Object Detection/Tracking as a “Black Box”

Instructor - Simon Lucey

16-423 - Designing Computer Vision Apps

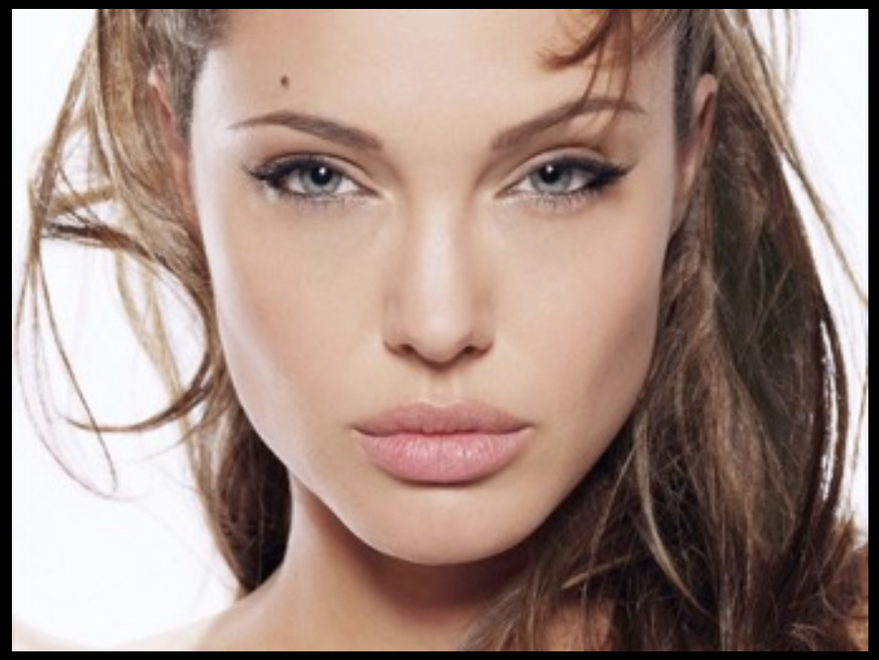
"The Virtually Impossible"

Today

- Motivation - Object Detection/Tracking
- Computer Vision as a “Black Box” - Considerations
- Detection
  - Computer Vision as a Service (VMX, Project Oxford, Clarifai).
  - OpenCV 3.0 (face and pedestrian detectors, what’s new?)
  - DLib C++ (create your own detector!!!)
  - Caffe (Deep Learning)
- Tracking
  - Correlation Filters (fast in tracking in just a few lines of code)
  - Predator (tracking an object efficiently/quickly)

Just a sampling - by no means a complete list!!!

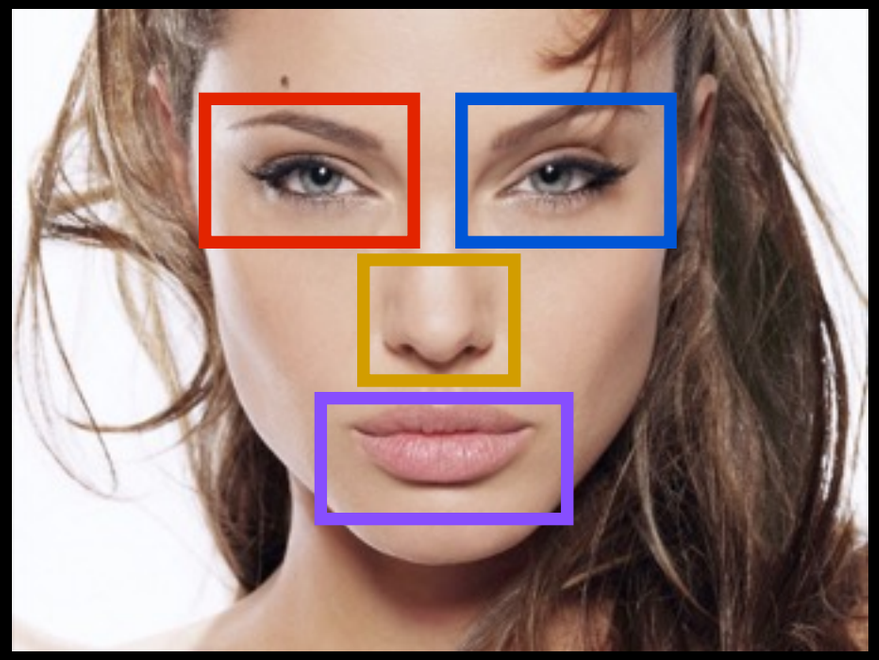
What is an Object?



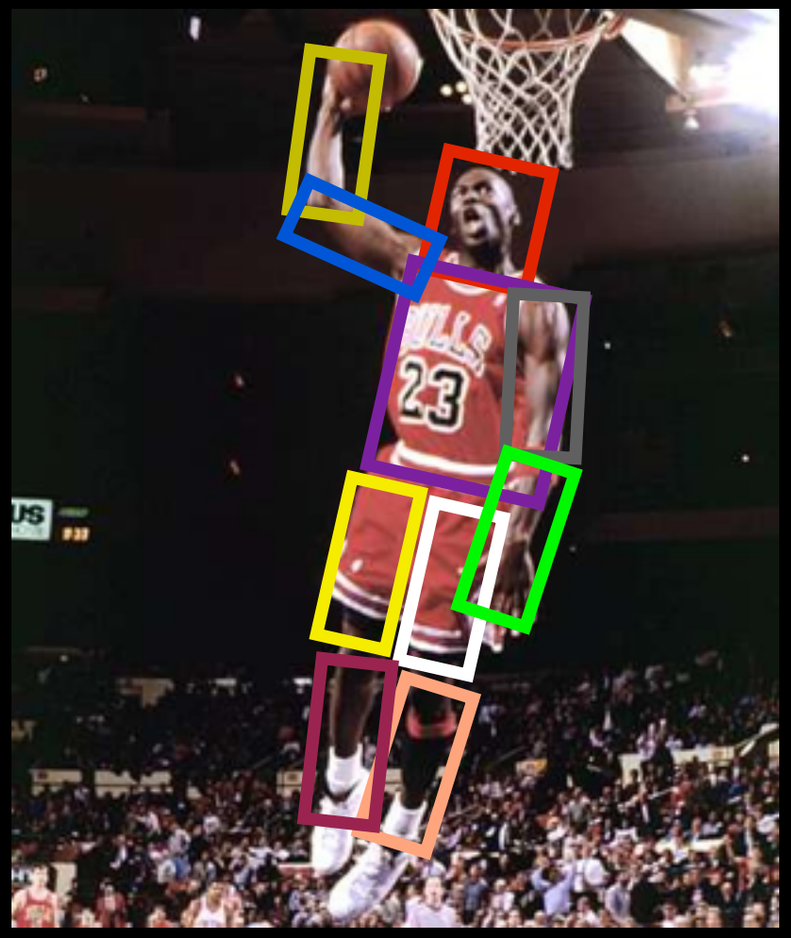
Face

Body

What is an Object?

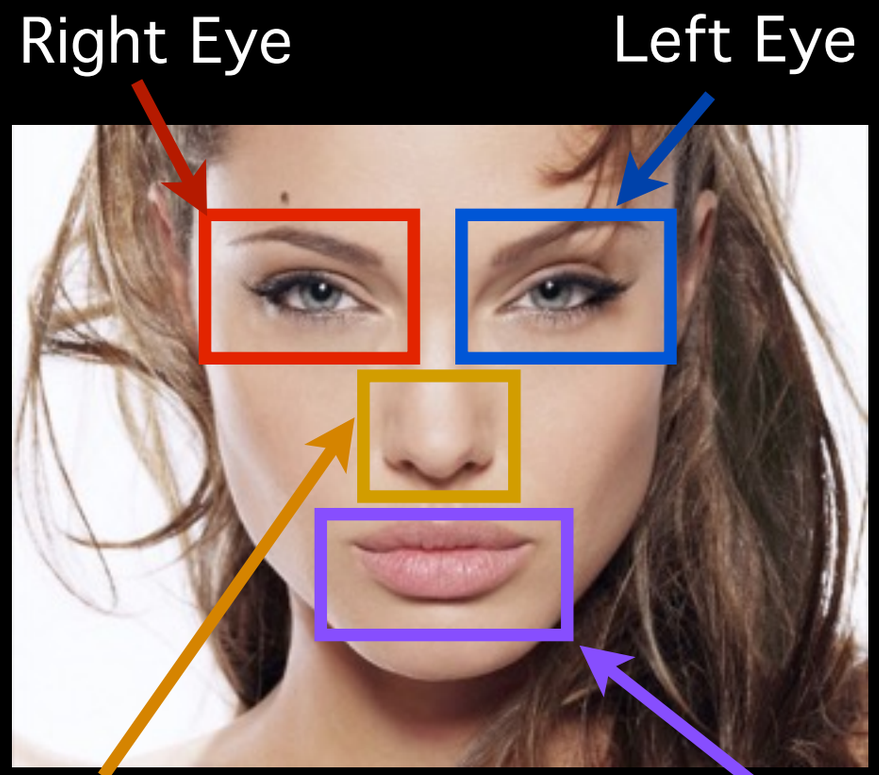


Face

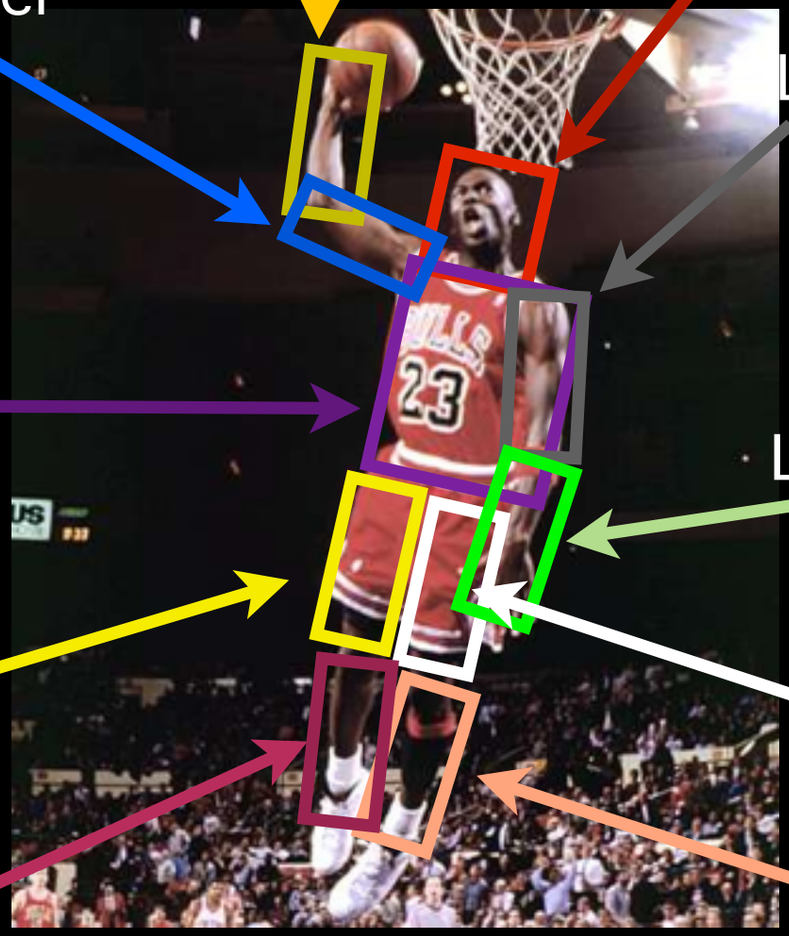


Body

What is an Object?

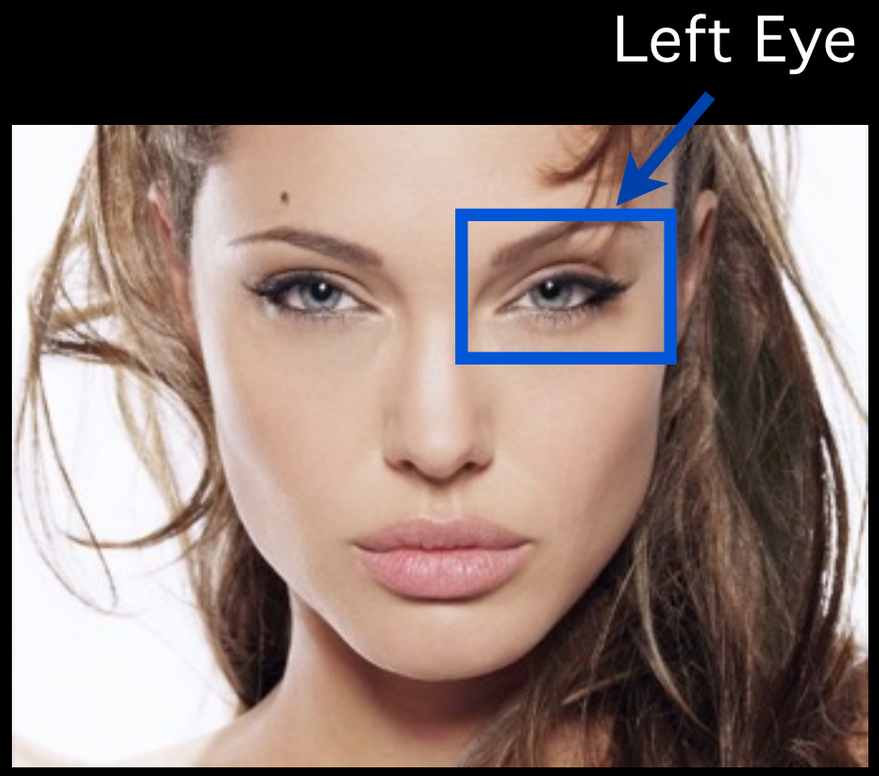


Face



Body

What is a Part?



