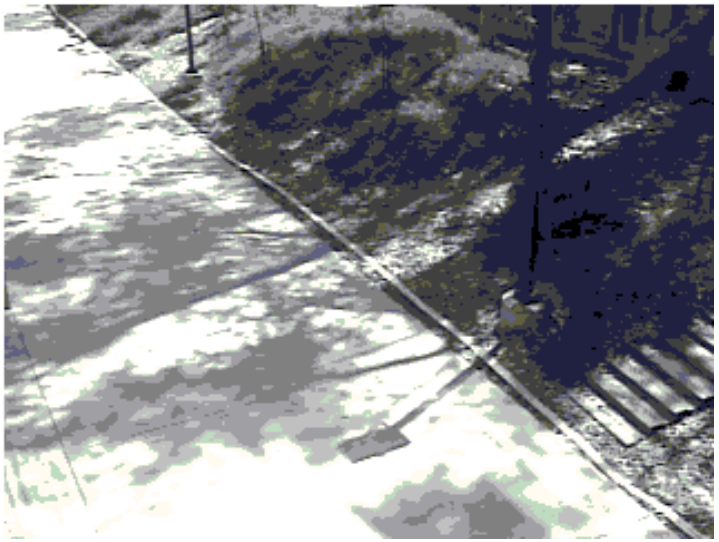


Constructing the reference image

- Learning the background
  - Capture *N* empty images and calculate the average background image

$$r(x,y) = \sum_{i=1:N} f_i(x,y) \,/\, N$$



1. **Calculate average reference image**
2. Capture current image
3. Perform image subtraction
4. Thresholding
5. Filter noise

Updating the reference image

- With gradual changes during processing
  - e.g. light changes during a day
- Then update the reference image

Updating the reference image

- With gradual changes during processing
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- Then update the reference image
  - Update speed α

