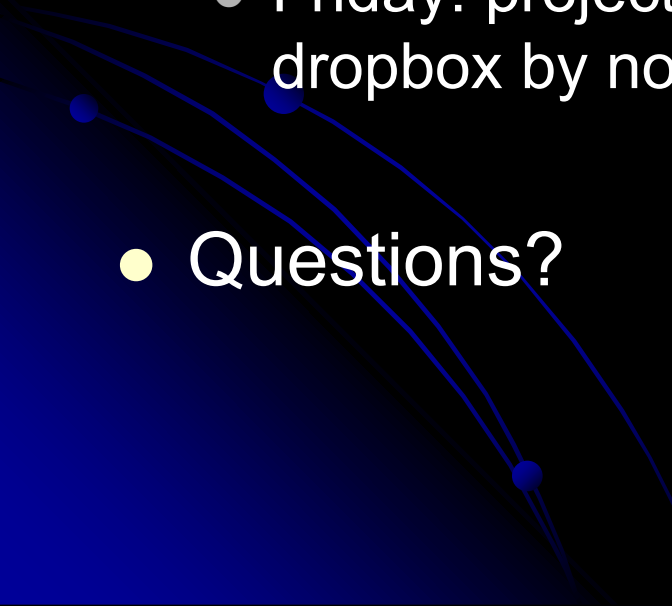


- This week
 - Today: Surveillance and finding motion vectors
 - Tomorrow: motion and tracking
 - Lab 7: due Wednesday
 - Thursday: Bayesian classifiers
 - Friday: project workday in class, **status report** due in dropbox by noon.
 - Questions?
- 

Motion

- New domain: image sequences.
- Additional dimension: time
- Cases:
 - Still camera, moving objects
 - Detection, recognition
 - Surveillance
 - Moving camera, constant scene
 - 3D structure of scene
 - Moving camera, several moving objects
 - Robot car navigation through traffic

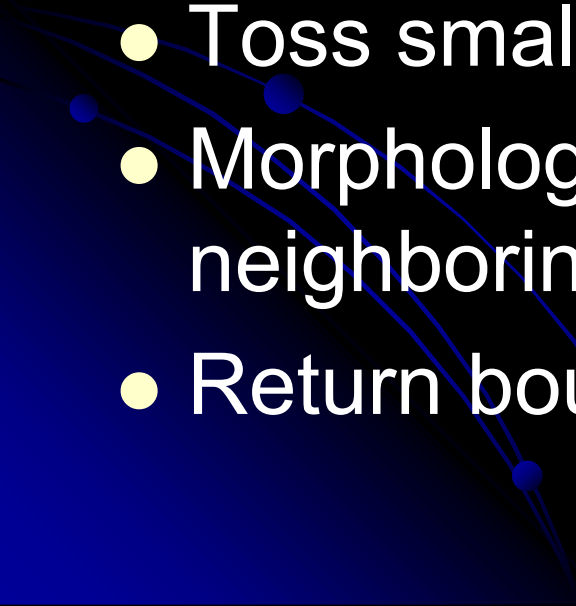
Surveillance

- Applications:
 - Military
 - Hospital halls during night
- Stationary camera, moving objects
- Separate background from objects

Finding moving objects

- Subtract images
- What next...
 - How could you use this to find moving objects?
 - Discuss with a classmate
 - Share with class

Processing ideas

- Subtract images
 - Mark those pixels that changed significantly (over threshold)
 - Connected components. Fill?
 - Toss small regions
 - Morphological closing to merge neighboring regions
 - Return bounding box
- 

Issues with image subtraction

- Background model
 - Simplest: previous frame
 - General: find mean M and variance of many frames
 - Consider the hospital hallway with a window
 - How to handle “drift” due to illumination changes?
 - For each pixel p with mean M : $M_{\text{new}} = \alpha M_{\text{old}} + (1-\alpha)p$
 - Consider what happens when a person enters the scene
 - Background model adapts to her
 - What happens when she leaves?
 - Mean changes, so detects background as foreground
 - Variance remains high, so can't detect new arrivals.
 - Answer: multiple models

Motion vectors

- Difference in motion of specific objects
- Show examples for pan.
- Create ones for zoom in/out.

- How to find?
 - 2 techniques
- 

What is image flow?

image_T

0	0	0	0	0	0	0	7
0	4	4	4	4	4	0	10
0	0	4	6	6	4	0	9
0	0	0	4	6	4	0	10
0	0	0	0	4	4	0	8
0	0	0	0	0	4	0	0
0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0

image_{T+ΔT}

0	0	0	0	0	0	0	7
0	0	0	0	0	0	0	10
0	4	4	4	4	4	0	9
0	0	4	6	6	4	0	10
0	0	0	4	6	4	0	8
0	0	0	0	4	4	0	0
0	0	0	0	0	4	0	0
0	0	0	0	0	0	0	0

- Notice that we can take partial derivatives with respect to x , y , and time.

Image flow equations

- Goal: to find where each pixel in frame t moves in frame $t+\Delta t$
 - E.g. for 2 adjacent frames, $\Delta t = 1$
 - That is, $\Delta x, \Delta y$ are unknown
- Assume:
 - Illumination of object doesn't change
 - Distances of object from camera or lighting don't change
 - Each small intensity neighborhood can be observed in consecutive frames: $f(x,y,t) \rightarrow f(x+\Delta x, y+\Delta y, t+\Delta t)$ for some $\Delta x, \Delta y$ (the correct motion vector).
- Compute a Taylor-series expansion around a point in (x,y,t) coordinates.
- Gives edge gradient and temporal gradient
- Solve for $(\Delta x, \Delta y)$

Limitations

- Assumptions don't always hold in real-world images.
- Doesn't give a unique solution for flow
 - Sometimes motion is ambiguous
 - "Live demo"