Face

Not Left Eye

When is a Collection of Parts an Object?

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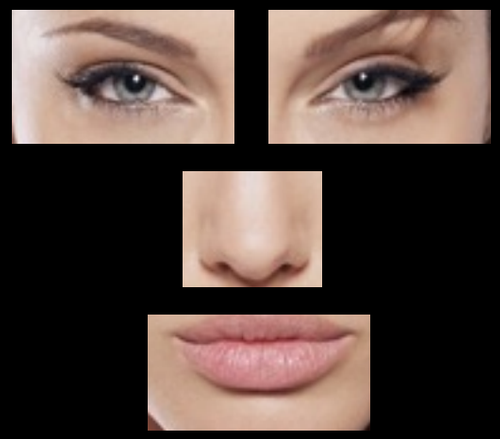
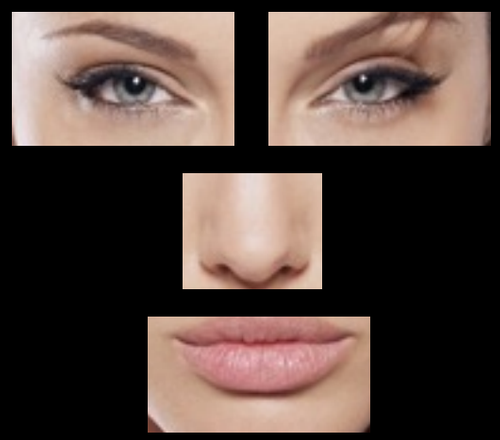
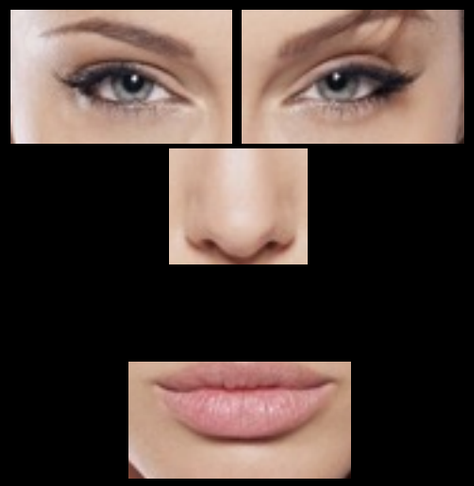


Face

When is a Collection of Parts an Object?

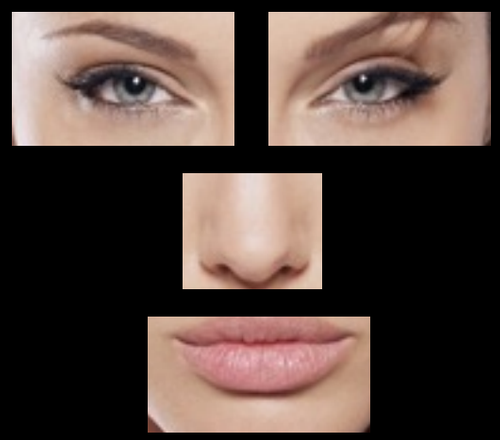


Face

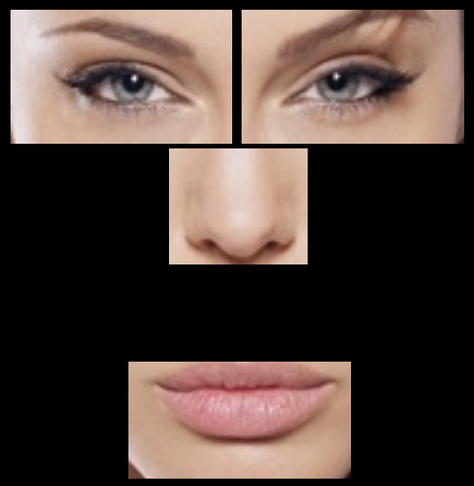


Face

When is a Collection of Parts an Object?



Face



Face

Not a Face

What is an Object?

"A collection of semantically meaningful components with geometrical constraints on their spatial configuration"

Data

Best Method is Domain Specific

No Silver Bullet

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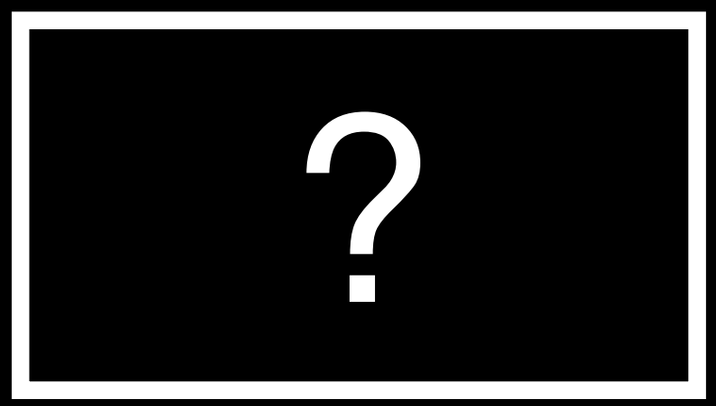
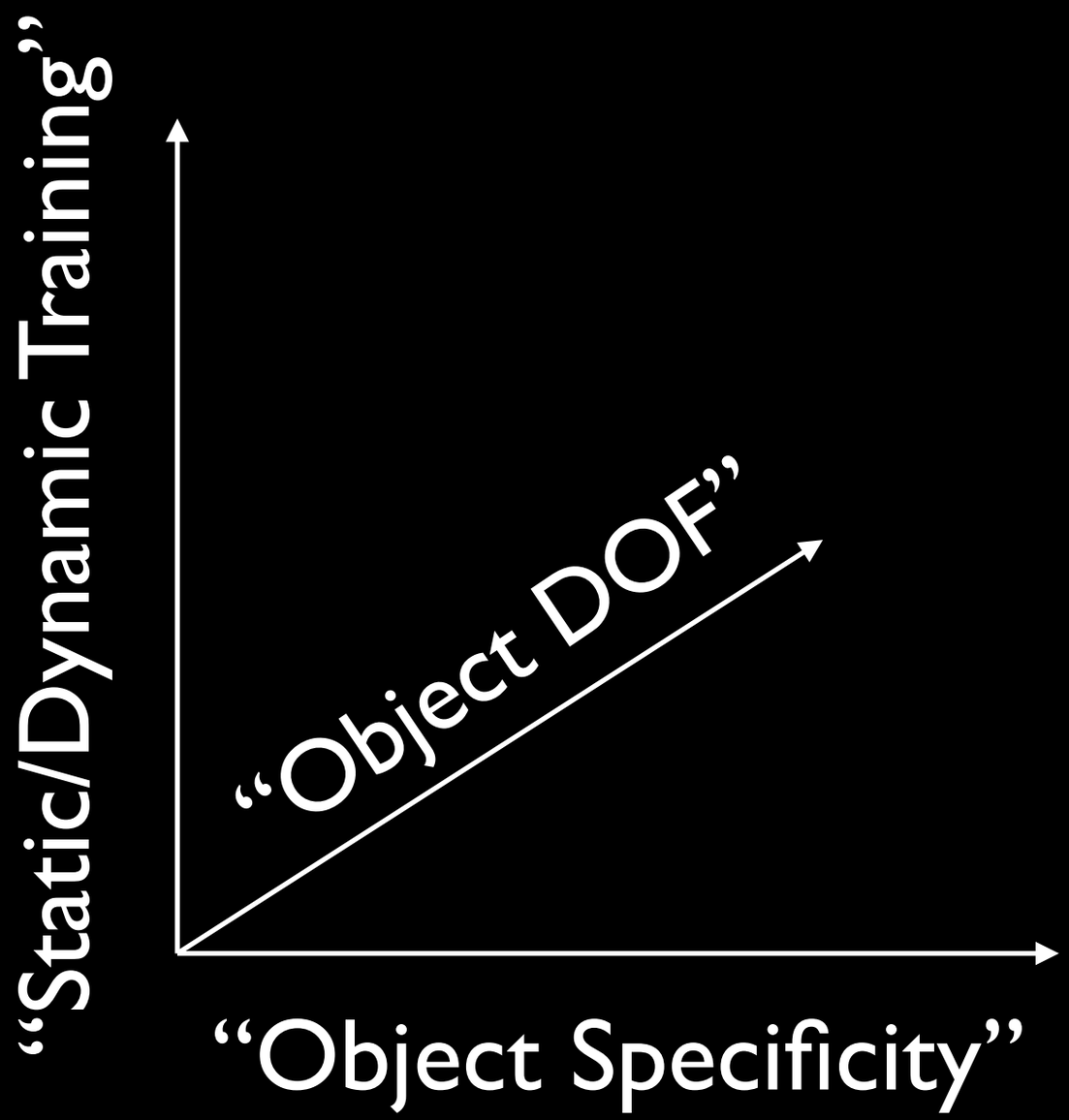
Computer Vision as a “Black Box”

- Increasingly, people want to employ computer vision in a variety of new applications.
- Want to use Computer Vision as a “Black Box” - i.e. do not care about how it works as along as it does what it is supposed to do.
- Your ability to treat computer vision as a “Black Box” is a function of what you want to do.
- In this lecture, we will try and give a brief overview of the this space.



Solutions Exist

- You need to consider where your problem/task lies.



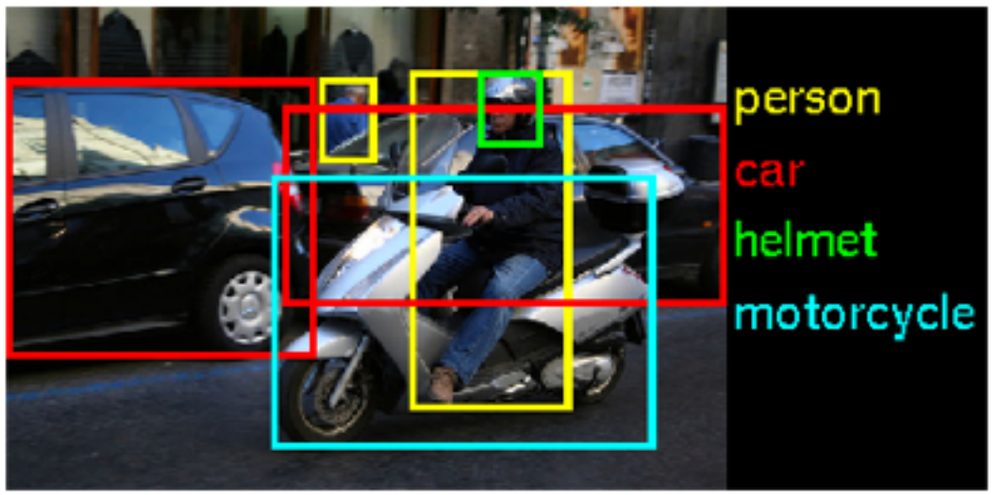
?

Object Specificity

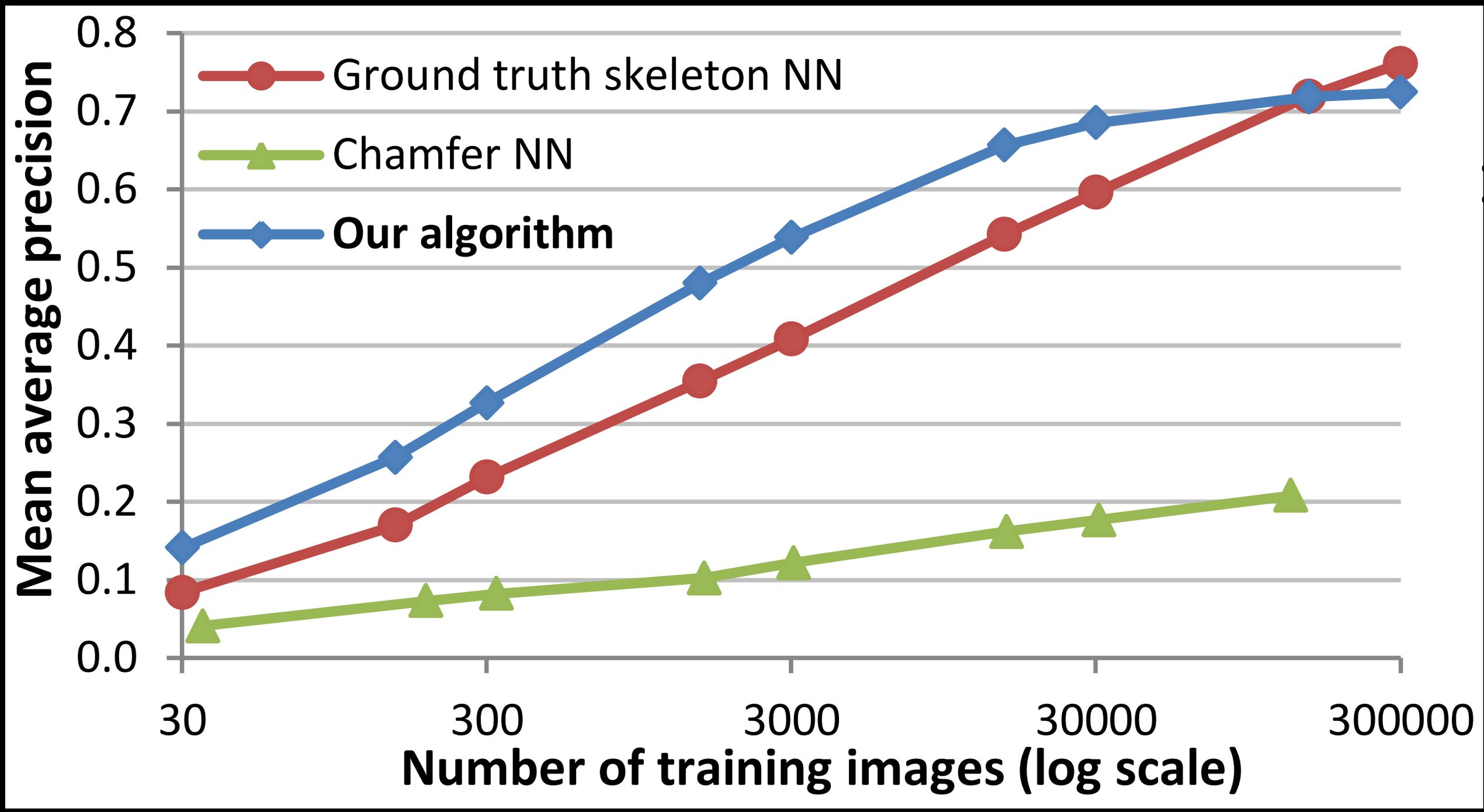
- Faces (well established - mature)

- Bodies (becoming more mature)

- General Objects (emerging)

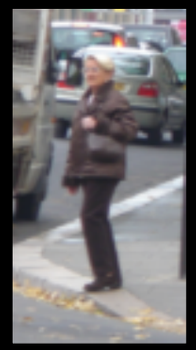


“Big Data Effect”



Taken from - Shotton et al. “Real-Time Human Pose Recognition in Parts from Single Depth Images” CVPR 2011.