$$r_{new}(x,y) = \alpha \cdot r_{old}(x,y) + (1- \alpha) \cdot f(x,y)$$

Update speed
$\alpha = 0.98$

Global vs. local thresholds

1. Acquire reference image
2. Capture current image
3. Perform image subtraction
4. Thresholding
5. Filter noise

- So far:
  - Image subtraction

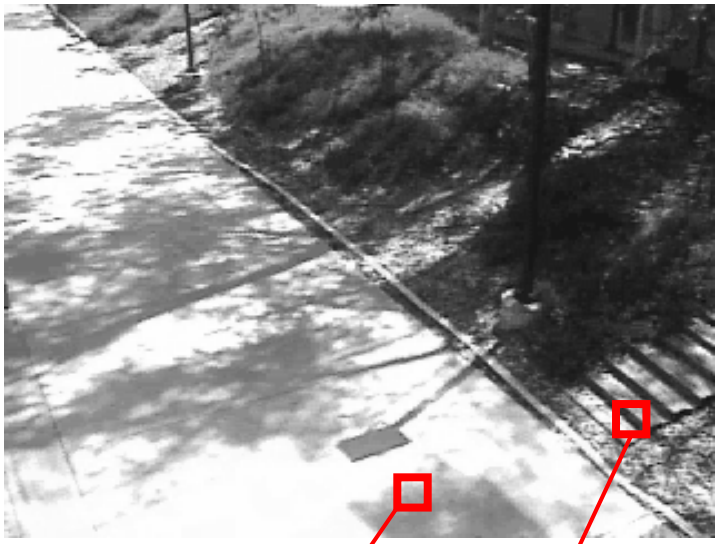
$$g(x,y) = |f(x,y) - r(x,y)|$$

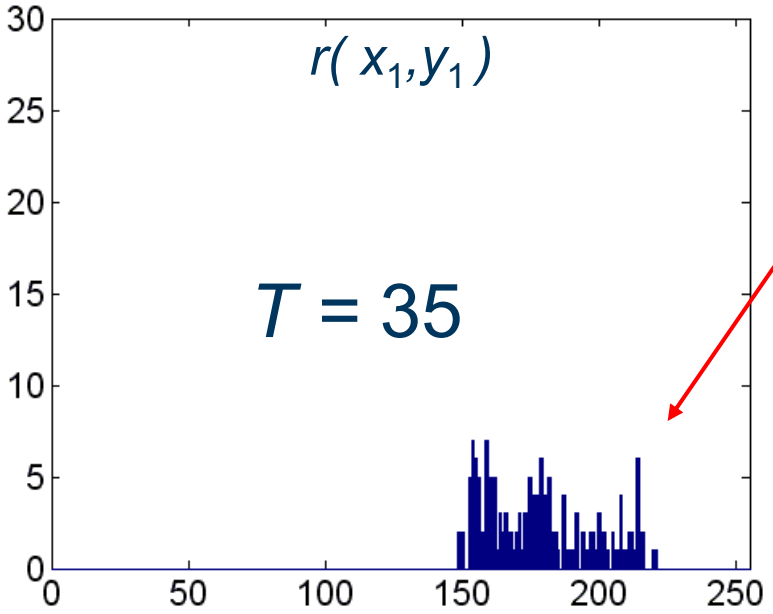
  - Global threshold T to obtain binary image b

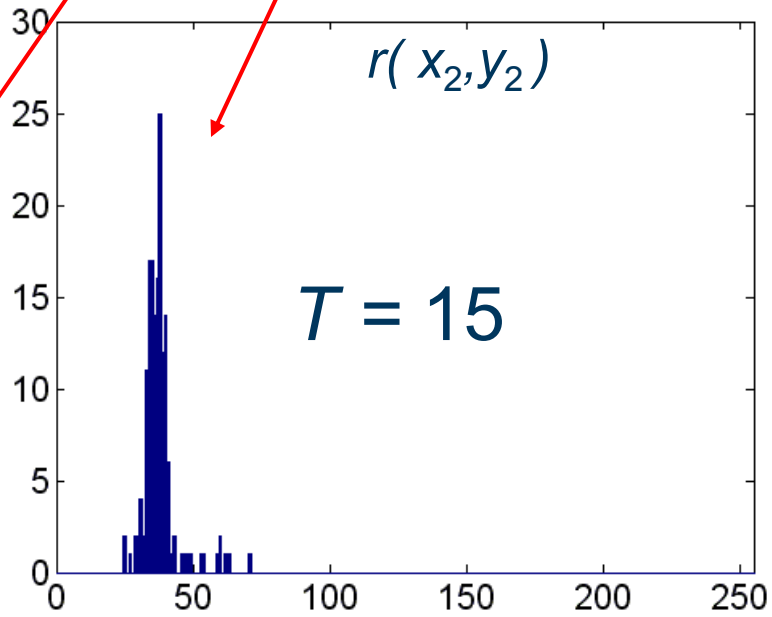
$$b(x,y) = \begin{cases} 0, & \text{if } g(x,y) < T \\ 255, & \text{else} \end{cases}$$

