Creating Better Correlation Filters

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Motivation

Why do we care?

- Correlation is typical not even tried for difficult problems.
- ASEF and MOSSE provide a way to get "better" output from a correlation filter.
- Correlation is commonly used. (Taught in most beginning image processing classes.)
- Implementation is simple.
- ASEF and MOSSE are often more accurate. and much faster than state of the art detection and tracking algorithms.

Overview

- Correlation Review
- Constructing Better Filters:
  - Person Detection
- Filter Based Tracking
- Homework Tips

Correlation and Convolution

- Cross Correlation - Aligned Signal

$$(f \star h)[x] = \sum_{dx=-\infty}^{\infty} f[dx]h[x+dx]$$

- Convolution - Reversed Signal

$$(f * h)[x] = \sum_{dx=-\infty}^{\infty} f[dx]h[x-dx]$$

Convolution Theorem

- Convolution is simpler in the Fourier Domain.

$$f * h = \mathcal{F}^{-1}(\mathcal{F}(f) \odot \mathcal{F}(h)) = \mathcal{F}^{-1}(F \odot H)$$

- Convolution.

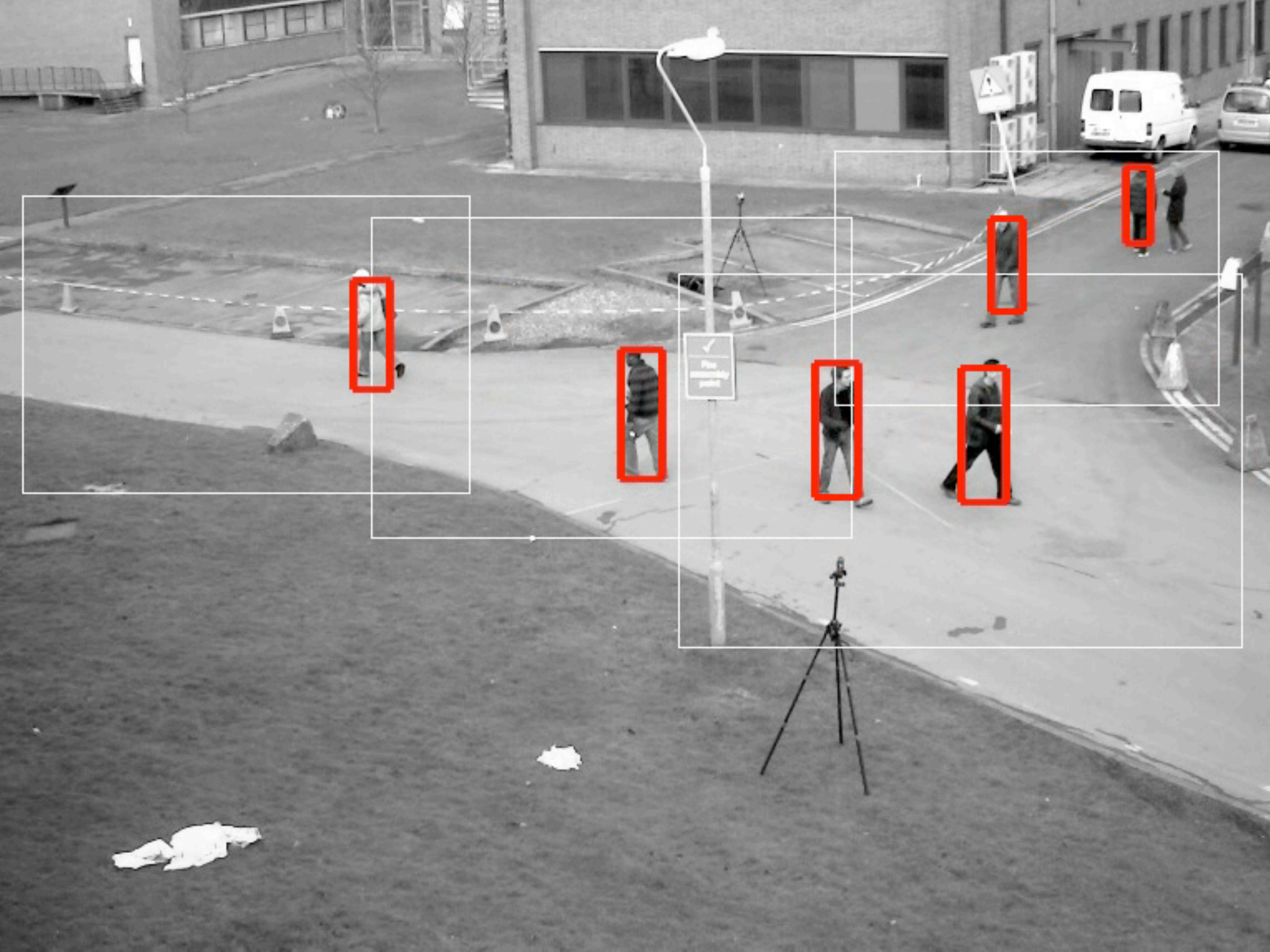
$$G = F \odot H$$

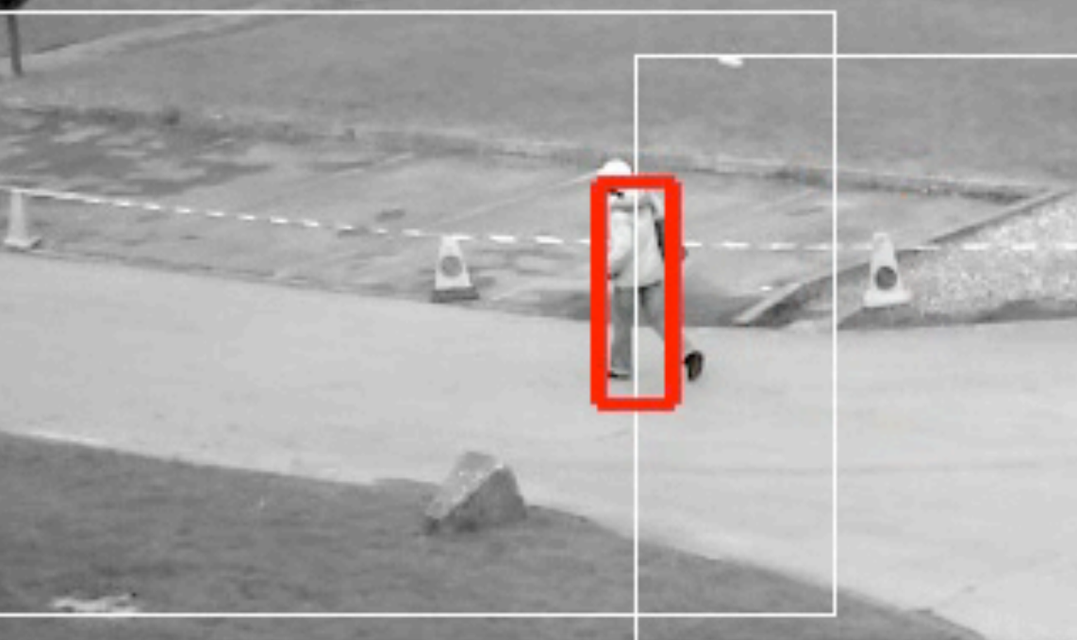
- Correlation.

$$G = F \odot H^*$$

- What does this do to an image?

$$\mathcal{F}^{-1}(\mathcal{F}(f)^*)$$



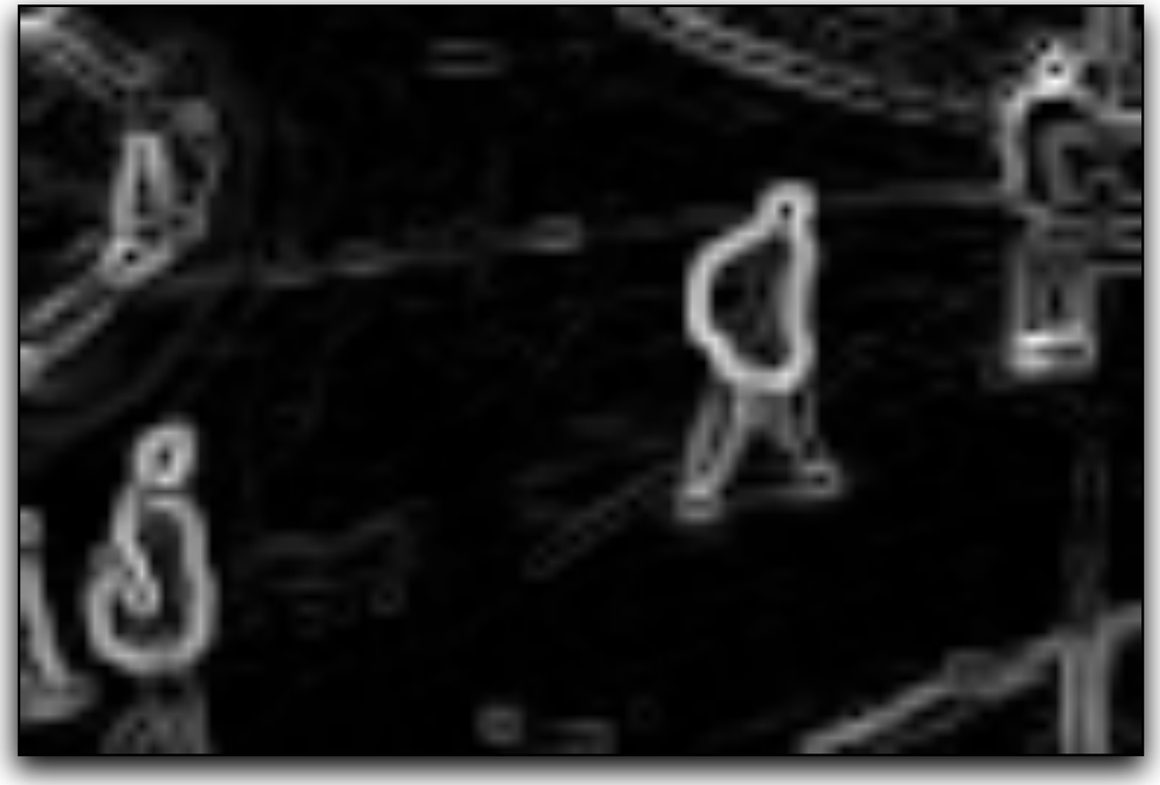


Preprocessing

The variety of clothing colors
causes problems for detection.

