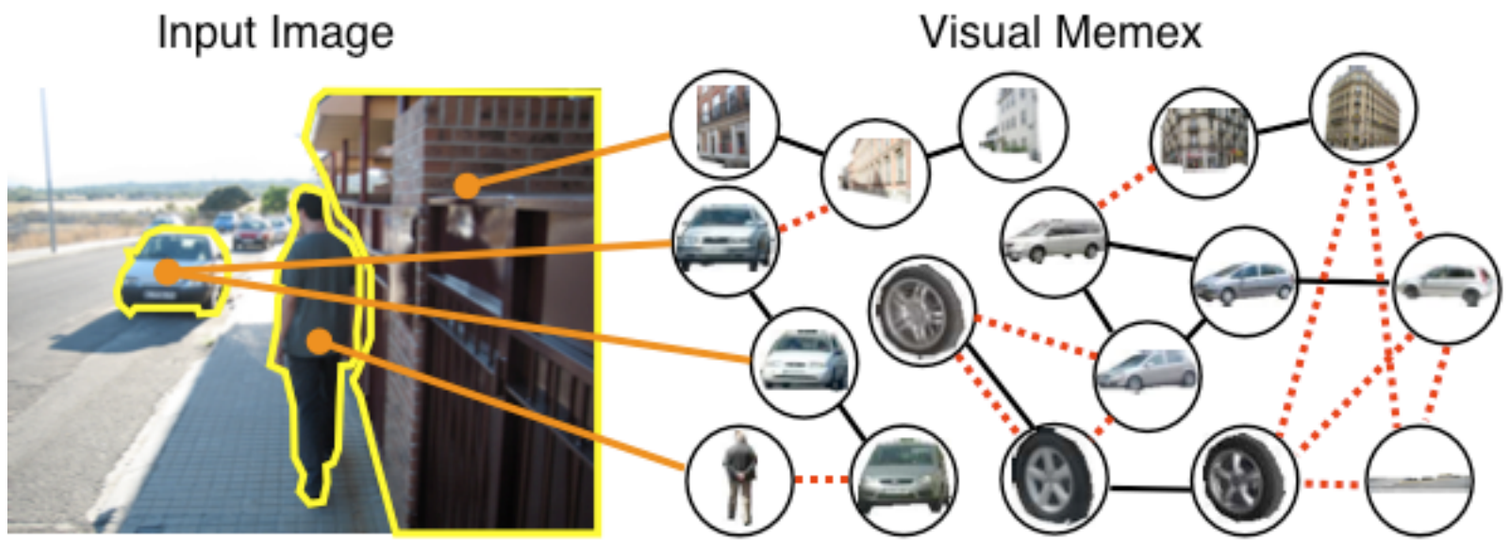
Beyond Categories:
The Visual Memex Model for Reasoning About Object Relationships



Tomasz Malisiewicz and Alexei (Alyosha) Efros

NIPS 2009

Presented at CMU's misc-read on 11/4/2009

Overview

- Motivation
- Visual Memex Model
- Evaluation Task: Context Challenge
- Results and Comparisons to Baselines
- Examples

Understanding an Image

slide by Fei Fei, Fergus & Torralba

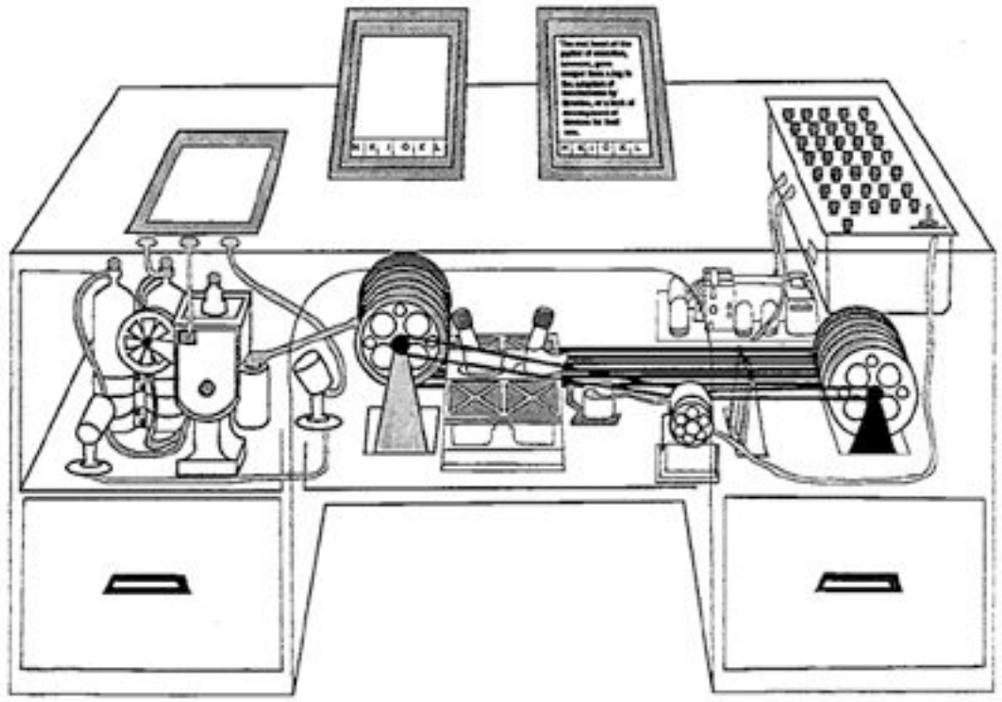
Object naming

slide by Fei Fei, Fergus & Torralba

Object naming / Object categorization

slide by Fei Fei, Fergus & Torralba

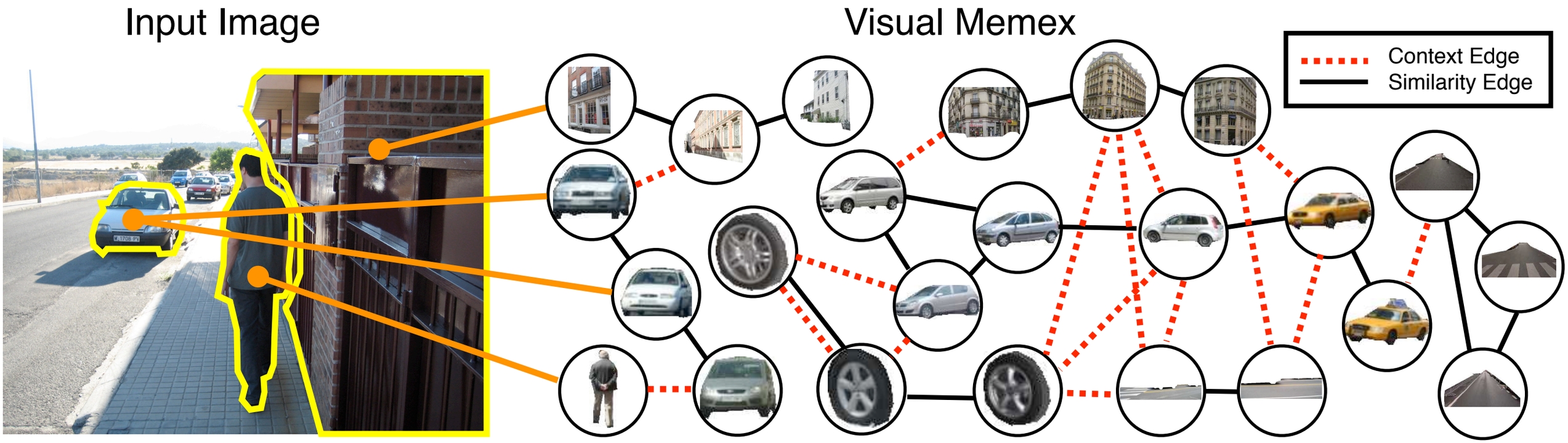
Vannevar Bush' Memex



Memex: A device to organize concepts and ideas via a web of associations (and not indexing)

