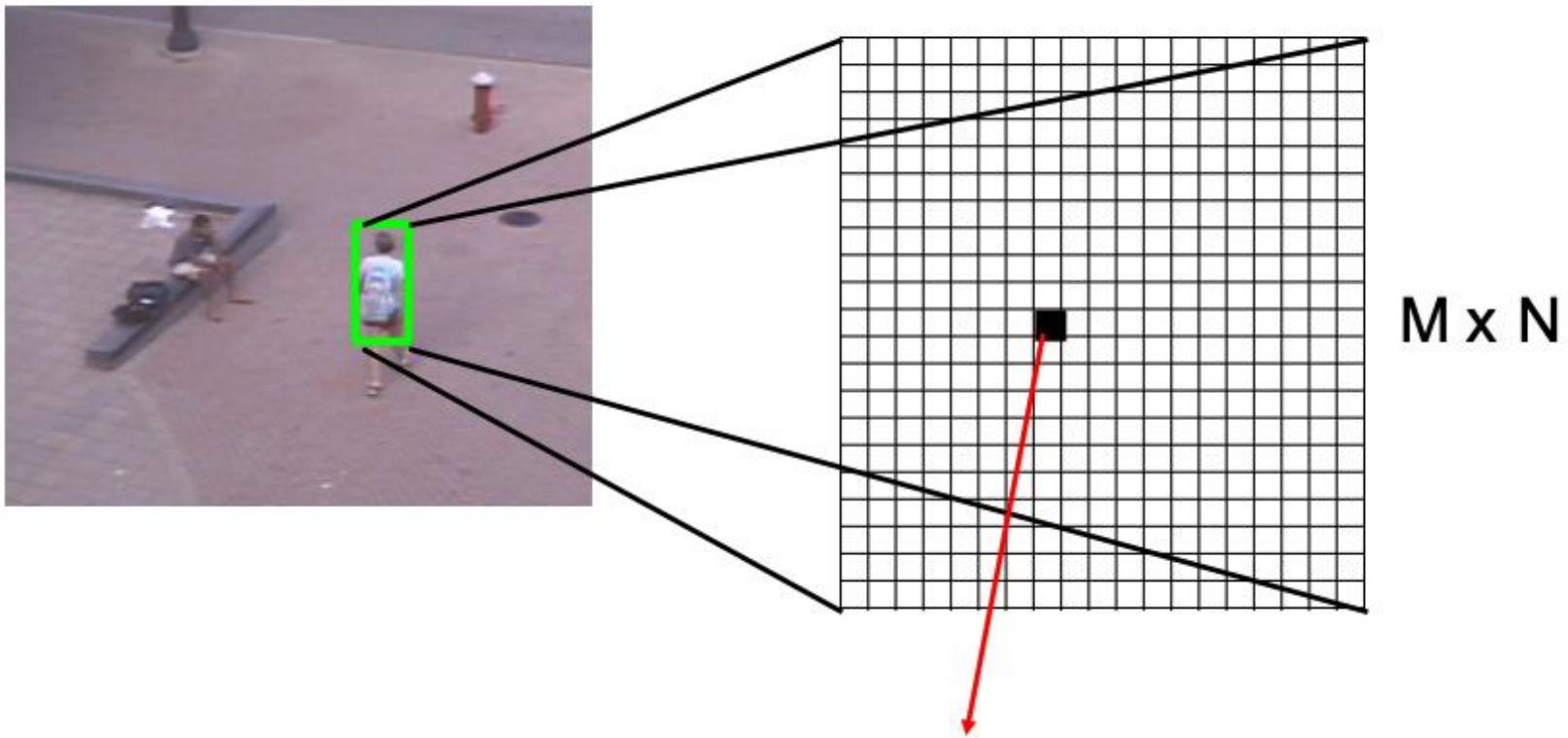
Covariance Tracking

Computer Vision (CS0029)

Motivation

- Capture spatial and statistical properties, and their correlation
- Can fuse different types of features
  - Location
  - Color
  - Edges
  - Motion
- Low dimensional representation (fast)
- Scale Invariance

