Algorithms for Object Detection and Tracking

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MathWorks

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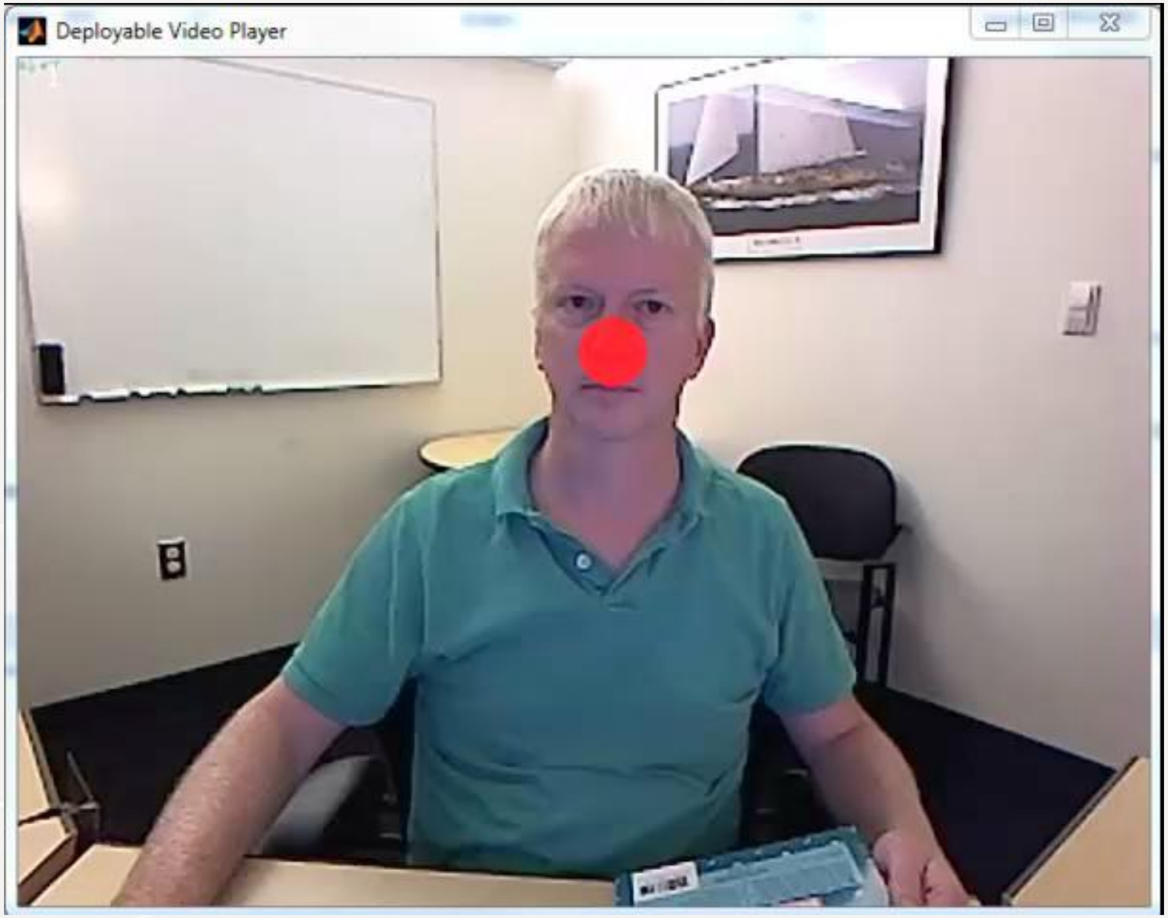
Object Detection vs. Object Tracking

