Designing Applications that See
Lecture 5: Motion and Tracking

Dan Maynes-Aminzade

22 January 2008

Reminders

- Assignment #1 due now
- Assignment #2 available next Tuesday
- Bring your webcams on Thursday for the Processing Tutorial
- Sunday is the add deadline

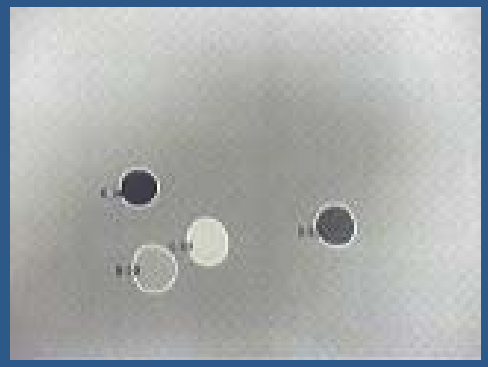
Today's Goals

- Learn how to detect, measure, and predict motion in a video sequence
- Get a high-level overview of some different tactics for tracking moving objects

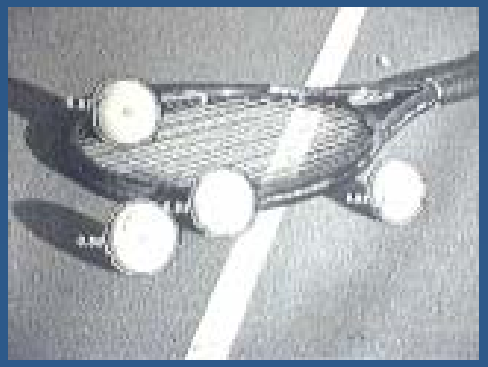
Outline

- Look at some of your videos from Assignment #1
- Learn about some motion and tracking techniques and try them out on your videos
  - Frame differencing
  - Background subtraction
  - Motion templates
  - Optical flow
  - Color tracking

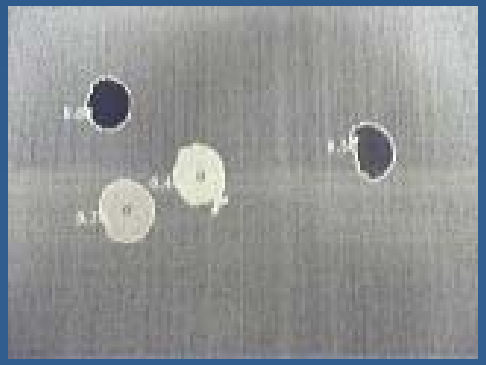
Tennis Balls



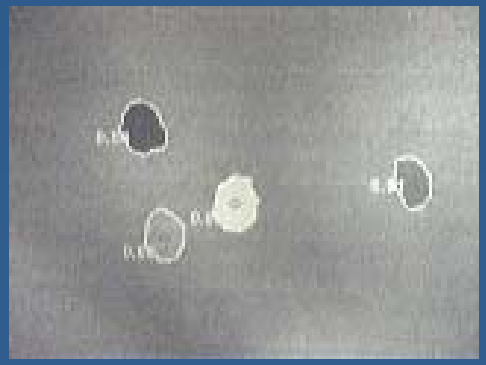
Carl



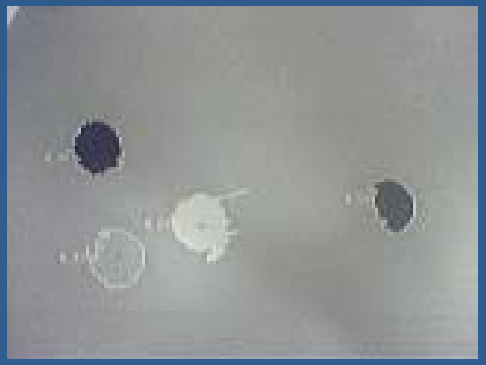
Marcello



Eric



Yangfan



Michael

Intersection

Farmers' Market

Foosball

Fish

Around the House

Bikes

Clothes

Driving

Fish

Kitchen

Laundry

Ping-Pong

Plate

Sandwich

Traffic

Types of Motion Determination

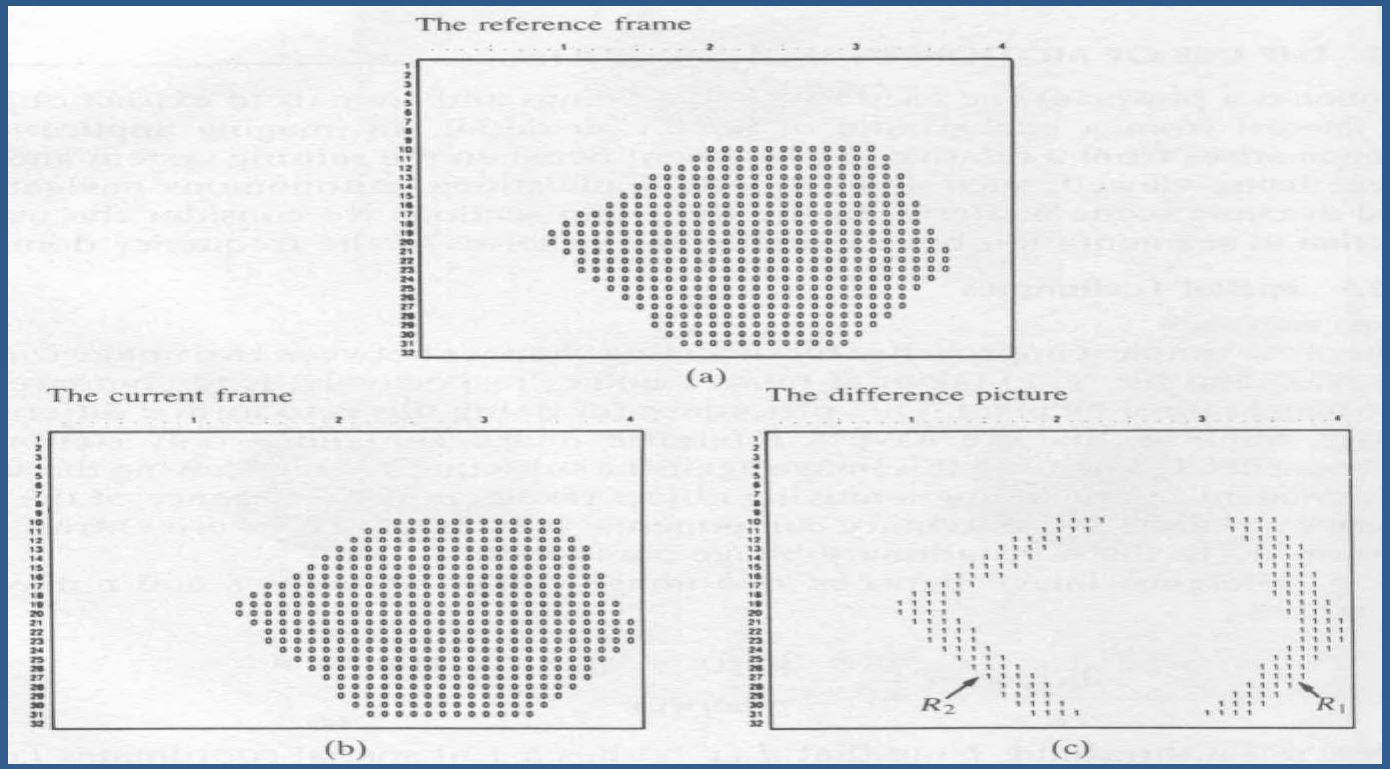
- Motion Detection: identifying whether or not image points are moving
- Motion Estimation: identifying how image points are moving
- Motion Segmentation: identifying moving objects from moving points

Extracting Moving Objects

- Simple case: static background, with only the object of interest in motion

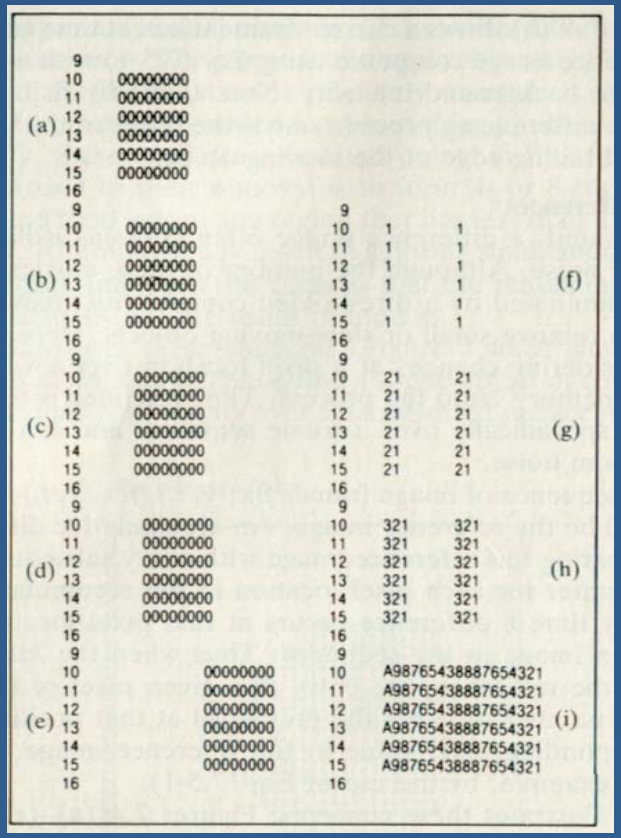
Solution: Frame Differencing

- Subtract current frame from previous frame, and threshold the result



Accumulative Frame Differencing

- Estimate motion direction by accumulating motion history over a range of frames



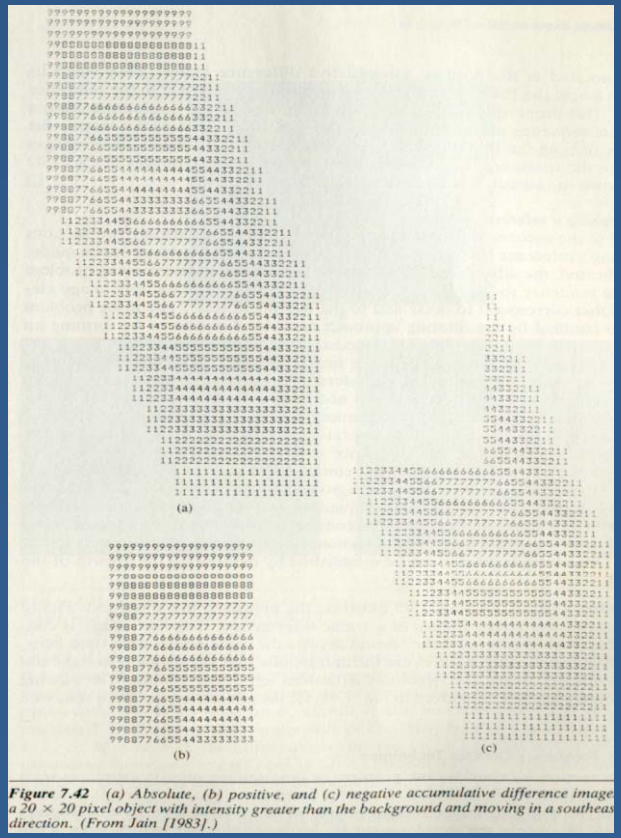
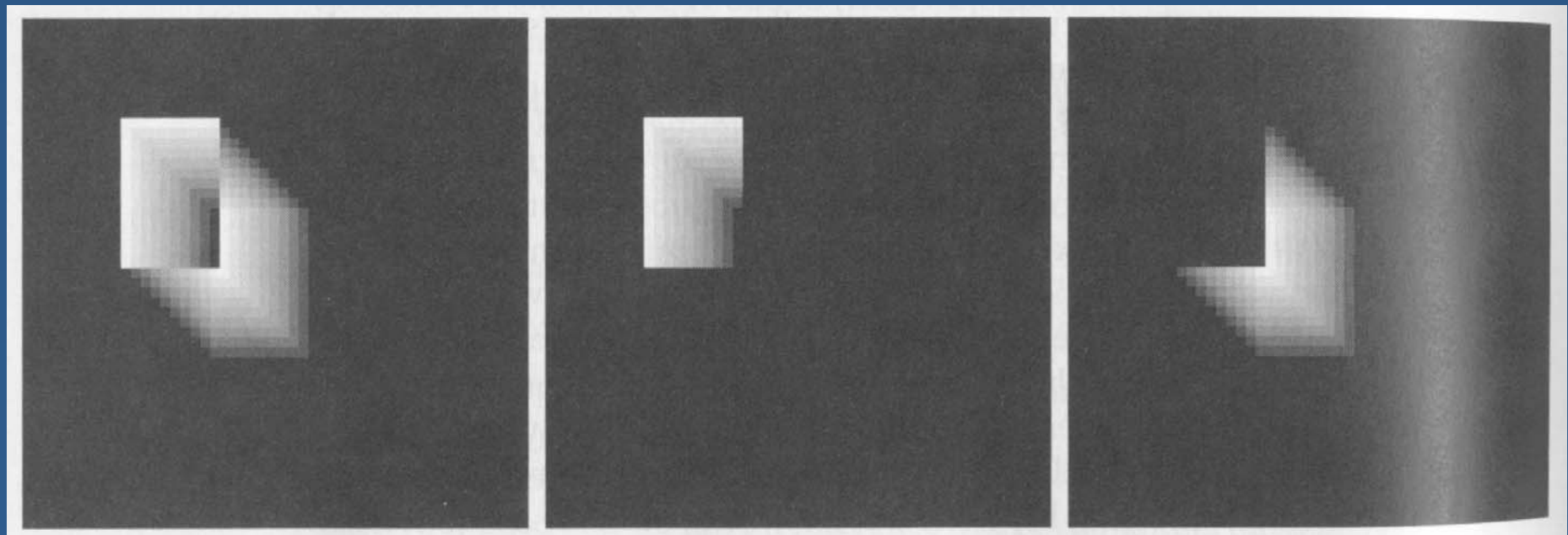