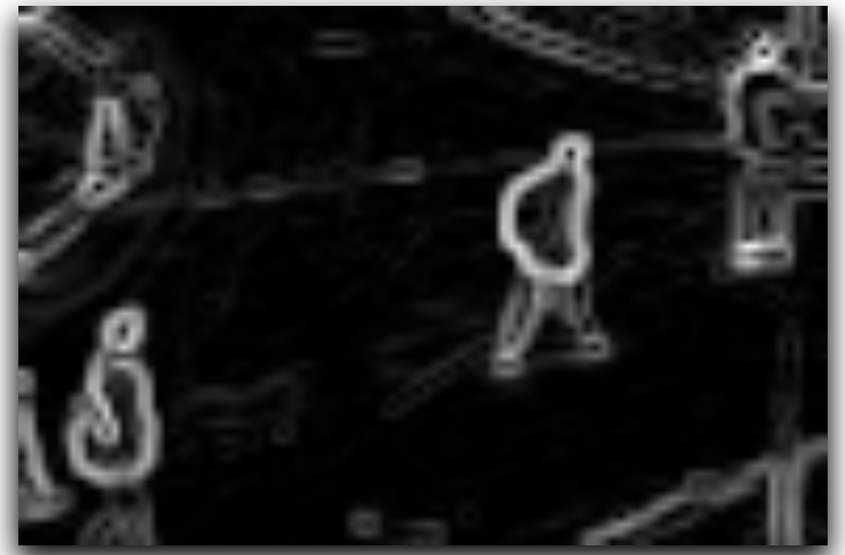
Original Frame

Gradient Magnitude



Correlation

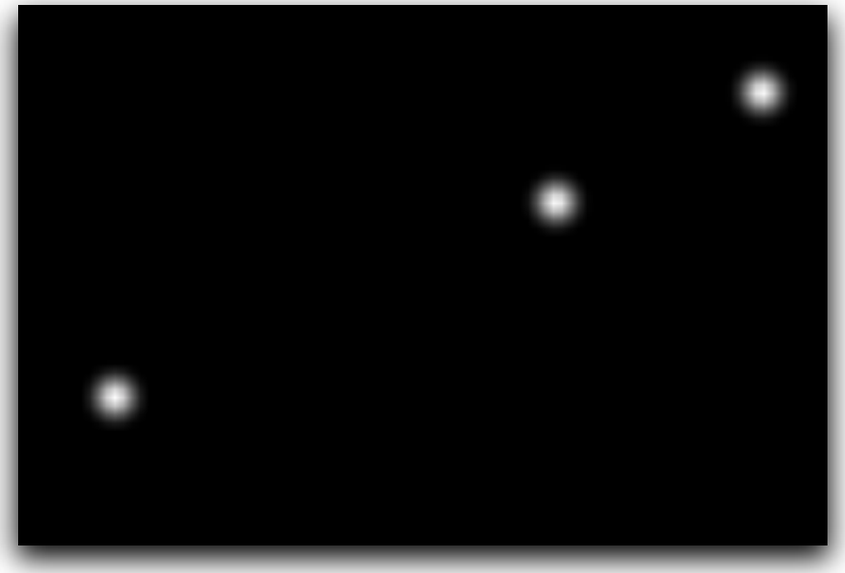
Input - f



Filter - h

?

Output - g



$$f \otimes h = g$$

$$F \odot H^* = G$$

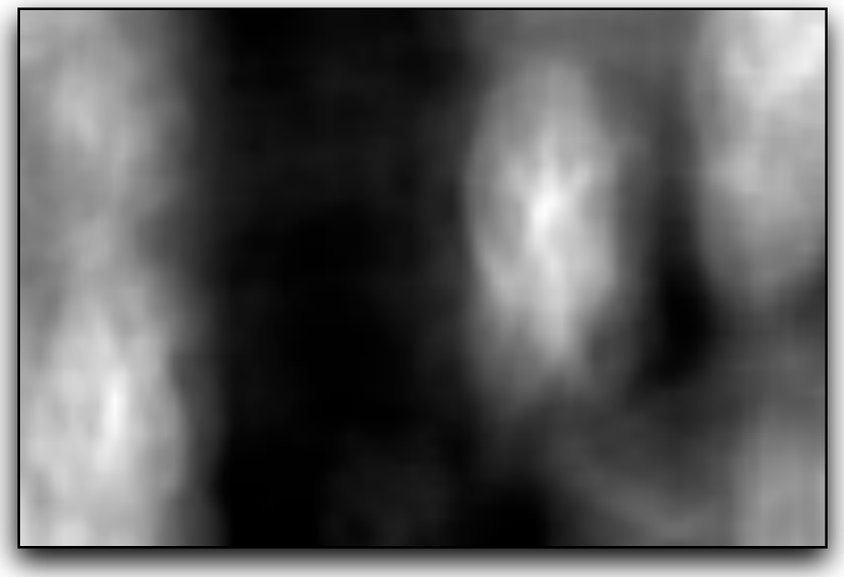
Problem: Learn a filter that maps the input to the output.

Training A Better Filter

Input

Filter

Output



Simple templates just don't work.

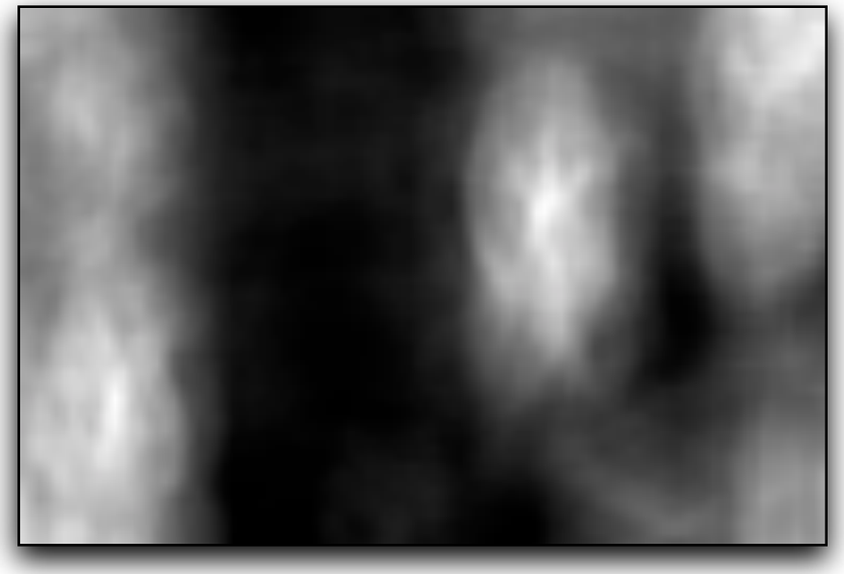
The Solution....
Average of Synthetic Exact Filters (CVPR 2009)

Exact Filters

Training Image

?

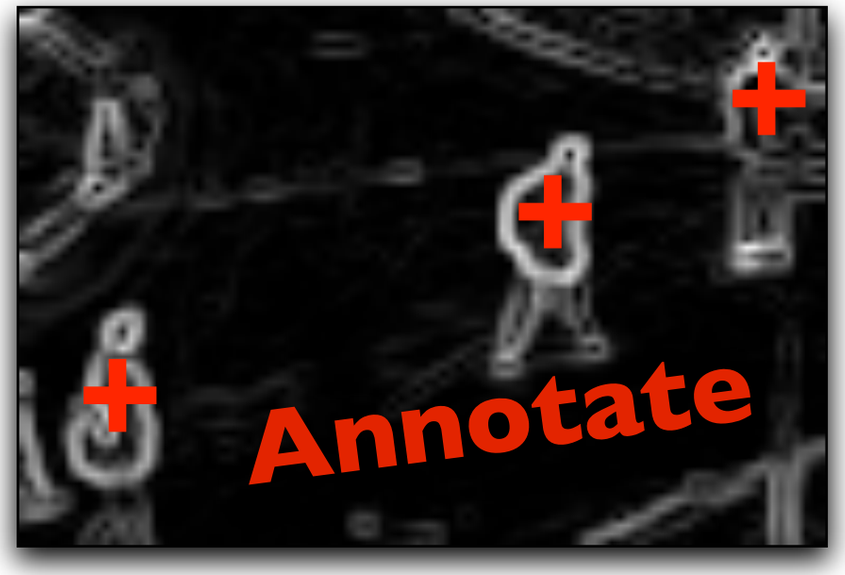
Output



$$F_i \odot H_i^* = G_i$$

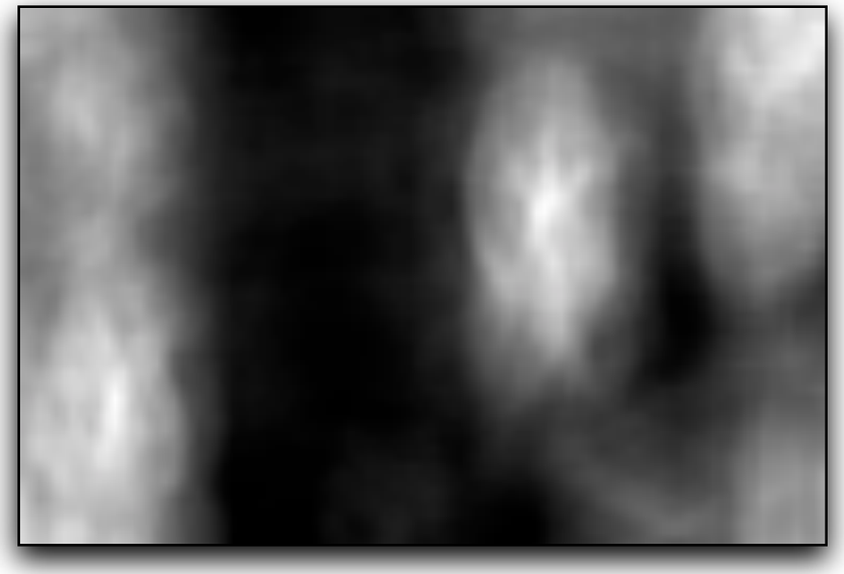
Exact Filters

Training Image



?

