Cell Detection in Microfluidic Channels

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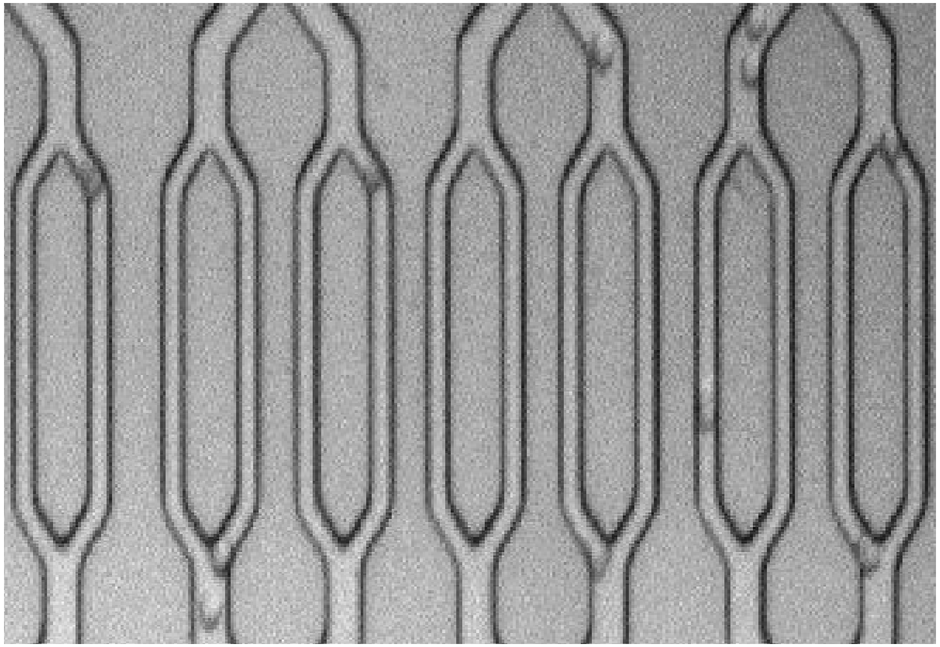
Motivation

People in the microfluidics community are interested the behaviors of cells inside microchannels: cell position across time

Typical cell detection technique relies on the background subtraction and intensity thresholding.

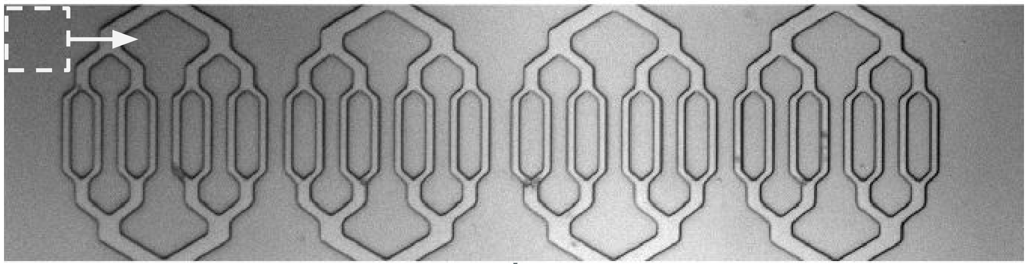
Challenges:

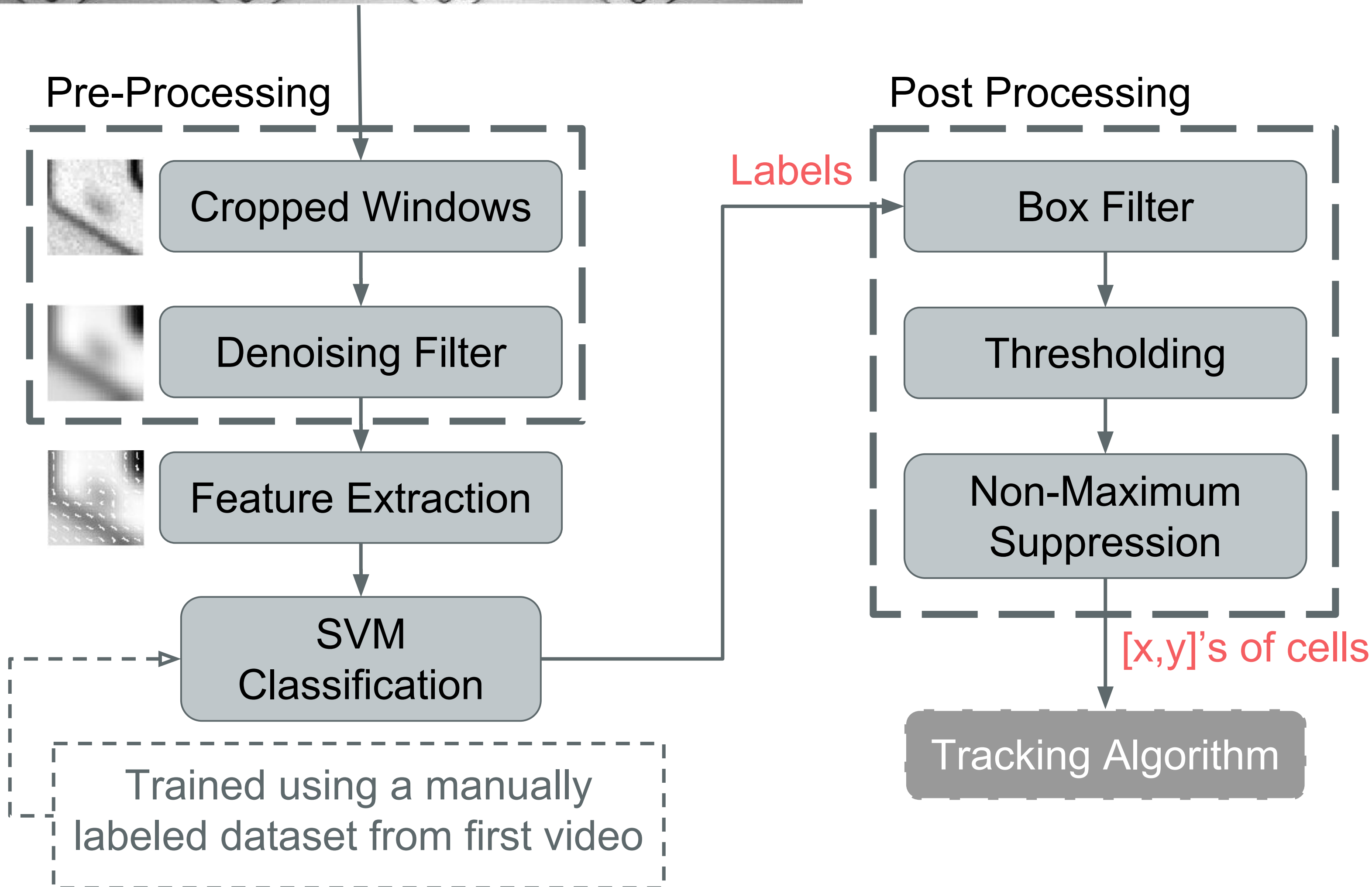
- Cells vary in size and shape
- Cells can deform
- Experimental limitations (e.g. thermal noise in video recording, change of illumination intensity over time)



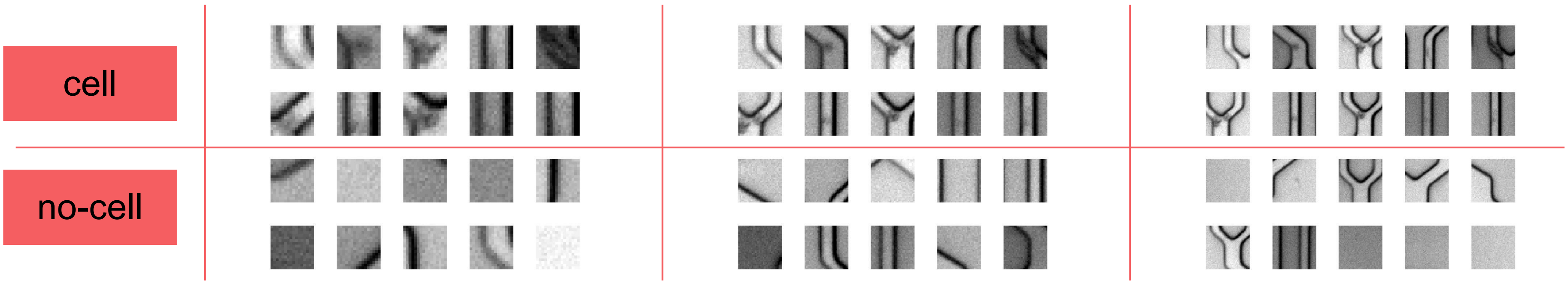
Can we apply machine learning to improve cell detection and tracking?

