HTTP://BIT.LY/CODEMOTION2013

COMPUTER VISION

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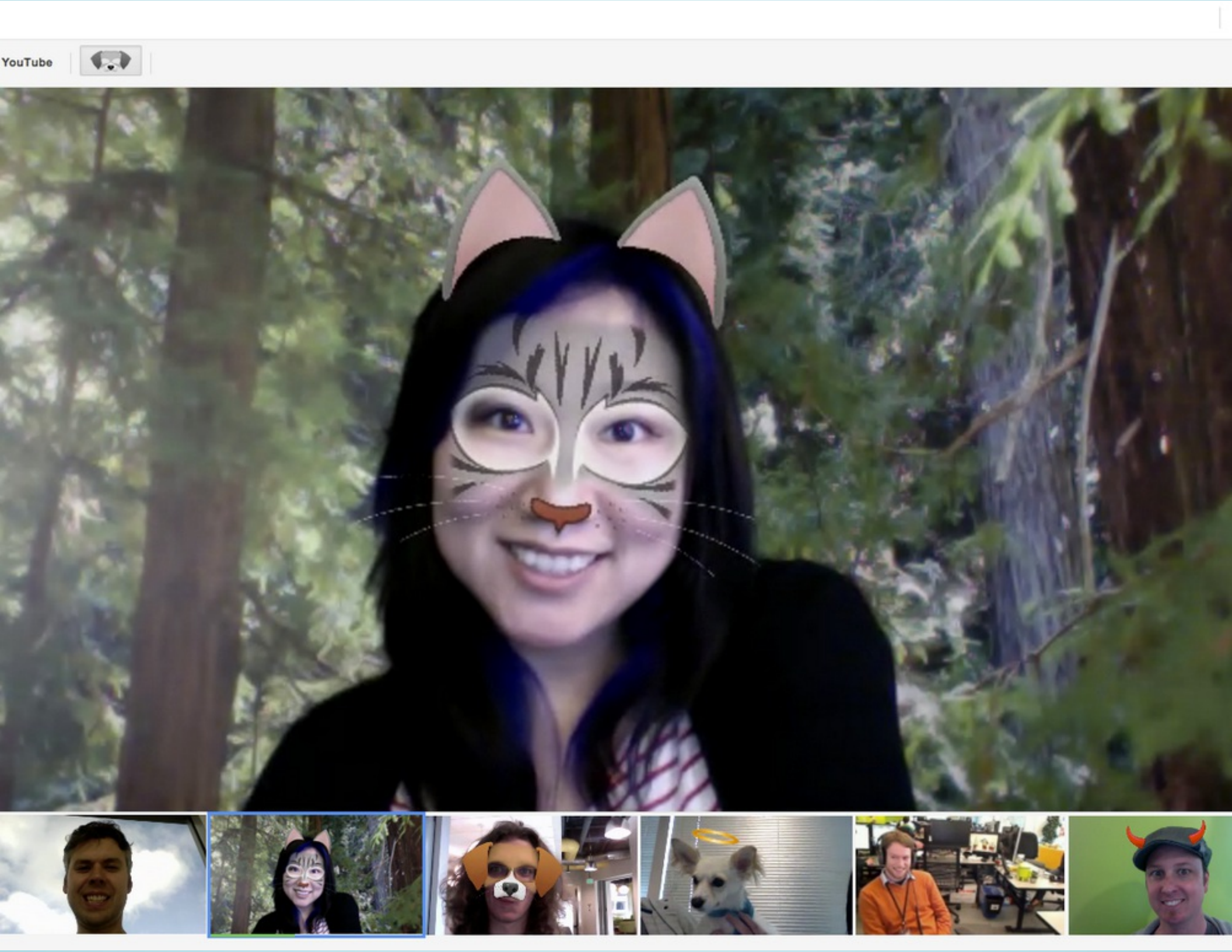
DISCLAIMER

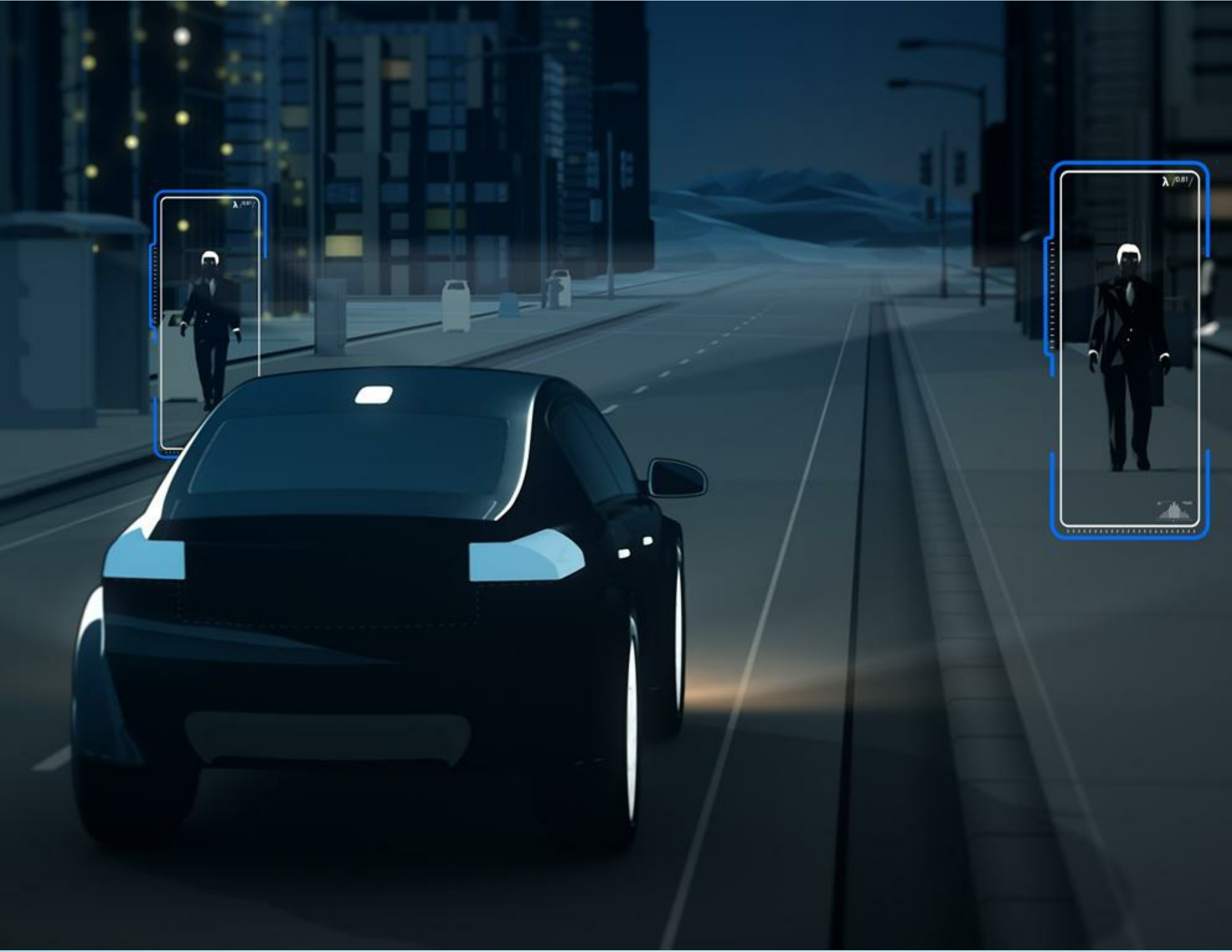
JUST AN AMATEUR

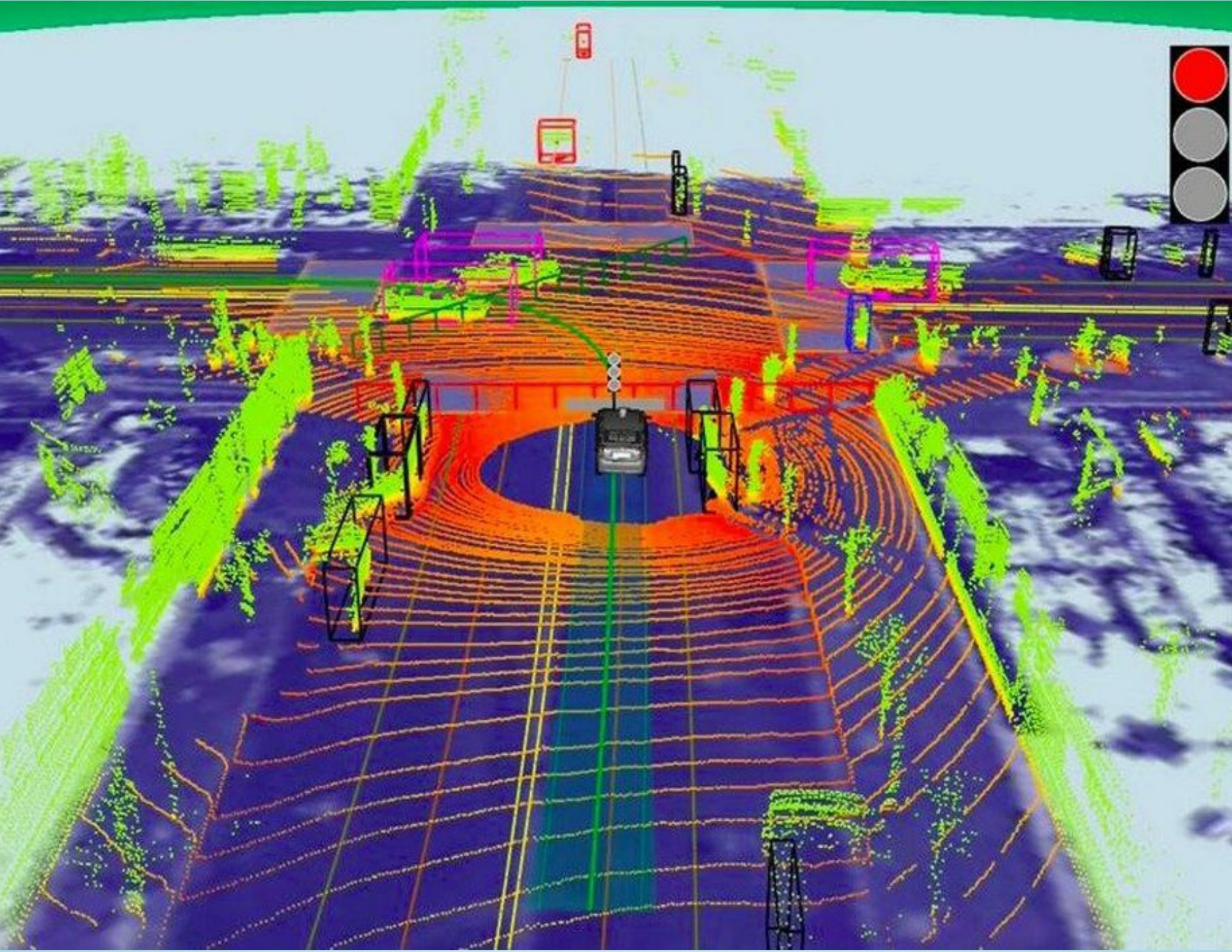
The Nikon S60. Detects up to 12 faces.