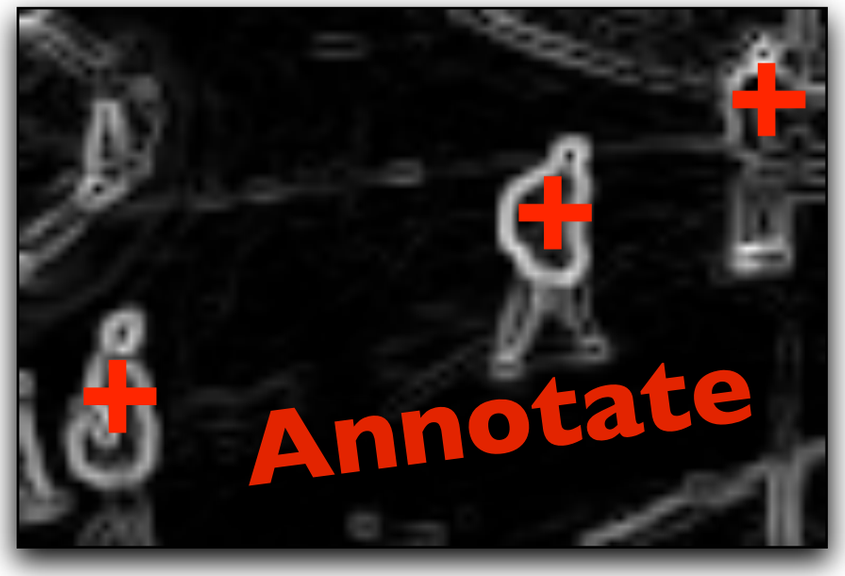
Output



$$F_i \odot H_i^* = G_i$$

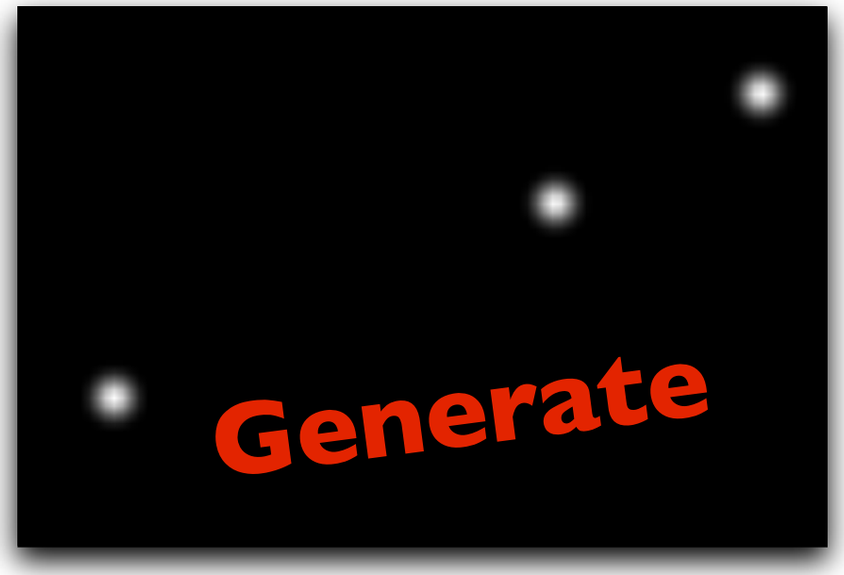
Exact Filters

Training Image



?