Machine-Learning Approach

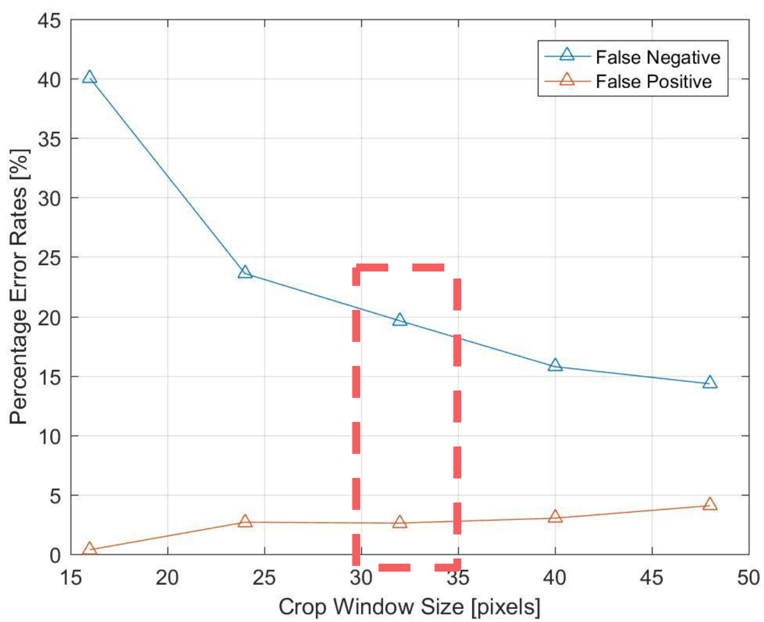




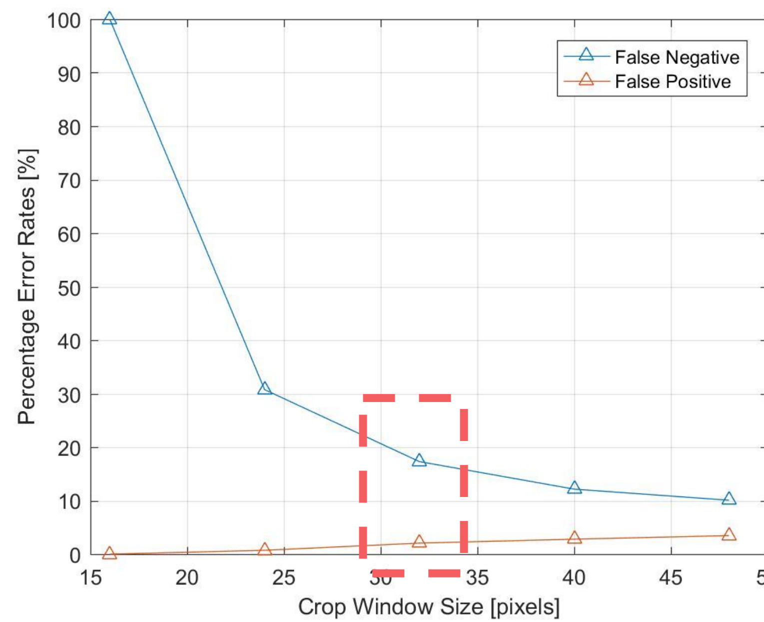
Cropping Window Size



Window size = 16x16 | Window size = 32x32 | Window size = 48x48

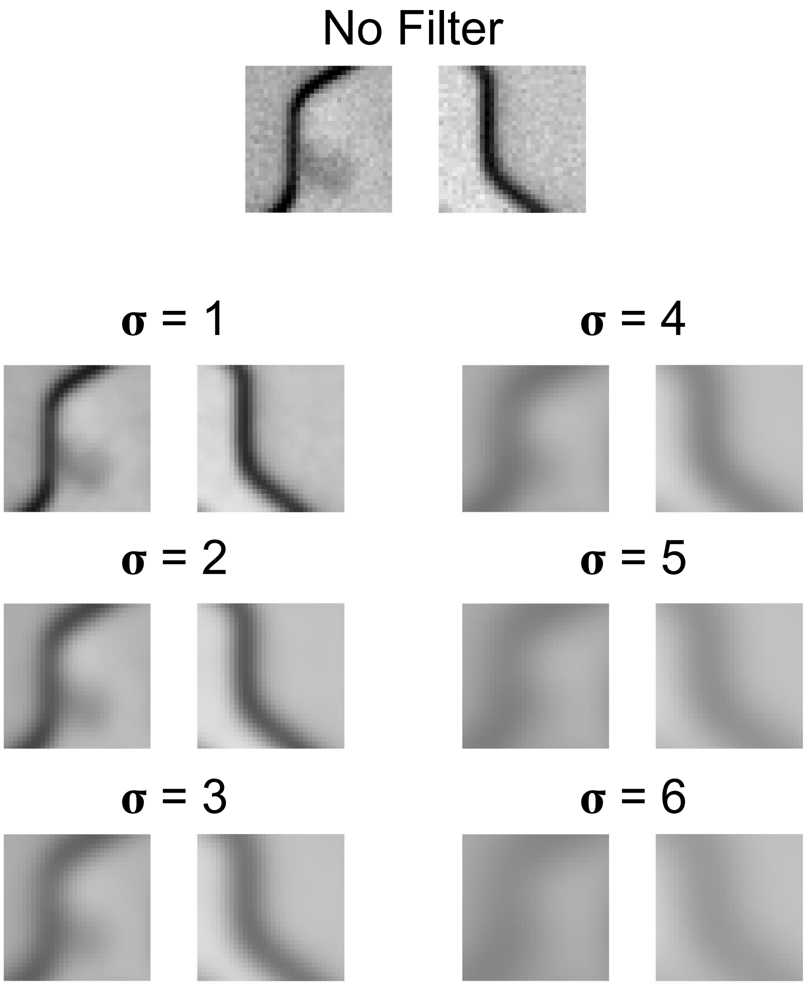


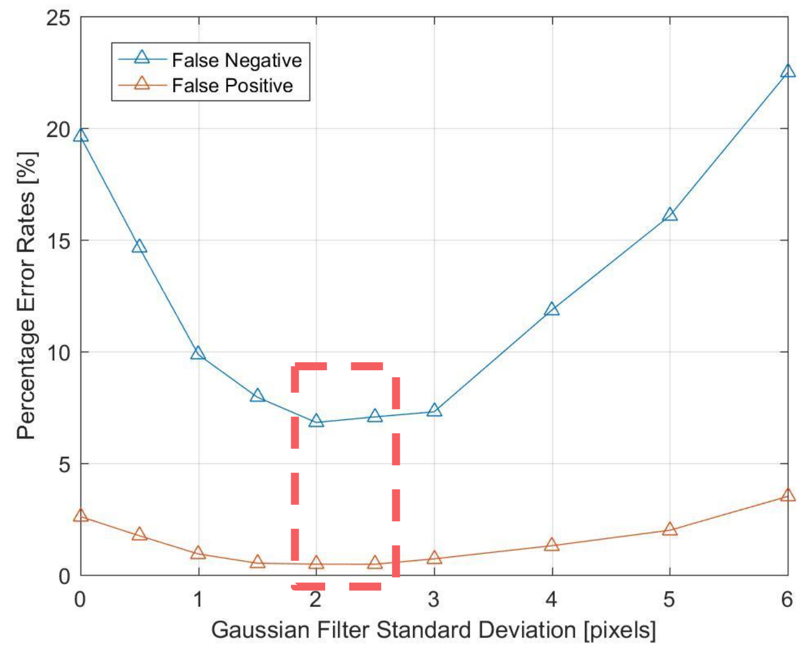
HOG window = 4x4



HOG window = 8x8

Denoising Filter (Gaussian Filter)





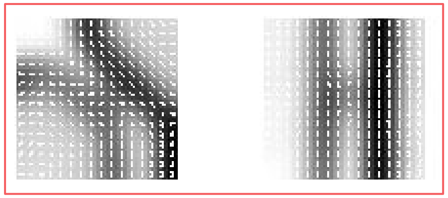
The error rates are lowest around **σ** = 2-2.5.

