A Bayesian Approach to Unsupervised One-Shot Learning of Object Categories

Li Fei-Fei Rob Fegus Pietro Perona
Presenter:
Tuyen Huynh – Duy Vu

Slides from Li Fei-Fei http://www.vision.caltech.edu/feifeili/Fei-Fei_KUL2003.pdf

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Goal

One-Shot learning of object categories.

Algorithm	Training Examples	Categories
Rowley et al.	~500	Faces
Schneiderman, et al.	~2,000	Faces, Cars
Viola et al.	~10,000	Faces
Burl, et al. Weber, et al. Fergus, et al.	200 ~ 400	Faces, Motorbikes, Spotted cats, Airplanes, Cars

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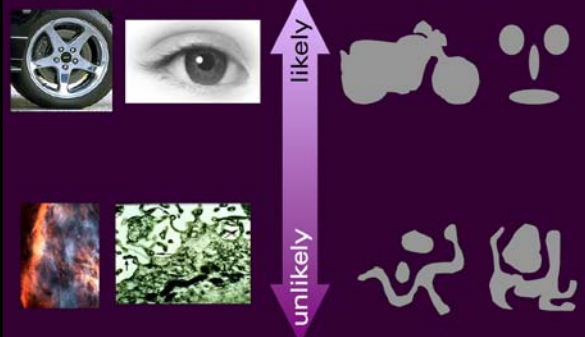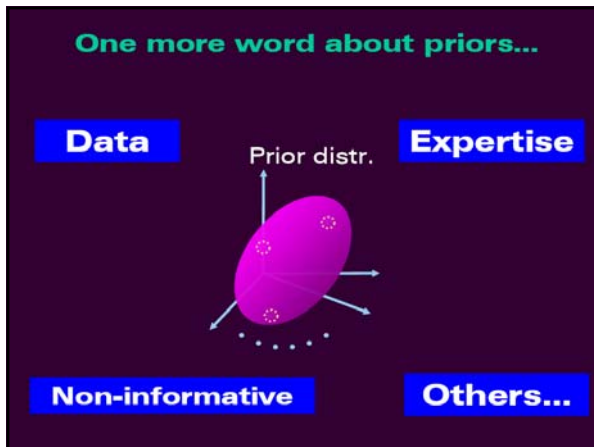## Words of wisdom from statisticians

error
Test
~5 x (# of params)
N*
Bayes error
Train
training examples (N)
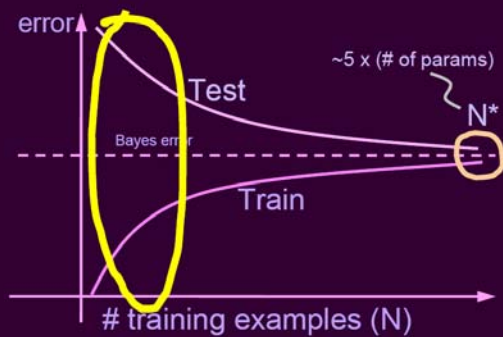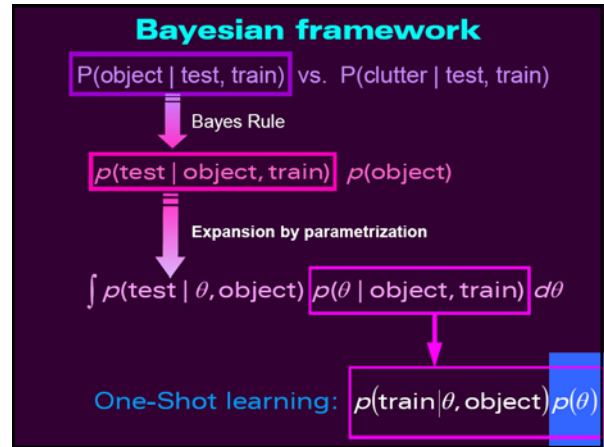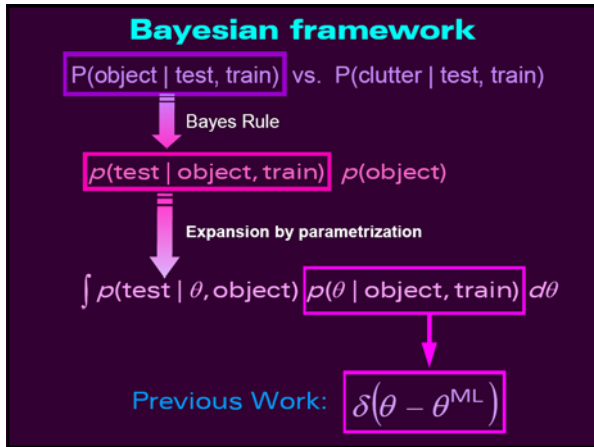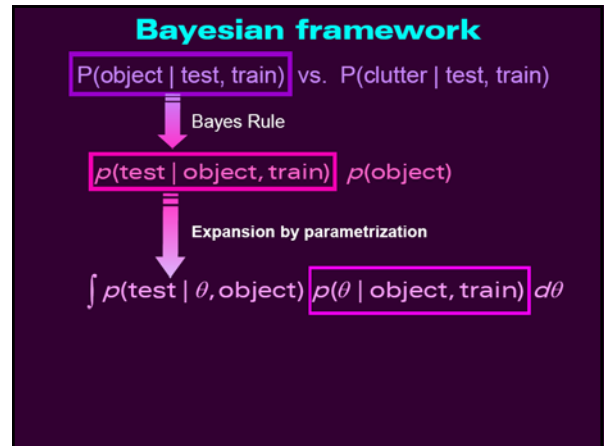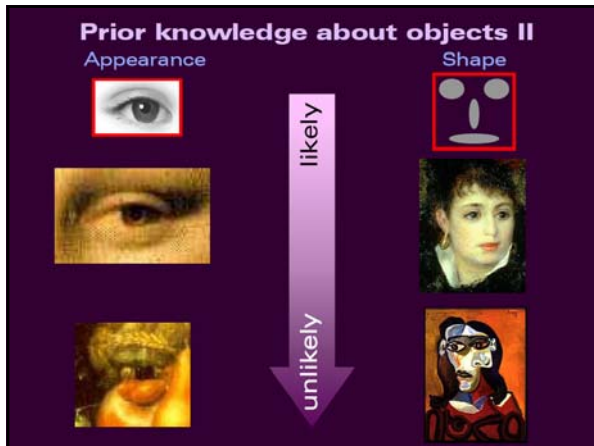