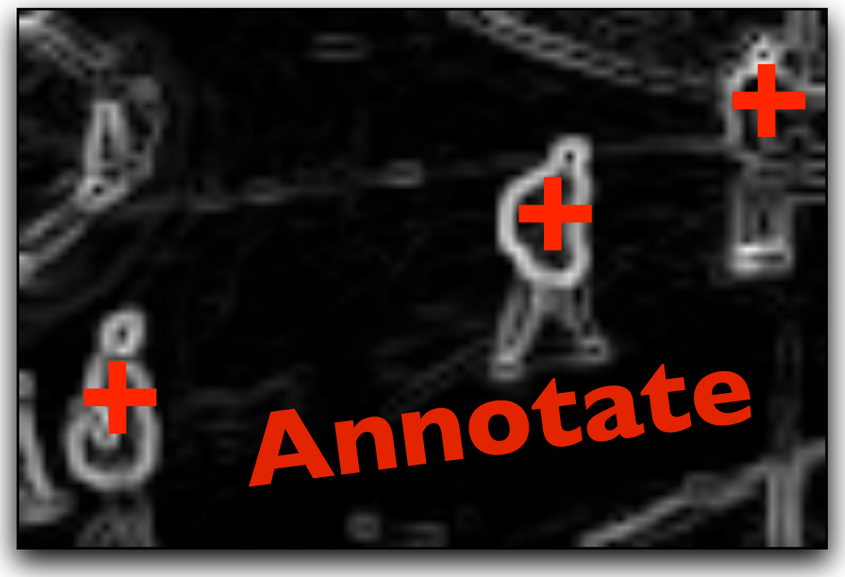
Output



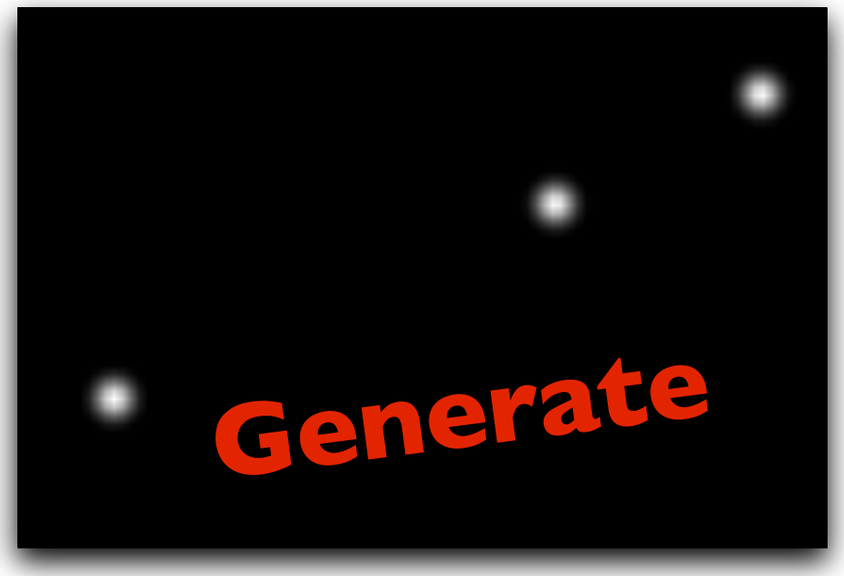
$$F_i \odot H_i^* = G_i$$

Exact Filters

Training Image



Output



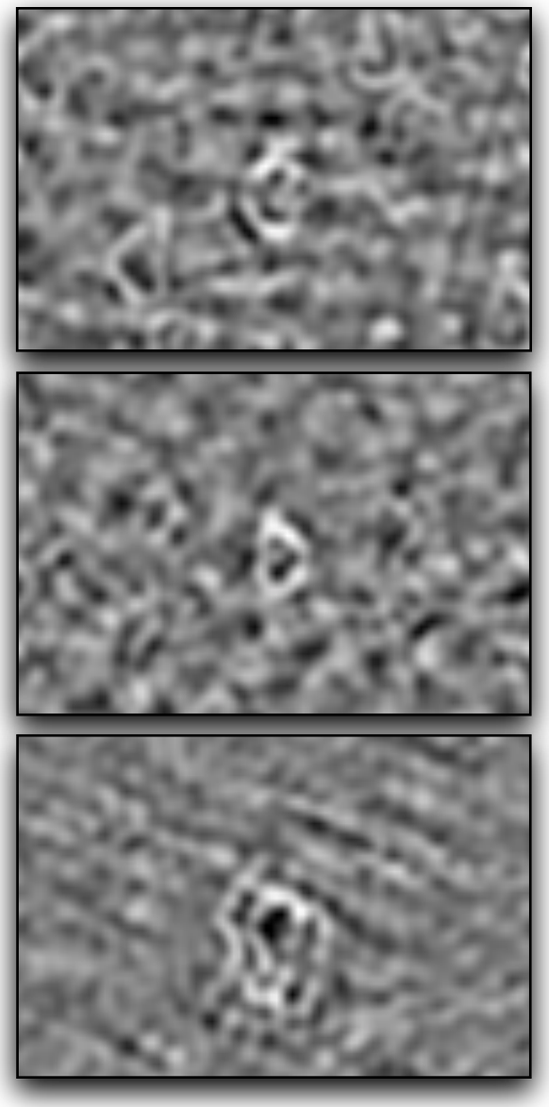
$$F_i \odot H_i^* = G_i$$

$$H_i^* = \frac{G_i}{F_i}$$

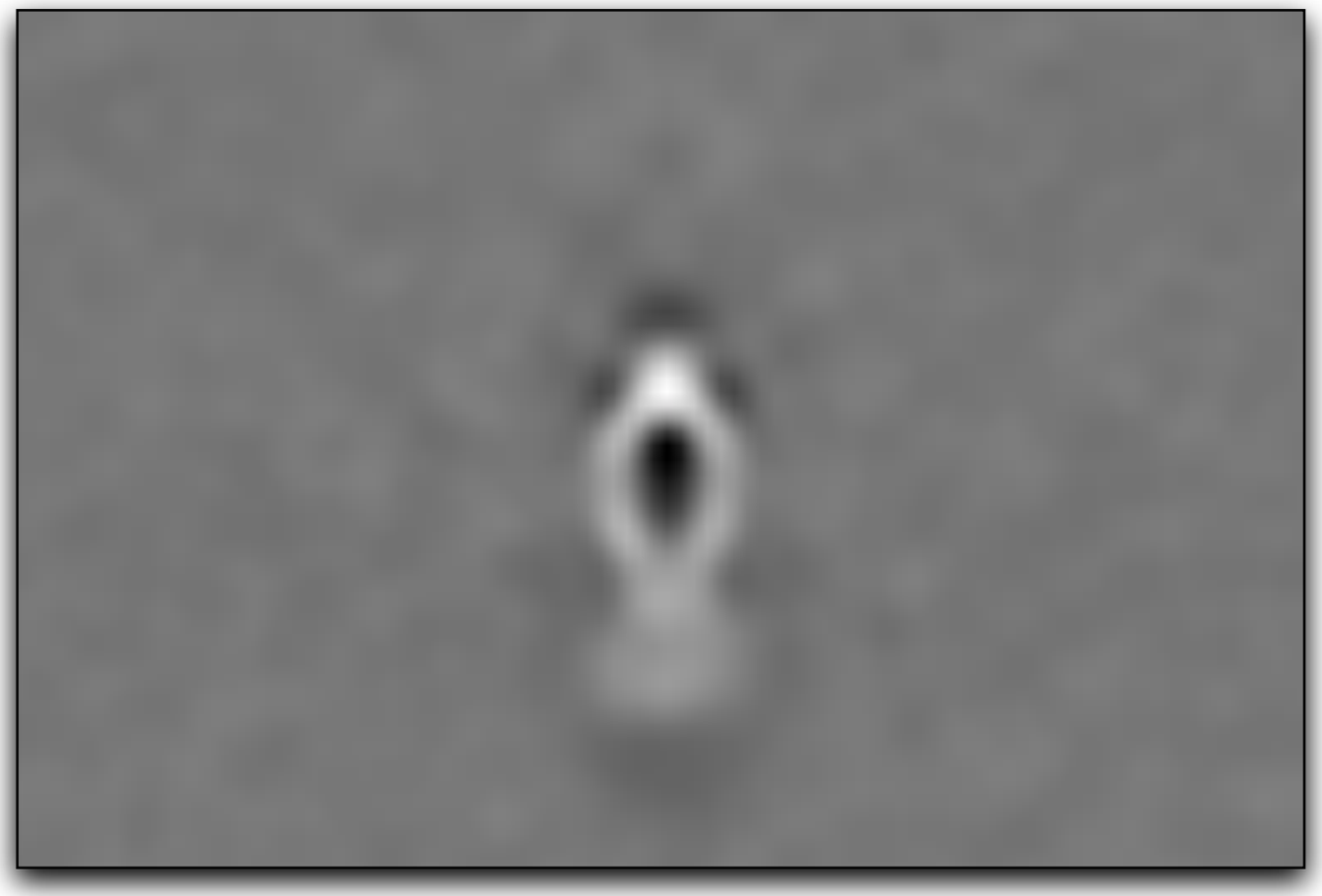
ASEF Filter

$$H^* = \frac{1}{N}\sum_{i=1}^{N}\frac{G_i}{F_i}$$

Exact Filters



AVERAGE



Original

Preprocessed

Target

Exact Filter

ASEF Filter

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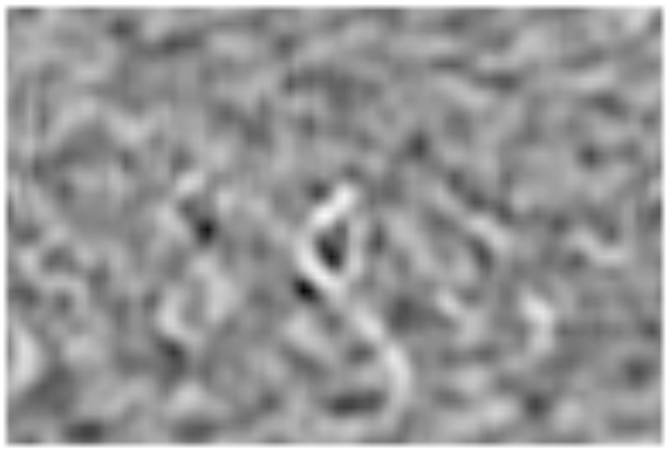
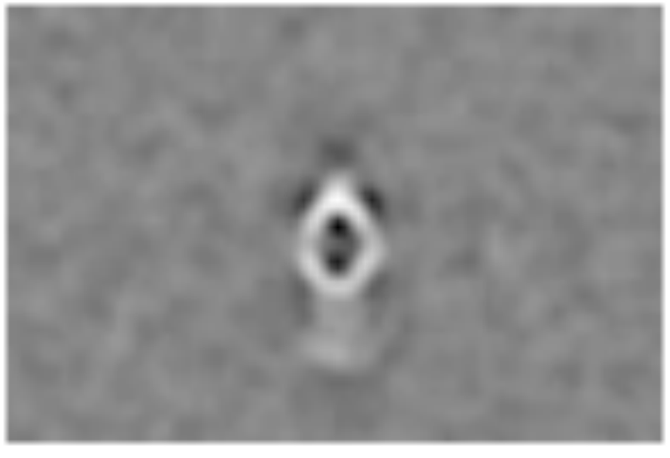
Original

Preprocessed

Target



Exact Filter



ASEF Filter

Training in realtime

Original

Preprocessed

Target

Exact Filter

ASEF Filter

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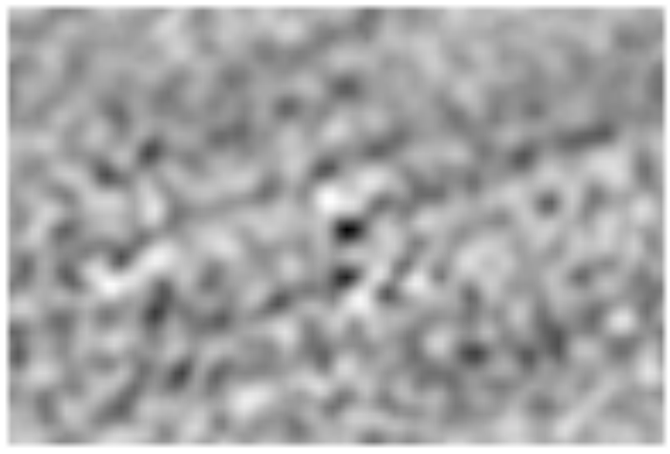
Training in realtime

Original

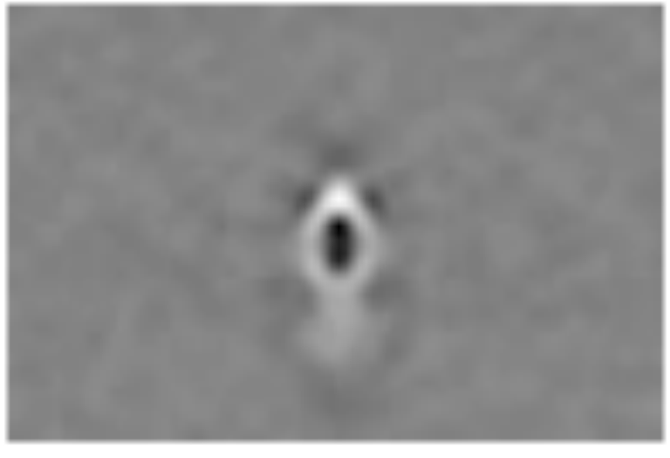
Based on 25 manually annotated frames

Preprocessed

Target



Exact Filter



ASEF Filter

Total Training Time = 12 seconds

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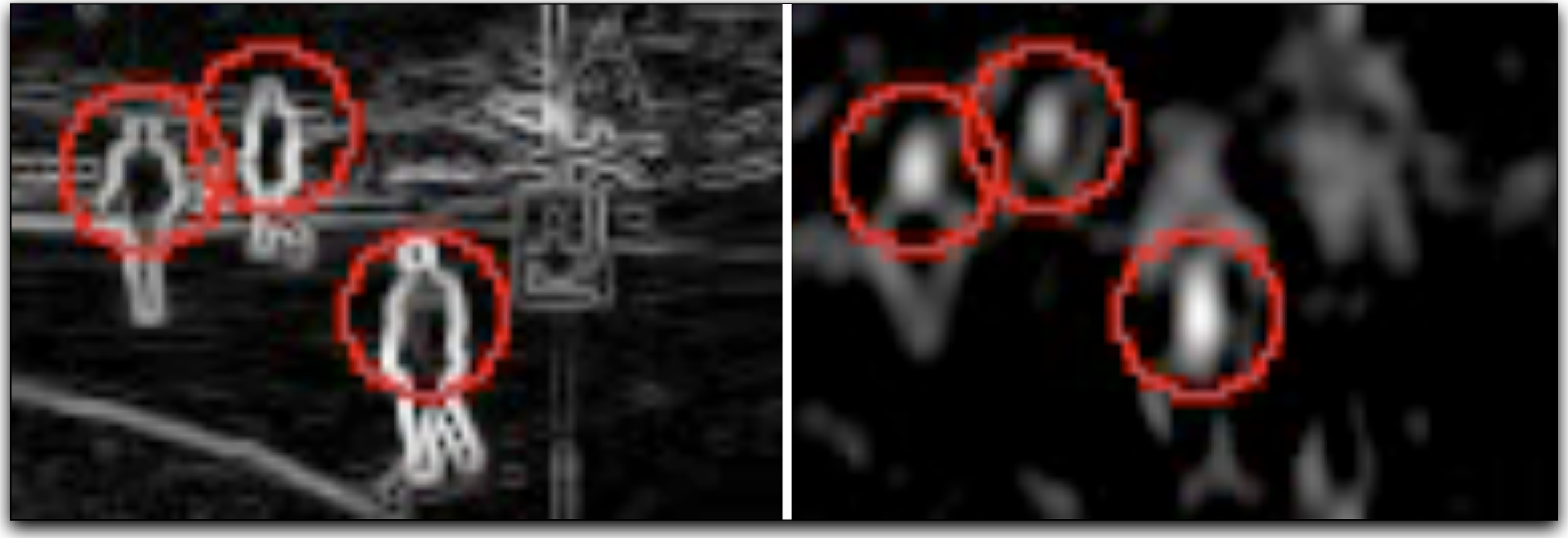
Detection

Find the local maxima that exceed a given threshold.