Feature Extraction Methods

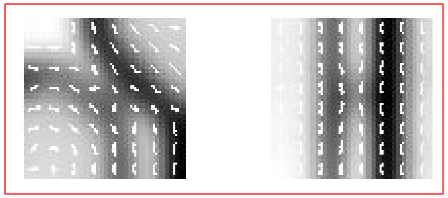
- HOG
- Dense-SIFT
- Gabor Filter
- Pre-trained CNNs
  - AlexNet
  - VGG

HOG

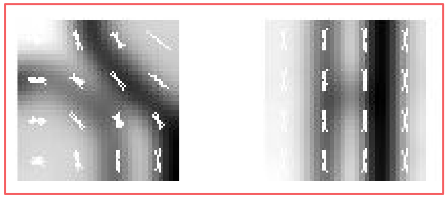
- Cell sizes



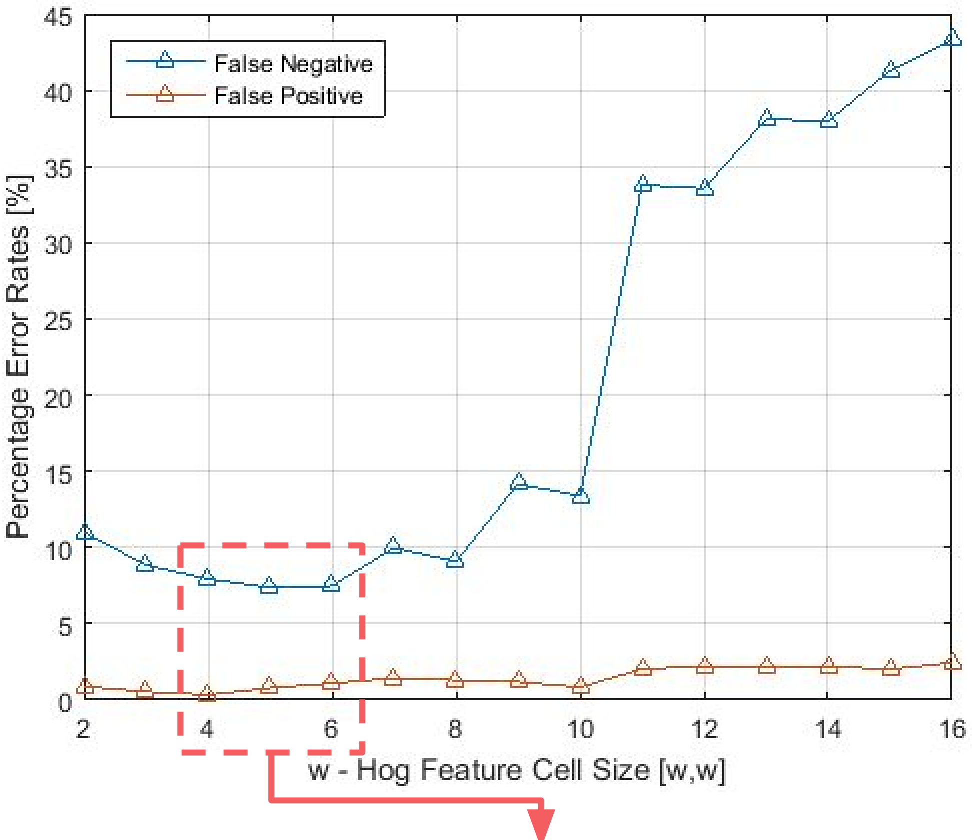
[2,2]



[4,4]



[8,8]

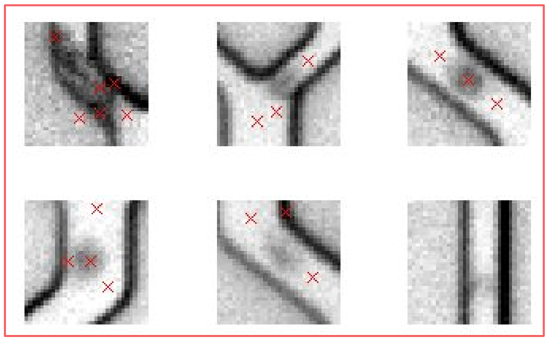


False positive vs. false negative trade-off

- **Expected total # of cell vs non-cell windows**
- **Post-processing & tracking**

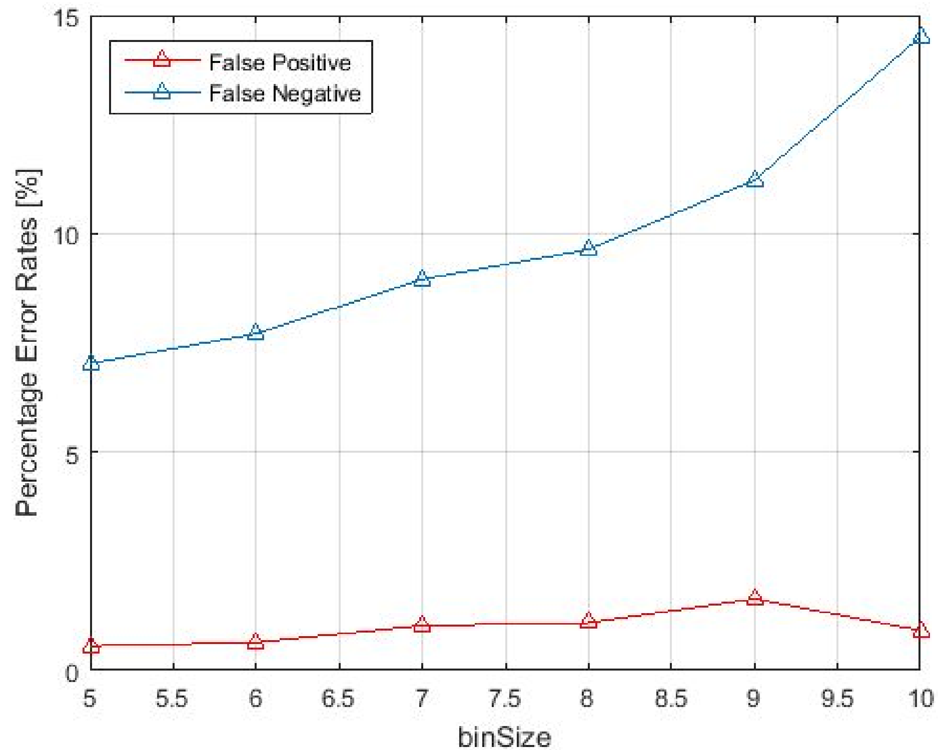
Dense-SIFT

- SIFT is too sparse for this application



- Dense-SIFT
  - No automatic smoothing - need to use our own filter
  - No keypoint selection - dense output
  - Uniform bin sizes - not related to keypoint scale

Parameter: binSize
the size of a SIFT spatial bin in pixels

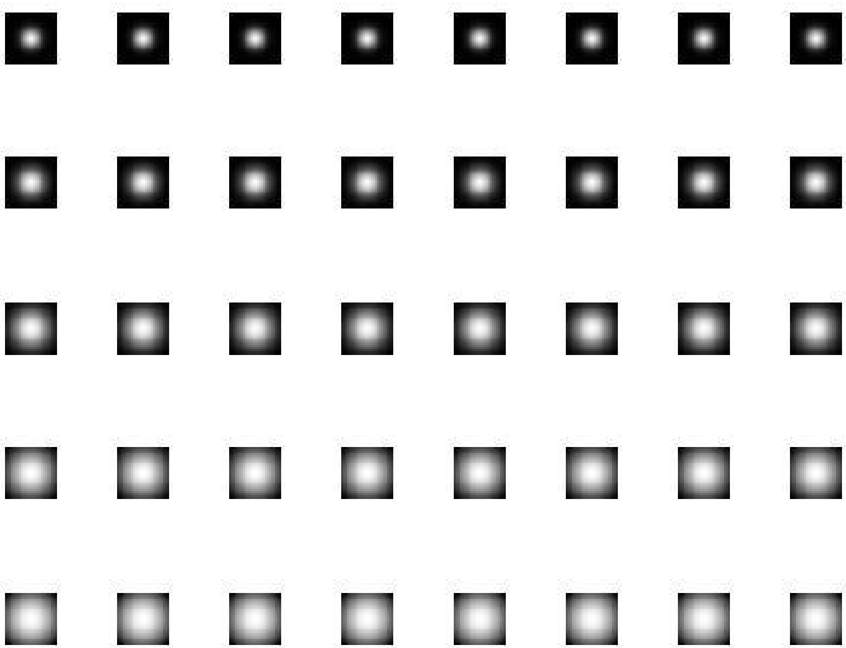


http://www.vlfeat.org/overview/dsift.html

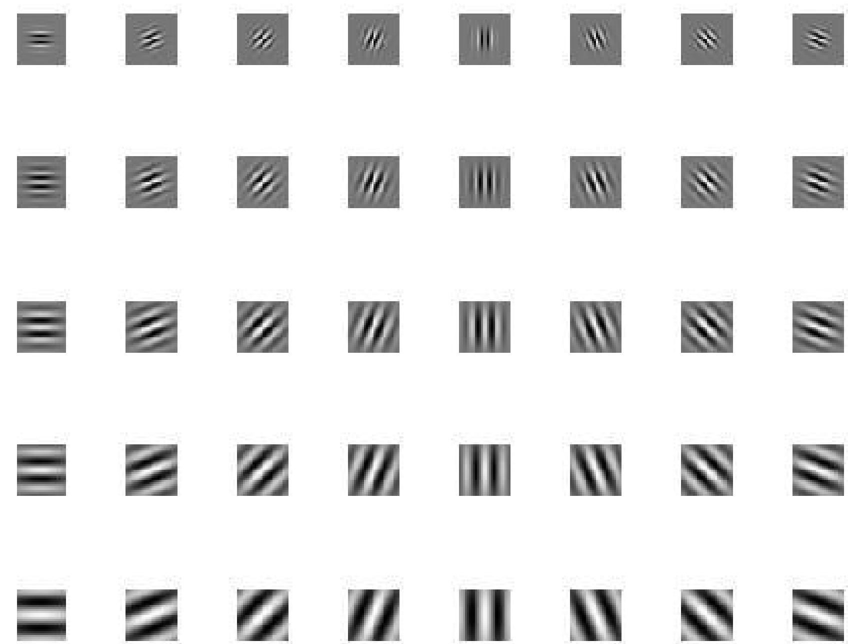
Gabor filter (1)