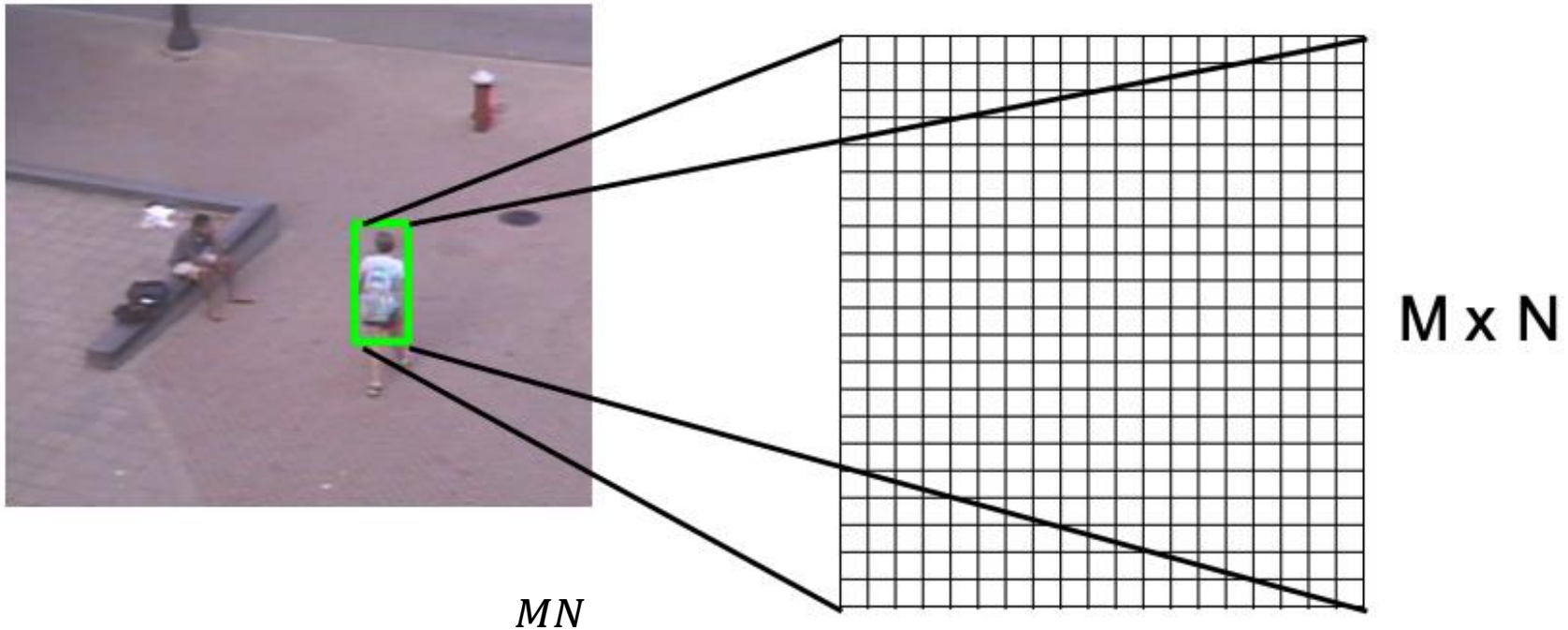
Covariance Descriptor



Feature vector (for each pixel) $f_k = [\, x\ y\ R\ G\ B]^T$

d x 1

Covariance Matrix



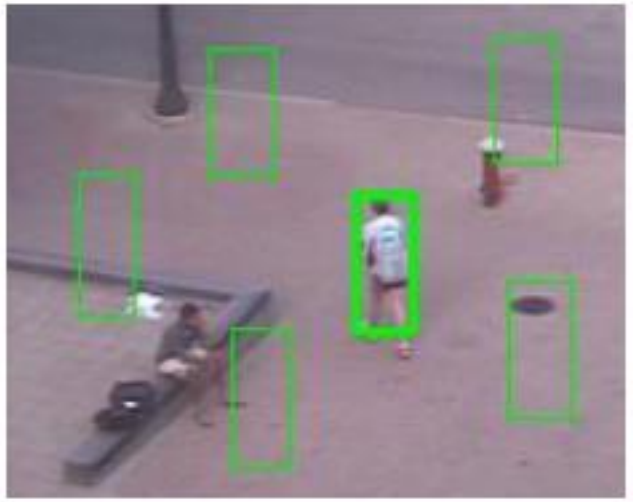
$$C^{Model} = \frac{1}{MN}\sum_{k=1}^{MN}(f_k - \mu)(f_k - \mu)^T$$

dxd

Mean of all f_k

Finding the Best Match

C^{Model}



Candidate matches

- For each possible patch region in the next image, find its covariance matrix
- Compare C^{Model} to the covariance matrices of all possible patch regions in next image
- Find the patch in next image whose distance from C^{Model} is minimum

Comparing Covariance Matrices

- Find the distance between 2 covariance matrices
- Space of covariance matrices is not vector!
  - Simple arithmetic matrix subtraction would not work
- The space of covariance matrices is a Riemannian Manifold
- Distance metric
  - $\varrho\left(C^{Model}, C^{Candidate}\right) = \sqrt{\sum_{k=1}^{d} \lambda_k \ln(\ (C^{Model}, C^{Candidate}))_2}$
  - $\lambda_k(C^{Model}, C^{Candidate})$ is generalized eigenvalues
    - Scipy: scipy.linalg.eig()