V. B. "As We May Think," The Atlantic, 1945

Visual Memex Model

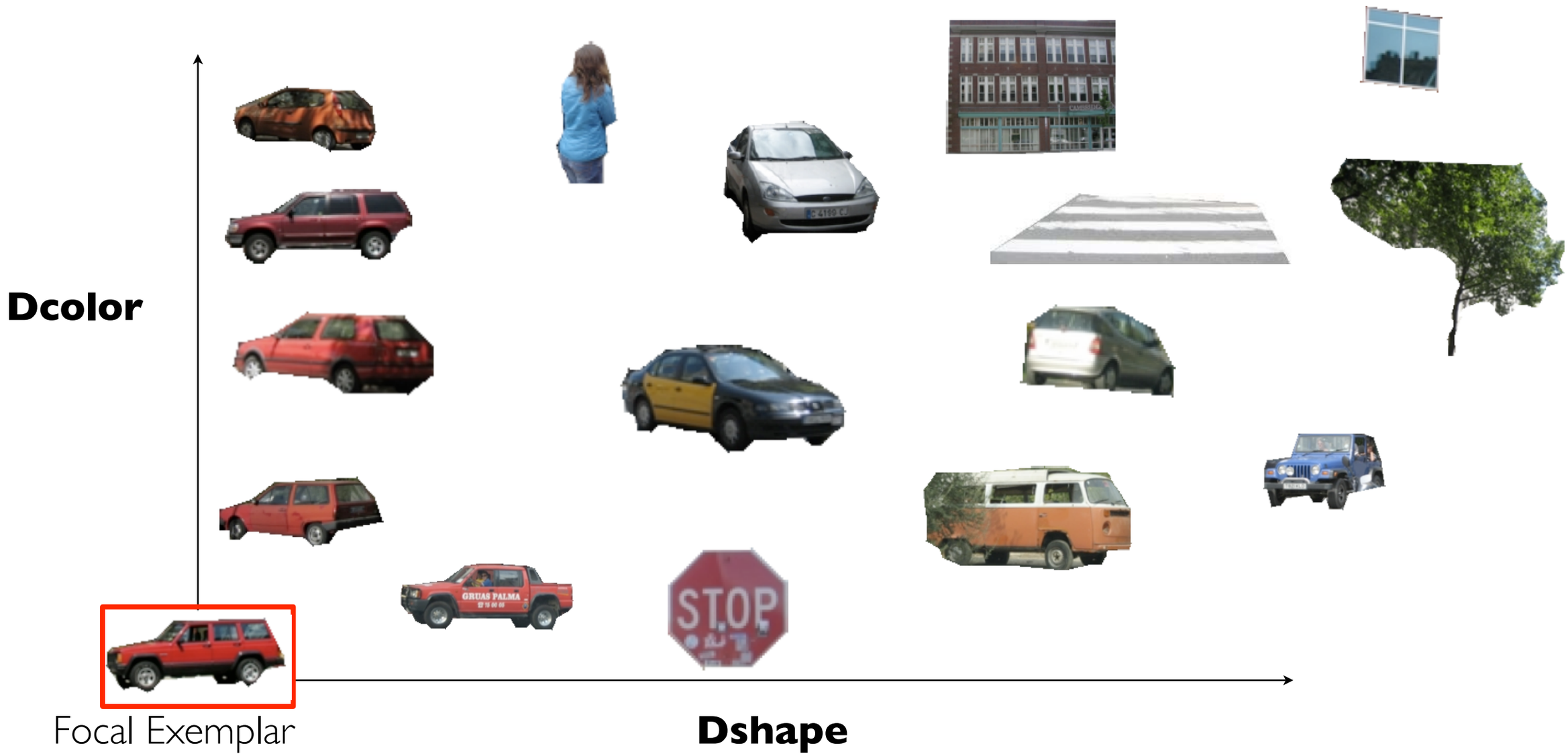


Learning Similarity Edges

- Per-exemplar distance function learning algorithm from CVPR 2008

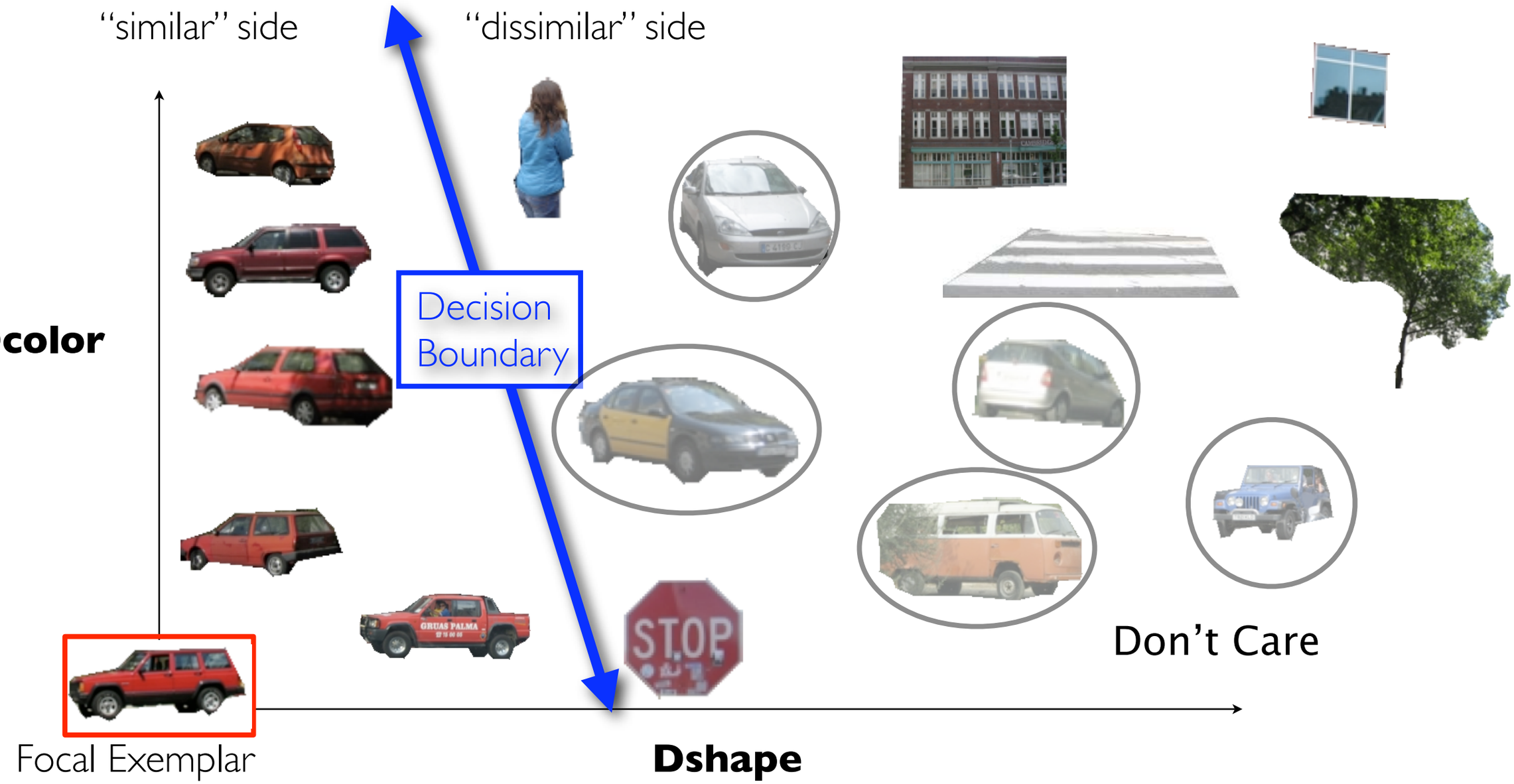
Type	Name	Dimension
Shape	Centered Mask	32x32=1024
	BB Extent	2
	Pixel Area	1
Texture	Right Boundary Tex-Hist	100
	Top Boundary Tex-Hist	100
	Left Boundary Tex-Hist	100
	Bottom Boundary Tex-Hist	100
	Interior Tex-Hist	100
Color	Mean Color	3
	Color std	3
	Color Histogram	33
Location	Absolute Mask	8x8=64
	Top Height	1
	Bot Height	1

Learning Similarity Edges



$$f(\mathbf{w}, b, \boldsymbol{\alpha}) = \frac{\lambda}{2}||\mathbf{w}||^2 + \sum_{i \in C} \boldsymbol{\alpha}_i \, L(-(\mathbf{w}^T \mathbf{d}_i + b)) + \sum_{i \notin C} L(\mathbf{w}^T \mathbf{d}_i + b) - \sigma||\,\boldsymbol{\alpha}\,||^2$$

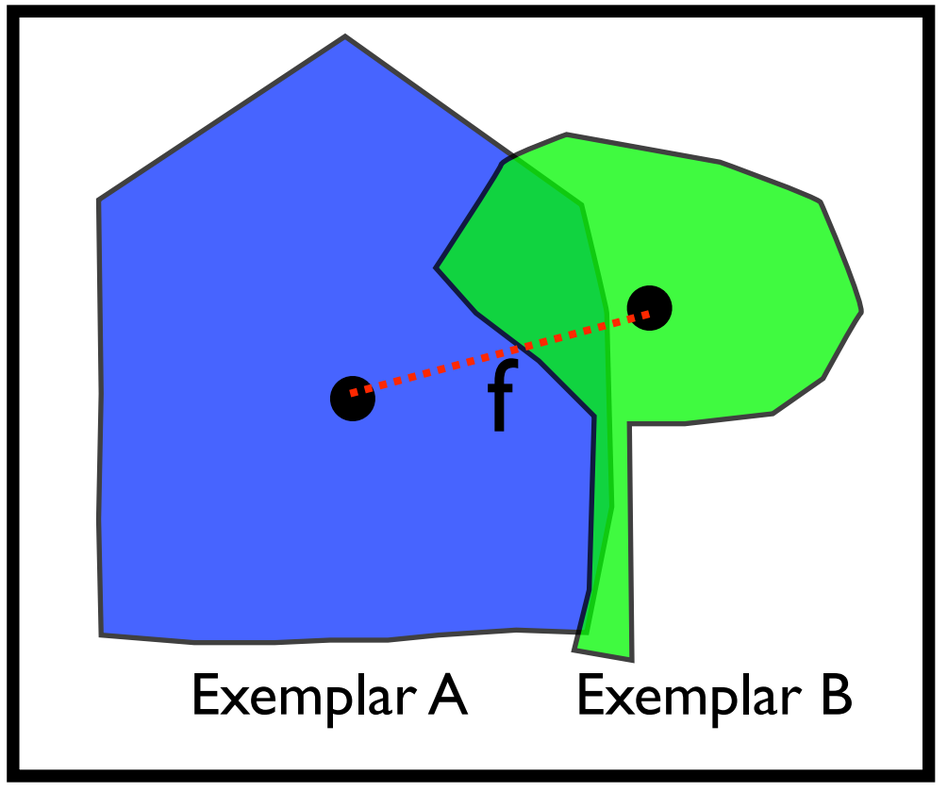
Learning Similarity Edges



$$f(\mathbf{w}, b, \boldsymbol{\alpha}) = \frac{\lambda}{2}||\mathbf{w}||^2 + \sum_{i \in C} \boldsymbol{\alpha}_i \, L(-(\mathbf{w}^T \mathbf{d}_i + b)) + \sum_{i \notin C} L(\mathbf{w}^T \mathbf{d}_i + b) - \sigma||\,\boldsymbol{\alpha}\,||^2$$

