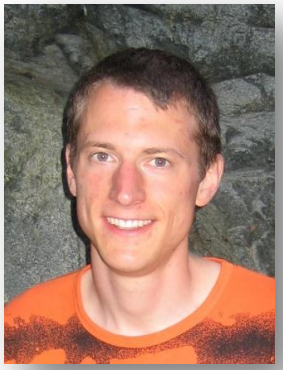
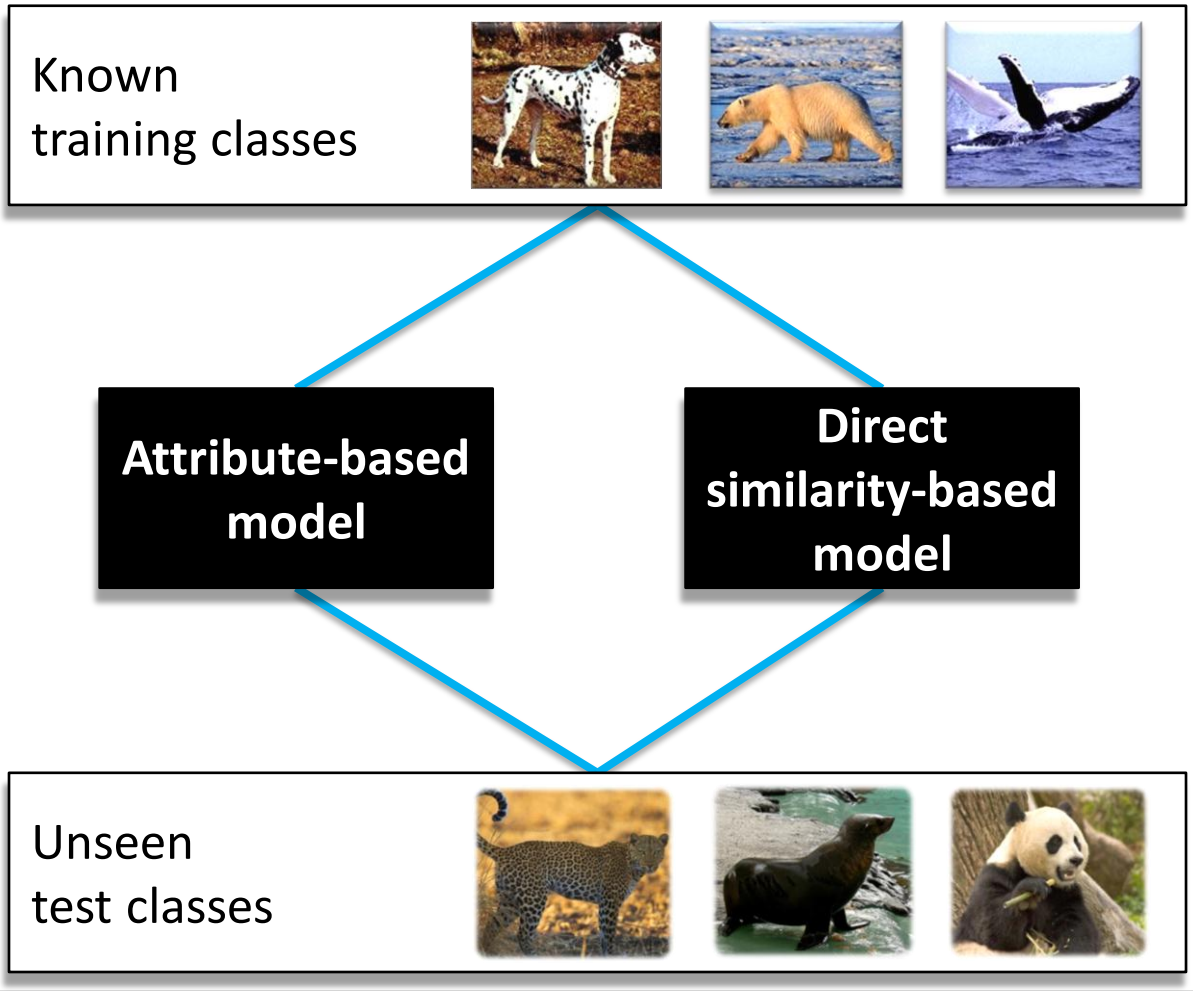
# Combining Language Sources and Robust Semantic Relatedness for Attribute-Based Knowledge Transfer



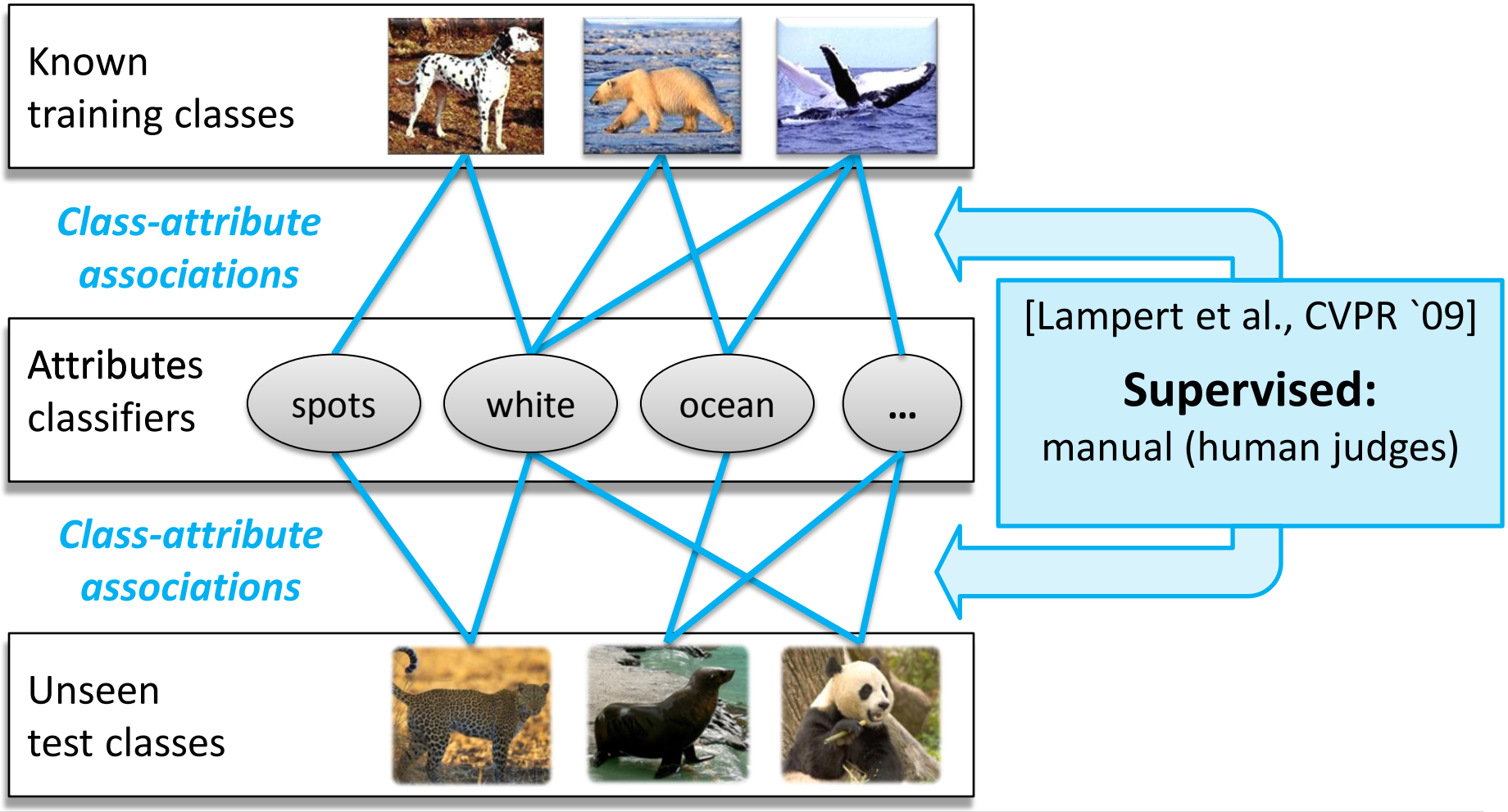

**Marcus Rohrbach**[1,2] Michael Stark[1,2] György Szarvas[1] Bernt Schiele[1,2]

[1]Department of Computer Science, TU Darmstadt [2]MPI Informatics, Saarbrücken

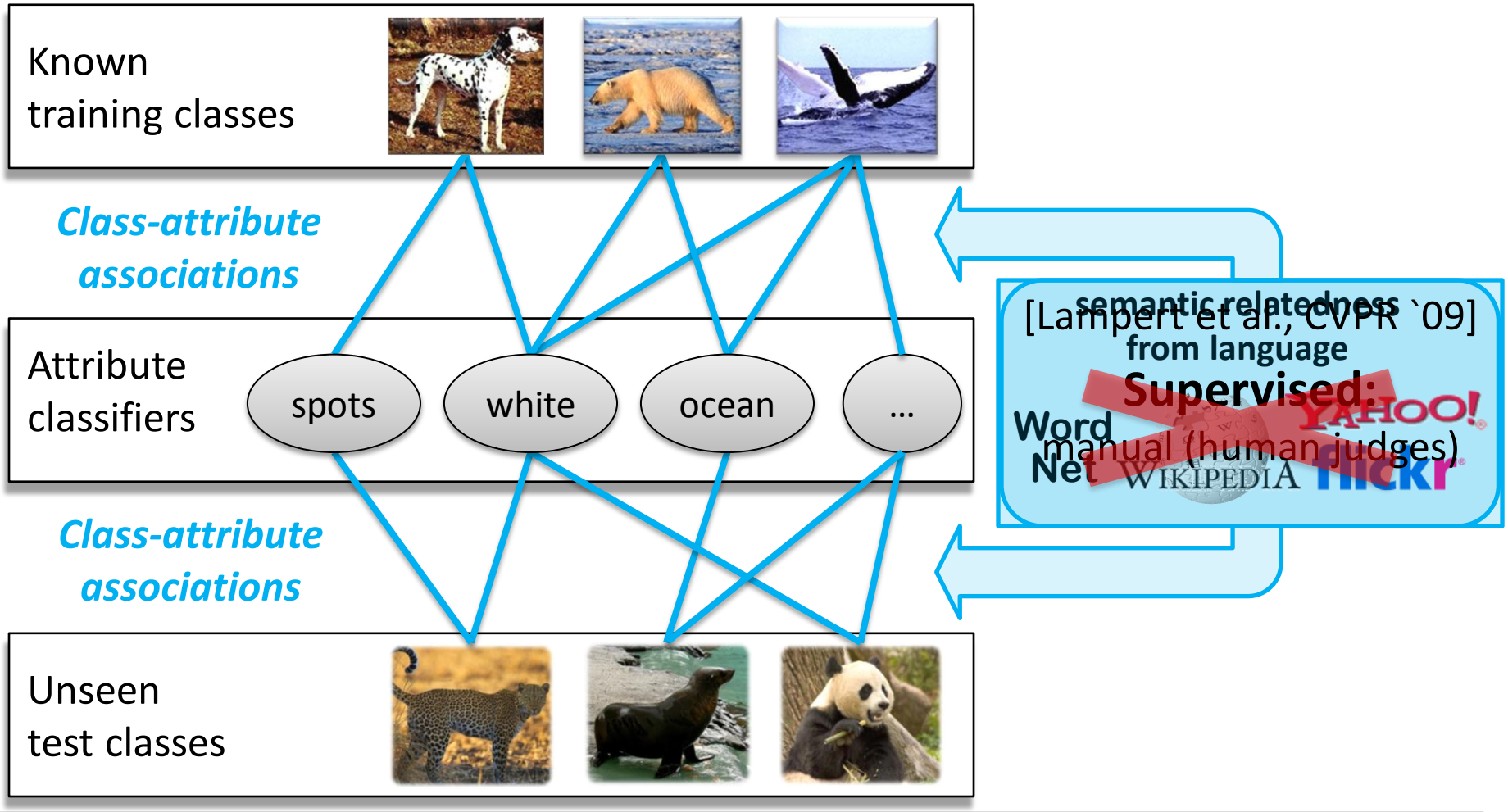
# Knowledge transfer for zero-shot object class recognition



# Attribute-based model [Lampert et al., CVPR `09]



# Attribute-based model [Rohrbach et al., CVPR `10]



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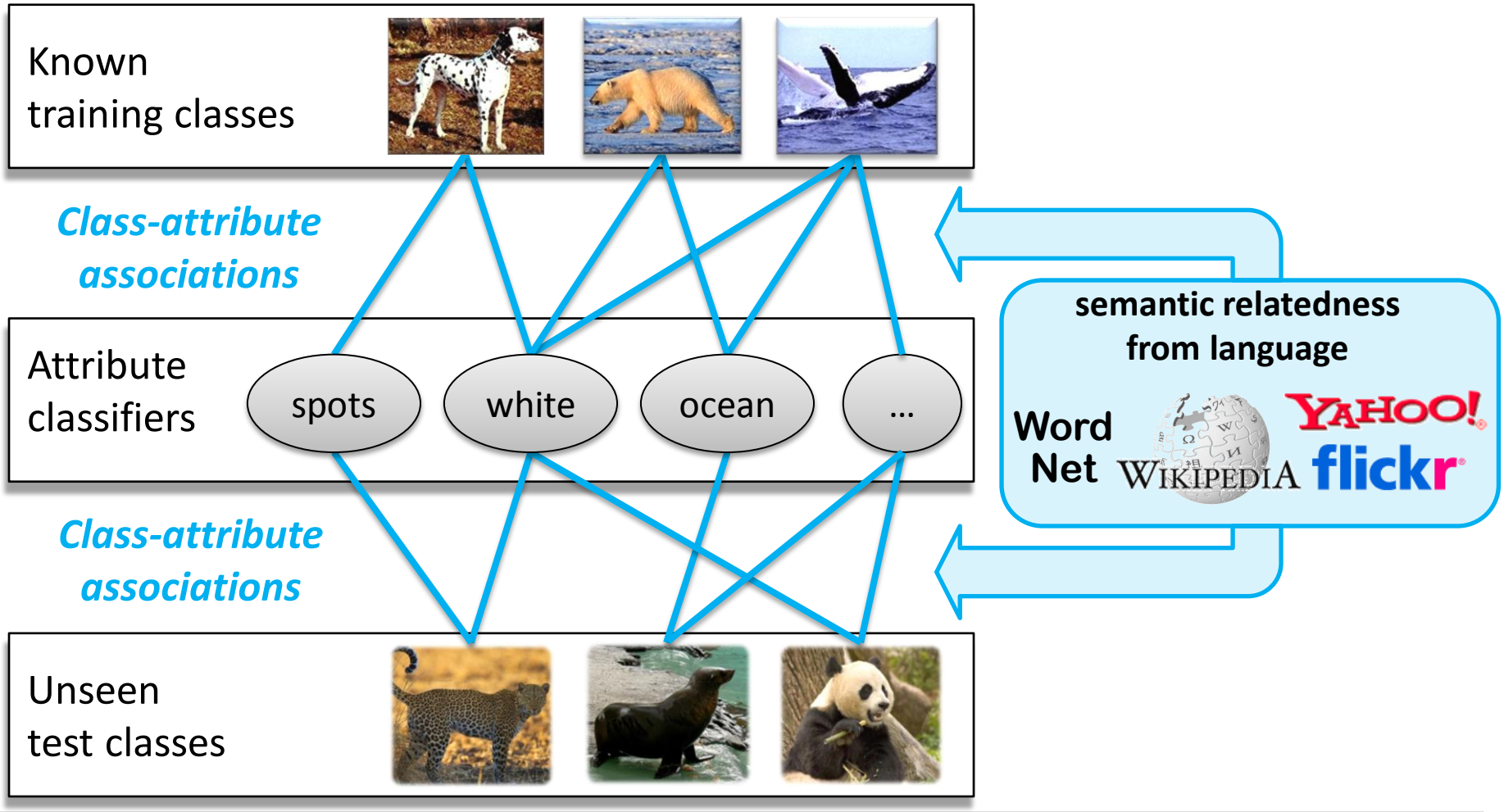

