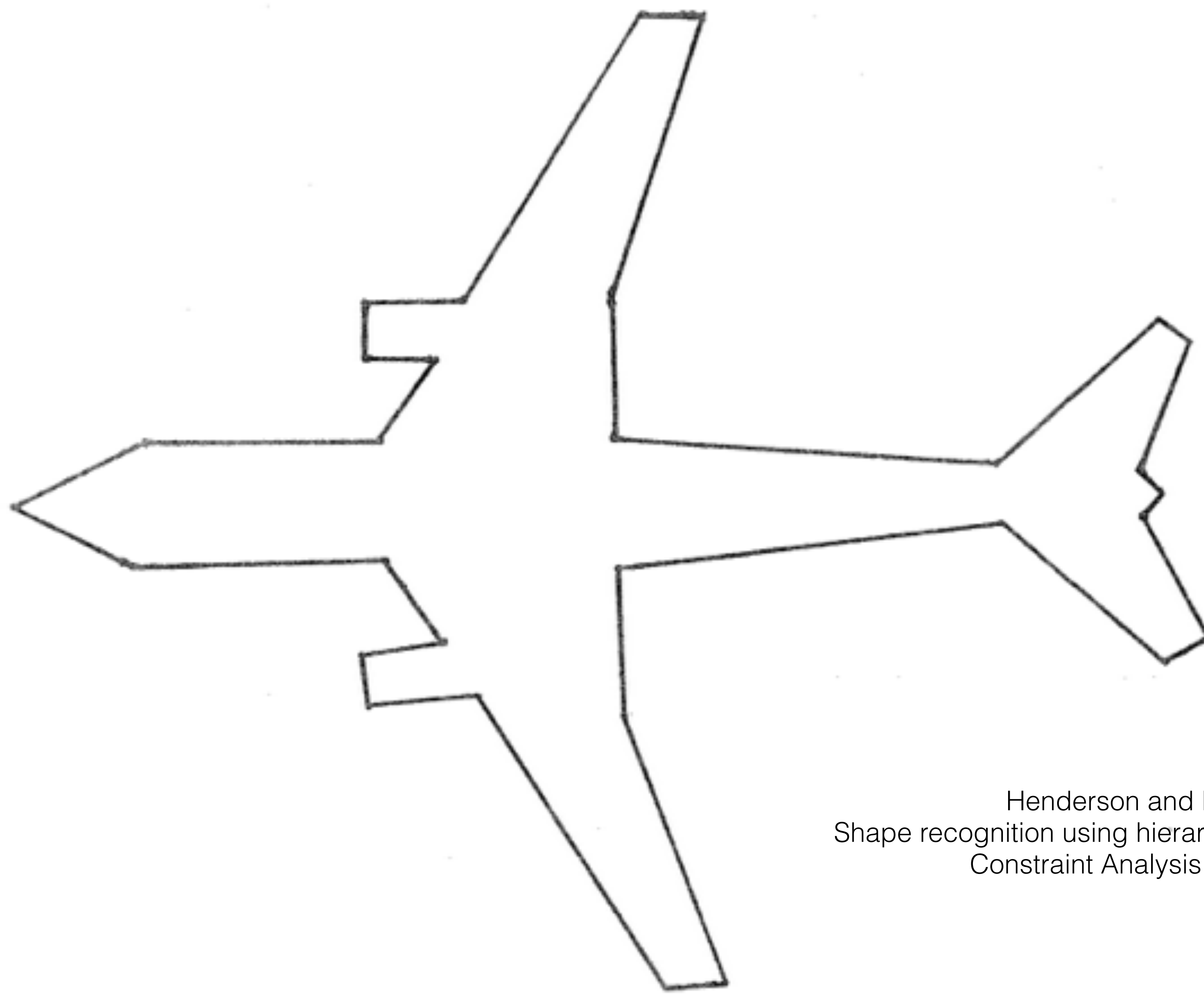


Henderson and Davis.
Shape recognition using hierarchical
Constraint Analysis. 1979

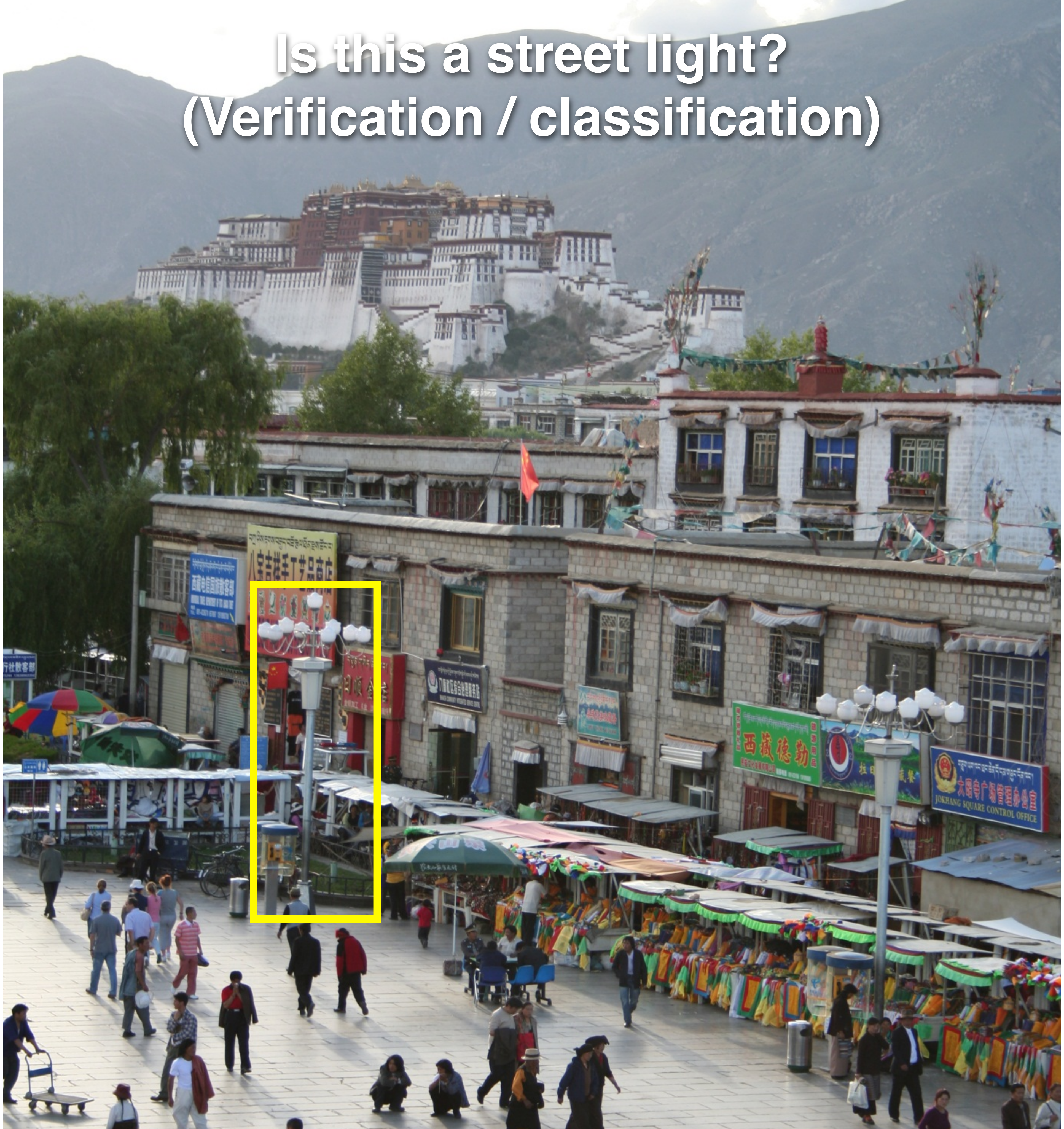
Object Recognition

16-385 Computer Vision (Kris Kitani)

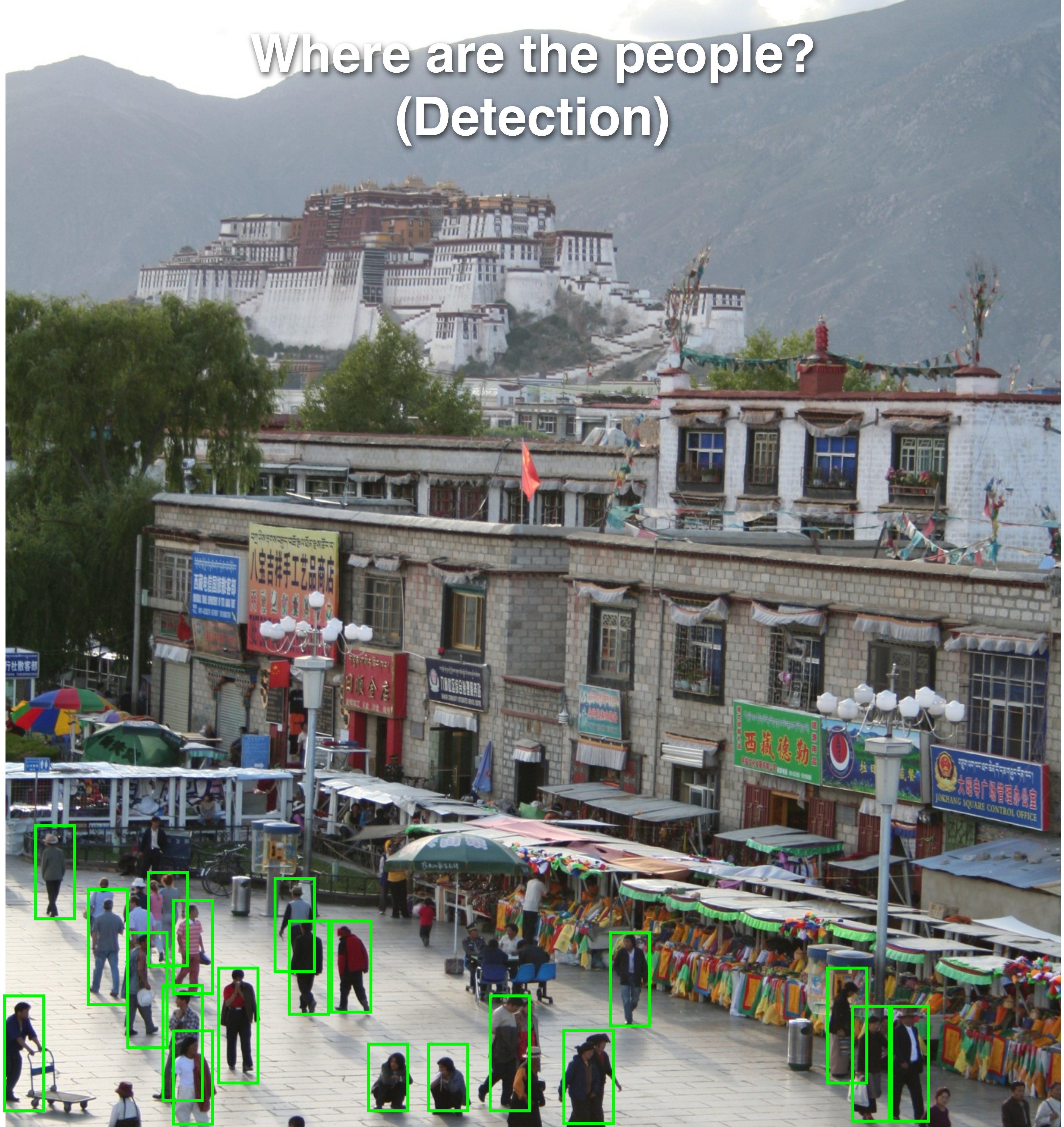
Carnegie Mellon University

What do we mean by ‘object recognition’?

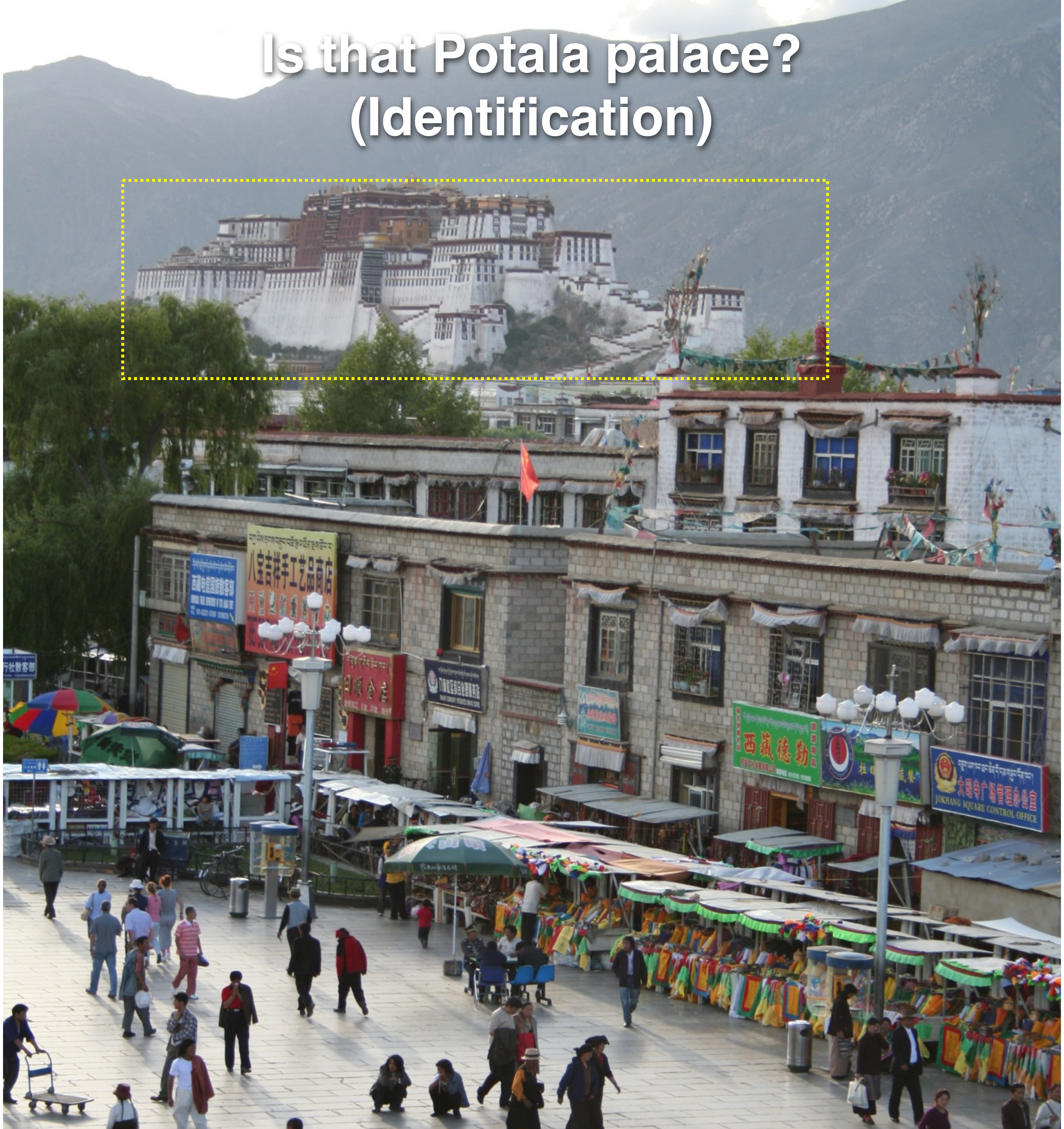
Is this a street light?
(Verification / classification)