Global vs. local thresholds

- With local pixel variation
- Then apply local thresholds





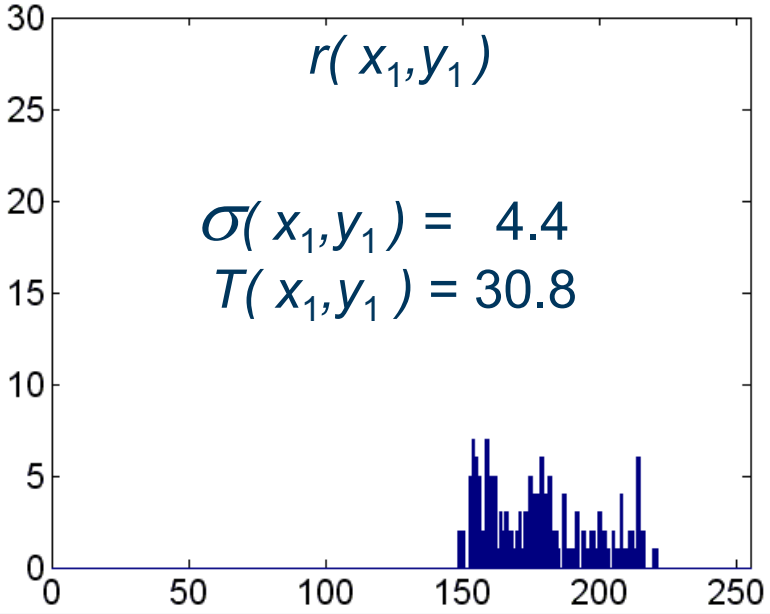


Global vs. local thresholds

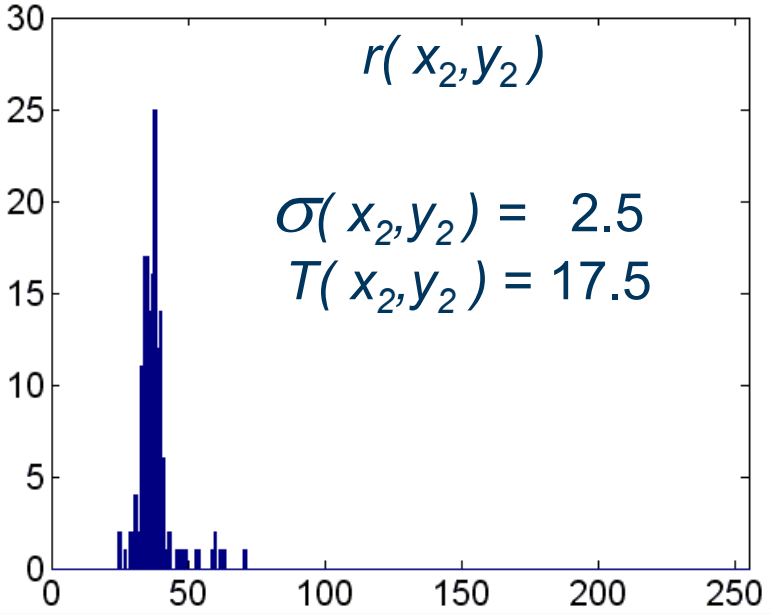
- Apply local threshold
  - Calculate mean and standard variation σ
  - Define T in terms of σ

$$T(x,y) = \beta \cdot \sigma(x,y)$$

  - *Choose (global) β*



$\beta = 7$



Global vs. local thresholds

- Apply local threshold

1. **Calculate mean and standard variation for each pixel**
2. Capture current image
3. Perform image subtraction
4. **Threshold according to standard variation**
5. Filter noise

- Local thresholds + reference image updating is a powerful background subtraction method – especially if you can choose your background

Image differencing

- With very dynamic scenes which can not be learned
- Then choose the previous frame as the reference frame

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- Then choose the previous frame as the reference frame

$$r_t(x,y) = f_{(t-1)}(x,y)$$

- Different reference image (depending on application)