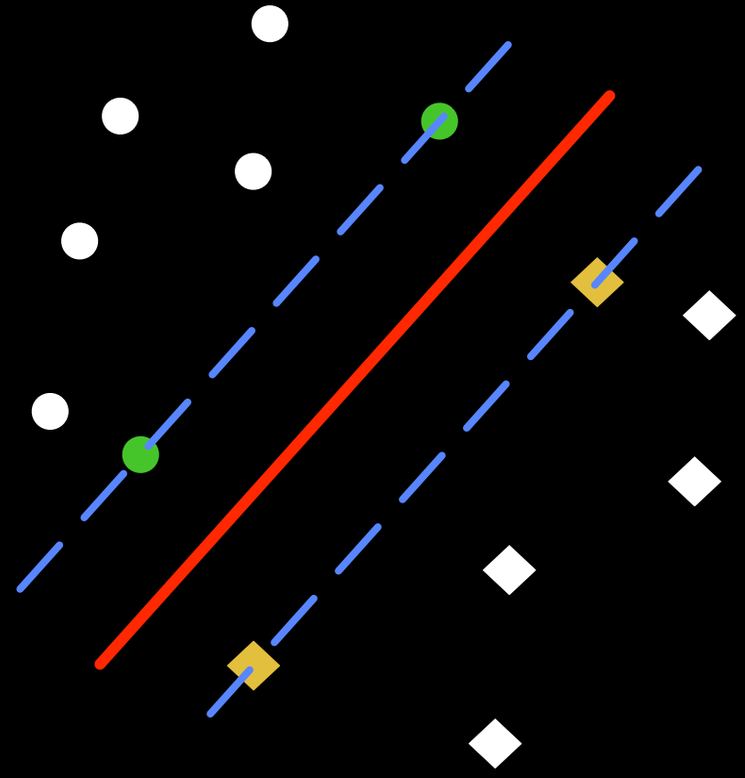


200 West


200 West

Hard Negative Mining

- Hard Negative Mining comes about from realization that not ALL samples are important when learning a classifier.
- Useful for “Big Data” as one does not need to keep all data in memory during learning.



Hard Negative Mining

- Common methodology (Dalal & Triggs, 2005) is to,
- Start with random negatives, then repeat
  1. Train model
  2. Harvest false positive to define “hard negatives”.
- HNM is largely based on heuristics.
- Notoriously slow and messy to determine the hard negatives.

Static/Dynamic Training

- We can categorize object detection methods into two camps
  1. **static training** - involves learning a detector from a dataset that is static and does not change from application to application (e.g. face detection).
  2. **dynamic training** - involves using your own dataset for the object you are wanting to detect.
- Dynamic training is also useful in object tracking - where one wants to employ a “track by update” paradigm.

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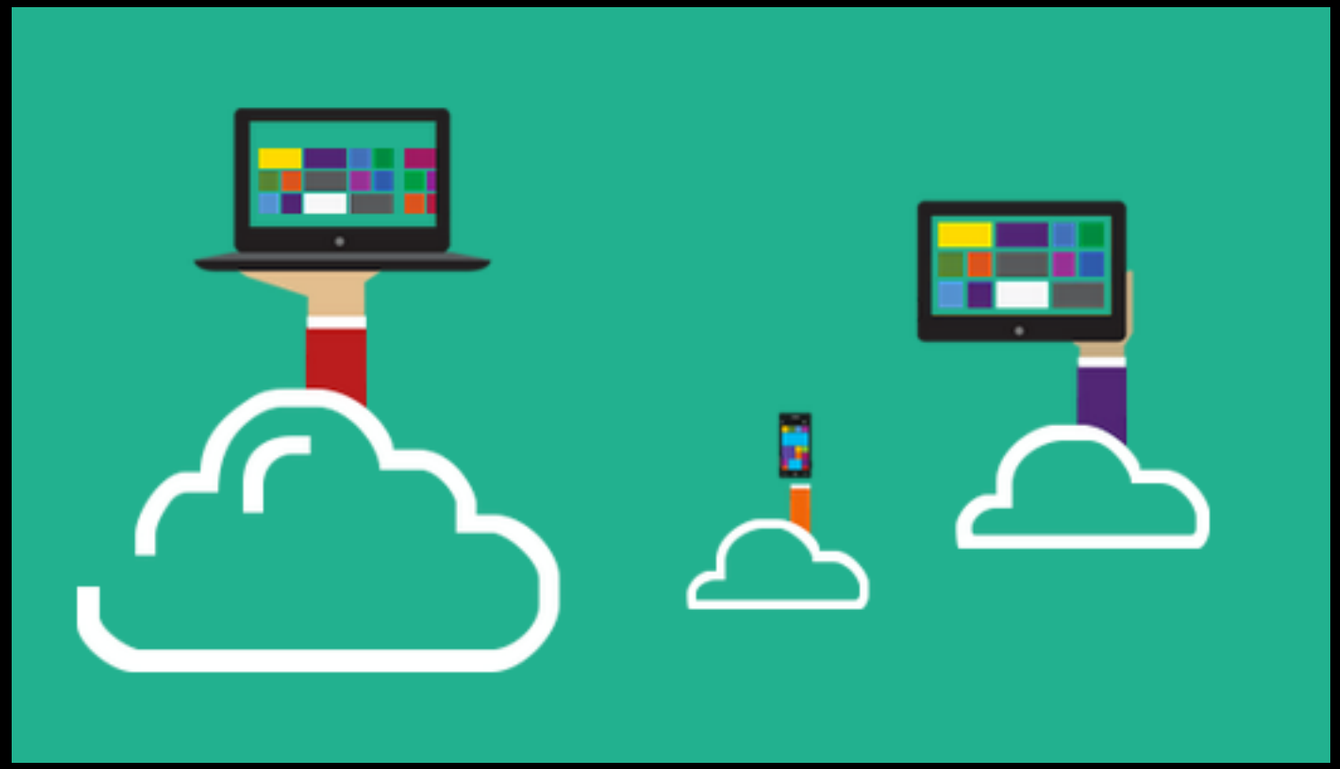
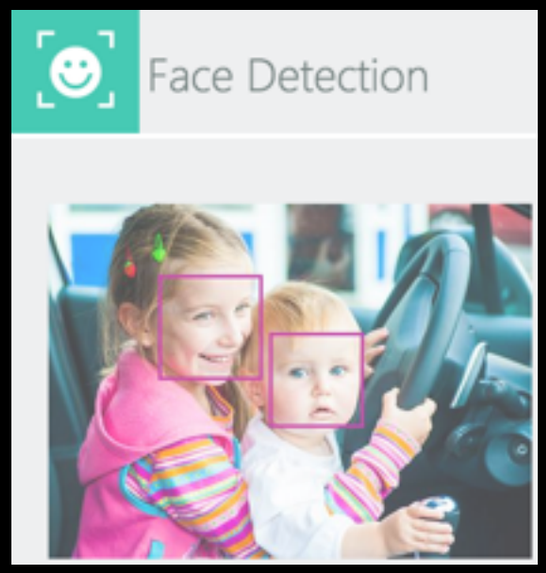
Computer Vision as a Service

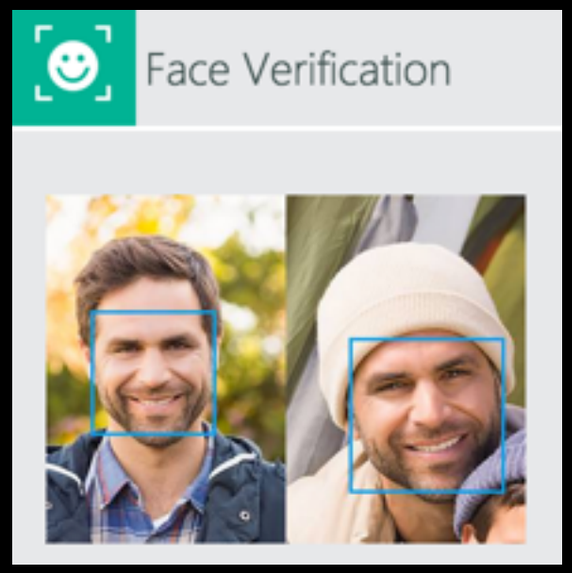
- Provide computer vision services through the cloud.
- Increasingly popular as developers do not need any intimate knowledge of computer vision.
- Pros - automatically support multiple platforms.
- Drawbacks - have to consider bandwidth & speed.

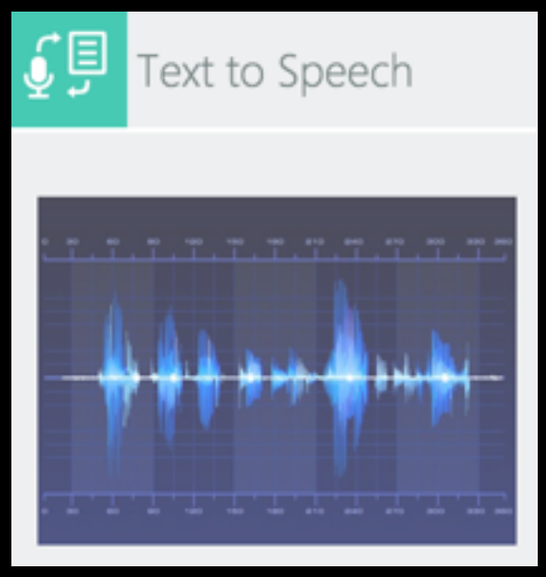


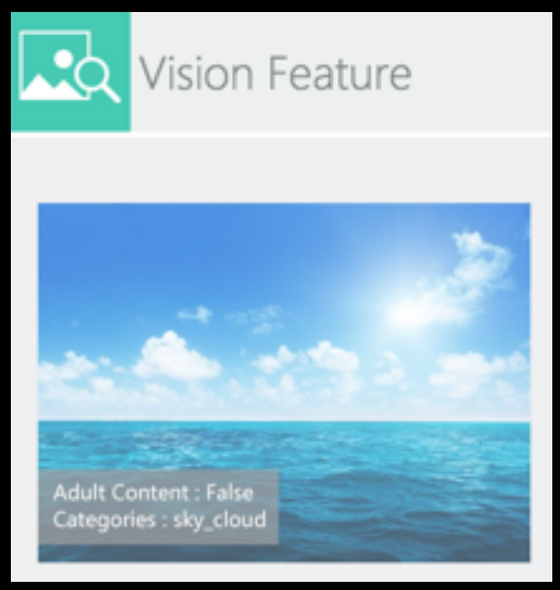
Project Oxford

- Well known in this space is "Project Oxford" from Microsoft.
- Contains an evolving portfolio of REST APIs & SDKs enabling developers to easily add intelligent services.
- Other services include - VMX & Clarifai.









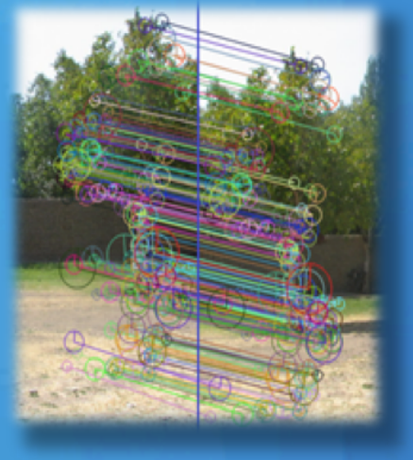
What can OpenCV do?

Image Processing

Filters

Transformations

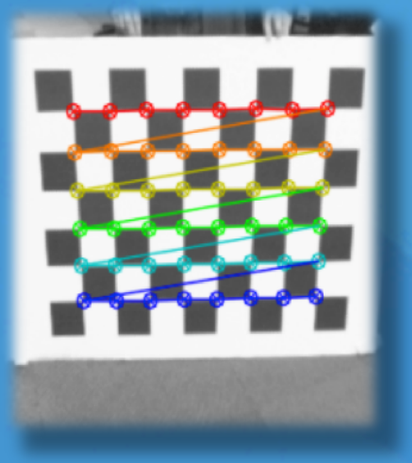
Edges, contours



Robust features

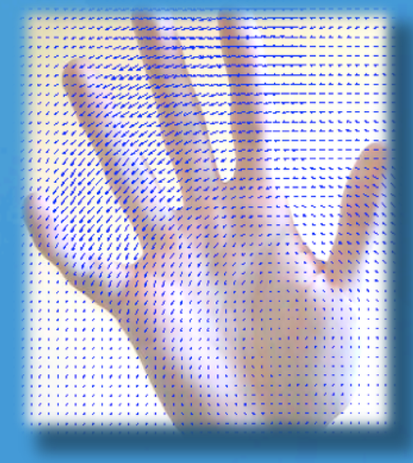
Segmentation

Video, Stereo, 3D

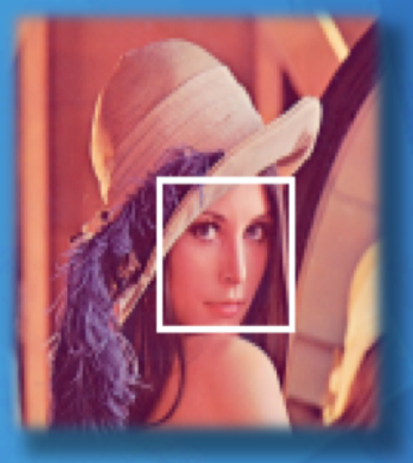


Calibration

Pose estimation



Optical Flow



Detection and recognition

Depth

itseez

What can OpenCV do?