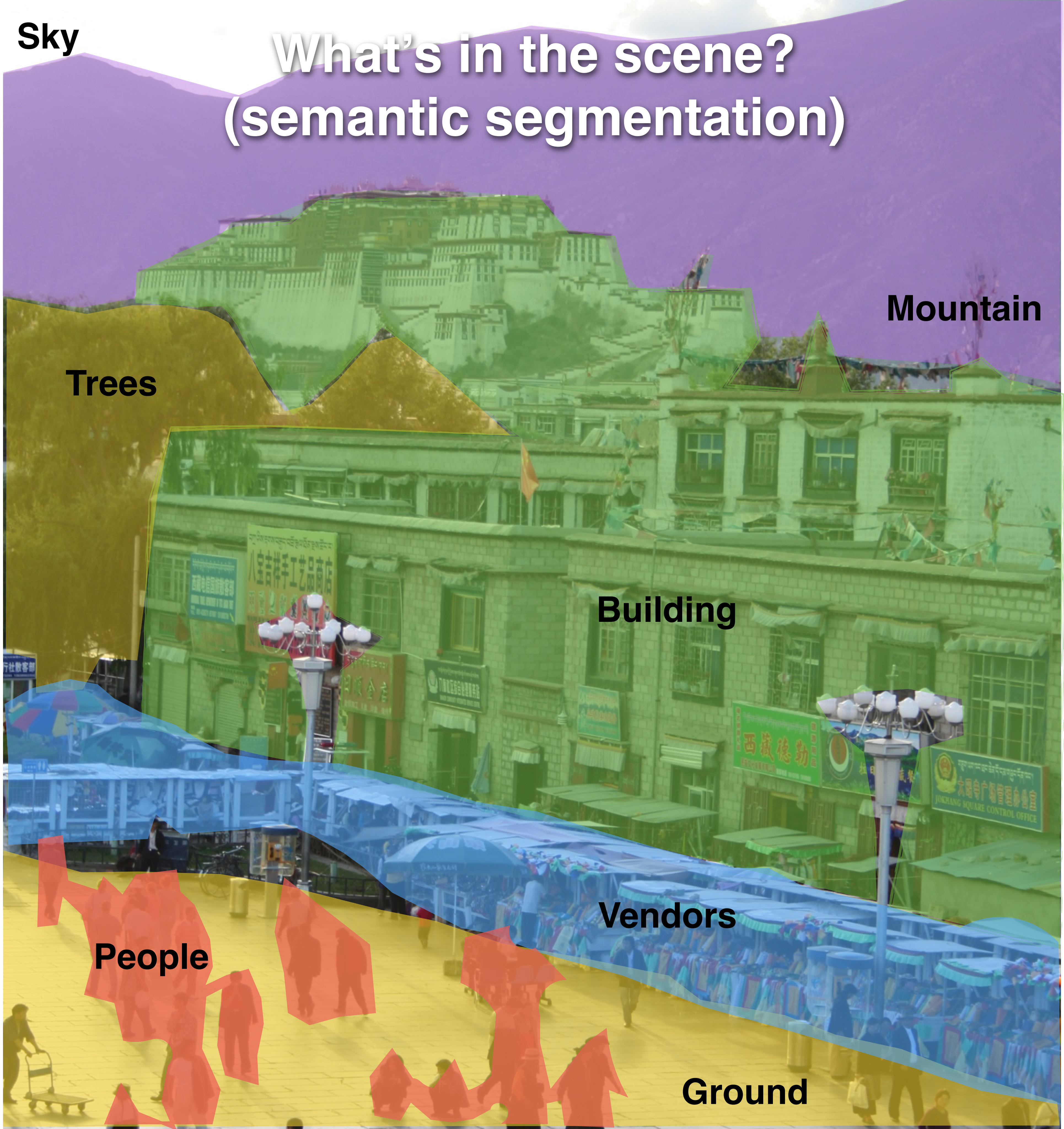
Where are the people?
(Detection)



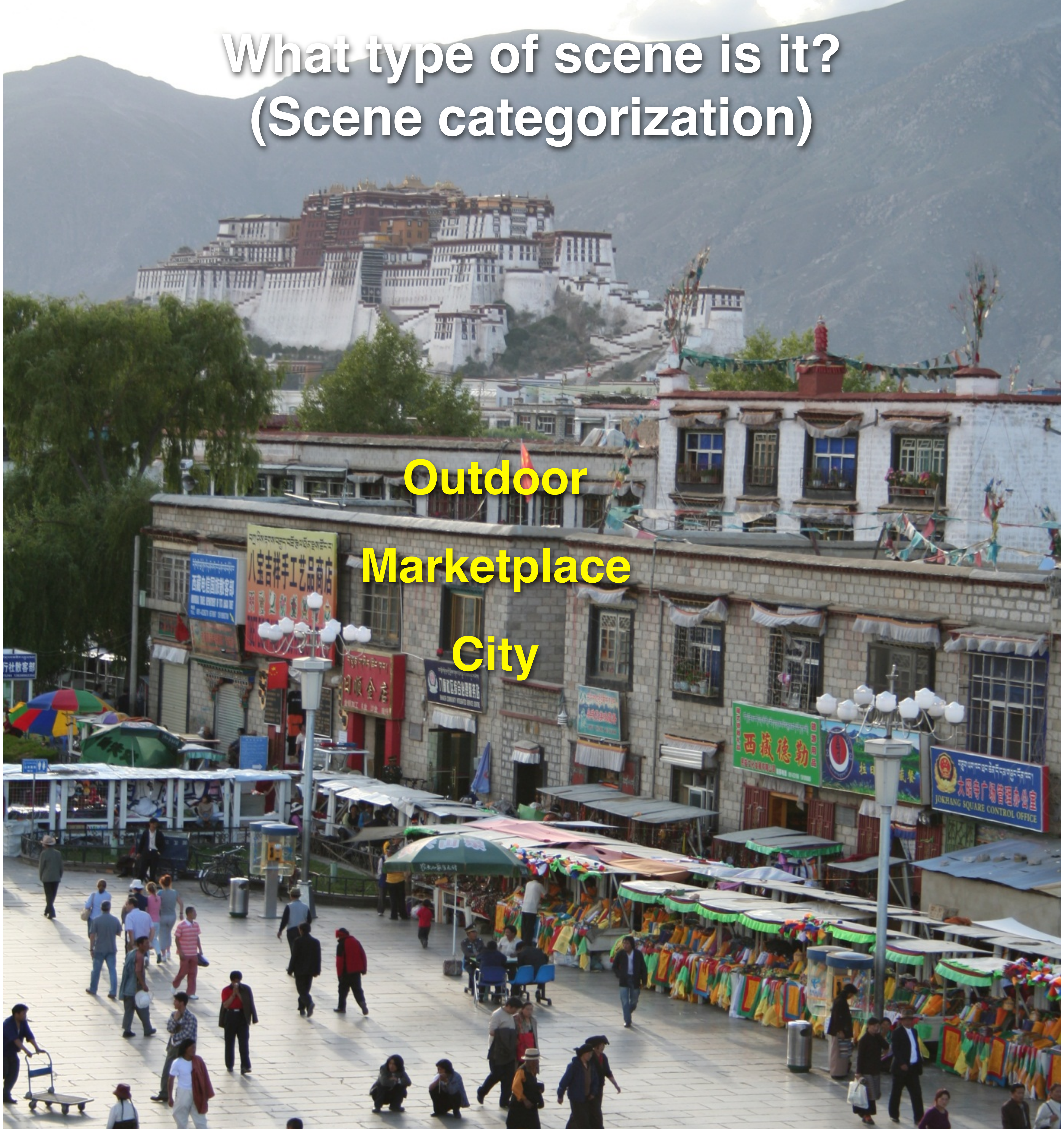
Is that Potala palace?
(Identification)



What's in the scene? (semantic segmentation)



What type of scene is it?
(Scene categorization)



Challenges

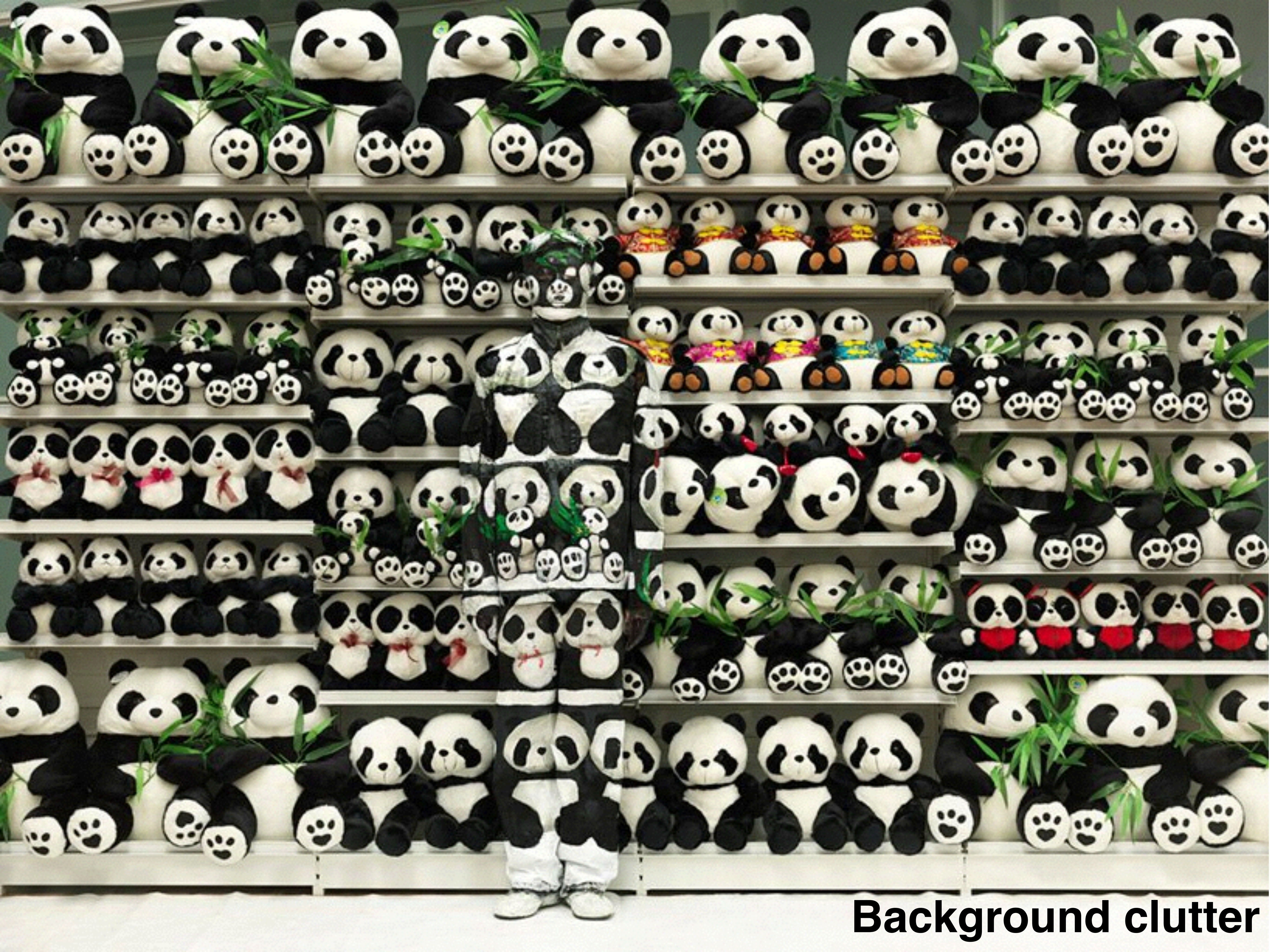
(Object Recognition)