Figure 7.42 (a) Absolute, (b) positive, and (c) negative accumulative difference image a 20 × 20 pixel object with intensity greater than the background and moving in a southea direction. (From Jain [1983].)

Motion History Image



a b c

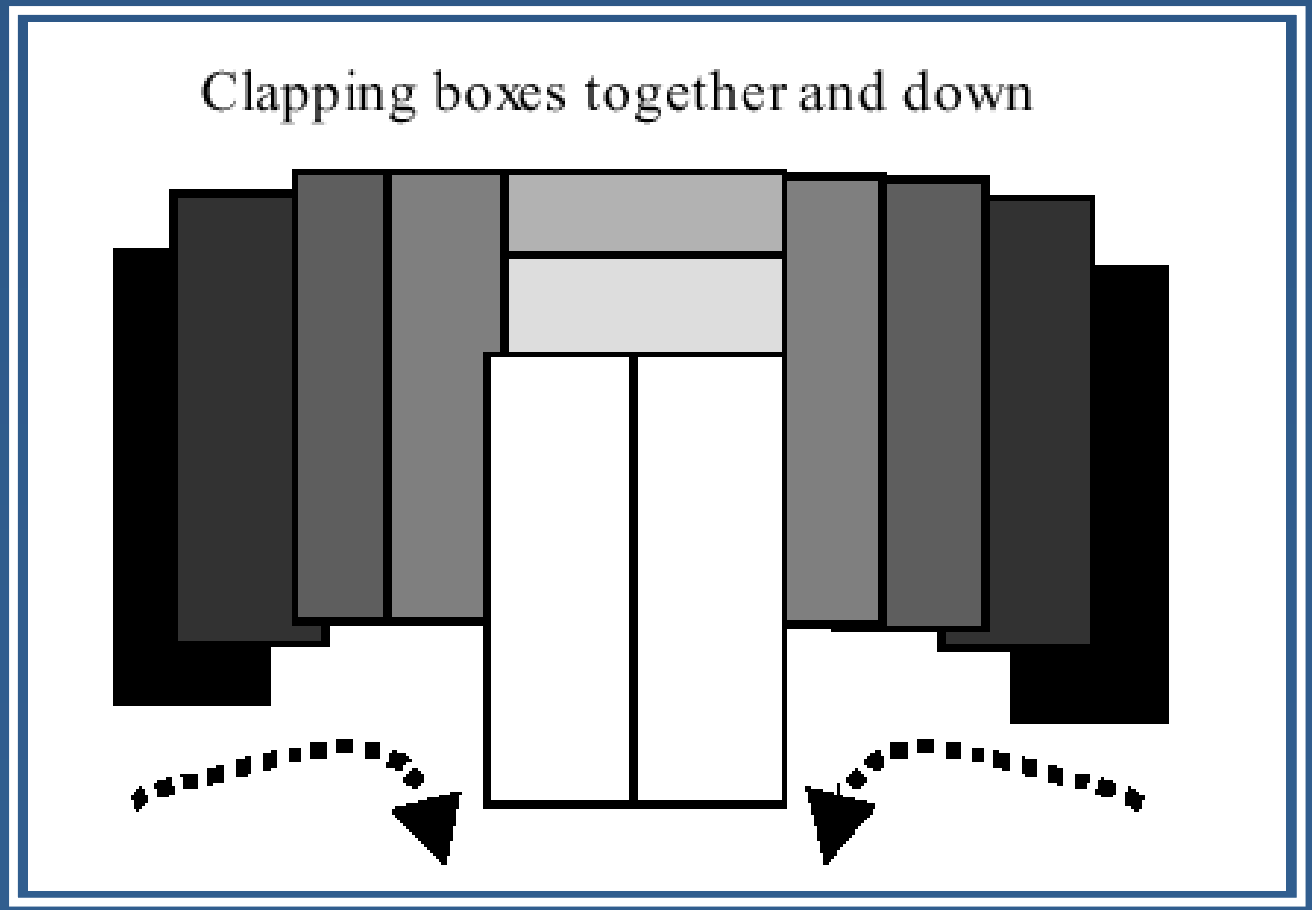
FIGURE 10.49 ADIs of a rectangular object moving in a southeasterly direction. (a) Absolute ADI. (b) Positive ADI. (c) Negative ADI.

Multiple Moving Objects?

(courtesy of Sebastian Thrun)

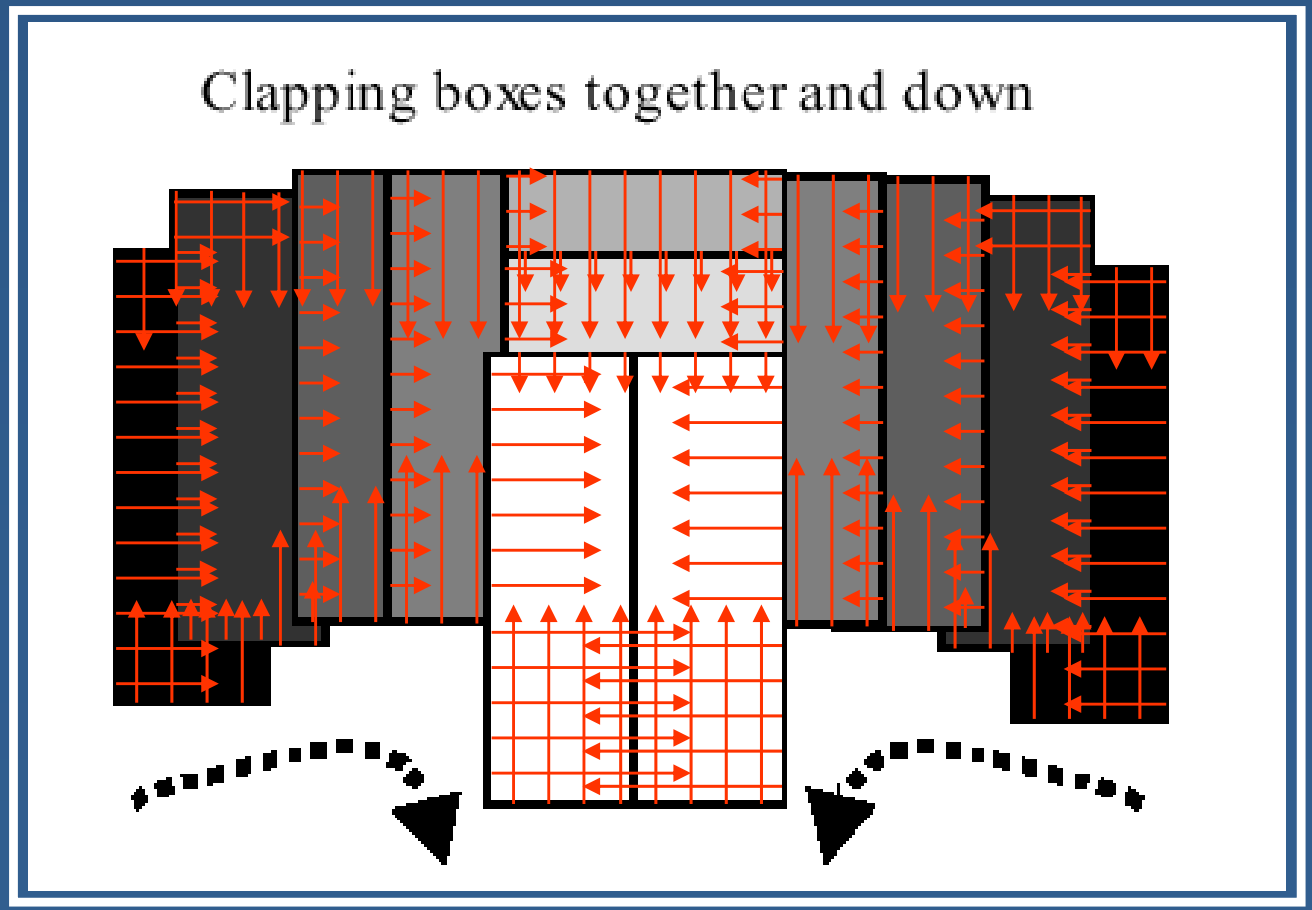
Motion Segmentation

- Add timestamp to current motion history image, and overlay it on top of the older ones