YouTube


FLORIDA
TUR TLE
HELPING SEA TURTLES SURVIVE
©


776-5459






WALL-E


LUMIX
GH2


130

HARDWARE

CAMERAS

- Compact cameras
- DSLR cameras (Reflex)
- Micro cameras
- USB cameras (webcams)
- IP cameras
- Depth field / 3D cameras

CHOOSING A CAMERA

- Volume / Weight
- Size of the sensor, bigger is always better
- Focal Length
- Resolution
- Light conditions
- Adjustable
- Price

PHOTOGRAPHY 101

3 PILLARS

- Shutter speed
- Aperture
- ISO (Film speed)

http://bit.ly/poBjKi

ALSO

- White balance
- etc

SHUTTER SPEED

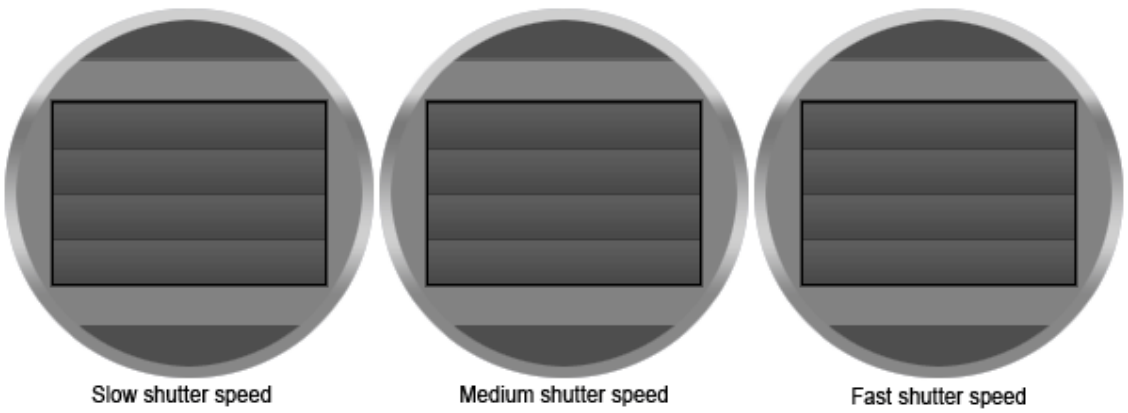
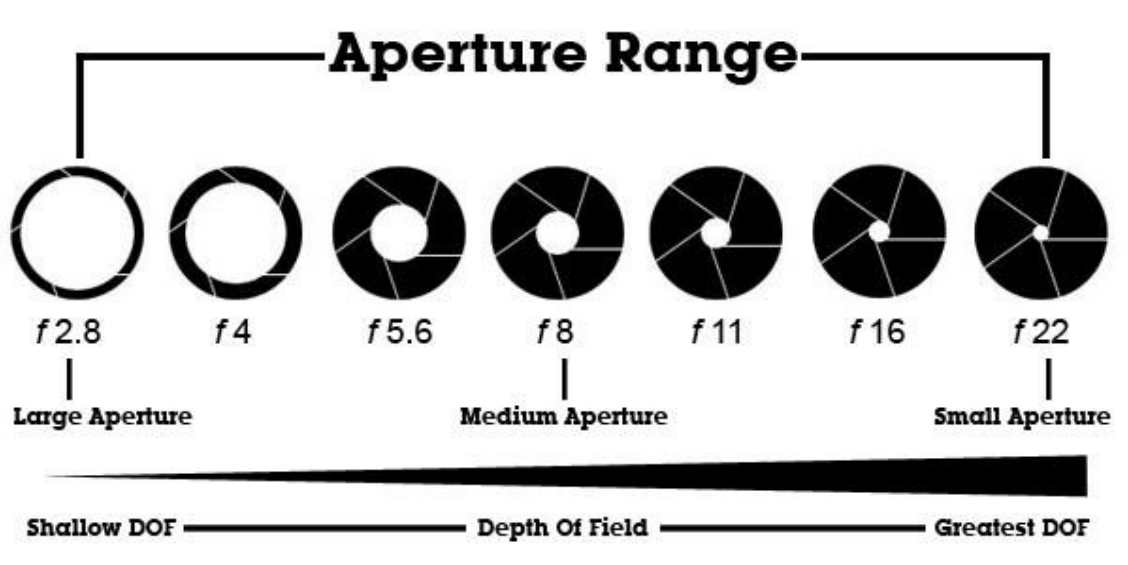


Fig 1.6.2 The appearance of the shutter at various speeds.

http://bit.ly/17hSKG

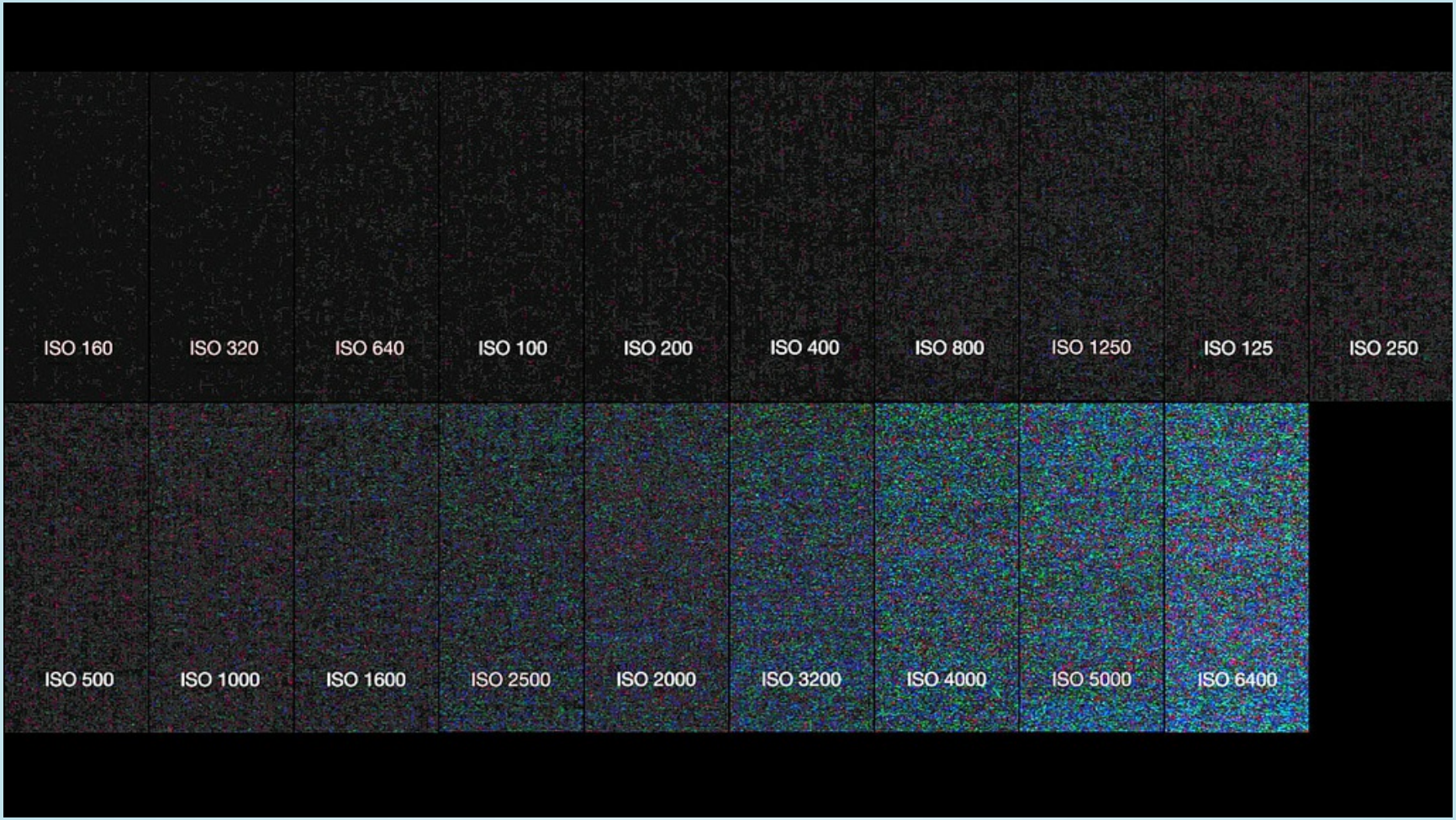
APERTURE

Depth of field



http://bit.ly/158gbyW

ISO


ISO 160
ISO 320
ISO 640
ISO 100
ISO 200
ISO 400
ISO 800
ISO 1250
ISO 125
ISO 250
ISO 500
ISO 1000
ISO 1600
ISO 2500
ISO 2000
ISO 3200
ISO 4000
ISO 5000
ISO 6400

LIBGPHOTO2

- Linux Open Source project
- Handles digital cameras DSLRs/compact cameras through USB.
- Supports MTP and PTP v1 & v2.


FUJINON LENS
8x
ZOOM
FUJIFILM
FULL-HD
34.4mm 1:3.6-6.3

VISION

Compact Cameras

- Many take from 6-15 seconds using libgphoto2.
- Rarely can stream video in real time.
- Rarely can adjust camera settings on the go.

VISION

DSLRs

- Good time response.
- Very well supported, many features.
- Many camera parameters adjustable on the fly.


2.1.4
1:1.4
JAPAN

VISION

Micro Cameras

- Custom drivers
- Proprietary ports


Logitech
Carl Zeiss
Tessar 2.0/3.1
2MP Autofocus

VISION

Webcams

- Bad resolution
- Handled through V4L2
- Poor performance in bad lighting conditions
- Not very adjustable

EXTRA

- Lenses
- Number of cameras

SOFTWARE

OPENCV

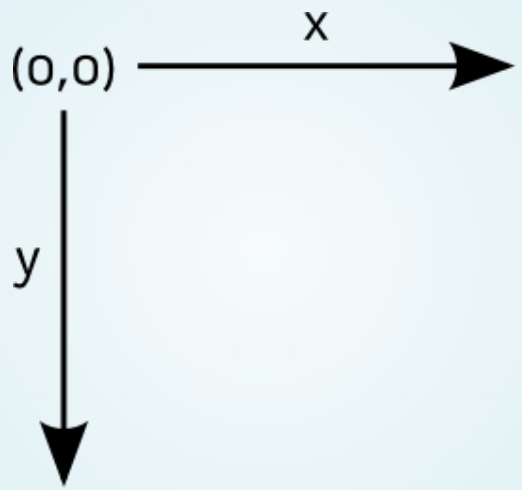
- Open Source
- Known and respected
- C++ powered
- Python bindings
- Low level concepts, hard for newbies
- opencv-processing and others

SIMPLECV

- Built on top of OpenCV using Python
- Not a replacement
- High level concepts and data structures
- It also stands on the shoulders of others giants: numpy, Orange, scipy...
- Well, yeah, it uses camelCase
- simplecv-js

HELLO WORLD

COORDINATES



FEATURE DETECTION

- Edges
- Lines
- Corners
- Circles
- Blobs

BLOB

A region of an image in which some properties are constant or vary within a prescribed range of values.