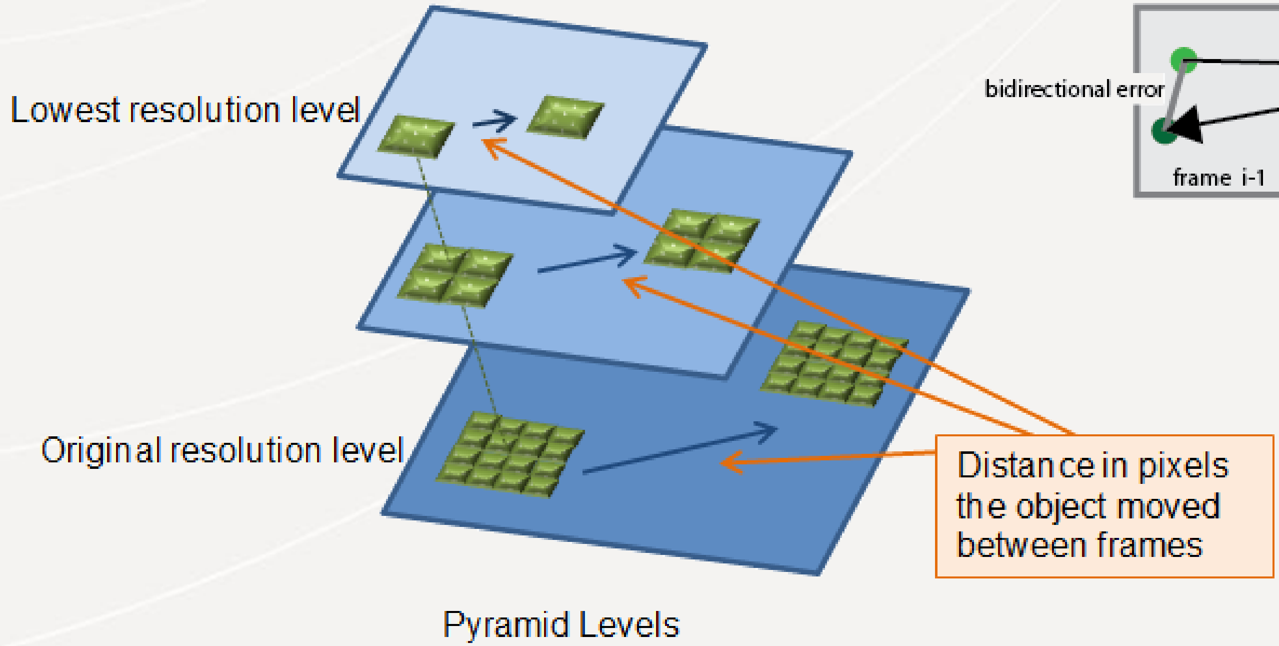


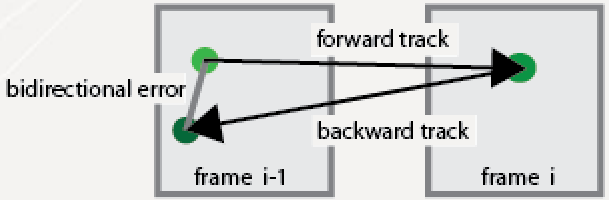
Algorithms Covered Today

- Kanade-Lucas-Tomasi (KLT) point tracking
- Background subtraction with Gaussian mixture models
- Kalman filtering to predict locations
- Hungarian algorithm for assigning detections to tracks

Kanade-Lucas-Tomasi (KLT)

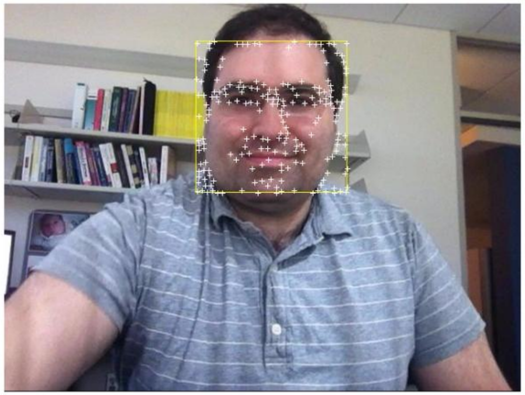
- Algorithm for tracking points across frames (sparse optical flow)
- Bottom-up (pixel-based) approach to tracking
- Require a priori detection to track (e.g., Viola-Jones)