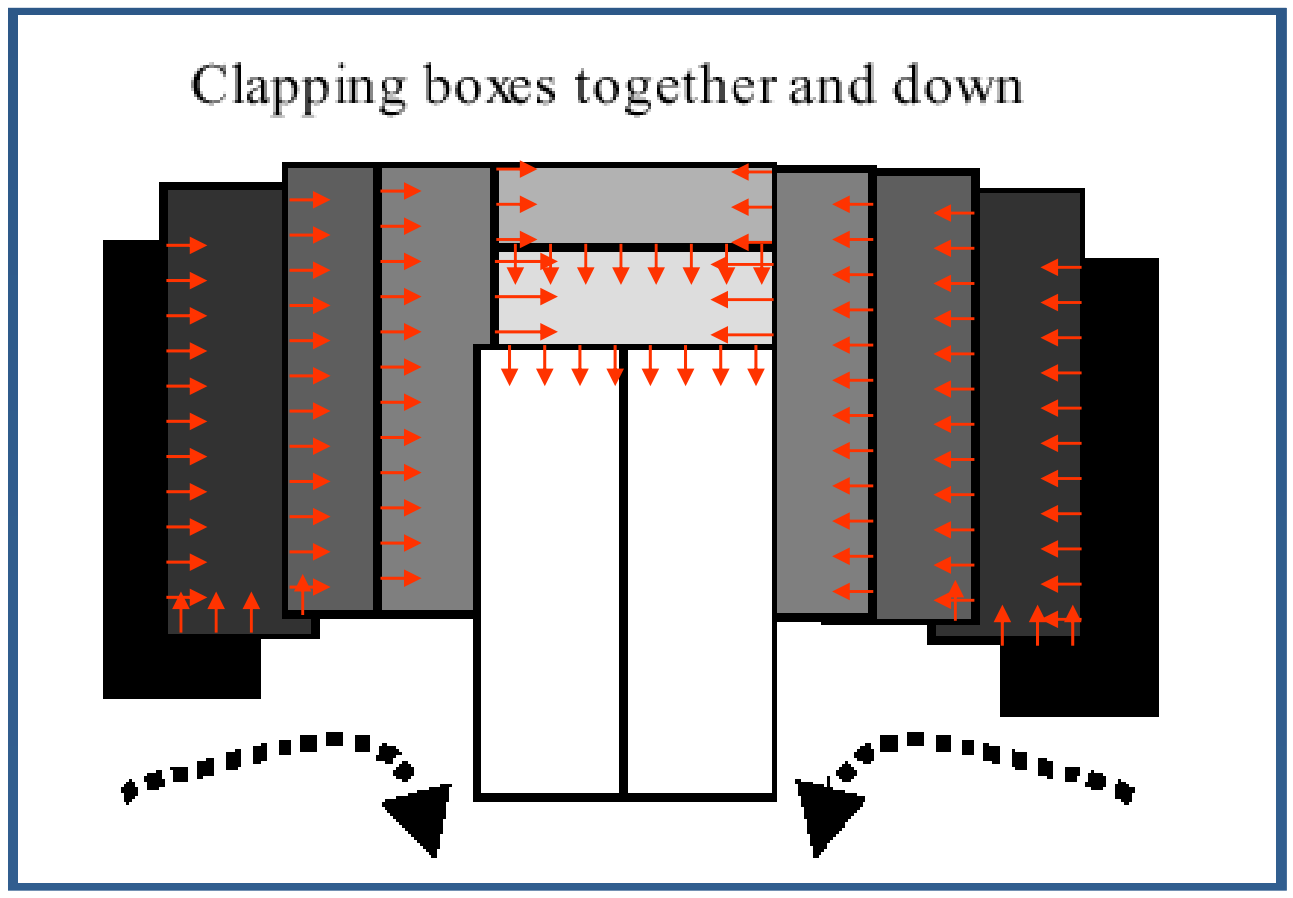
Motion Segmentation

- Measure the gradients of the stack of motion history images



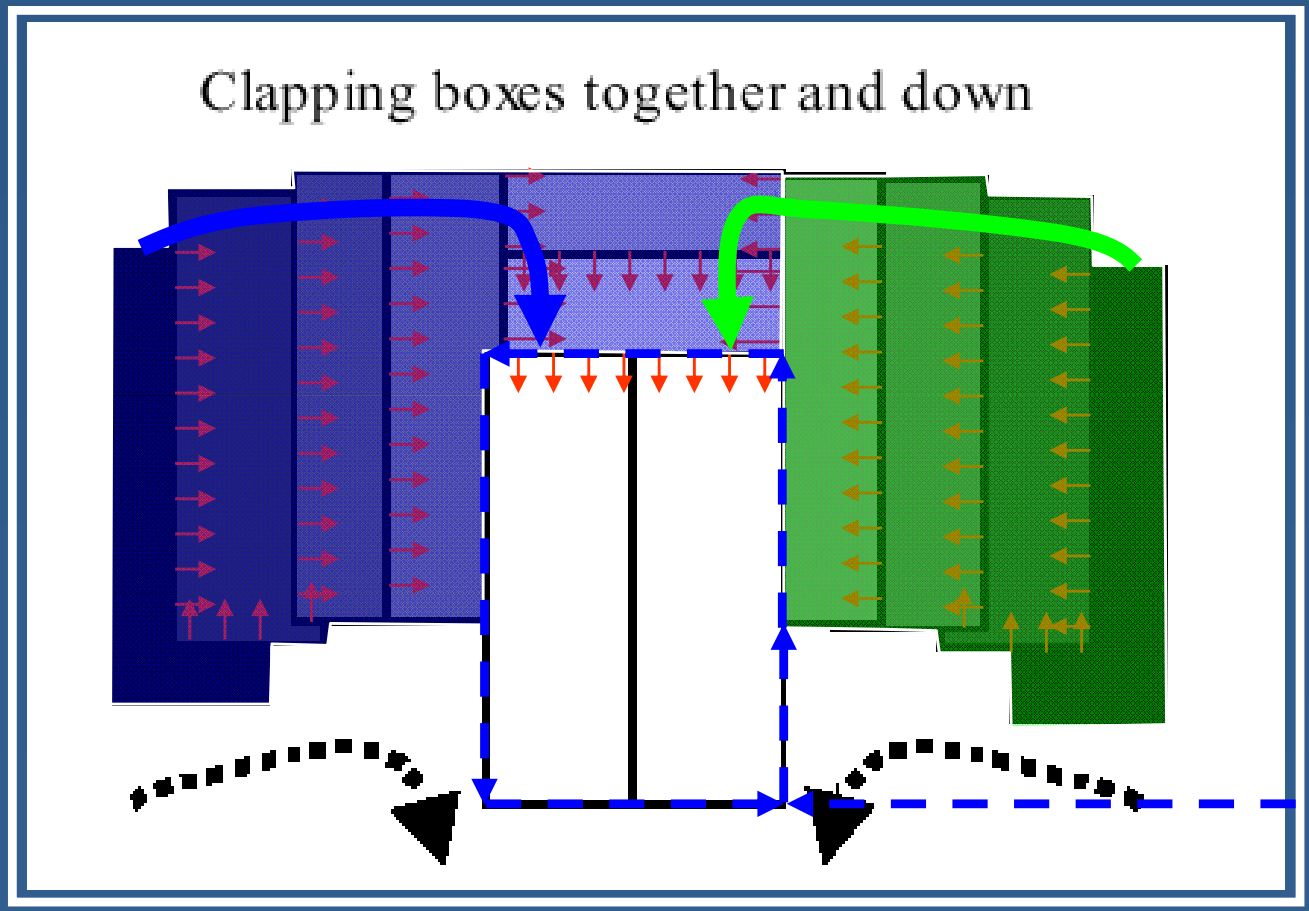
Motion Segmentation

- Ignore motion template edges resulting from too large of a time delay



Motion Segmentation

- Find boundaries of most recent motions and fill them in to segment motion regions



Let's Try It Out!

Background Subtraction

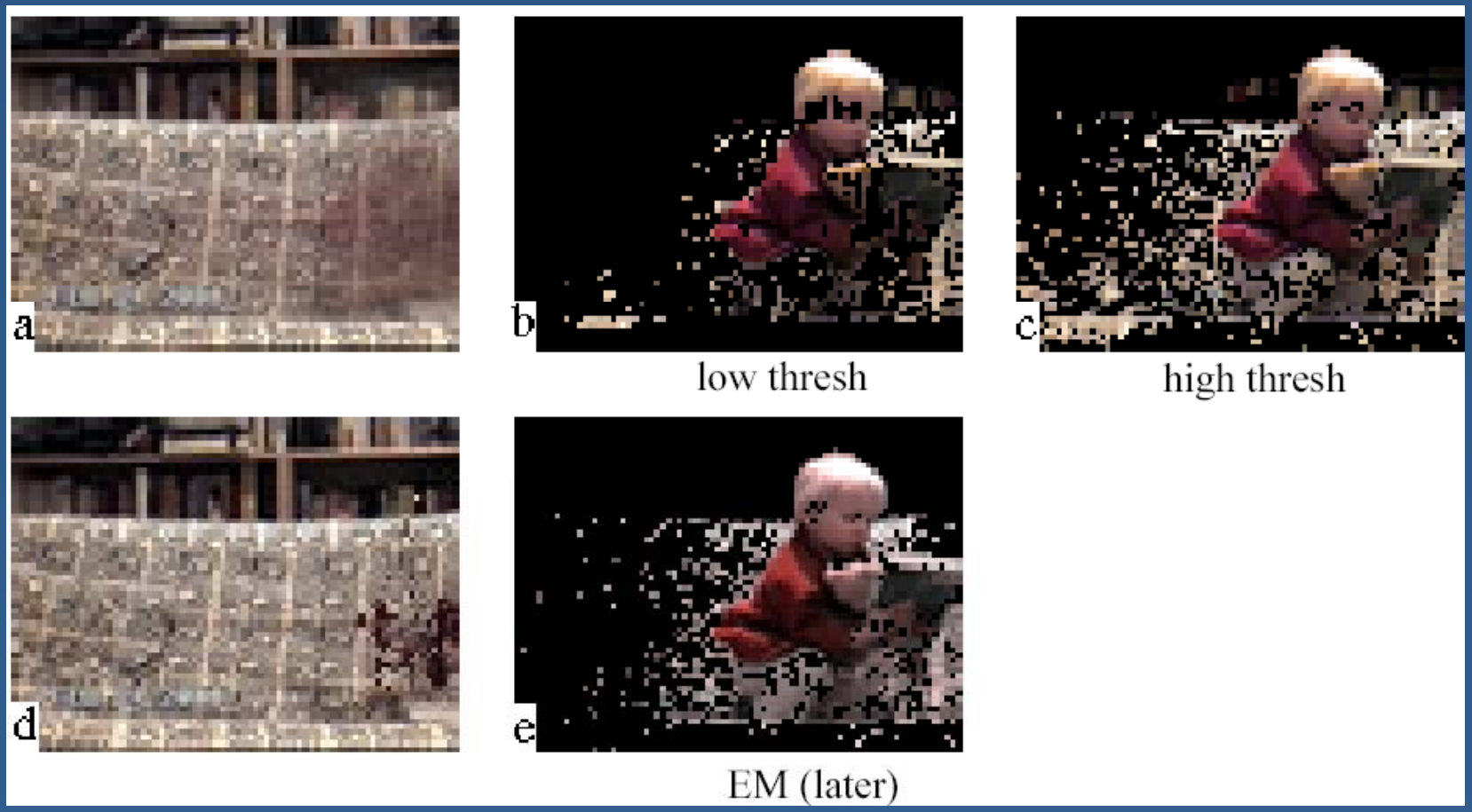
- If we know what the background looks like, we can ignore it to focus on things that are moving or changing

Blue Screen

Video Example

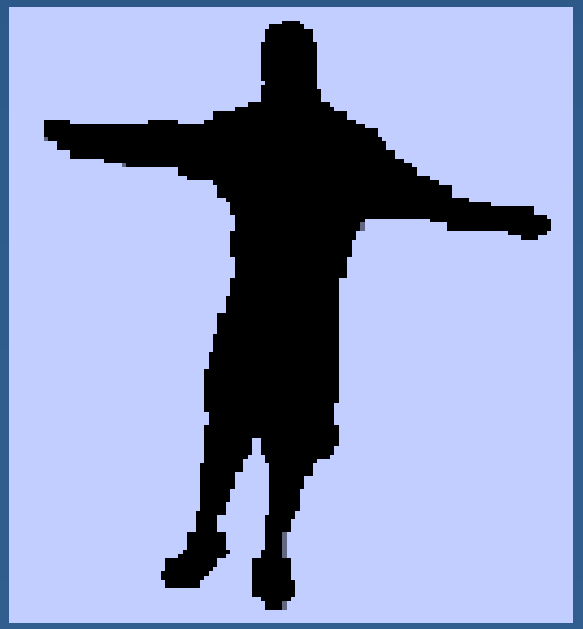
(courtesy of Frank Dellaert)