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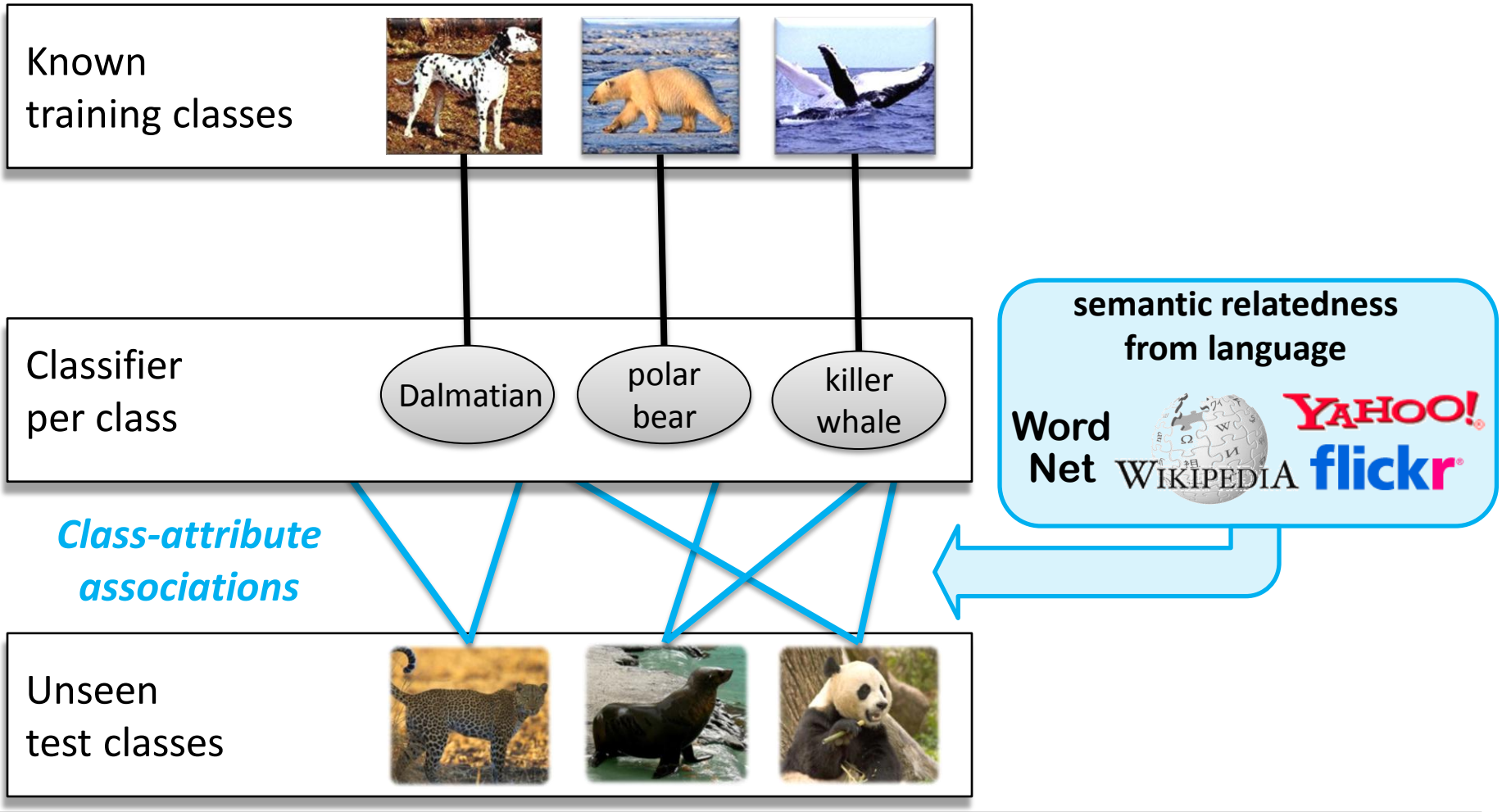

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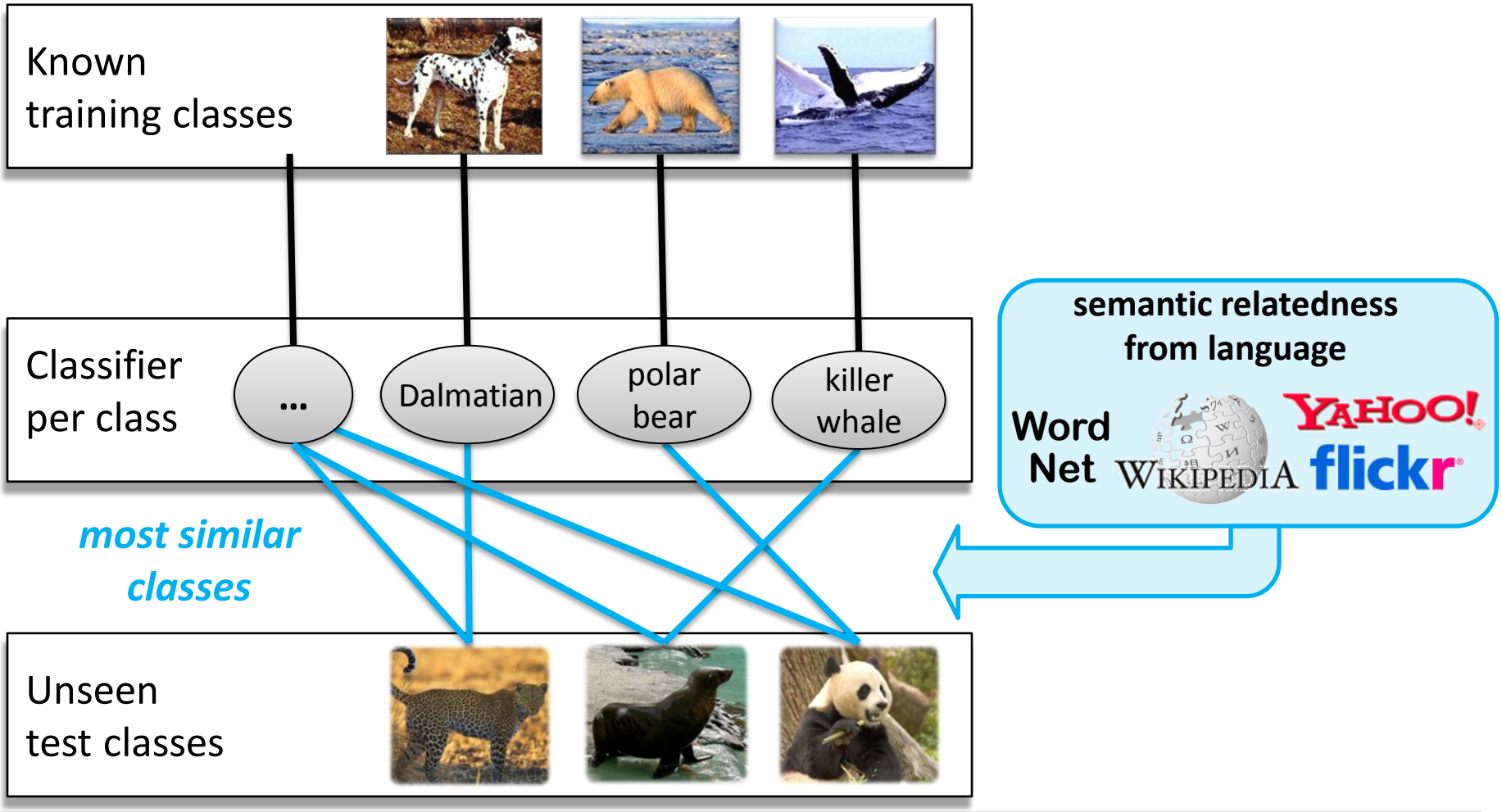

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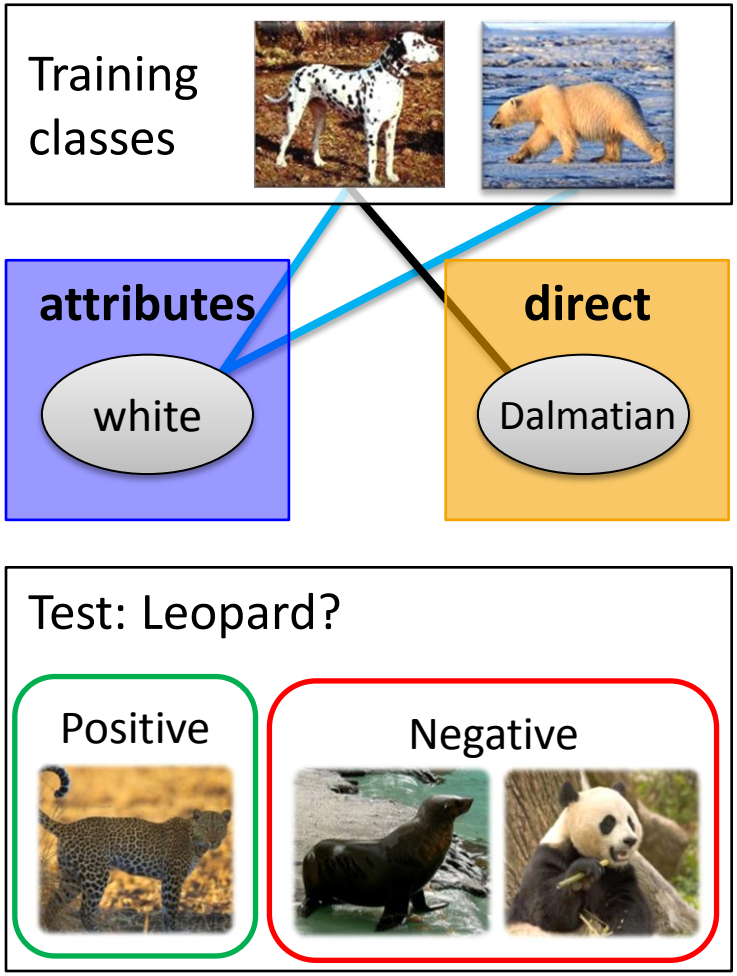


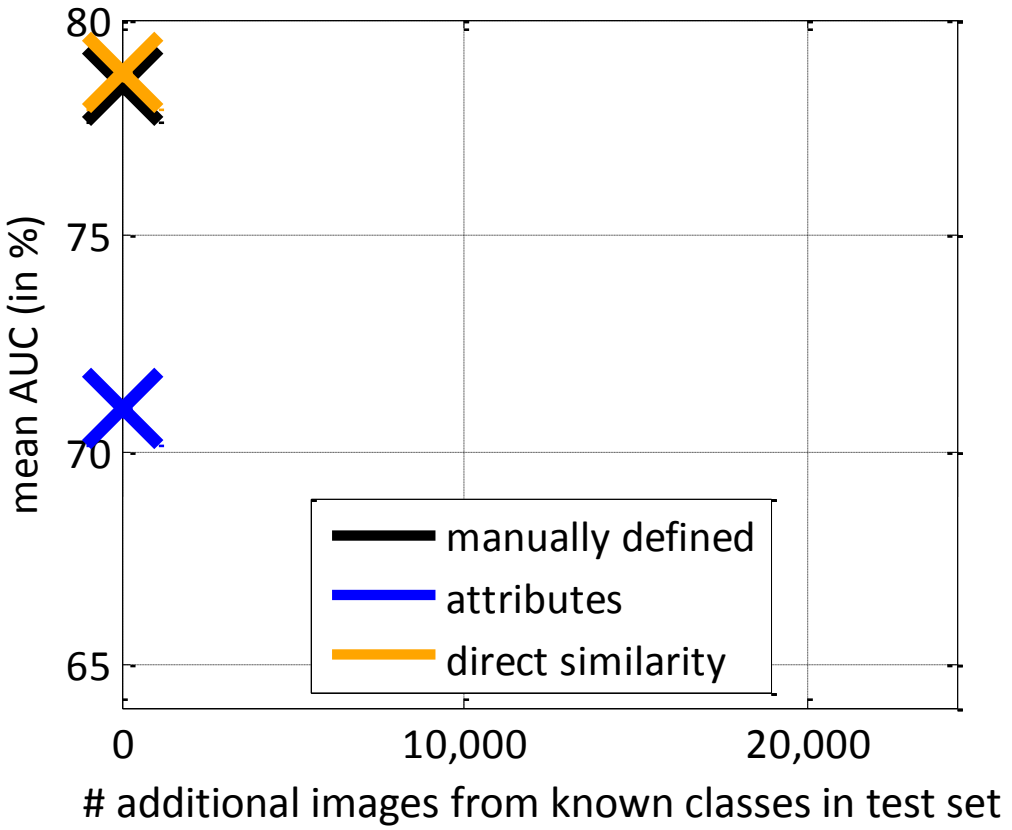

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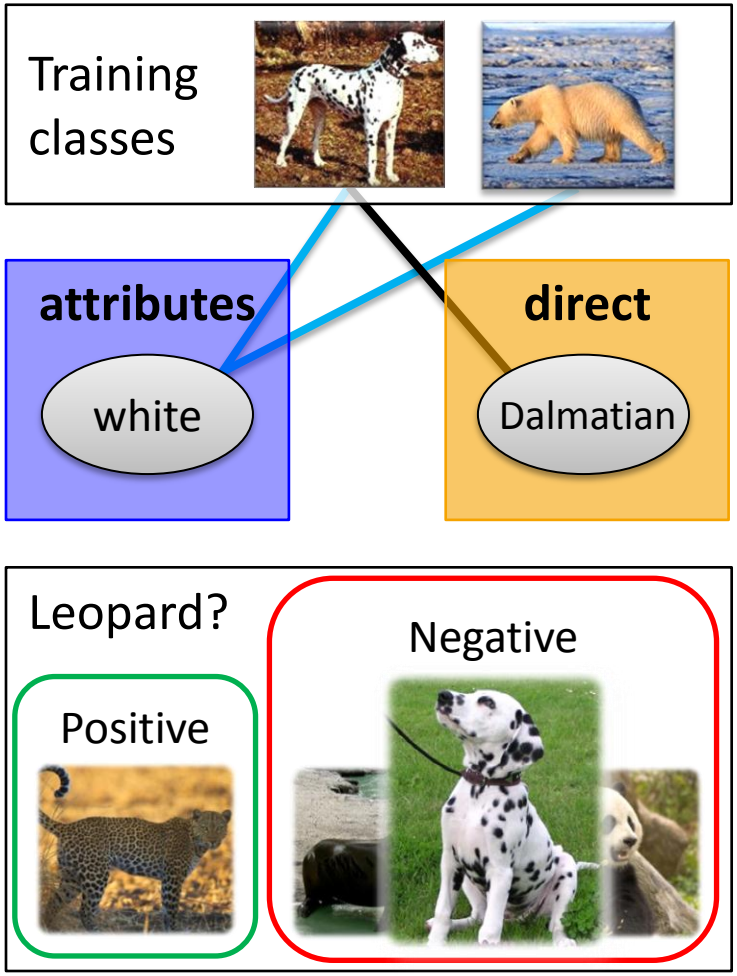
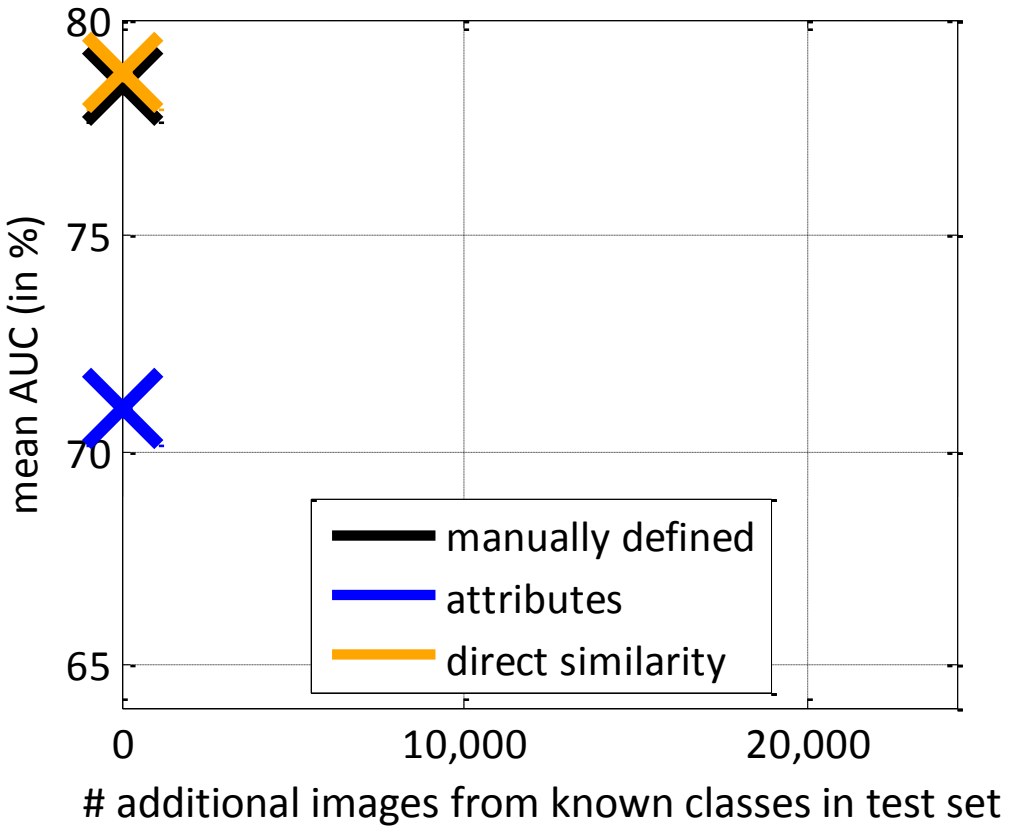
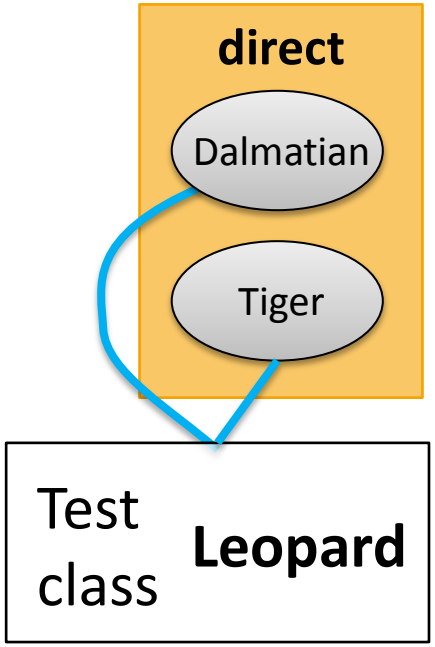