- 5 scale, 8 orientations of gabor filters
- Filter size was optimized among (3x3), …, (31,31)

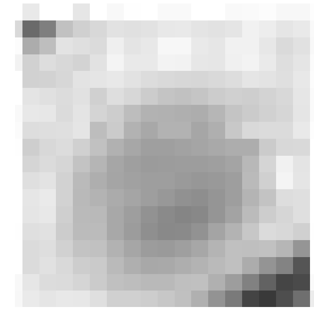
- magnitudes

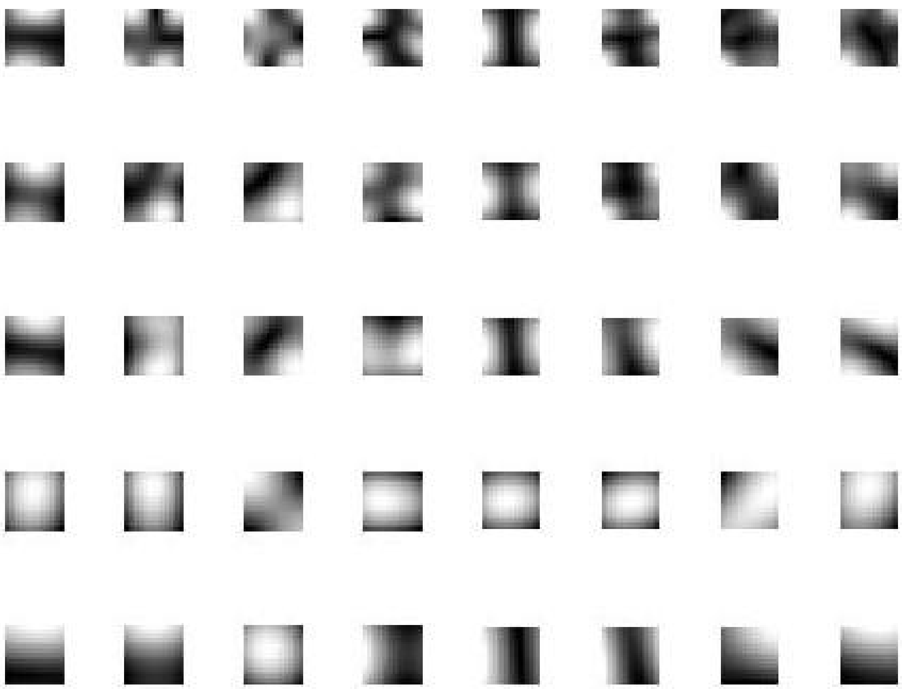


- real parts

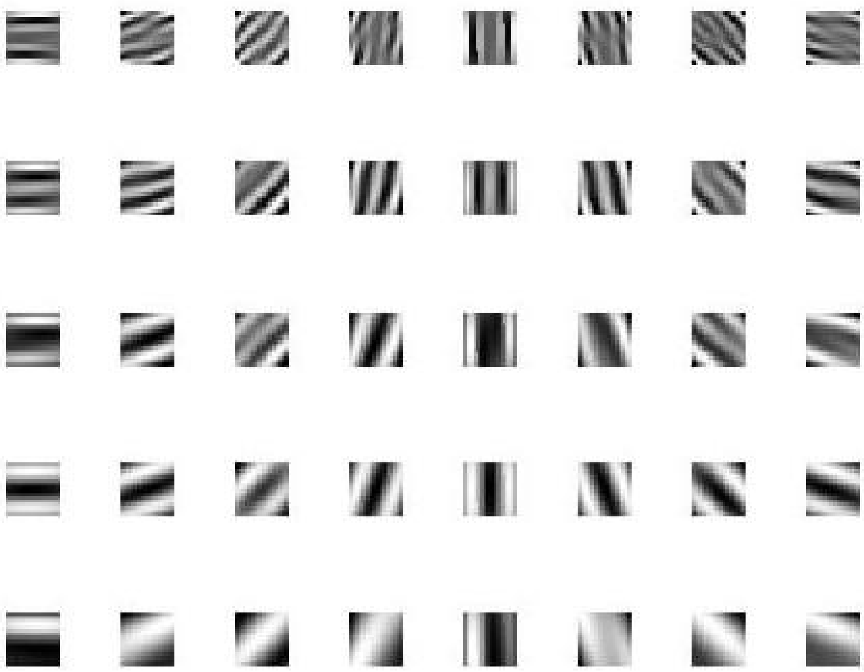


Gabor (2): positive feature



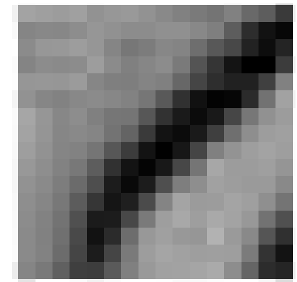


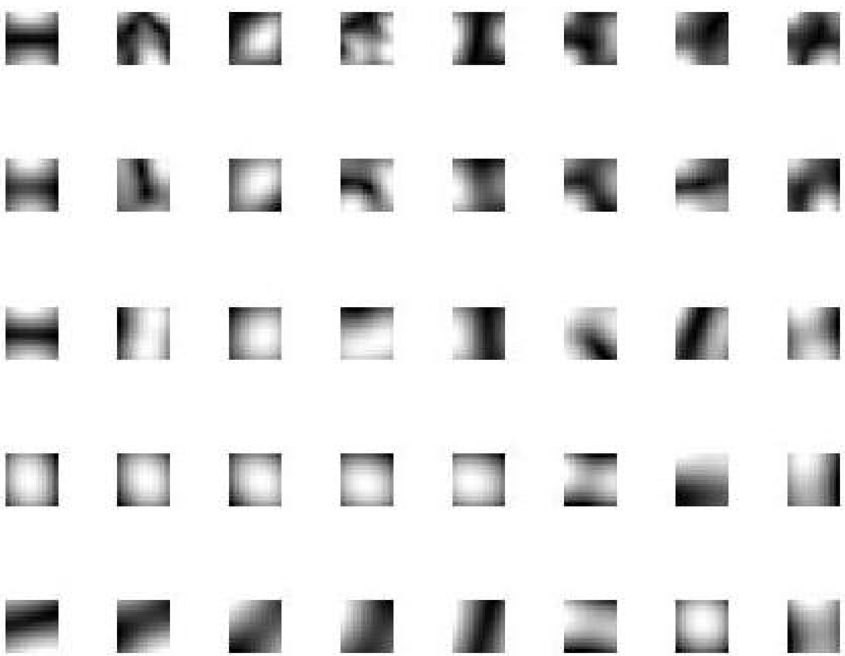
<magnitude of responses>



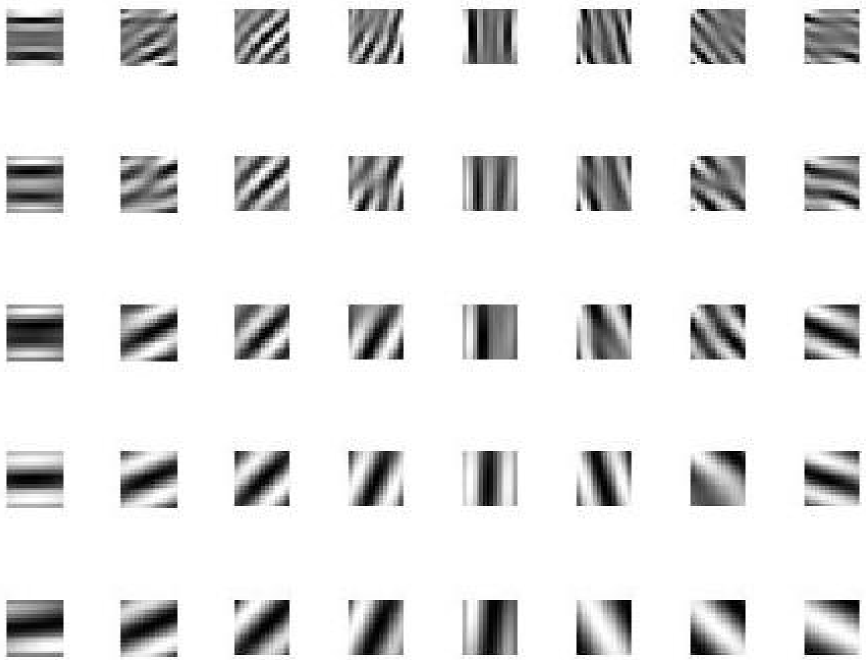
<real part of responses>

Gabor (3) : negative feature