Subtraction and Thresholding



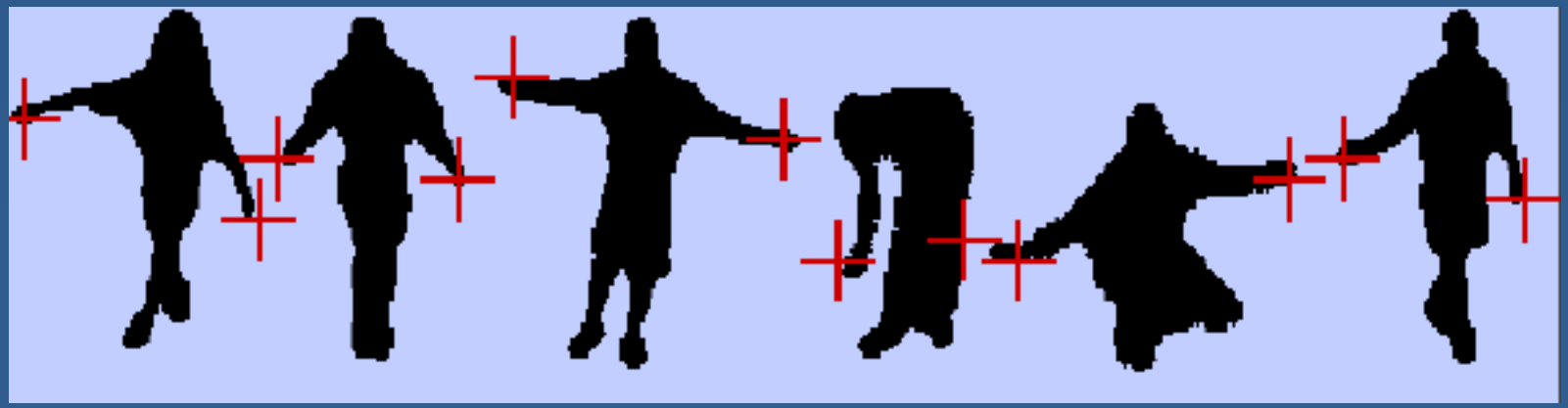
Basic Background Subtraction

- Assume background is mostly static
- Build a background model by averaging pixel values across a range of frames
- Given a new image, generate a silhouette by marking the pixels that are significantly different from the "background" value



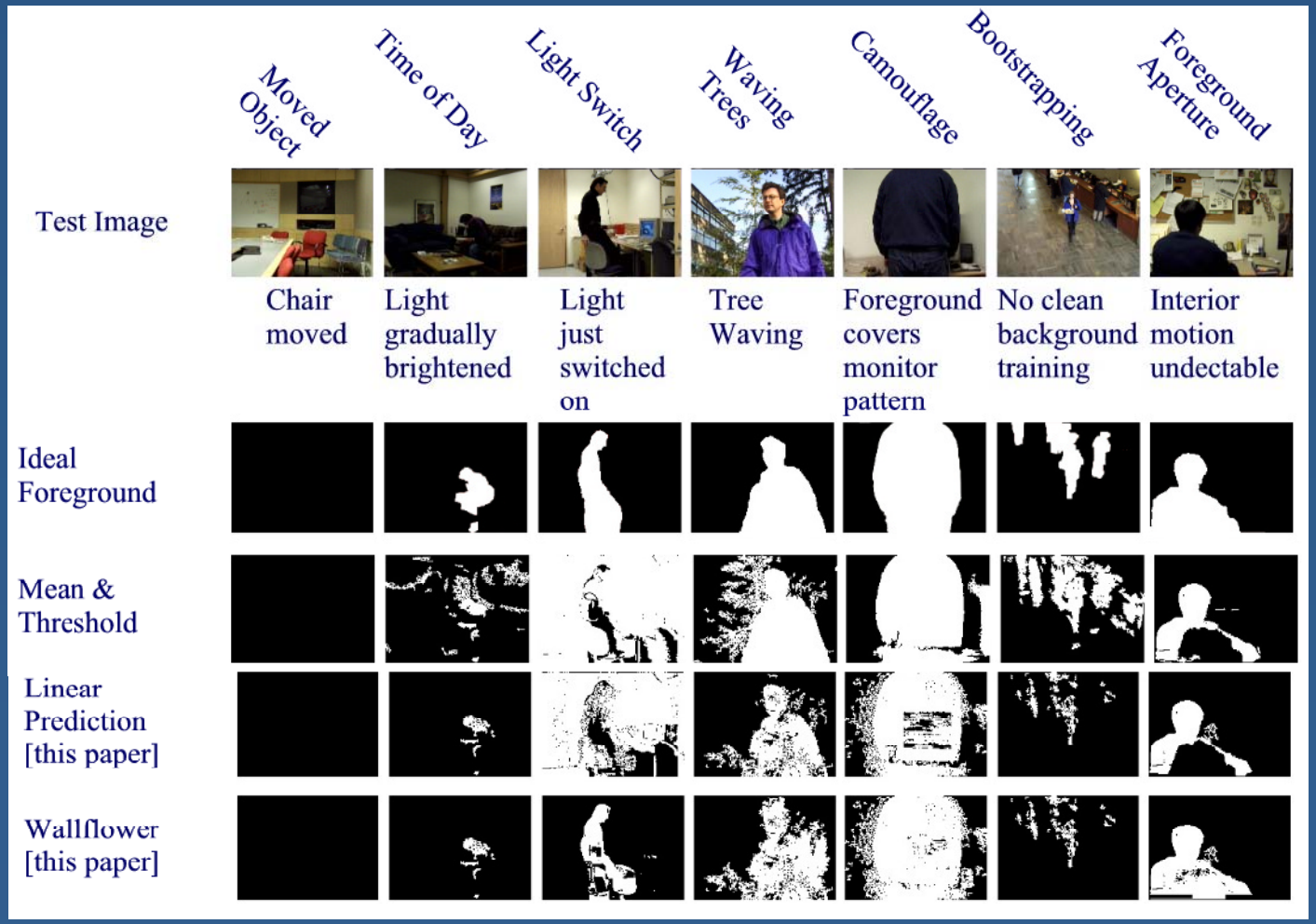
Finding Subparts

- Look at contour shape and mark points farthest from the center as hands
- Can be combined with a skin color model for better results



Pfinder Example

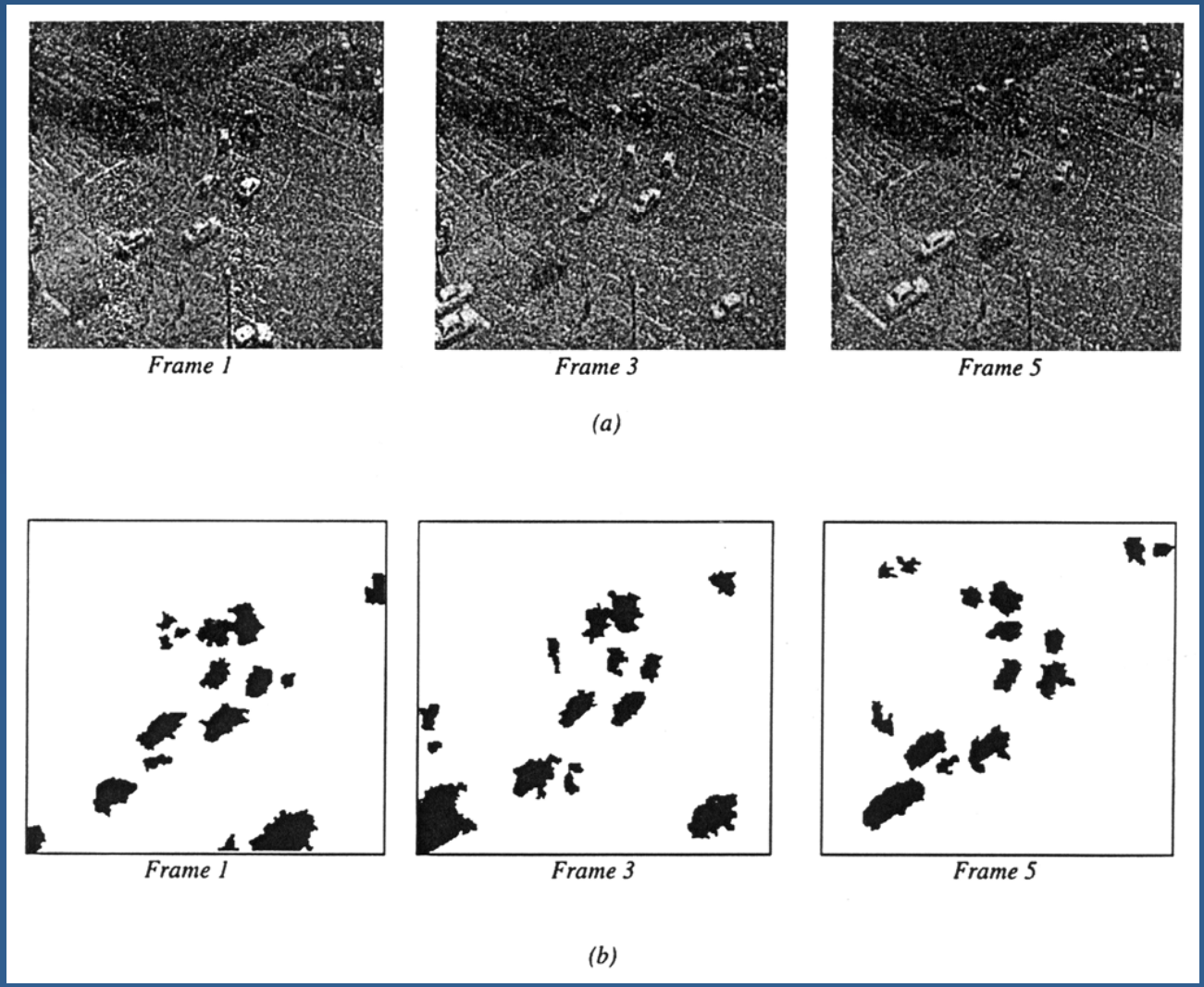
Dynamic Backgrounds?



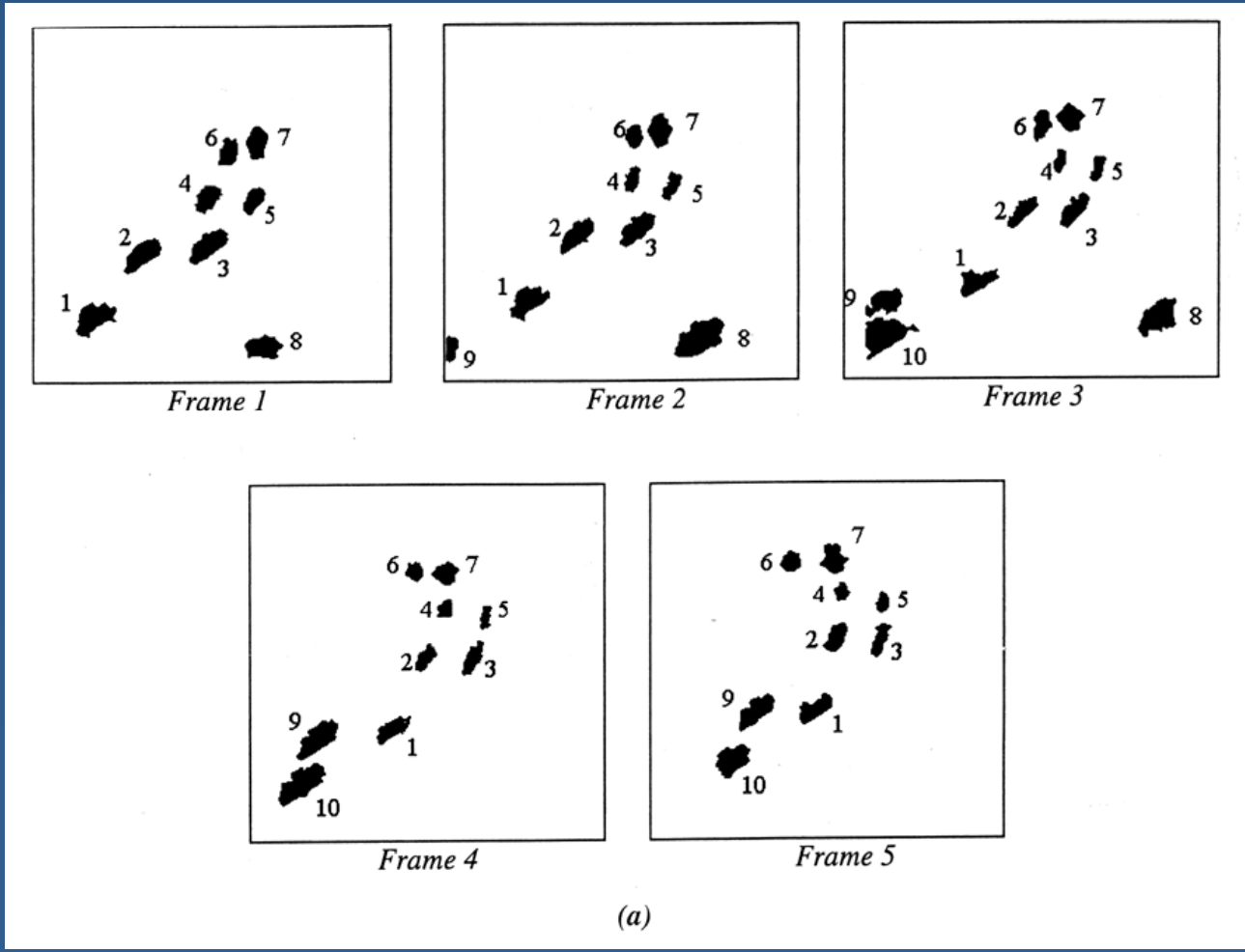
(courtesy of Kentaro Toyama)

Let's Try It Out!