Viewpoint variation

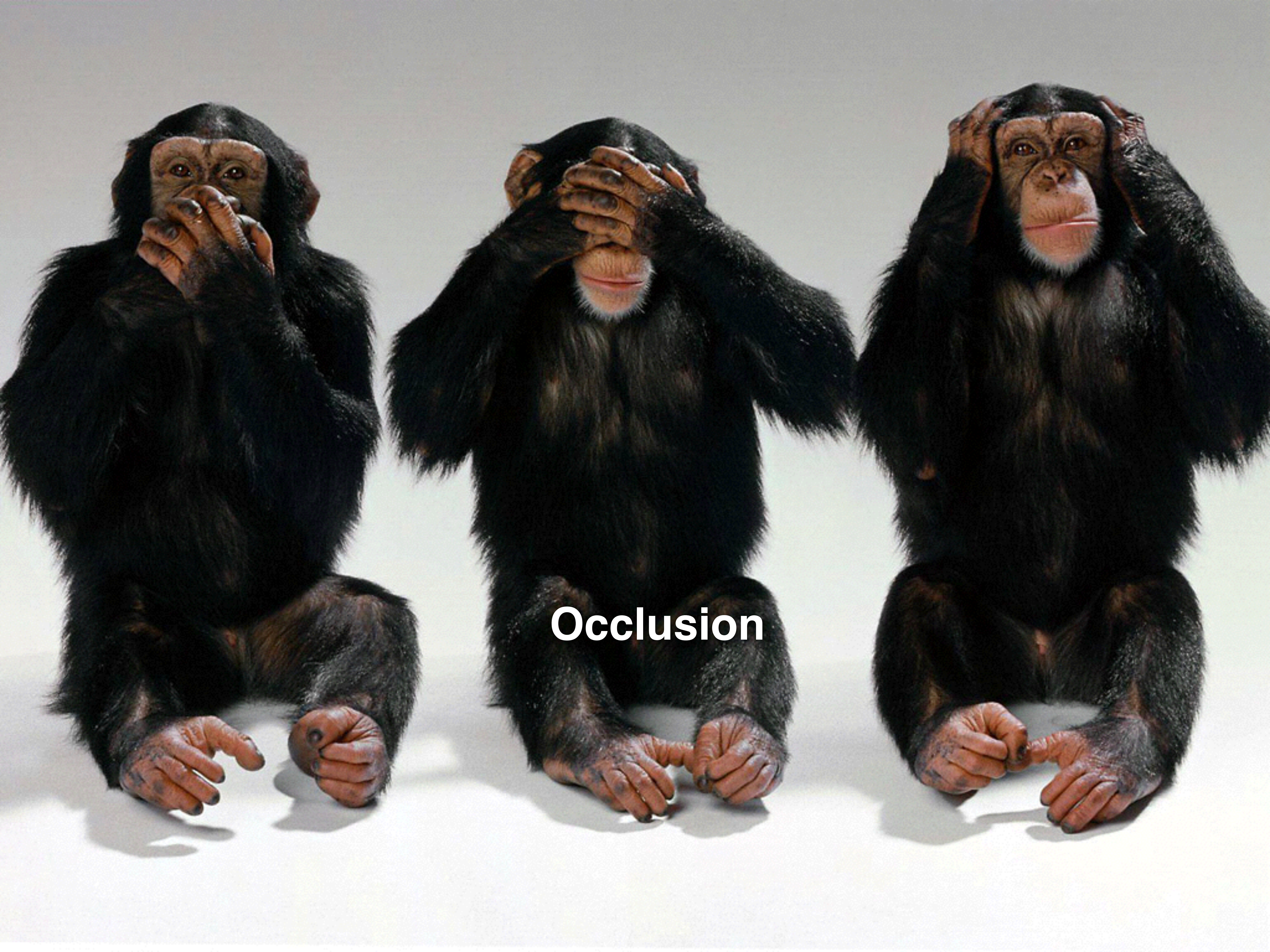

Illumination variation

Scale variation



Background clutter

Deformation

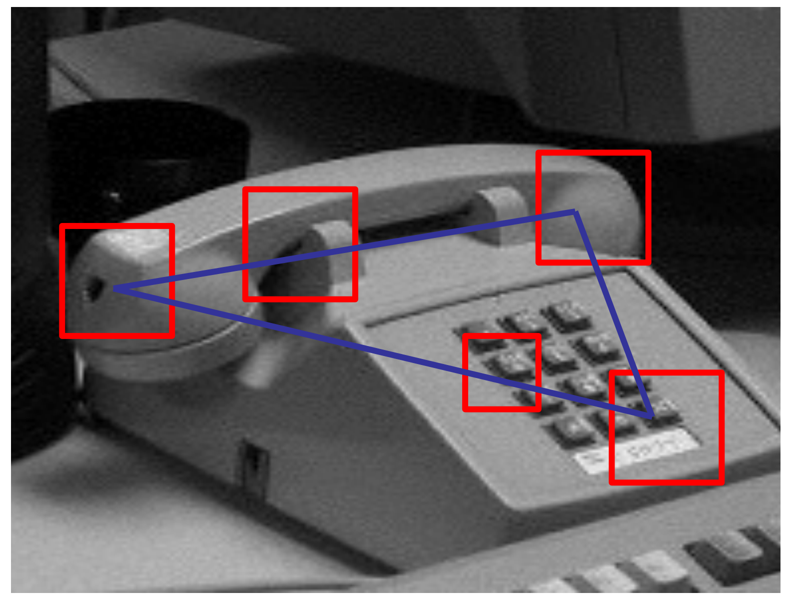

Occlusion

Intra-class variation

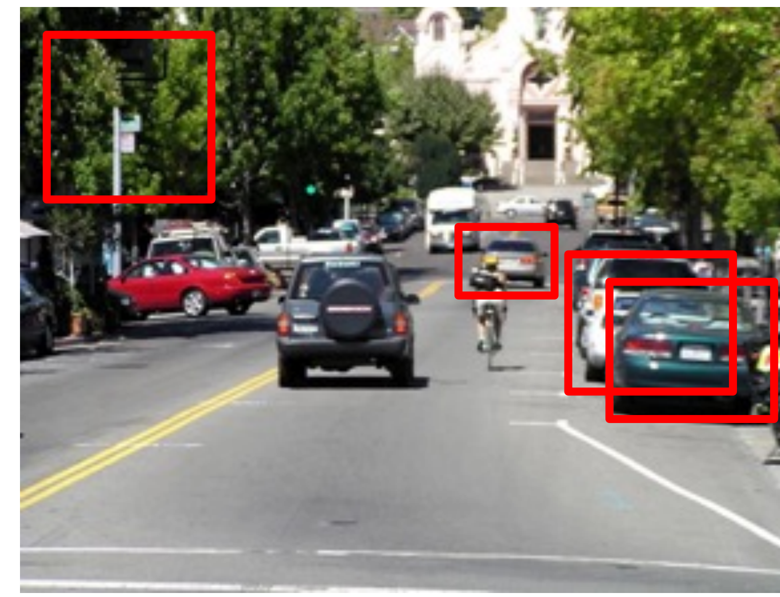
Common approaches

Common approaches: object recognition

Feature Matching



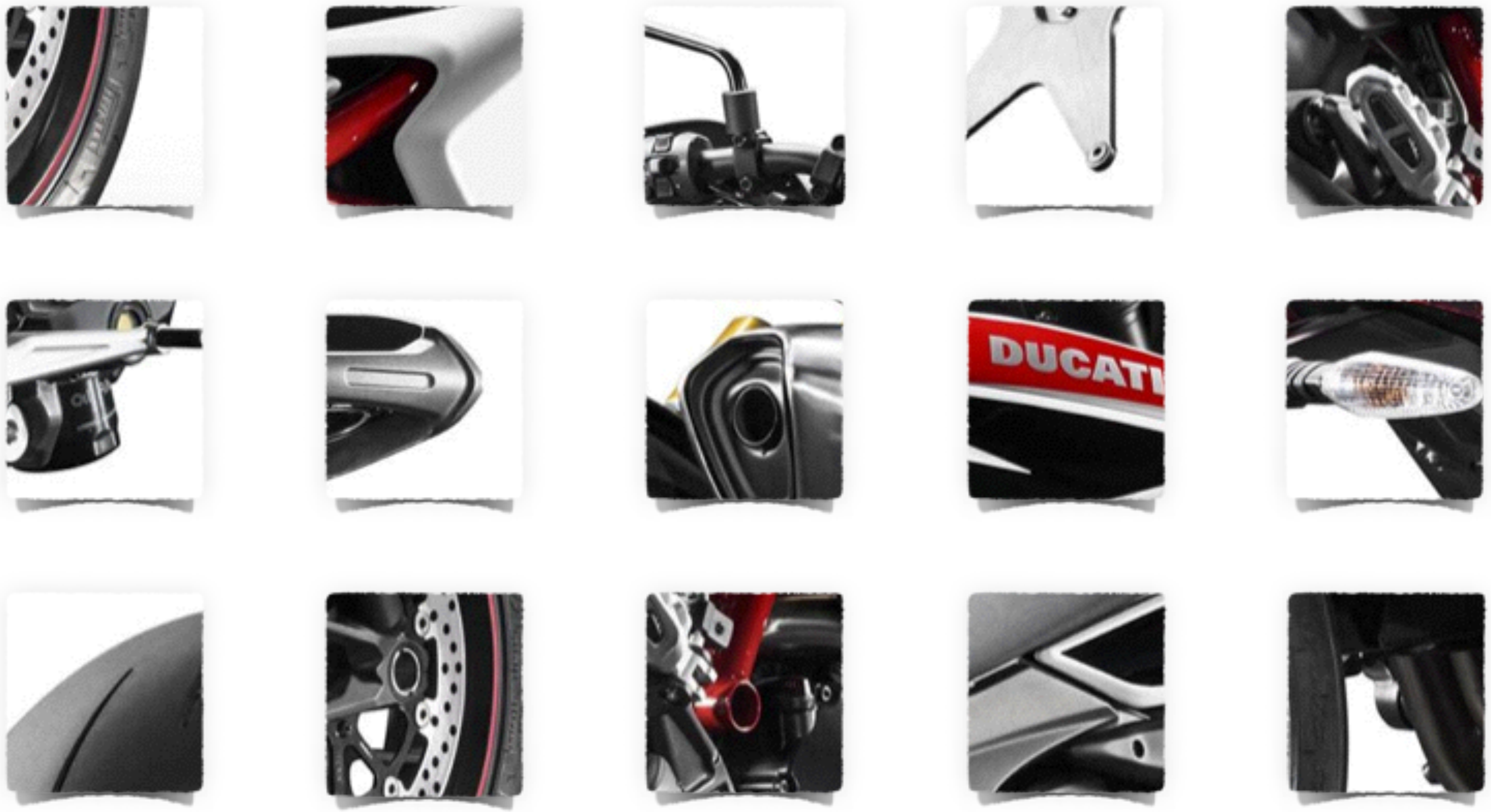
Spatial reasoning



Window classification

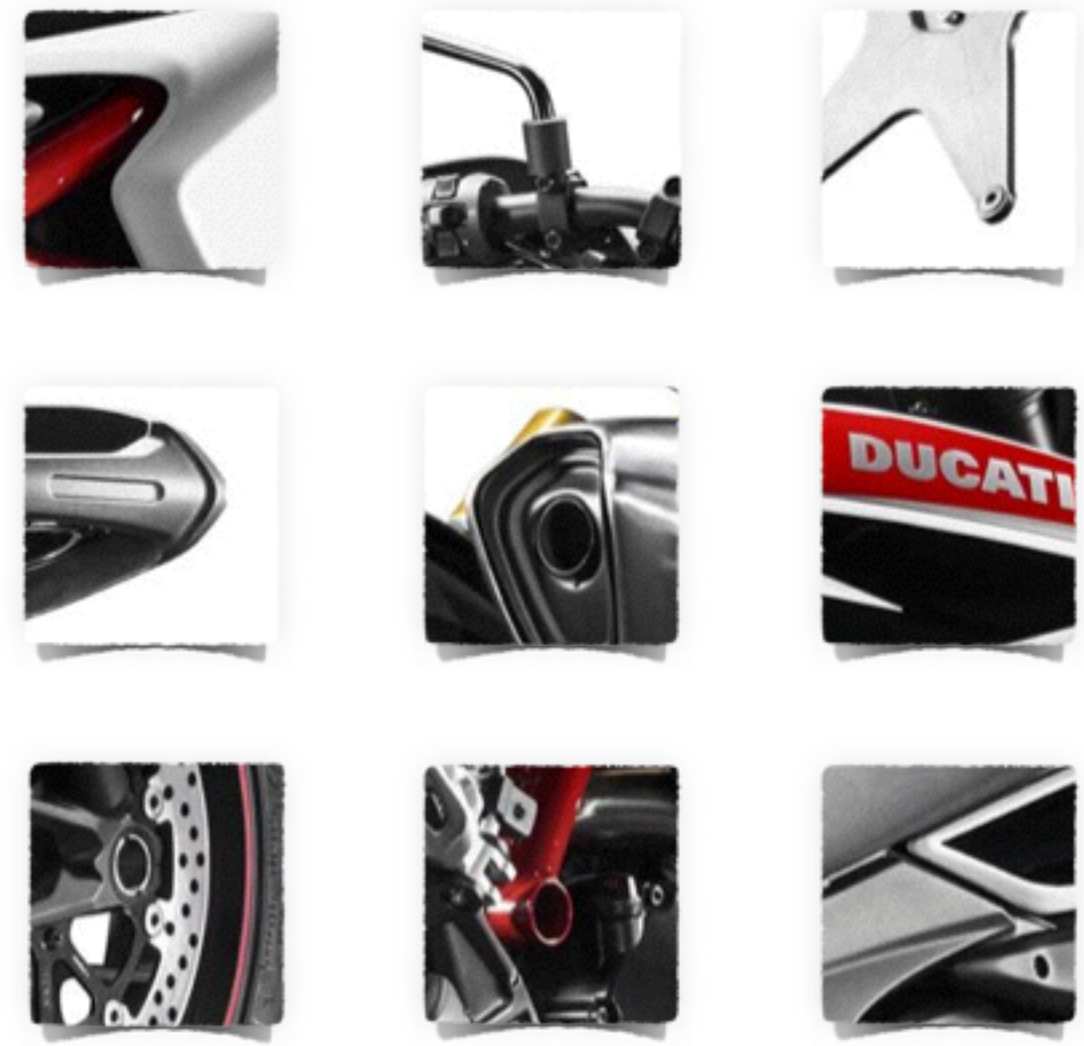
Feature matching

What object do these parts belong to?



Some local feature are
very informative

An object as



a collection of local features

(bag-of-features)

- deals well with occlusion
- scale invariant
- rotation invariant

Are the positions of the parts important?

Pros

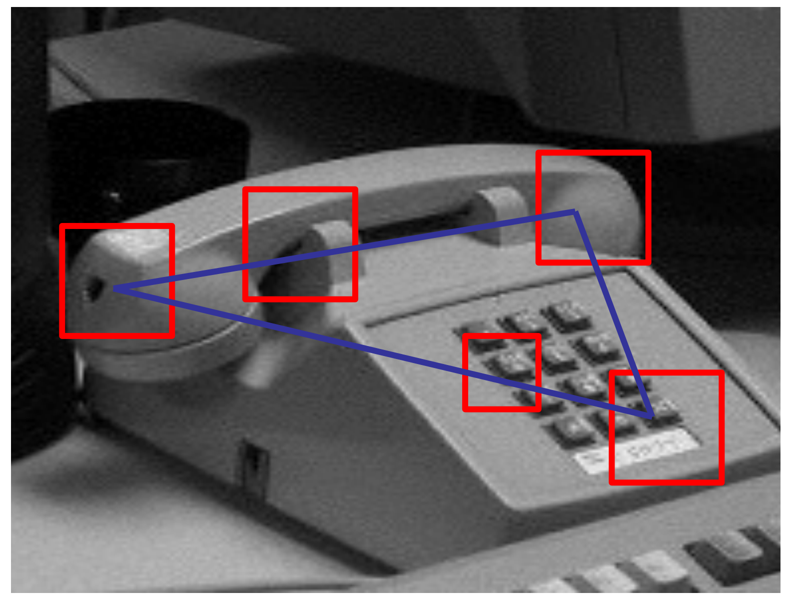
- Simple
- Efficient algorithms
- Robust to deformations