Summary of main points...

- Goal: one-shot learning
- Intuition: use general prior knowledge
- Approach: full Bayesian
  - Marginalize over all θ
- Implementation:
  - Probability models
  - Variational EM

Prior knowledge about objects I

Appearance   Shape

likely

unlikely

Slide 1: Prior knowledge about objects II

Appearance   Shape

likely

unlikely

Slide 2: Bayesian framework

P(object | test, train) vs. P(clutter | test, train)

Bayes Rule

$p(\text{test} \mid \text{object}, \text{train})\ p(\text{object})$

Expansion by parametrization

$\int p(\text{test} \mid \theta, \text{object})\ p(\theta \mid \text{object}, \text{train})\ d\theta$

Slide 3: Bayesian framework

P(object | test, train) vs. P(clutter | test, train)

Bayes Rule

$p(\text{test} \mid \text{object}, \text{train})\ p(\text{object})$

Expansion by parametrization

$\int p(\text{test} \mid \theta, \text{object})\ p(\theta \mid \text{object}, \text{train})\ d\theta$

Previous Work: $\delta\left(\theta - \theta^{\text{ML}}\right)$

Slide 4: Bayesian framework

P(object | test, train) vs. P(clutter | test, train)

Bayes Rule

$p(\text{test} \mid \text{object}, \text{train})\ p(\text{object})$

Expansion by parametrization

$\int p(\text{test} \mid \theta, \text{object})\ p(\theta \mid \text{object}, \text{train})\ d\theta$

One-Shot learning: $p(\text{train} \mid \theta, \text{object})\ p(\theta)$

Slide 5: One more word about priors...