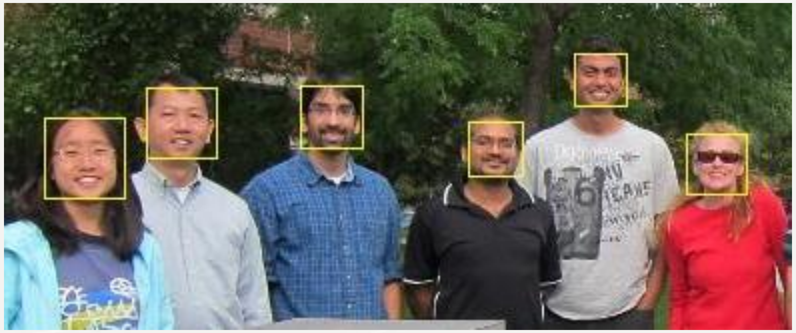
Application Examples for KLT

- Driver alertness indicator
- Autofocus for digital cameras
- Cell motility—movement of a live cell under a microscope
- Automatic privacy filtering
- High speed object deformation



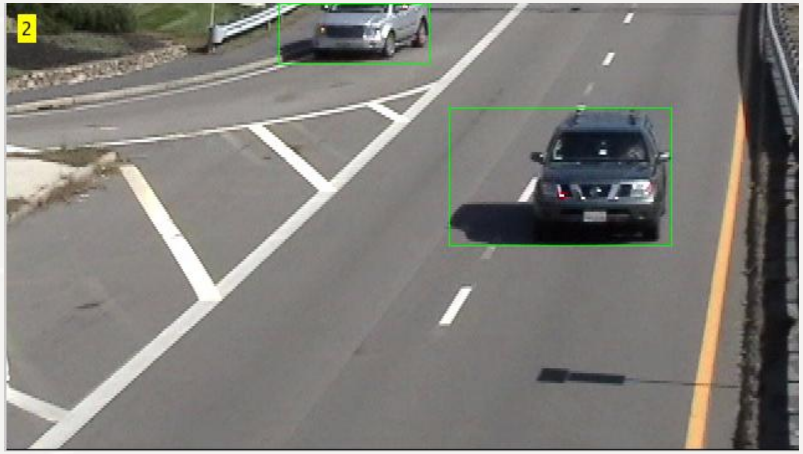
Multiple Object Detection and Tracking

Viola Jones



HOG + SVM

Background subtraction using Gaussian mixture models (with video)



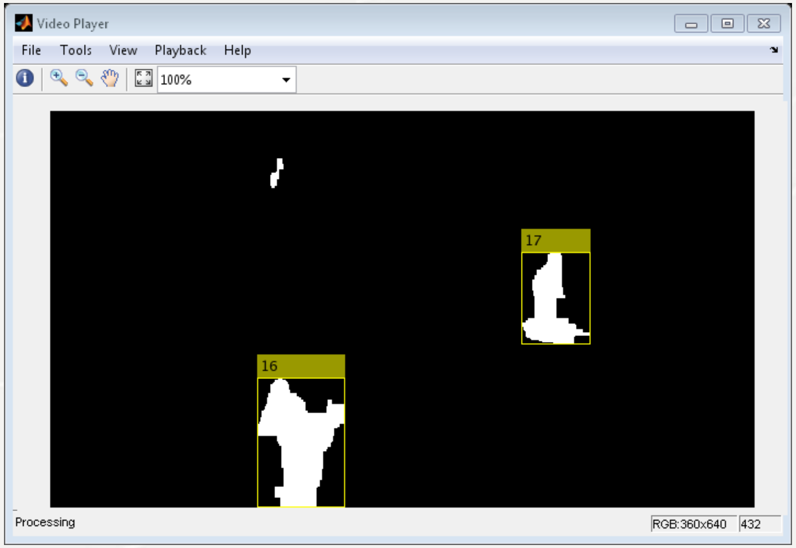
Background Subtraction Using Gaussian Mixture Models