Cons

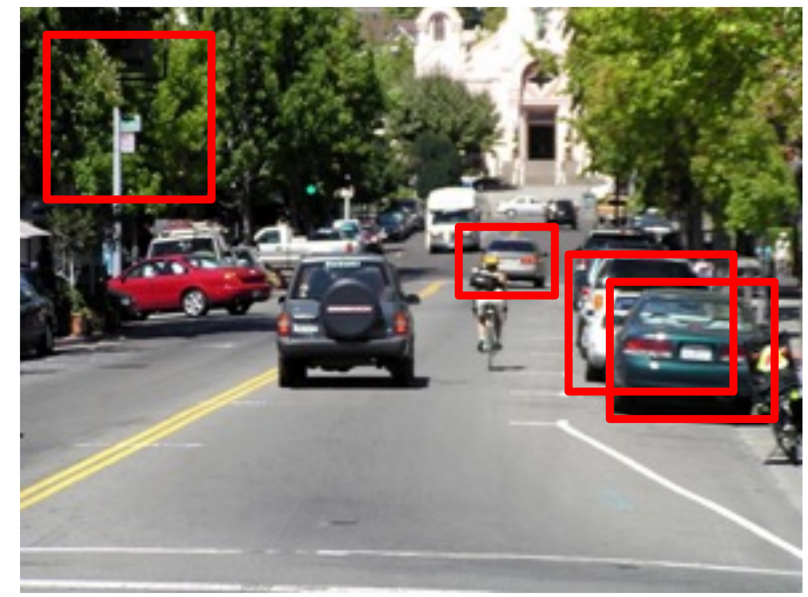
- No spatial reasoning

Common approaches: object recognition

Feature Matching



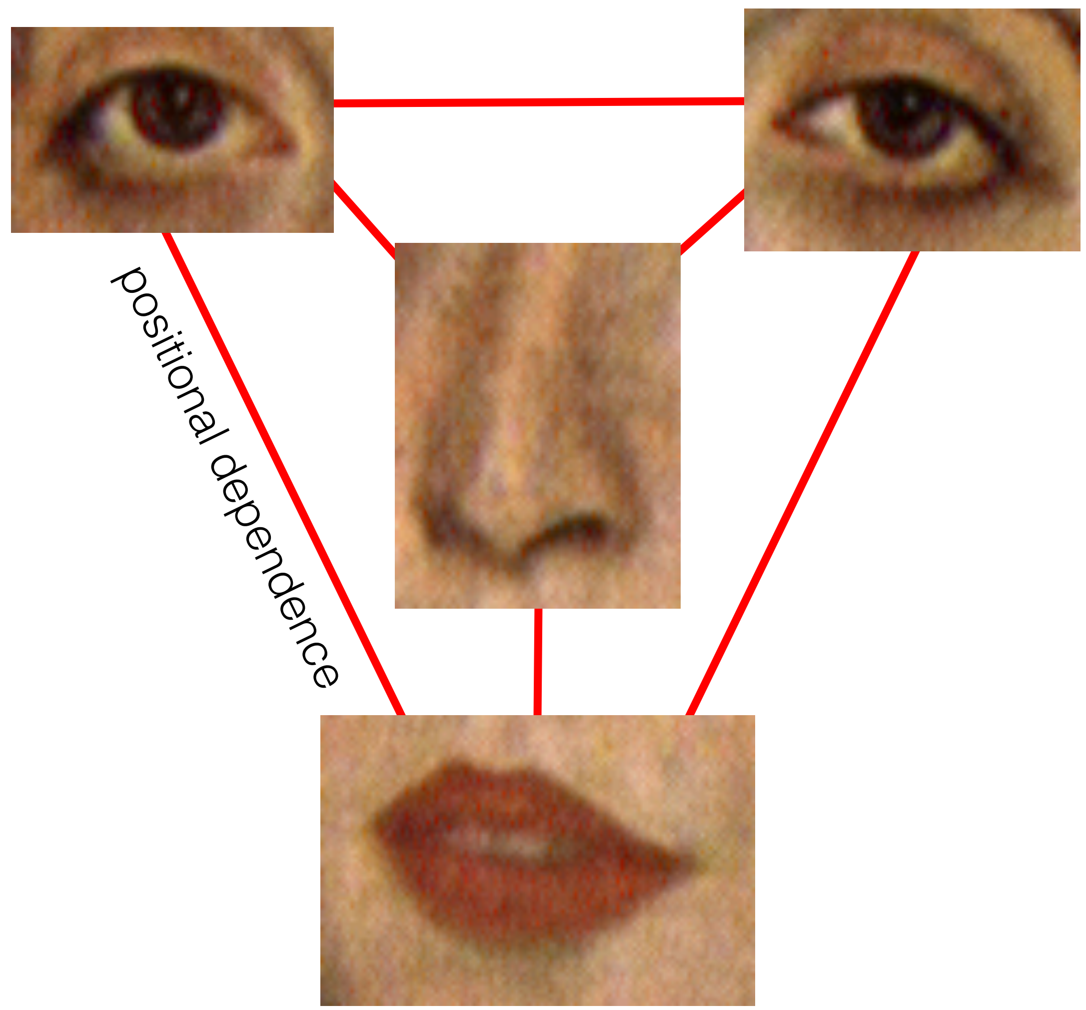
Spatial reasoning



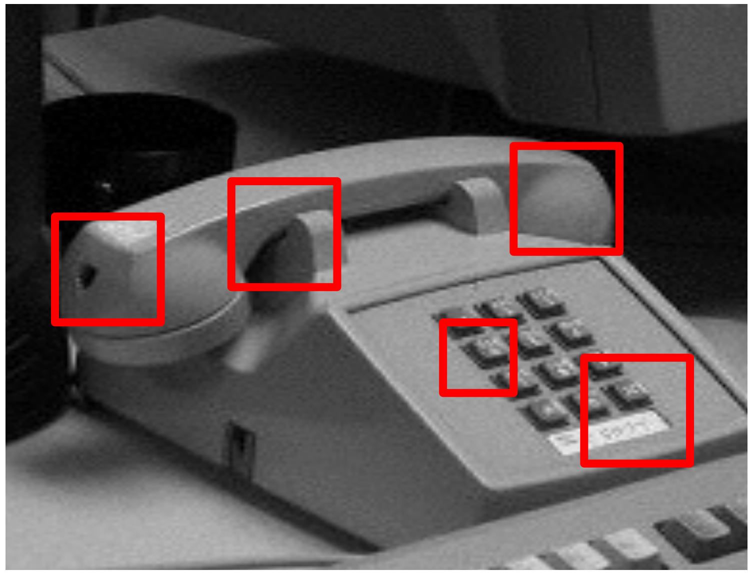
Window classification

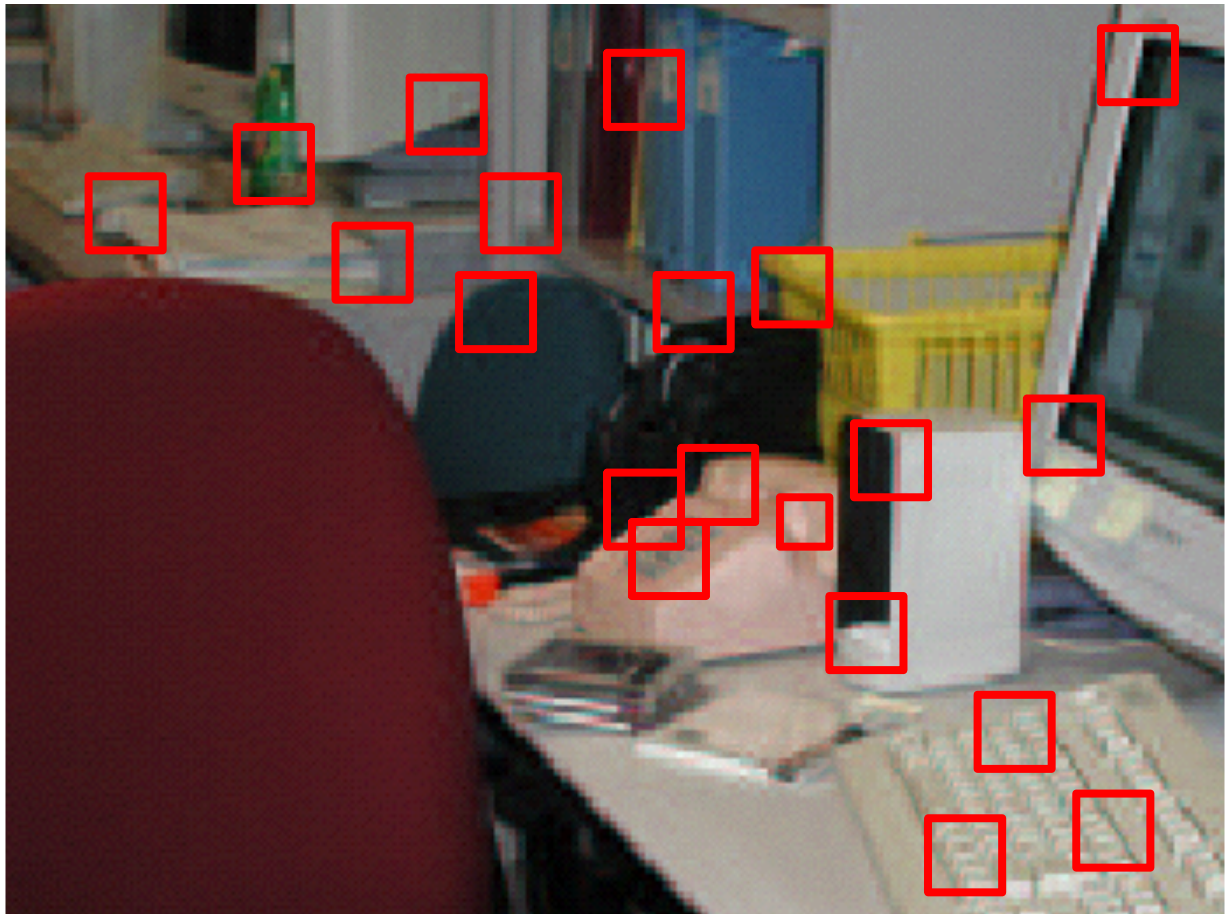
Spatial reasoning

The position of every part depends on the positions of all the other parts



Many parts, many dependencies!