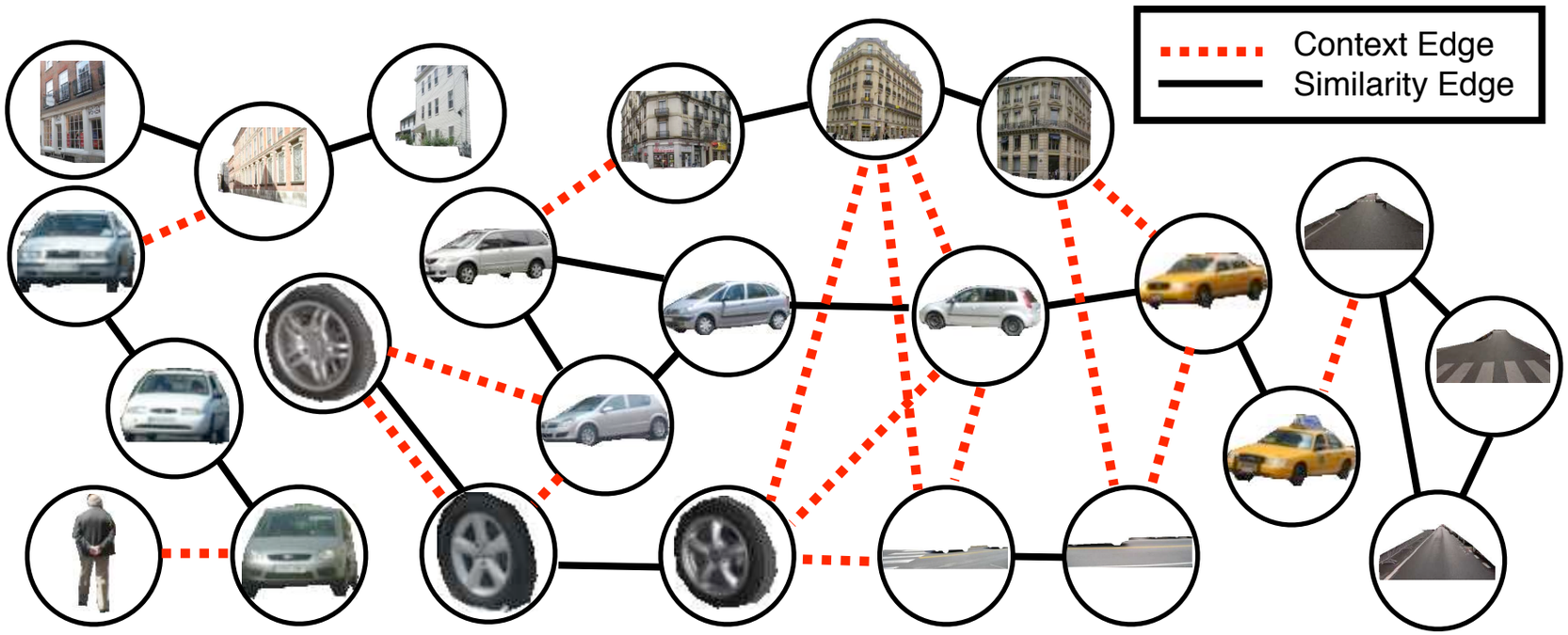
Context Edges

- Compute pairwise feature for each pair of exemplars in a single image
- Overlap, Scale, Displacement, Bottom-pixel Height $\mathbf{f} \in \Re^{10}$
- No appearance!



$$K(\mathbf{f}, \mathbf{f}') = e^{-\alpha_1 || \mathbf{f} - \mathbf{f}' ||^2}$$

Visual Memex Model



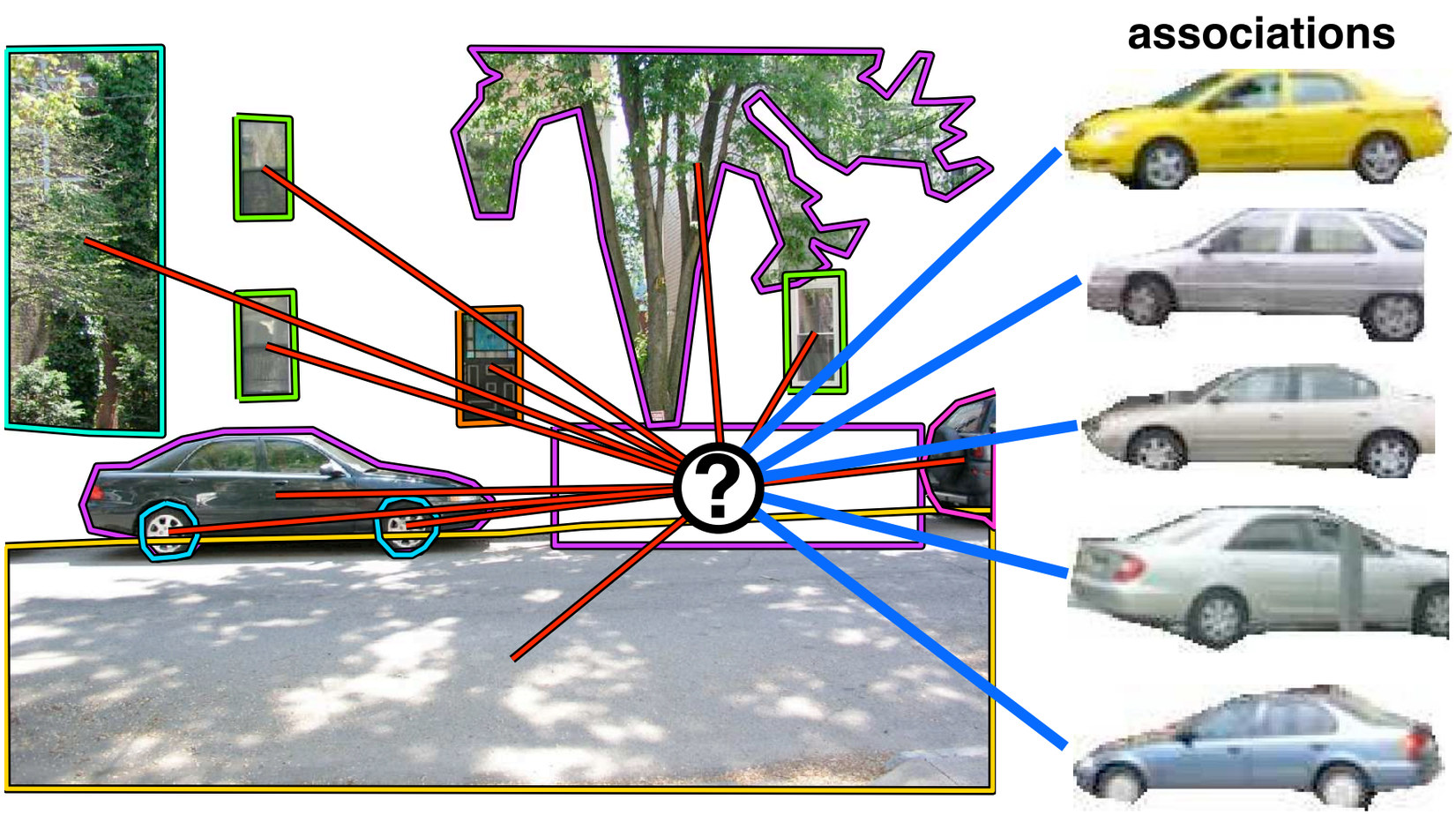
$$G = (V, E_S, E_C, \{D\}, \{\mathbf{f}\})$$

$$N = 87,802 \qquad |E_S| = 276,782 \qquad |E_C| = 989,106$$

Evaluation Task: Context Challenge

- Compare against Category-Based models
- Perform context-only recognition "without local appearance"
- Motivated by Torralba: "How far can you go without running an object detector?"
- Our context is object-centered as opposed to Torralba's scene-centered GIST context

Context Challenge



Visual Memex Inference

- **Goal**: Create exemplar associations for hidden region given K supporting object regions
- **Approach**: Score the assignment of every exemplar to the hidden region

Visual Memex Inference

Appearance Features of supporting objects $\{S_1, \ldots, S_K\}$

Soft Associations between supporting objects and Memex exemplars $A_j^a = e^{-D_a(S_j)}$