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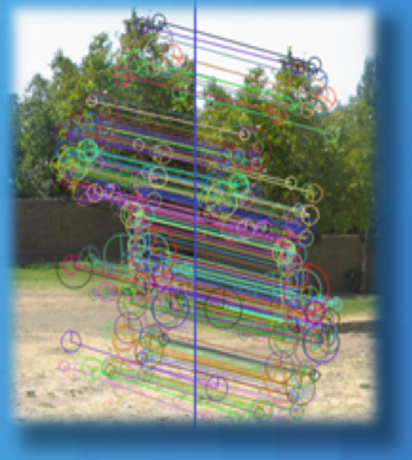
Edges, contours



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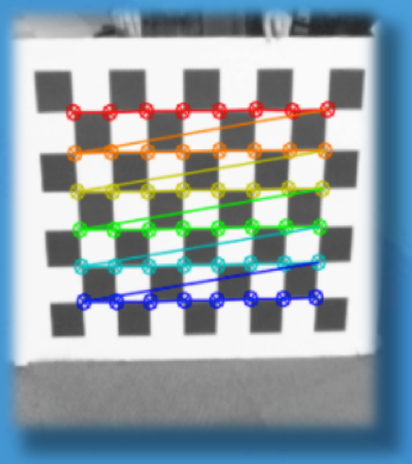
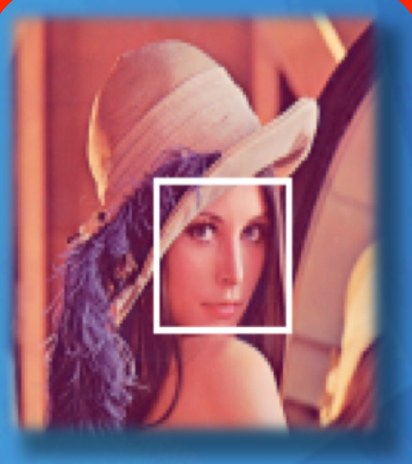


Calibration

Pose estimation

Optical Flow



Detection and recognition

Depth

itseez

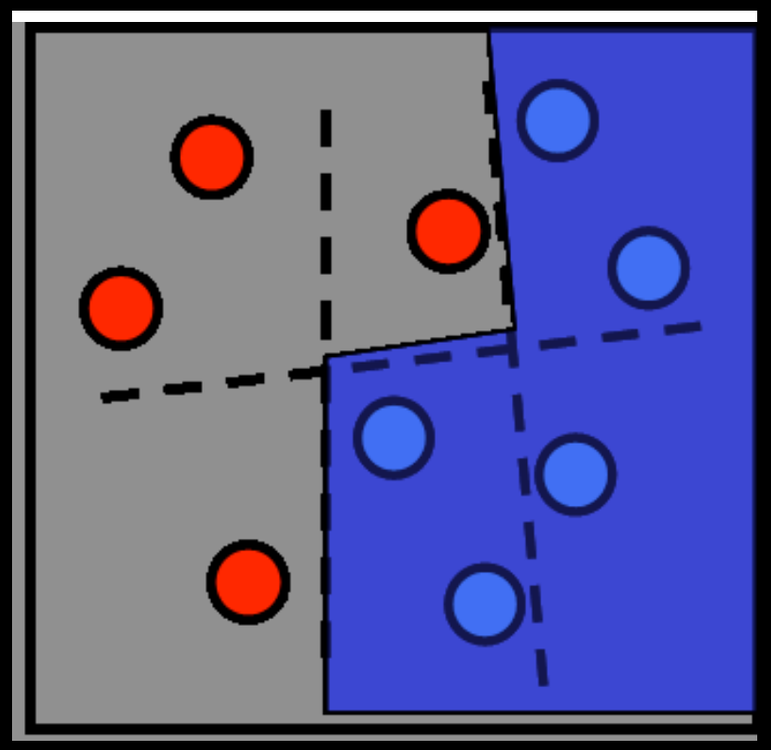
OpenCV 3.0

- In terms of detectors all the standards one are still there:-
  - Viola & Jones style face detector.

  - Dalal & Triggs style pedestrian detector.

- Support in 3.0 now for deformable parts based models.

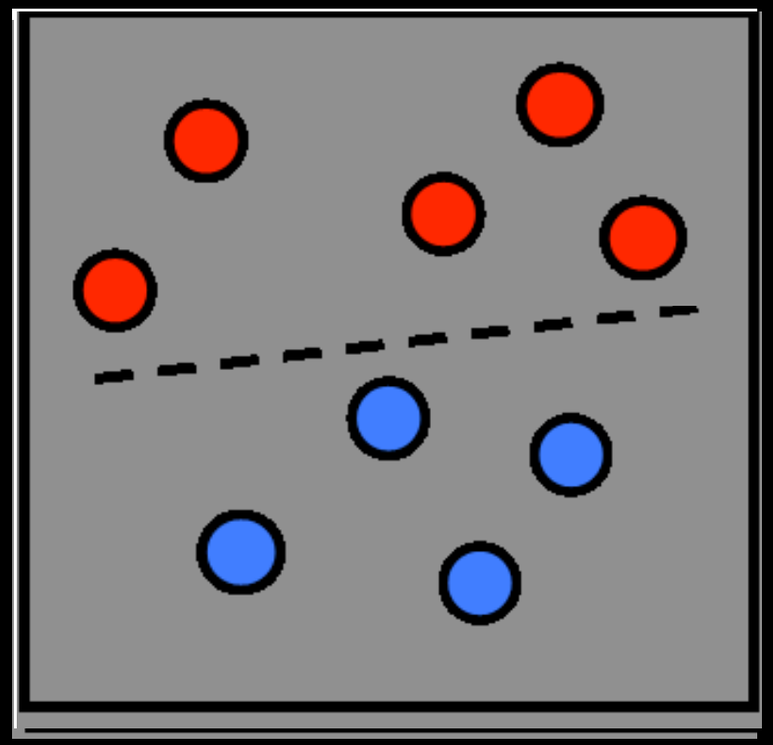
Viola & Jones



Computationally Expensive

“High Capacity”

Viola & Jones

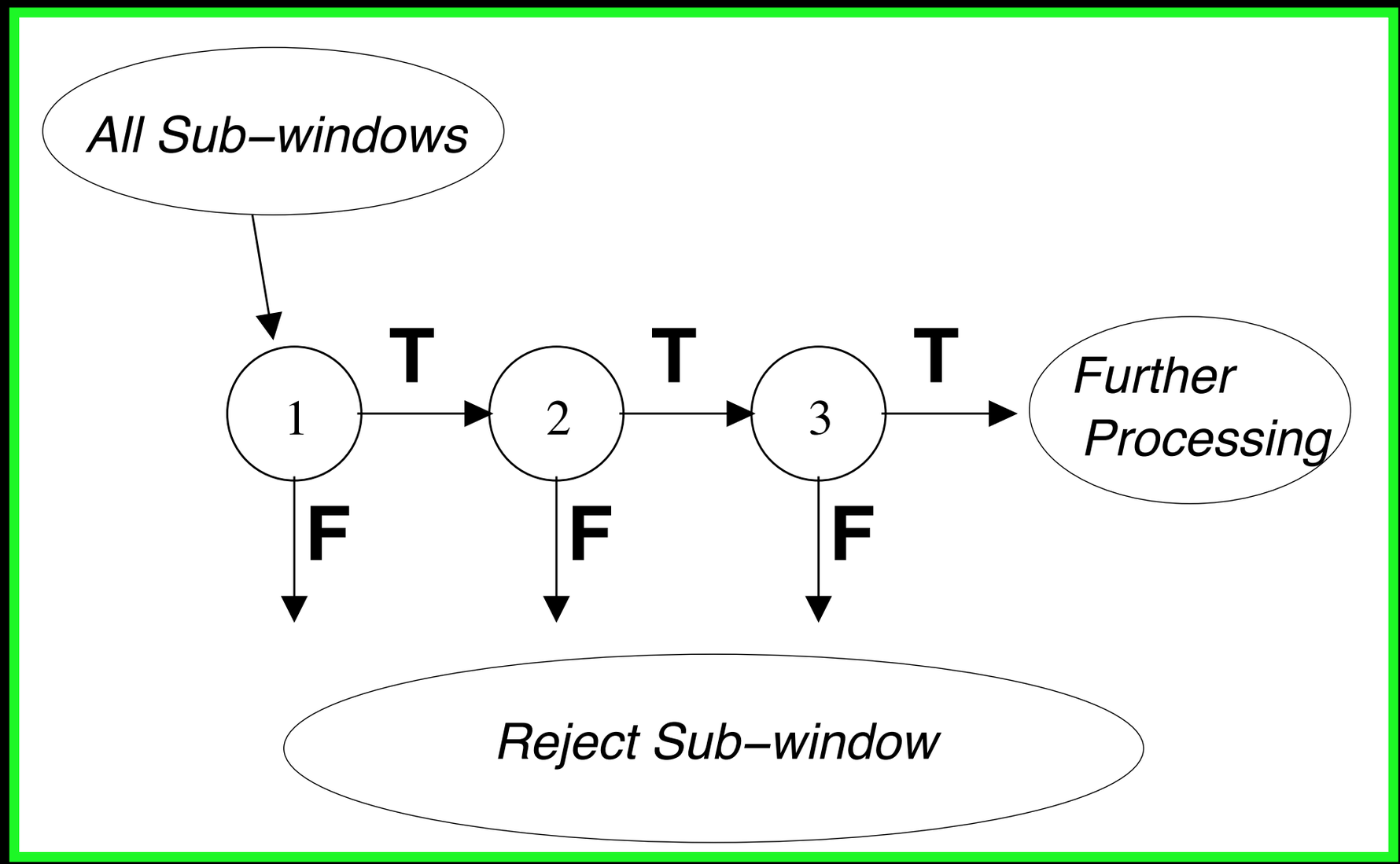


Computationally Cheap

“Low Capacity”

Viola & Jones

- Instead of searching all regions of an image with the same complexity classifier, we can use a cascade.



Viola & Jones

- Vast majority of regions in an natural image can be rejected using small capacity classifiers.

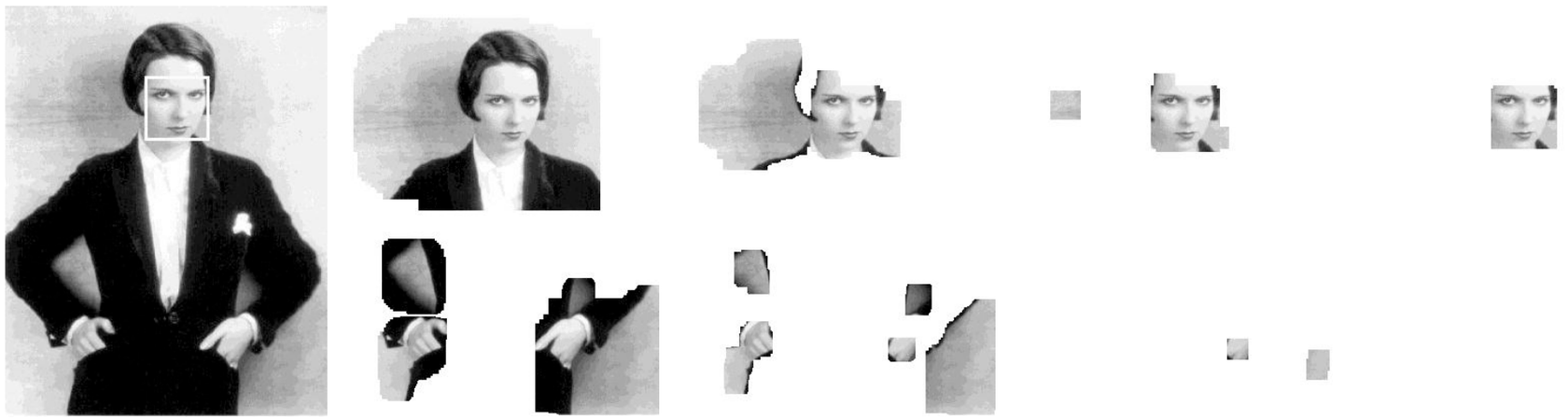
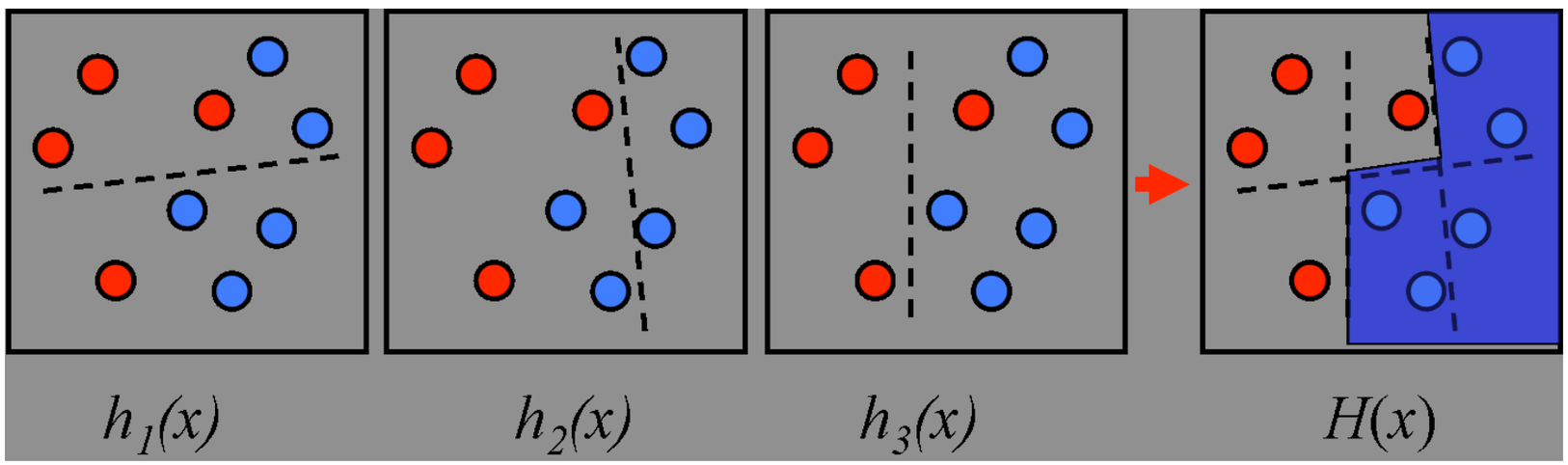