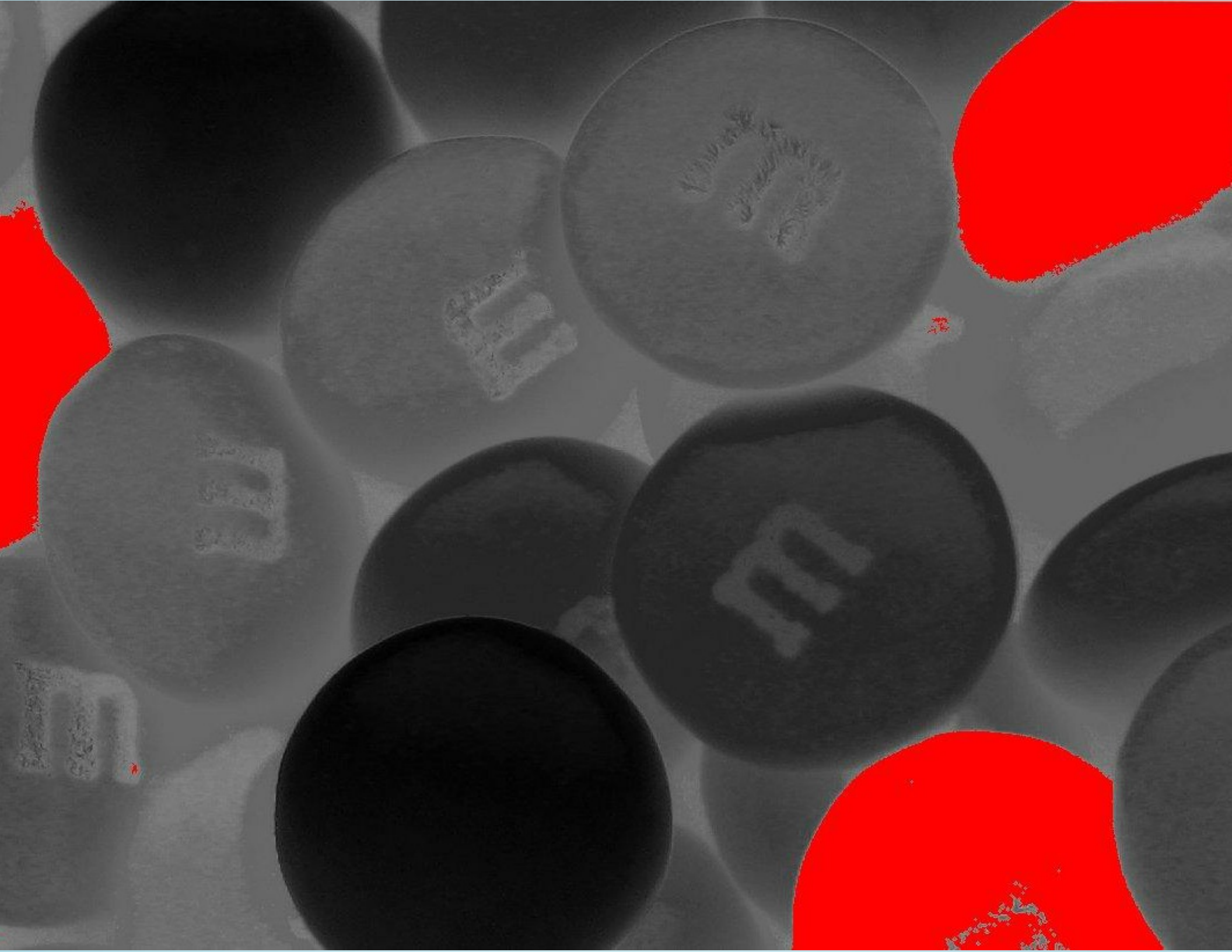
Blue M&Ms are blobs

```
m_and_ms = Image('m&ms.jpg')
blue_dist = m_and_ms.colorDistance(Color.BLUE)
blue_dist.show()
```

BLUE BLOBS

```
blue_dist = blue_dist.invert()
blobs = blue_dist.findBlobs()
print len(blobs)
>> 122

blobs.draw(Color.RED, width=-1)
blue_dist.show()
```



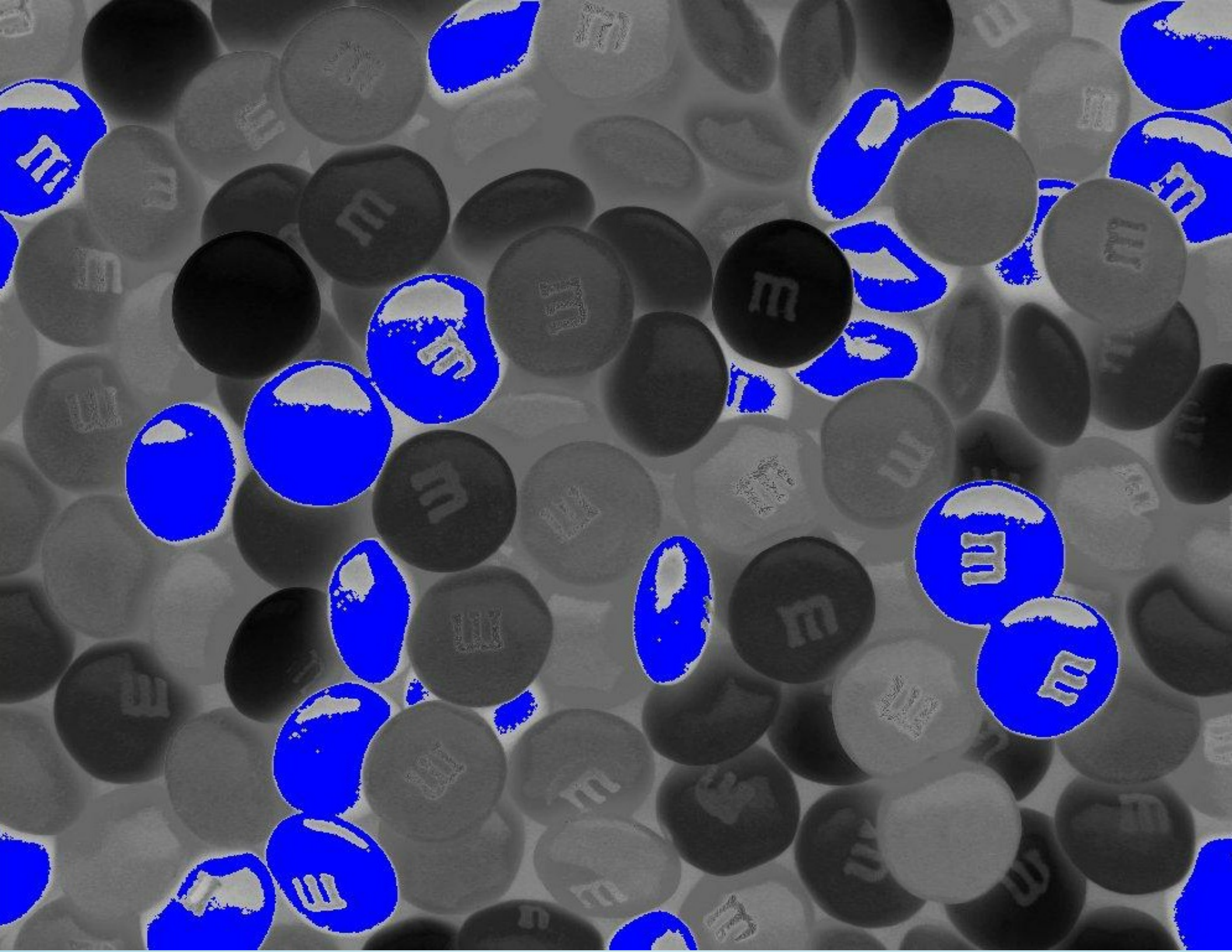
POLISHING IT

findBlobs(minsize, maxsize, threshval, ...)

```
blue_dist.findBlobs(minsize=200)
blobs = blobs.filter(blobs.area() > 200)
len(blobs)
>> 36

average_area = np.average(blobs.area())
>> 37792.77

blue_dist = blue_dist.scale(0.35)
blobs = blue_dist.findBlobs(threshval=177, minsize=100)
len(blobs)
>> 25
```



RULES

- Dynamic is better than fixed, but harder to achieve.
- If color is not needed, drop it, at least until needed.
- The smaller the picture, less information, faster processing.
- Always use the easiest solution, which will usually be the fastest too.
- Real life vs laboratory situations.
- Some things are harder than they look like.
- When working in artificial vision, don't forget about other input sources (time, sounds, etc).

GOLDEN RULE

- Always do in hardware what you can do in hardware.

COLOR SPACES

RGB / BGR

image.toRGB()

HSV (HUE SATURATION VALUE)

image.toHSV()

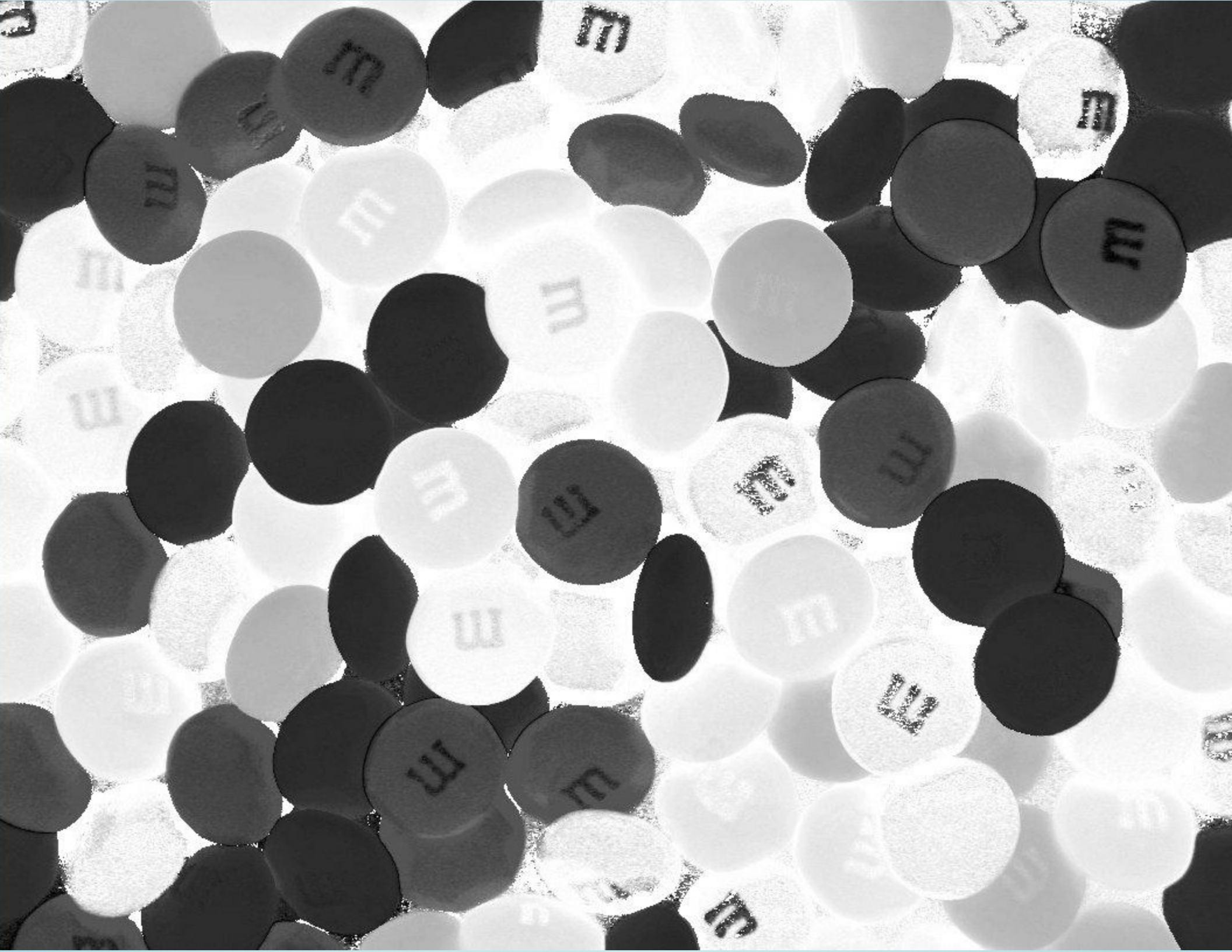
YCBCR

image.toYCbCr()

http://bit.ly/1dSSoI2

HUEDISTANCE

blue_hue_dist = m_and_ms.hueDistance((0,117,245))