Exemplar-Exemplar Pairwise Potential $\Psi(e_i, e_j, \mathbf{f}_{ij})$

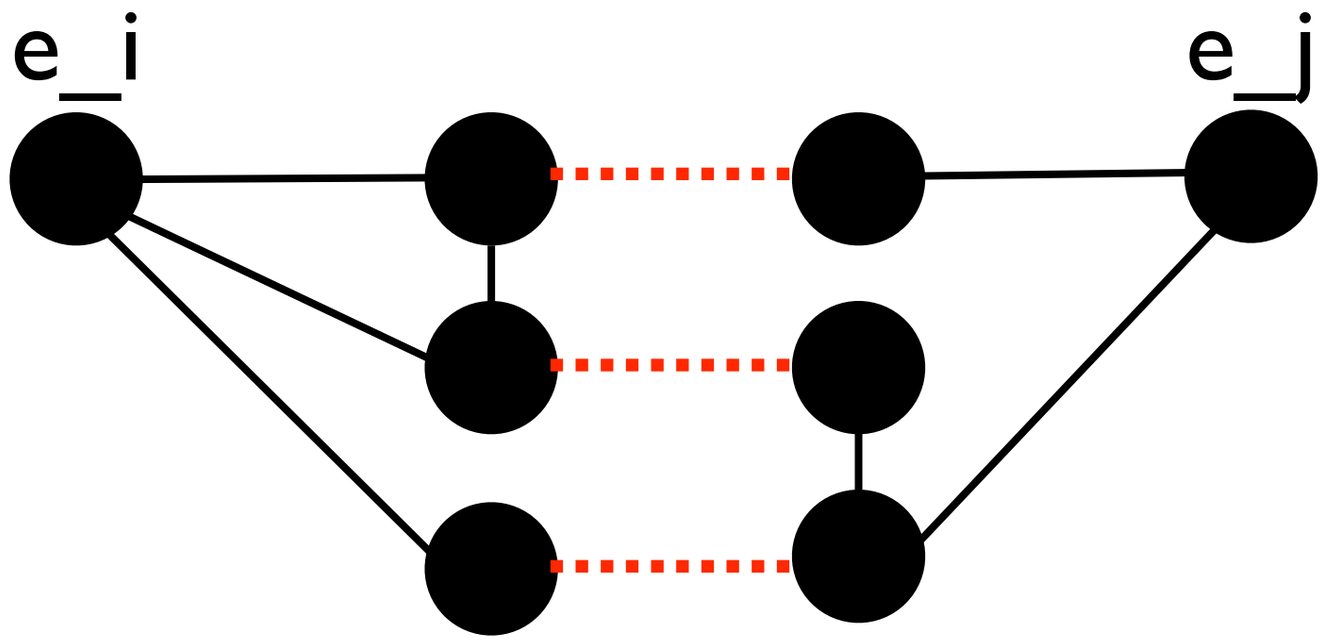
$$p(e_i|A_1, \ldots, A_K, \mathbf{f}_{i1}, \ldots, \mathbf{f}_{iK}) \propto \prod_{j=1}^{K} \sum_{a=1}^{N} A_j^a \Psi(e_i, e_a, \mathbf{f}_{ij})$$

“Densification” Potential

Visual Memex Adjacency Matrix

$$W_{uv} = [(u,v) \in E_S]$$

$$\log \Psi(e_i, e_j, \mathbf{f}_{ij}) = \frac{\sum_{(u,v)\in E_C} W_{iu} W_{jv} K(\mathbf{f}_{ij}, \mathbf{f}_{uv})}{\sum_{(u,v)\in E_C} W_{iu} W_{jv}}$$

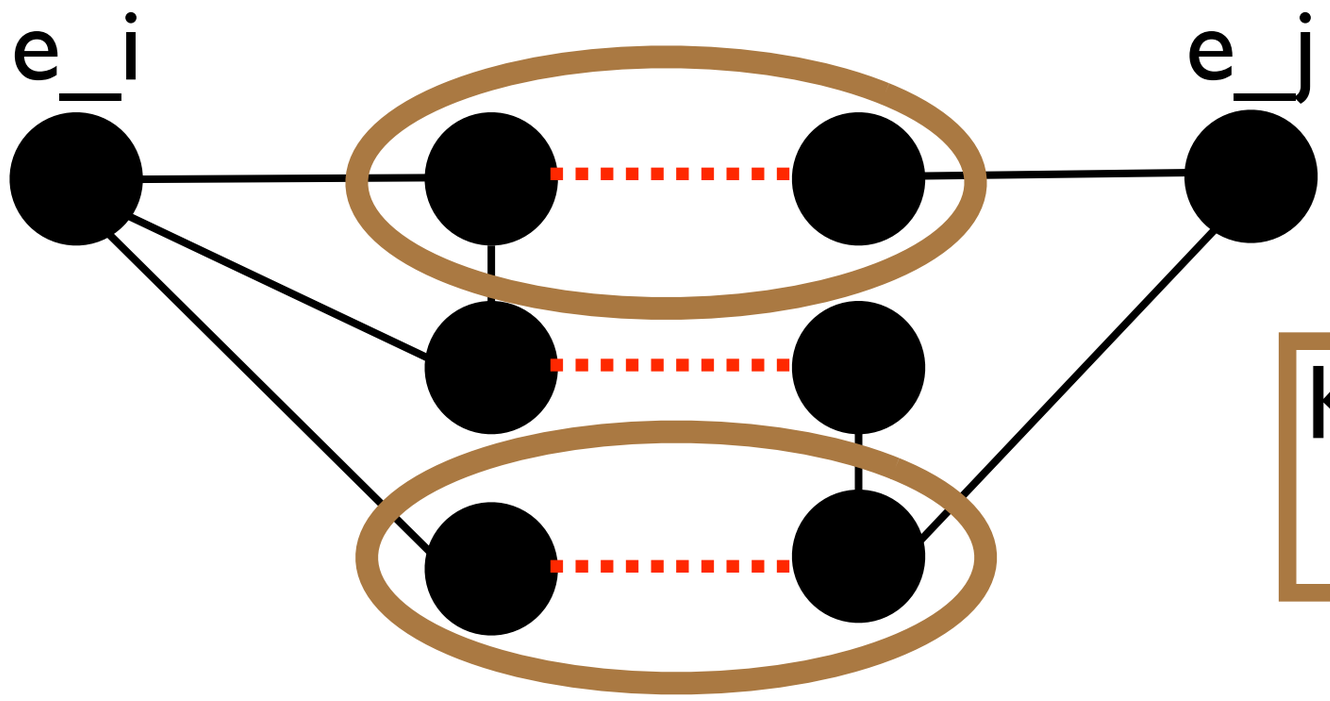


“Densification” Potential

Visual Memex Adjacency Matrix

$$W_{uv} = [(u,v) \in E_S]$$

$$\log \Psi(e_i, e_j, \mathbf{f}_{ij}) = \frac{\sum_{(u,v)\in E_C} W_{iu} W_{jv} K(\mathbf{f}_{ij}, \mathbf{f}_{uv})}{\sum_{(u,v)\in E_C} W_{iu} W_{jv}}$$



KDE with these features

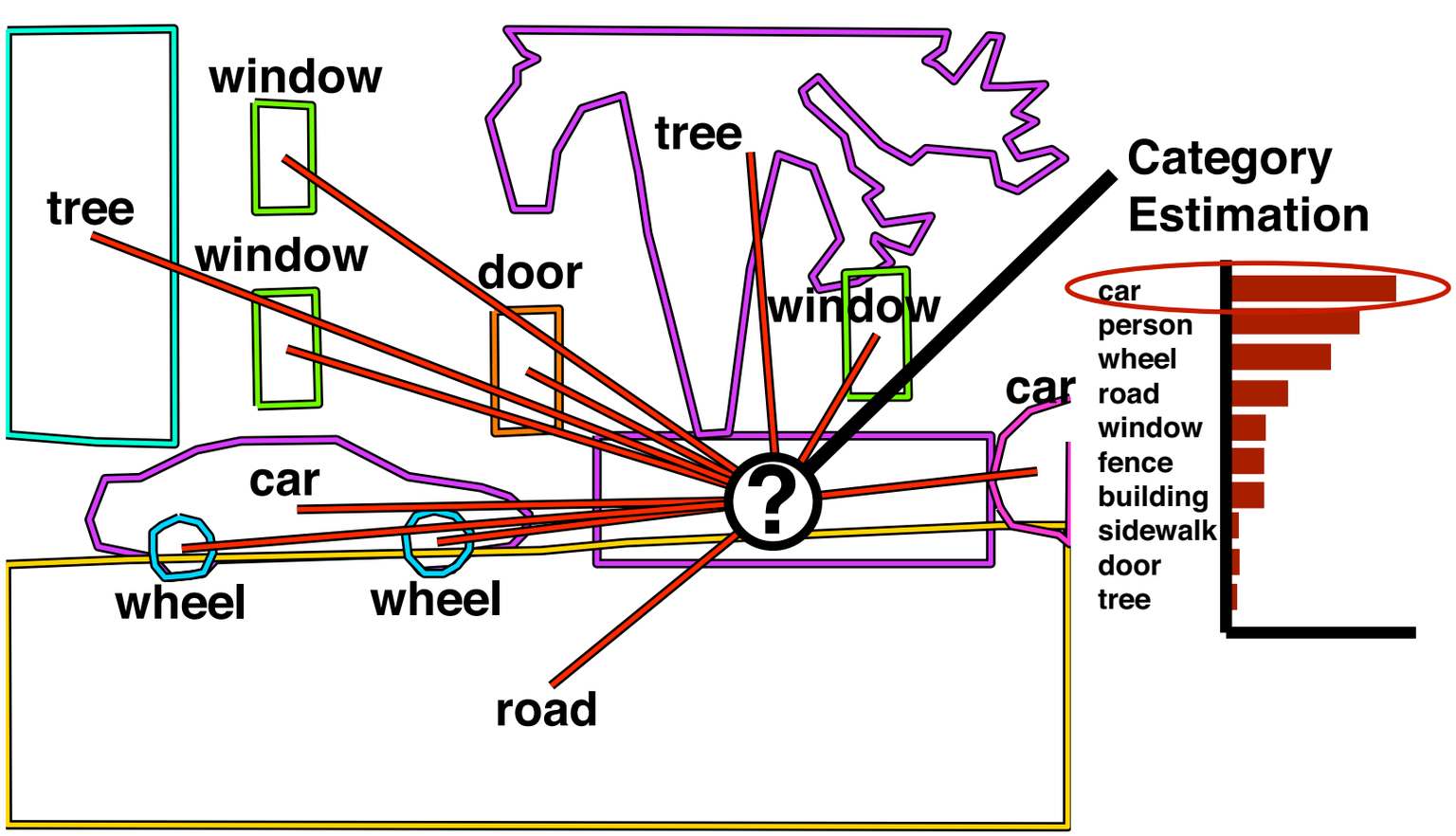
Baselines

- Category-based parametric CoLA model (Serge Belongie's Vision Group)
- Category-based Reduced Memex (categories for objects + nonparametric context model)