Preprocessed Input

Correlation Output

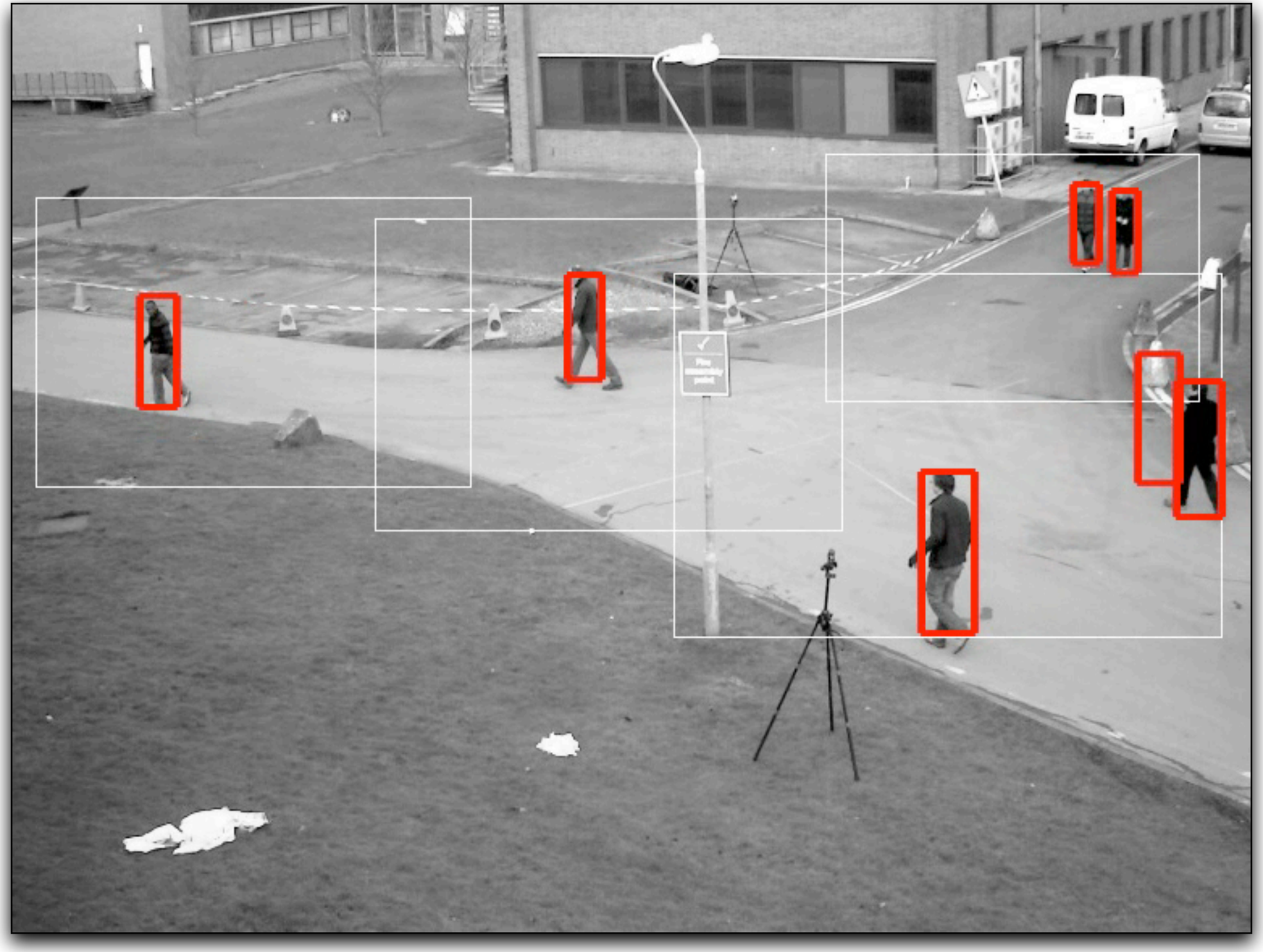


Other Algorithms

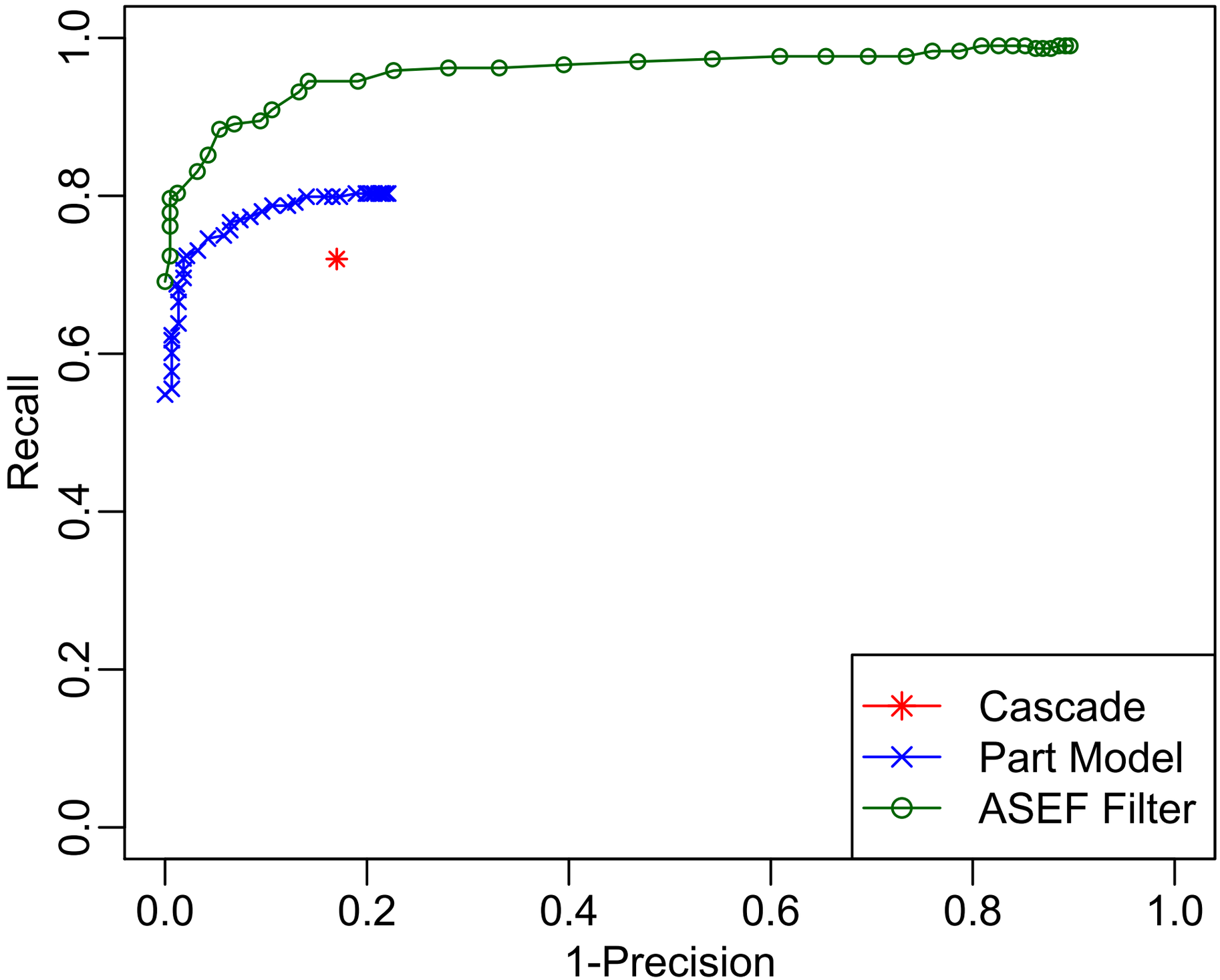
- **OpenCV Cascade Detector** - Viola and Jones. 2001.
  - Well known
  - Real time

- **Parts Based** - P. Felzenszwalb, et. al. 2008.
  - State of the Art
  - Prior Baseline