IDEAL

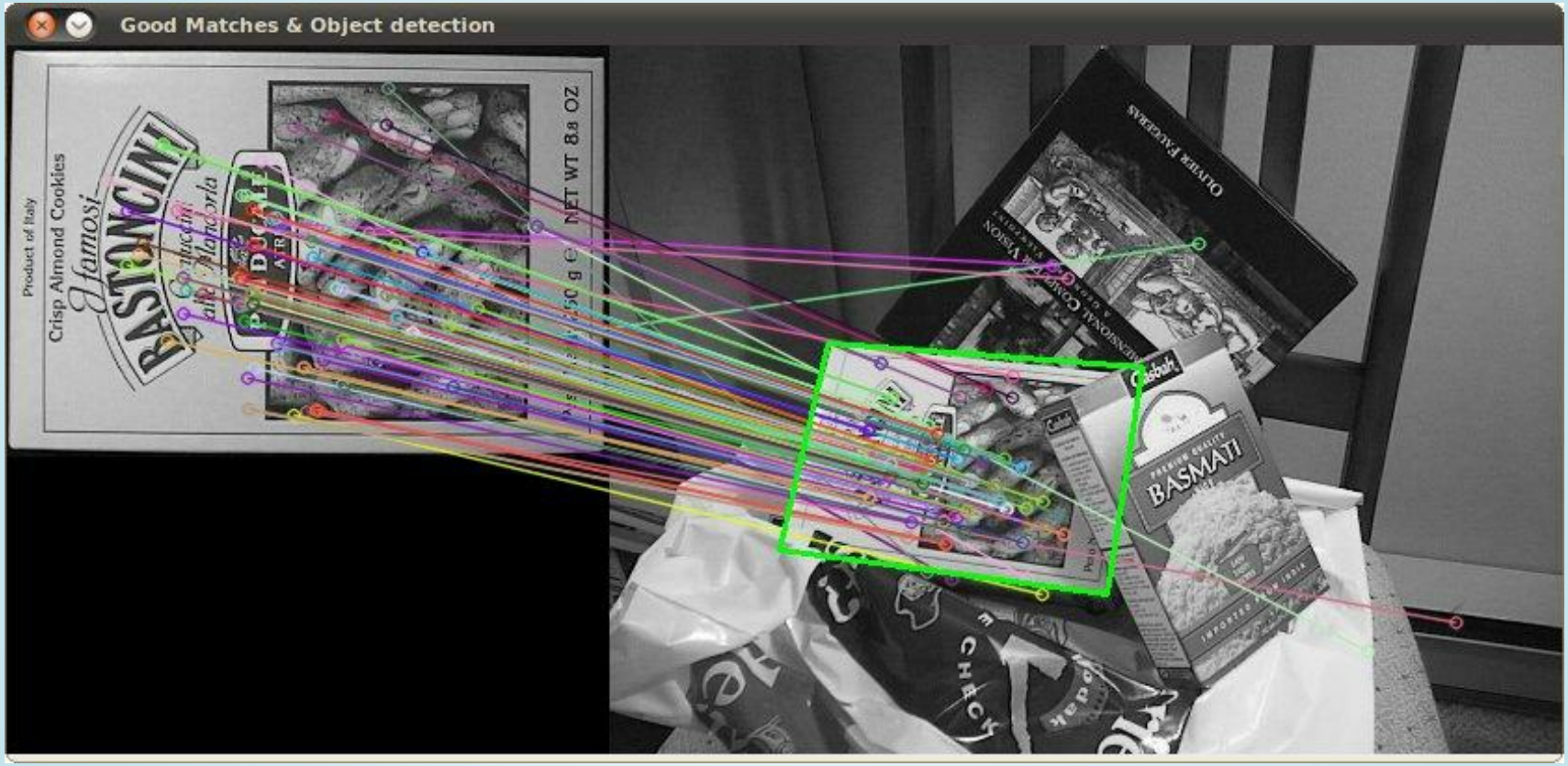
```
blue_hue_dist = m_and_ms.hueDistance(Color.BLUE)
```

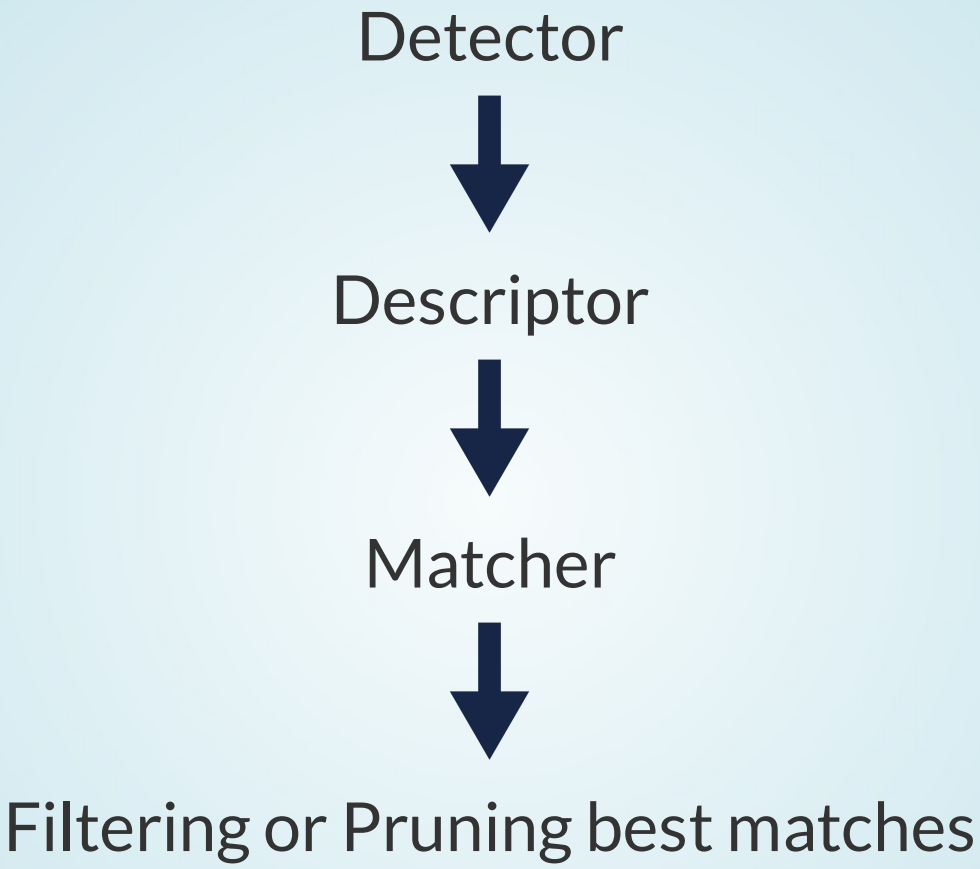
BINARIZE

- Creates a binary (black/white) image. It's got many parameters you can tweak.
- Use Otsu's method by default, adjusting the threshold dynamically for better results.

```
blue_dist.binarize(blocksize=501).show()
```

MATCHING


Good Matches & Object detection
BASTONCINI
Crisp Almond Cookies
Product of Italy
NET WT 8.8 OZ
BASMATI


Detector
Descriptor
Matcher
Filtering or Pruning best matches

DETECTORS

They need to be effective with changes in:

- Viewpoint
- Scale
- Blur
- Illumination
- Noise

DETECTORS

Find ROIs

CORNERS

- Hessian Affine
- Harris Affine
- FAST

KEYPOINTS

- SIFT
- SURF
- MSER
- ORB (Tracking)
- BRISK (Tracking)
- FREAK (Tracking)

MANY MORE

DESCRIPTORS

Speed vs correctness

- SURF
- SIFT
- LAZY
- ORB
- BRIEF
- RIFF
- etc.

MATCHERS

- FLANN
- Brute Force

PRUNING

- Cross-check
- Ratio-Test
- shape overlapping

MATCHING

- Template or Query image (Choose wisely)
- Sample or Train image

```
result_image = sample.drawKeypointMatches(template)
```

```
skp, tkp = sample.findKeypointMatches(template)
```

skp - Keypoints matched in sample
tkp - Keypoints matched in template

FINDKEYPOINTMATCH

- Detection: Hessian affine
- Description: SURF
- Matching: FLANN Knn
- Filtering: Lowe's ratio test
- find an Homography
- Returns a FeatureSet with one KeypointMatch

TEMPLATE

MANUFACTURER'S COUPON EXPIRES

LIMIT ONE COUPON PER CUSTOMER

Dole

Eat Bright
Eat Right

Lemon Blueberry Chicken Salad

(recipe on back)

MANUFACTURER'S COUPON EXPIRES 4/30/13

LIMIT ONE COUPON PER CUSTOMER

Dole

SAVE 75¢

on any ONE (1) DOLE® Salad Blend, All Natural Salad Kit or Extra Veggie™ Salad

(Excludes DOLE® Classic Iceberg, Shreds and non-kit Coleslaws)


SAMPLE
SAVE $1
fiora
DELALLO
$1.00 OFF
any 2 bags of Whole Wheat Pasta
$1.00 off
APPLEGATE
ROUSES
SAVE 75¢
on any two (2) Mrs. Cubbison's® Salad Toppings
Dole
Eat Bright
Eat Right
Lemon Blueberry Chicken Salad
(recipe on back)
Dole
SAVE 75¢
on any ONE (1) DOLE® Salad Blend, All Natural Salad Kit or Extra Veggie™ Salad
(Excludes DOLE® Classic Iceberg, Shreds and non-kit Coleslaws)
WHOLE FOODS MARKET
PLU: 606674 Expires 5/31/13
Redeemable only at Whole Foods Market®
$1.00 off
any ONE (1) 10-oz (6-ct) GlutenFree Bakehouse® Cream Biscuits
Limit one coupon per purchase of specified product(s) per individual. Void if altered, transferred, reproduced, exchanged, sold, purchased, or where prohibited or restricted by law. No monetary value. Valid only in the U.S.A. Expires 5/31/13.
$1.00 off
any ONE (1) 1.75-lb Wellshire Virginia Ham Nuggets or Black Forest Ham
$1.50 off
any ONE (1) Seeds of Change Product
SEEDS of CHANGE
SPECIAL LIMITE
$.25 off one
64 oz. bottle
of evamor
Redeemable only at Whole Foods Market® Expires 05/31/13
$1.00 off
any ONE (1) Organic Valley Cottage Cheese
ORGANIC VALLEY
FARMER-OWNED

FINDKEYPOINTMATCH

```
coupons = Image("coupons.jpg")
coupon = Image("coupon.jpg")
match = coupons.findKeypointMatch(coupon)
match.draw(width=10, color=Color.GREEN)
uno.save("result.jpg")
```