# Attributes vs. direct similarity

Test images

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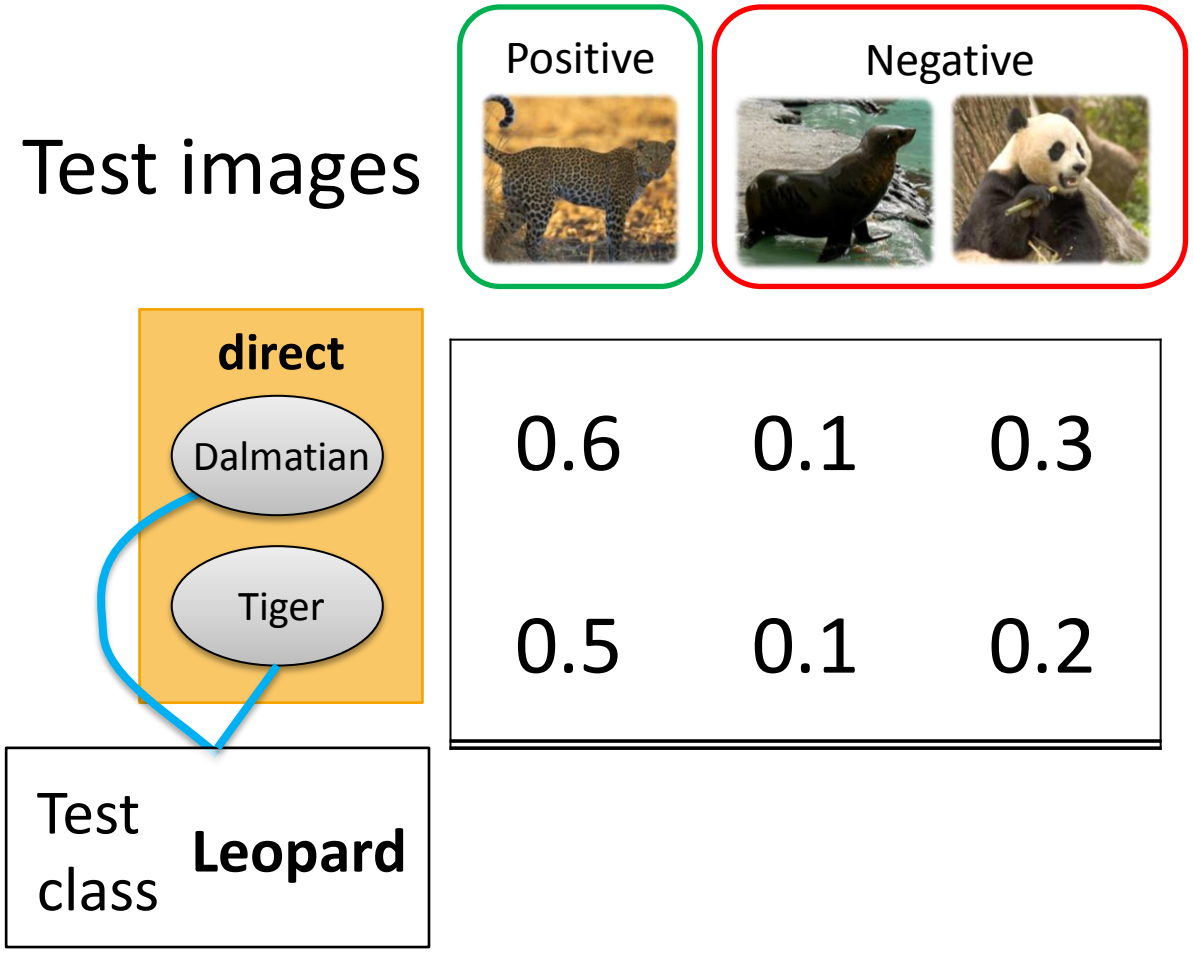

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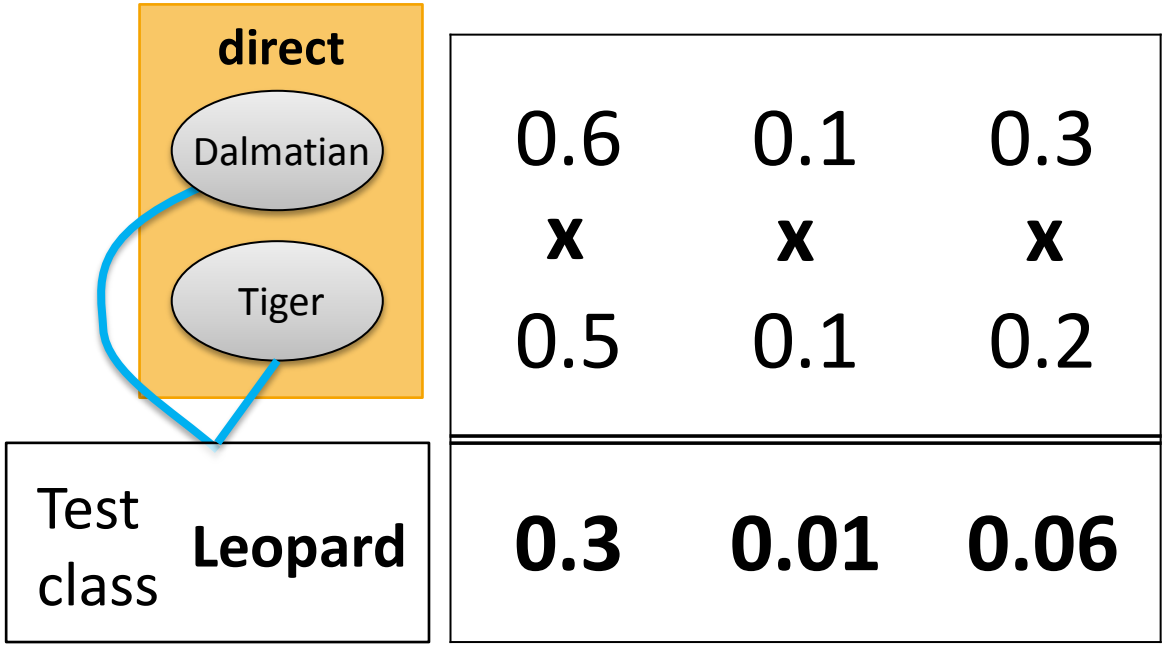

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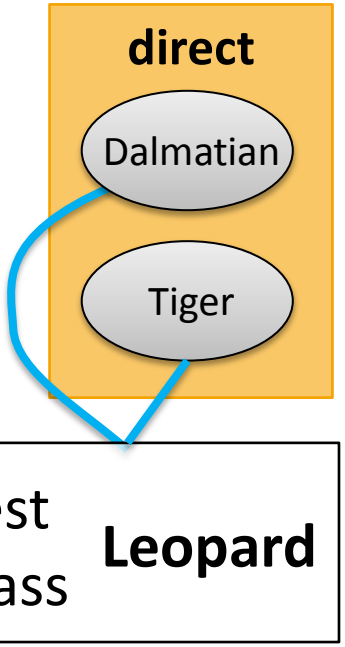
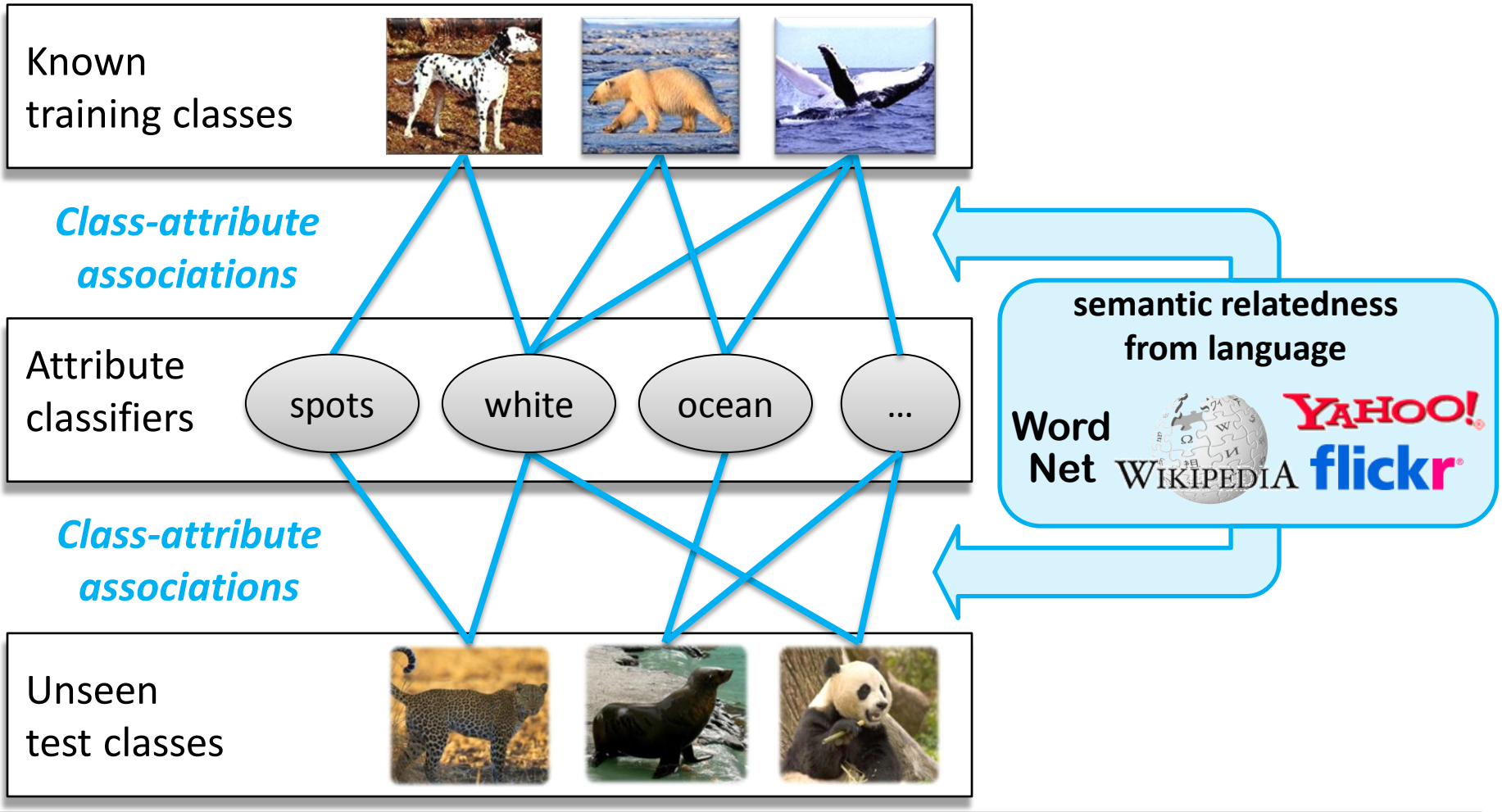



| | | | |
|---|---|---|---|
| 0.6 | 0.9 | 0.1 | 0.3 |
| 0.5 | 0.4 | 0.1 | 0.2 |
| **0.3** | **0.36** | **0.01** | **0.06** |

# Attribute-based model [Rohrbach et al., CVPR `10]



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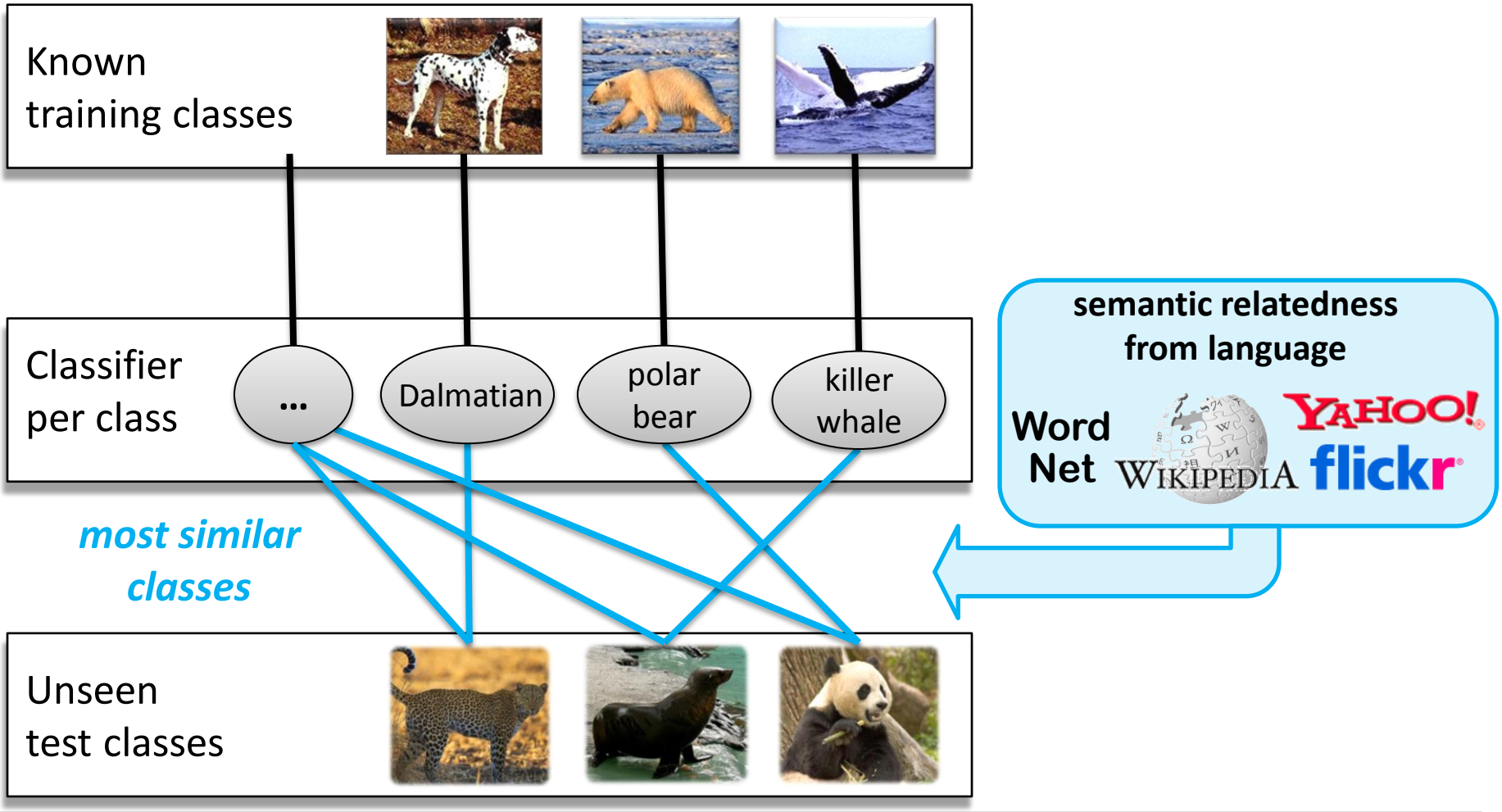