$$r_t(x,y) = f_{(t-k)}(x,y)\ ,\ k = 2,3,\ldots$$

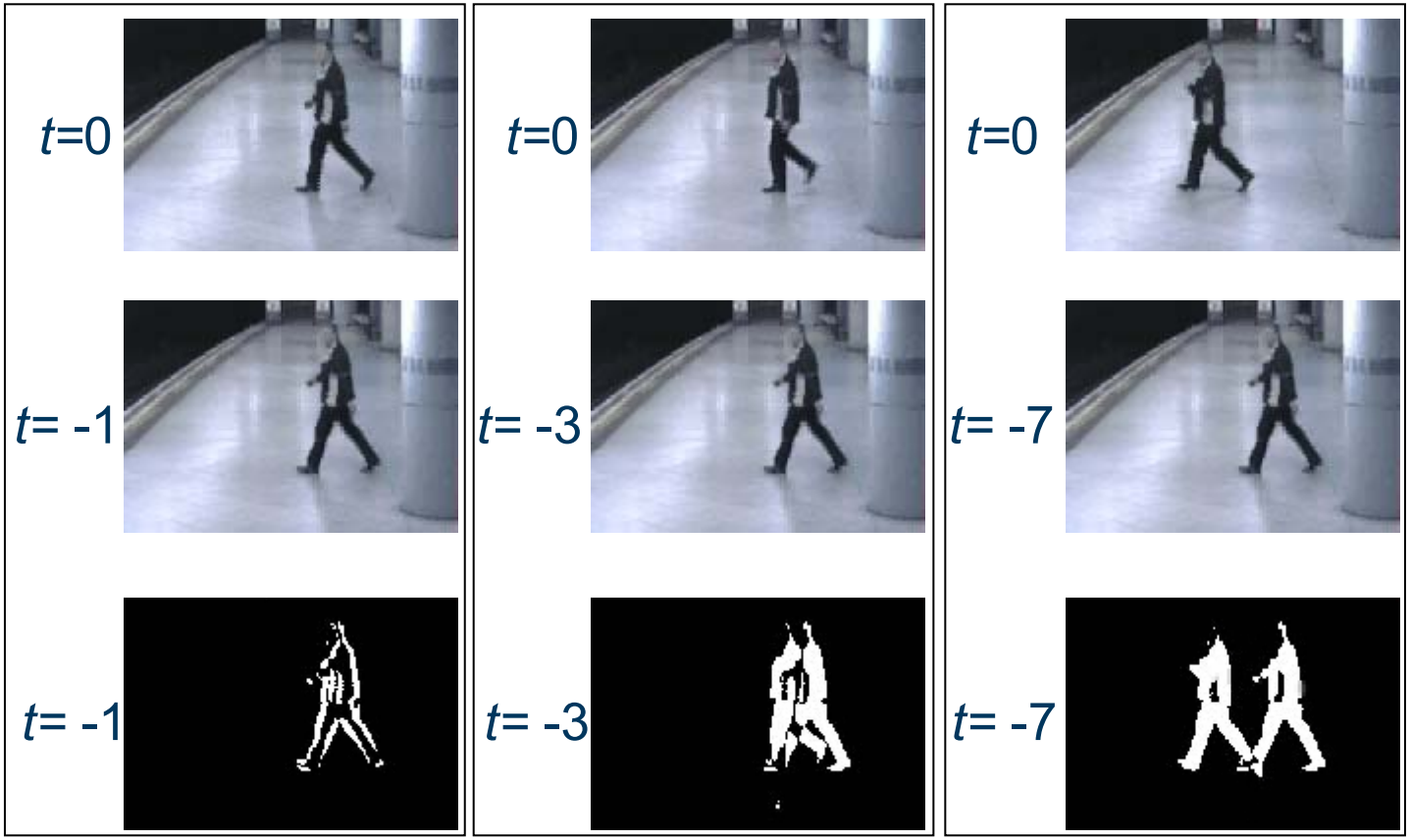
- Double differencing

$$g_t(x,y) = [f_t(x,y) - r_{1,t}(x,y)] \text{ AND } [f_t(x,y) - r_{2,t}(x,y)]$$

Image differencing vs. background subtraction

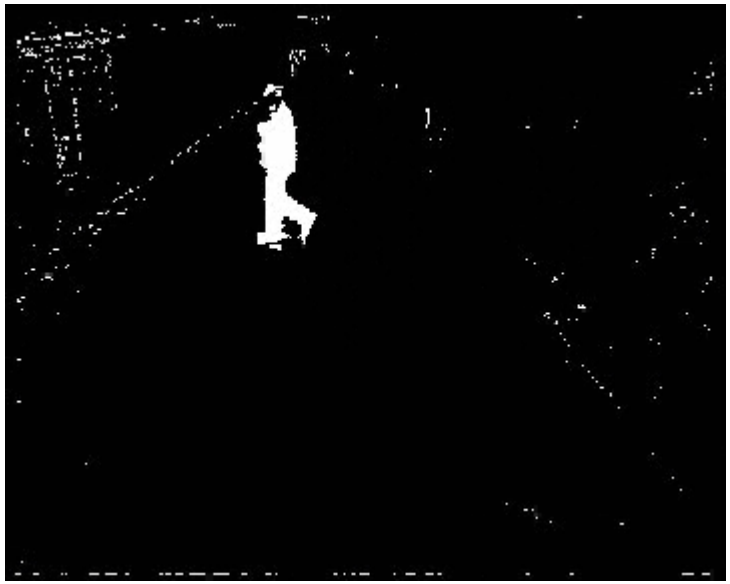
Image differencing	Background subtraction
• Handles dynamic scenes • Detects only motion • Detection results in ghosts	• Requires static background • Detects stationary objects • Detects whole objects

Ghosts:



Noise filtering

- Single pixels are likely to appear
  - Pixel-noise
- Apply Median filter
  - Depending on filter size, bigger spots can be erased
- Alternatives:
  - Morphology
  - Temporal filtering
  - Restrictions on size, shape



Summing up…

- The general algorithm for segmentation:

1. Acquire reference image
2. Capture current image
3. Perform image subtraction
4. Thresholding
5. Filter noise

- Learn reference image from a set a frames
- Update the reference image continuously
- Learn the standard variation and apply local thresholds
- Apply image differencing in dynamic scenes

Next topics – advanced segmentation

- Shadows and light changes
- Multi-modal background models
- Learning background with non-empty images
- Layered background models
- Optical flow for segmentation

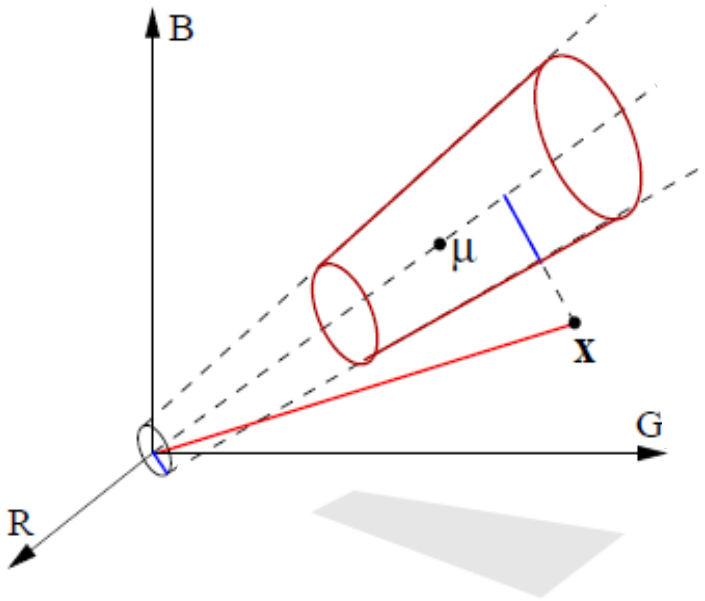
Shadows and light changes

- Shadows and light changes cause false positives

- Solution: separate color and intensity
  - HSV-color space
  - Codebook background subtraction method
    - One method to handle advanced issues in segmentation