Keeping Track of Objects



Blob Tracking



Let's Try it Out!

More Complex Motion

(courtesy of J.M. Rehg)

More Complex Motion

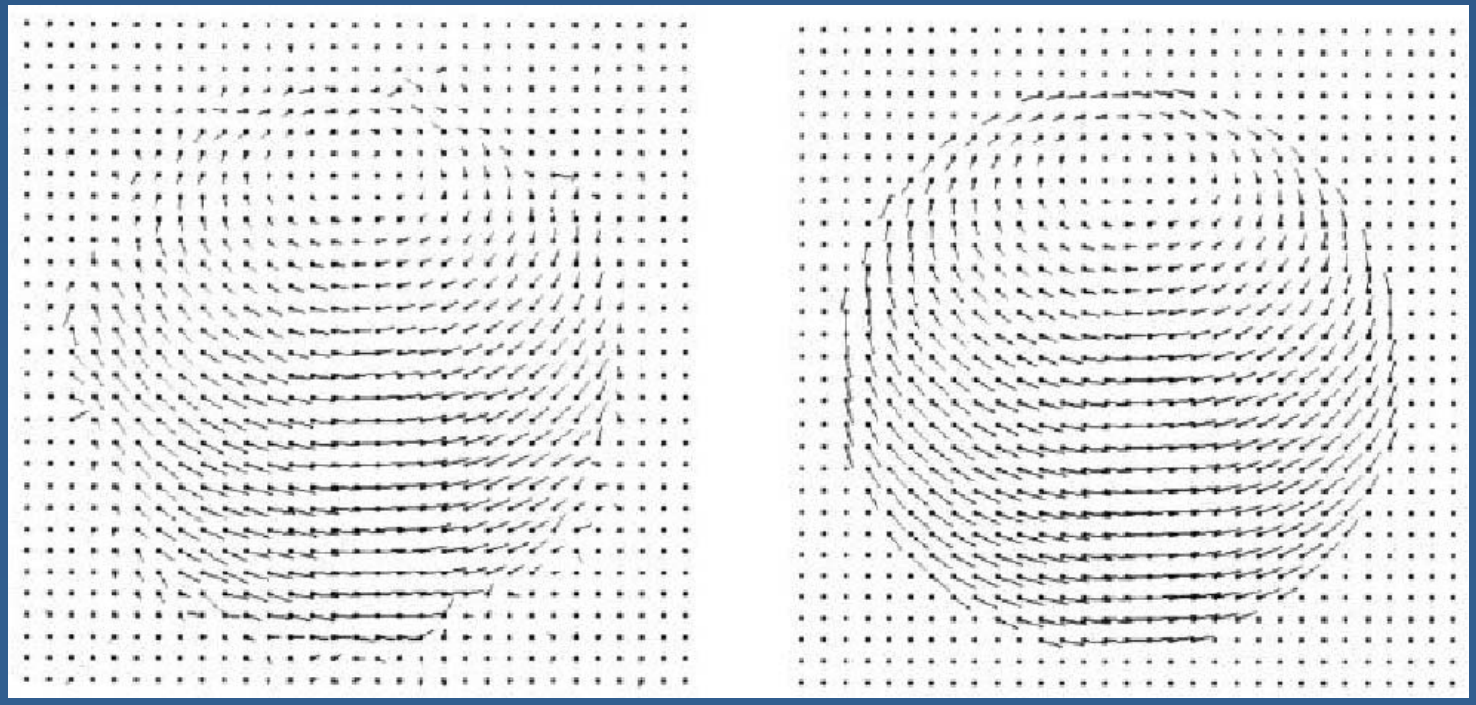
(courtesy of J.M. Rehg)

More Complex Motion

(courtesy of J.M. Rehg)

Optical Flow

- A 2-D velocity field describing the motion in an image sequence
- A vector at each pixel indicates its motion direction between neighboring frames



Characterizing Motion

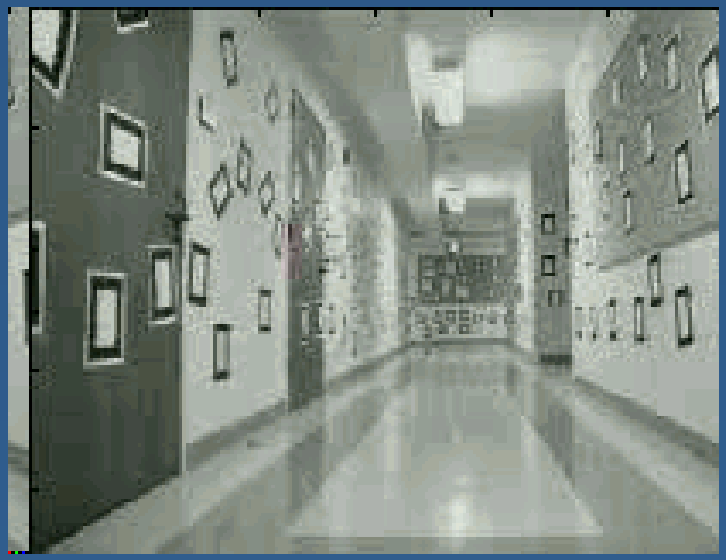
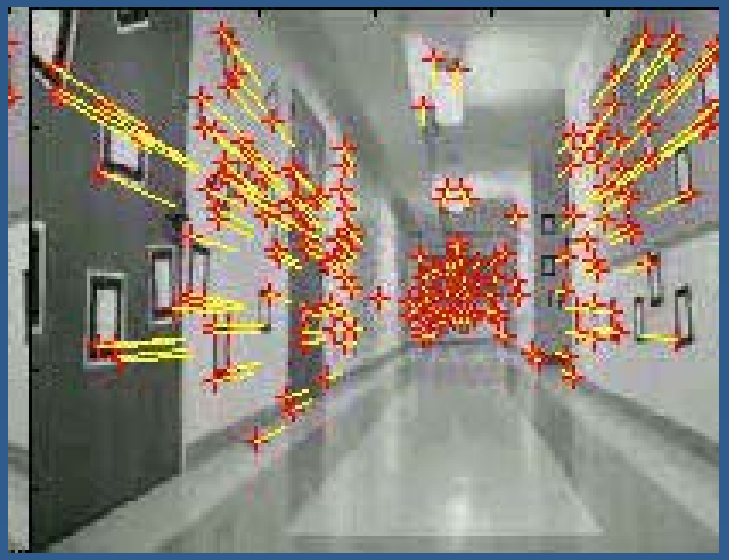