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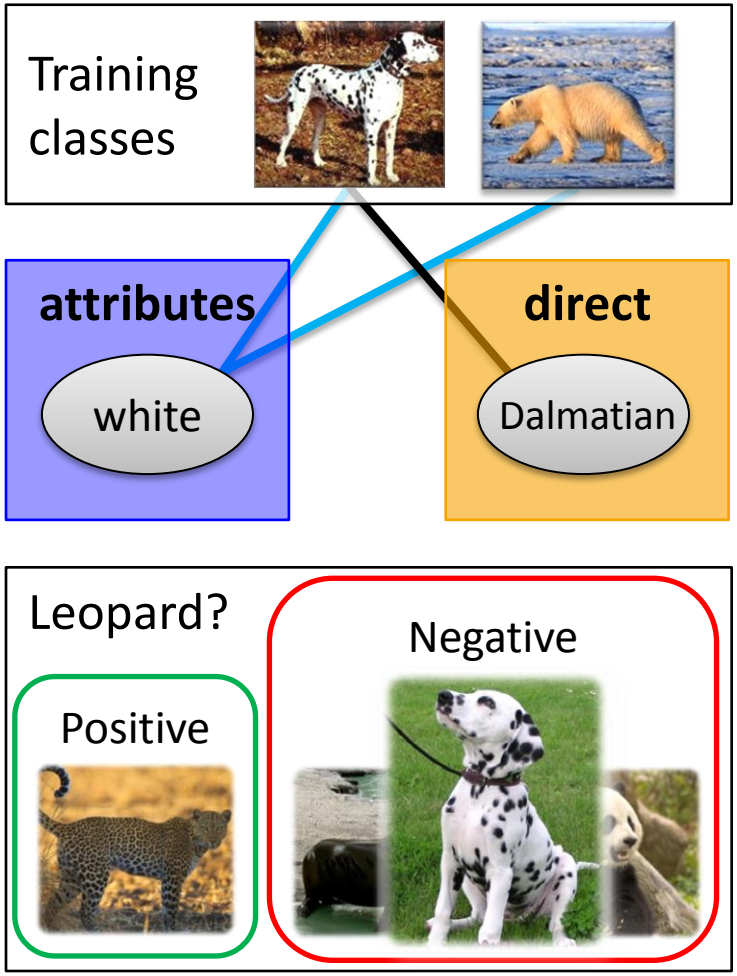


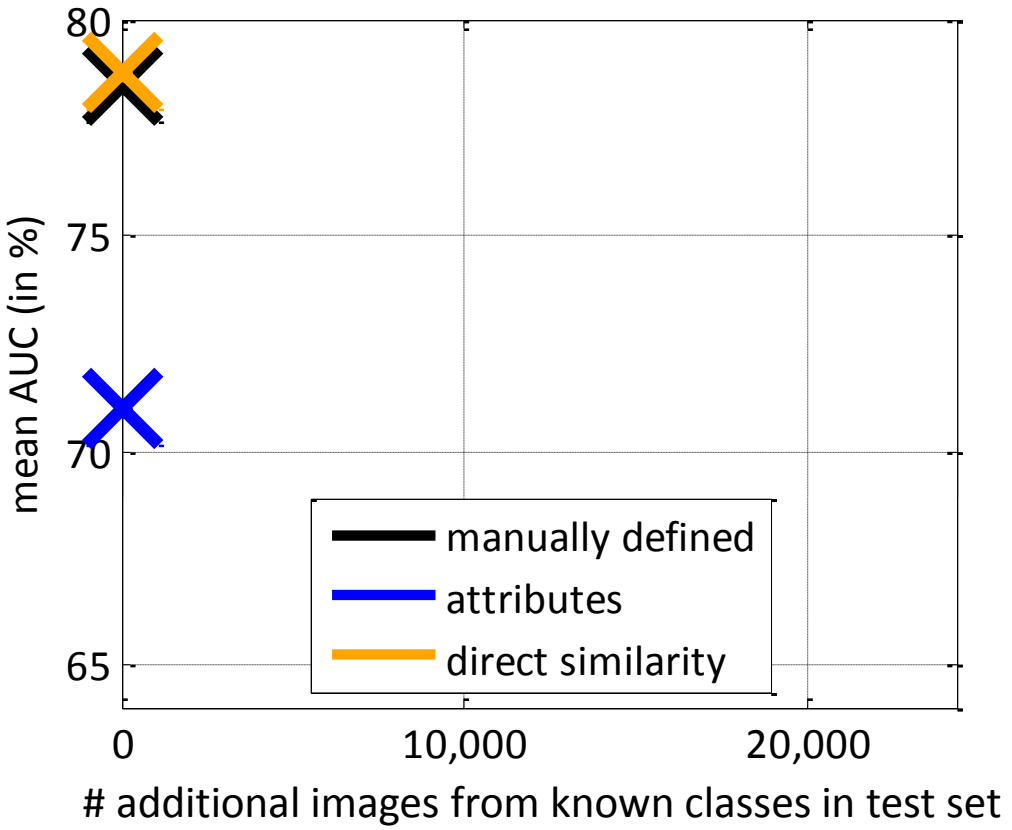

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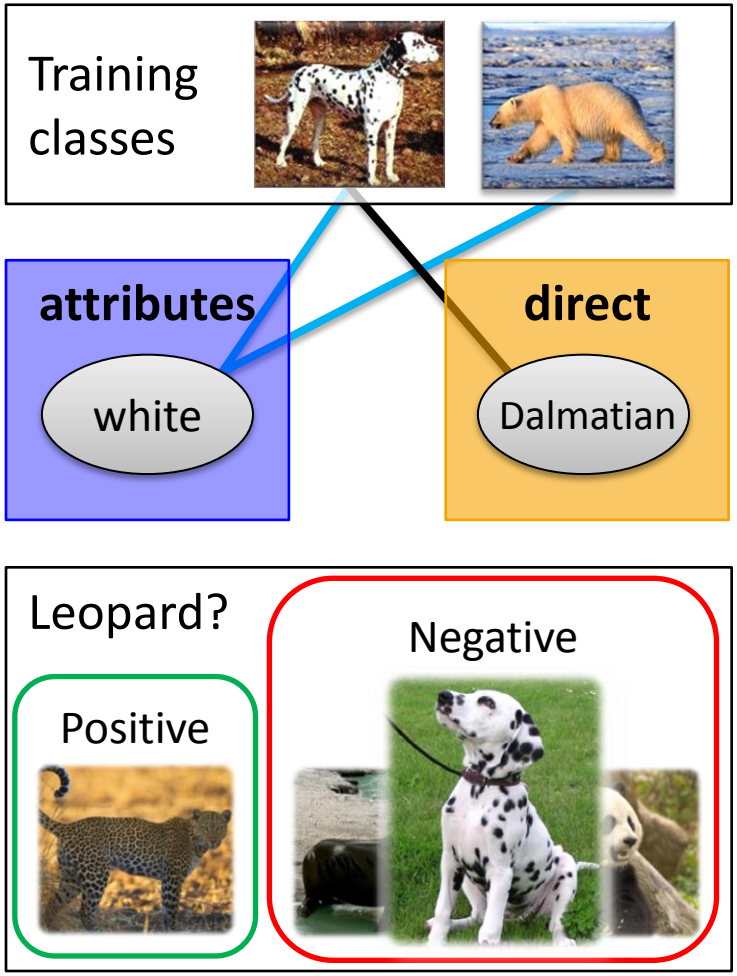
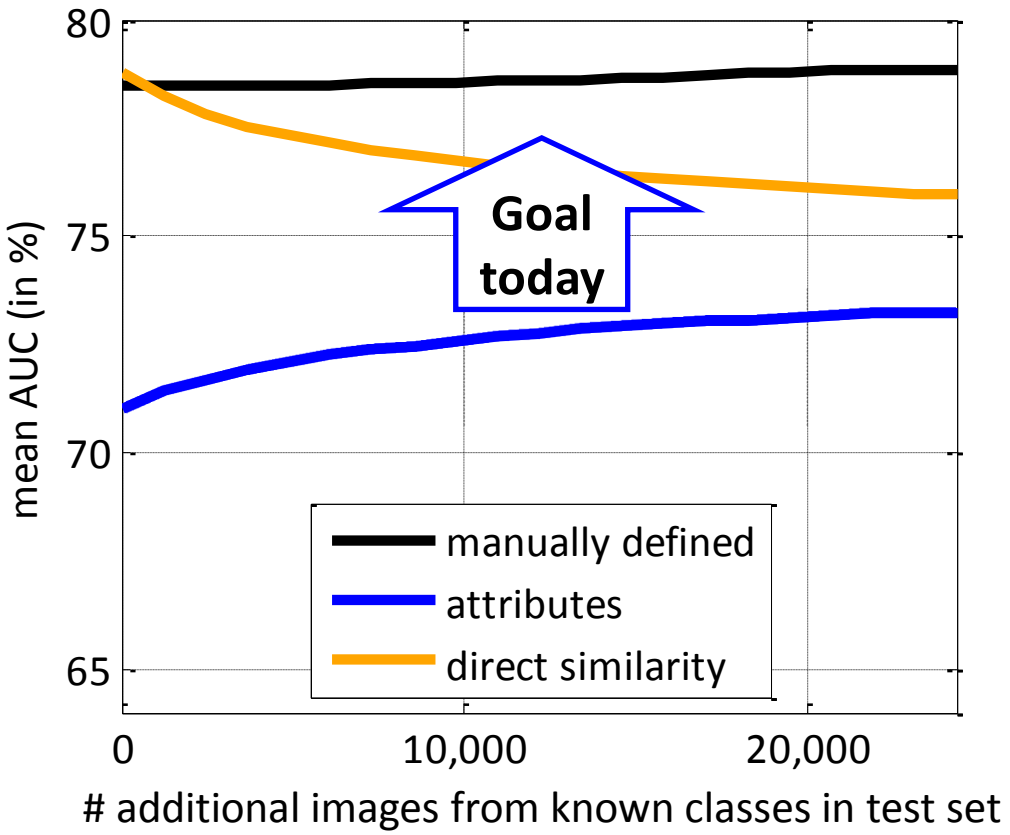


# Outline

- Motivation
- **Dataset & measures**
- Improve attribute-based knowledge transfer
  1. Importance of parameter selection
  2. New measures
  3. Combining measures
  4. Expanded attribute inventory
  5. Classifier level fusion
- Conclusion
  - Goal reached?

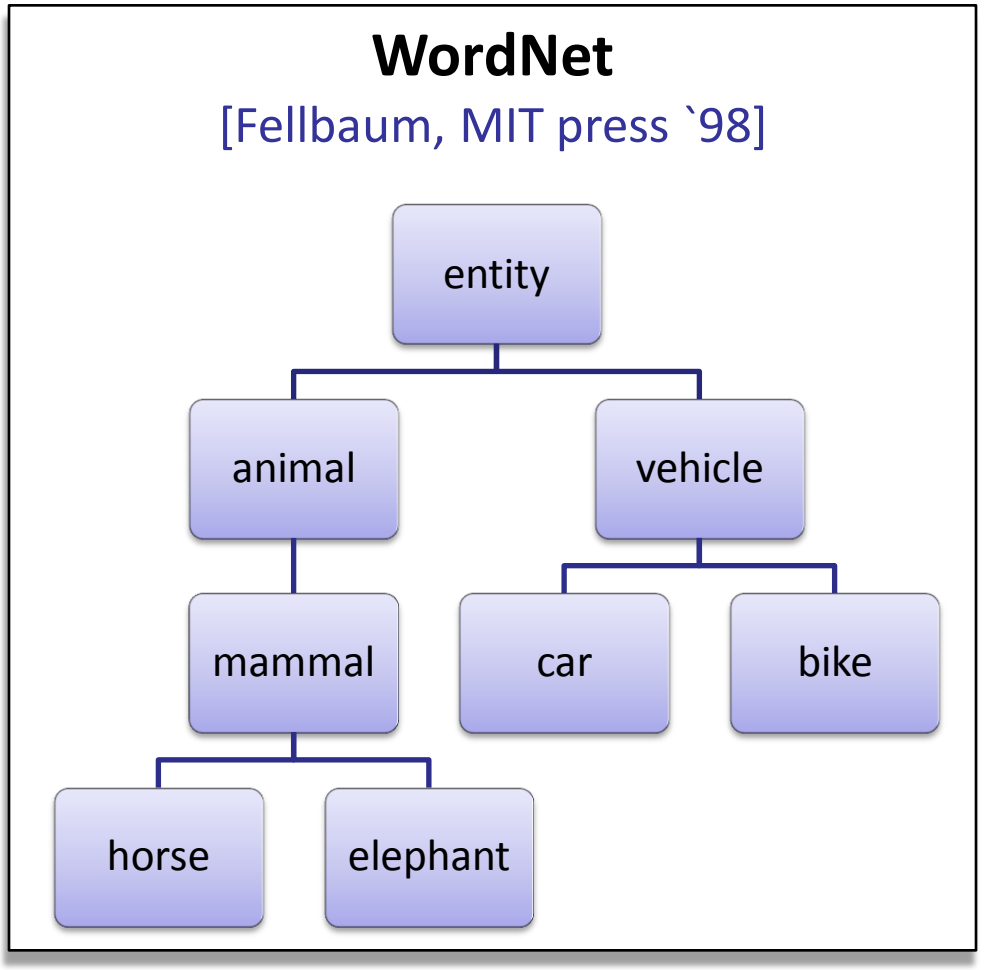
# Experimental Setup

- Animals with attributes dataset
  [Lampert et al., CVPR `09]
  - 40 training, 10 test classes (**disjoint**)
  - ≈ 30.000 images total
  - Downsampled to 92 training images per class
  - Manual associations to 85 attributes

- Image classification
  - SVM: Histogram intersection kernel
  - Area under ROC curve (AUC) - chance level: 50%
  - Mean over all 10 test classes

# Semantic Relatedness Measures [Rohrbach et al., CVPR `10]

- **WordNet**
  - **Lin measure**
    [Budanitsky & Hirst, CL `06]



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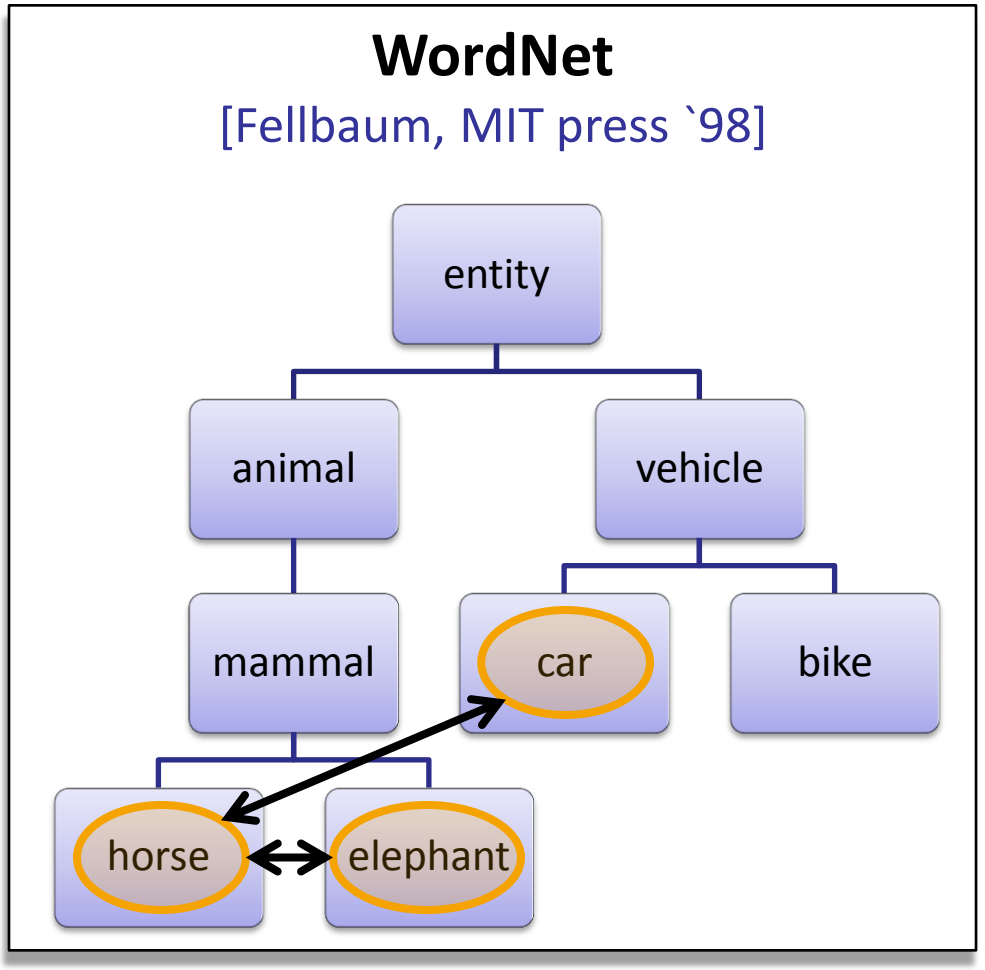