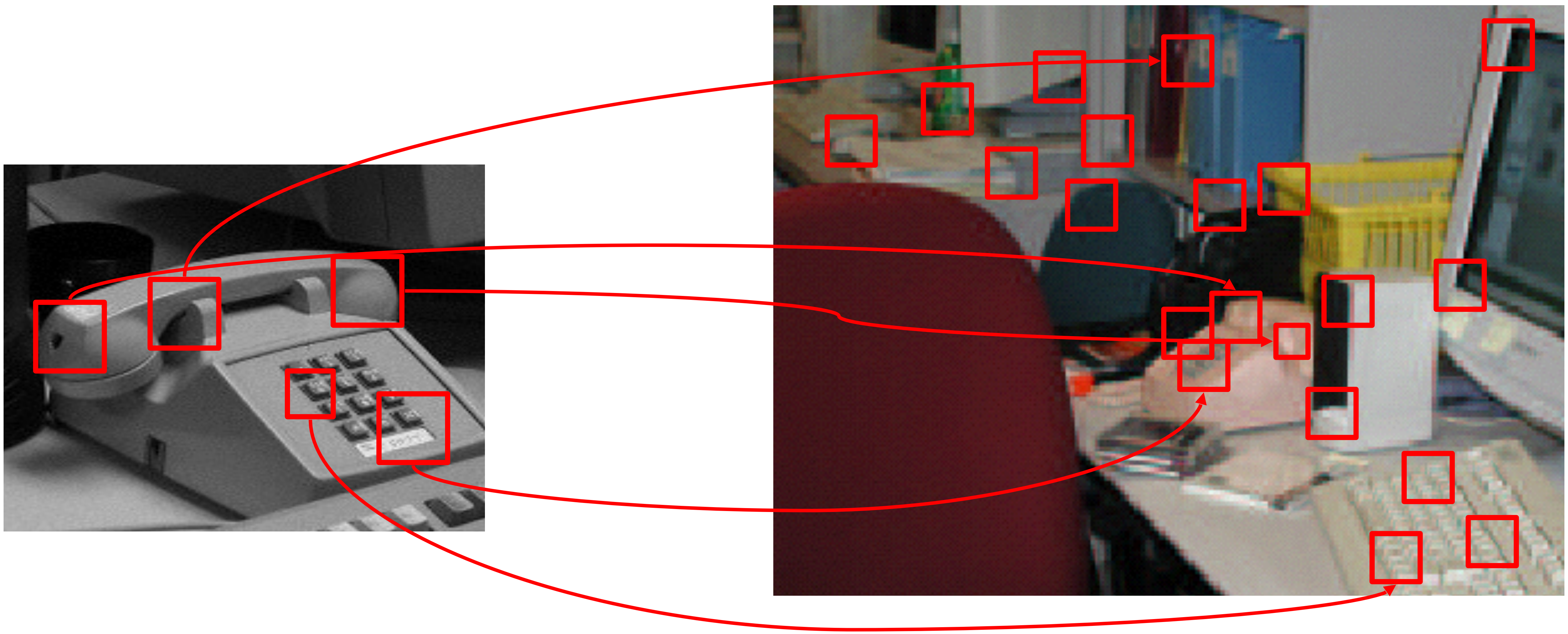




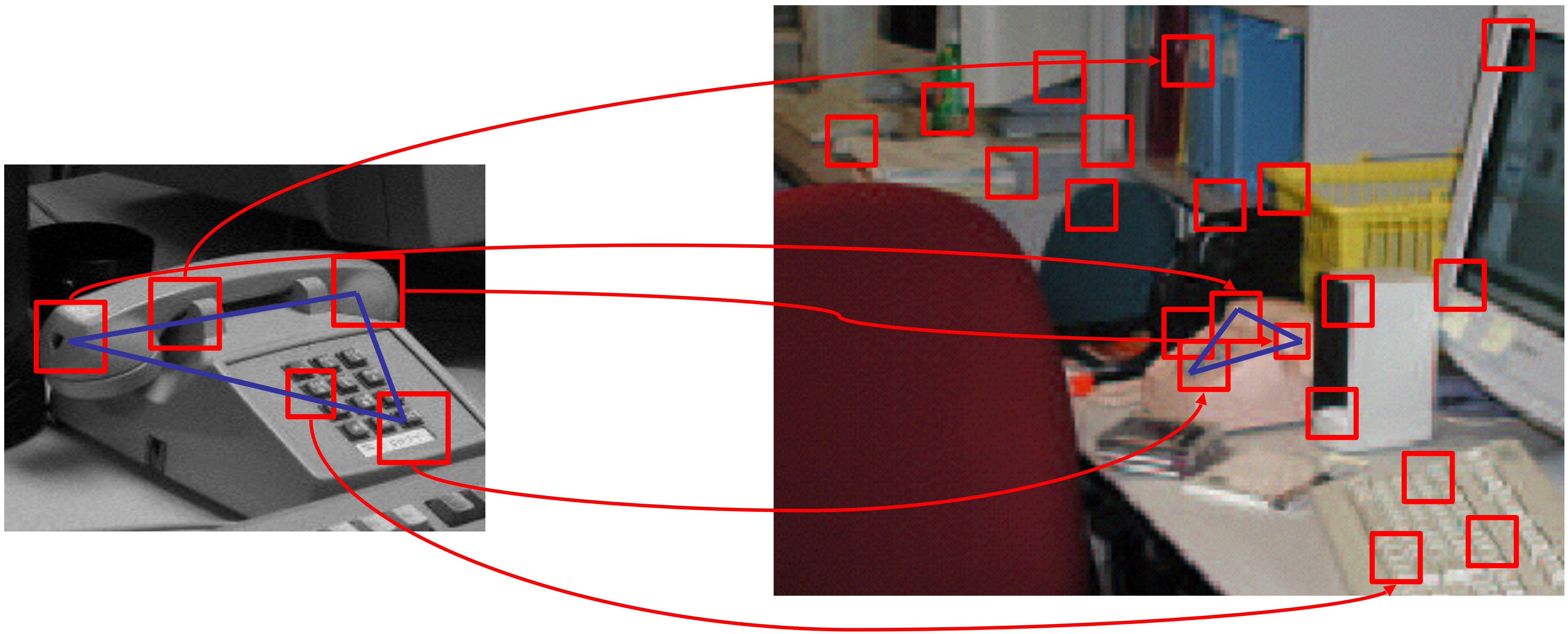
1. Extract features

2. Match features

3. Spatial verification



1. Extract features 2. Match features 3. Spatial verification



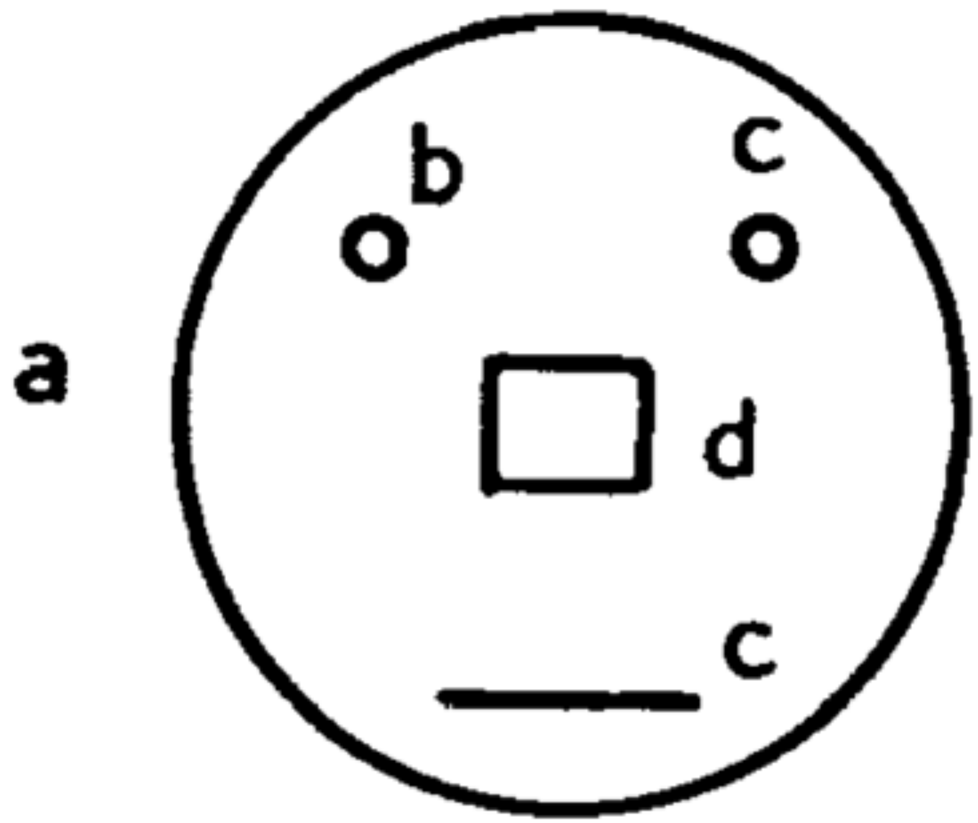
1. Extract features

2. Match features

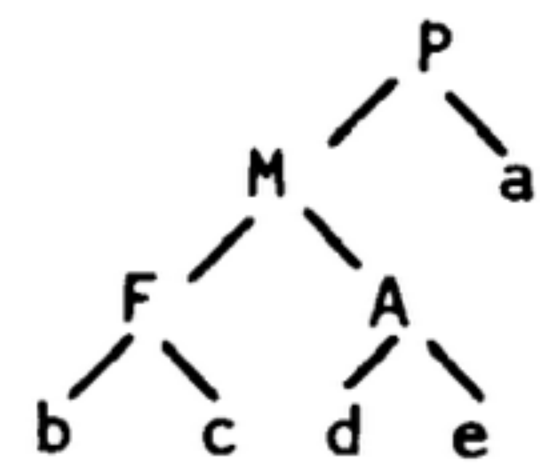
3. Spatial verification

an old idea…

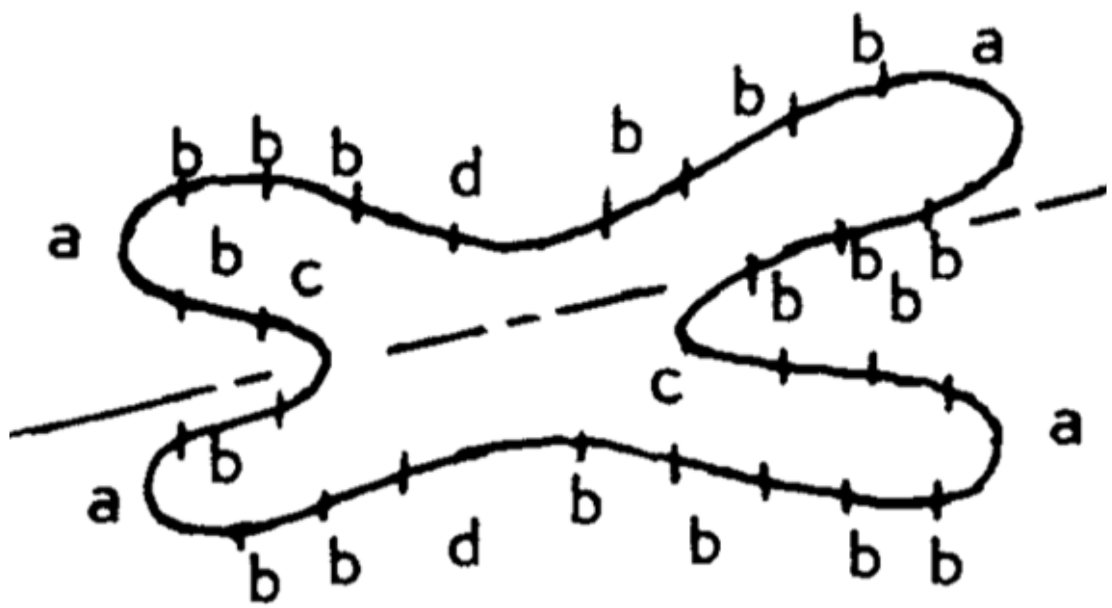
Fu and Booth. Grammatical Inference. 1975



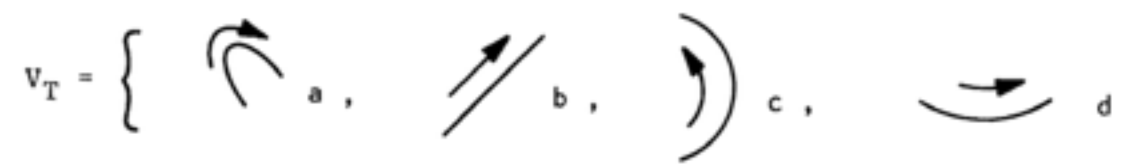
Scene



Structural (grammatical) description

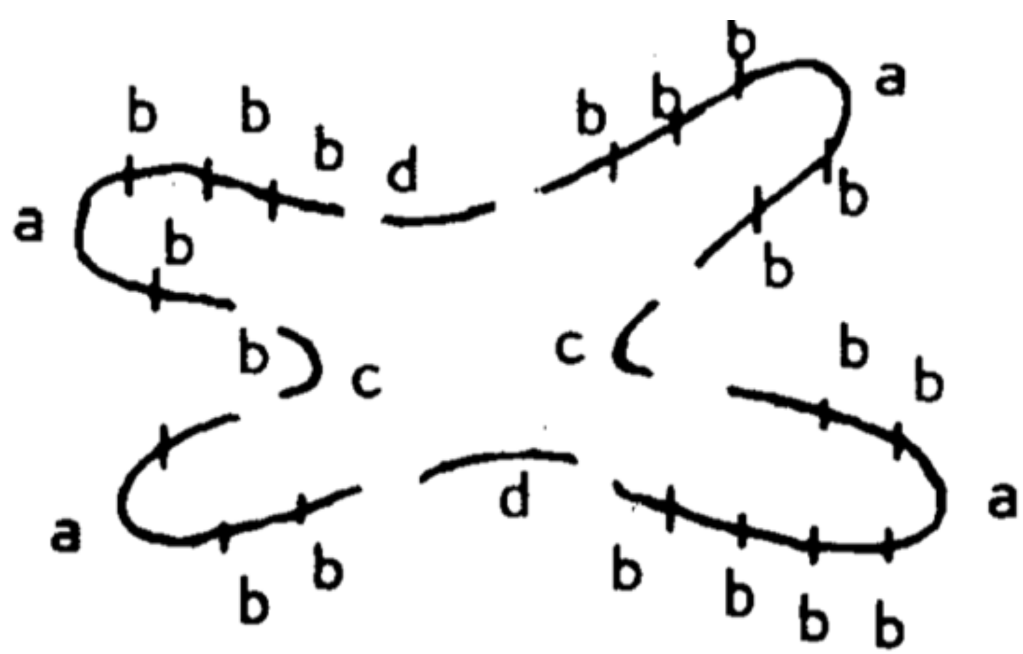


Coded Chromosome



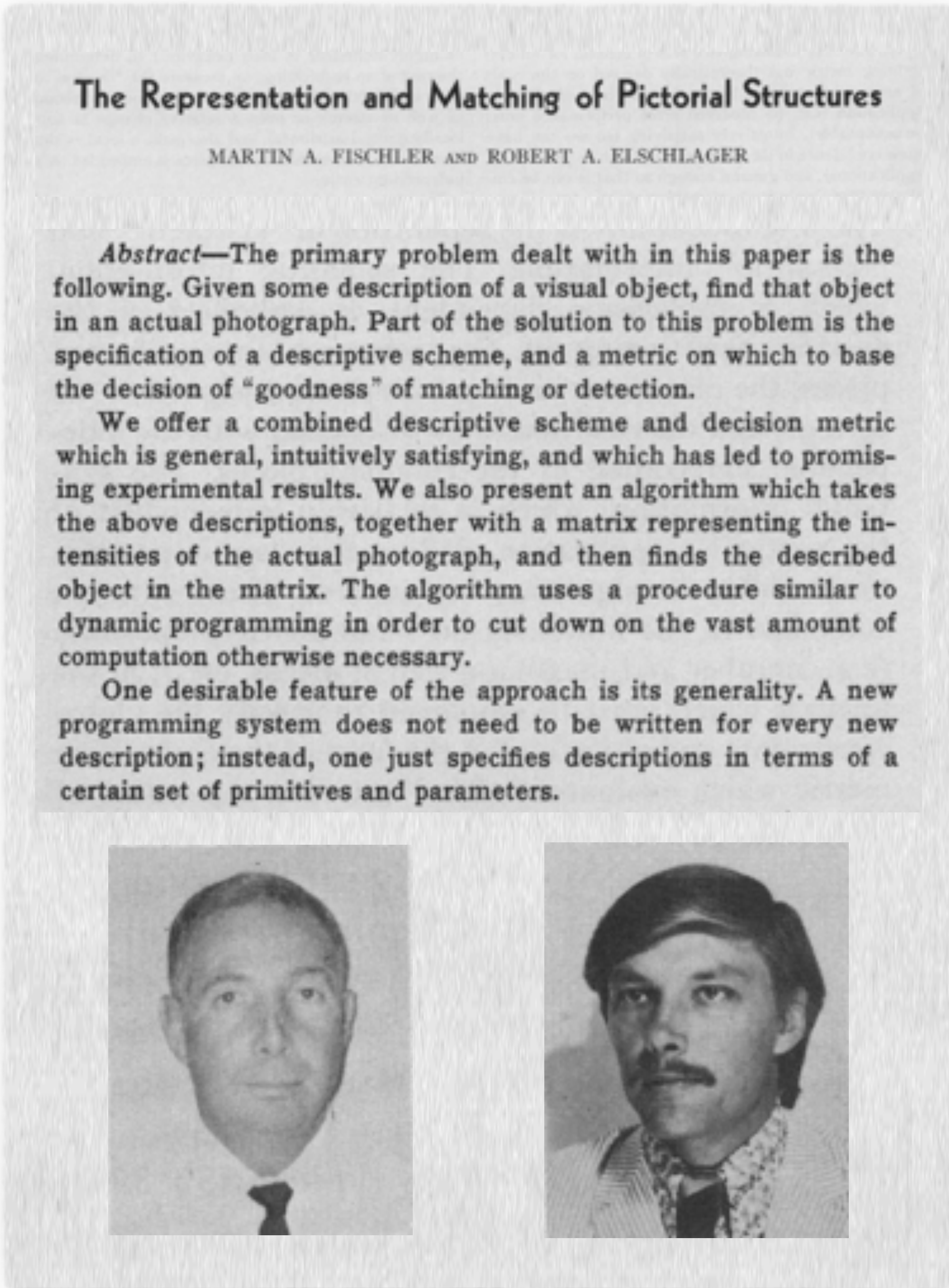
x = cdabbbdbbbabbcbbabbbbdbbabb

Substructures of Coded Chromosome



S_1 = {[b[[[a]b]b]b]; [b[b[b[a]]b]b];

[b[b[[[a]b]b]b]b]; [b[b[a]]b]}



The Representation and Matching of Pictorial Structures

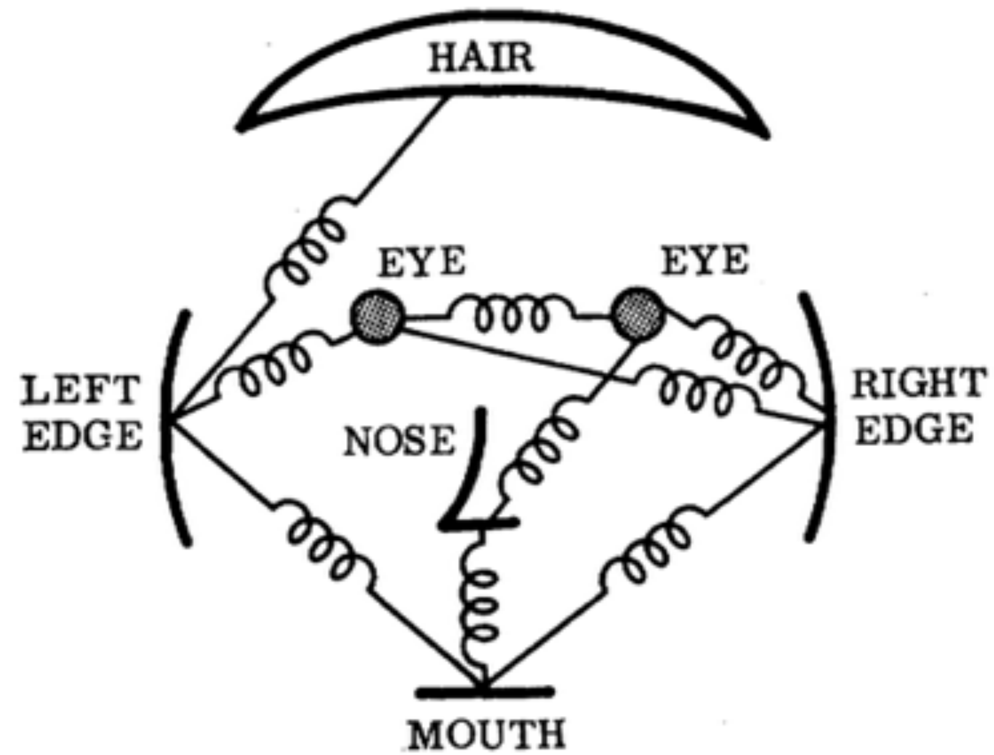
MARTIN A. FISCHLER AND ROBERT A. ELSCHLAGER

Abstract—The primary problem dealt with in this paper is the following. Given some description of a visual object, find that object in an actual photograph. Part of the solution to this problem is the specification of a descriptive scheme, and a metric on which to base the decision of "goodness" of matching or detection.

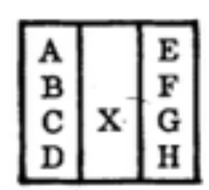
We offer a combined descriptive scheme and decision metric which is general, intuitively satisfying, and which has led to promising experimental results. We also present an algorithm which takes the above descriptions, together with a matrix representing the intensities of the actual photograph, and then finds the described object in the matrix. The algorithm uses a procedure similar to dynamic programming in order to cut down on the vast amount of computation otherwise necessary.

One desirable feature of the approach is its generality. A new programming system does not need to be written for every new description; instead, one just specifies descriptions in terms of a certain set of primitives and parameters.

1972



Description for left edge of face



VALUE(X)=(E+F+G+H)-(A+B+C+D)

Note: VALUE(X) is the value assigned to the L(EV)A corresponding to the location X as a function of the intensities of locations A through H in the sensed scene.