Figure 4: **From left to right:** *input image, followed by portions of the image which contain un-reject patches after the sequential evaluation of 1* (13.3% patches remaining), *10* (2.6%), *20* (0.01%) *and 30* (0.002%) *support vectors. Note that in these images, a pixel is displayed if it is part of any remaining un-rejected patch at any scale, orientation or position This explains the apparent discrepancy between the above percentages and the visual impression.*

Viola & Jones

- Boosting is ideally suited to be used with box filters.
- Techniques like AdaBoost, LogitBoost or GentleBoost can naturally learn a complex classifier from a cascade of weak classifiers.

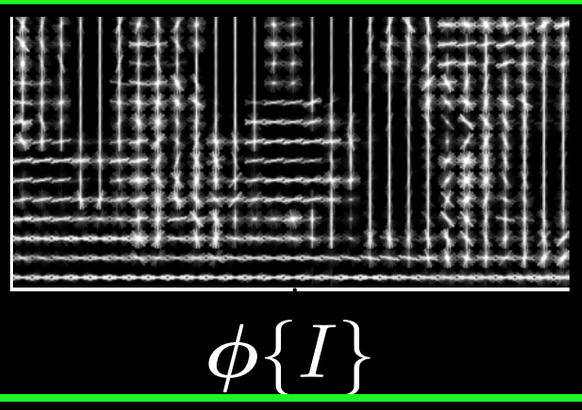
$$H(\mathbf{x}) \;=\; \text{sign}\left(\sum_{m=1}^{M} \alpha_m h_m(\mathbf{x})\right)$$



Deformable Parts Models

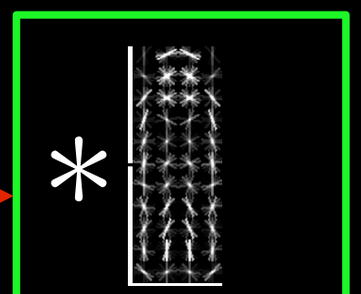
I

Feature Extraction

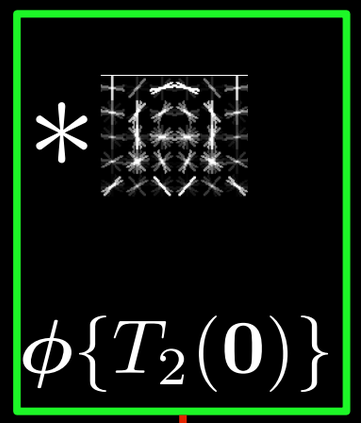


$\phi\{I\}$

Local Search



$\phi\{T_1(\mathbf{0})\}$



$\phi\{T_2(\mathbf{0})\}$

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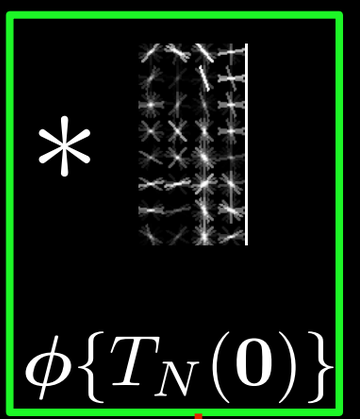
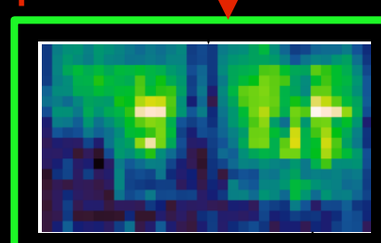
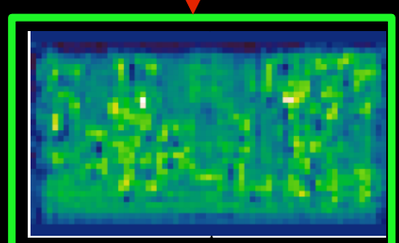


$\phi\{T_N(\mathbf{0})\}$

Part Responses

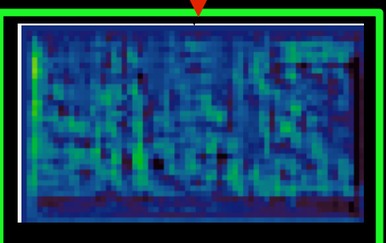


D_1



D_2

.....

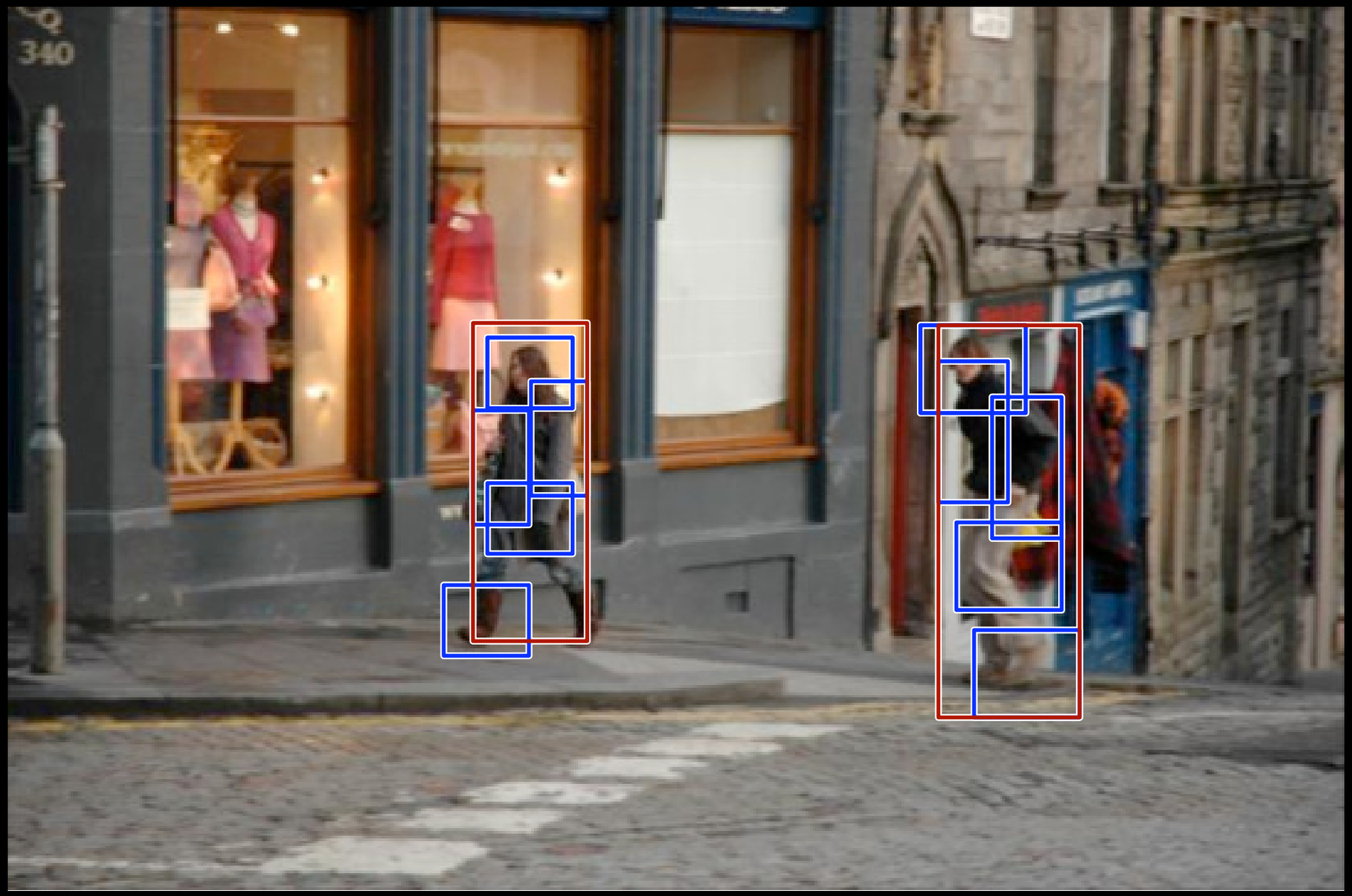


D_N

Color Encoding of Filter Responses

Felzenszwalb, Girshick, McAllester & Ramanan, 2010

Deformable Parts Models



Felzenszwalb, Girshick, McAllester & Ramanan, 2010

`Dlib` C++ for Computer Vision

- `Dlib` is a general purpose cross-platform C++ library designed using contract programming and modern C++ techniques.
- It is open source software and licensed under the Boost Software License.
- Code is platform independent (Windows, Linux, MAC OS X).
- Check out more details at the link - http://dlib.net/
- Very useful set of vision and learning tools.

Why `Dlib` is useful?

- What makes `Dlib` very cool, is its ability to train your own object detectors quickly and easily.
- This is hard to do in OpenCV as it relies on something called “Hard Negative Mining”.
- Requires setting tricky parameters, and can often takes hours/days to train a model.

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Dlib - Make your own detector!

- Dlib - uses the well known HOG - SVM pipeline for object detection - Dalal & Triggs 2005.
- Does not rely on HNM, instead employs Structural Support Vector Machine (SVM).
- No need for negative training set, no messy parameters.
- Using this tutorial authors were able to learn a face detector in just a few minutes using Dlib.

Visualization of HOG Detector →

`Dlib` versus OpenCV

Red Box - `Dlib`

Blue Circles - `OpenCV`

Taken from http://blog.dlib.net/2014/02/dlib-186-released-make-your-own-object.html.

`Dlib` versus OpenCV

Red Box - `Dlib`

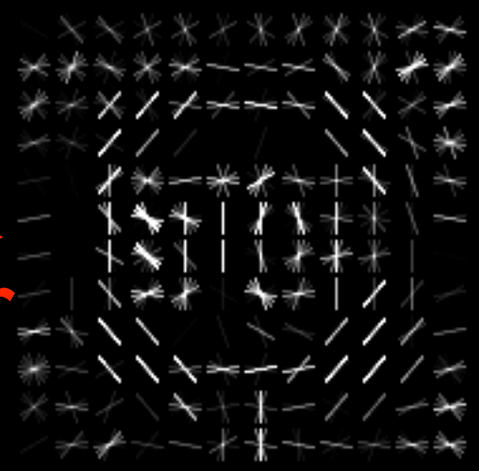
Blue Circles - `OpenCV`

Taken from http://blog.dlib.net/2014/02/dlib-186-released-make-your-own-object.html.

`Dlib` versus OpenCV

- Another example - 8 images of stop signs downloaded and labeled.
- `Dlib` was then used to create a HOG detector.

Visualization of HOG Detector →



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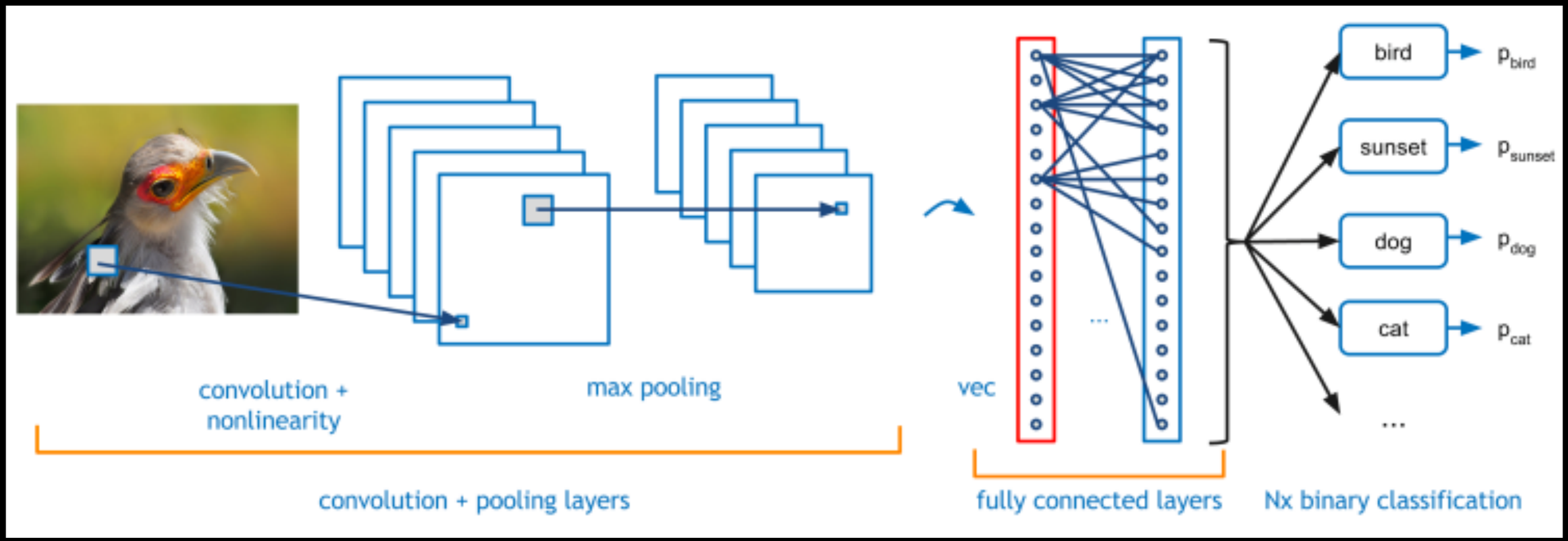
CAFFE

- Deep-learning has taken the vision world by storm.
- Essentially an extension of neural networks.
- State of the art for object detection (e.g Imagenet).
- CAFFE is one of the most popular packages.