CoLA Baseline

$$p(y_i|y_1,\ldots,y_K,\mathbf{f}_{i1},\ldots,\mathbf{f}_{iK},\boldsymbol{\theta}) = \frac{1}{Z}\prod_{j=1}^{K}\Psi(y_i,y_j,\mathbf{f}_{ij},\boldsymbol{\theta})$$

$$\log\Psi(y_i,y_j,\mathbf{f}_{ij},\boldsymbol{\theta}) \quad = \quad [h(\mathbf{f}_{ij})^T]\,\boldsymbol{\theta}(y_i,y_j)$$



Reduced KDE Memex

- No distance function learning
- Just connect all exemplars of the same category

$$\log \Psi(y_i, y_j, \mathbf{f}_{ij}) = \frac{\sum_{(u,v)\in E_C} \delta_{y_i y_u} \delta_{y_j y_v} K(\mathbf{f}_{ij}, \mathbf{f}_{uv})}{\sum_{(u,v)\in E_C} \delta_{y_i y_u} \delta_{y_j y_v}}$$

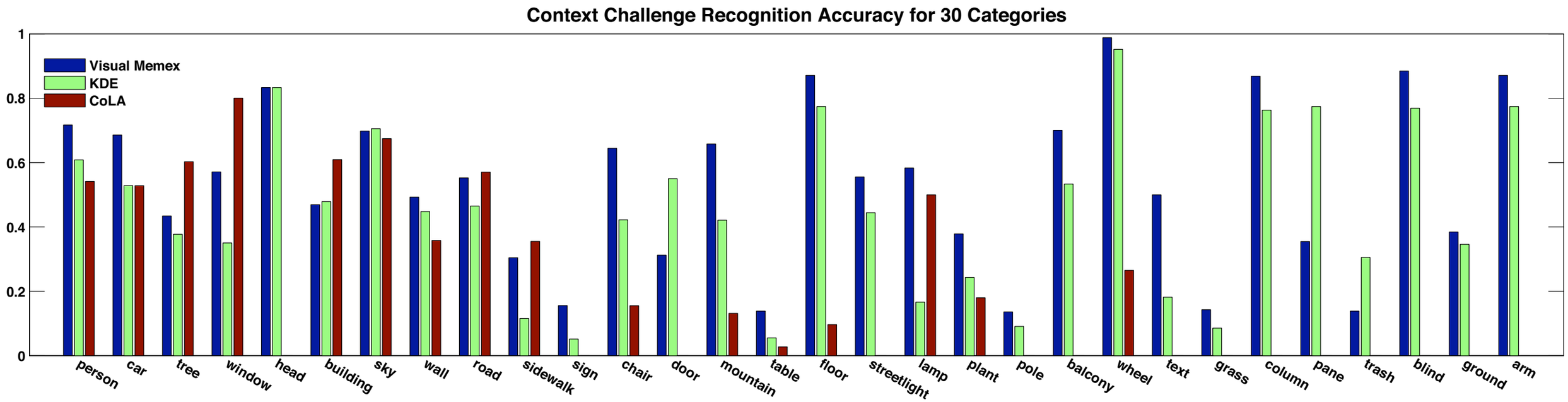
Results

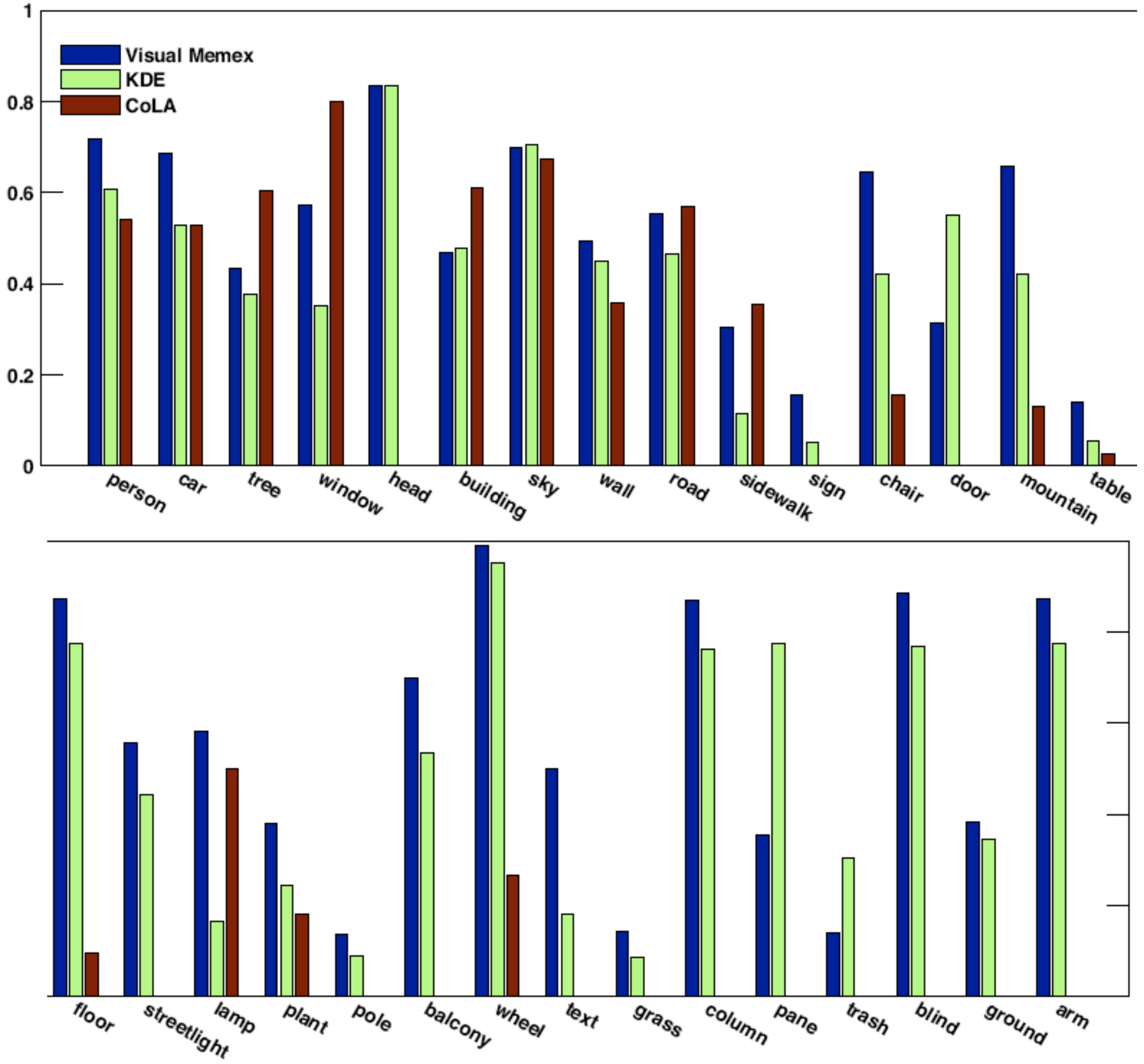
- 200 Densely labeled LabelMe images
- Solve separate Context Challenge task for a single object while fixing supporting objects