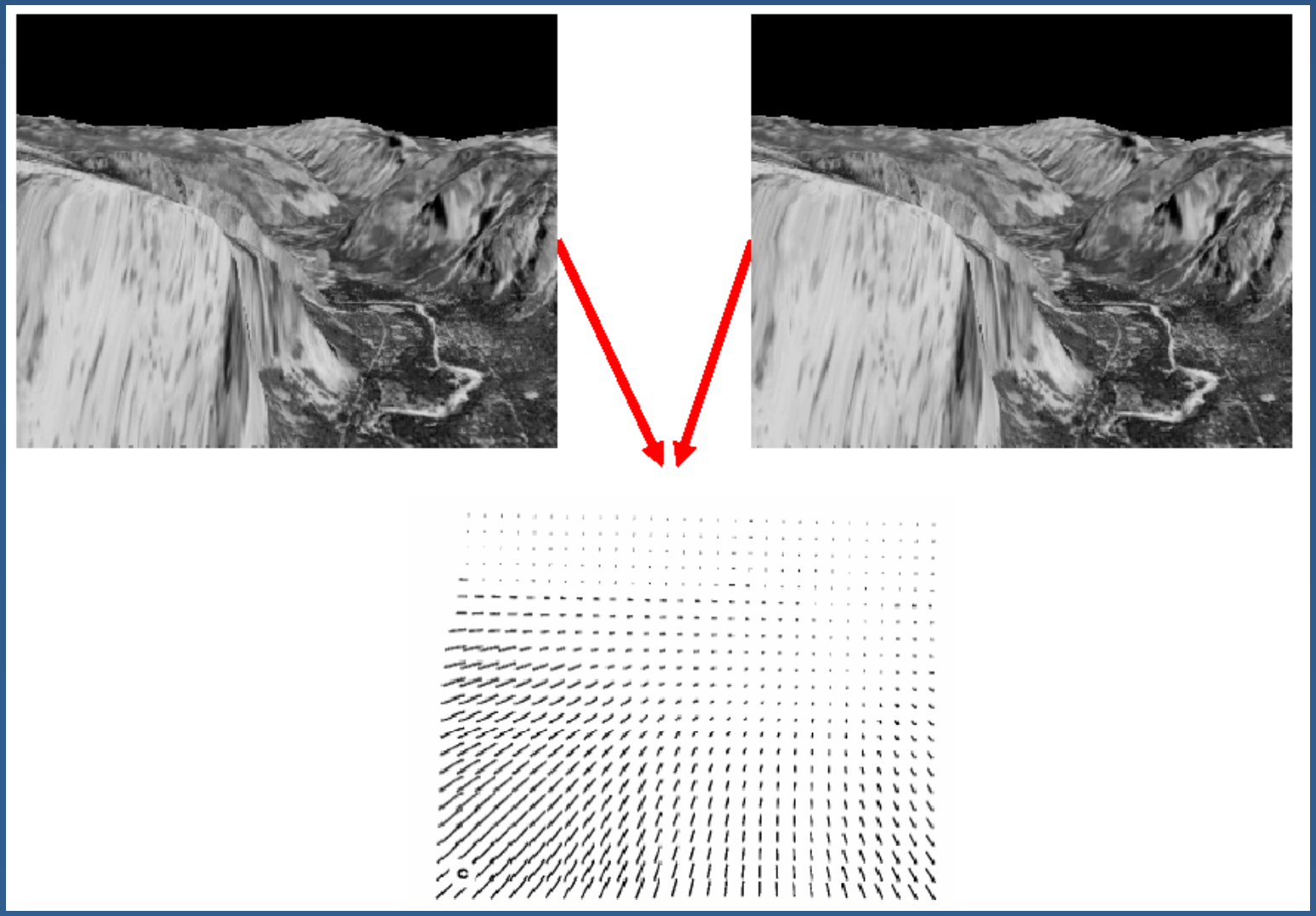
Image Sequence



Flow Vectors

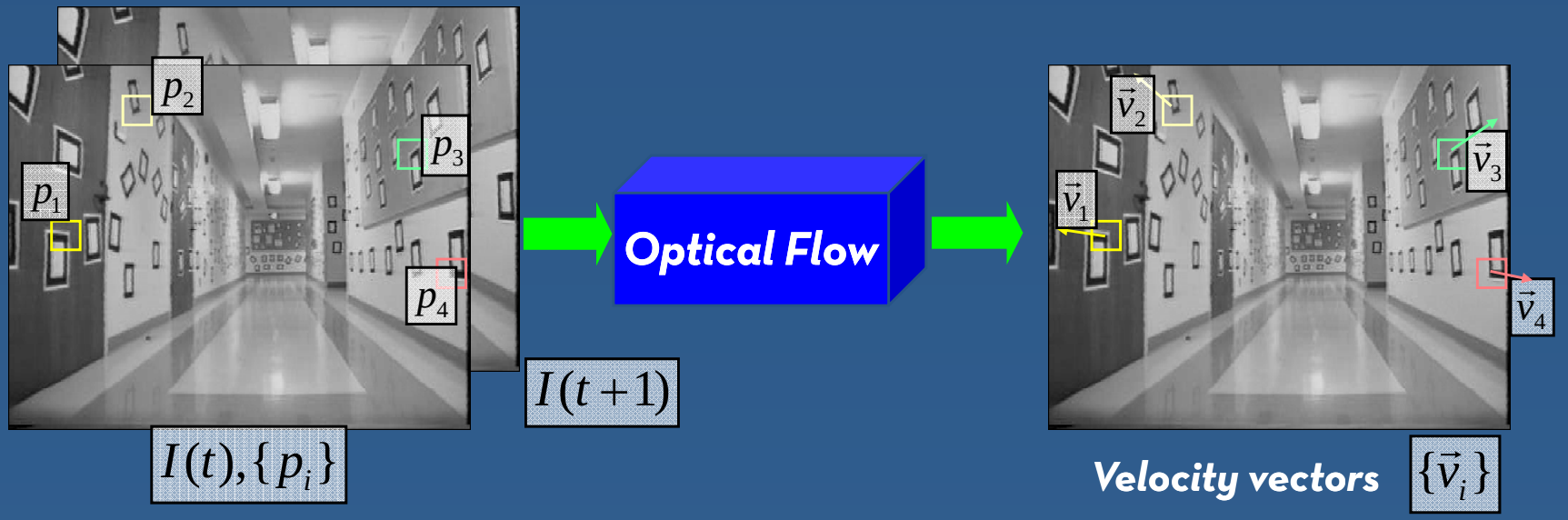
(courtesy of Sebastian Thrun)

Computing Optical Flow



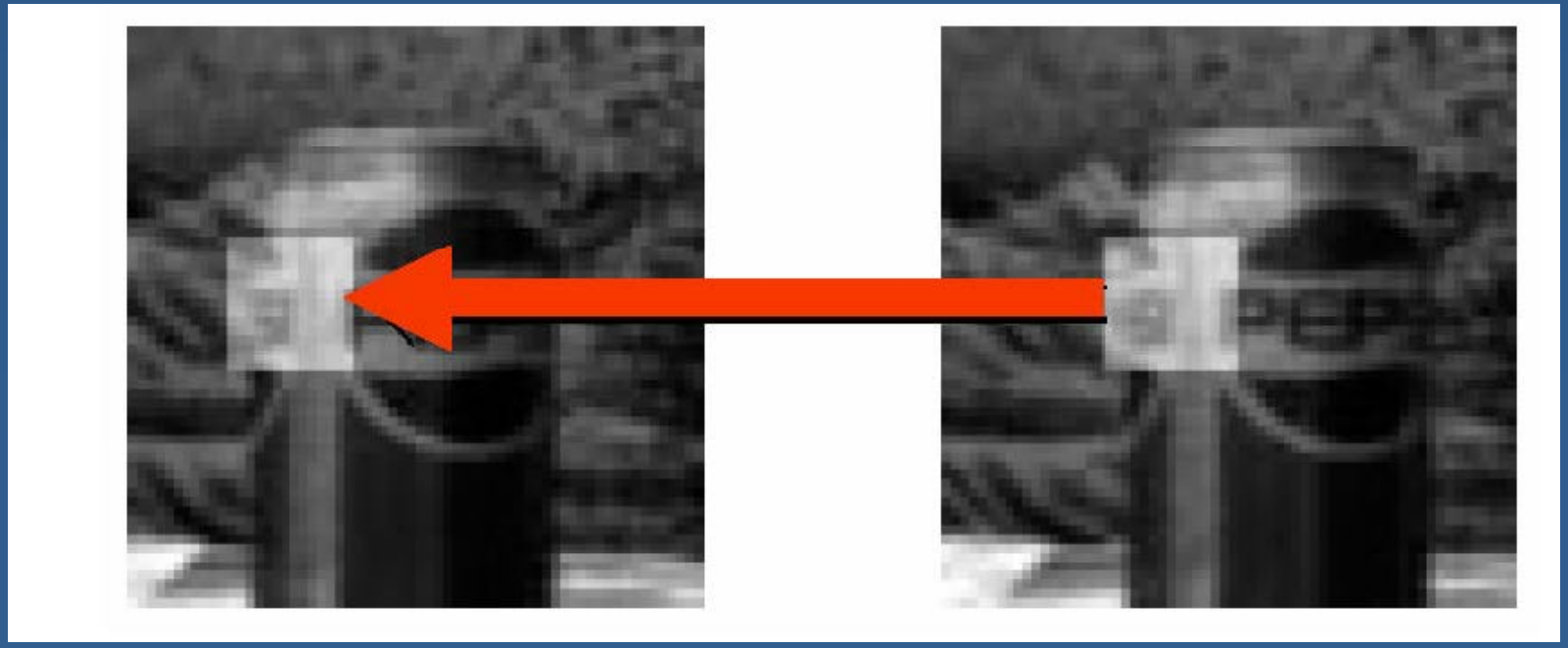
(courtesy of Michael Black)

Tracking Local Features



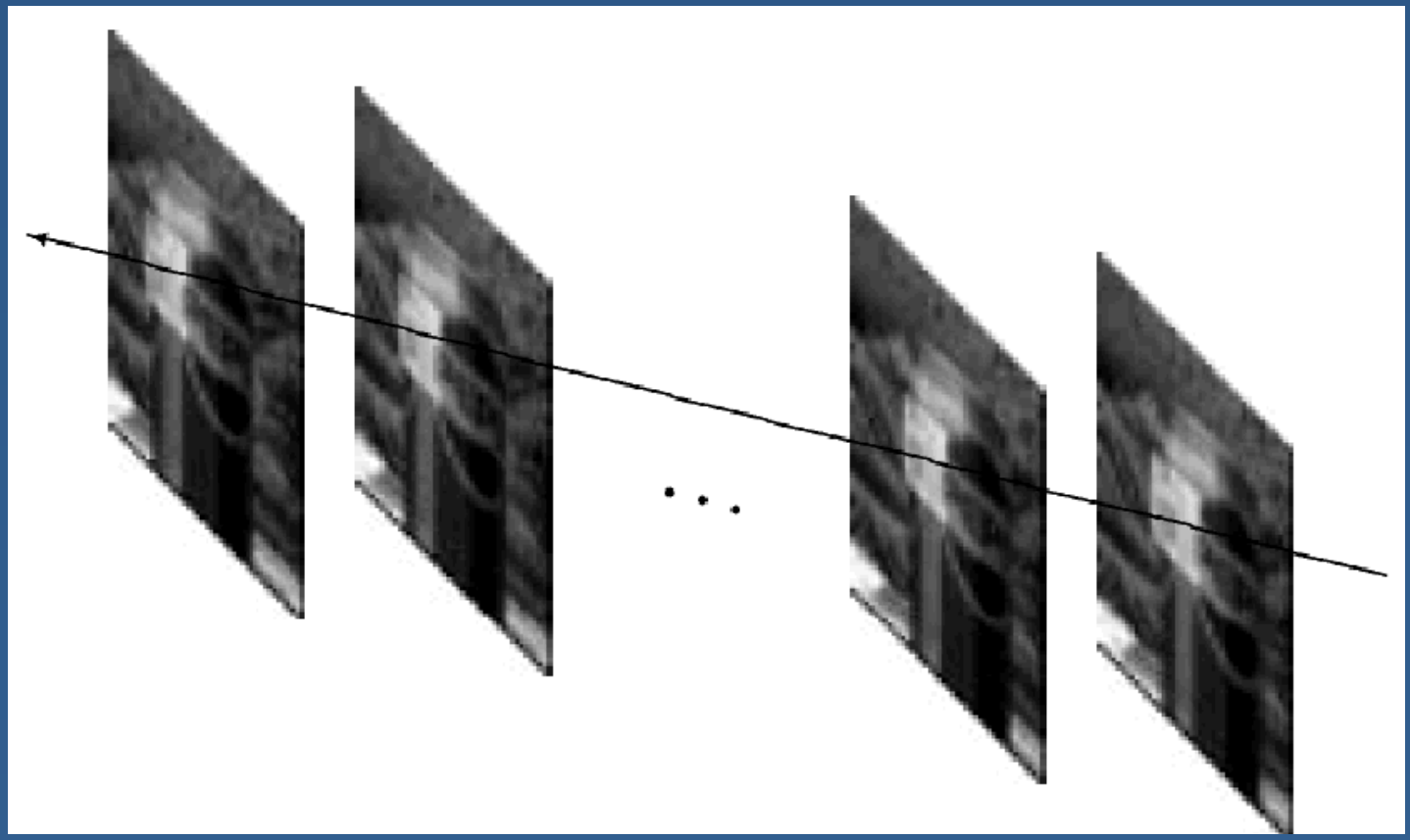
Optical Flow Assumptions

- Brightness constancy: though regions may move around, the brightness within a small region will not change