Taken from - DIY Deep Learning for Vision.

CAFFE

- Open framework, models, and worked examples for deep learning.
- Pure C++ / CUDA architecture for deep learning.
- Command line, Python, MATLAB interfaces.
- Fast, well-tested code.
- Tools, reference models, demos, and recipes.
- Seamless switch between CPU and GPU.

Prototype

Train

Deploy

Taken from - DIY Deep Learning for Vision.

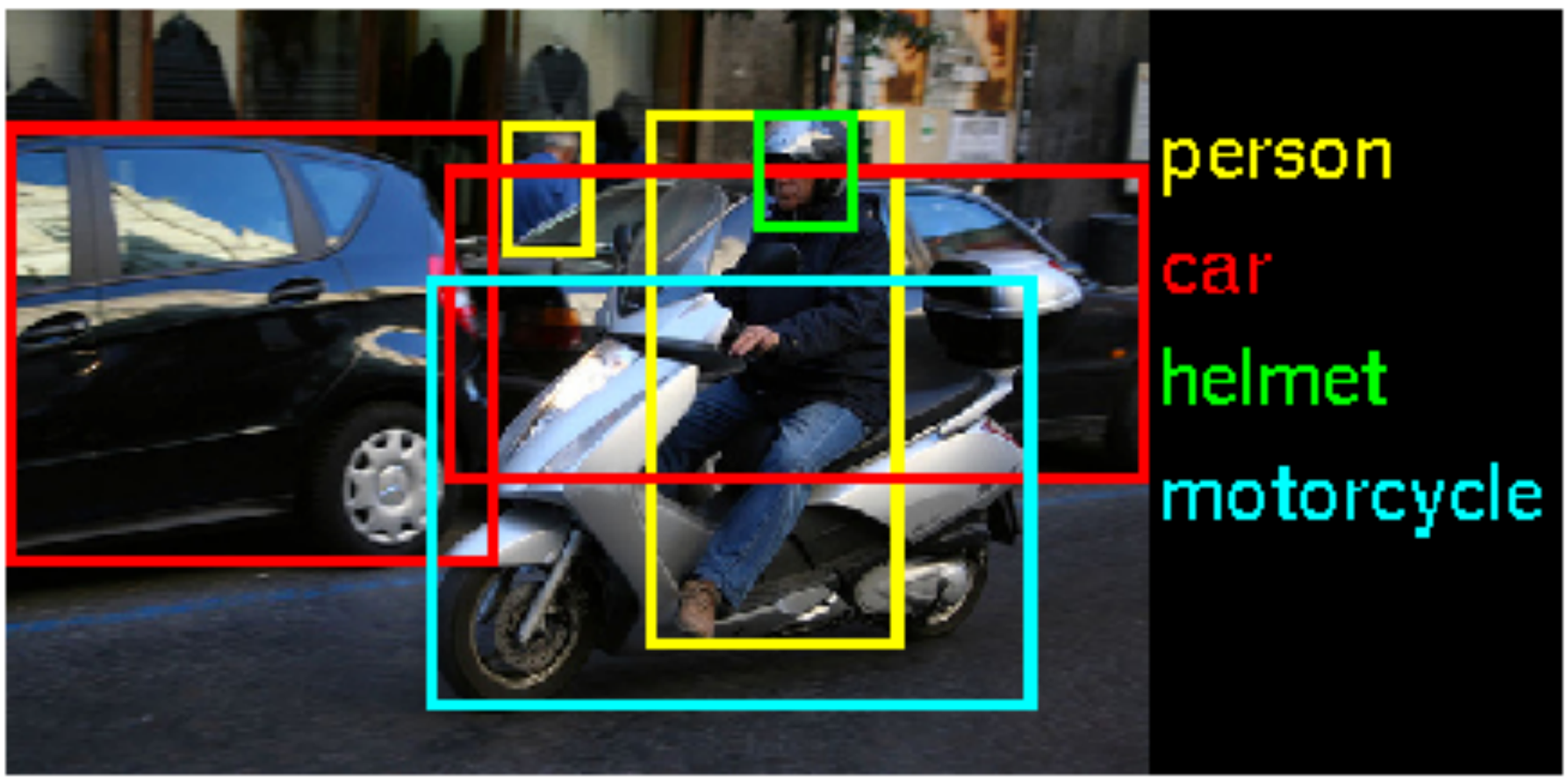
CAFFE

- Pre-trained models are openly available at the CAFFE Model Zoo.
- open collection of deep models to share innovation
  - VGG ILSVRC14 + Devil models in the zoo
  - Network-in-Network / CCCP model in the zoo
  - MIT Places scene recognition model in the zoo
  - help disseminate and reproduce research
  - bundled tools for loading and publishing models

Taken from - DIY Deep Learning for Vision.

CAFFE

- Developed in Berkley.
- Released under BSD-Clause 2 license.
- See here for very good tutorial on its use.
- Other packages in use - notably Torch 7 & MatConvNet.



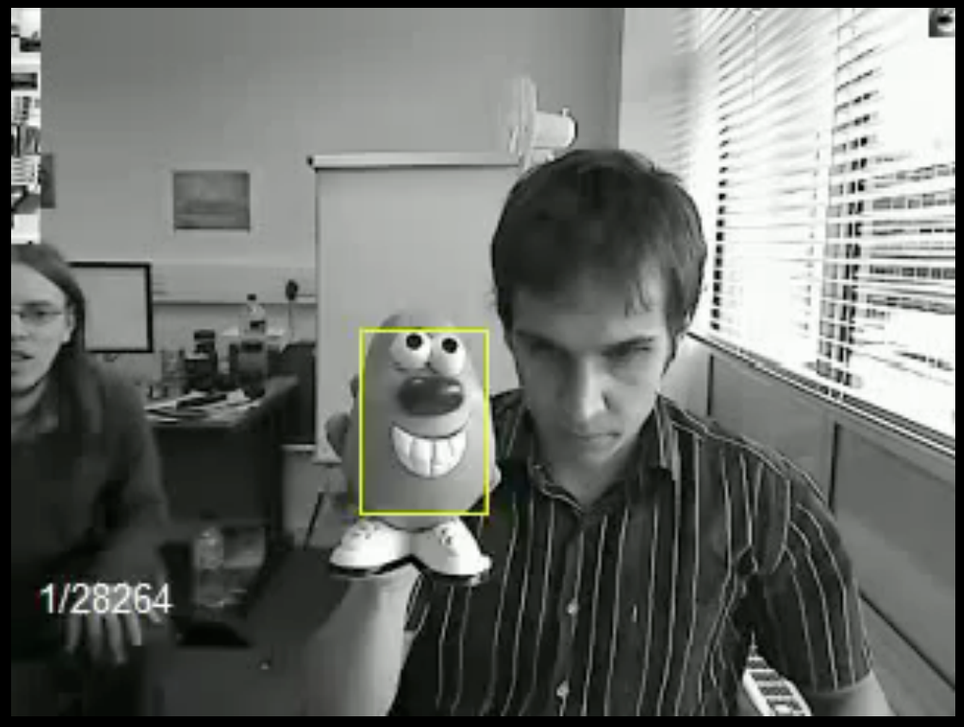
Today

- Motivation - Object Detection/Tracking
- Computer Vision as a “Black Box” - Considerations
- Detection
  - Computer Vision as a Service (VMX, Project Oxford, Clarifai).
  - OpenCV 3.0 (face and pedestrian detectors, what’s new?)
  - DLib C++ (create your own detector!!!)
  - Caffe (Deep Learning)
- Tracking
  - Correlation Filters (fast in tracking in just a few lines of code)
  - Predator (tracking an object efficiently/quickly)

Just a sampling - by no means a complete list!!!

Predator Tracker

- Predator - or Track-Learning-Detection (TLD)
- Based on Kalal et al. ICCV 2011.
- Released under GPL v3.0.



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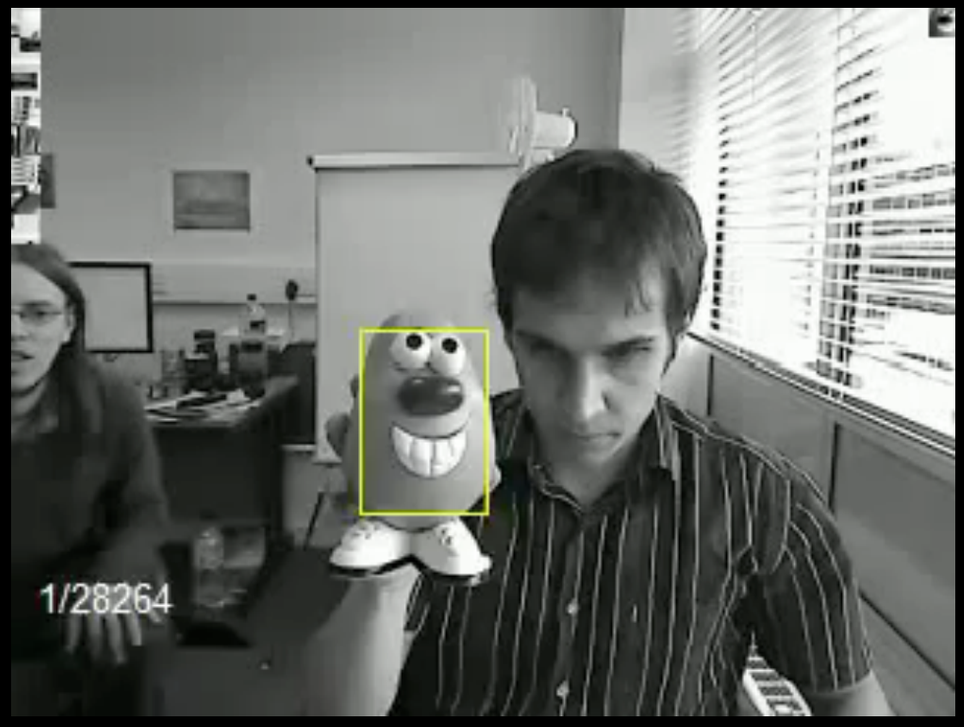


Predator Tracker

zk00006 / OpenTLD

Watch 183 S

Official source code for TLD

15 commits | 1 branch | 0 releases | 1 contributor

Branch: master | OpenTLD / +

Update README

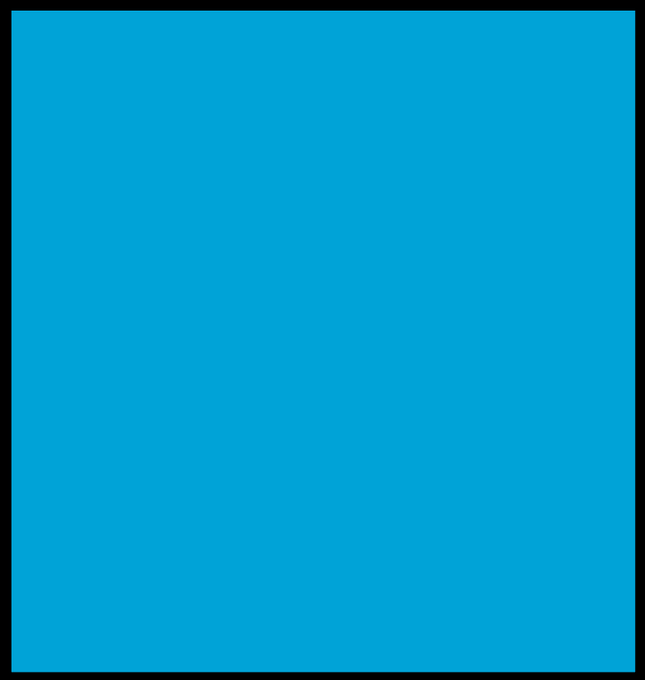
zk00006 authored on May 22, 2014 — latest commit 953e2df965

_input	first commit	5 years ago
_output	first commit	5 years ago
bbox	first commit	5 years ago
img	first commit	5 years ago
mex	first commit	5 years ago
other	first commit	5 years ago

Taken from https://github.com/zk00006/OpenTLD.