Results

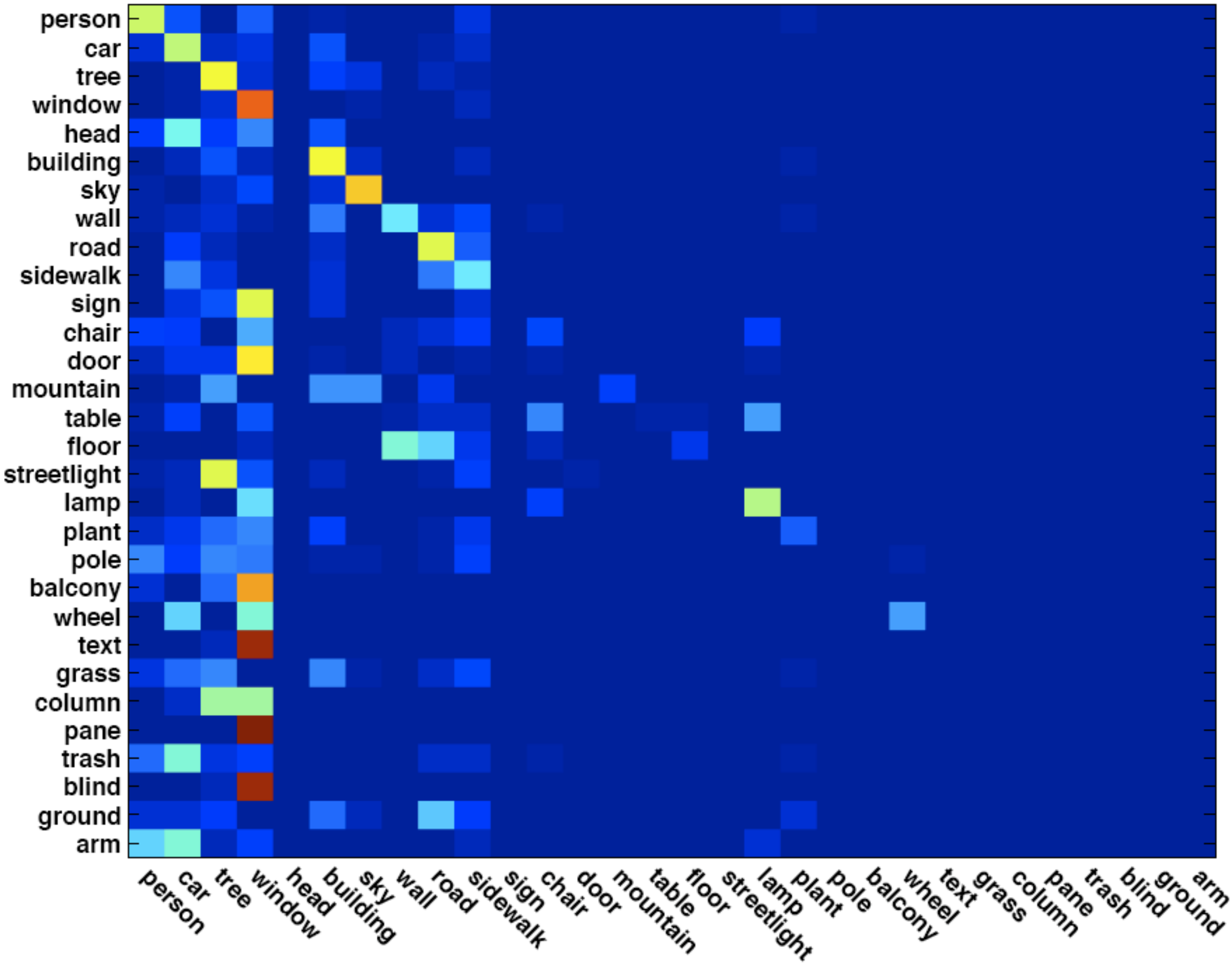
	Overall	Per-Category
Visual Memex	**0.527**	**0.534**
KDE Memex	0.430	0.454
CoLA	0.457	0.213

Per-Category Results

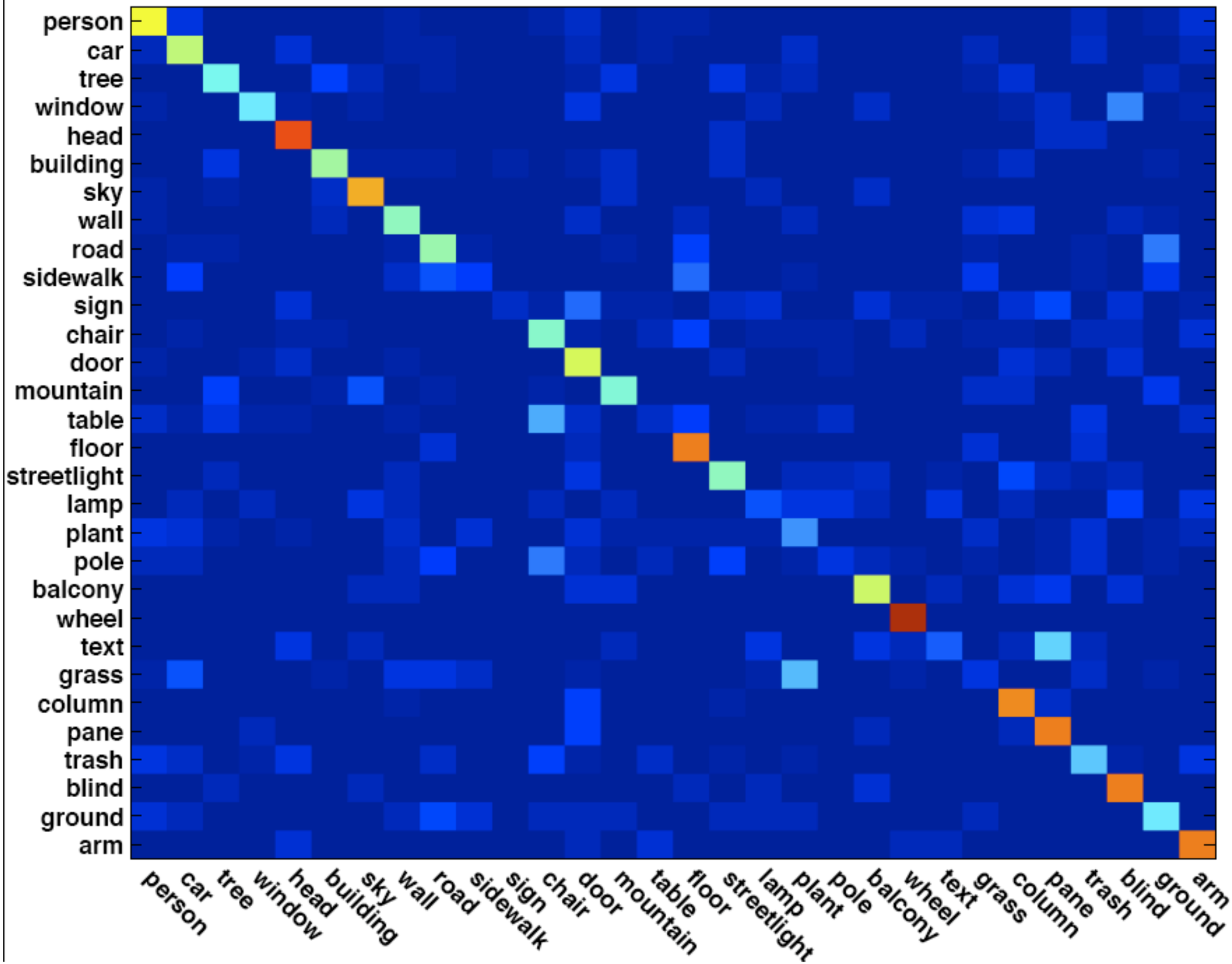



Visual Memex
KDE
CoLA
1
0.8
0.6
0.4
0.2
0
person
car
tree
window
head
building
sky
wall
road
sidewalk
sign
chair
door
mountain
table
floor
streetlight
lamp
plant
pole
balcony
wheel
text
grass
column
pane
trash
blind
ground
arm