# Semantic Relatedness Measures [Rohrbach et al., CVPR `10]

- WordNet
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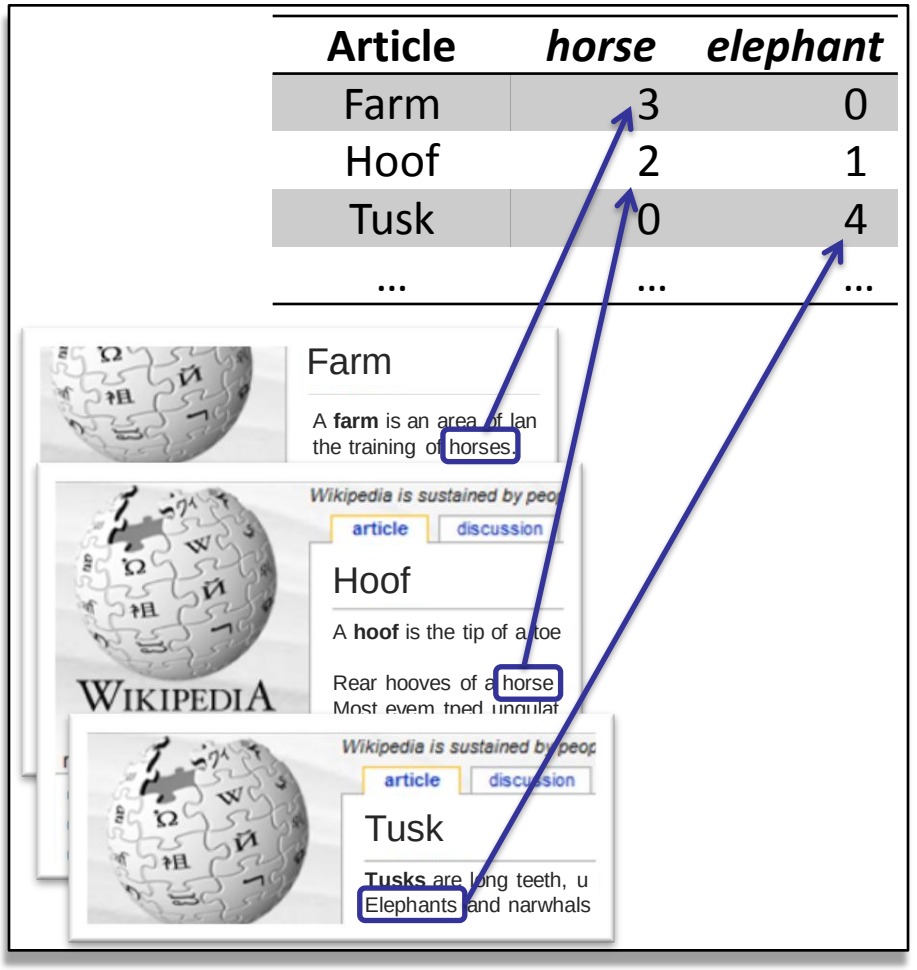
- **Wikipedia**
  - **Explicit Semantic Analysis**
    [Gabrilovich & Markovitchl, IJCAI `07]



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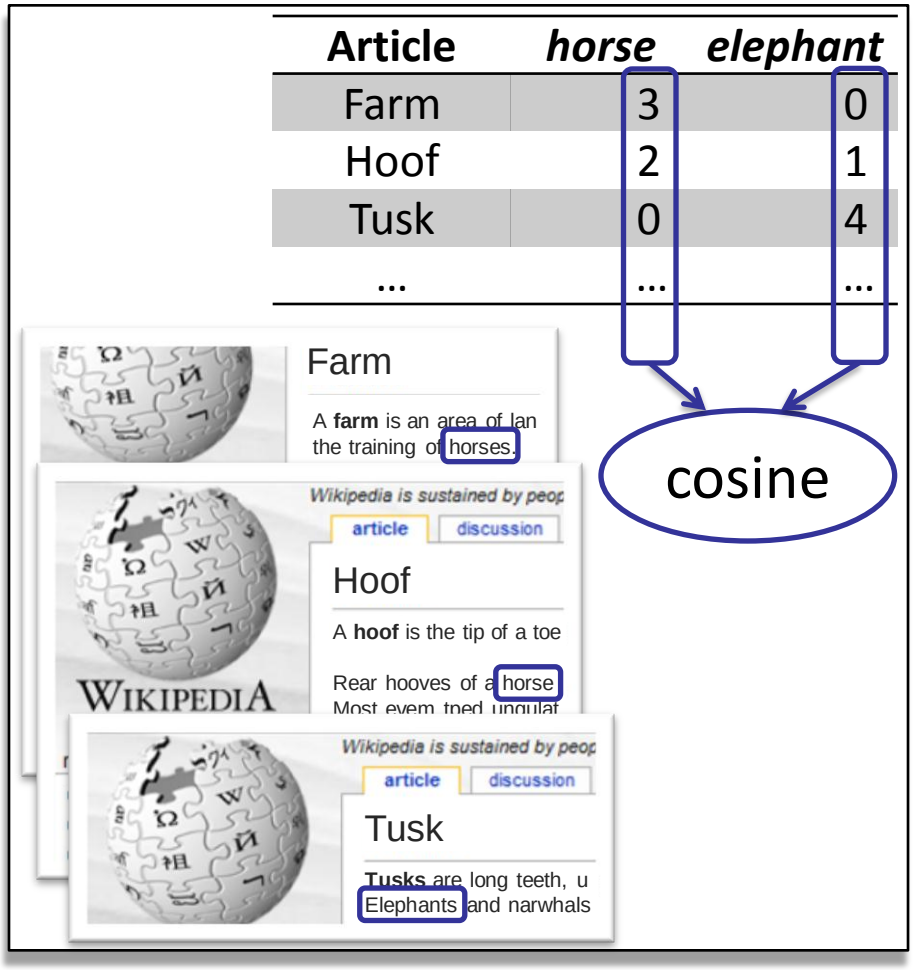

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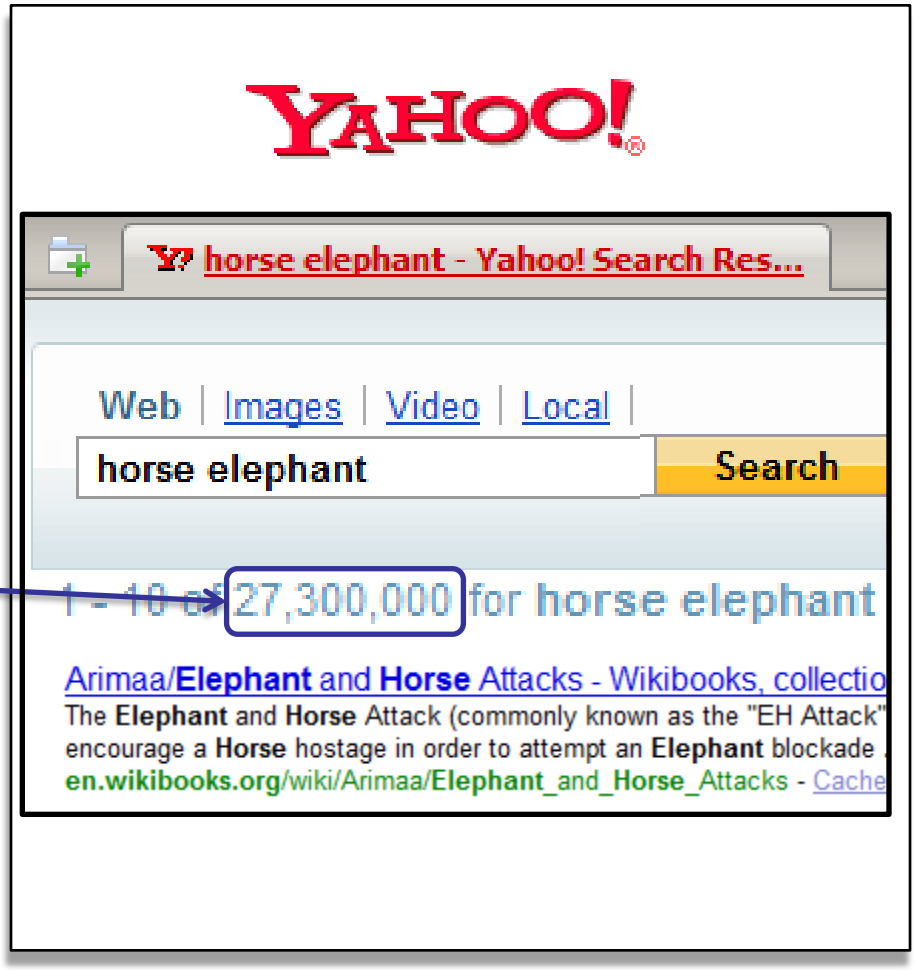
- **Word Wide Web**
  - **Hitcount (Dice coeffient)**
    [Kilgarriff & Grefenstette, CL `03]



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- Word Wide Web
  - Hitcount (Dice coeffient)
    [Kilgarriff & Grefenstette, CL `03]
- **Image search**
  - **Visually more relevant**
  - **Hitcount (Dice coeffient)**

| web search | image search |
|---|---|
| *We watched a **horse** race yesterday. [..] Tomorrow we go in the zoo to look at the baby **elephant**.* | [http://www.flickr.com/photos/lahierophant/2099973716/]  *„the dance of the **horse** and **elephant**“* |
| Incidental co-occurence | Terms refer to same entity (the image) |
| YAHOO! | YAHOO! flickr |

# Outline

- Motivation
- Dataset [Lampert, CVPR 09] & measures [Rohrbach, CVPR 10]
- **Improve attribute-based knowledge transfer [this paper]**
  1. **Importance of parameter selection**
  2. **New measures**
  3. **Combining measures**
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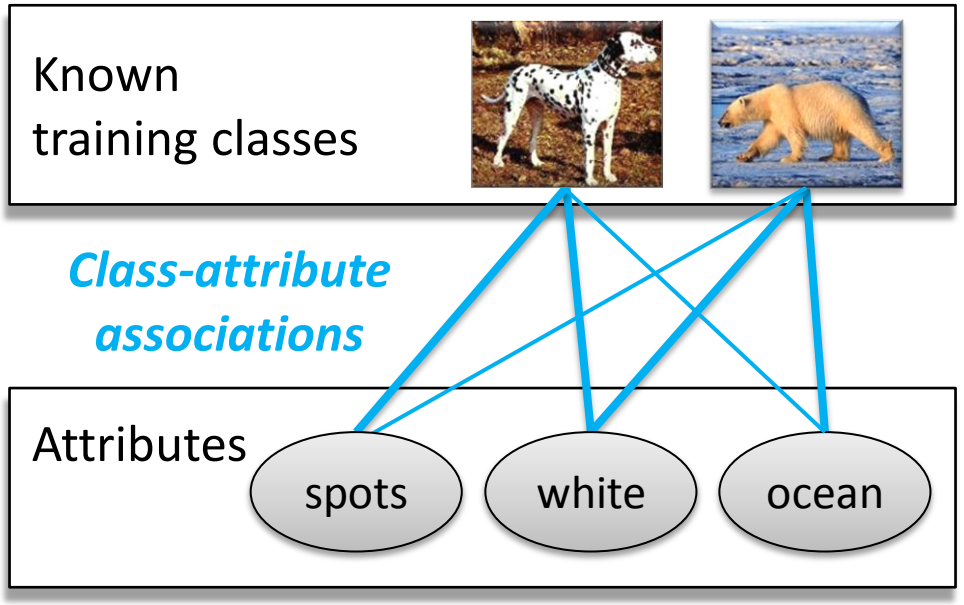
# Importance of Parameter Selection

| | spots | white | ocean |
|---|---|---|---|
| Dalmatian | 0.9 | 0.6 | 0.1 |
| polar bear | 0.2 | 0.8 | 0.9 |



# Importance of Parameter Selection

- Binarization threshold:

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Binarize

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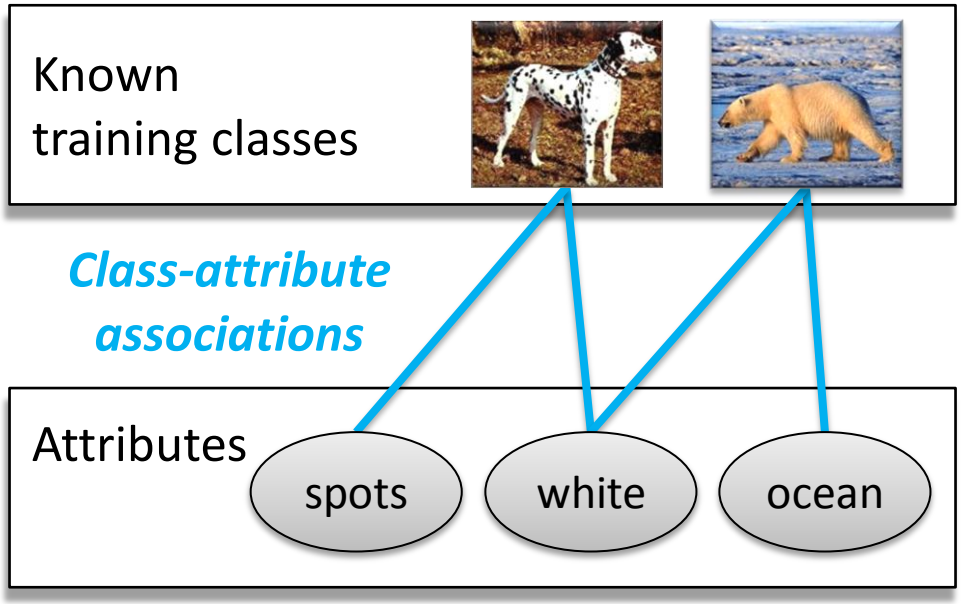
| polar bear | 0 | 1 | 1 |




- [Lampert et al., CVPR `09]: Mean

# Importance of Parameter Selection - Results

- Binarization threshold:

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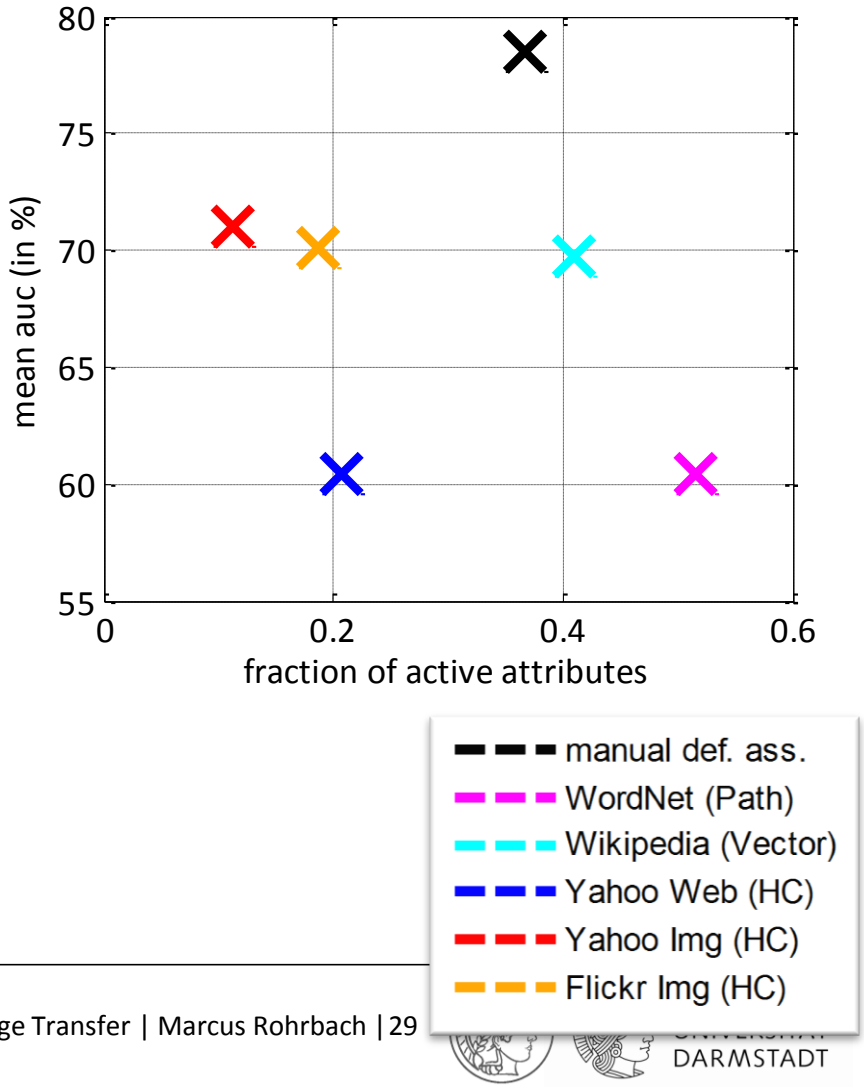
  - [Lampert et al., CVPR `09]: Mean

- Fraction of active attributes differs strongly



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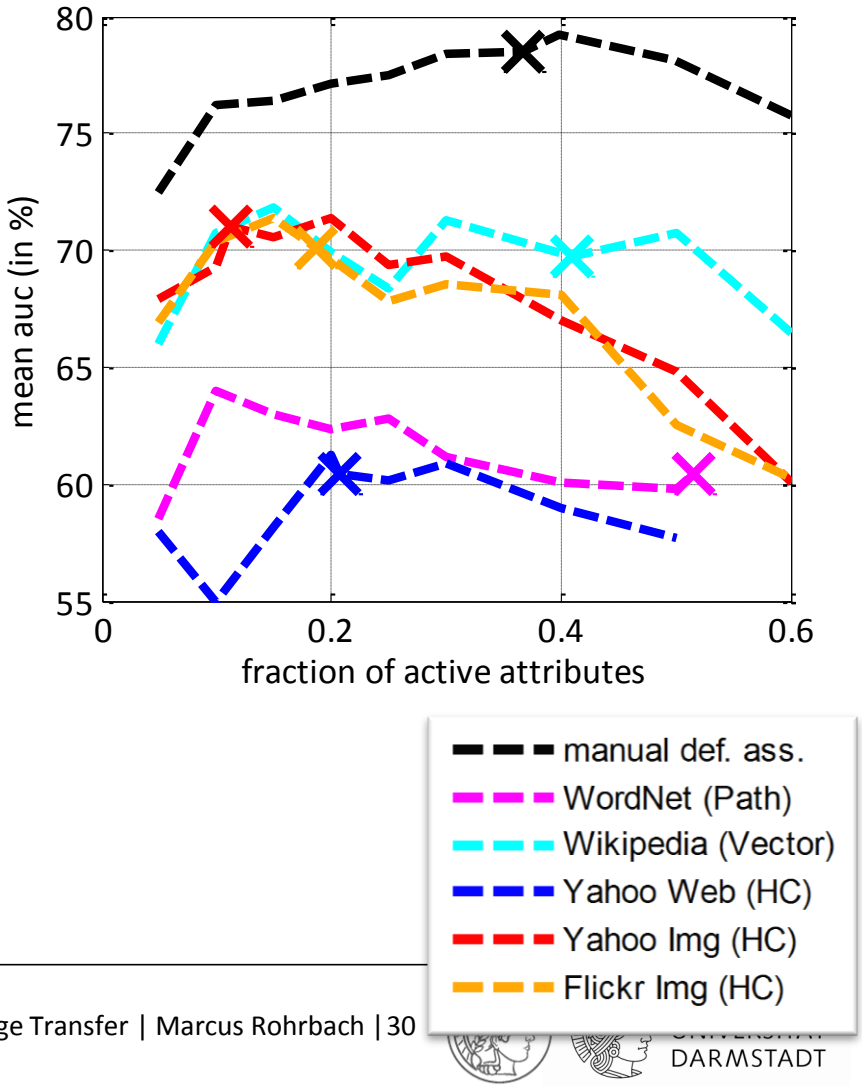


# Yahoo Near

- Yahoo web search
  - ✘ Distant co-occurrences increase noise.