A more modern probabilistic approach…

think of locations as random variables (RV)

vector of RVs:
set of part locations

$$\boldsymbol{L} = \{\overset{\text{RV}}{L_1}, \overset{\text{RV}}{L_2}, \ldots, \overset{\text{RV}}{L_M}\}$$

A more modern probabilistic approach…

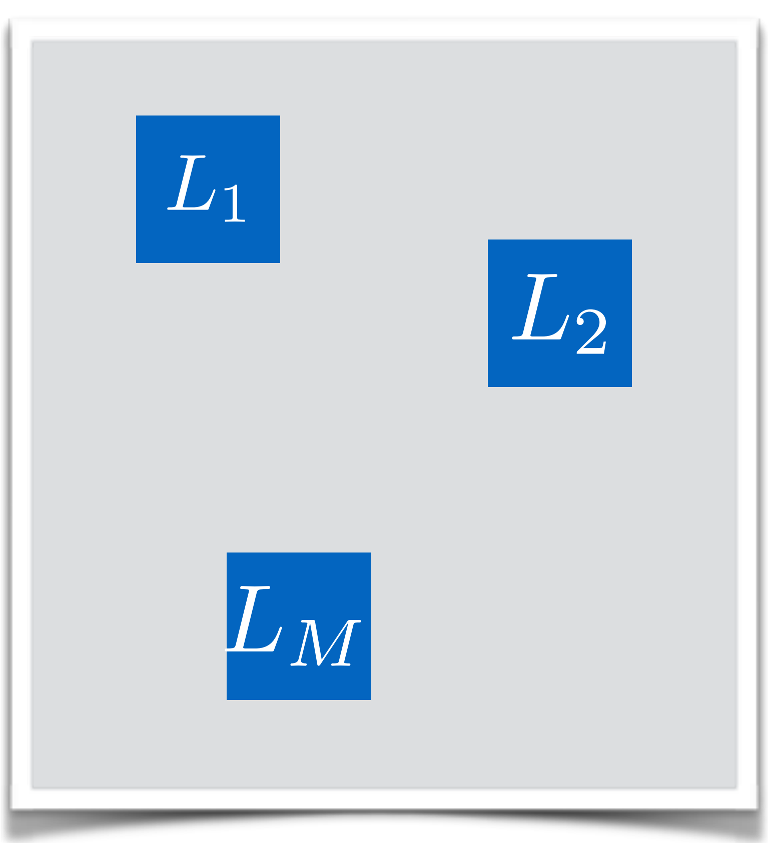
think of locations as random variables (RV)

RV RV RV

vector of RVs:
set of part locations

$$\boldsymbol{L} = \{L_1, L_2, \ldots, L_M\}$$

image (N pixels)



What are the dimensions of R.V. L?

How many possible combinations of part locations?

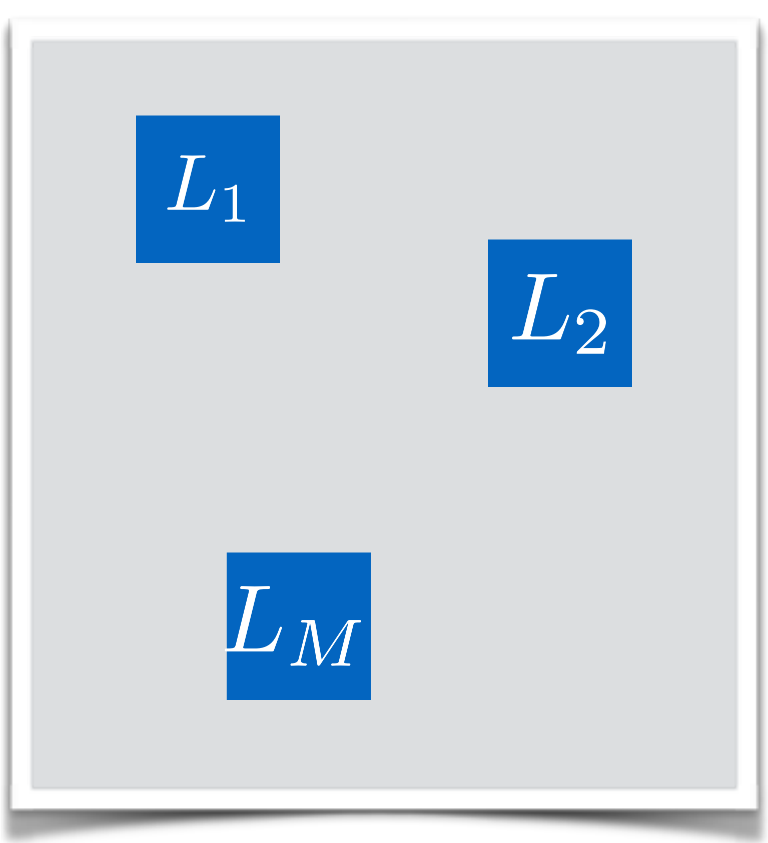
A more modern probabilistic approach…

think of locations as random variables (RV)

vector of RVs:
set of part locations

$$\boldsymbol{L} = \{\overset{\text{RV}}{L_1}, \overset{\text{RV}}{L_2}, \ldots, \overset{\text{RV}}{L_M}\}$$

image



What are the dimensions of R.V. L?

$$L_m = [\, x \; y \,]$$

How many possible combinations of part locations?

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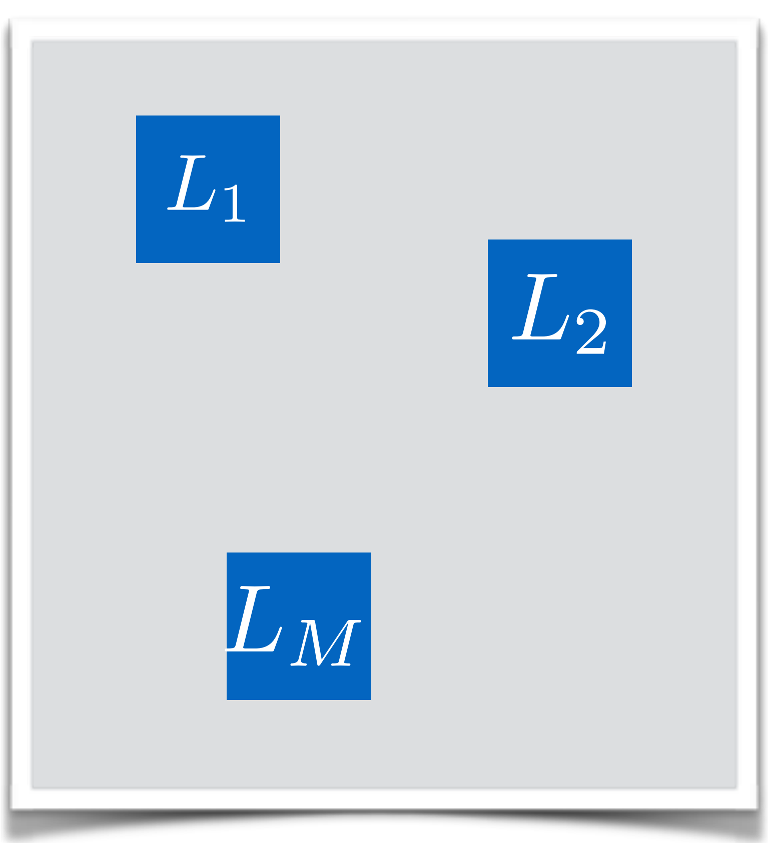
image



What are the dimensions of R.V. L?

$$L_m = [\, x \; y \,]$$

How many possible combinations of part locations?

$$N^M$$

Most likely set of locations L is found by maximizing:

part locations image

$$\underbrace{p(\boldsymbol{L}|\boldsymbol{I})}_{\text{Posterior}} \propto \underbrace{p(\boldsymbol{I}|\boldsymbol{L})}_{\text{Likelihood}}\underbrace{p(\boldsymbol{L})}_{\text{Prior}}$$

Posterior

Likelihood:
How likely it is to observe image I given that the M parts are at locations L
(scaled output of a classifier)

Prior:
spatial prior controls the geometric configuration of the parts

What kind of prior can we formulate?

Given any collection of selfie images,
where would you expect the nose to be?

*What would be an appropriate **prior**?*

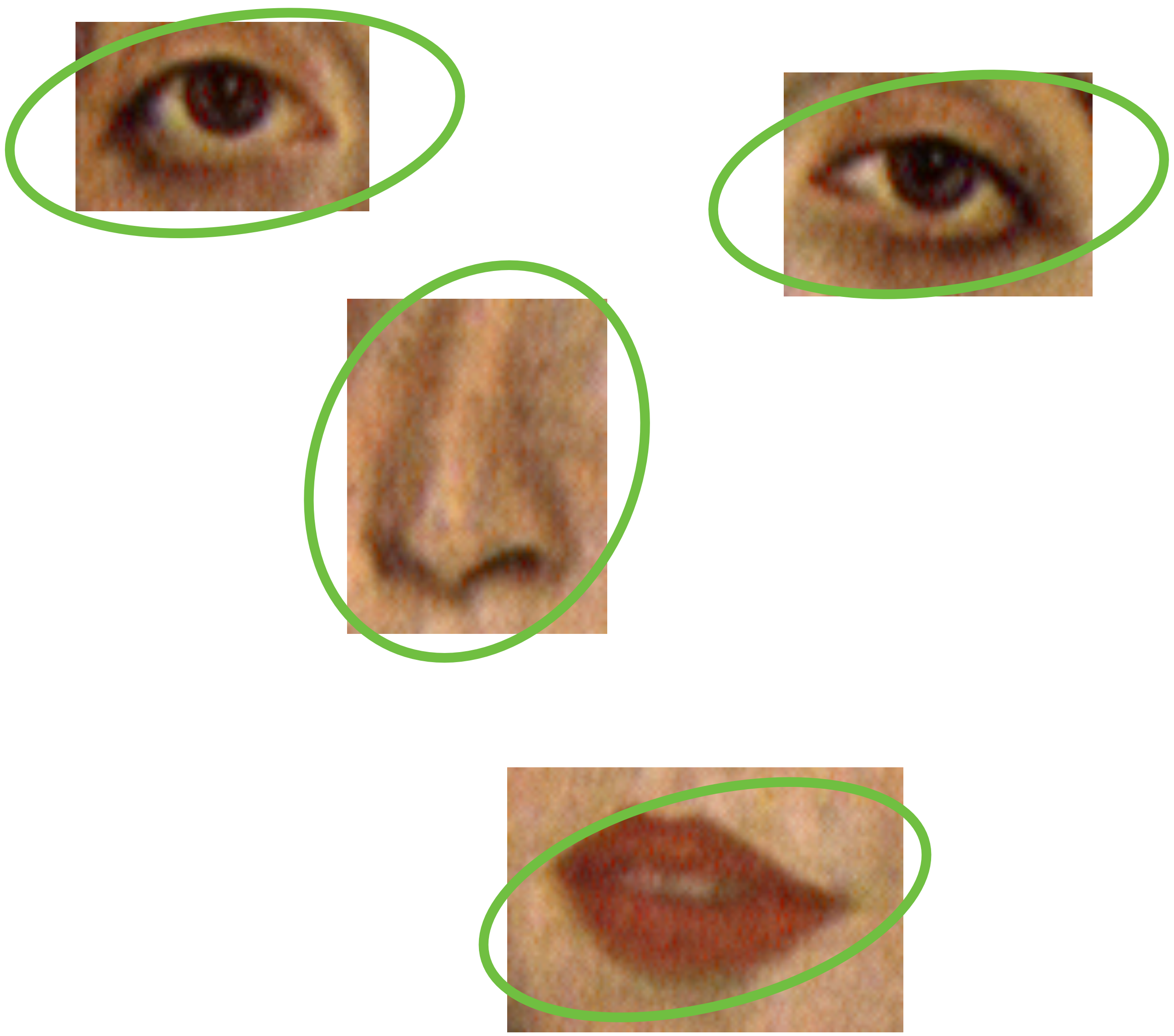
$$P(L_{\text{nose}}) = ?$$

A simple factorized model

$$p(\boldsymbol{L}) = \prod_{m} p(L_m)$$

Break up the joint probability into
smaller (independent) terms

Independent locations

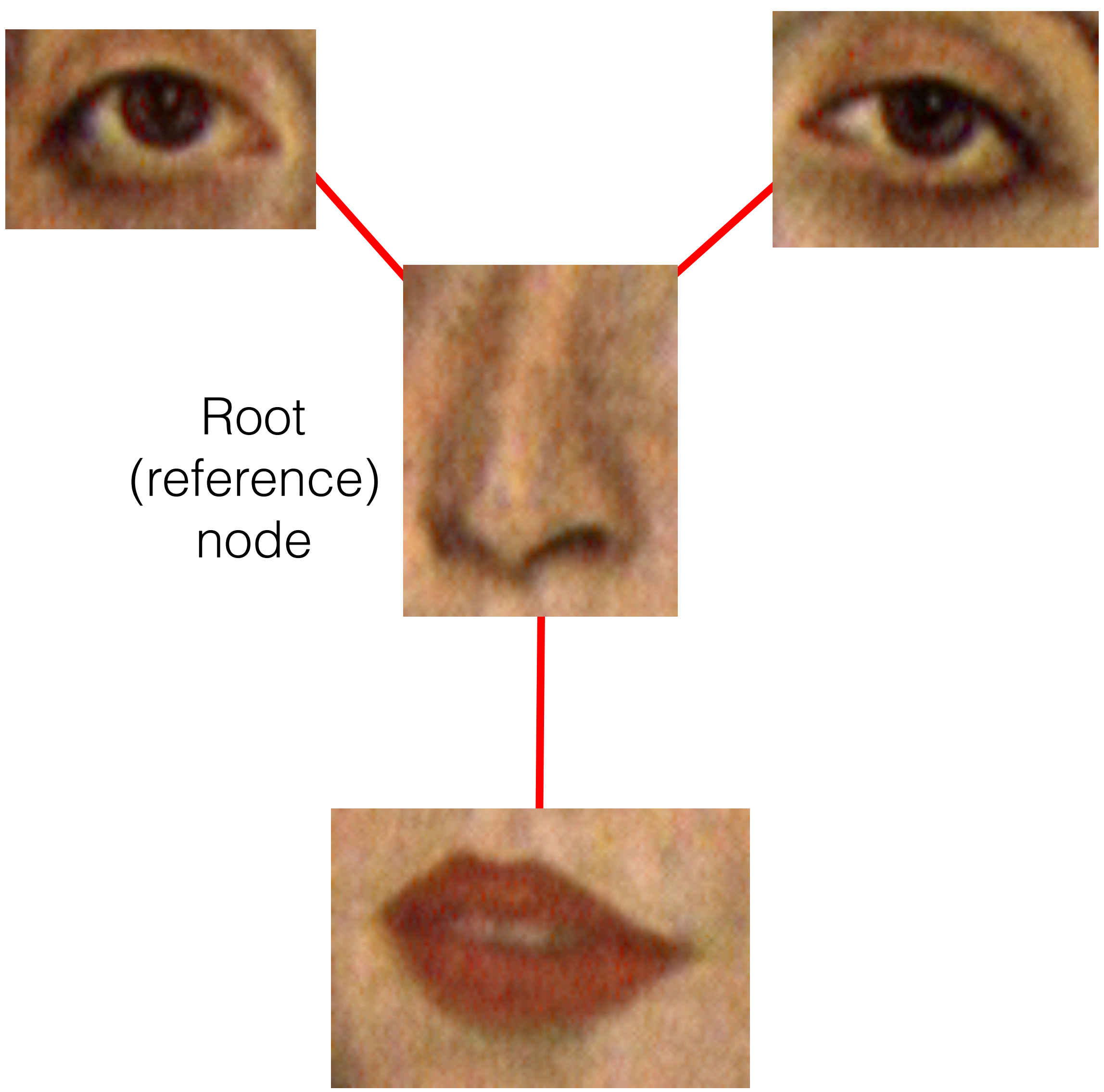


$$p(\boldsymbol{L}) = \prod_m p(L_m)$$

Each feature is allowed to move independently

Does not model the **relative** location of parts at all

Tree structure
(star model)