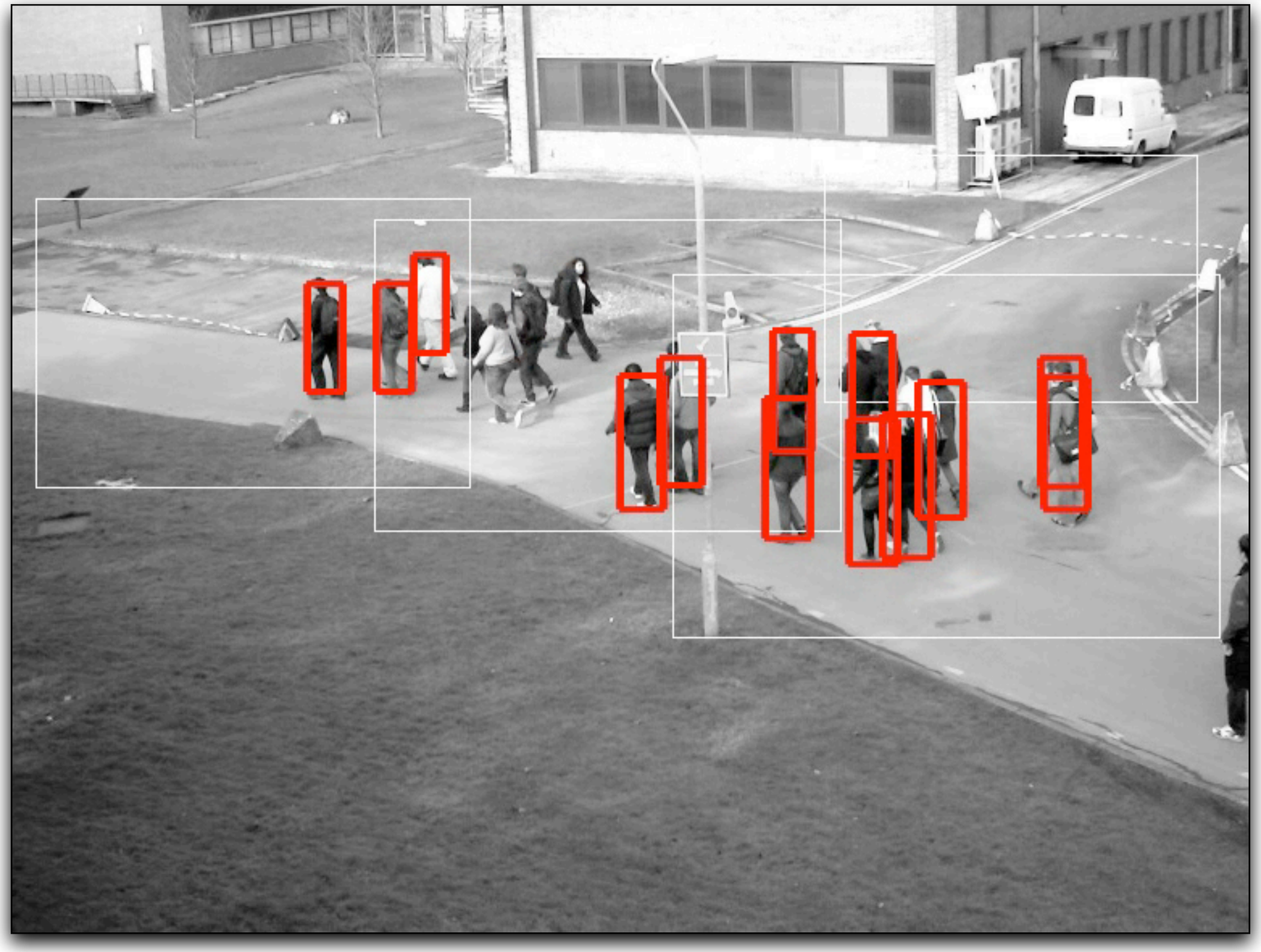
Sparse Sequence



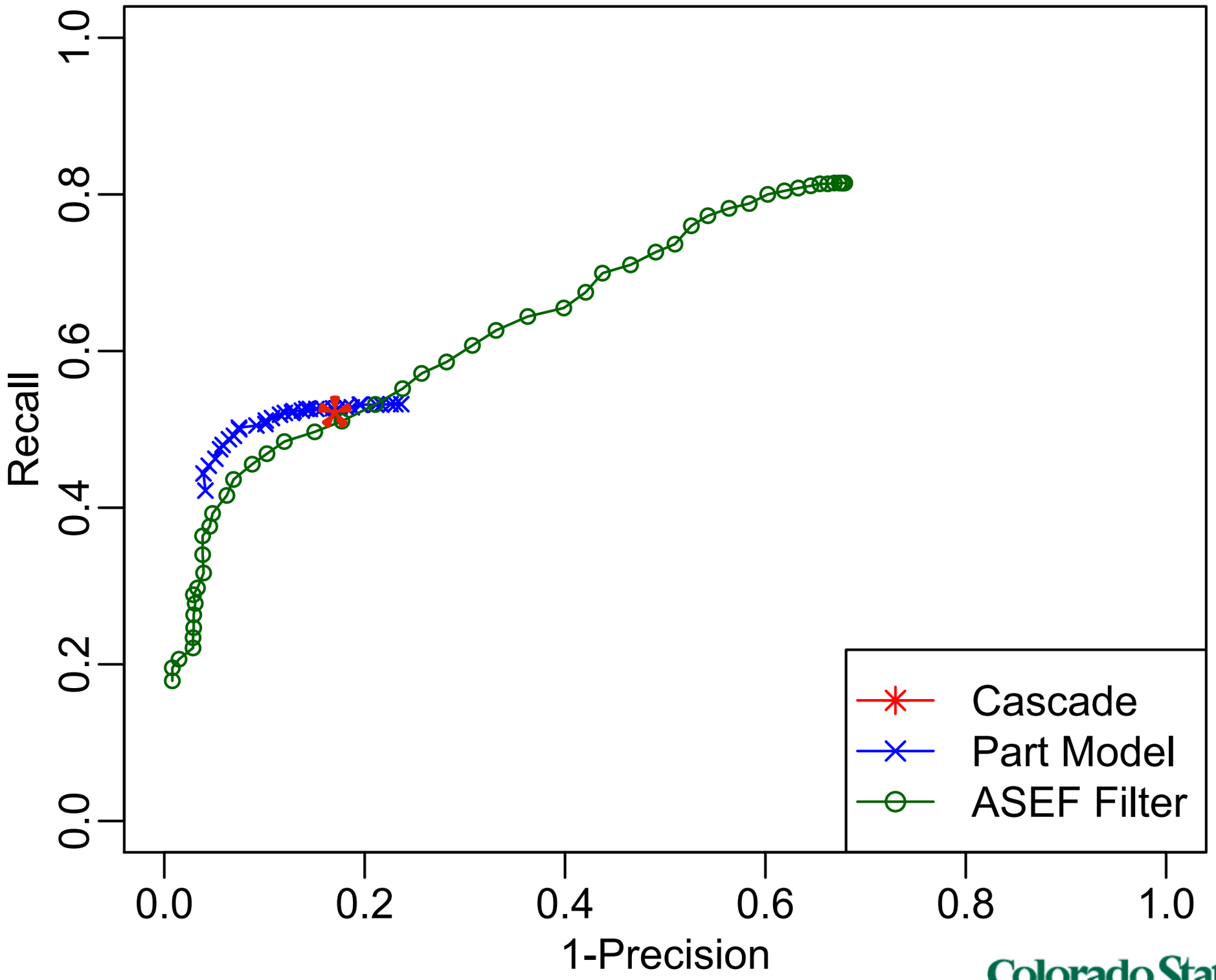
Sparse Sequence



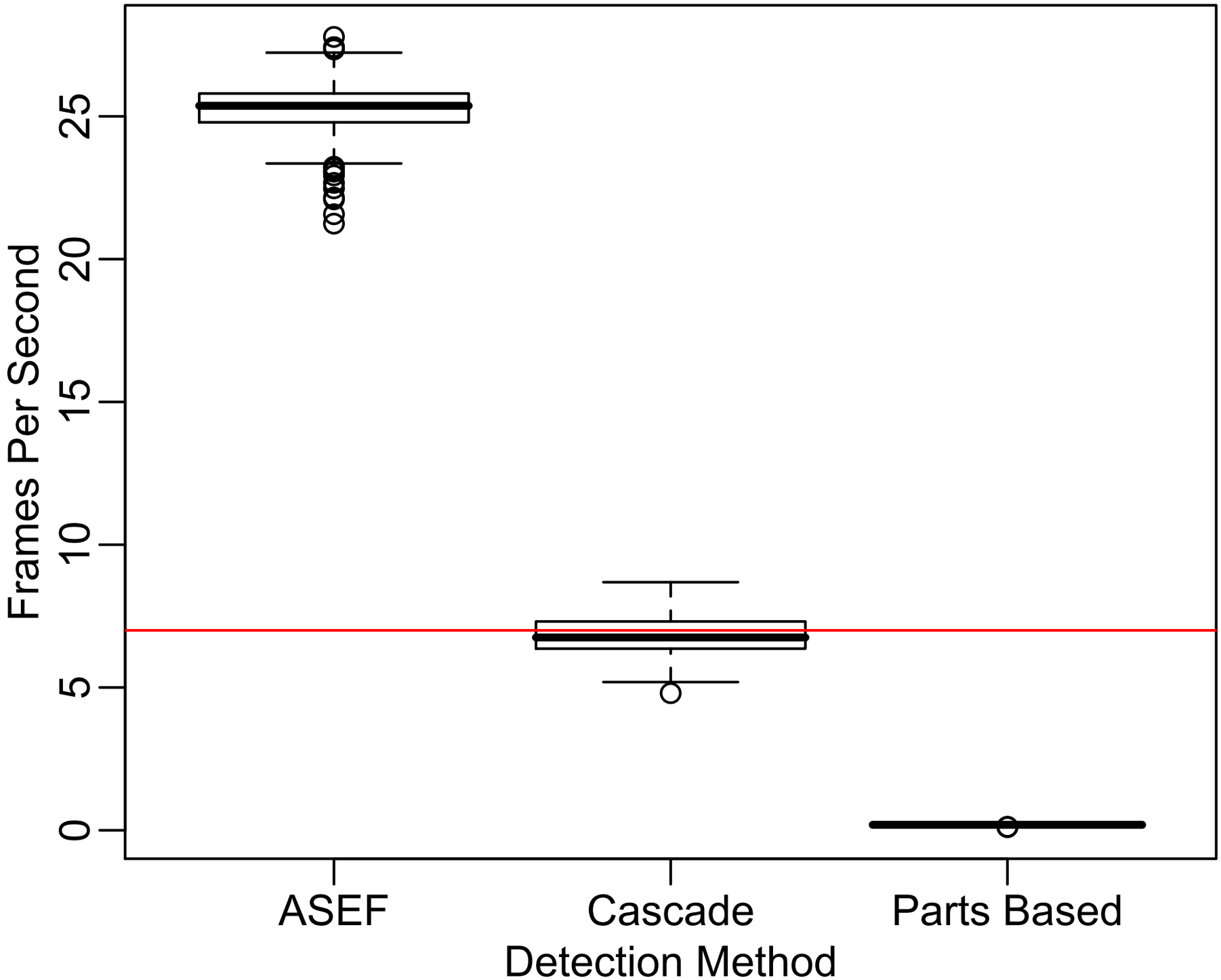
Crowded Sequence



Crowded Sequence



Detection Speed



Visual Tracking

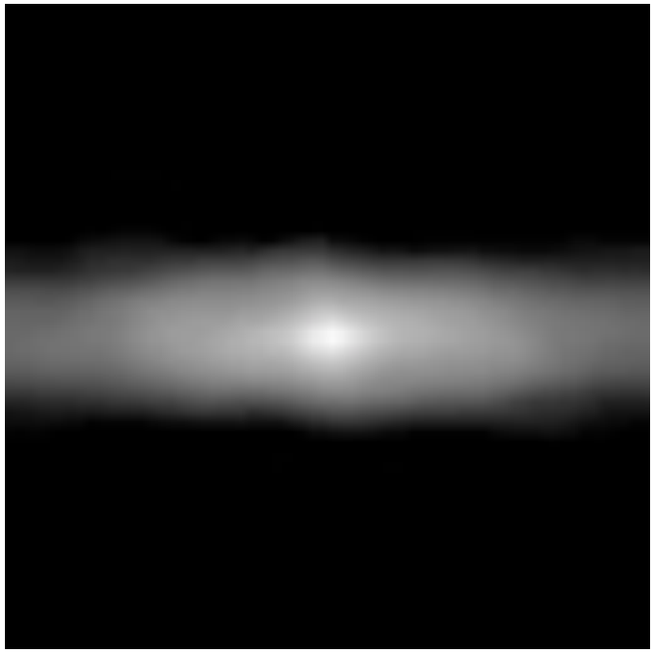
- MOSSE = Minimum Output Sum of Squared Error.
- Use ASEF or MOSSE to produce better peaks.
- Adapt to the changing appearance of the target.
- State of the Art tracking capability.
- Fast track updates: 669 fps

Simple Template

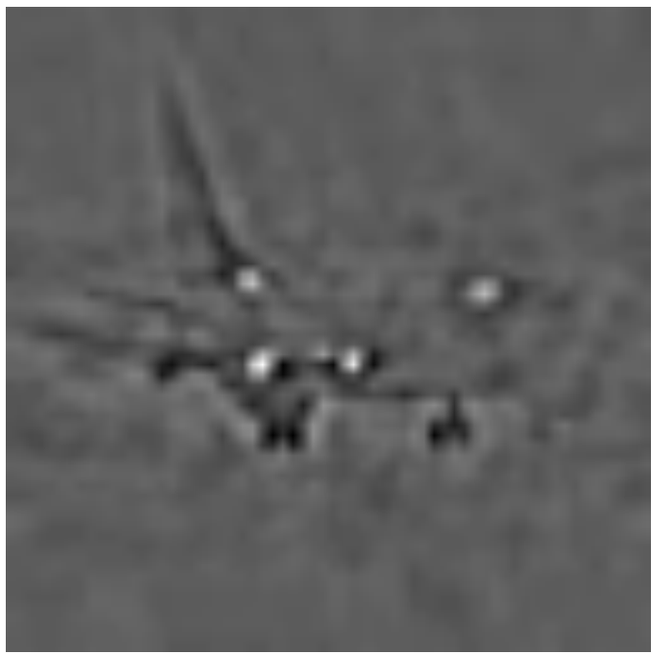
MOSSE Filter

Input, Filter, and Output

Mean Template



MOSSE



Failure Detection

- Peak-To-Sidelobe Ratio (PSR)

$$PSR = \frac{g_{\max} - \mu_{\mathtt{sl}}}{\sigma_{\mathtt{sl}}}$$

- Measures the strength of the output peak.
- For MOSSE or ASEF it can be used to determine occlusion or tracking failure.