Data

Expertise
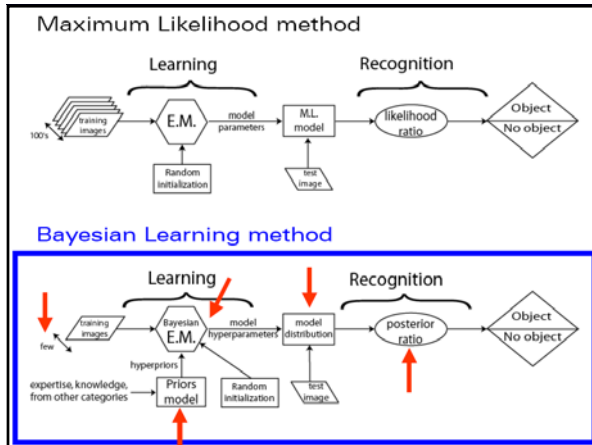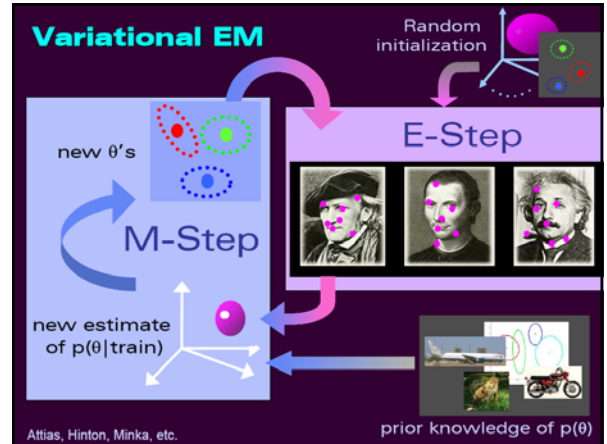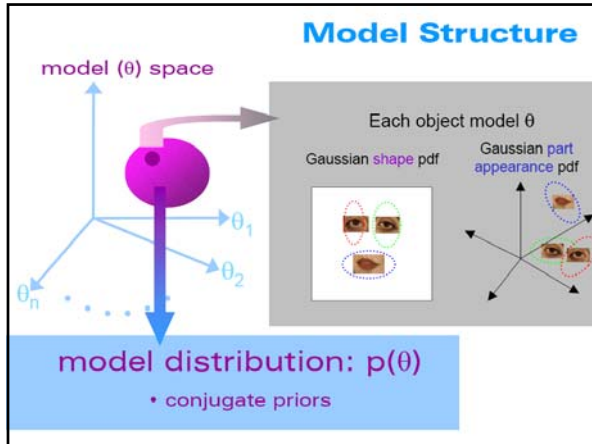
Prior distr.

Non-informative

Others...

Slide 6: Representing θ

Main issues:

• measuring the similarity of parts

• representing the configuration of parts

- Fischler & Elschlager 1973
- Yuille '91
- Brunelli & Poggio '93
- Lades, v.d. Malsburg et al. '93
- Cootes, Lanitis, Taylor et al. '95
- Amit & Geman '95, '99
- Perona et al. '95, '96, '98, '00, '03
- Agarwal & Roth '02

Model Structure

model (θ) space

Each object model θ

Gaussian shape pdf

Gaussian part appearance pdf

model distribution: p(θ)
- conjugate priors

Variational EM

Random initialization

new θ's

M-Step

E-Step

new estimate of p(θ|train)

prior knowledge of p(θ)

Attias, Hinton, Minka, etc.

Maximum Likelihood method

Learning   Recognition

100's training images → E.M. → model parameters → M.L. model → likelihood ratio → Object / No object

Random initialization

test image

Bayesian Learning method

Learning   Recognition

few training images → Bayesian E.M. → model hyperparameters → model distribution → posterior ratio → Object / No object

hyperpriors

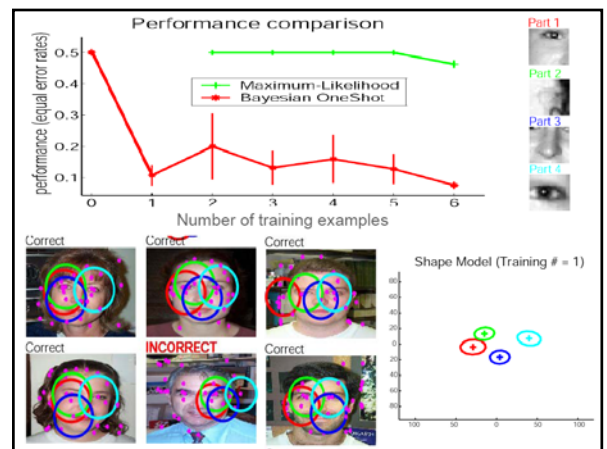expertise, knowledge, from other categories → Priors model
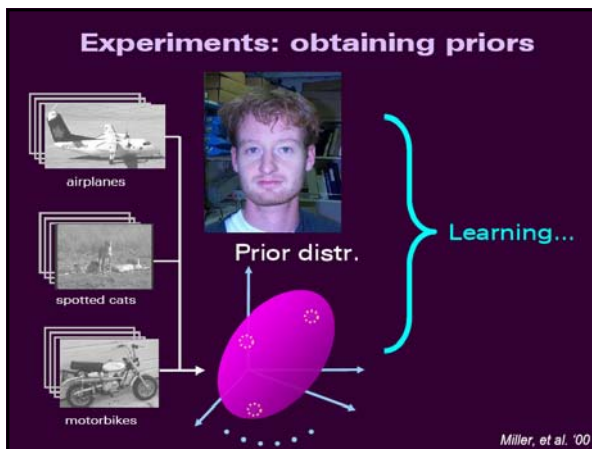
Random initialization

test image

Experiments

Training:
1- 6 images
(randomly drawn)

Testing:
50 fg/ 50 bg images
object present/absent

Datasets

faces   airplanes   spotted cats   motorbikes

[www.vision.caltech.edu]

Experiments: obtaining priors

airplanes

spotted cats

motorbikes

Prior distr.