**Yahoo web search**

*We wanted to go **horse** riding yesterday. However, on the way to the stables our car had a flat **tire**.*

Incidental co-occurrence

YAHOO!

# **Yahoo Near** [Delezoide et al., OntoImage `08]

- Yahoo web search
  - ✘ Distant co-occurrences increase noise.
- Yahoo Near
  - ✓ Enforces local proximity
  - Distance max 4 words "*horse * * * * leg*"
  - Dice coefficient

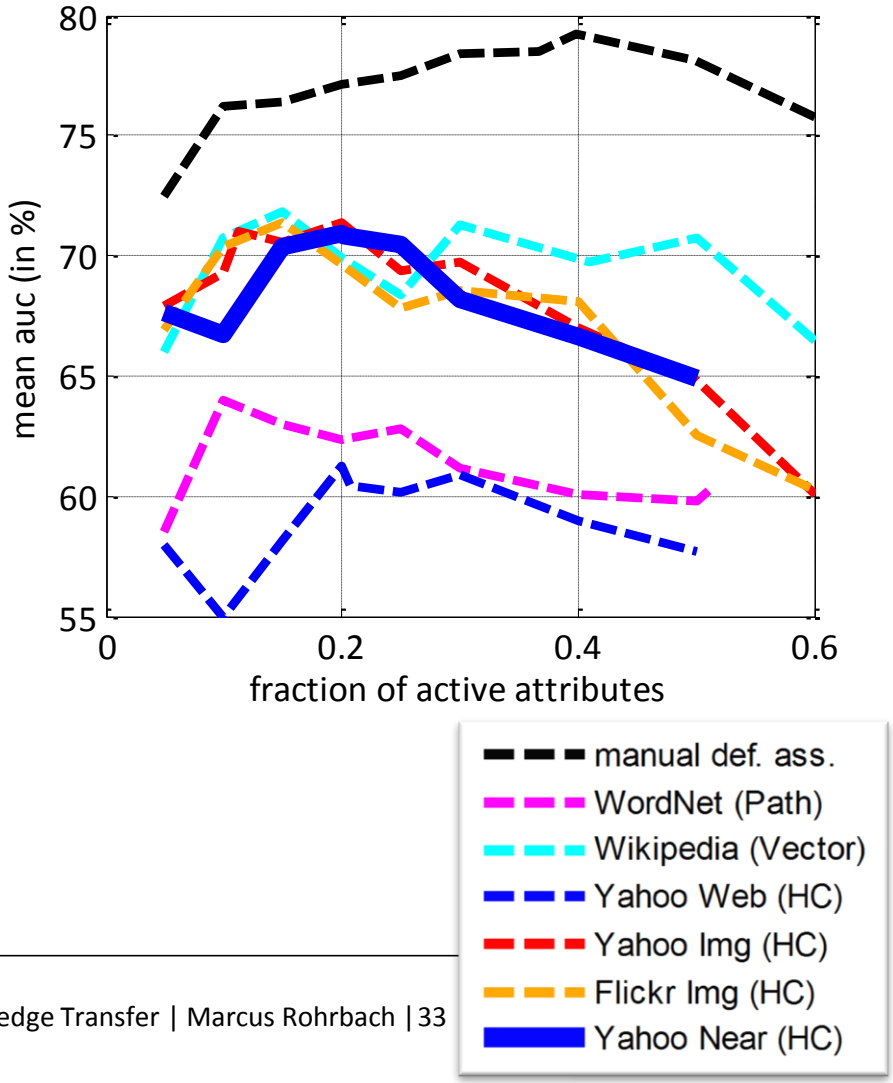
$$= \frac{HC(t_1\ NEAR\ t_2)}{HC(t_1) + HC(t_2)}$$

with $HC$ = Hitcount

| **Yahoo web search** | **Yahoo Near** |
| --- | --- |
| *We wanted to go **horse** riding yesterday. However, on the way to the stables our car had a flat **tire**.* | *We wanted to go horse riding yesterday. However, the **horse** had a broken **leg**.* |
| Incidental co-occurrence | Terms refer more likely to each other |
| YAHOO! | YAHOO! |

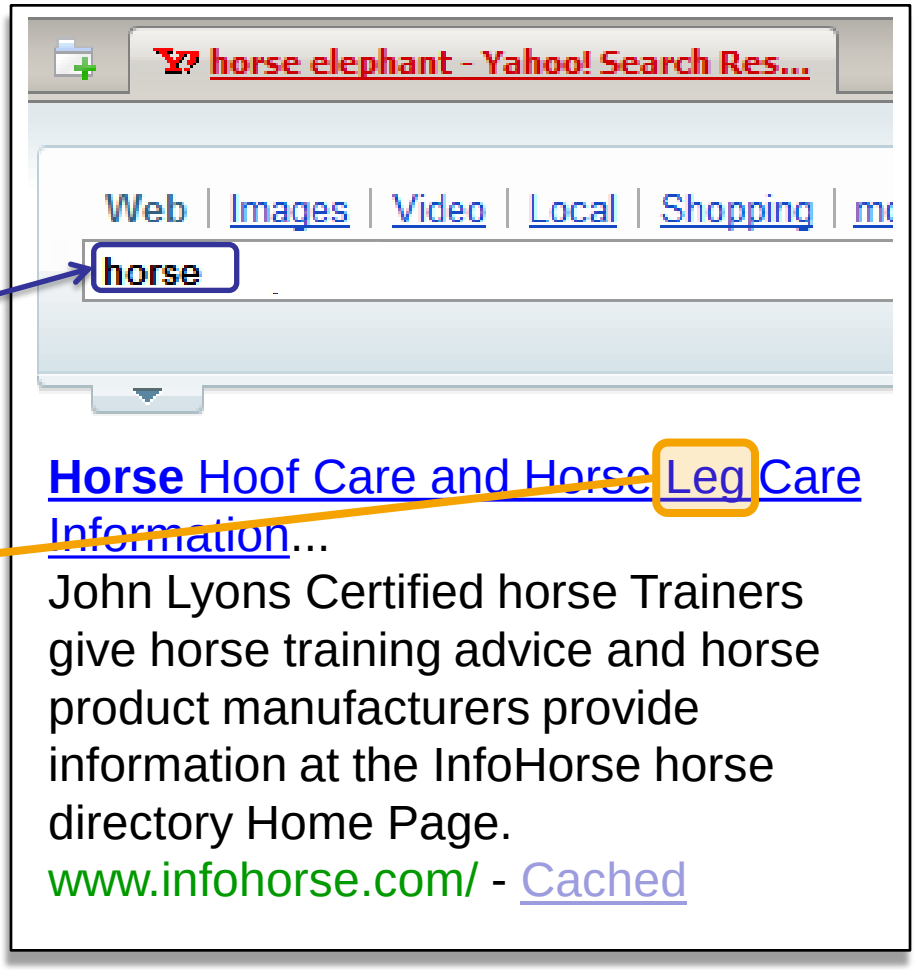
# Yahoo Near - Results

- Yahoo Near
  - Significantly improves over Yahoo web search
  - Similar to
    - Yahoo Image / Flickr Image



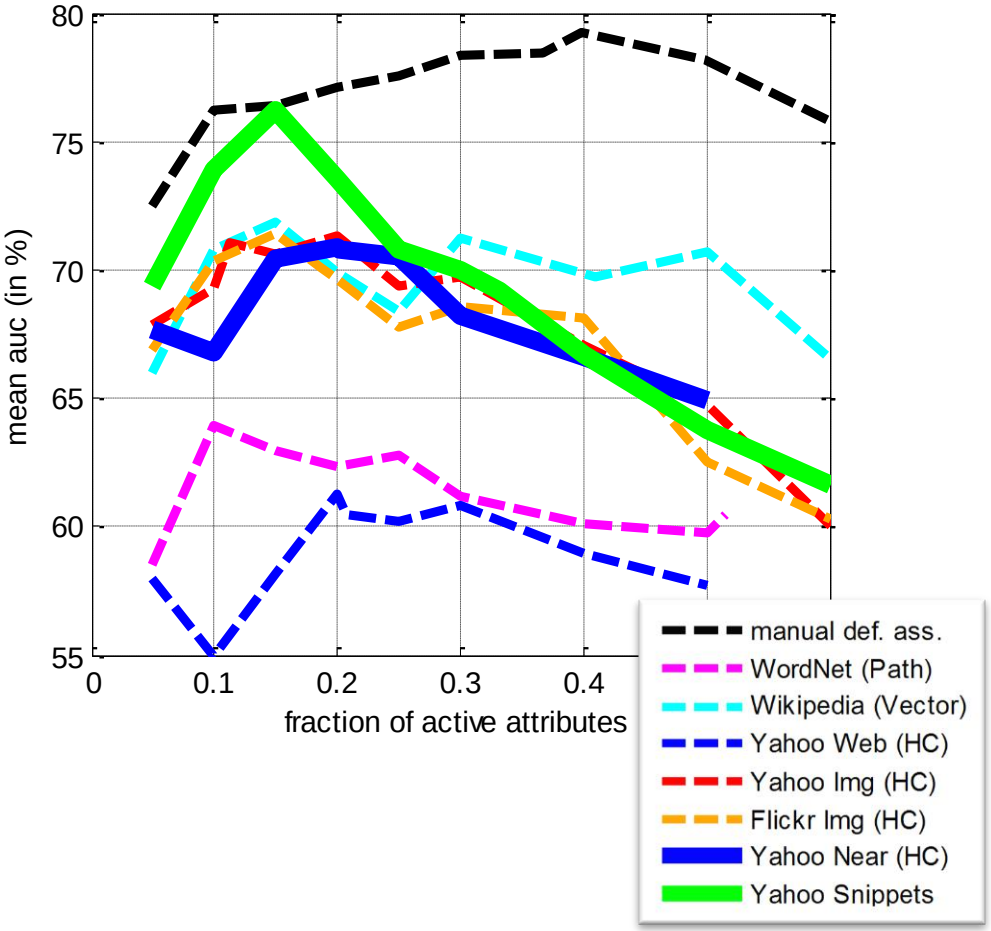
# **Yahoo Snippets** [Chen et al., ACL `06]

- Text snippets returned by search engine (first 1000)
- Approach
  - Query object term (*horse*)
  - Count attribute (e.g. *leg*) occurrence:
    $f(t_1@t_2) = f(leg@horse)$
  - And vice versa (*horse@ leg*)
- Dice $= \frac{f(t_2@t_1)+f(t_1@t_2)}{f(t_1@t_1)+f(t_2@t_2)}$



# Yahoo Snippets - Results

- Outperforms previous measures
  - ⇨ Benefit from search engine ranking
- Very good performance for small fraction of active attributes
  - ⇨ Top ranked associations are correct

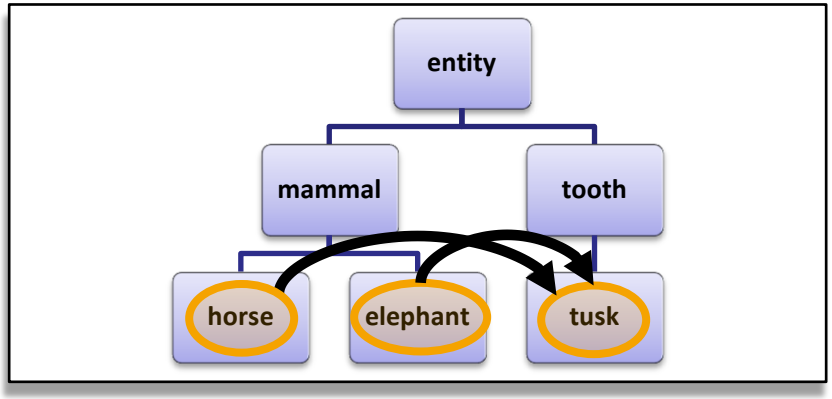


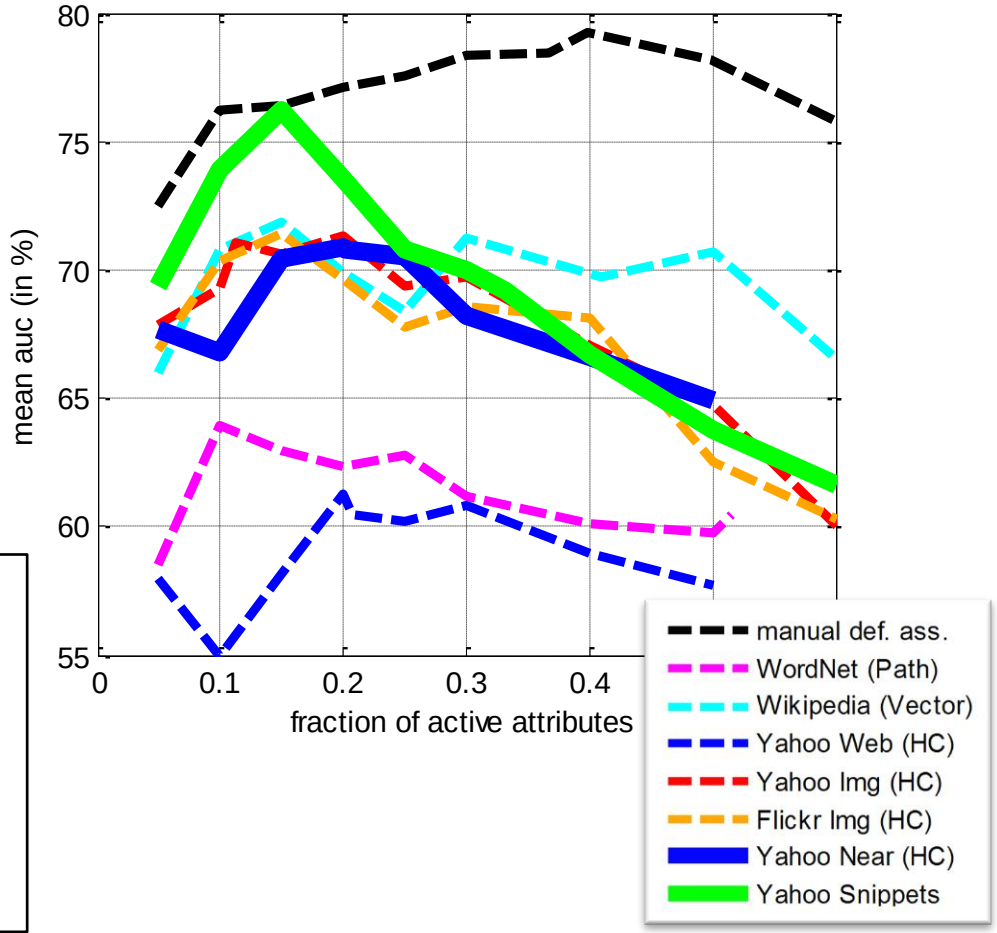
# Outline

- Motivation
- Dataset [Lampert, CVPR 09] & measures [Rohrbach, CVPR 10]
- **Improve attribute-based knowledge transfer [this paper]**
  1. **Importance of parameter selection**
  2. **New measures**
  3. **Combining measures**
  4. **Expanded attribute inventory**
  5. **Classifier level fusion**
- Conclusion
  - Goal reached?