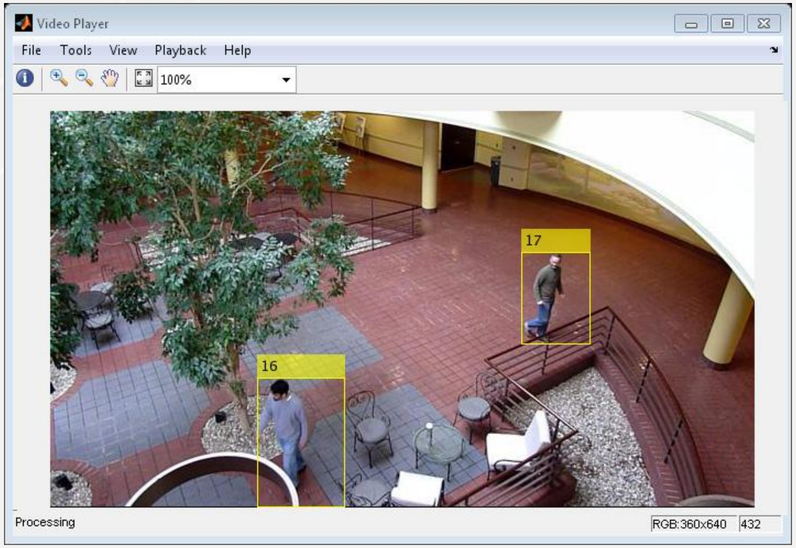
- The distribution of values is estimated for each pixel over time using a mixture of Gaussians.
- Values with high likelihood are background.
- Values with low likelihood are foreground (moving objects).
- This approach requires a stationary camera.

Key paper by Stauffer and Grimson, 1999

Moving From Detections to Tracking

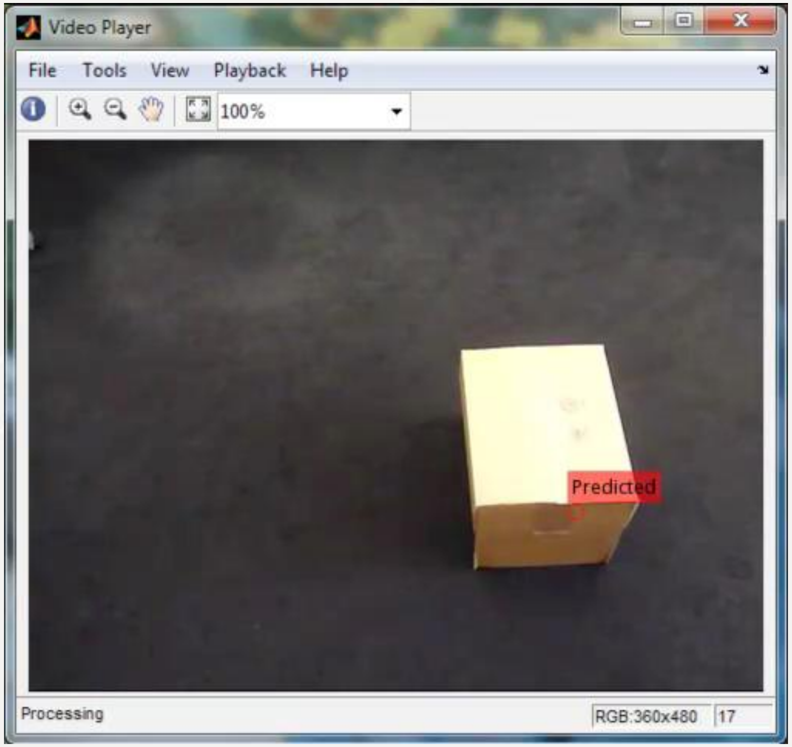
- Detect moving objects in each frame
- Estimate motion of each object with Kalman filter
- Assign detections to tracks using Hungarian algorithm
- Maintain tracks over time





Kalman Filter for Estimating Motion of an Object

- This approach maintains the state of each object (position and velocity).
- The predict operation can be used by itself to estimate ball's location when it is occluded by the box.
- Kalman not only predicts new positions, but also adapts when detections occur.