SAVE $1
ON ANY FIORA 12 ROLL BATH TISSUE OR 8 ROLL PAPER TOWELS
fiora
DELALLO
$1.00 OFF
any 2 bags of Whole Wheat Pasta
Dole
Eat Bright
Eat Right
Lemon Blueberry Chicken Salad
(recipe on back)
Dole
SAVE 75¢
on any ONE (1) DOLE® Salad Blend, All Natural Salad Kit or Extra Veggie™ Salad
(Excludes DOLE® Classic Iceberg, Shreds and non-kit Coleslaws)
$1.00 off
any ONE (1) 10.5-oz Applegate Family Pack
APPLEGATE
SAVE 75¢
on any two (2) Mrs. Cubbison's® Salad Toppings
MANUFACTURER COUPON
WHOLE FOODS MARKET
PLU: 606674 Expires 5/31/13
Redeemable only at Whole Foods Market®
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SEEDS of CHANGE
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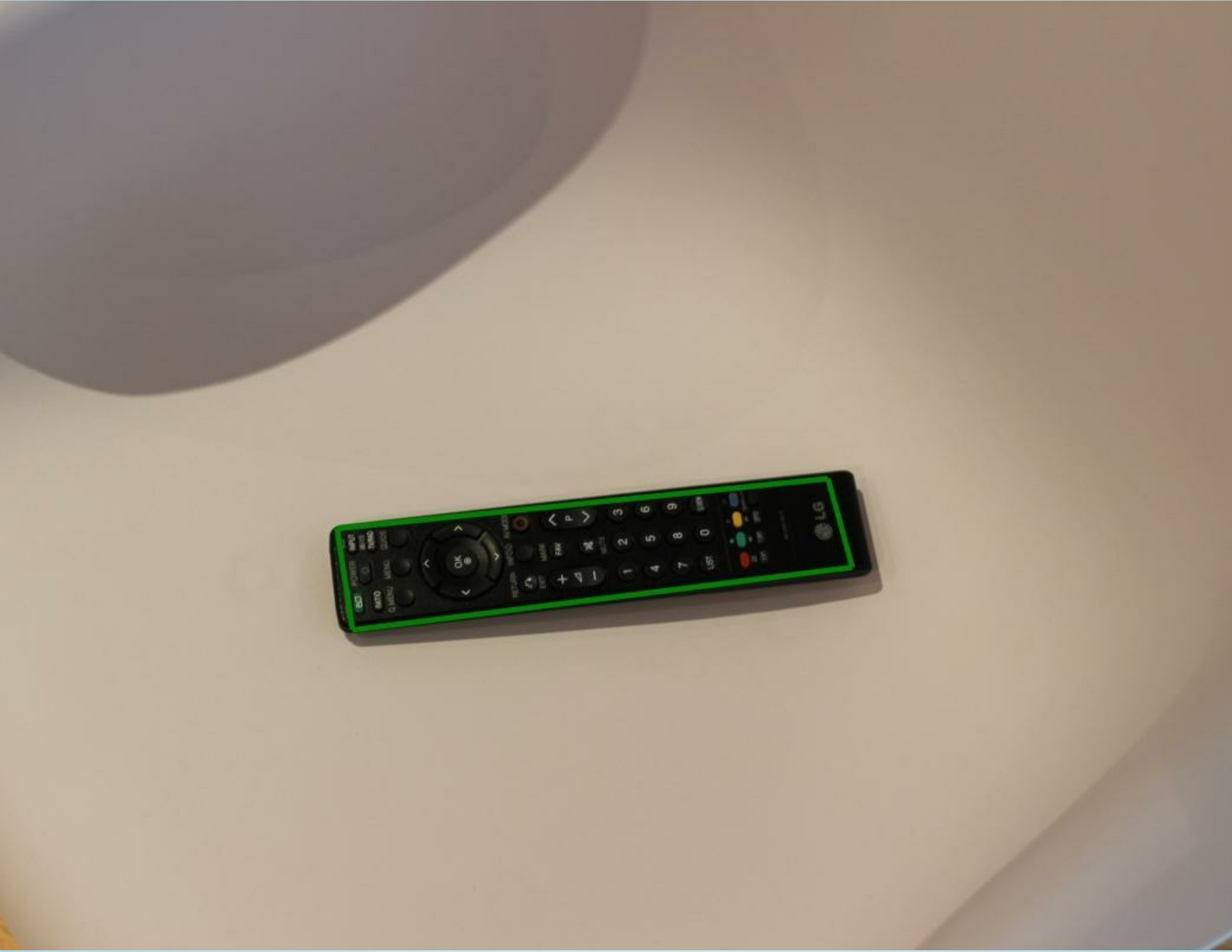
SPECIAL LIMITE
$.25 off one
64 oz. bottle
of evamor
$1.00 off
any ONE (1) Organic Valley Cottage Cheese
ORGANIC VALLEY
FARMER-OWNED

2ND EXAMPLE

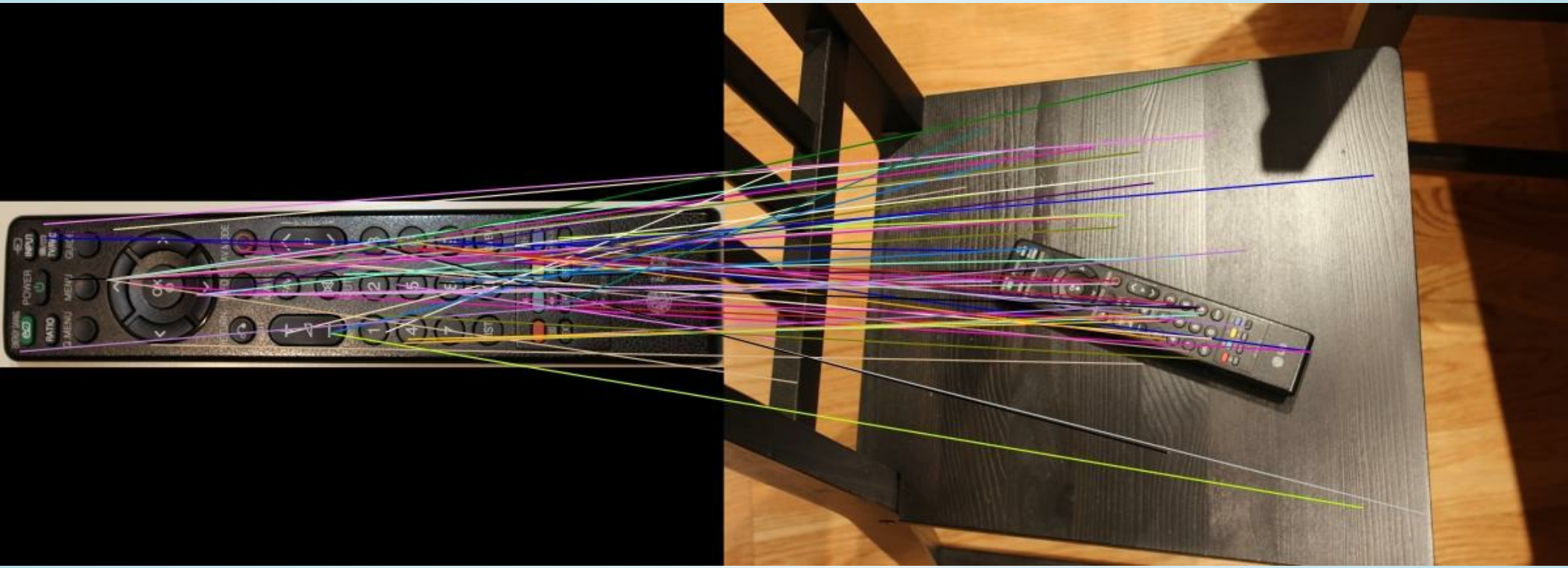

INPUT
TV/RAD
GUIDE
POWER
MENU
RATIO
Q.MENU
OK
AV MODE
INFO
MARK
FAV
MUTE
RETURN
EXIT
P
3
6
9
Q.VIEW
2
5
8
0
1
4
7
LIST
SUBTITLE
T.OPT
TEXT


LG
OK


POWER
INPUT
TV/RAD
OK
MENU
AV MODE
MARK
FAV
RETURN
EXIT
LIST
LG


FAILS

MANY OUTLIERS

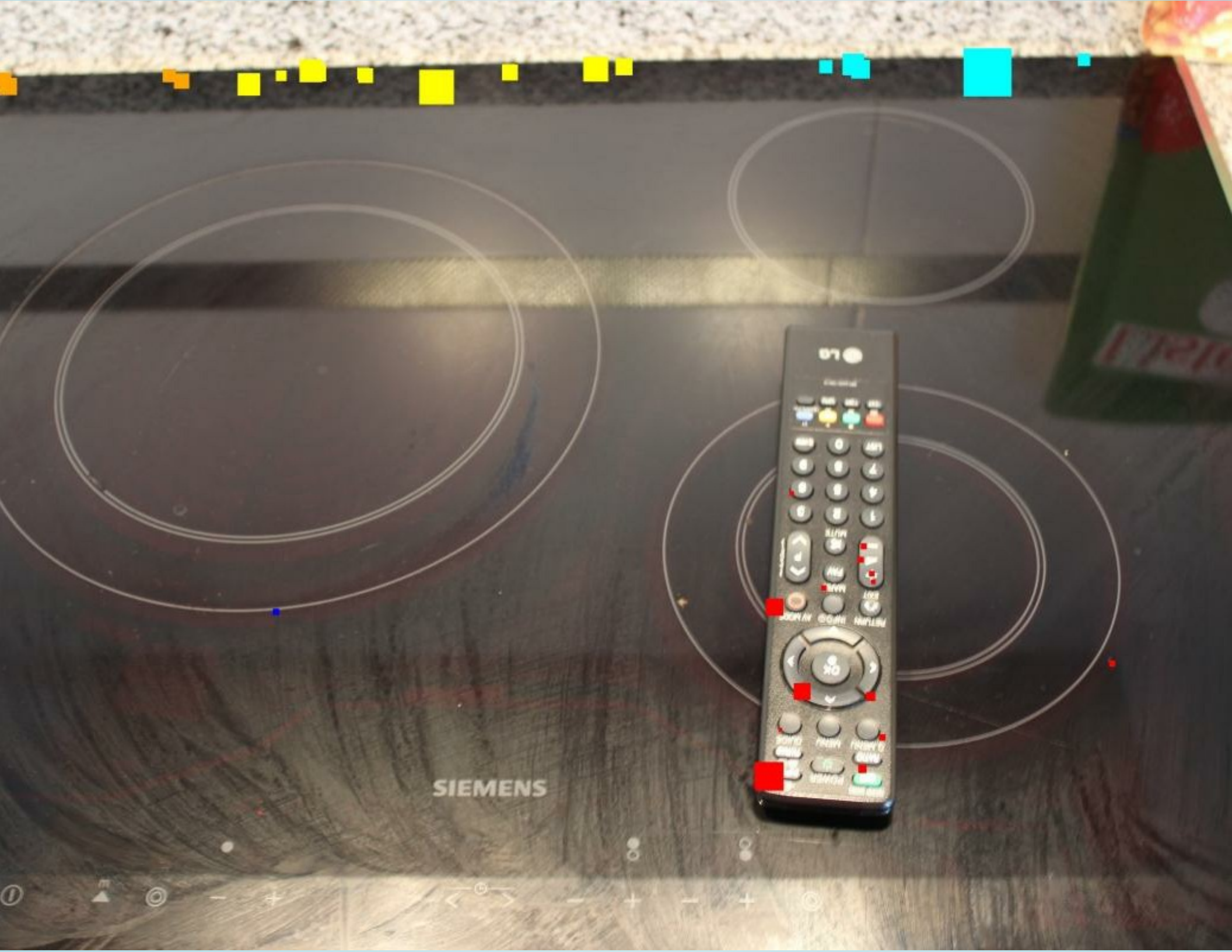


CLUSTERING

```
def find_clusters(keypoints, separator=None):
    features = FeatureSet(keypoints)
    if separator is None:
        separator = np.average(features.area())

    features = features.filter(
        features.area() > separator
    )
    return features.cluster(
        method="hierarchical",
        properties="position"
    )
```

BIGGEST CLUSTER

```
def find_biggest_cluster(clusters):
    max_number_of_clusters = 0
    for cluster in clusters:
        if len(cluster) > max_number_of_clusters:
            biggest_cluster = cluster
            max_number_of_clusters = len(cluster)

return biggest_cluster
```