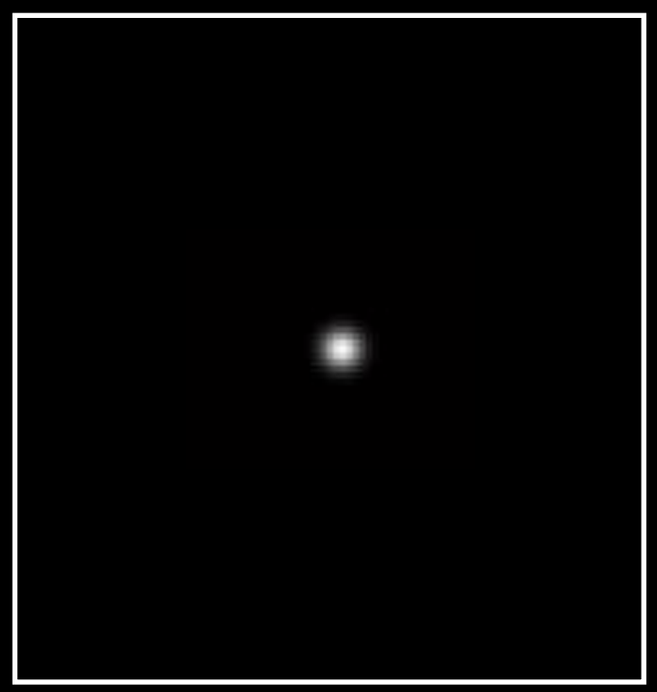
Correlation Filters

*



"unknown filter"
$\mathbf{h}$

"known signal" $\mathbf{x}$

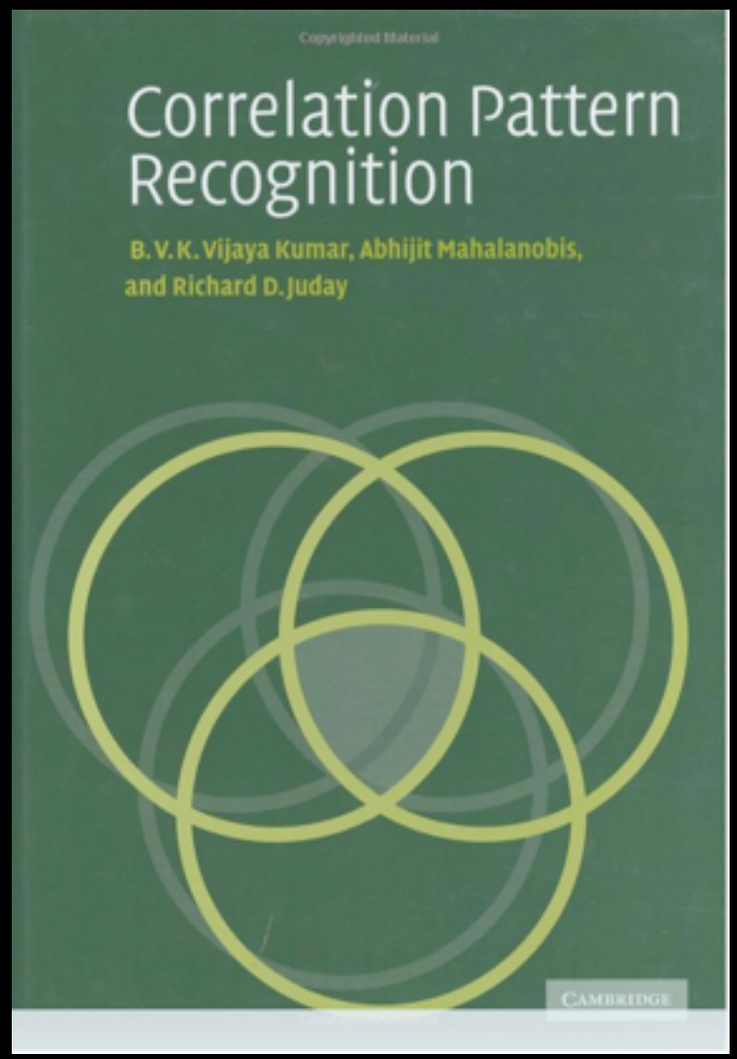


"known response" $\mathbf{y}$

Correlation Filters

- Can build a correlation filter from **5** lines of MATLAB code!!!

$$\hat{\mathbf{h}} = \hat{\mathbf{s}}_{xy} \circ^{-1} (\hat{\mathbf{s}}_{xx} + \lambda \mathbf{1})$$



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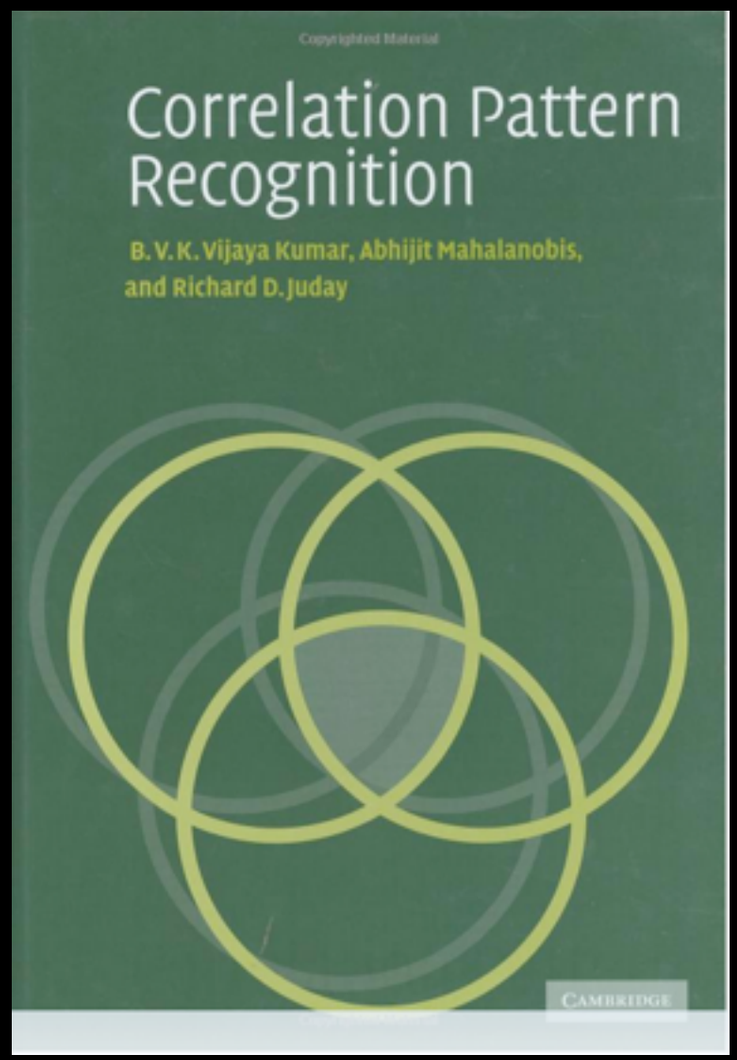
>> xf = fft2(x);
```



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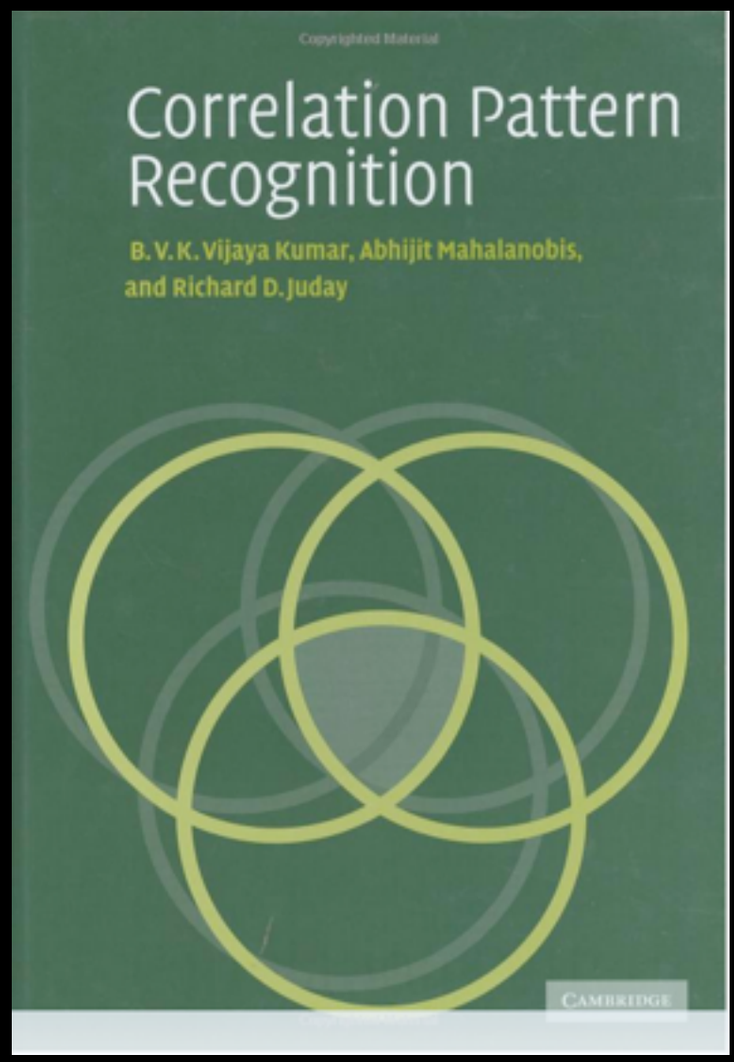

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>> sxx = xf.*conj(xf);
```

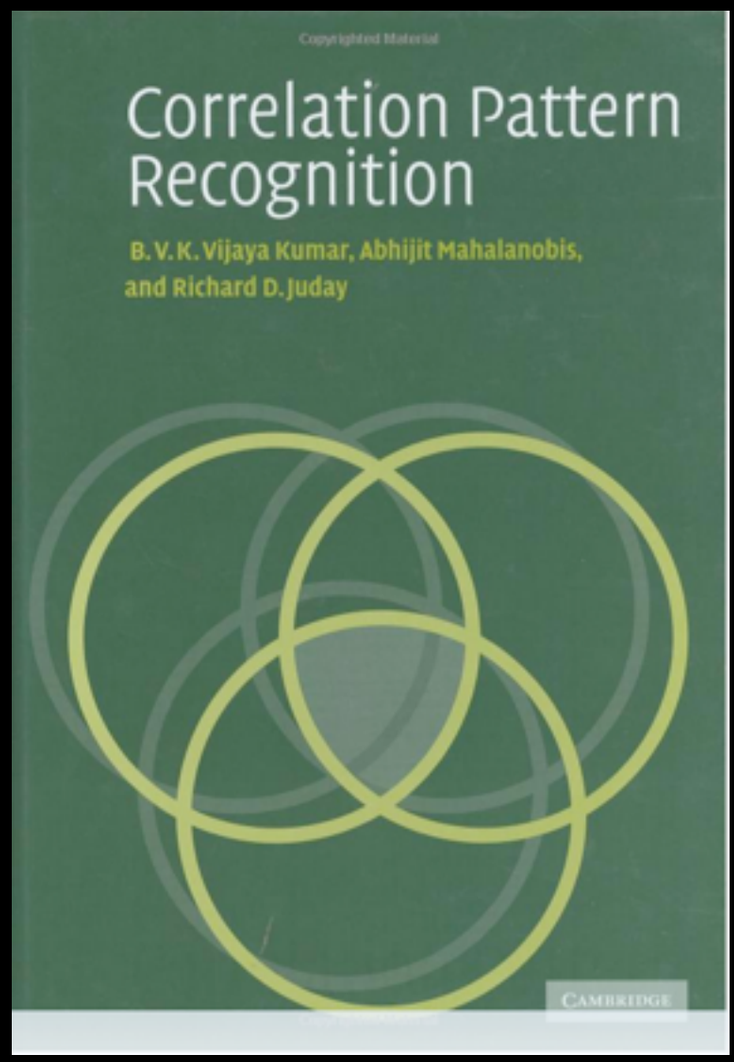

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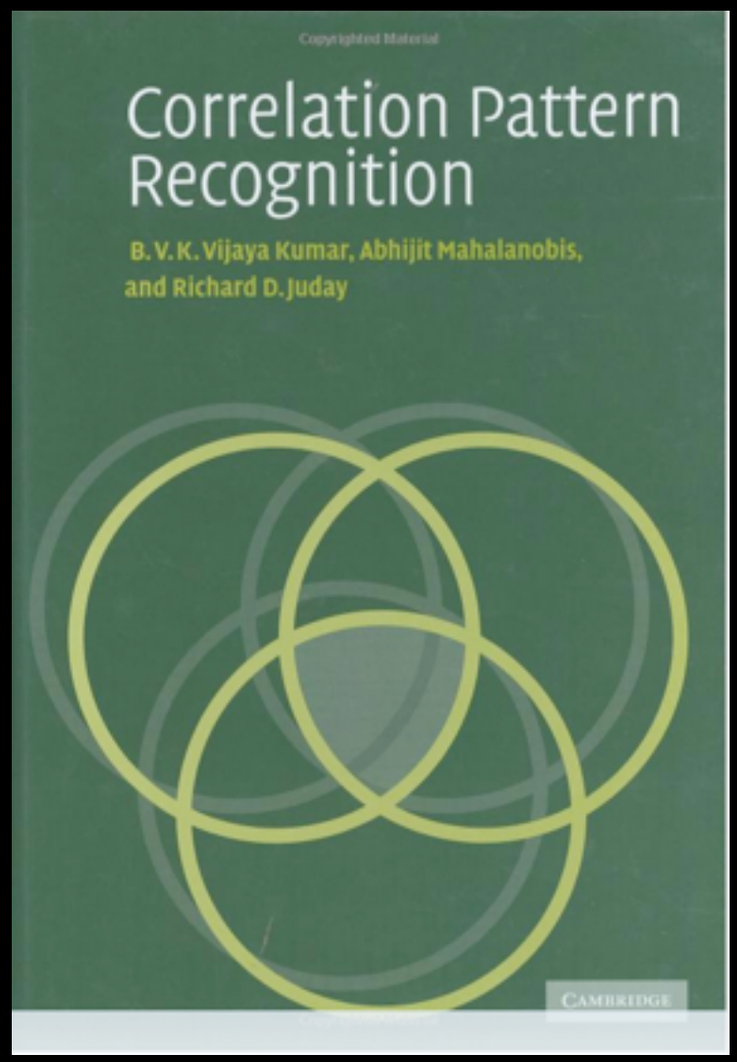