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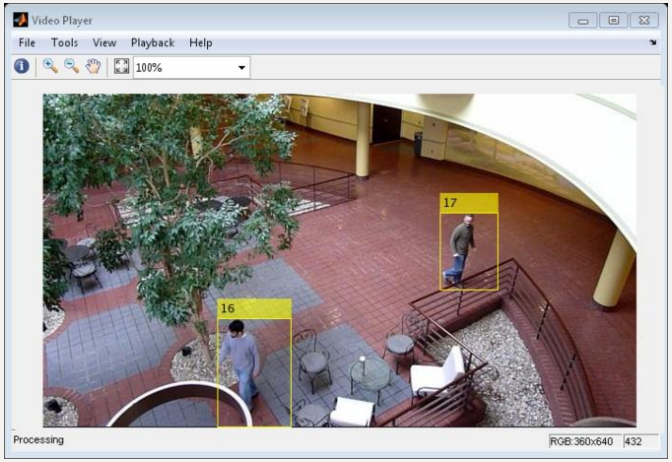
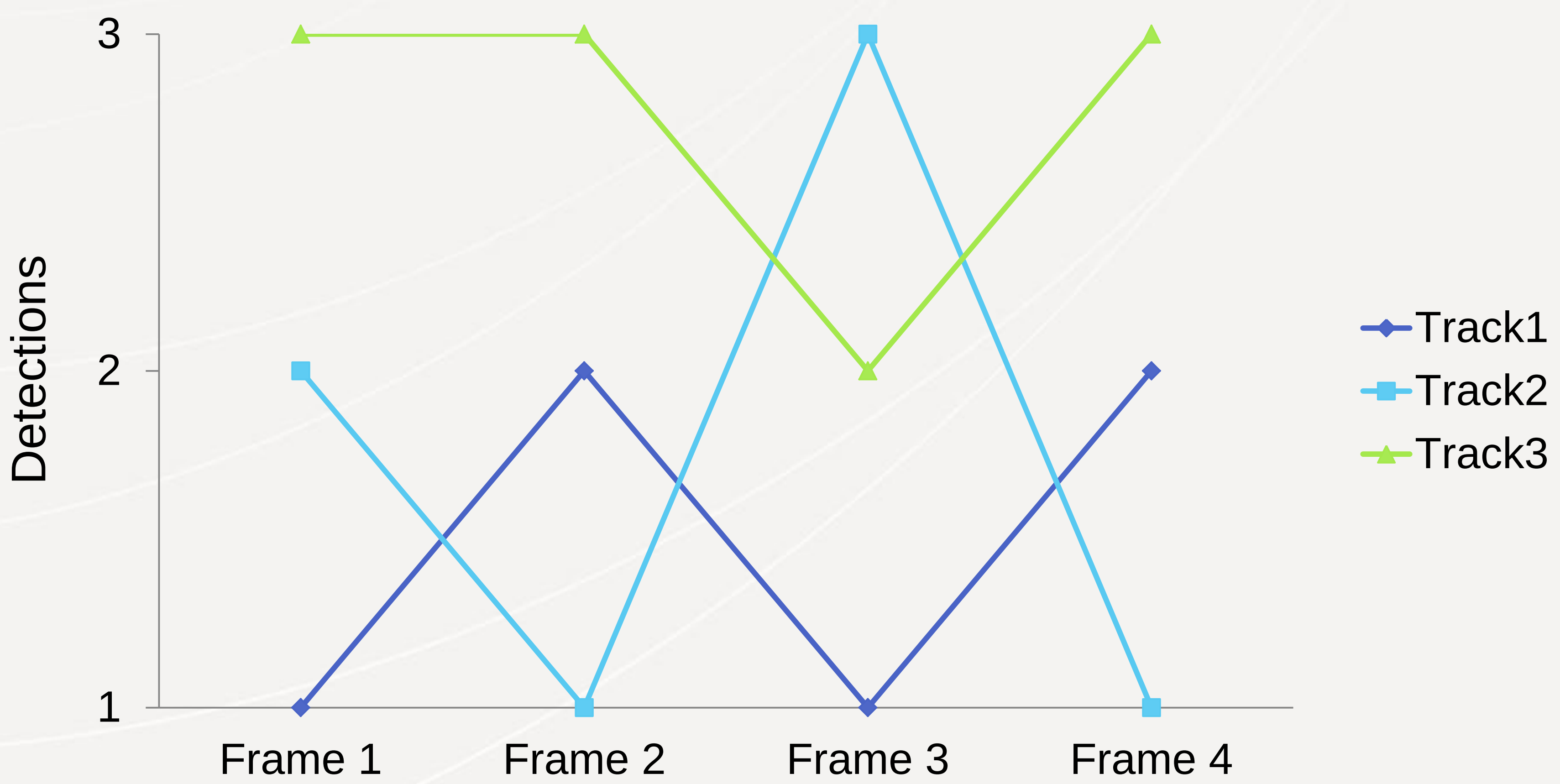
Differentiating Between Objects