SIEMENS


POWER
MENU
OK
LG

NORMAL DISTRIBUTION

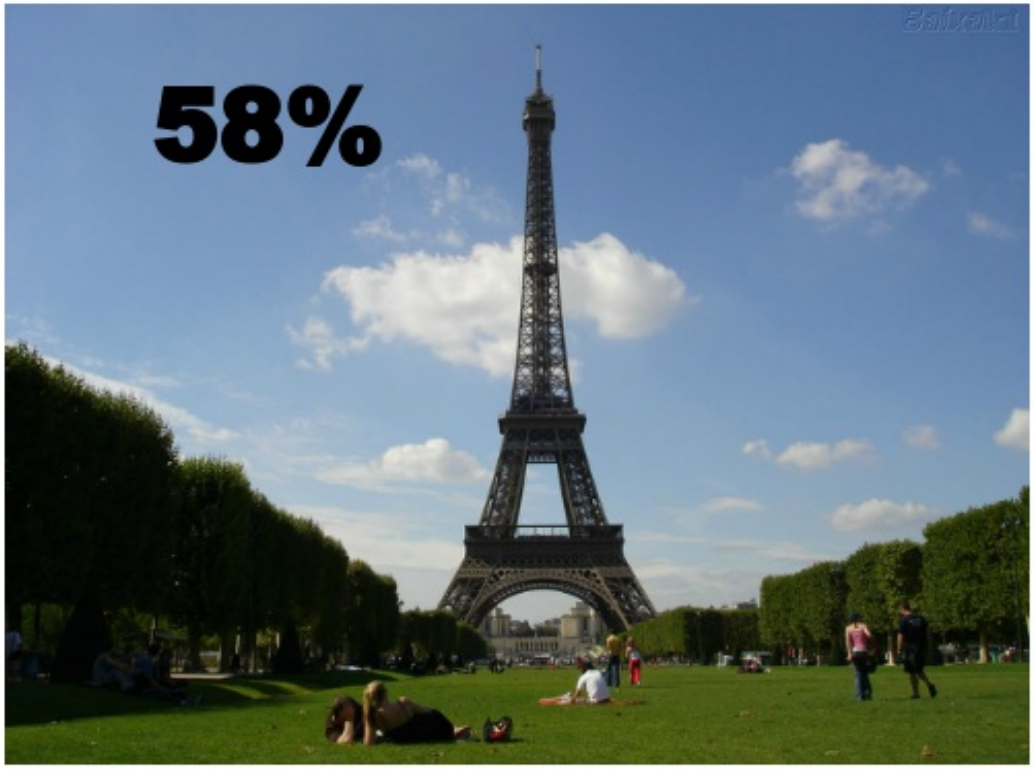
```
Point = namedtuple('Point', 'x y')
def distance_between_points(point_one, point_two):
    return sqrt(
        pow((point_one.x - point_two.x), 2) + \
        pow((point_one.y - point_two.y), 2)
    )

skp_set = FeatureSet(biggest_cluster)
x_avg, y_avg = find_centroid(skp_set)
centroid = Point(x_avg, y_avg)
uno.drawRectangle(
    x_avg, y_avg, 20, 20, width=30, color=Color.RED
)
```

NORMAL DISTRIBUTION

```
distances = []
for kp in biggest_cluster:
    distances.append(distance_between_points(kp, centroid))

mu, sigma = cv2.meanStdDev(np.array(distances))
mu = mu[0][0]
sigma = sigma[0][0]

for kp in skp:
    if distance_between_points(kp, centroid) < (mu + 2*sigma):
        uno.drawRectangle(
            kp.x, kp.y, 20, 20, width=30, color=Color.GREEN
        )
```