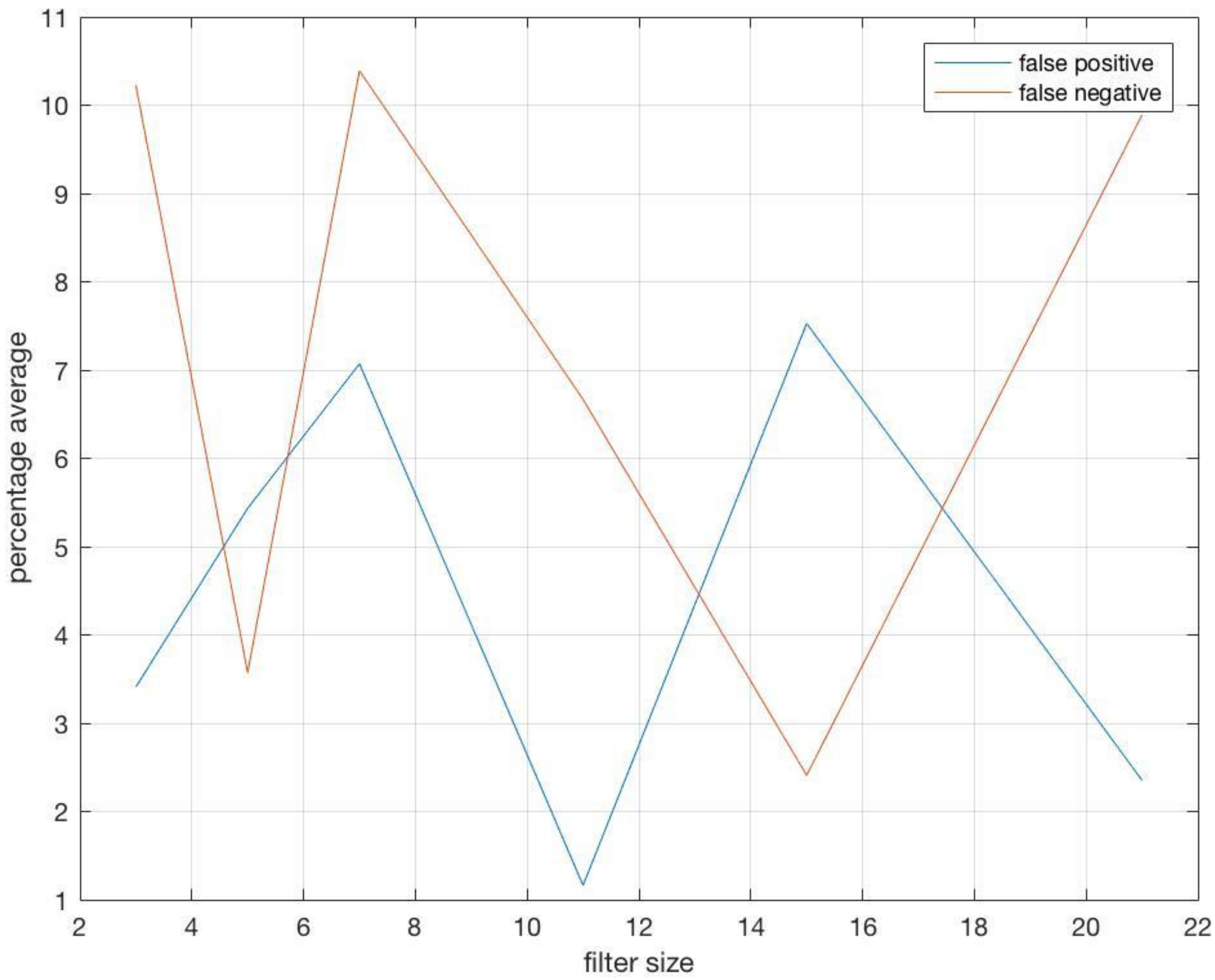


<Magnitude of responses>

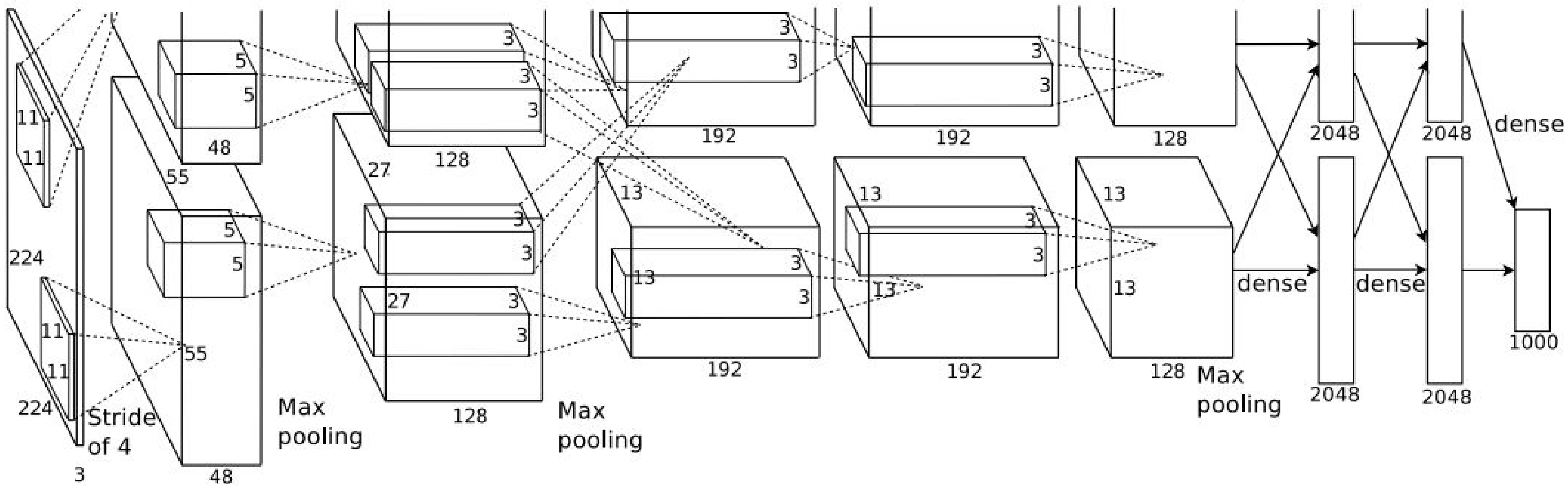


<Real parts of responses>

Gabor Filter

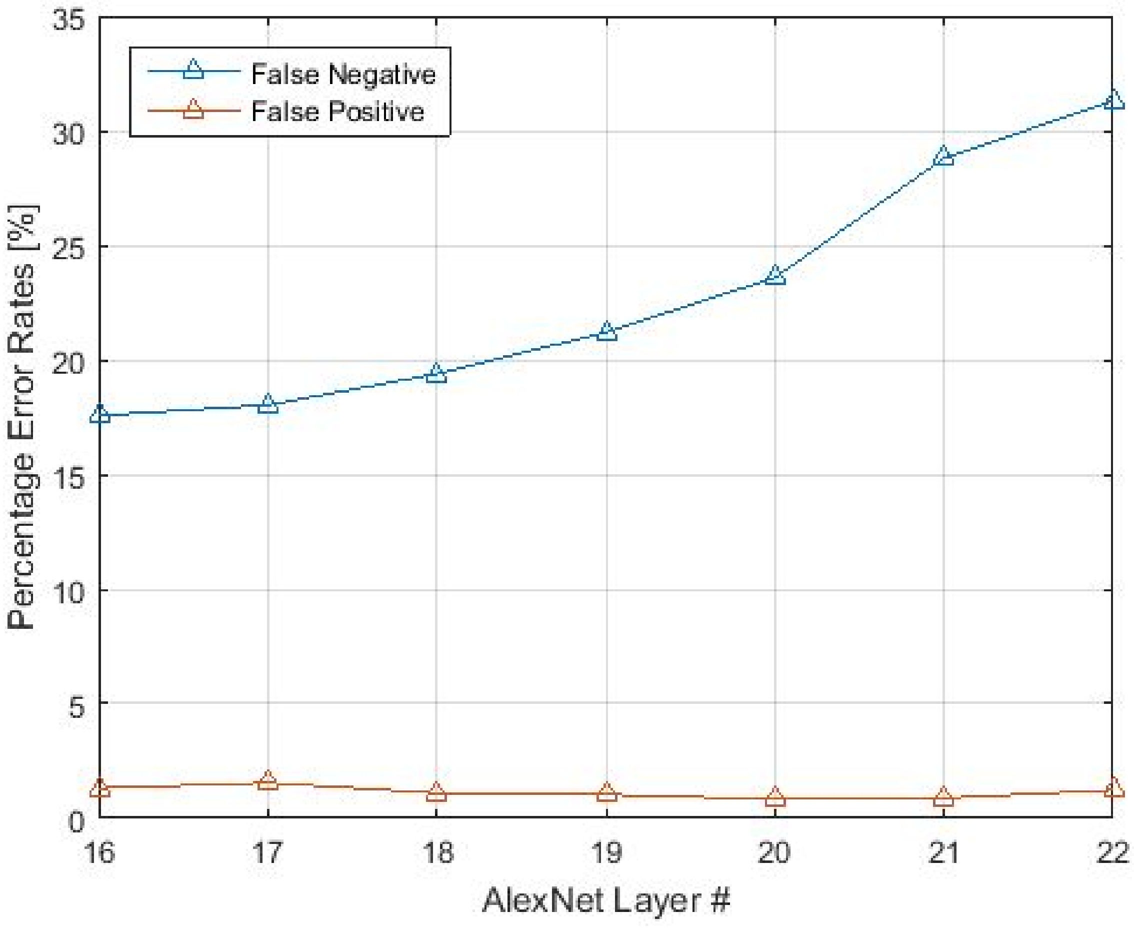


Pre-Trained CNN - AlexNet

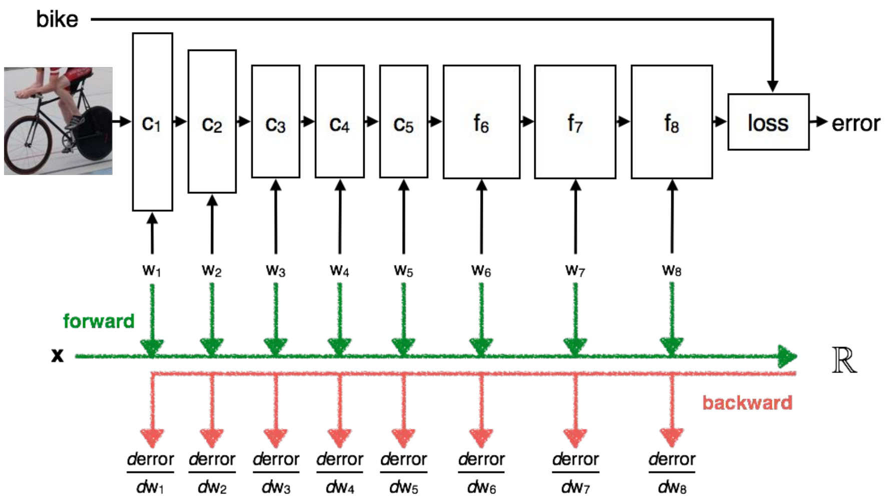


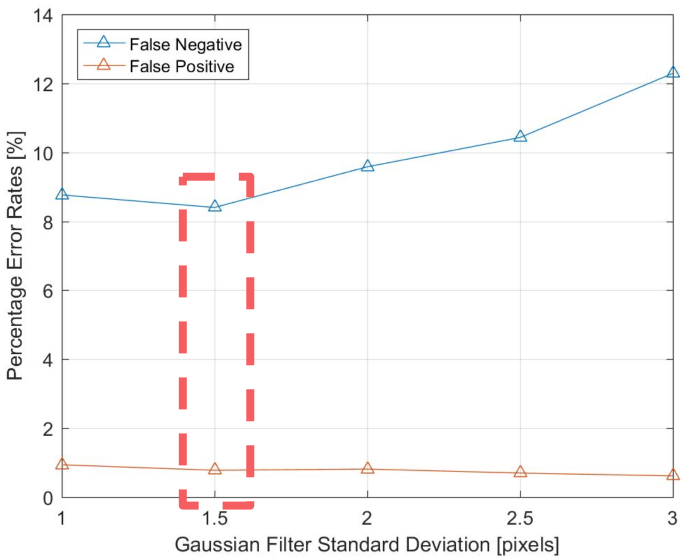
ImageNet classification with deep convolutional neural networks', *A. Krizhevsky and I. Sutskever and G. E. Hinton,*NIPS 2012 (BibTex and paper) Code from: http://www.vlfeat.org/matconvnet/pretrained/