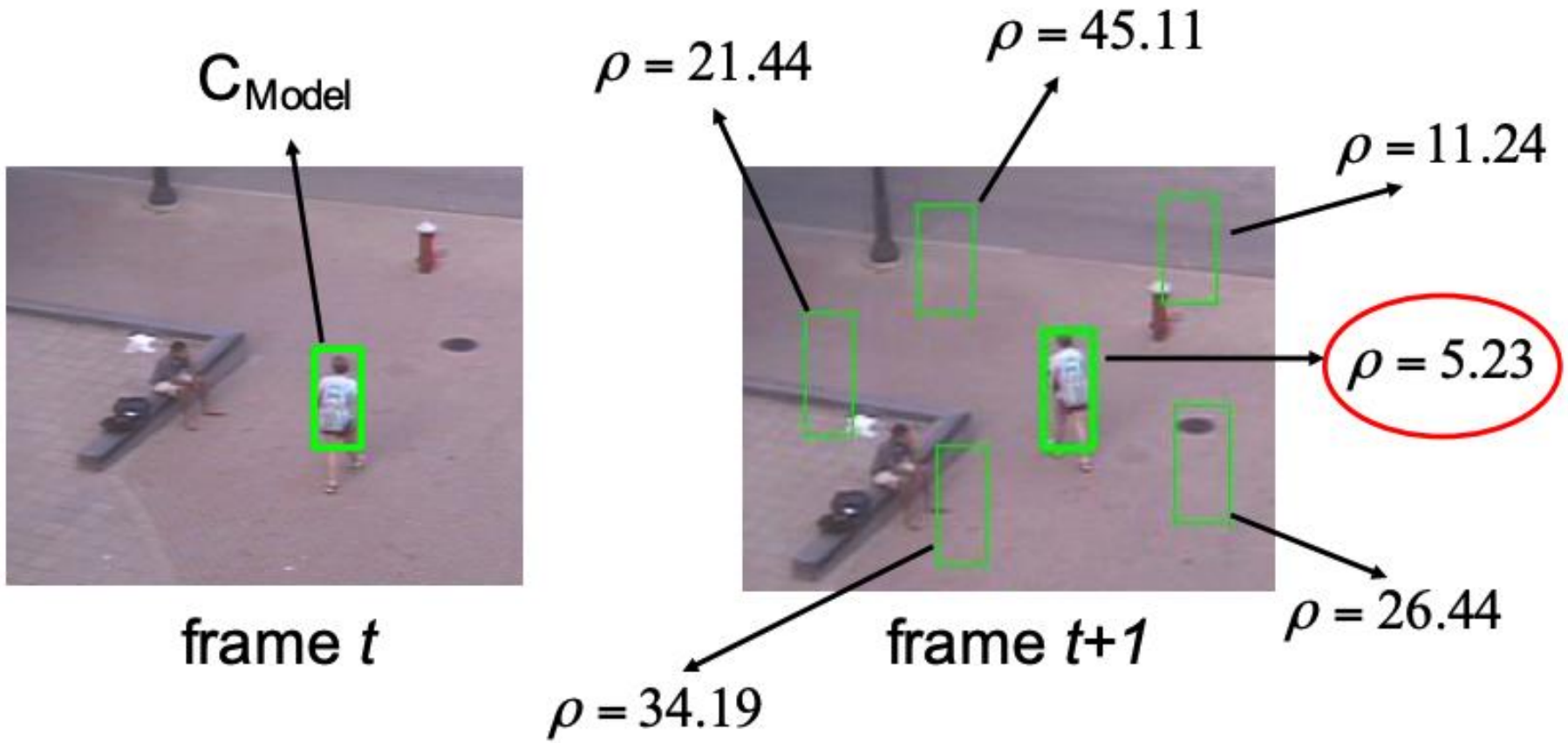
Algorithm

- Compute C^{Model} for known target in current image

- Scan all patches in next image
  - For each patch, compute covariance matrix $C^{Candidate}$
  - Find distance from C^{Model} :$\varrho\left(C^{Model}, C^{Candidate}\right)$

- Find patch region with minimum distance

Example


C_{Model}
frame *t*
$\rho = 21.44$
$\rho = 45.11$
$\rho = 11.24$
$\rho = 5.23$
$\rho = 26.44$
$\rho = 34.19$
frame *t+1*

Other

- Rotation invariance
  - Use radial distance instead of Cartesian position
  - $f_k = [r(x, y)\ R\ G\ B]^T$
- Model update
  - Calculate an average/smoothed covariance matrix by tacking the mean of the models from the past few frames, then use that as C^{Model}
  - Must calculate mean on manifold

Summary

- Algorithm for non-rigid object tracking

- Covariance Tracking
  - Covariance of spatial and statistical features
  - Low dimensional representation of object
  - Distance between matrices based on manifold distance