NORMAL DISTRIBUTION

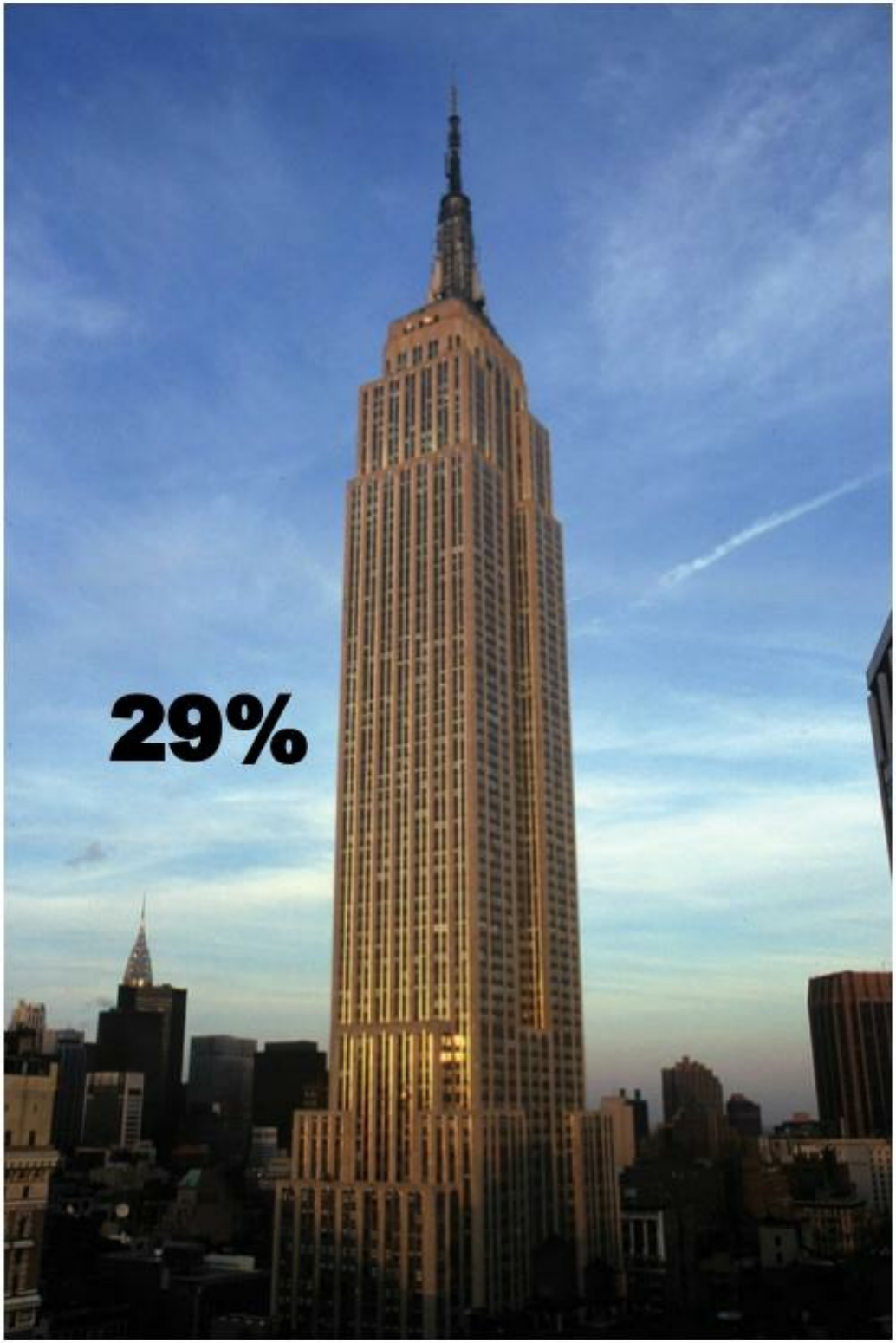
REAL WORLD EXAMPLE


58%


26%


29%


48%


29%


23%
HAPPY NEW YEAR!
Live Your Life IN 2012
NIVEA

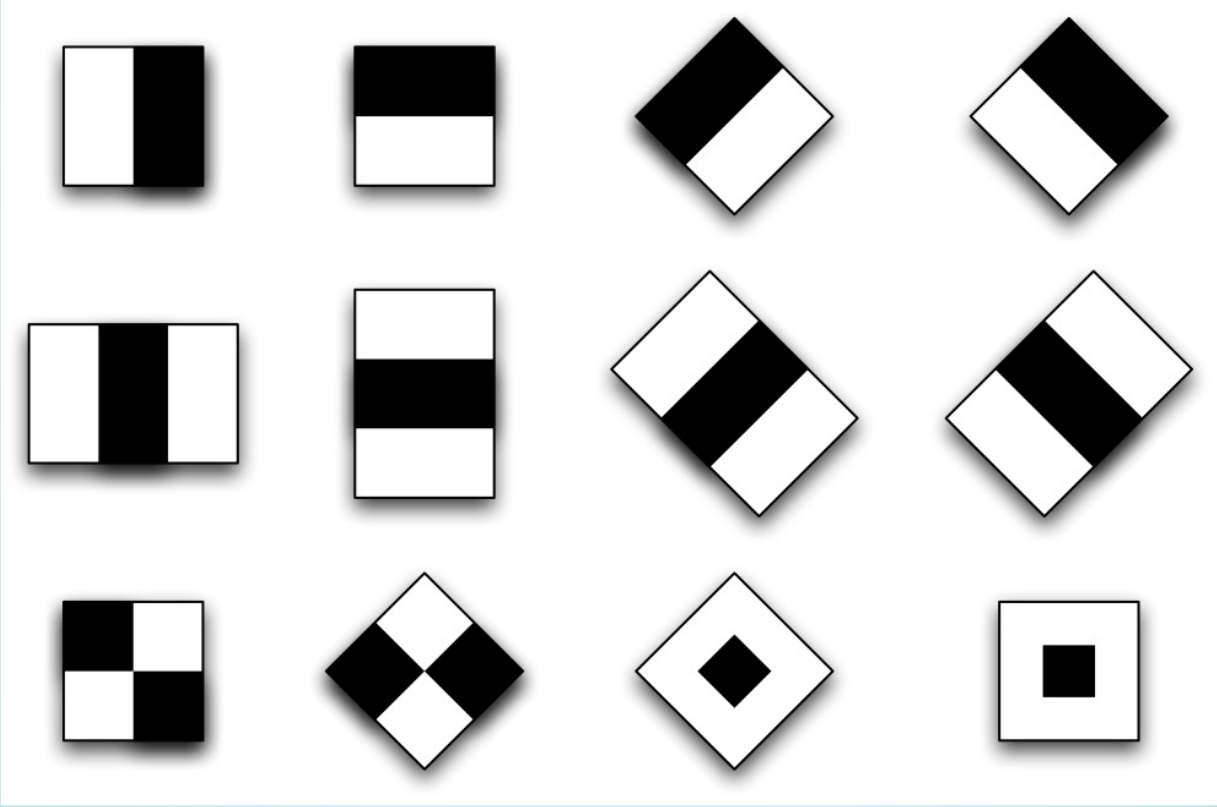

21%

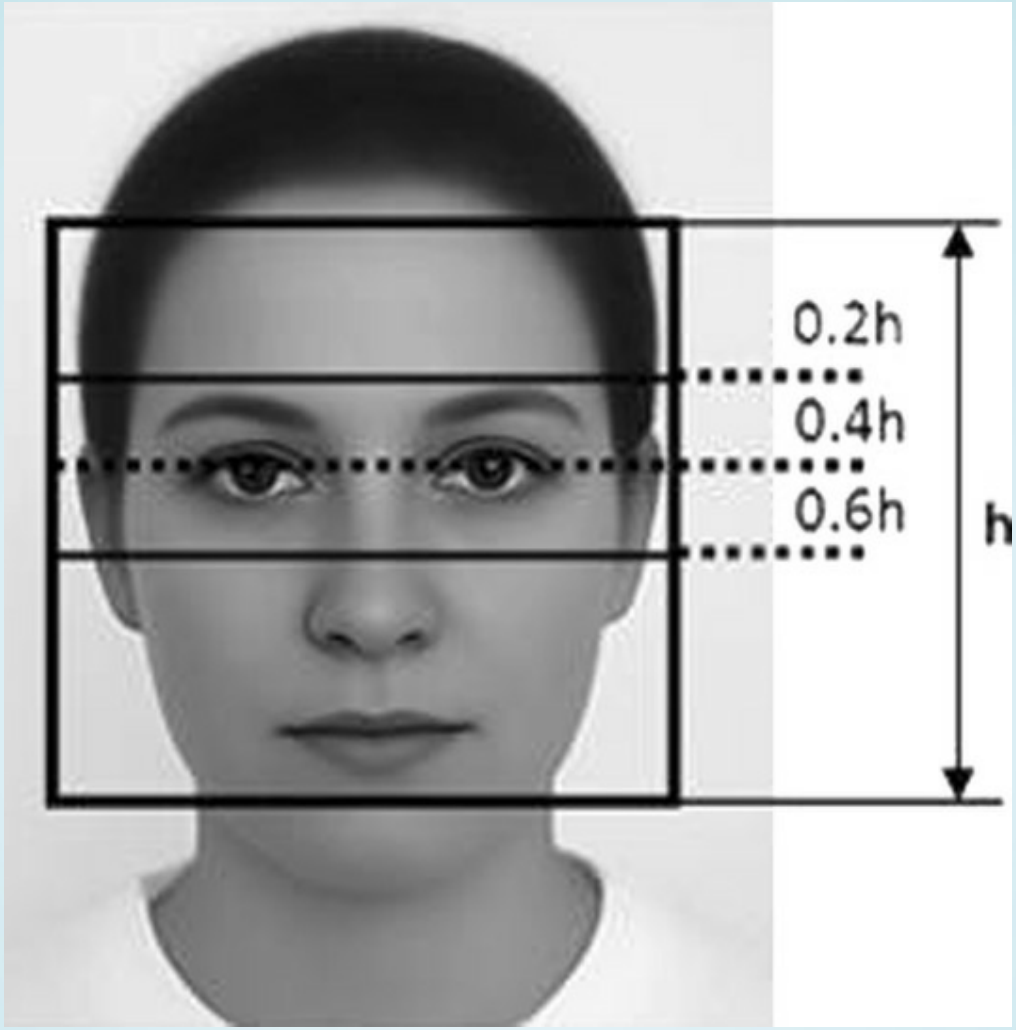
DETECTION

HAAR

FACE DETECTION

Haar-like features 2001 Viola-Jones




0.2h
0.4h
0.6h
h

HAAR

- Needs to be trained with hundreds/thousands
- Scale invariant
- NOT Rotation invariant
- Fast and robust
- Not only for faces

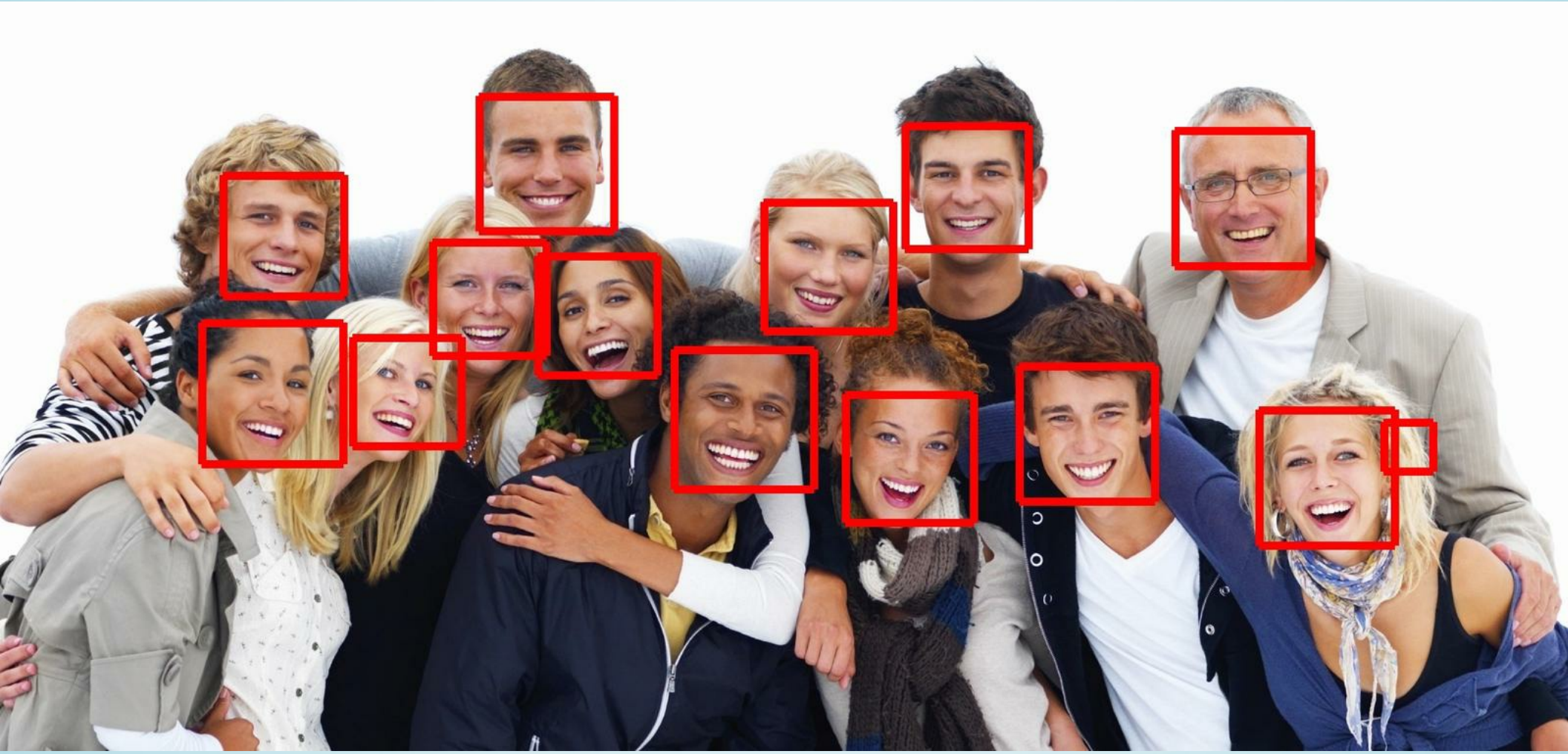
How face detection works

HAAR

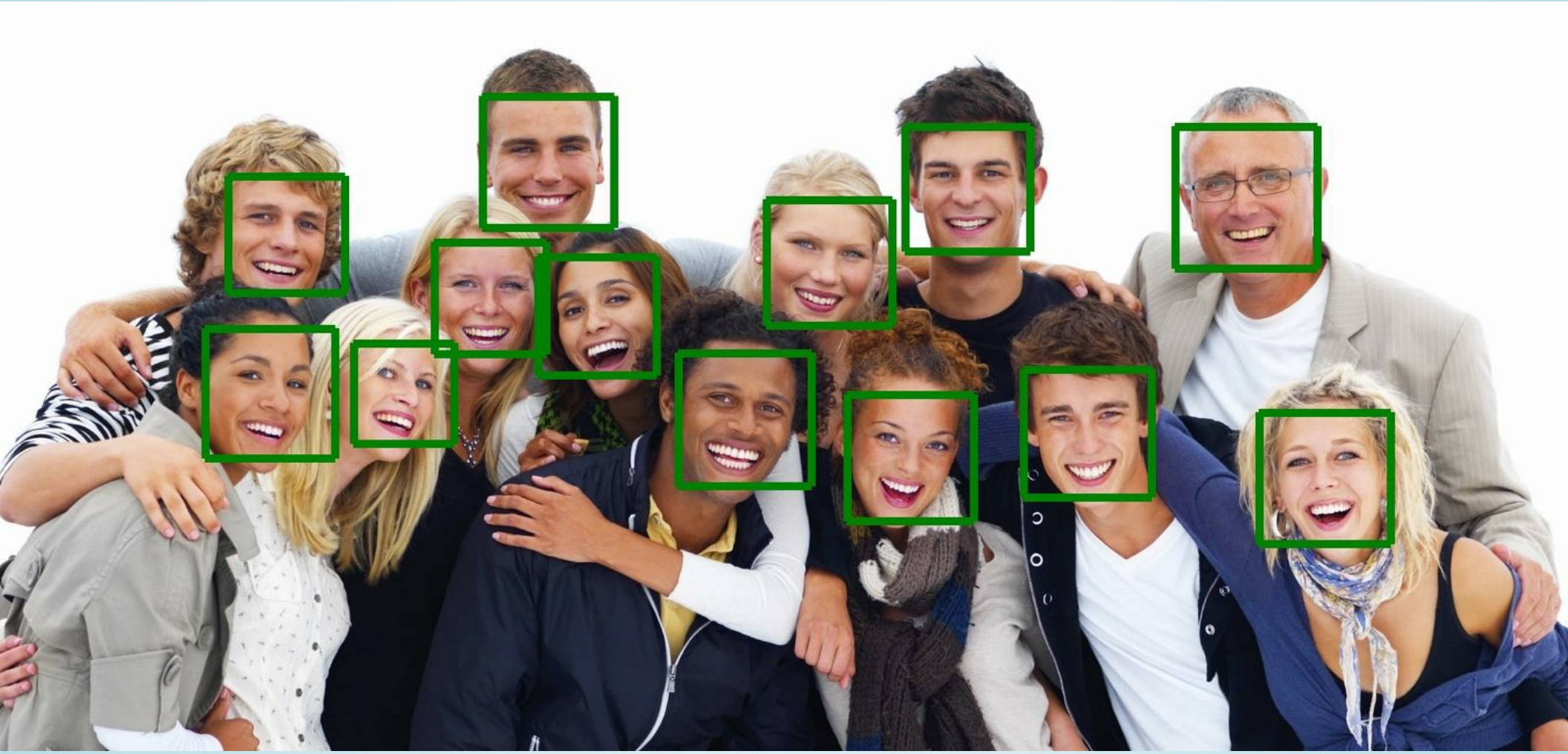
```
friends.listHaarFeatures()
['right_ear.xml', 'right_eye.xml', 'nose.xml', 'face4.xml', 'glasses.xml',
```

```
faces = friends.findHaarFeatures("face.xml")
faces.draw(width=10, color=Color.RED)
faces.save('result.jpg')
```

1 MISS FACE.XML



FACE2.XML



VIDEO DEMO

http://www.youtube.com/watch?v=VP3h8qf9GZ4

TRACKING

TRACKING

- Detection != tracking
- Uses information from previous frames
- Initially tracks what we want