Pre-Trained CNN - AlexNet



Pre-Trained CNN - VGG





- Images are resized before inputting in VGG
- 1000 features per image

Without tuning the parameters:

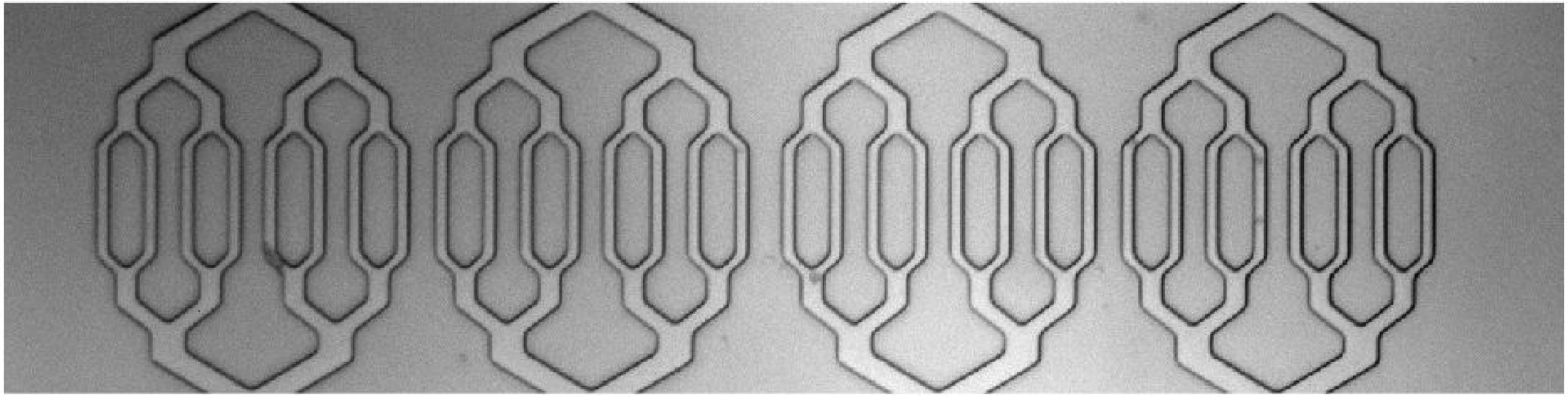
at σ = 1.5
False negative rate = 8.4%
False positive rate = 0.78%

From an Oxford Visual Geometry Group computer vision practical, authored by Andrea Vedaldi and Andrew Zisserman (Release 2016a)
These models are trained from 1.2M images in the ImageNet datasets to discriminate 1,000 different object categories.