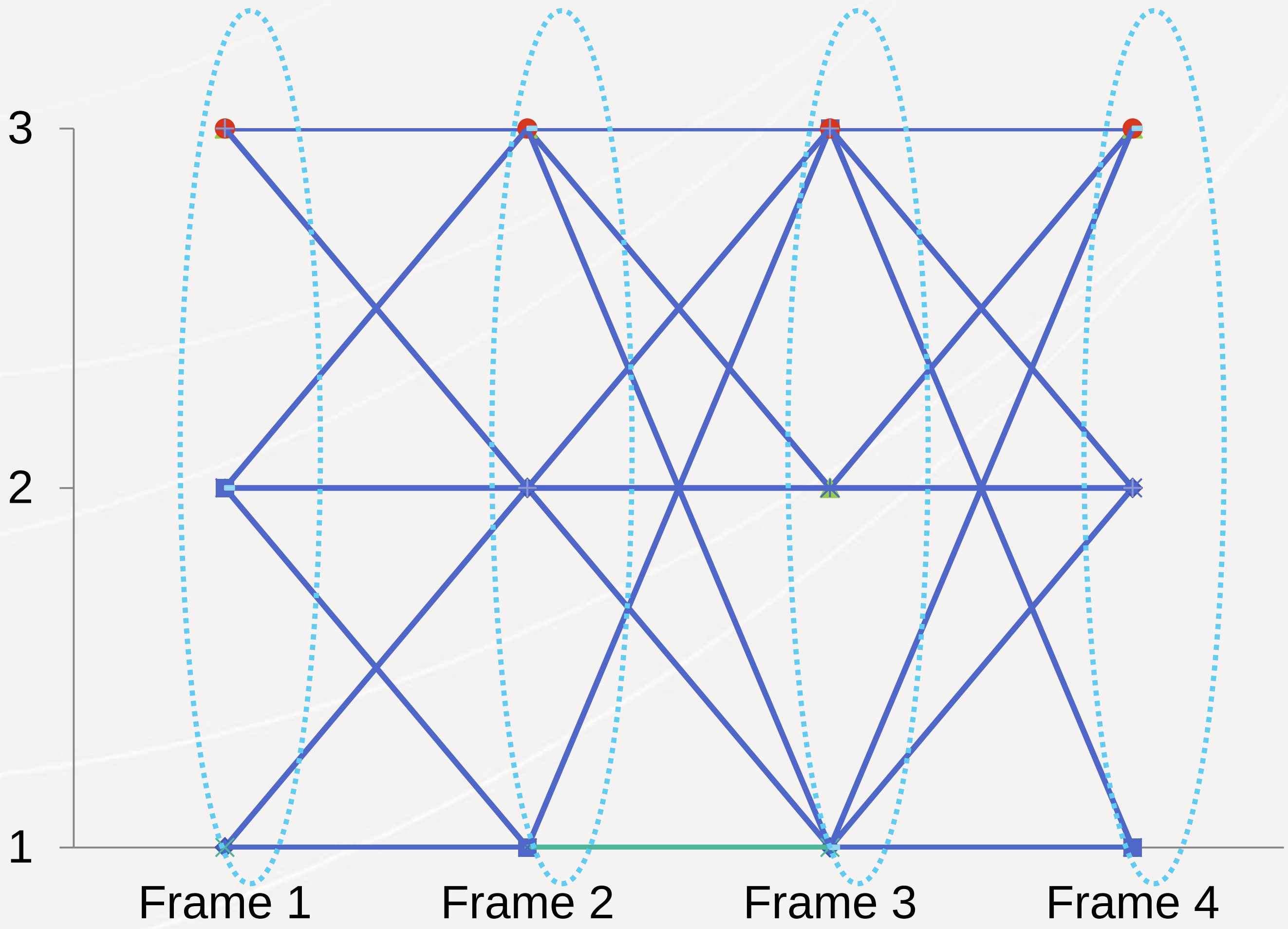
- Problem: What if objects obscure each other?
- Solution:
  - Create a track for each detected object
  - Detect objects in next frame
  - Associate detections with existing tracks
    - Use Kalman filter predictions as weights
- But how do you associate multiple objects?