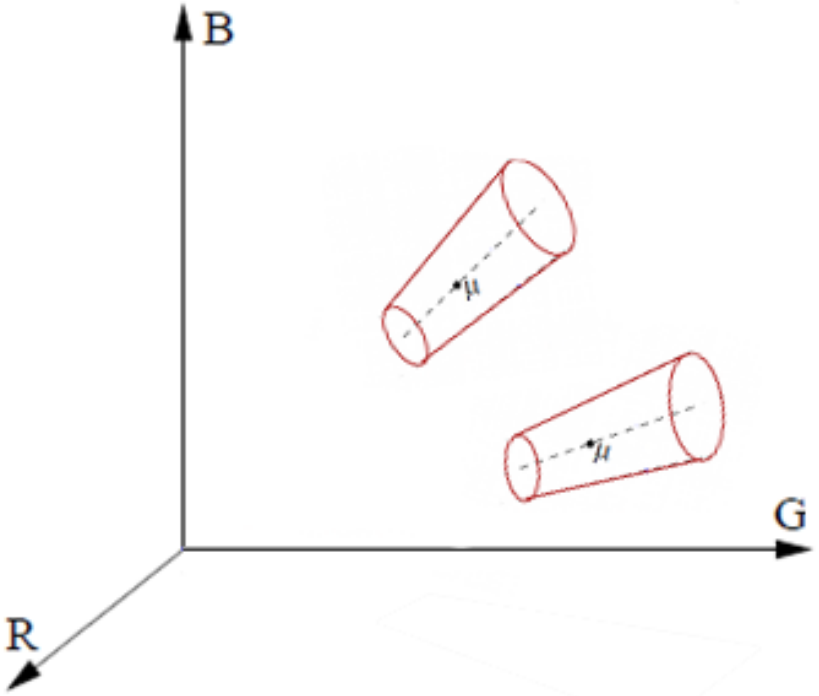
Shadows and light changes

- Color-model of codebook background subtraction:



Multi-modal background models

- Learn the background from *N* frames – *N*~300
- Allow multiple codewords for each pixel



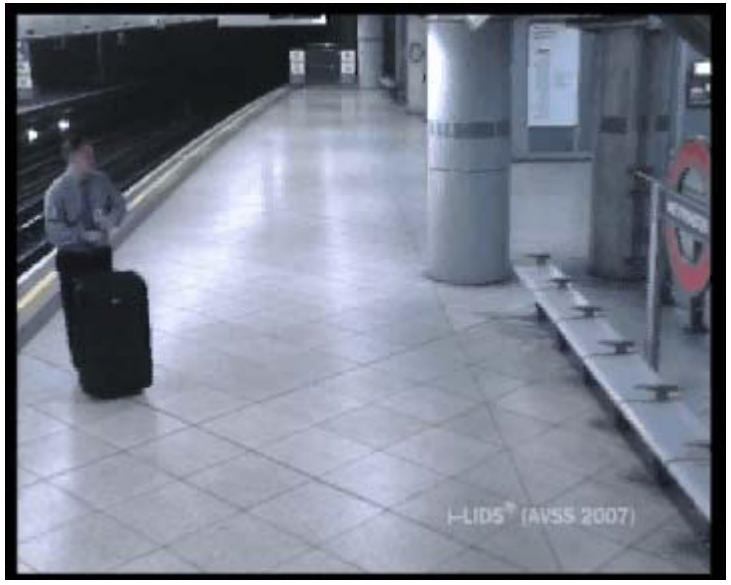
Learning background with non-empty images

- Learn the background from *N* frames – *N*~1000

- Evaluate all codewords after training
  - True background vs. false background
  - True: pixel values appear periodically
  - False: pixel values appear in bursts