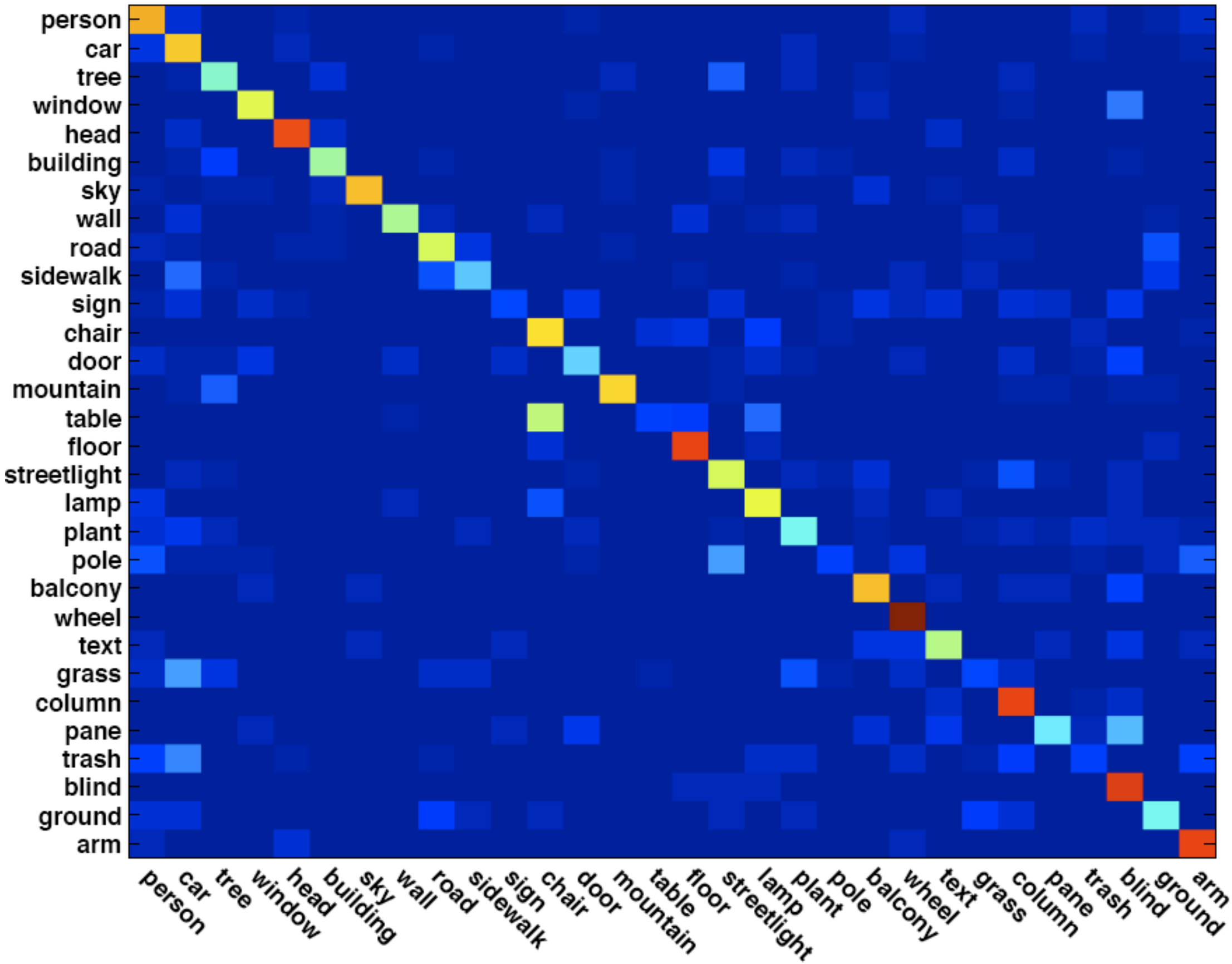
CoLA


person
car
tree
window
head
building
sky
wall
road
sidewalk
sign
chair
door
mountain
table
floor
streetlight
lamp
plant
pole
balcony
wheel
text
grass
column
pane
trash
blind
ground
arm

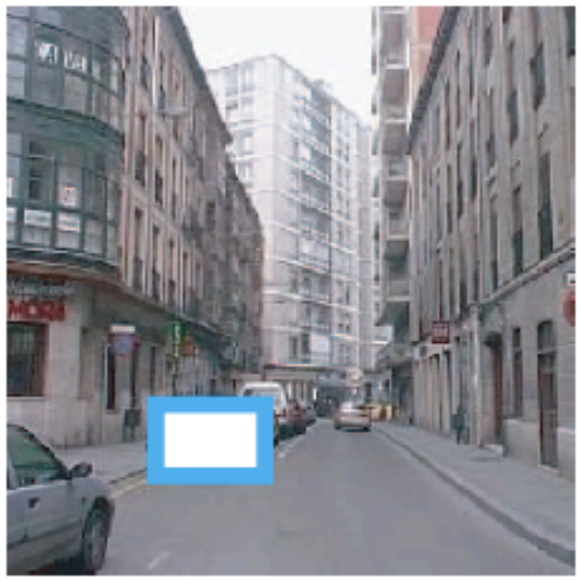
KDE


person
car
tree
window
head
building
sky
wall
road
sidewalk
sign
chair
door
mountain
table
floor
streetlight
lamp
plant
pole
balcony
wheel
text
grass
column
pane
trash
blind
ground
arm