MOSSE and ASEF

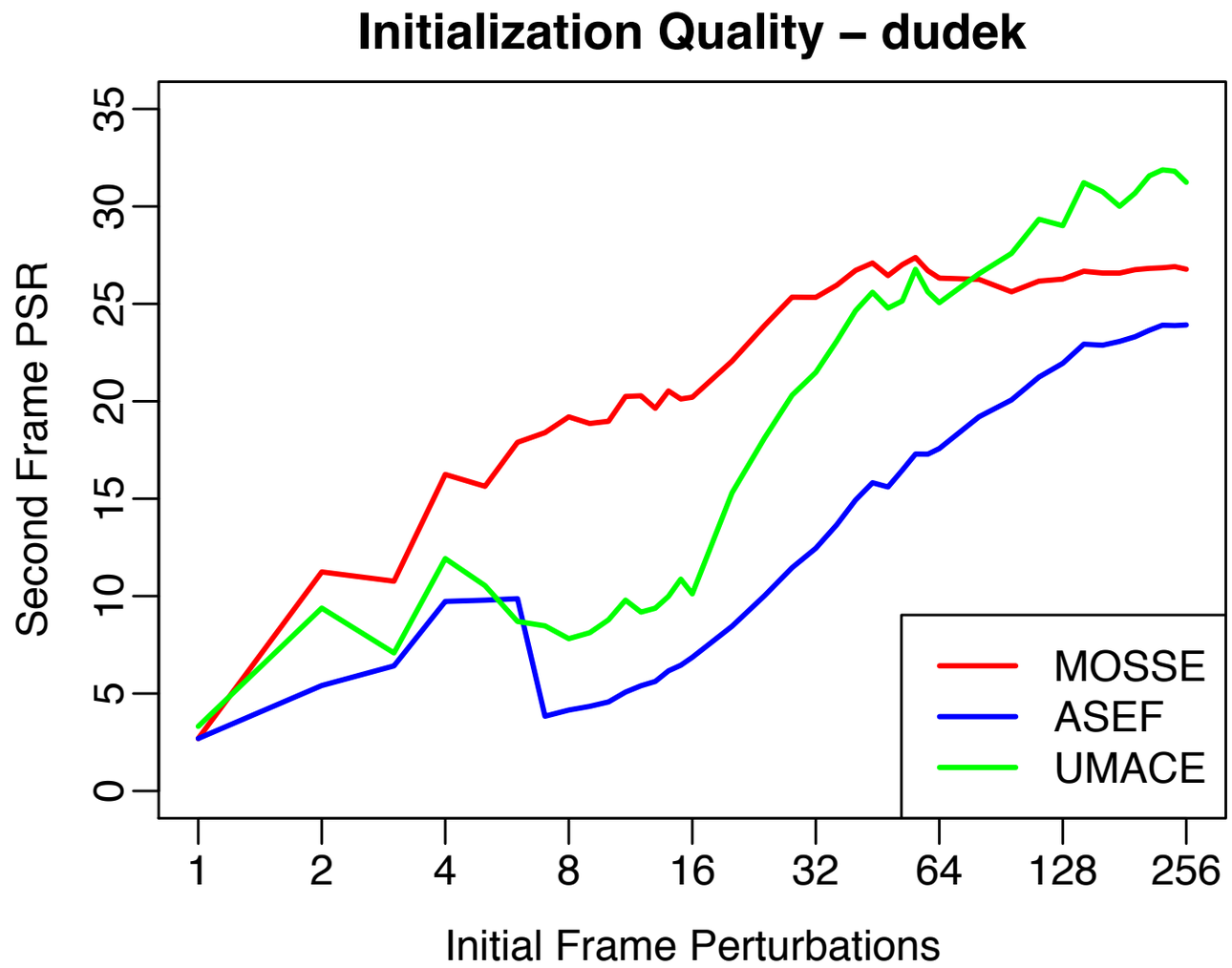
- MOSSE is in many ways similar to ASEF but is more stable when trained on just a few images.

ASEF

$$H^* = \frac{1}{N} \sum_i \frac{G_i \odot F_i^*}{F_i \odot F_i^*}$$

MOSSE

$$H^* = \frac{\sum_i G_i \odot F_i^*}{\sum_i F_i \odot F_i^*}$$

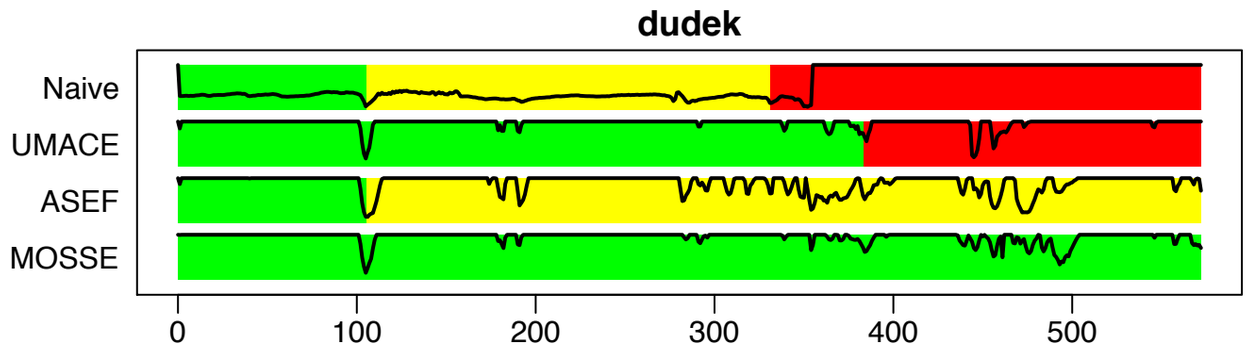


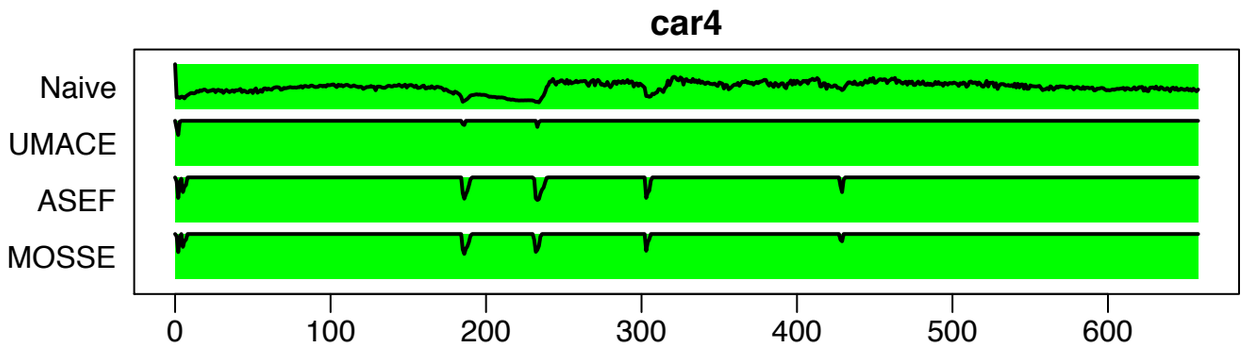
Tracking Algorithm

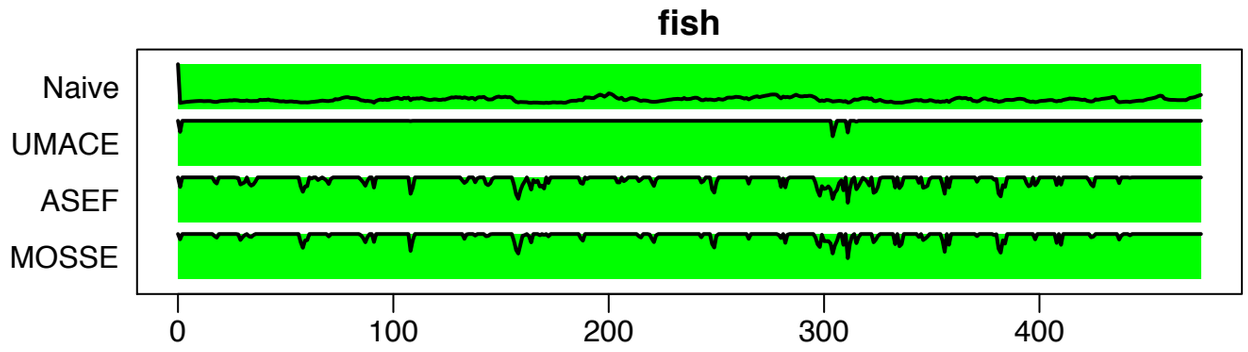
- Extract and rescale the tracking window.
- Correlate with the current filter to get the peak.
- Generate synthetic output with the peak at the new location.
- Update the filter using a running average.
- Update the track center to the new location.

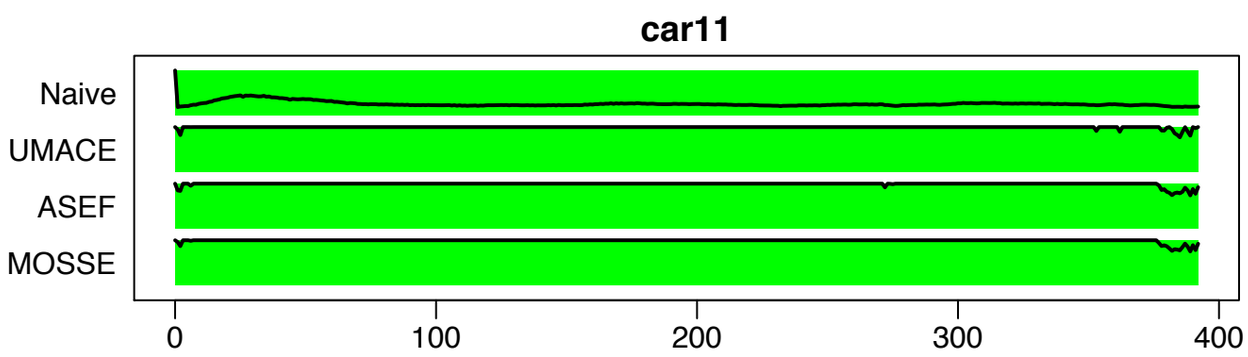
Tracking Ability

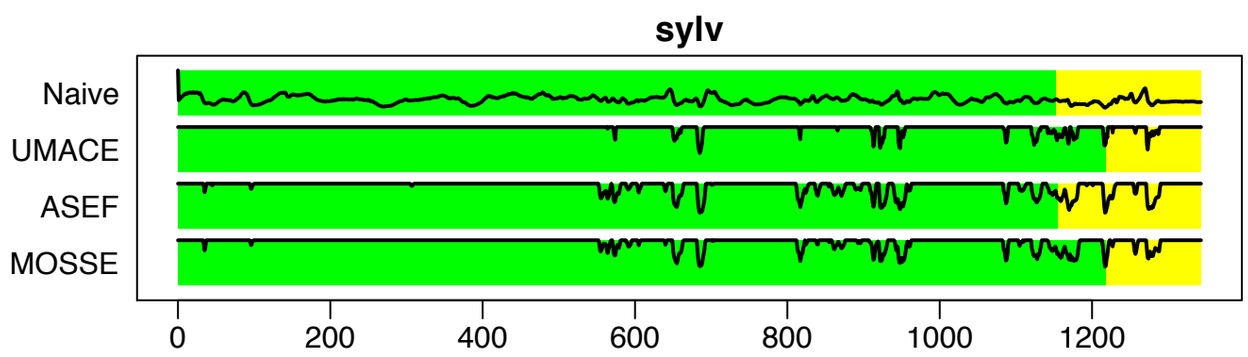
- Green - Good Track
- Yellow - Moderate Drift
- Red - Failed Track