Data Association Problem



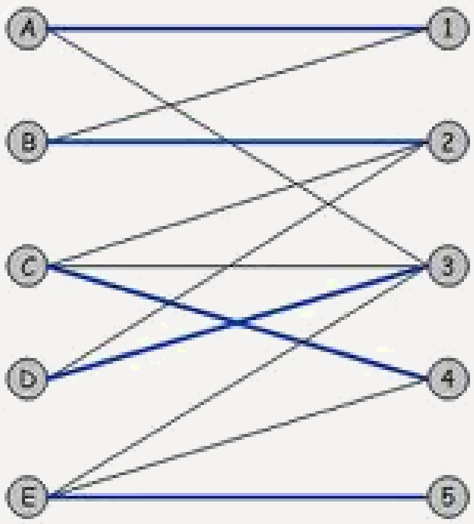
Problem Formulation



Imagine that this is a weighted graph…

Bipartite Graph matching

- The Assignment Problem, a.k.a. 2D assignment
- Can be formulated as minimum-cost matching
- Greedy approach is suboptimal
- Standard algorithms
  - Munkres (a.k.a. Hungarian)
  - Auction



Assigning Detections to Tracks Requires Cost

- Cost is defined as the distance between prediction and detection methods from Kalman filter.
- How well does a measurement match a prediction?

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  where O
- This approach:
  - Takes into account the <u>confidence of the prediction</u>
  - Allows users to pick a detection among many
  - Is essential for multiple object tracking

Cost Matrix

- Example: 2 tracks and 3 detections

	D1	D2	D3
T1	0.1	1.5	2.0
T2	1.2	0.1	1.1

Accounting for Unmatched Detections or Tracks

- Add dummy columns for unmatched (missing) tracks
- Add dummy rows for unmatched detections (new tracks)

"dummy cost" of having an unmatched track

	D1	D2	D3	M1	M2
T1	0.1	1.5	2.0	0.3	
T2	1.2	0.1	1.1		0.3
N1	0.3				
N2		0.3			
N3			0.3		

"dummy cost" of creating a new track

Multiple Object Detection and Tracking Example

Summary

- Object detection and tracking is complex.
- Tracking is not merely detecting on each frame.
- KLT provides a robust method for tracking a small number of objects.
- The Hungarian algorithm and Kalman filtering provide a method for tracking multiple objects subject to occlusion and noise.

Resources

- Object detection and tracking documentation in MATLAB
  - http://www.mathworks.com/help/vision/motion-analysis-and-tracking.html
- Embedded Vision Academy
  - http://www.embedded-vision.com/what-embedded-vision/embedded-vision-academy/functions/object-tracking
- Wikipedia
  - http://en.wikipedia.org/wiki/Video_tracking
  - http://en.wikipedia.org/wiki/Kanade-Lucas-Tomasi_Feature_Tracker
  - http://en.wikipedia.org/wiki/Background_subtraction
  - http://en.wikipedia.org/wiki/Hungarian_algorithm