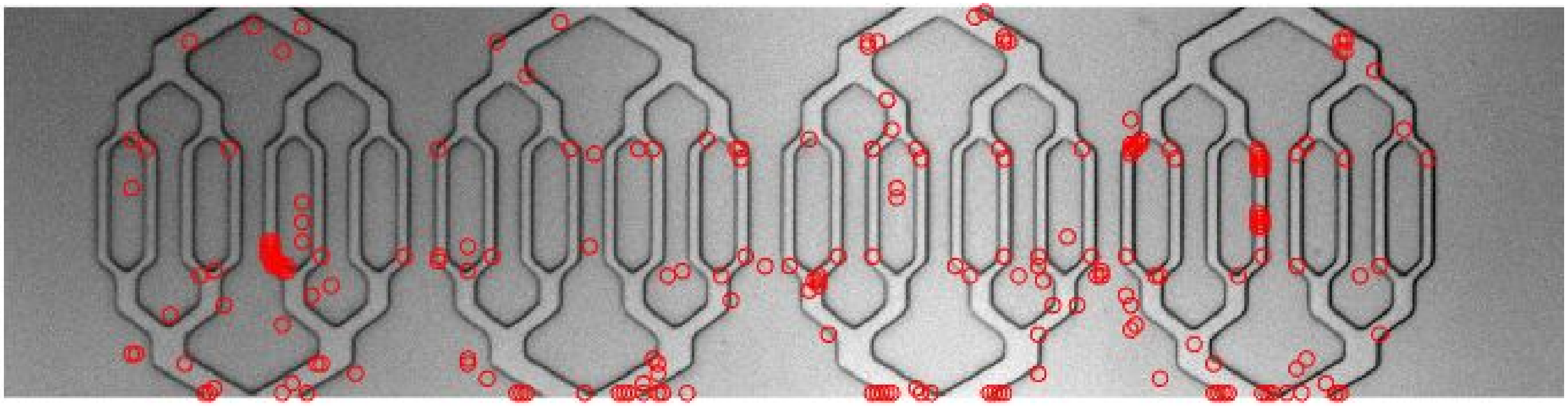
Summary of Results

Feature Extraction	False Positive	False Negative	Comments
HOG	0.68%	6.35%	Window size [32,32] Gaussian [15,15], σ=2.5 HOG window [5,5]; 100-fold
Dense-SIFT	0.56%	7.03%	Window size [32,32] Gaussian [9,9], σ=1.5; binSize = 5; 100-fold
AlexNet	1.31%	17.57%	Window size [32,32] Layer 16: 'pool5'; 10-fold
VGG	0.78%	8.40%	Window size [32,32] Gaussian [15,15], σ=1.5; averaged 10-fold validations
Gabor Filter	1.16%	6.67%	Subset of no cell training set Window size [16,16] 5 scales, 8 orientations, filter size 16; 10-fold

SVM Classification Result (HOG)

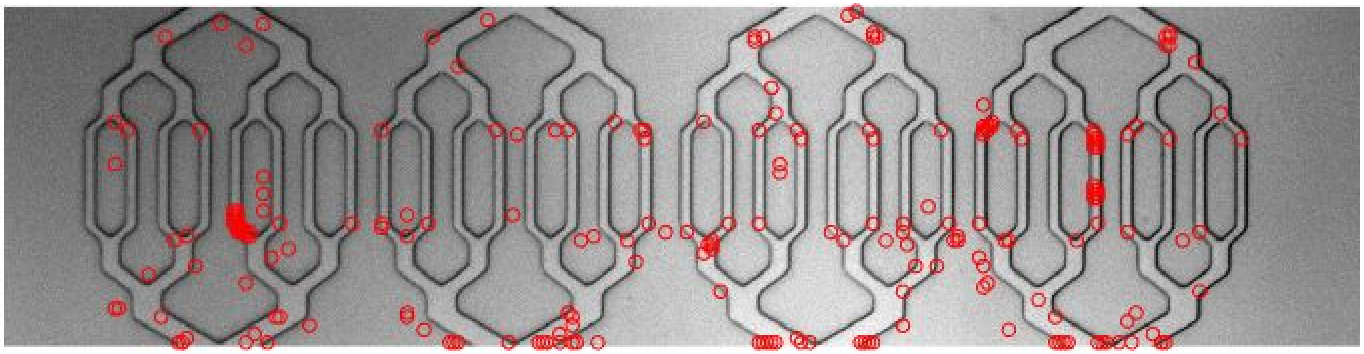


Input image

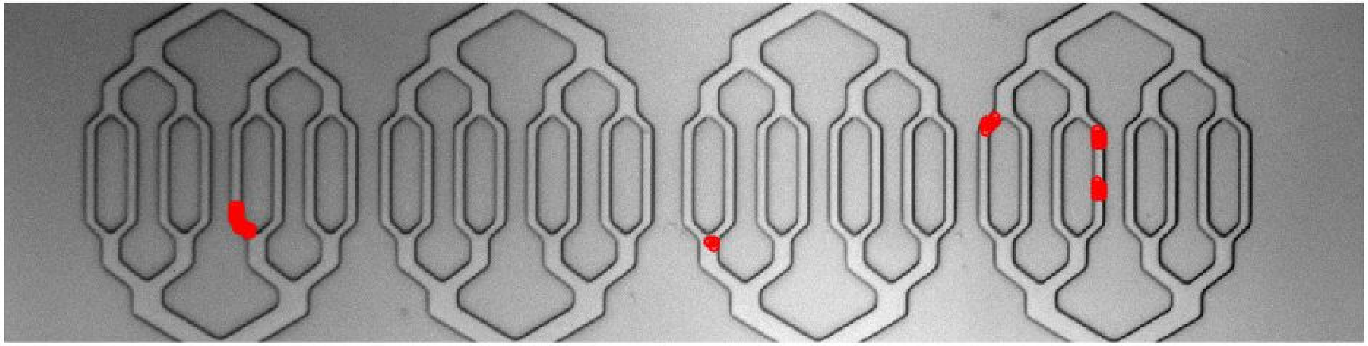


SVM classification result: each red circle marks an output label of “1” (=window containing a cell) at the center of the window

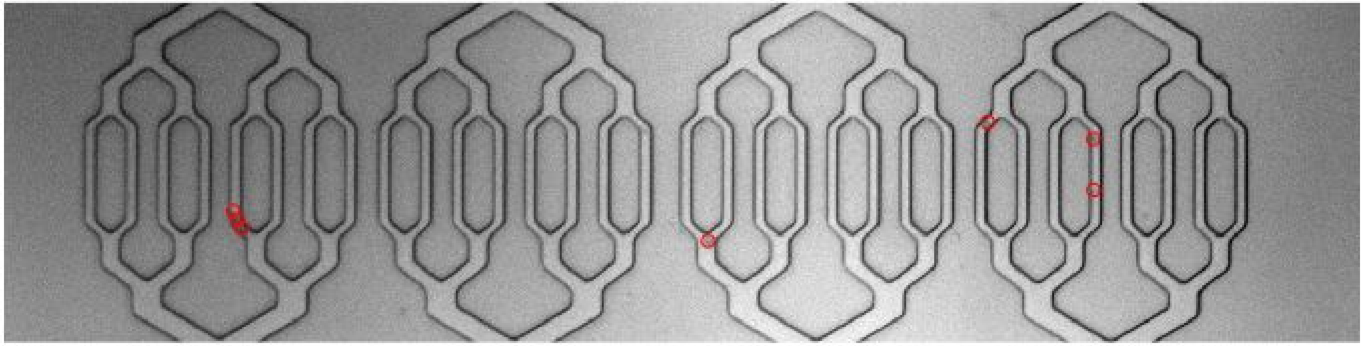
Post-Processing



SVM Result



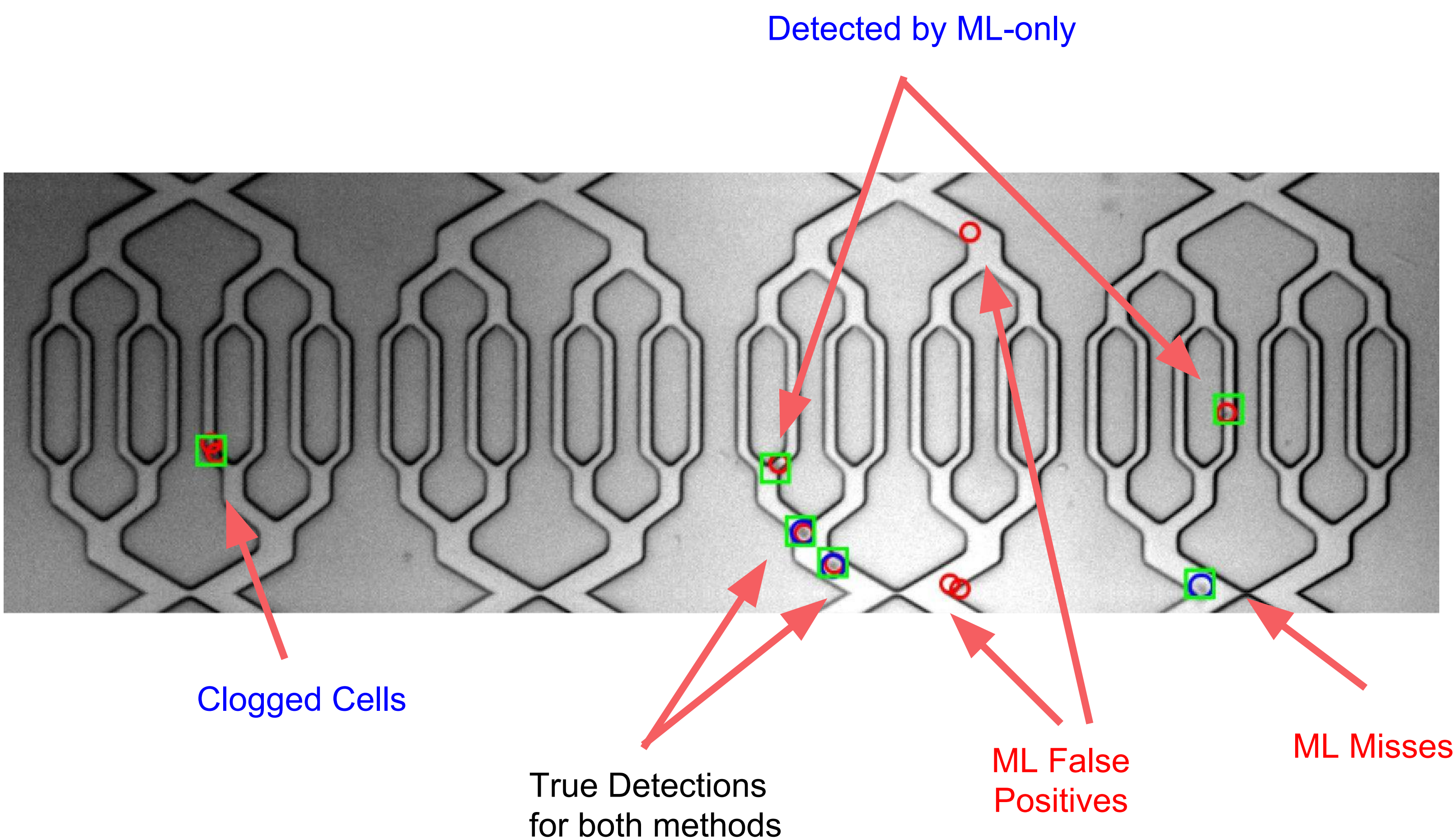
Remove any point that is by itself or only with one other point next to it