# Restriction to best five measures

- Not using
  - Yahoo Web
    - Replaced by Yahoo Near
  - WordNet
    - Not suitable for class-attributes associations



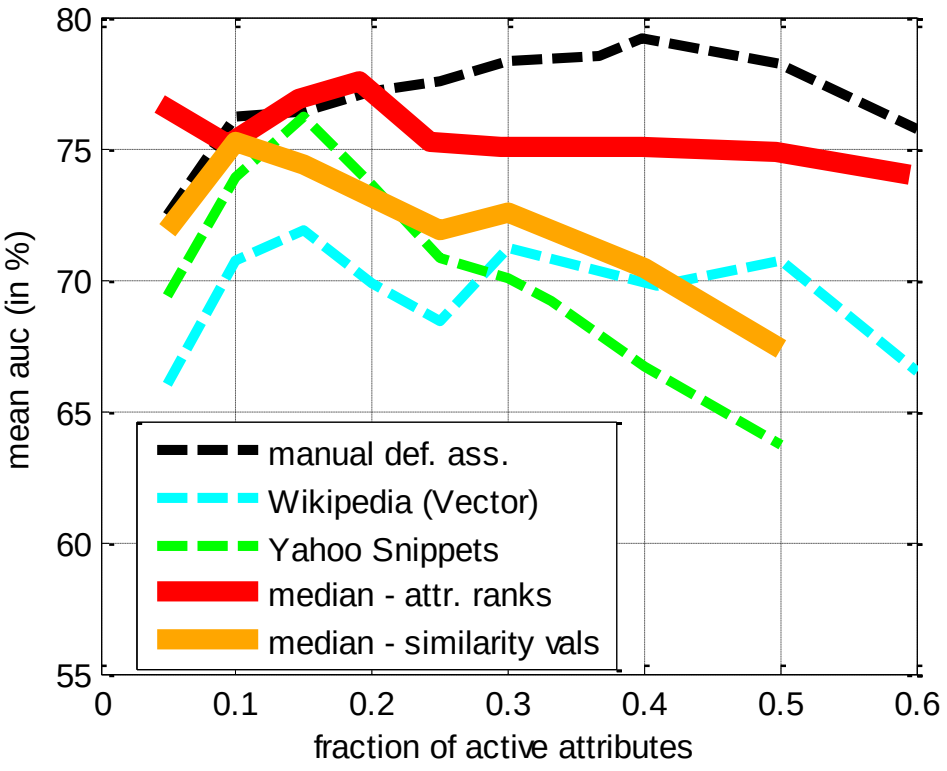
# Combined Semantic Relatedness Measures

- Benefit from complementary nature
- Combine measures
  - Median (robust)
  - Similarity values of measures
    - Differently distributed
    - Use attribute ranks instead

| Measure | False positive in Top 10 most similar to “big” |
|---|---|
| Wikipedia | Chihuahua |
| Yahoo Snippets | Chihuahua |
| Yahoo Image | Mole |
| Flickr Image | Rat |
| Yahoo Near | Beaver |

# Combined Semantic Relatedness Measures - Results

- Median attr. ranks (red)
  - Very high performance
    - For low and high fraction of active attributes
- Median similarity values (orange)
  - Does not significantly improve over individual measures



# Expanded Attribute Inventory

- Cluster attributes automatically (k-means)
  - Increase robustness
  - Expand attribute inventory

| | Black | White | Yellow | Brown |
|---|---|---|---|---|
| Dalmatian | 1 | 1 | 0 | 0 |
| Zebra | 1 | 1 | 1 | 0 |
| Giraffe | 0 | 0 | 1 | 1 |
| Leopard | 0 | 1 | 1 | 1 |
| Lion | 0 | 0 | 1 | 1 |

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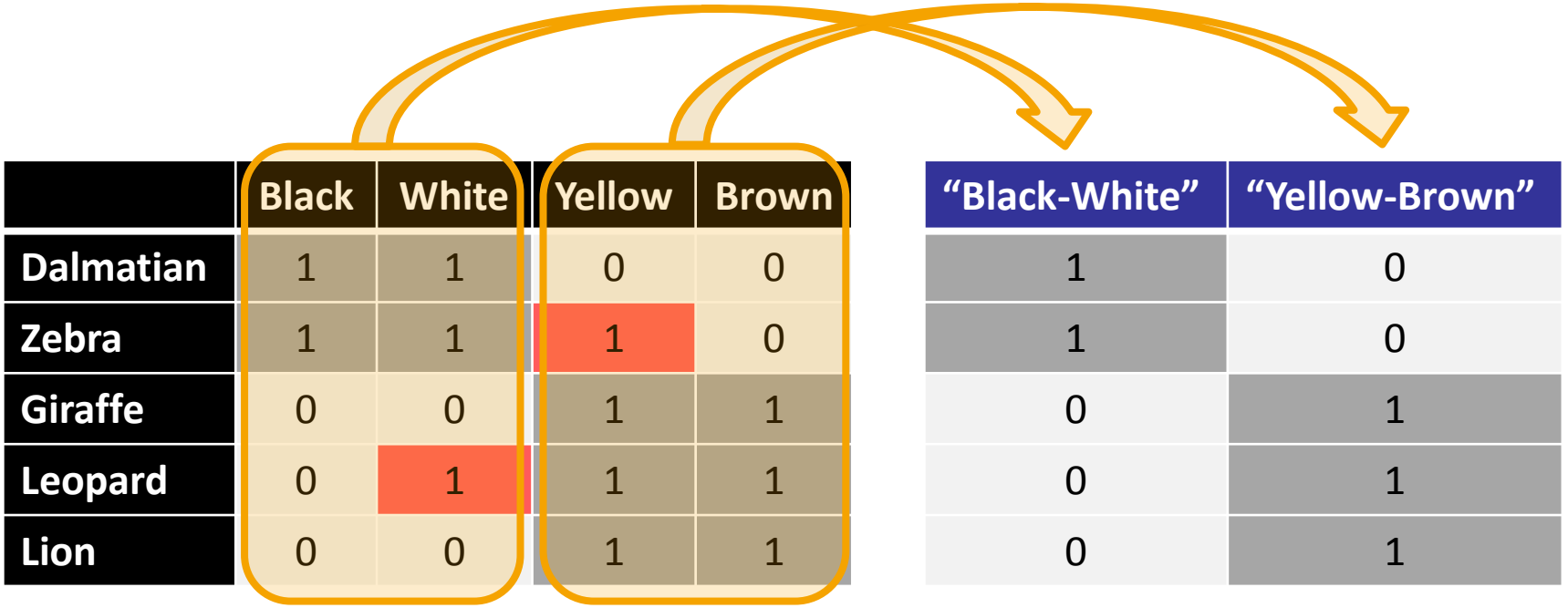
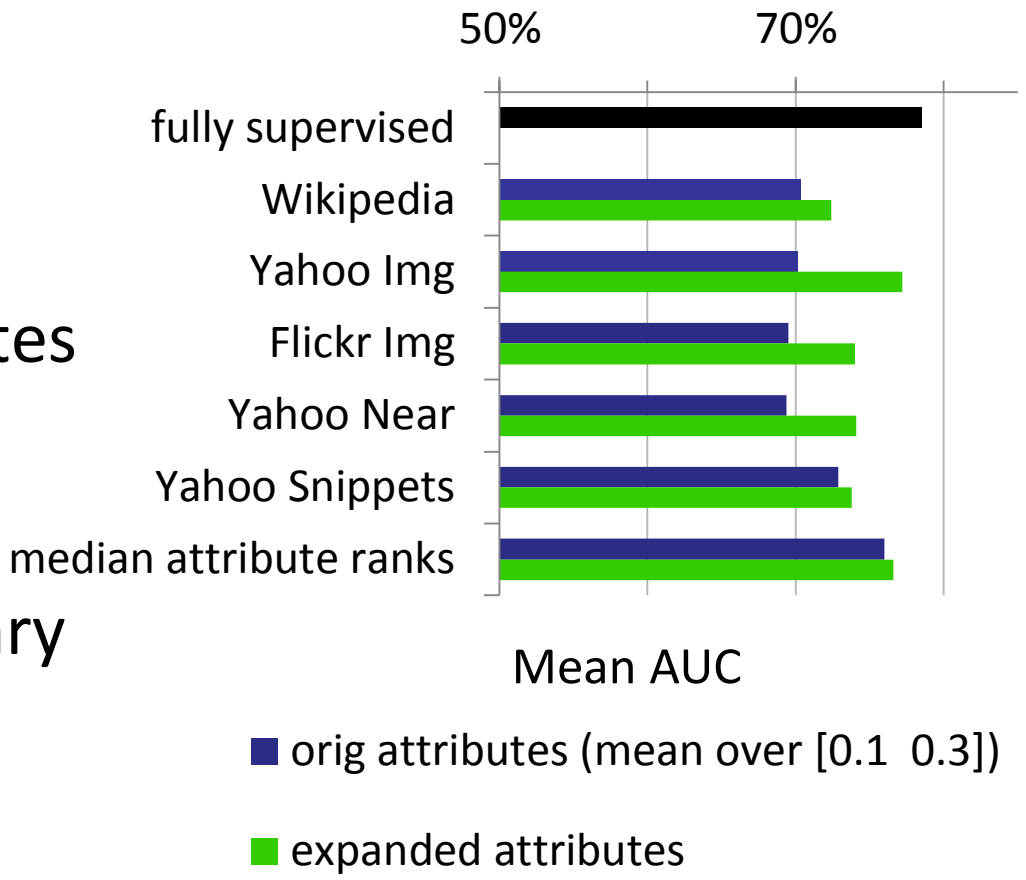


| | Black | White | Yellow | Brown | "Black-White" | "Yellow-Brown" |
|---|---|---|---|---|---|---|
| Dalmatian | 1 | 1 | 0 | 0 | 1 | 0 |
| Zebra | 1 | 1 | 1 | 0 | 1 | 0 |
| Giraffe | 0 | 0 | 1 | 1 | 0 | 1 |
| Leopard | 0 | 1 | 1 | 1 | 0 | 1 |
| Lion | 0 | 0 | 1 | 1 | 0 | 1 |

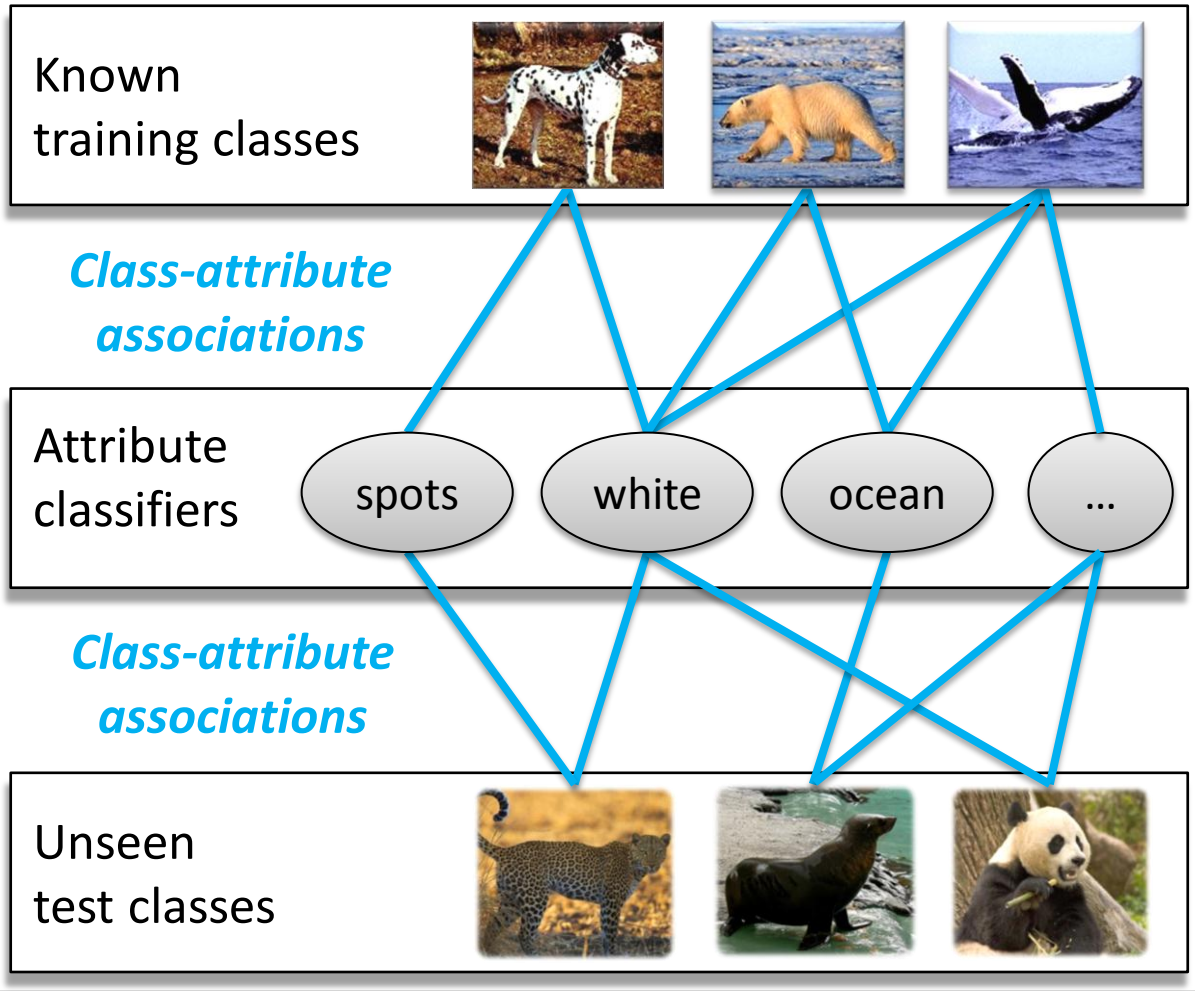
# Expanded Attribute Inventory - Results

- Performance improves
  - In all cases
- No. of expanded attributes
  - 164
- Cluster associations binary
  - No threshold to pick



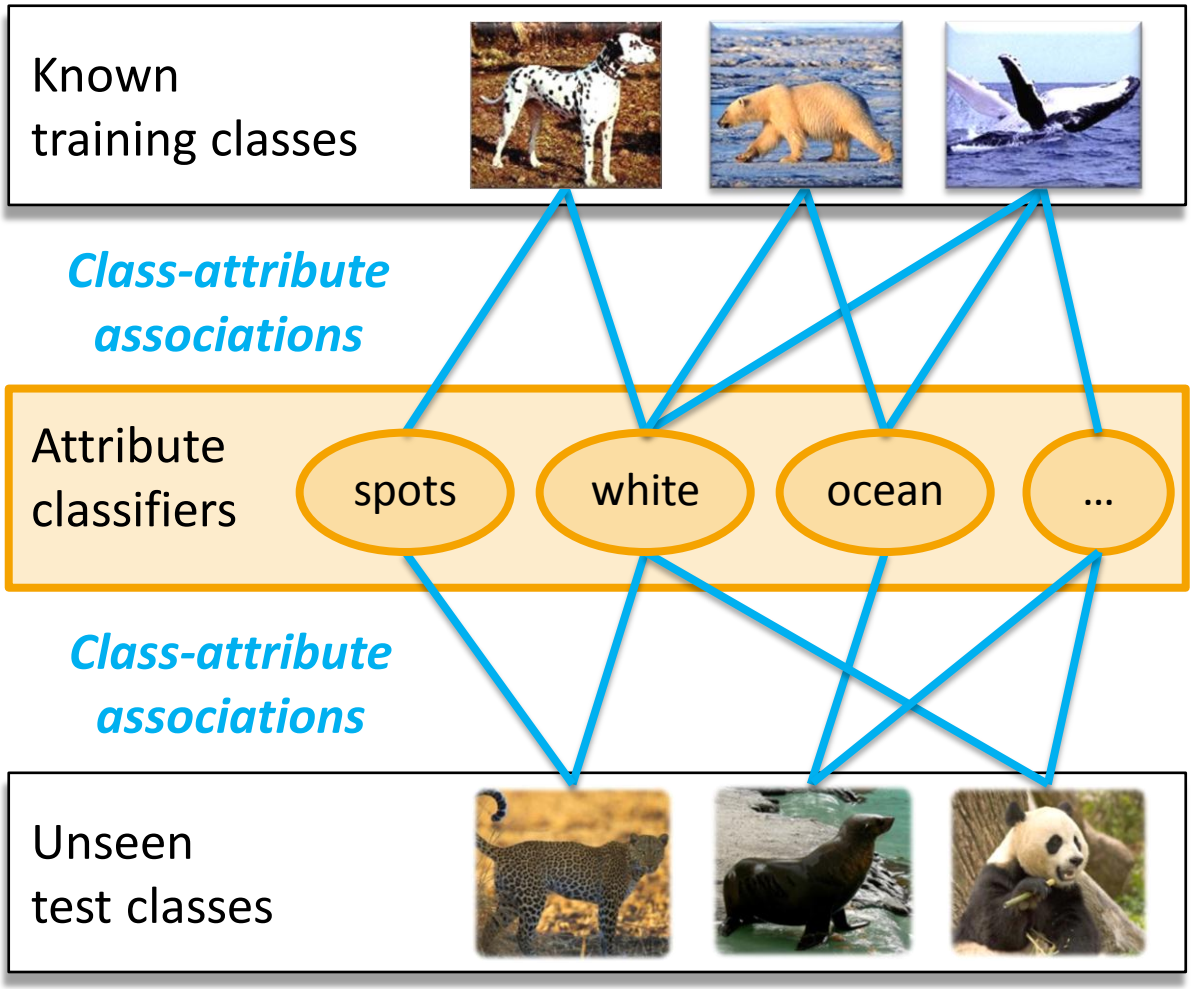
# Classifier Fusion

- So far:
  - Improved class-attribute associations (cyan)