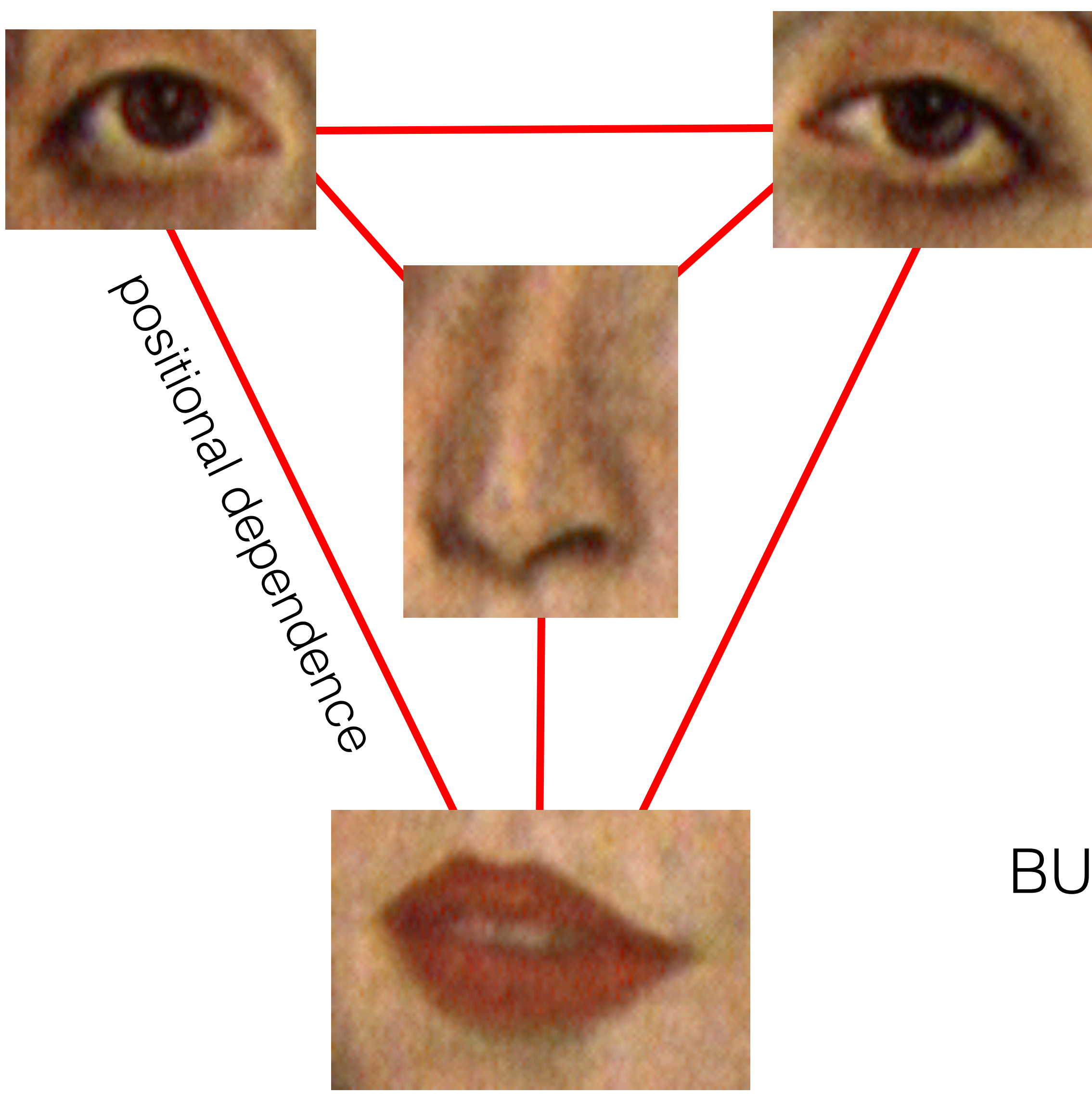


$$p(\boldsymbol{L}) = p(L_{\text{root}}) \prod_{m=1}^{M-1} p(L_m | L_{\text{root}})$$

Represent the location of all the parts relative to a single reference part

Assumes that one reference part is defined (who will decide this?)

Fully connected
(constellation model)



$$p(L) = p(l_1, \ldots, l_N)$$

Explicitly represents the
joint distribution of locations

<u>Good model:</u>
Models relative location of parts
BUT Intractable for moderate number of parts

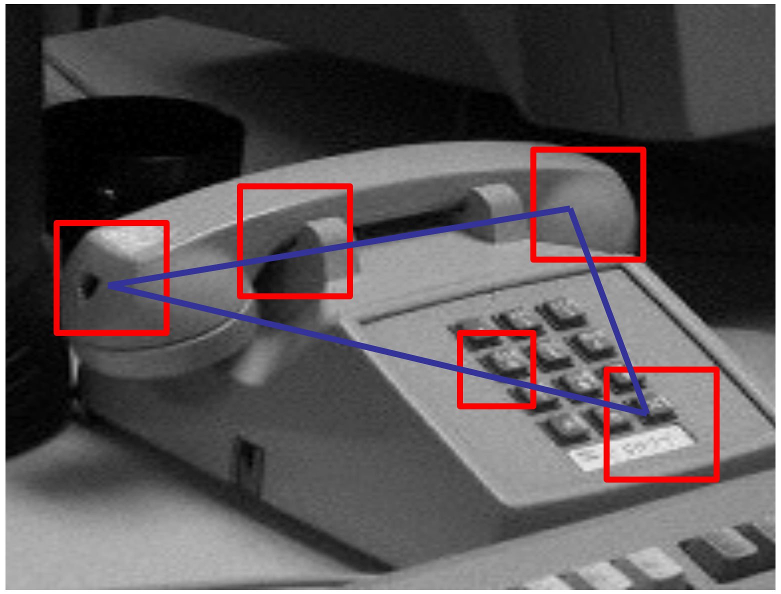
Pros

- Retains spatial constraints
- Robust to deformations

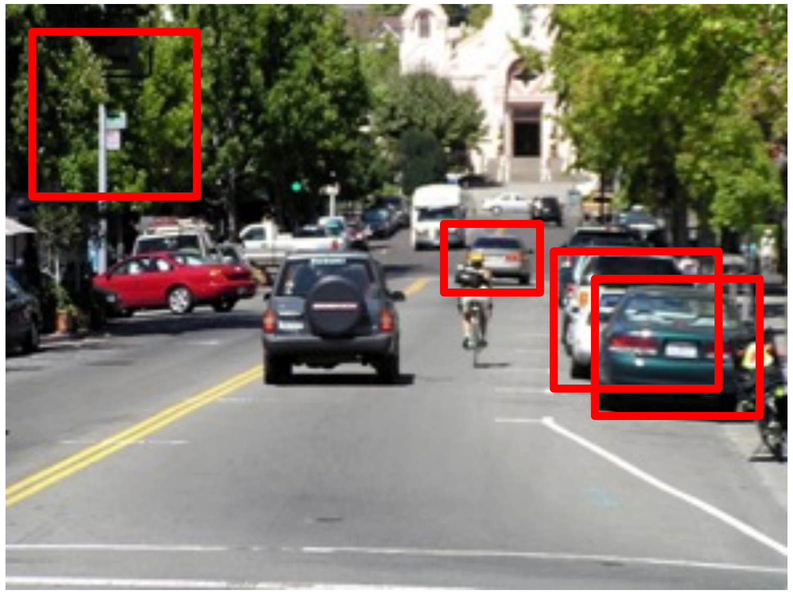
Cons

- Computationally expensive
- Generalization to **large** inter-class variation (e.g., modeling chairs)

Feature
Matching



Spatial
reasoning

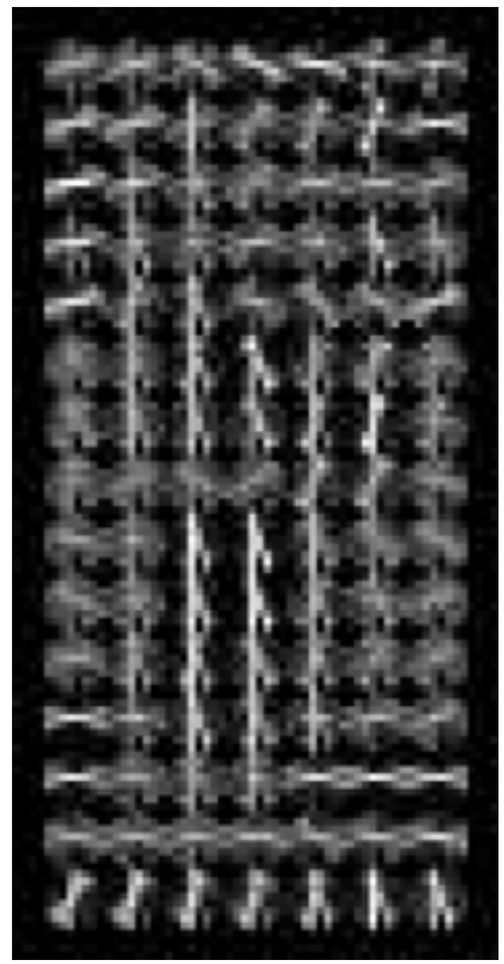


Window
classification

Window-based

Template Matching

1. get image window



2. extract features

3. classify

When does this work and when does it fail?

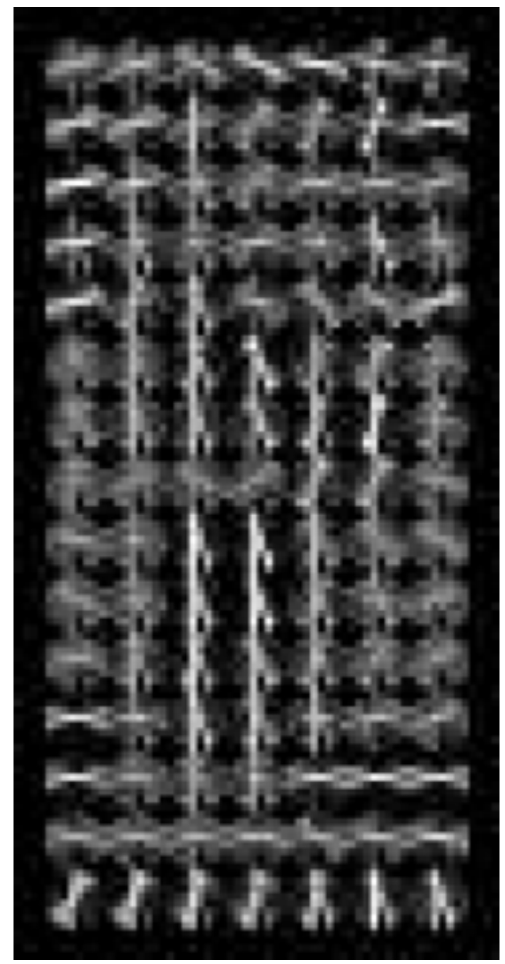
How many templates do you need?

Per-exemplar

find the ‘nearest’ exemplar, inherit its label

Template Matching

1. get image window
(or region proposals)



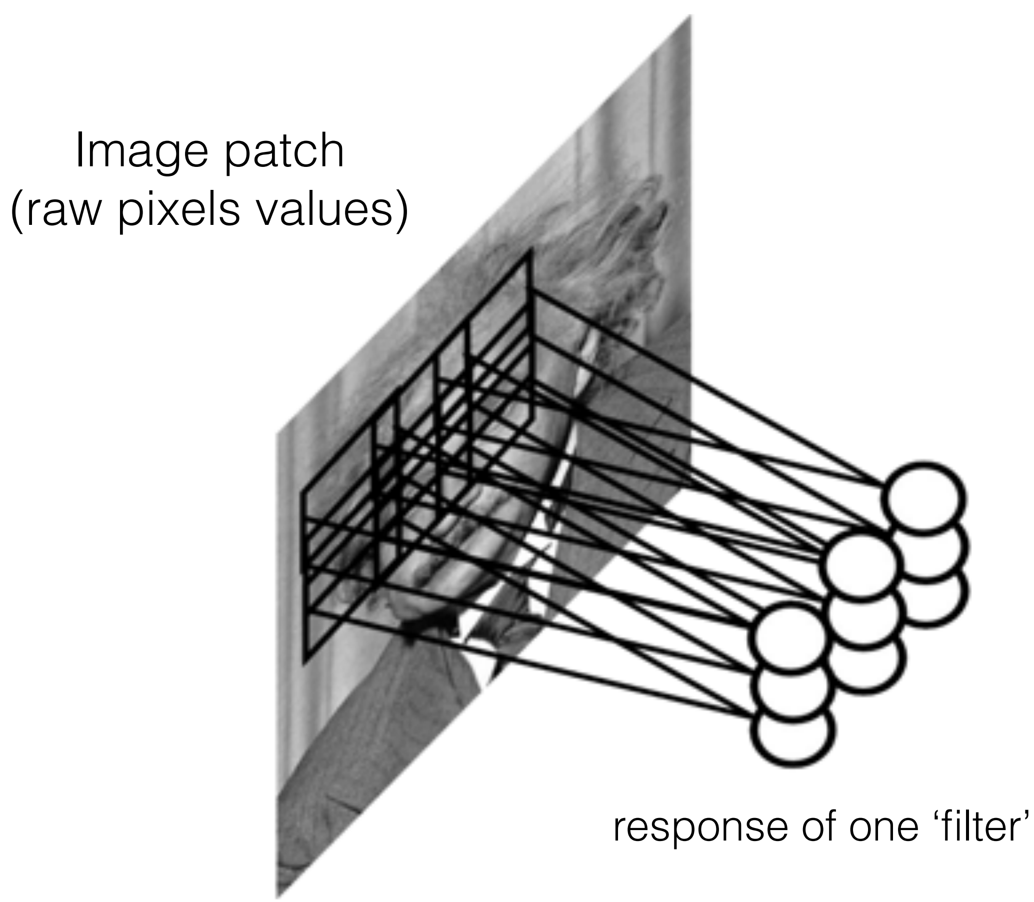
2. extract features

3. compare to template

Do this part with one big classifier
'end to end learning'