SOME ALTERNATIVES

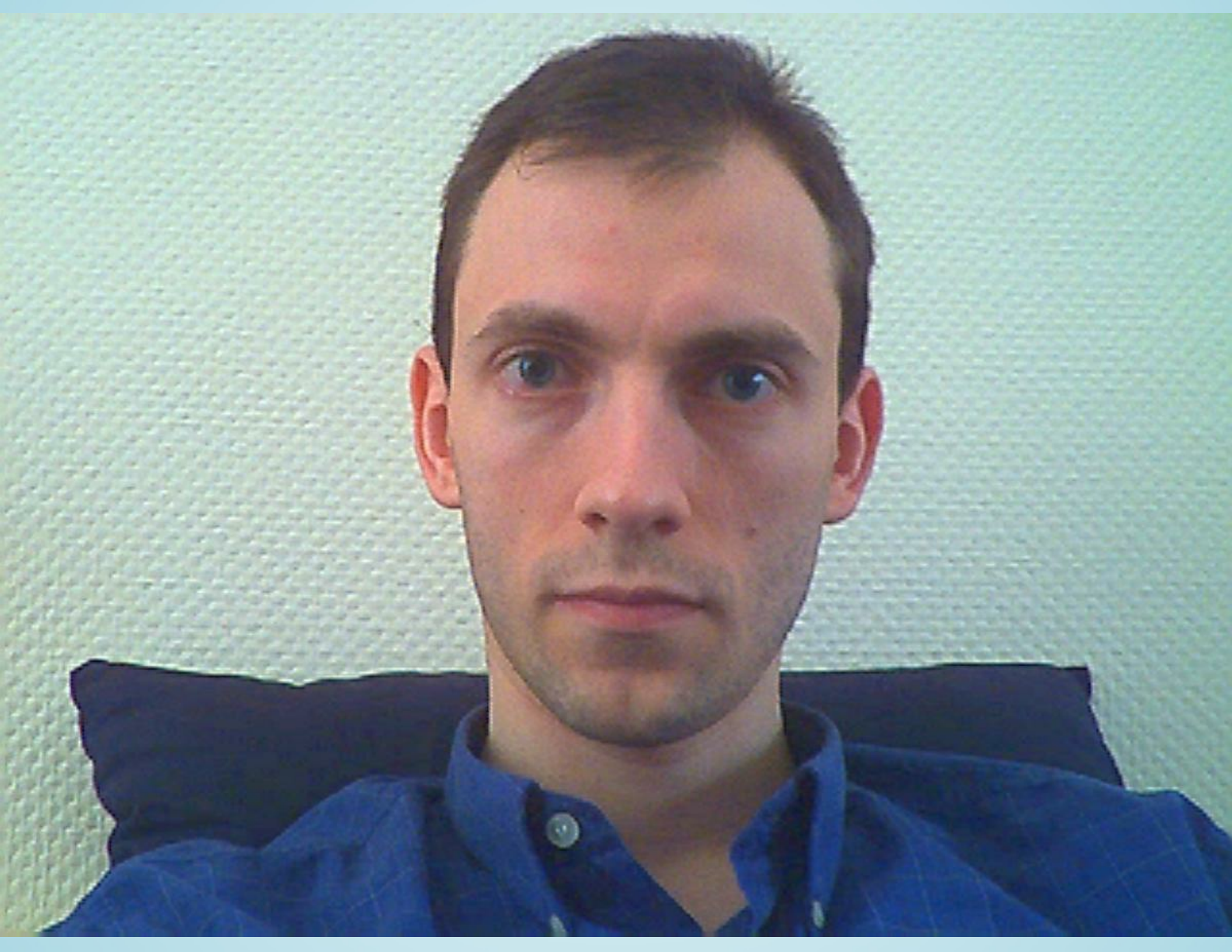
- Optic Flow: Lucas-Kanade
- Descriptors: SURF
- Probability/Statistics and histograms: Camshift

CAMSHIFT

- Effective for tracking simple and constant objects with homogeneous colors, like faces.
- Gary Bradski in 1998
- Original implementation has problems with similar color objects around or crossing trajectories and lightning changes.

SIMPLE EXAMPLE

```
from SimpleCV import *

video = VirtualCamera("jack.mp4", 'video')
video_stream = VideoStream(
    "jack_tracking.mp4", framefill=False, codec="mp4v"
)

track_set = []
current = video.getImage()

while (disp.isNotDone()):
    frame = video.getImage()
    track_set = frame.track(
        'camshift', track_set, current, [100, 100, 50, 50]
    )
    track_set.drawBB()
    current = frame
    frame.save(video_stream)
```



VIDEO DEMO

http://www.youtube.com/watch?v=QHOYG_CYPKo

MORE COMPLEX

Initialization

```
video_stream = VideoStream(
    "jack_tracking.avi", framefill=False,
    codec="mp4v"
)
video = VirtualCamera("jack.mp4", 'video')

disp = Display()

detected = False
current = video.getImage().scale(0.6)
tracked_objects = []
last_diff = None
```

```
while (disp.isNotDone()):
    frame = video.getImage().scale(0.6)

    # Scene changes
    diff = cv2.absdiff(frame.getNumpyCv2(), current.getNumpyCv2())
    if last_diff and diff.sum() > last_diff * 6:
        detected = False
    last_diff = diff.sum()

    # Detects faces and restarts tracking
    faces = frame.findHaarFeatures('face2.xml')
    if faces and not detected:
        tracked_objects = []
        final_faces = []
        for face in faces:
            if face.area() > 65:
                tracked_objects.append([])
                final_faces.append(face)
                detected = True
```

```
# Restart if tracking grows too much
if detected:
    for i, track_set in enumerate(tracked_objects):
        track_set = frame.track(
            'camshift', track_set, current,
            final_faces[i].boundingBox()
        )

        # Restart detection and tracking
        if track_set[-1].area > final_faces[i].area() * 3 \
            or not detected:
                detected = False
                break

        # Update tracked object and draw it
        tracked_objects[i] = track_set
        track_set.drawBB()

current = frame
frame.save(video_stream)
```

MOG

BACKGROUND SUBSTRACTION

- Separate people and objects that move (foreground) from the fixed environment (background)
- MOG - Adaptative Mixture Gaussian Model

VIDEO DEMO

http://www.youtube.com/watch?v=wm7HWdYSYkI

BACKGROUND SUBSTRACTION

```
mog = MOGSegmentation(
    history=200, nMixtures=5, backgroundRatio=0.3, noiseSigma=16,
    learningRate=0.3
)

video = VirtualCamera('semaforo.mp4', 'video')
video_stream = VideoStream("mog.mp4", framefill=False, codec="mp4v")

while (disp.isNotDone()):
    frame = video.getImage().scale(0.5)

    mog.addImage(frame)
    # segmentedImage = mog.getSegmentedImage()
    blobs = mog.getSegmentedBlobs()
    if blobs:
        blobs.draw(width=-1)

    frame.save(video_stream)
```

RED-LIGHT HAL

RED LIGHT RUNNERS

1- Detect if traffic light is red, otherwise it's green. Using hysteresis.
2- Project a line for runners.
3- Do MOG and pruning for finding cars.
4- When traffic light is RED, if a car blob intersects the line, then it's a runner.
5- Recognize car to count it only once.

```
red_light_bb = [432, 212, 13, 13]
cross_line = Line(
    frame.scale(0.5), ((329, 230), (10, 360))
)

RED = False
number_of_opposite = 0
HISTERESIS_FRAMES = 5
```

```
def is_traffic_light_red(frame):
    red_light = frame.crop(*red_light_bb)

    # BLACK (30, 28, 35)
    # RED  (21, 17, 51)
    if red_light.meanColor()[2] > 42:
        return True

    return False
```

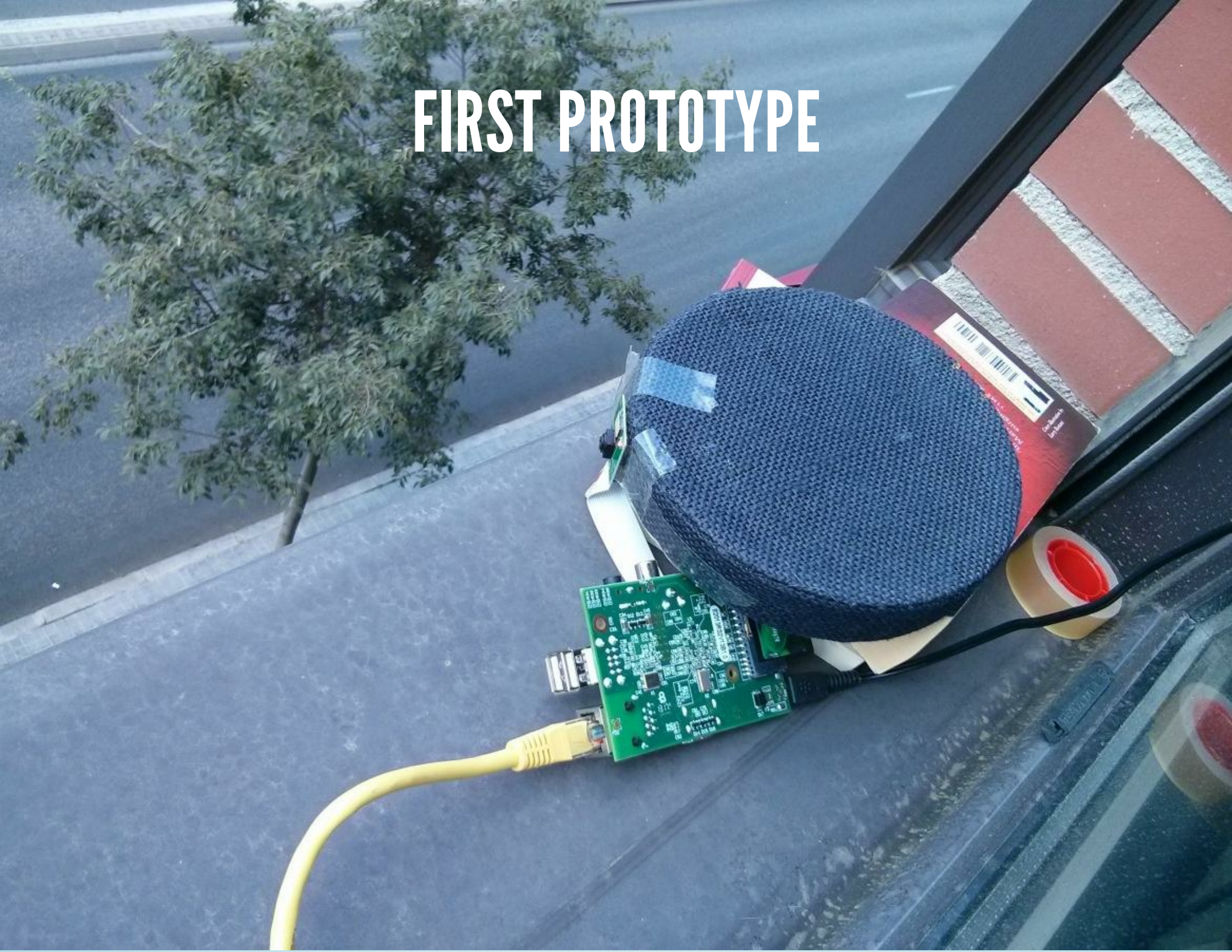
```
def hysteresis(red_detected=False, green_detected=False):
    global RED, number_of_opposite

    if RED and green_detected:
        number_of_opposite += 1
        if number_of_opposite == HISTERESIS_FRAMES:
            RED = False
            number_of_opposite = 0
    elif not RED and red_detected:
        number_of_opposite += 1
        if number_of_opposite == HISTERESIS_FRAMES:
            RED = True
            number_of_opposite = 0
    else:
        number_of_opposite = 0
```

```
while (disp.isNotDone()):
    frame = video.getImage()
    small_frame = frame.scale(0.5)
    mog.addImage(small_frame)

    if is_traffic_light_red(frame):
        hysteresis(red_detected=True)
        if RED:
            blobs = mog.getSegmentedBlobs()
            if blobs:
                big_blobs = blobs.filter(blobs.area() > 1000)

                for car in big_blobs:
                    if cross_line.intersects(car.getFullMask()):
                        # RED LIGHT RUNNER
                        small_frame.drawRectangle(
                            *car.boundingBox(), color=Color.RED, width=3
                        )
    else:
        hysteresis(green_detected=True)

    small_frame.save(disp)
```

VIDEO DEMO

http://www.youtube.com/watch?v=RfG0HTiuBYY

FIRST PROTOTYPE



RASPBERRY

- Raspberry SimpleCV Raspicam
- Autonomous system, ethernet connected, uploads runner videos online.
- No night time support yet.
- Slower, not real time, discards green parts.

THANKS

QUESTIONS?