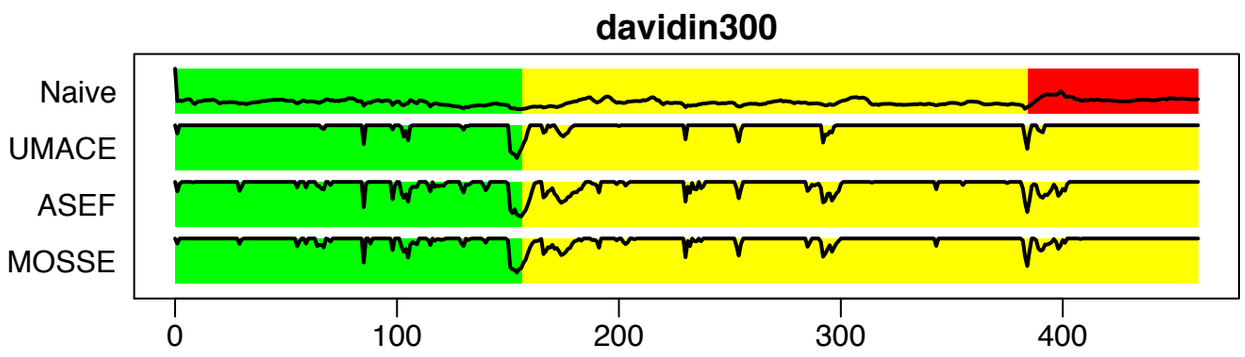


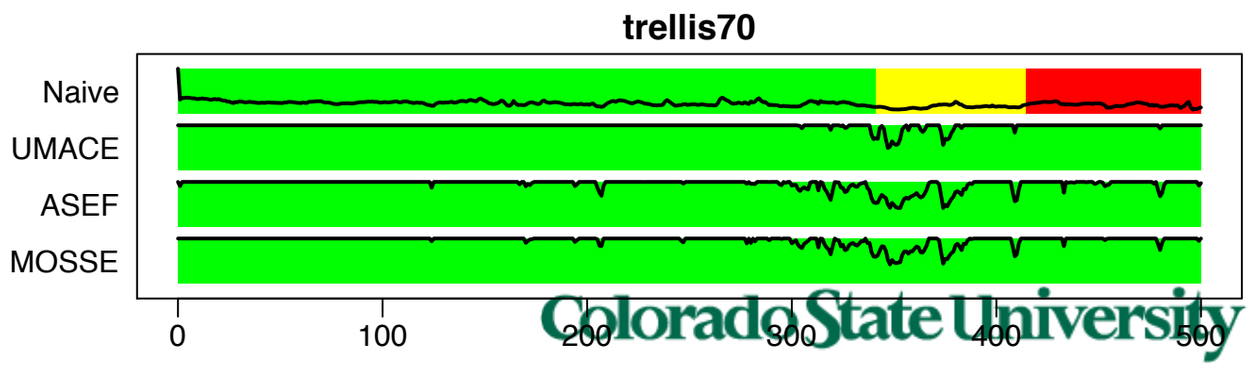




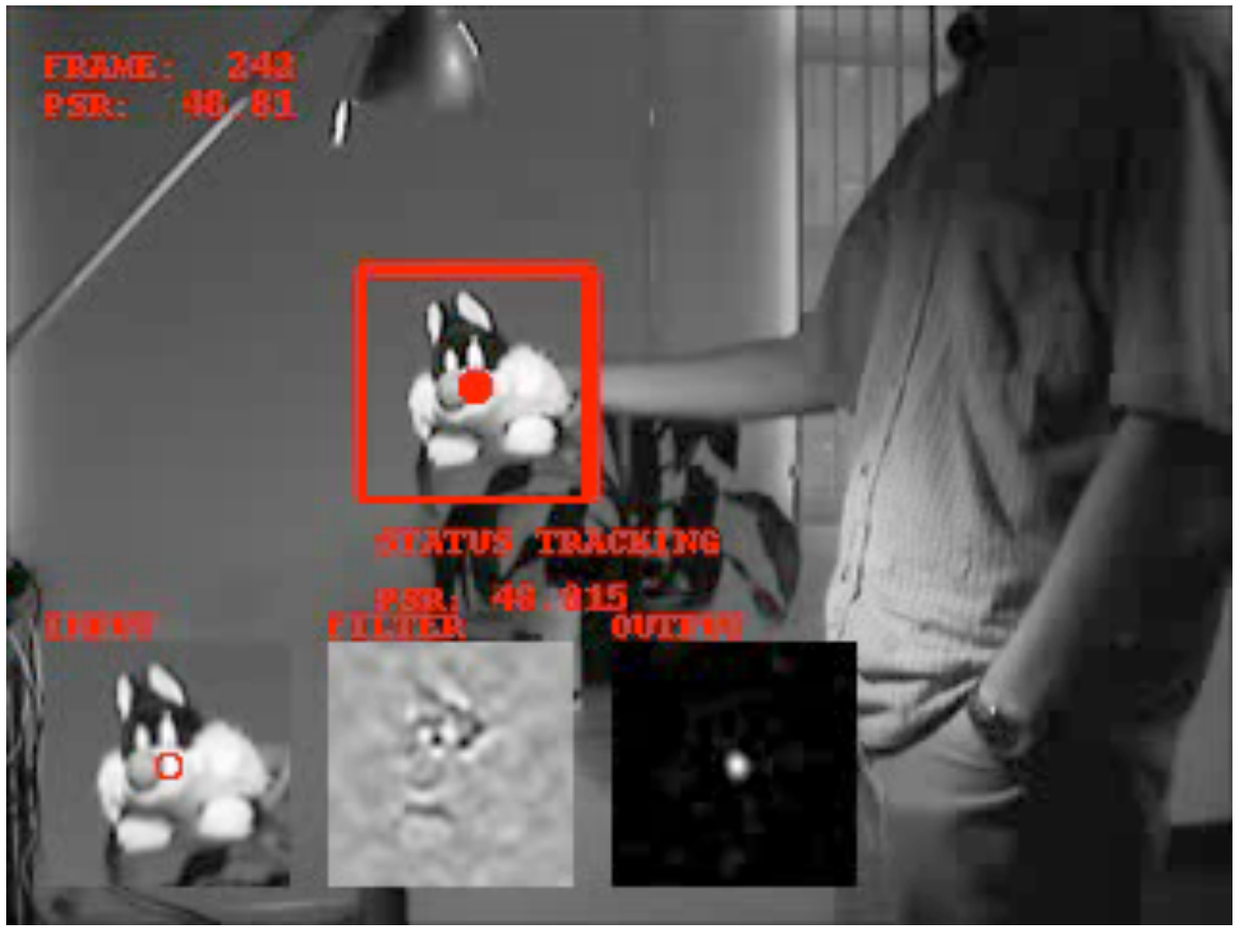






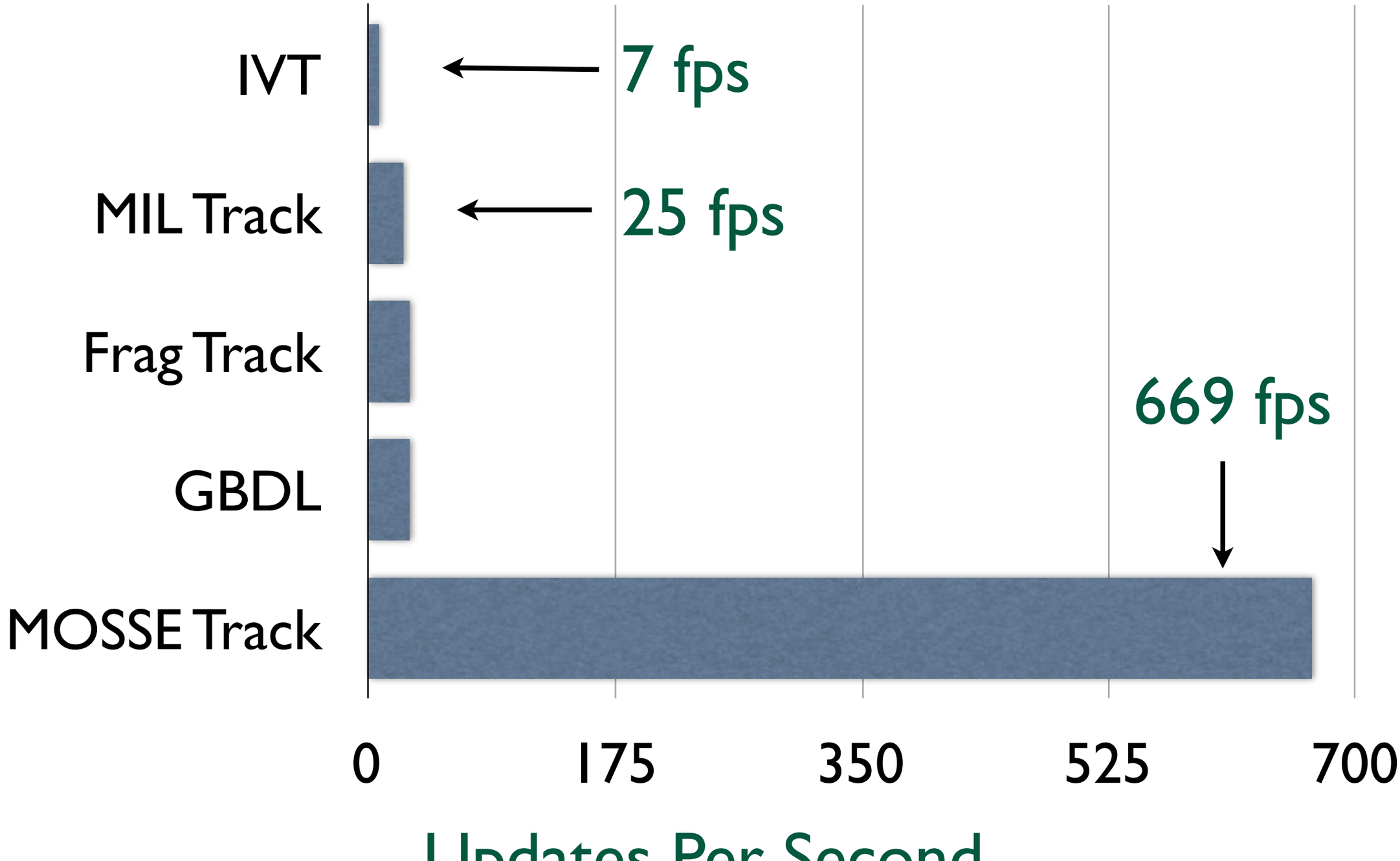


MOSSE vs. IVT


FRAME: 242
PSR: 46.81
STATUS TRACKING
PSR: 46.815
INPUT
FILTER
OUTPUT


243

Tracking Speed



Conclusions

- ASEF filters are easily trained for detection tasks.
- The concept is simple, map the training input to desired output.
- Better background suppression, stronger peaks.
- The recall and precision scores are better
- Much faster than the alternatives.

Tips for better tracking

- Only Convolve with a small portion of the input image.

  Focus on the Target. Boost Speed. Eliminate False Positives.

- Recenter Pixel Values: Zero Mean/One Standard Deviation.

  Average output of Zero. Reduces edge effects.

- Windowing: Cosine Window/Hamming Window

  Focus on the center of the image. Eliminate Edge Effect.

- Running Average: $\bar{H}_n = \lambda H_n + (1 - \lambda)\bar{H}_{n-1} \qquad \lambda = 0.05$

  Improves stability. Less susceptible to noise or occlusion.

- Use a technique such as MOSSE.