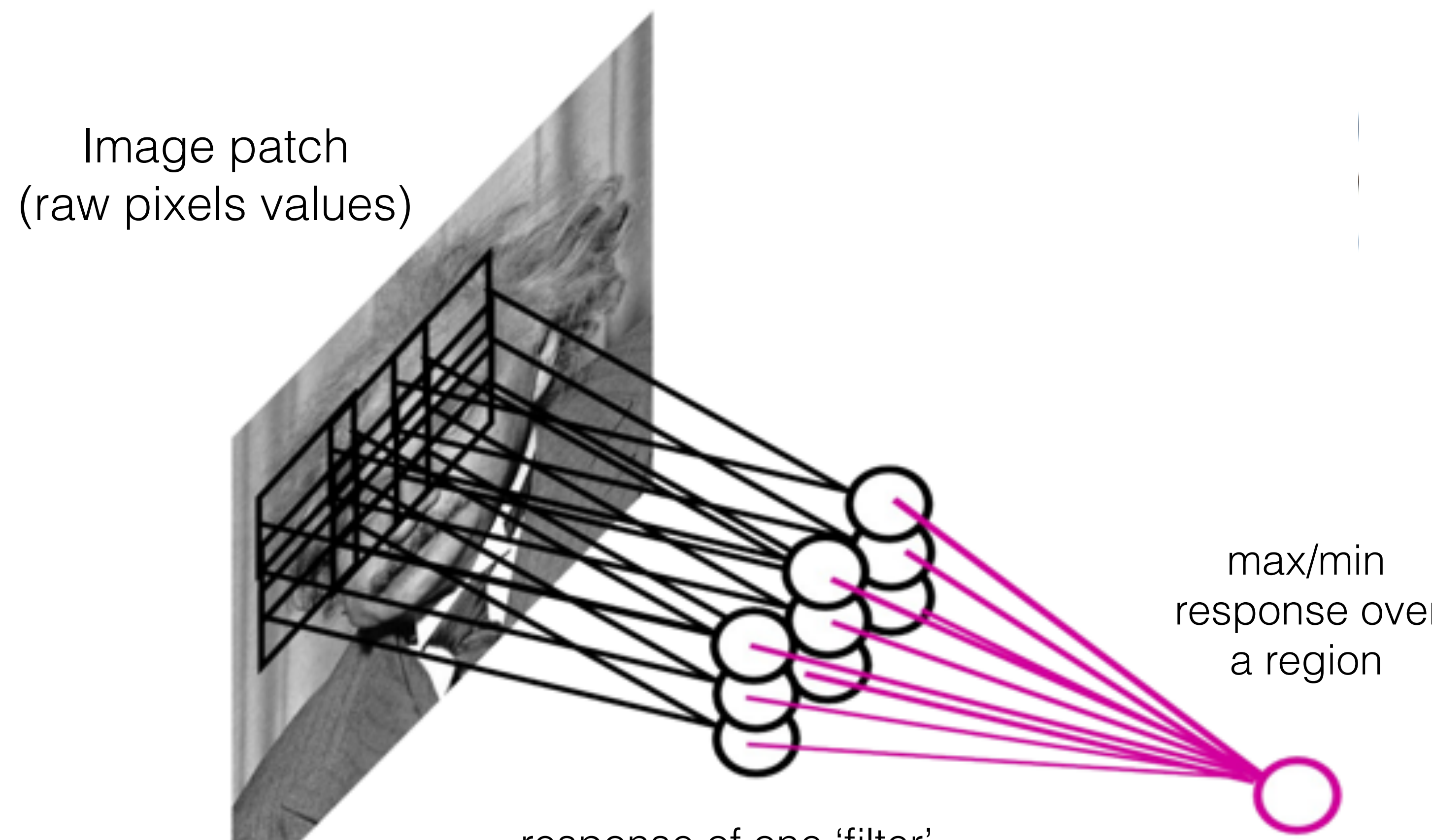
Convolutional Neural Networks

Convolution

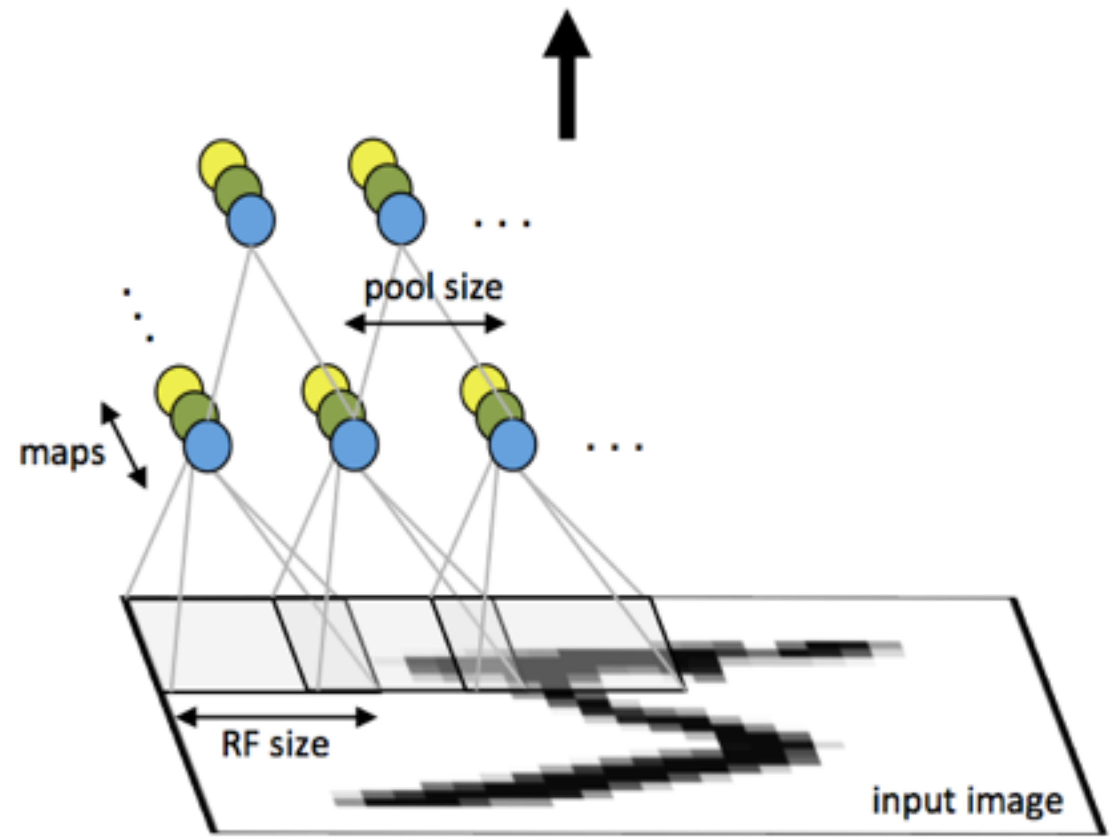


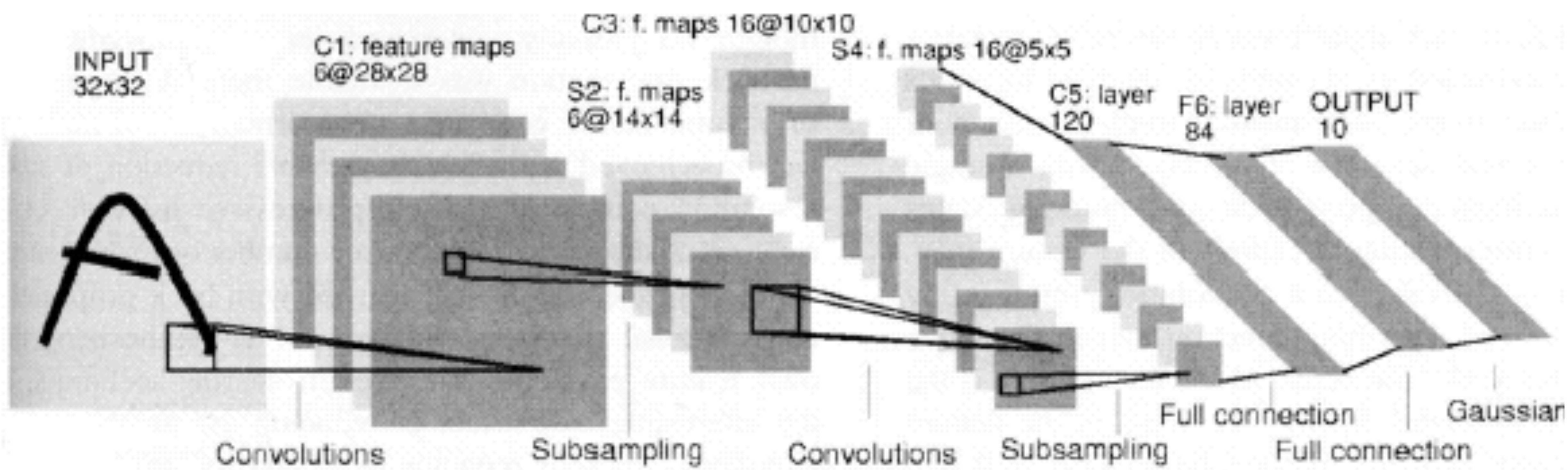
A 96 x 96 image convolved with 400 filters (features) of size 8 x 8 generates about 3 million values (89^2x400)

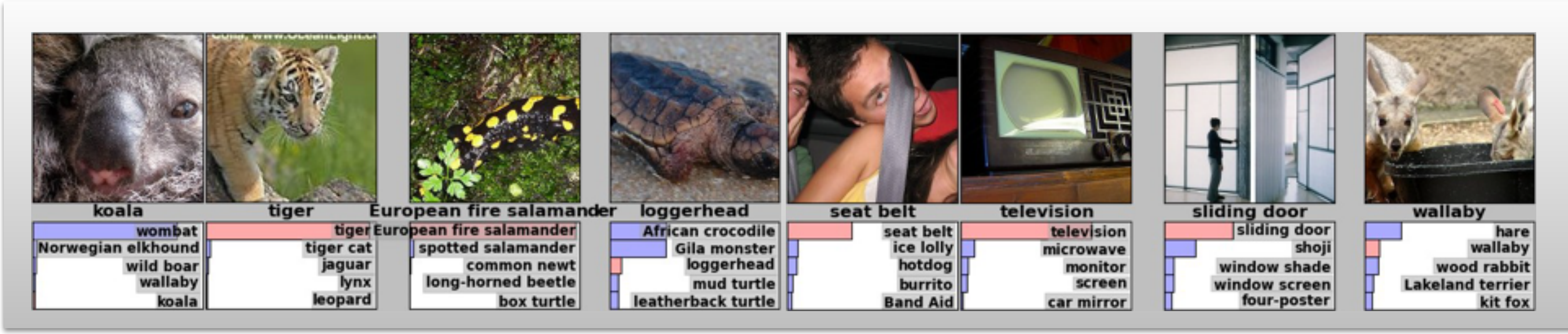
Pooling

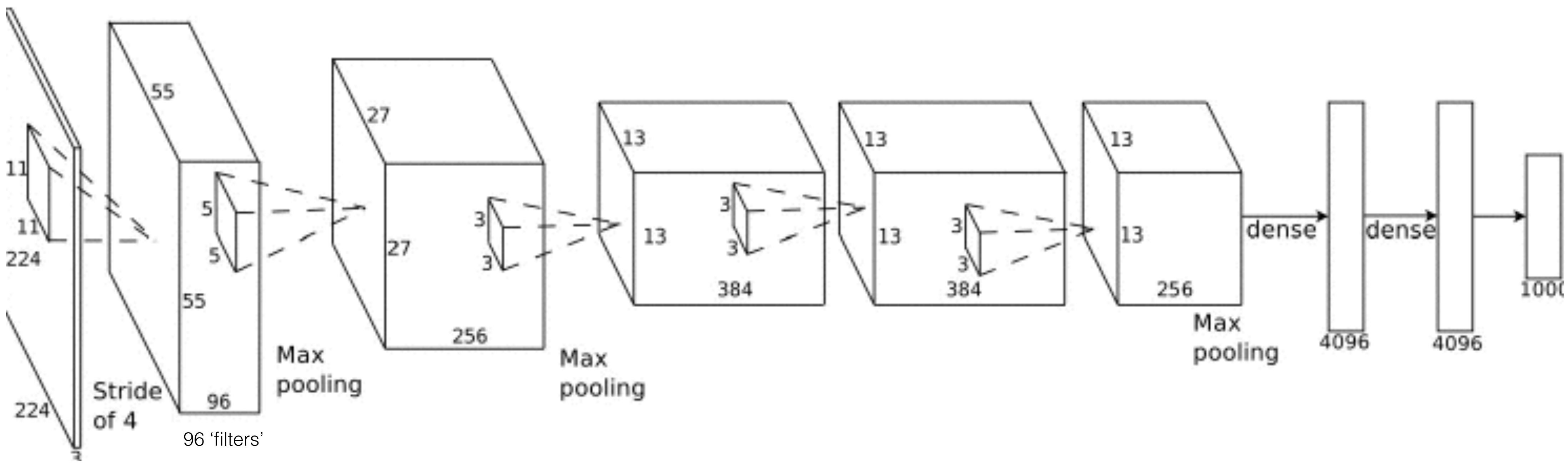


Pooling aggregates statistics and lowers the dimension of convolution


pool size
maps
RF size
input image


INPUT
32x32
C1: feature maps
6@28x28
S2: f. maps
6@14x14
C3: f. maps 16@10x10
S4: f. maps 16@5x5
C5: layer
120
F6: layer
84
OUTPUT
10
Convolutions
Subsampling
Convolutions
Subsampling
Full connection
Full connection
Gaussian





224/4=56

630 million connections
60 millions parameters to learn

Krizhevsky, A., Sutskever, I. and Hinton, G. E.
ImageNet Classification with Deep Convolutional Neural Networks, NIPS 2012.

Pros

- Retains spatial constraints
- Efficient test time performance

Cons

- Many many possible windows to evaluate
- Requires large amounts of data
- Sometimes (very) slow to train

How to write an effective CV resume

Deep Learning

+1-DEEP-LEARNING deeplearning@deeplearning `http://deeplearning`

Summary: Deep Learning

Experience: Deep Learning

Education

Deep Learning Deep Learning *?*
Deep Learning Deep Learning *Deep Learning*

Experience

Deep Learning *Deep Learning .*
Deep Learning *Deep Learning, Deep Learning*

- Deep Learning Deep Learning Deep Learning Deep Learning Deep Learning Deep Learning
- Deep Learning Deep Learning Deep Learning Deep Learning Deep Learning Deep Learning Deep Learning Deep Learning Deep Learning
- Deep Learning Deep Learning Deep Learning Deep Learning Deep Learning Deep Learning Deep Learning Deep Learning

Deep Learning in another country *Deep Learning*
Deep Learning , *Deep Learning , Deep Learning*

- Deep Learning ... wait.. Deep Learning Deep Learning Deep Learning Deep Learning Deep Learning Deep Learning Deep Learning Deep Learning
- Deep Learning Deep Learning Deep Learning Deep Learning Deep Learning Deep Learning Deep Learning Deep Learning

Deep Learning *Deep Learning*
Deep Learning *Deep Learning*

- Very Deep Learning

Publications

1. **Deep Learning in Deep Learning** People who do Deep Learning things. Conference of Deep Learning.
2. **Shallow Learning... Nawww.. Deep Learning bruh** Under submission while Deep Learning

Patent

1. **System and Method for Deep Learning**. Deep Learning, Deep Learning , Deep Learning , Deep Learning