Learning...

Miller, et al. '00

Performance comparison

Part 1
Part 2
Part 3
Part 4

performance (equal error rates)

Maximum-Likelihood
Bayesian OneShot

Number of training examples

Correct   Correct   Correct

Shape Model (Training # = 1)

Correct   INCORRECT   Correct

3
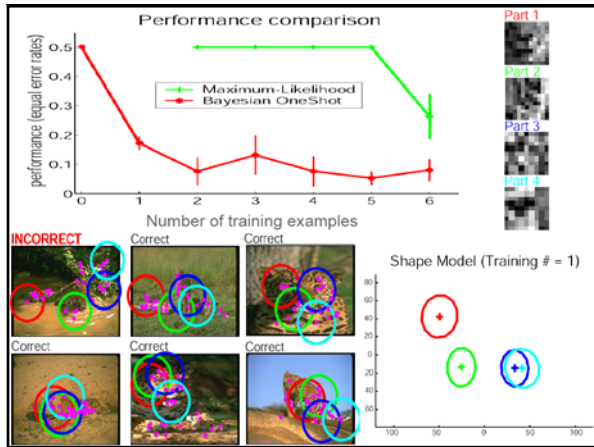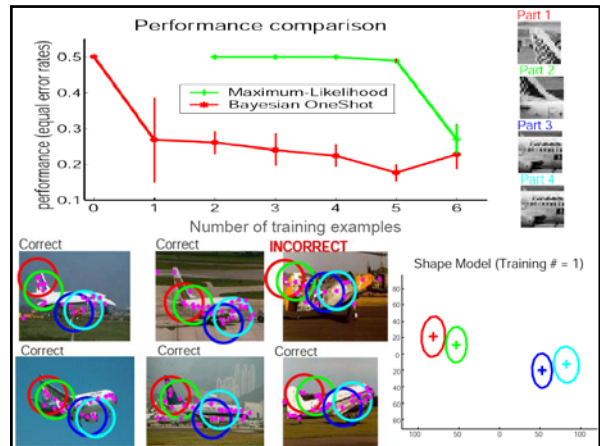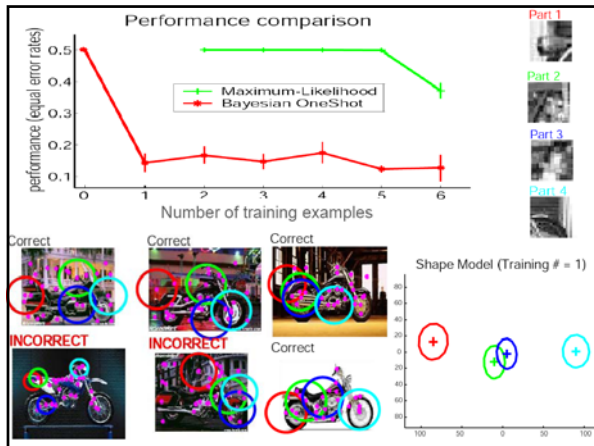
Algorithm	Training Examples	Categories	Results (error)
Burl, et al. Weber, et al. Fergus, et al.	200 ~ 400	Faces, Motorbikes, Spotted cats, Airplanes, Cars	5.6 - 10 %
Bayesian One-Shot	1 ~ 5	Faces, Motorbikes, Spotted cats, Airplanes	8 – 15 %

Summary

- Learning categories with one example is possible
- Can reduce # of training example from ~300 to 1~5 using prior from other categories

References

- L. Fei-Fei, R. Fergus, and P. Perona. A Bayesian approach to unsupervised One-Shot learning of Object categories. *IEEE Inter. Conf. Computer Vision.* 2003
- L. Fei-Fei, R. Fergus and P. Perona. One-Shot learning of object categories. *IEEE Trans. Pattern Analysis and Machine Intelligence, Vol28(4), 594 - 611, 2006*
- Video of Fei-Fei's talk at ICCV 2003: http://www.robots.ox.ac.uk/~awf/iccv03videos/ICCV03-S11-P2-DIVX-MP3.avi
- Variational Bayes: http://www.variational-bayes.org/