Visual Memex



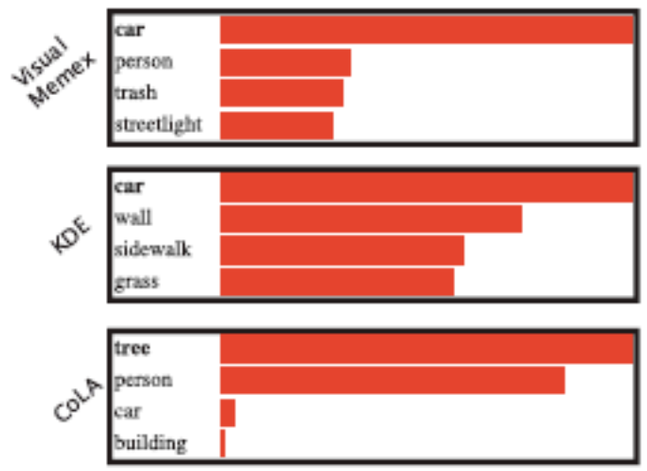
Input Image + Hidden Region

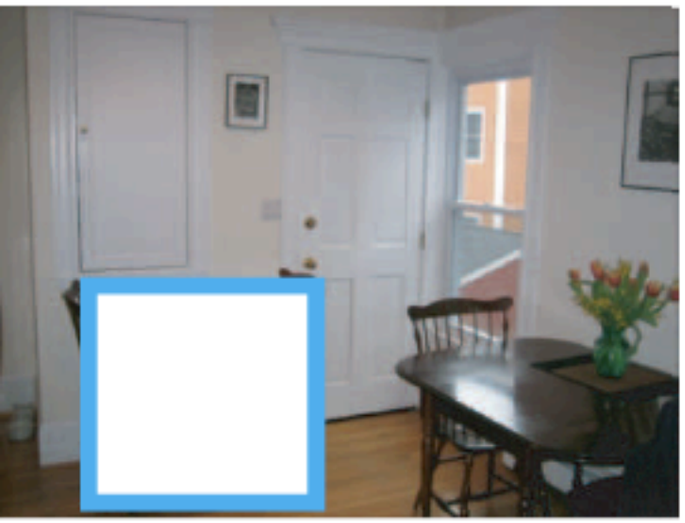


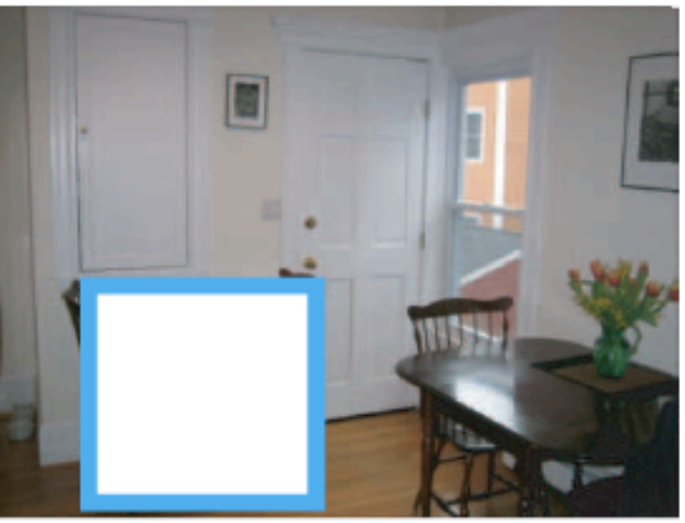
Input Image + Hidden Region

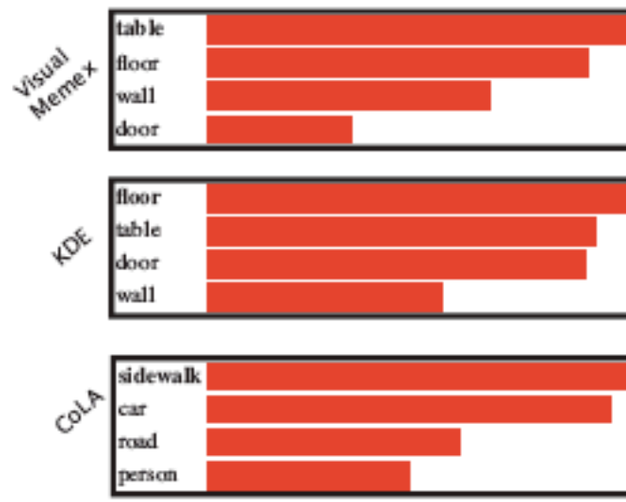
Visual Memex Exemplar Predictions

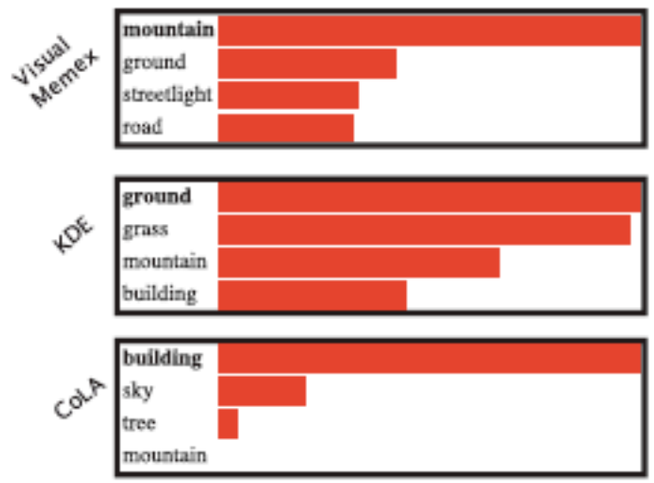
Categorization Results

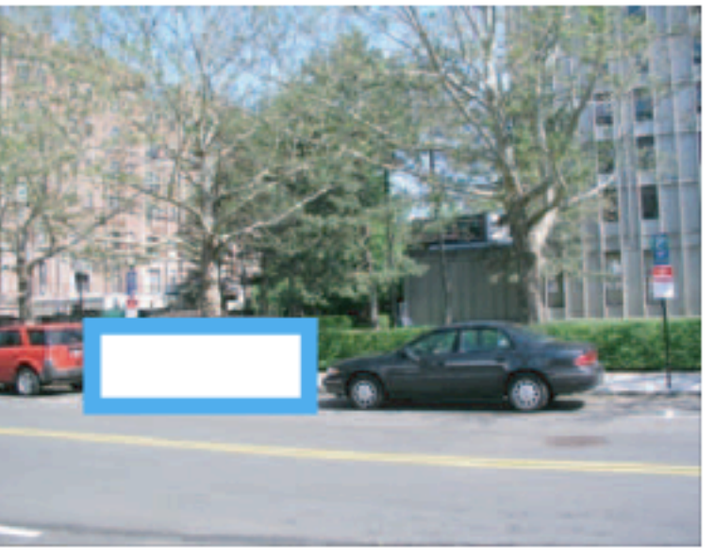


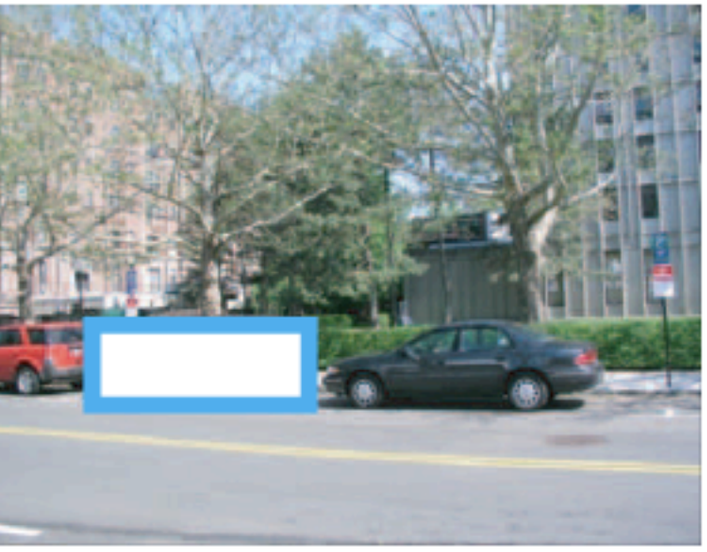


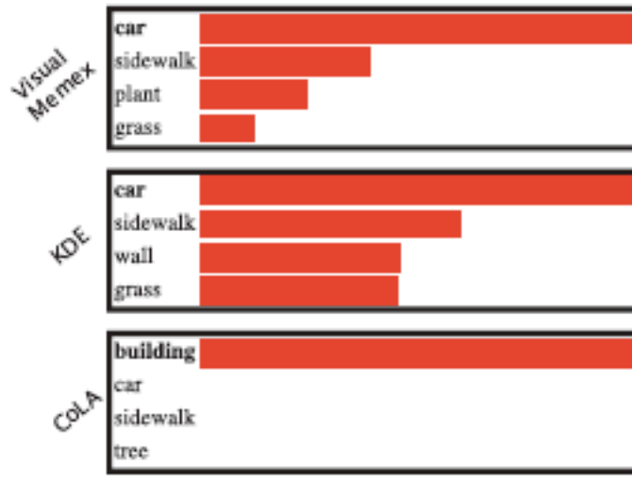


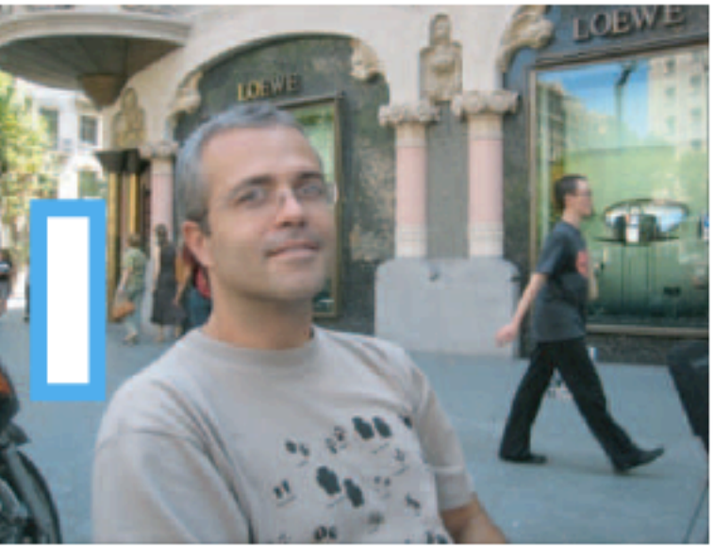

Visual Memex
table
floor
wall
door
KDE
floor
table
door
wall
CoLA
sidewalk
car
road
person

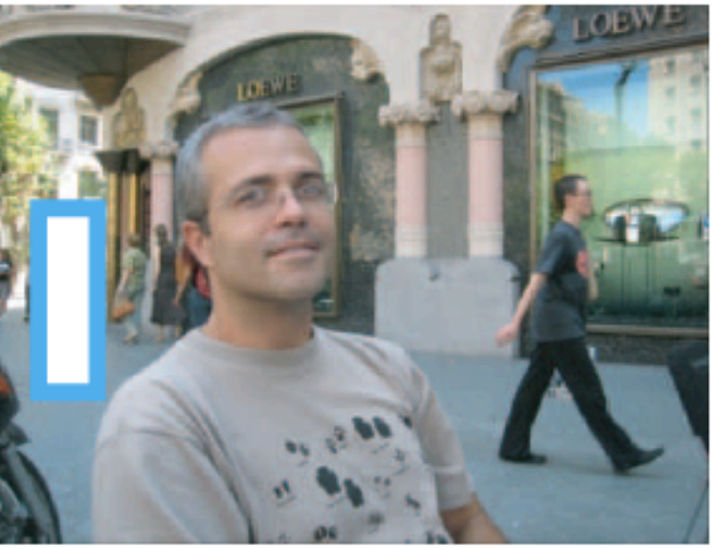

Visual Memex
mountain
ground
streetlight
road
KDE
ground
grass
mountain
building
CoLA
building
sky
tree
mountain

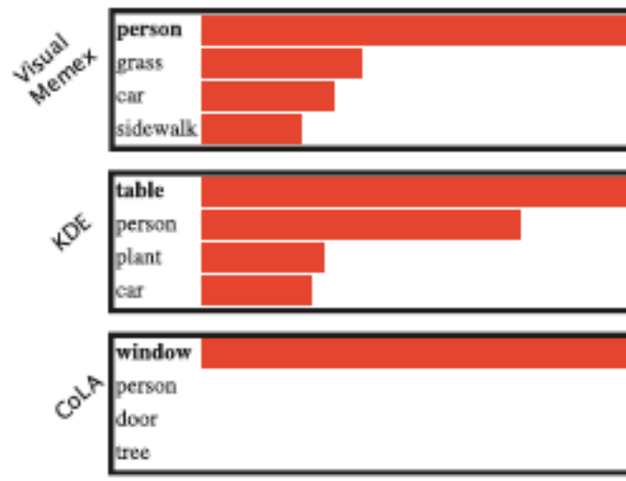


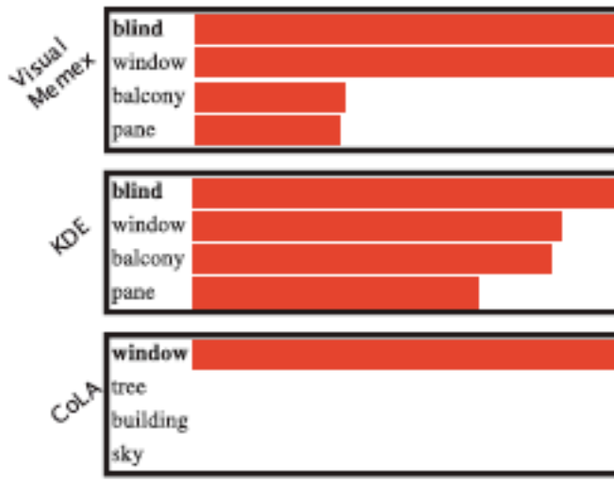


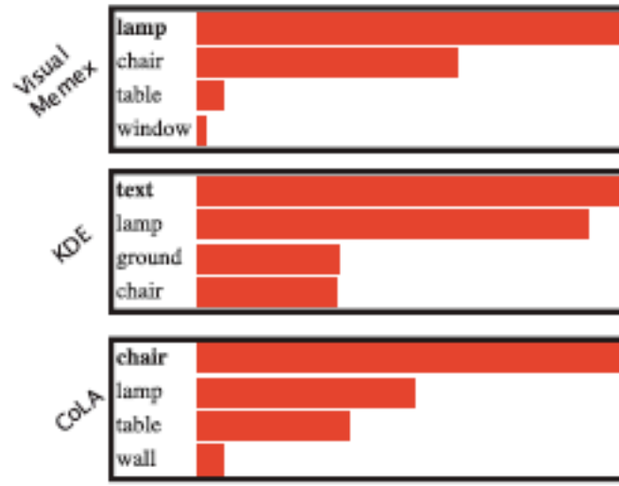

Visual Memex
car
sidewalk
plant
grass
KDE
car
sidewalk
wall
grass
CoLA
building
car
sidewalk
tree


LOEWE
LOEWE


LOEWE
LOEWE


Visual Memex
person
grass
car
sidewalk
KDE
table
person
plant
car
CoLA
window
person
door
tree


Visual Memex
blind
window
balcony
pane
KDE
blind
window
balcony
pane
CoLA
window
tree
building
sky


Visual Memex
lamp
chair
table
window
KDE
text
lamp
ground
chair
CoLA
chair
lamp
table
wall

Conclusion

- Visual Memex is a Category-free approach to Modeling Object Relationships
- Is distance function learning without labels possible? (Then the entire approach would be category-free)
- Can the Visual Memex be applied to scene parsing where only an image is given?