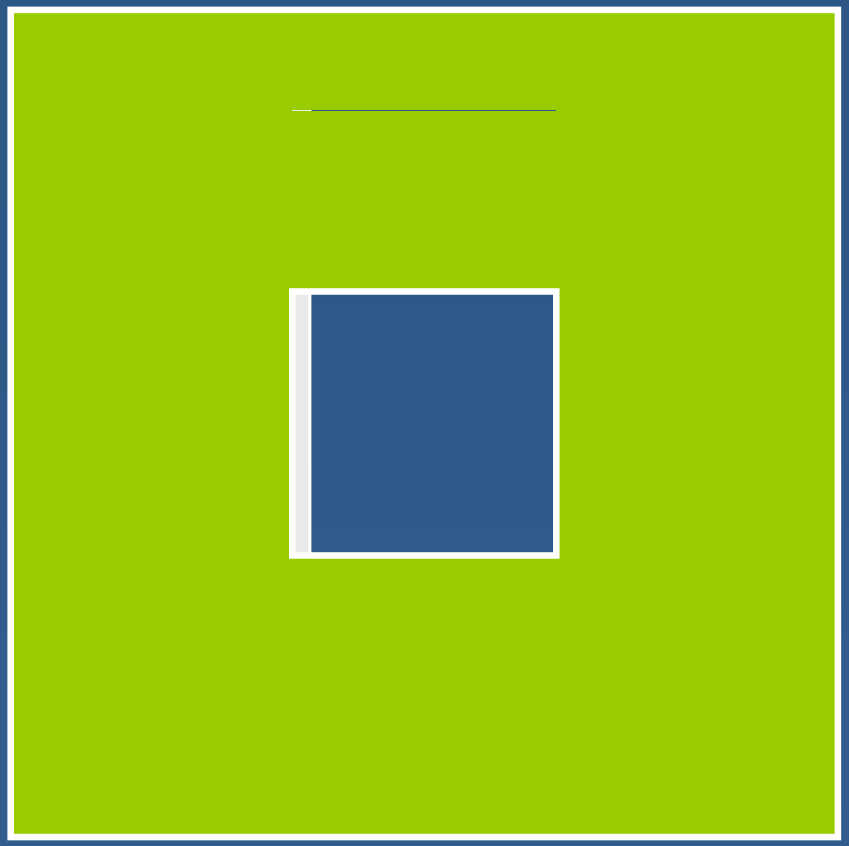


Optical Flow Assumptions

- Temporal persistence: gradual motion over time



Aperture Problem

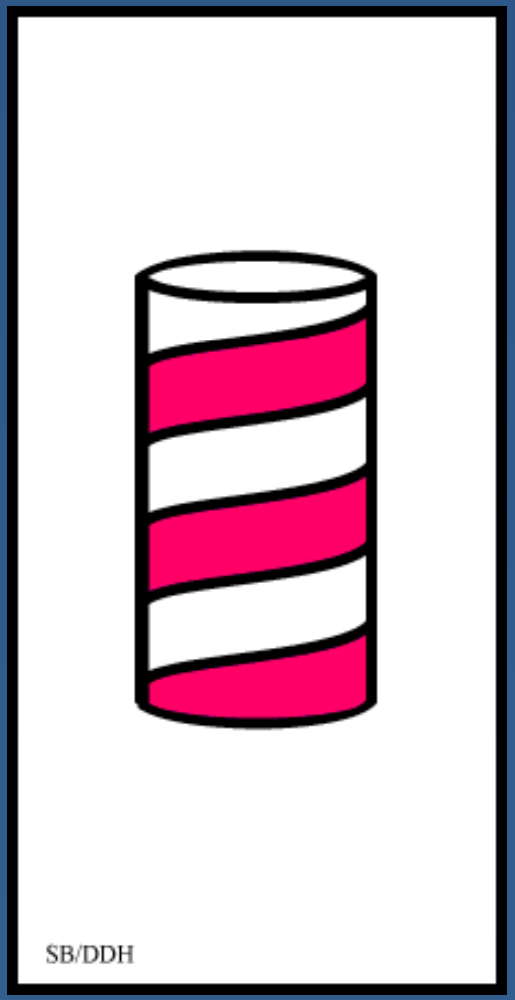


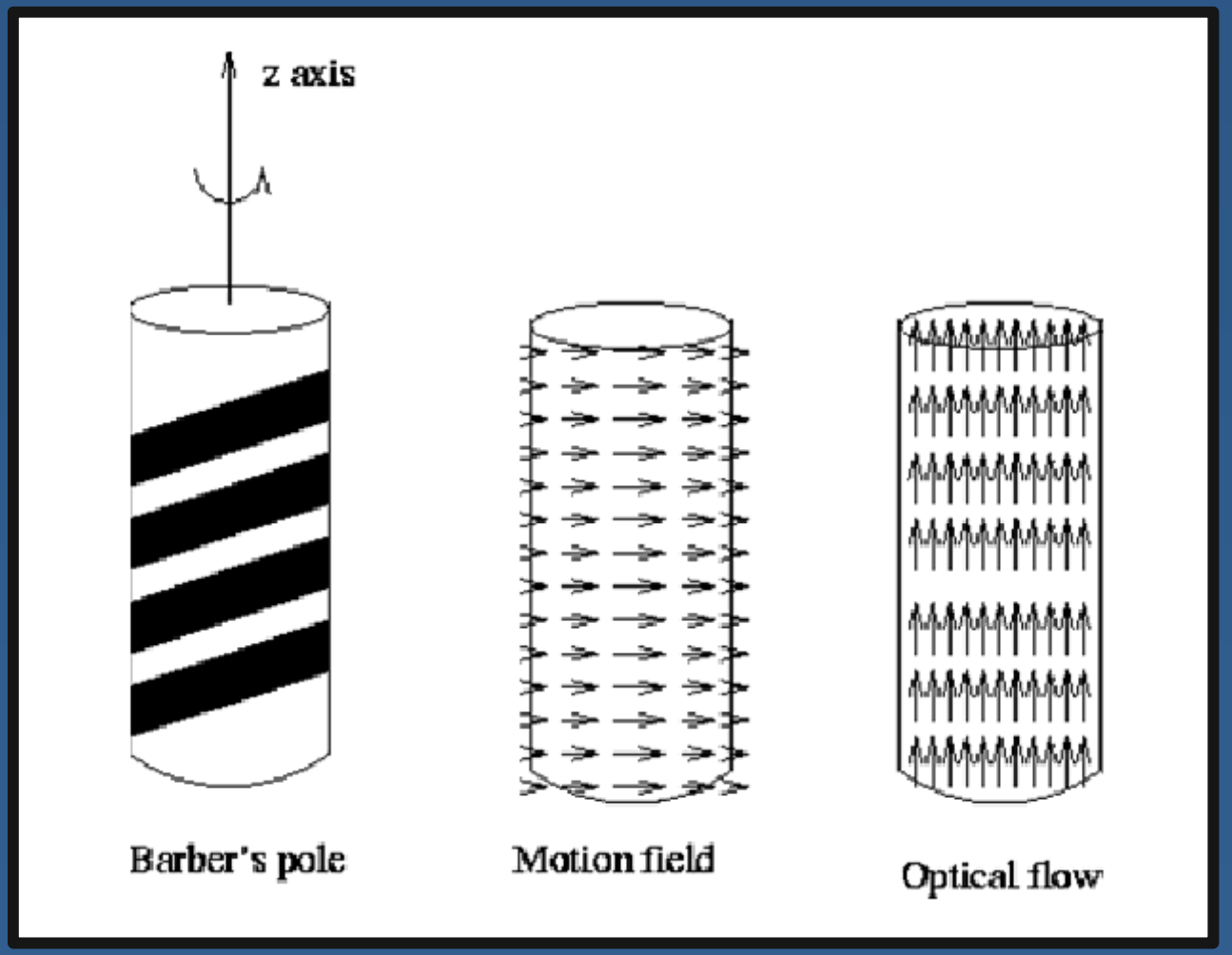
Aperture Problem

- Motion along just an edge is ambiguous

(courtesy of Sebastian Thrun)

Another Example





Harris Corners

Let's Try It Out!

Segmentation by Clustering

Image

Clusters on intensity

Clusters on color

Simple Clustering Algorithms

Algorithm 15.3: Agglomerative clustering, or clustering by merging

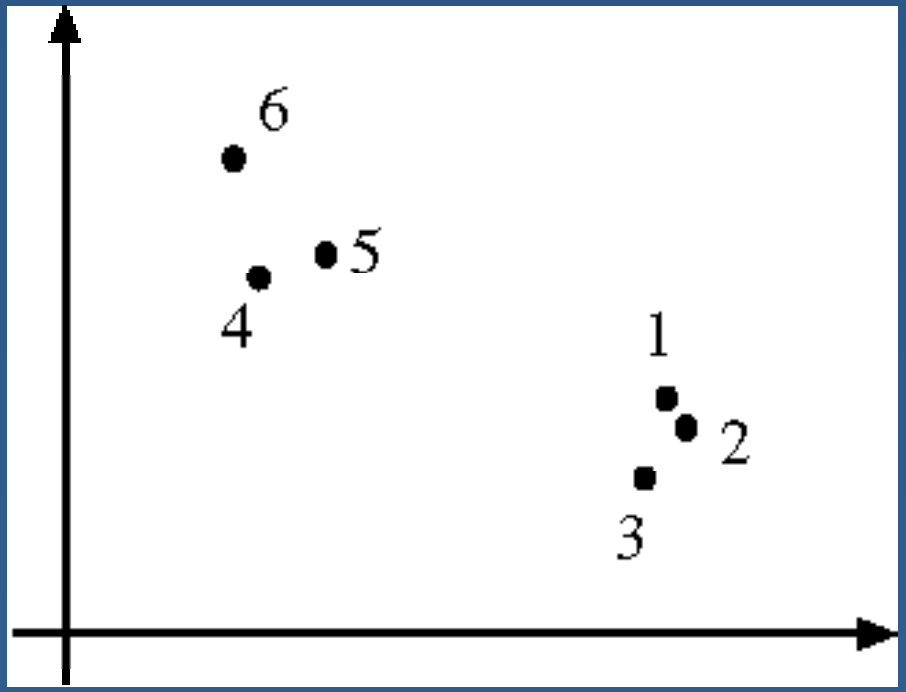
```
Make each point a separate cluster
Until the clustering is satisfactory
     Merge the two clusters with the
       smallest inter-cluster distance
end
```

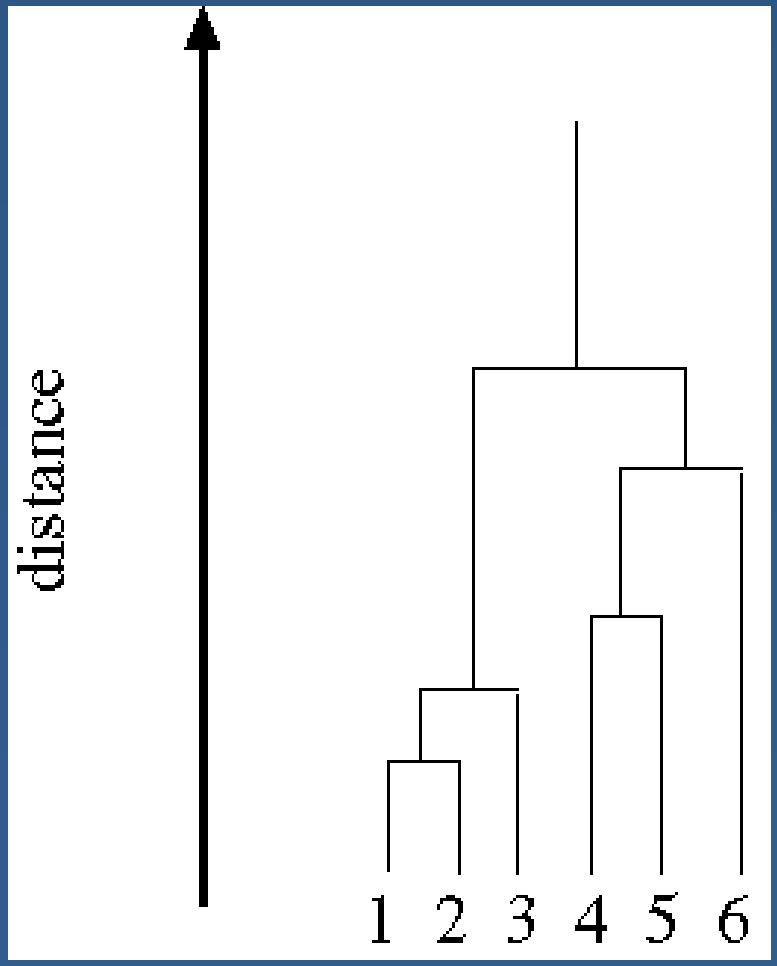
Algorithm 15.4: Divisive clustering, or clustering by splitting

```
Construct a single cluster containing all points
Until the clustering is satisfactory
     Split the cluster that yields the two
       components with the largest inter-cluster distance
end
```

(courtesy of Marc Pollefeys)

Clustering Example

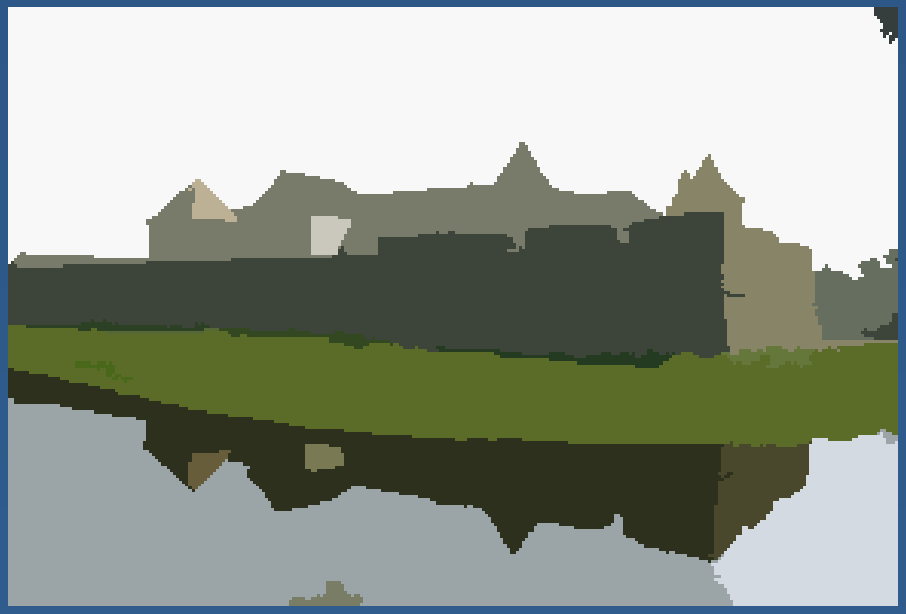




(courtesy of Marc Pollefeys)