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```
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>> yf = fft2(y);
>> sxx = xf.*conj(xf);
>> sxy = xf.*conj(yf);
>> hf = sxy./(sxx + 1e-3);
```

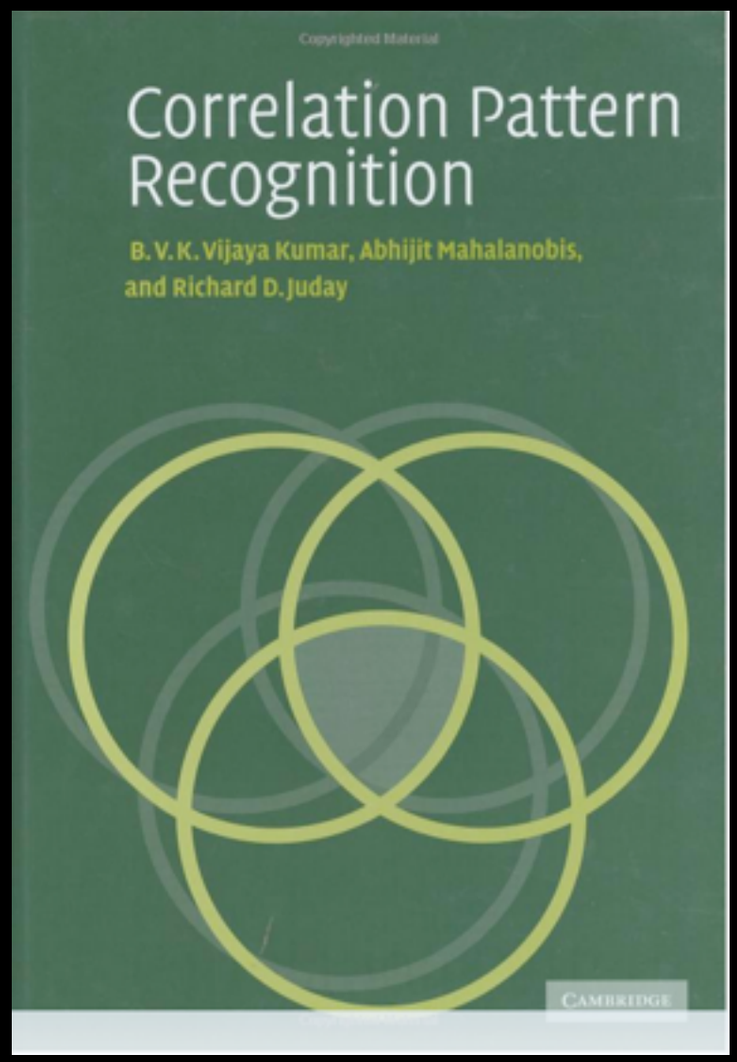

Algorithm	Frame Rate	CPU
FragTrack[1]	realtime	Unknown
GBDL[19]	realtime	3.4 Ghz Pent. 4
IVT [17]	7.5fps	2.8Ghz CPU
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Taken from Bolme et al. CVPR 2010.

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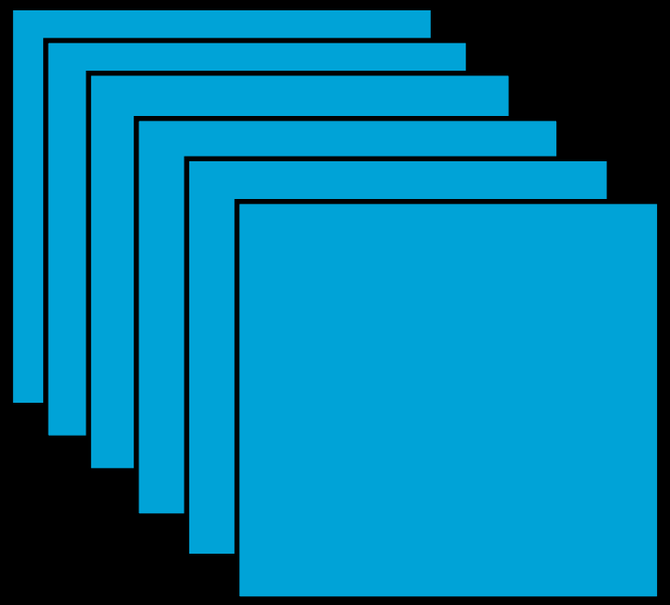
HOG - Correlation Filters

*



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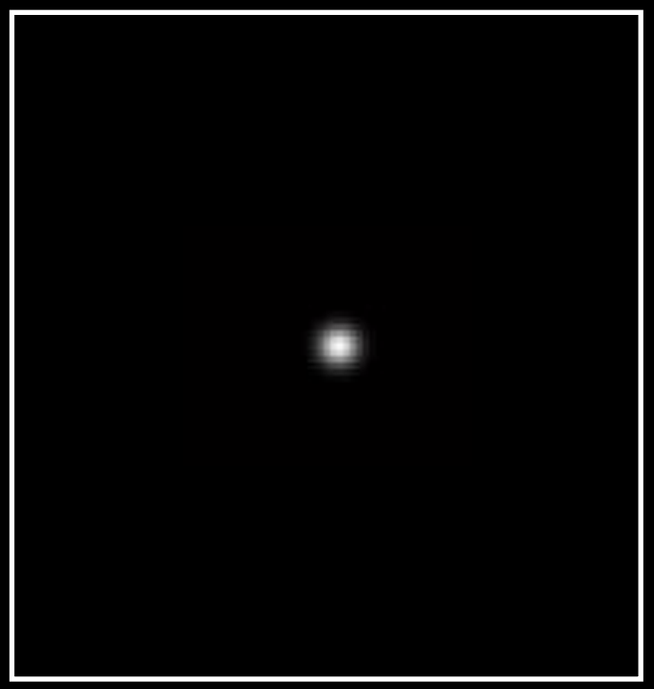
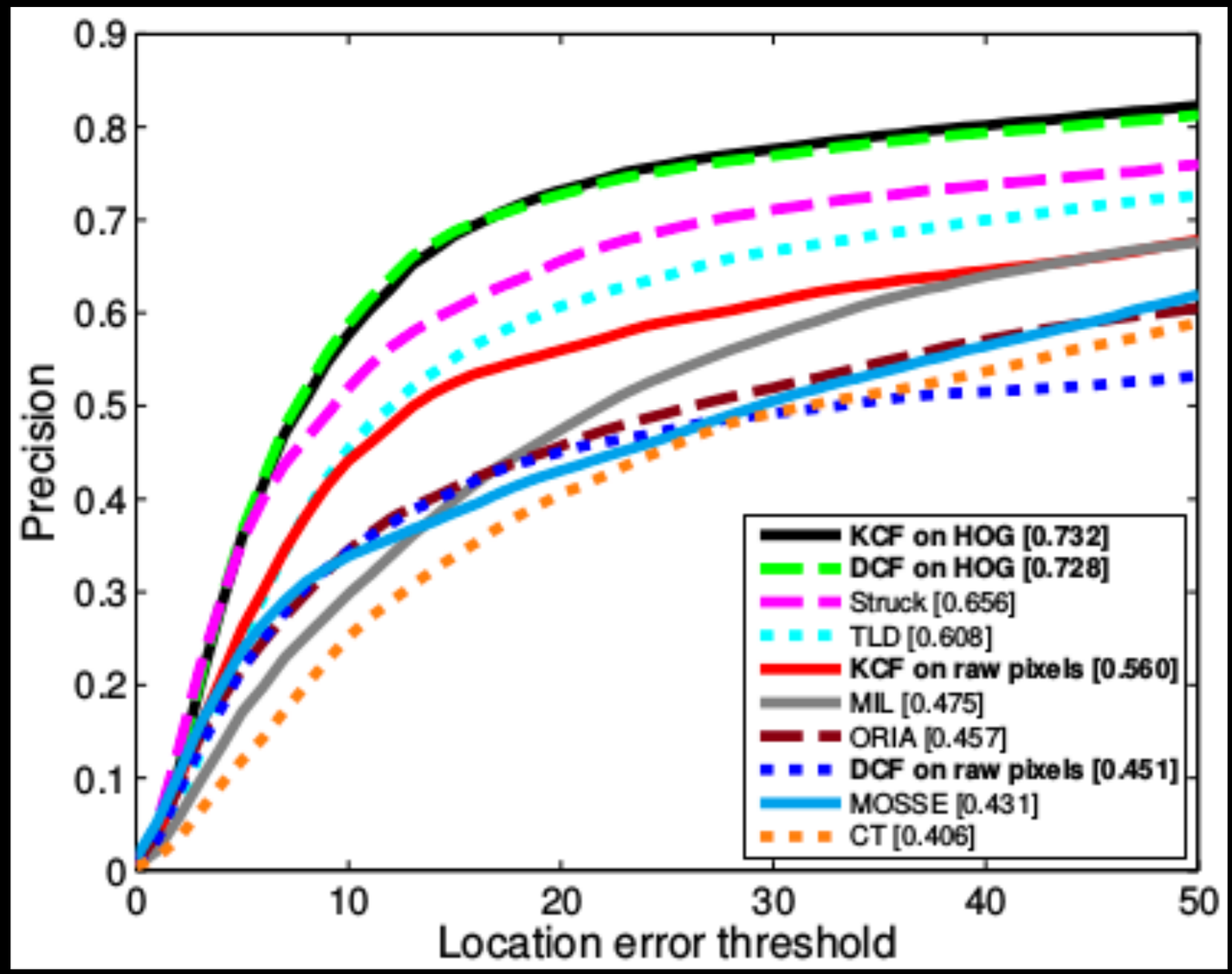


“known response” $\mathbf{y}$

Kiani, Sim and Lucey ICCV 2013.

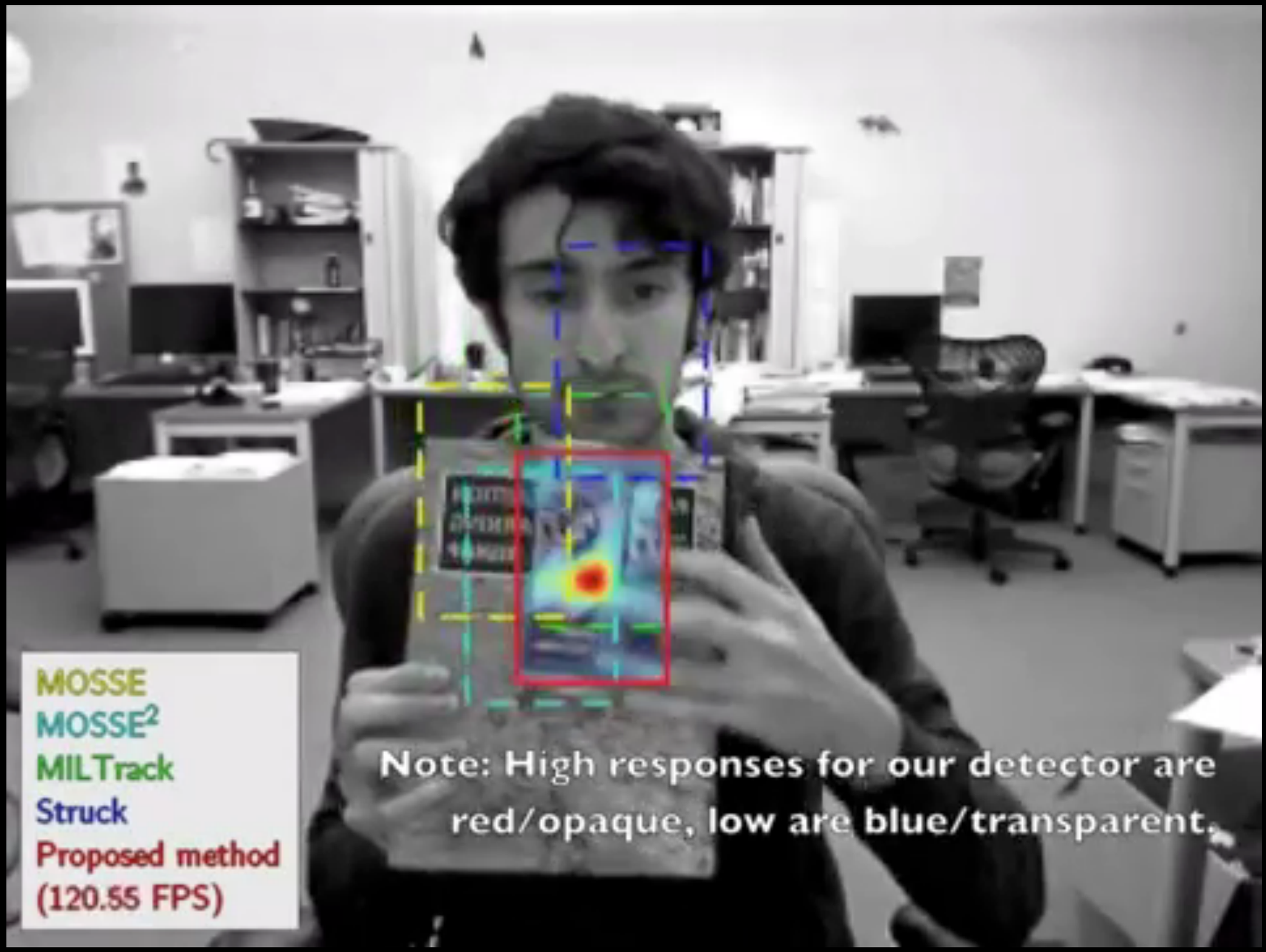
Kernelized Correlation Filters

- State of the art are “Kernelized Correlation Filters”.
- Code available in MATLAB and Python.



Henriques et al. PAMI 2015.

Kernelized Correlation Filters



Kernelized Correlation Filters