Keep only one point in each cluster that has the maximum number of closeby points

Comparison of Cell Detection Techniques

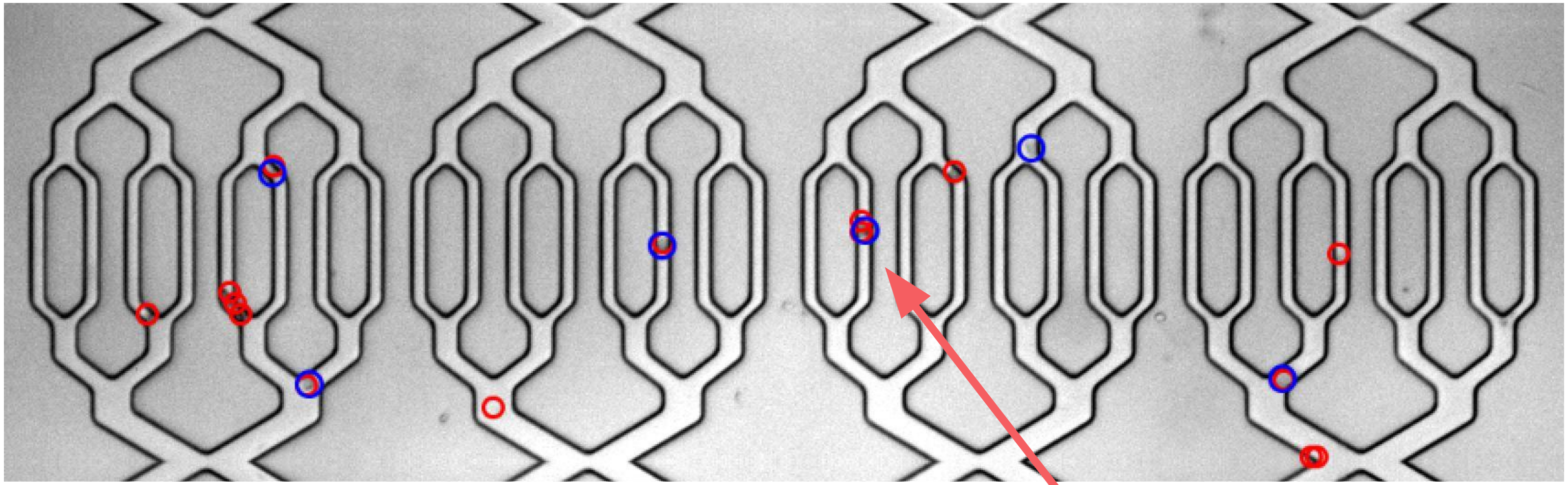
Video 0001 snapshot
- Manual inputs
- Non-machine-learning (non-ML) method
- Our machine-learning (ML) method



Comparison of Cell Detection Techniques

Video 0011 snapshot

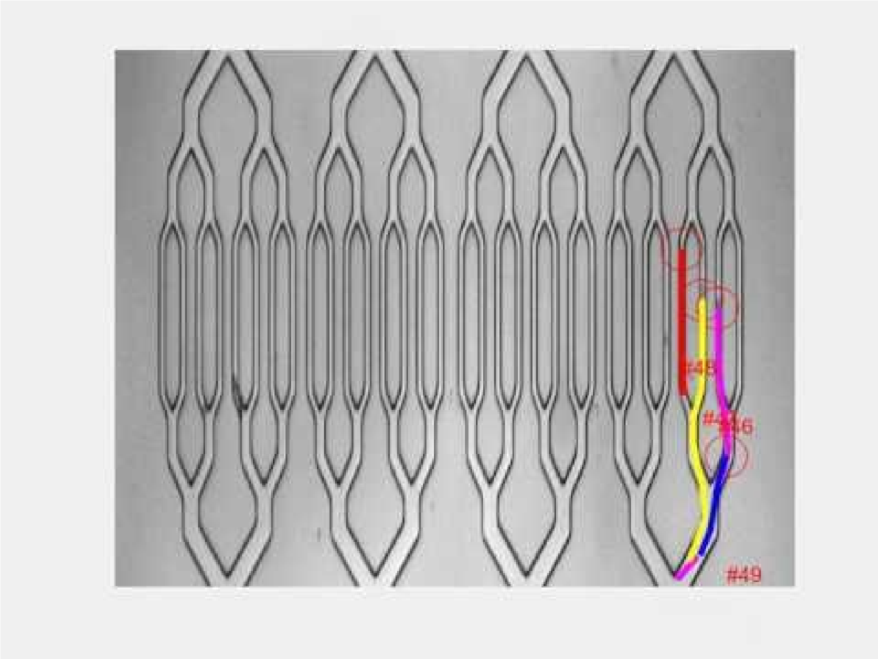
- Non-machine-learning (non-ML) method
- Our machine-learning (ML) method



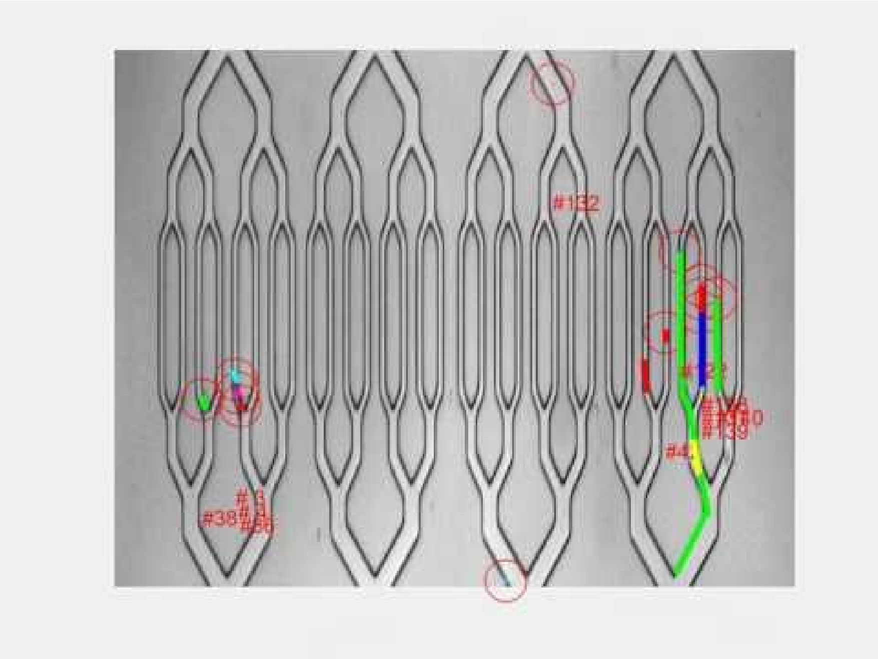
One cell is detected as two by ML

Tracking (Results from Video 0011)

Non-ML



HOG + SVM (Our Method)



Note that

- The tracking algorithm relies on the minimal distance cost.
- The tracking algorithm has been fine-tuned for non-machine learning method.
- Some issues can arise when there are missed detections and false positives.

Conclusions & Future Work

1. HOG + SVM -> Detects 89.8% of the cells correctly in 150 frames of test video
2. Most of the feature extraction methods achieve similar performances
3. Tracking part needs to be improved

Future work

1. Larger dataset to improve generalization
2. Try other blob extraction technique e.g. surf
3. Improved post processing to reduce FN rate