Mean Shift Segmentation

Original Image

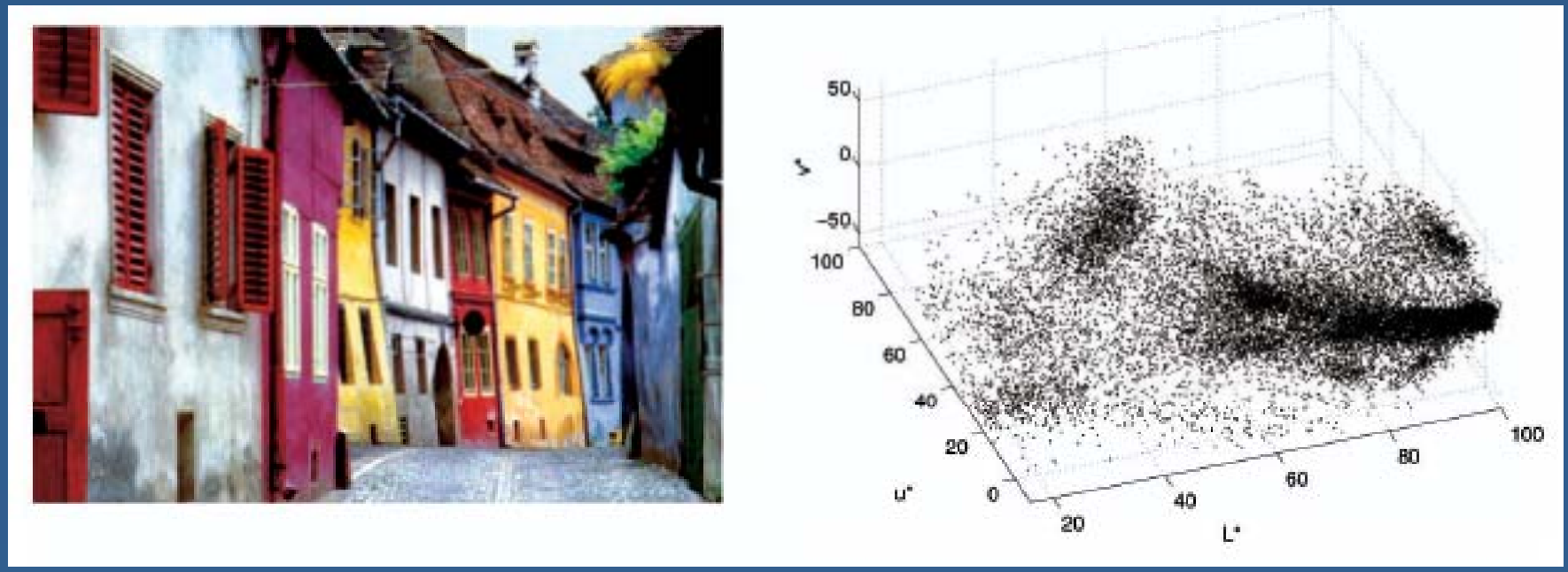


Segmented Image

(courtesy of D. Comaniciu)

Mean Shift Algorithm

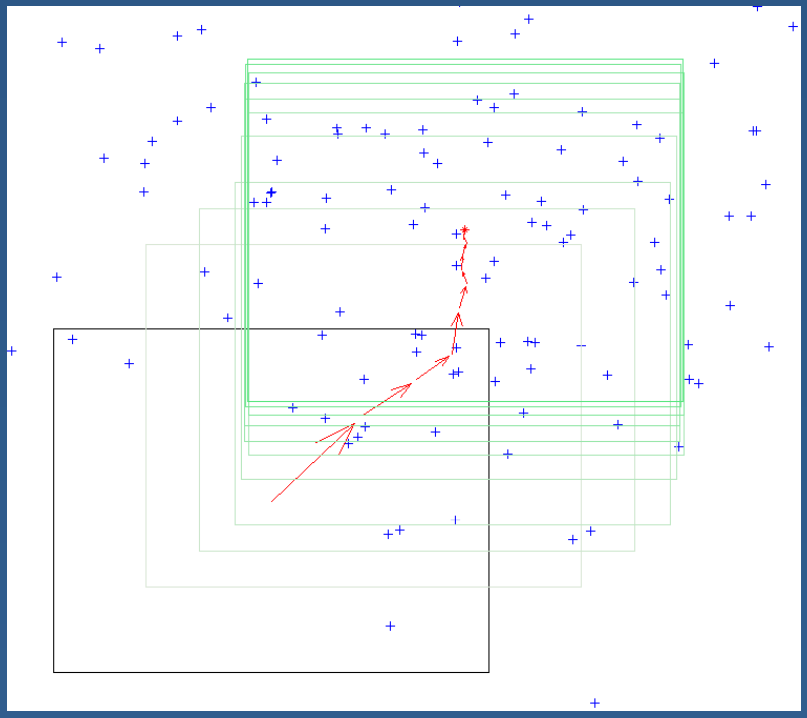
- Goal: find the points of highest density ("modes") in the data distribution



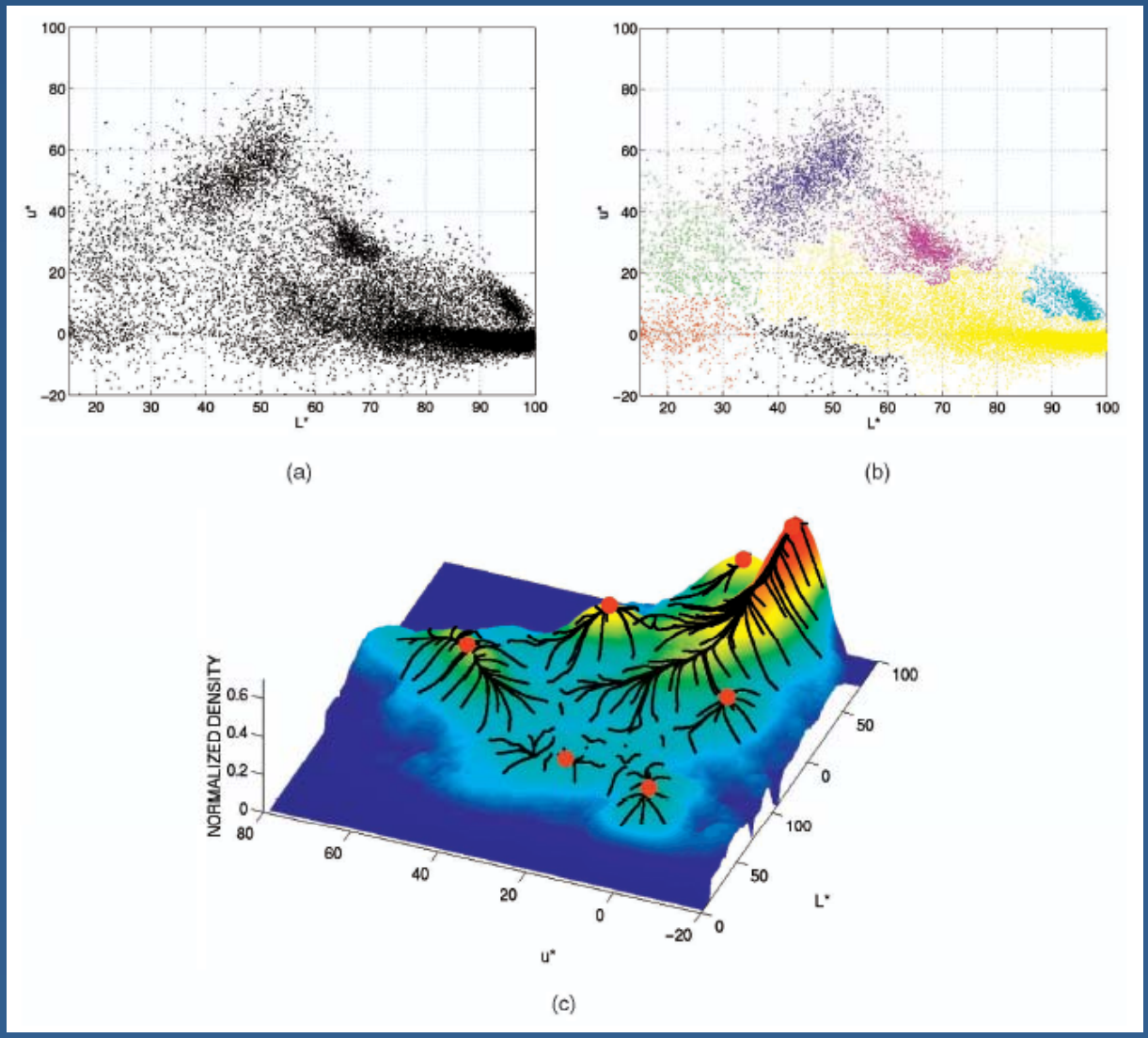
(courtesy of D. Comaniciu)

Mean Shift Algorithm

1. Choose a search window size.
2. Choose the initial location of the search window.
3. Compute the mean location (centroid of the data) in the search window.
4. Center the search window at the mean location computed in Step 3.
5. Repeat Steps 3 and 4 until convergence.



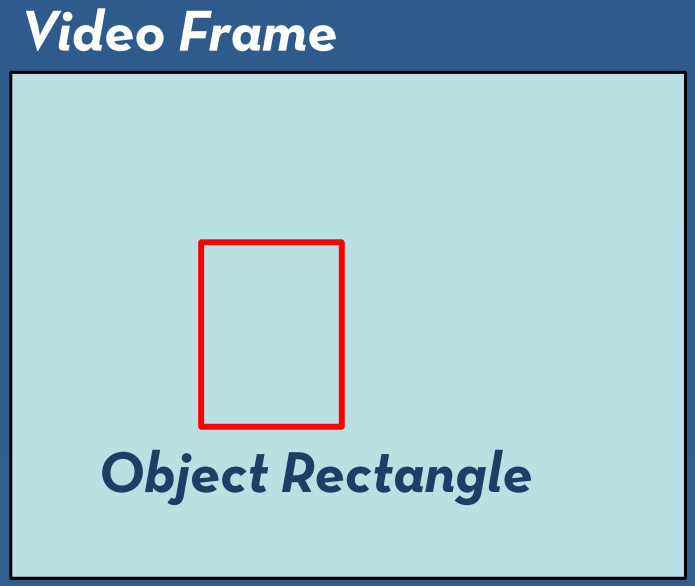
Mean Shift Results



(courtesy of D. Comaniciu)

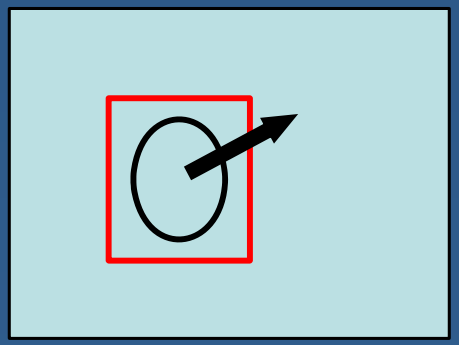
Continuously Adaptive Mean Shift

- A version of the mean shift algorithm can be applied to object tracking based on color
- Start with a object location and an object color profile (hue distribution histogram)



Continuously Adaptive Mean Shift

- Calculate "backprojection" image: probability that each pixel came from the same hue distribution as the tracked object



- Use Mean Shift Algorithm to find the new object center given its back projection and the initial position of search window

(courtesy of G. Bradski)

CAMSHIFT Example



(courtesy of Robin Hewitt)

Let's Try It Out!

Summary

- Motion is often much more useful than static image features for understanding what is happening
- There are many tactics for detecting, measuring, and segmenting motion
  - You'll try some out in Assignment #2
  - We'll have more hands-on practice during the next two workshop sessions
- Think about how you might use motion sensing in your project