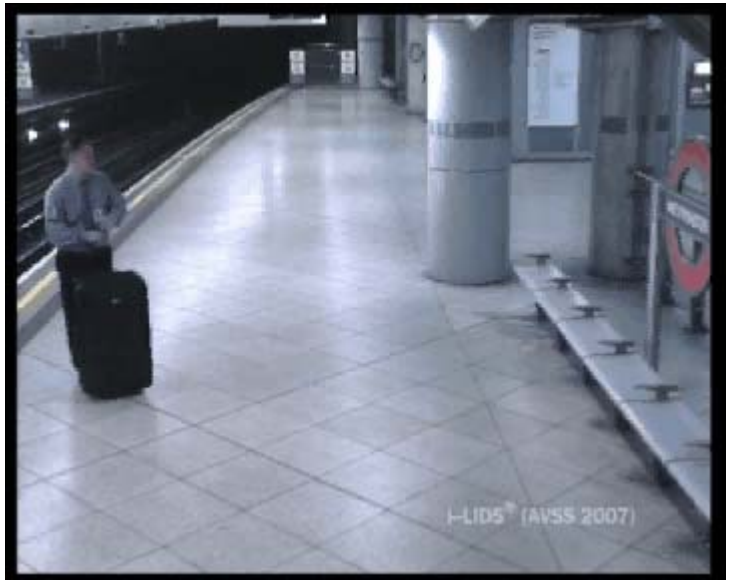
Layered background models

- Parts of the scene can become temporary background
  - e.g. parked cars, left behind luggage, the train
- Reference image updating adapts over time



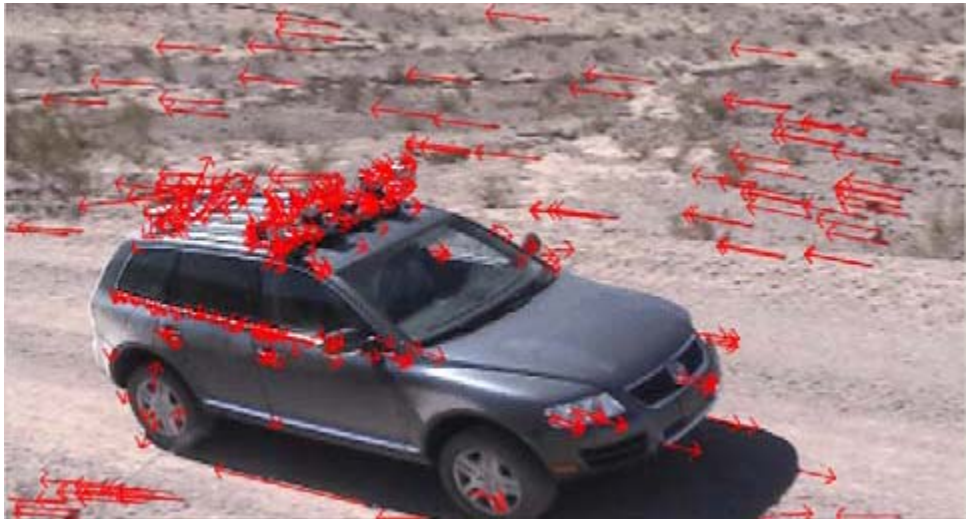
Layered background models

- Alternative: use multiple layers of background
  - Continuously evaluate all foreground regions
    - IF pixel values appear periodically for *N* frames
    - THEN add new codeword to the background model
  - Delete expired codewords



Optical flow for segmentation

- Moving cameras make reference images impossible (e.g. car-mounted cameras)
  - Both objects and background move
- Solution:
  - Estimate motion direction between frames
  - Objects with motion different than average motion can be identified



Summing up …

- Advanced background subtraction addresses many real life problems
- … but the problem of segmentation is not solved
- Still an area of research:
  - Combining color segmentation with edges
  - Applying regional information
  - Applying contextual information

Exercises

1. Acquire reference image
2. Capture current image
3. Perform image subtraction
4. Thresholding
5. Filter noise

- Download Matlab script + videos
  - Segment hand.avi with different thresholds
- Implement:
  - Learn reference image from a set a frames
    - Use the first 100 frames in sun_and_trees.avi
  - Update the reference image continuously
    - Use the first 40 frames of office_light.avi for background
  - Learn the standard variation and apply local thresholds
    - Use the first 100 frames in sun_and_trees.avi
  - Apply image differencing in dynamic scenes
    - sun_and_trees.avi is a good test case
- Mini project

Mini-project

- To do (for each group)
  - Find information and learn the principle
  - Implement a working prototype
  - Hand-in report (3-5 pages) about: principle, usage, algorithm, your implementation and results
  - Present your work (10-20min)
- Hand-in report: 9/4 at 12.00
- Presentation: 13/4