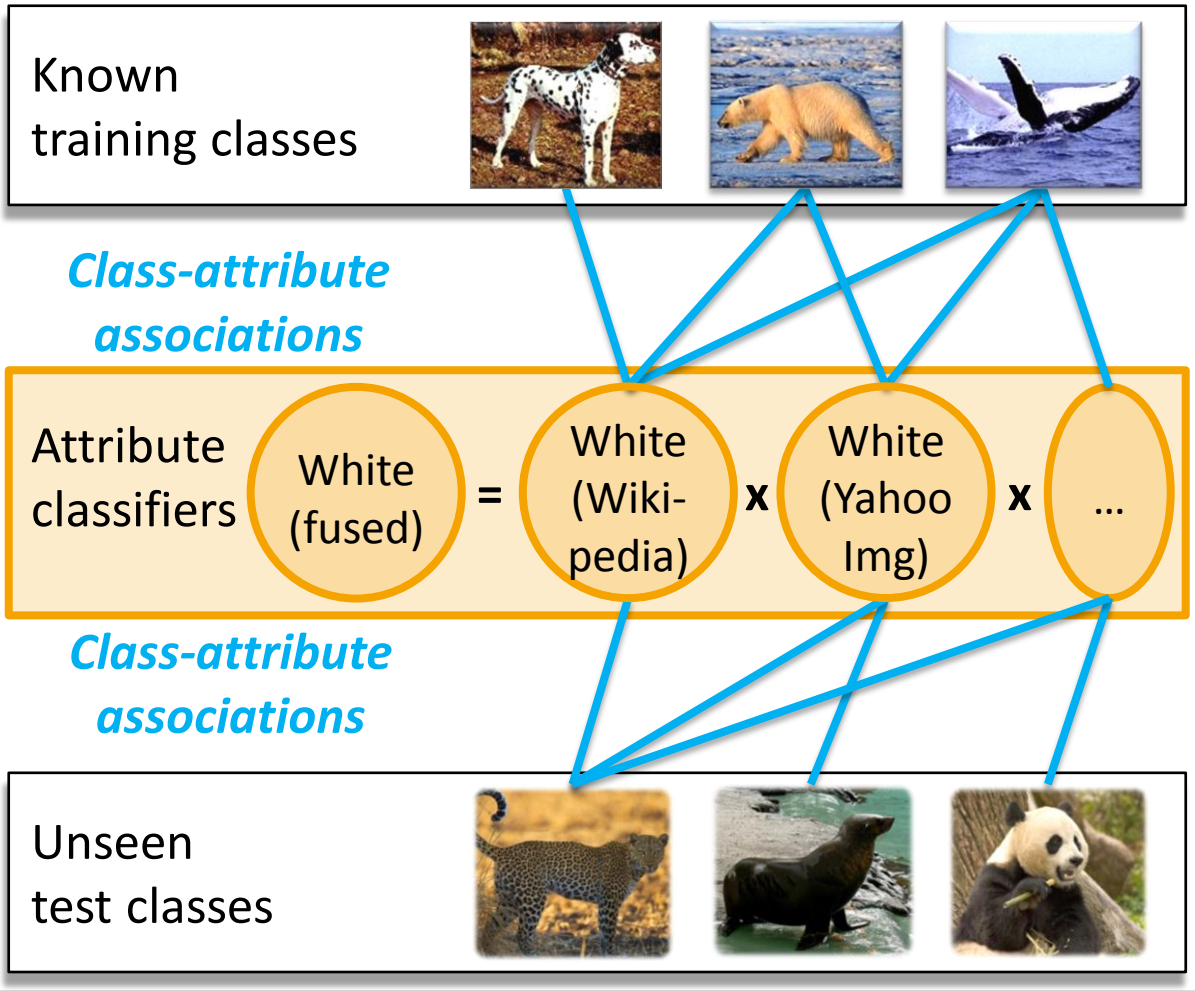
# Classifier Fusion - Results

- So far:
  - Improved class-attribute associations (cyan)
- Now:
  - Combine attribute classifiers of different measures
  - Product of probabilities



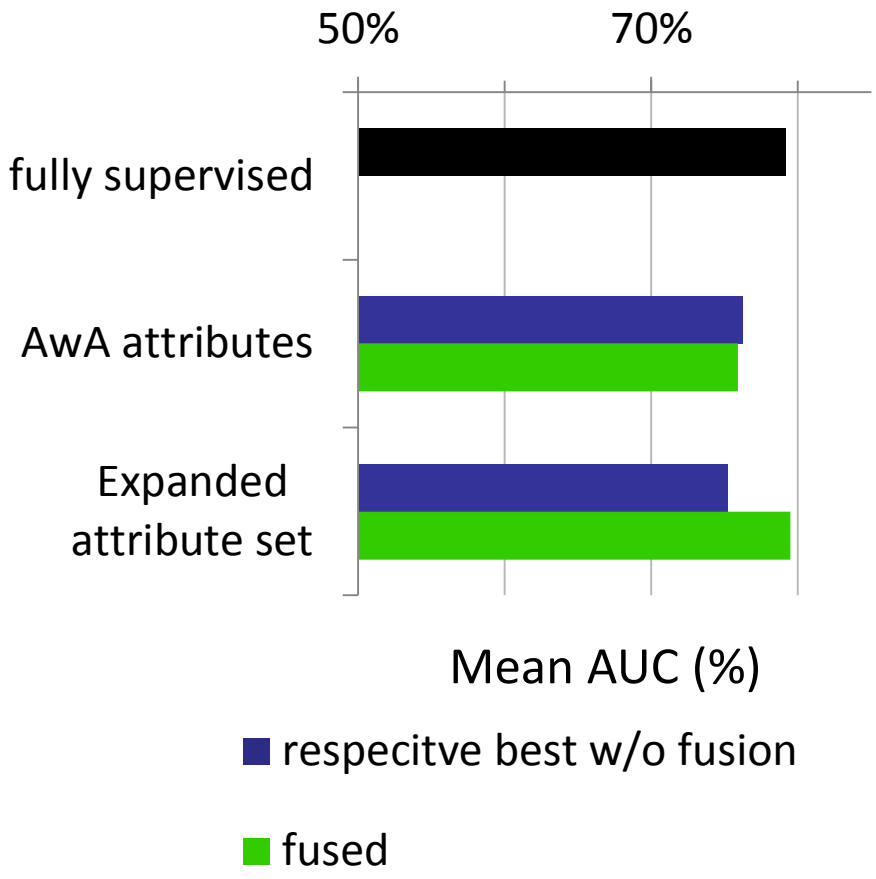
# Classifier Fusion - Results

- So far:
  - Improved class-attribute associations (cyan)
- Now:
  - Combine attribute classifiers of different measures
  - Product of probabilities



# Classifier Fusion - Results

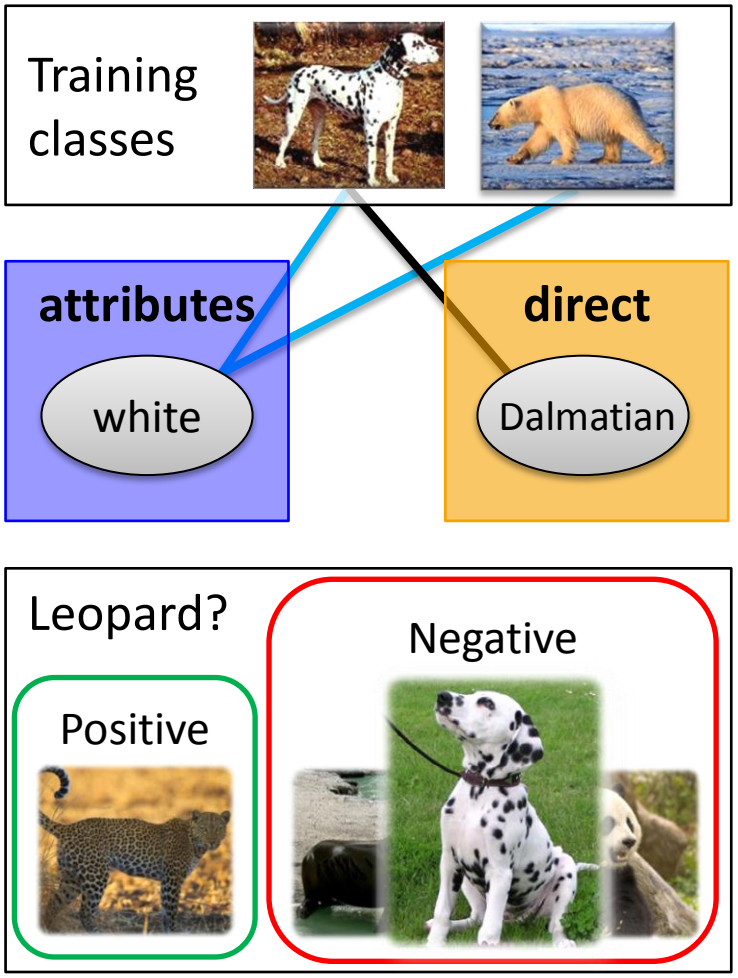
- Performance **on par** with fully supervised
  - Expanded attribute set (164 clustered)
- More stable results for AwA attributes.
  - No improvements for peak performance

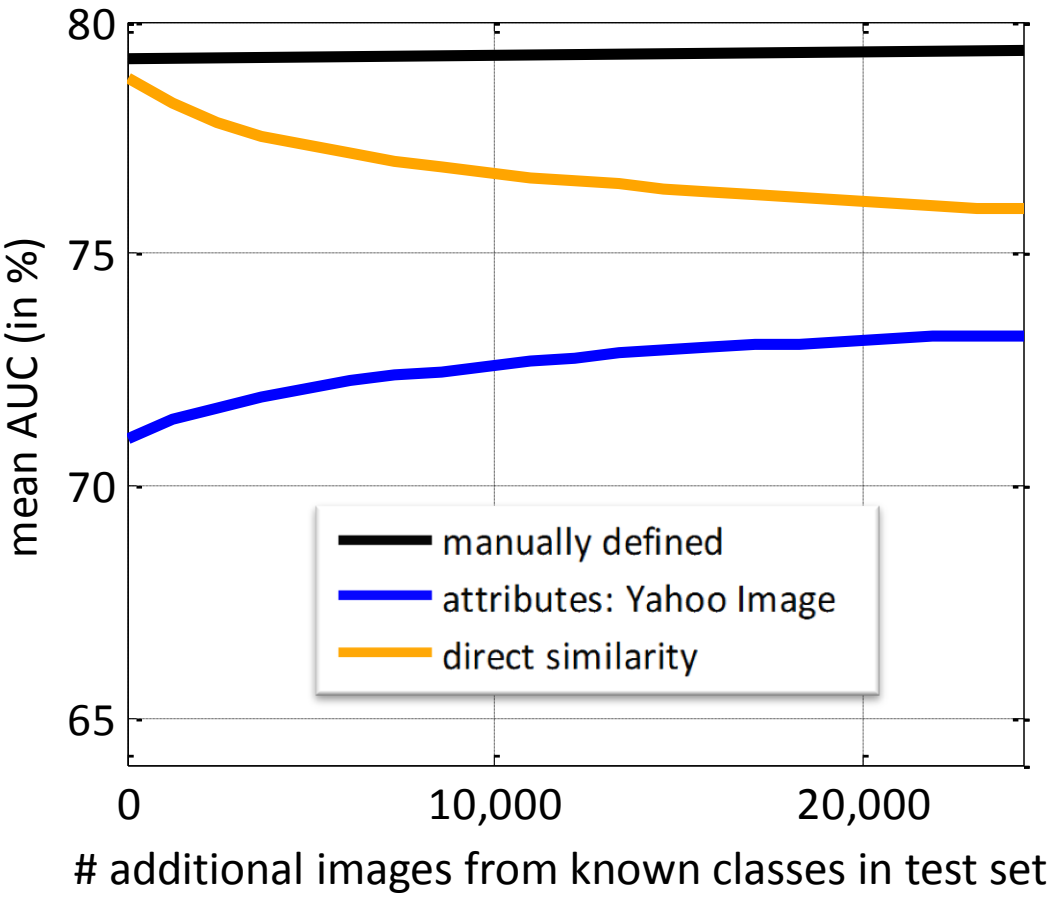


# Outline

- Motivation
- Dataset [Lampert, CVPR 09] & measures [Rohrbach, CVPR 10]
- Improve attribute-based knowledge transfer [this paper]
  1. Importance of parameter selection
  2. New measures
  3. Combining measures
  4. Expanded attribute inventory
  5. Classifier level fusion
- **Conclusion**
  - **Goal reached?**

# Conclusion

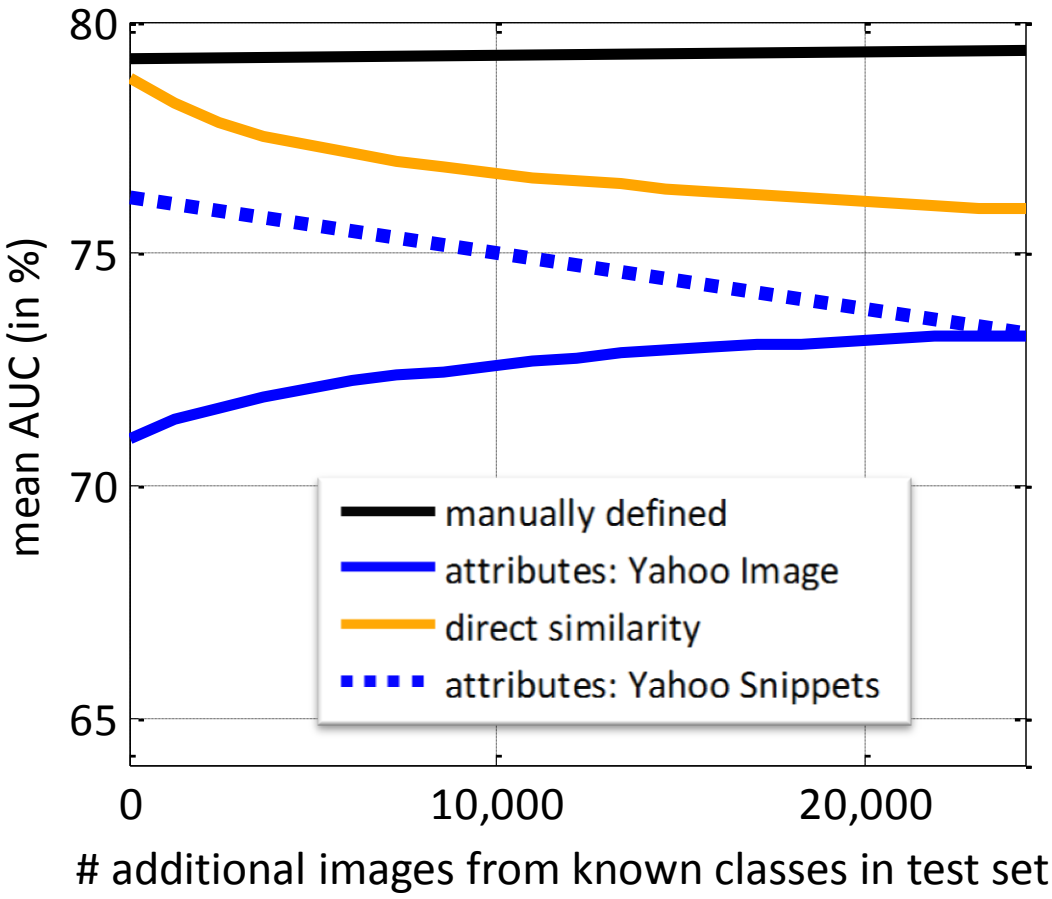


# Conclusion

Improvements by

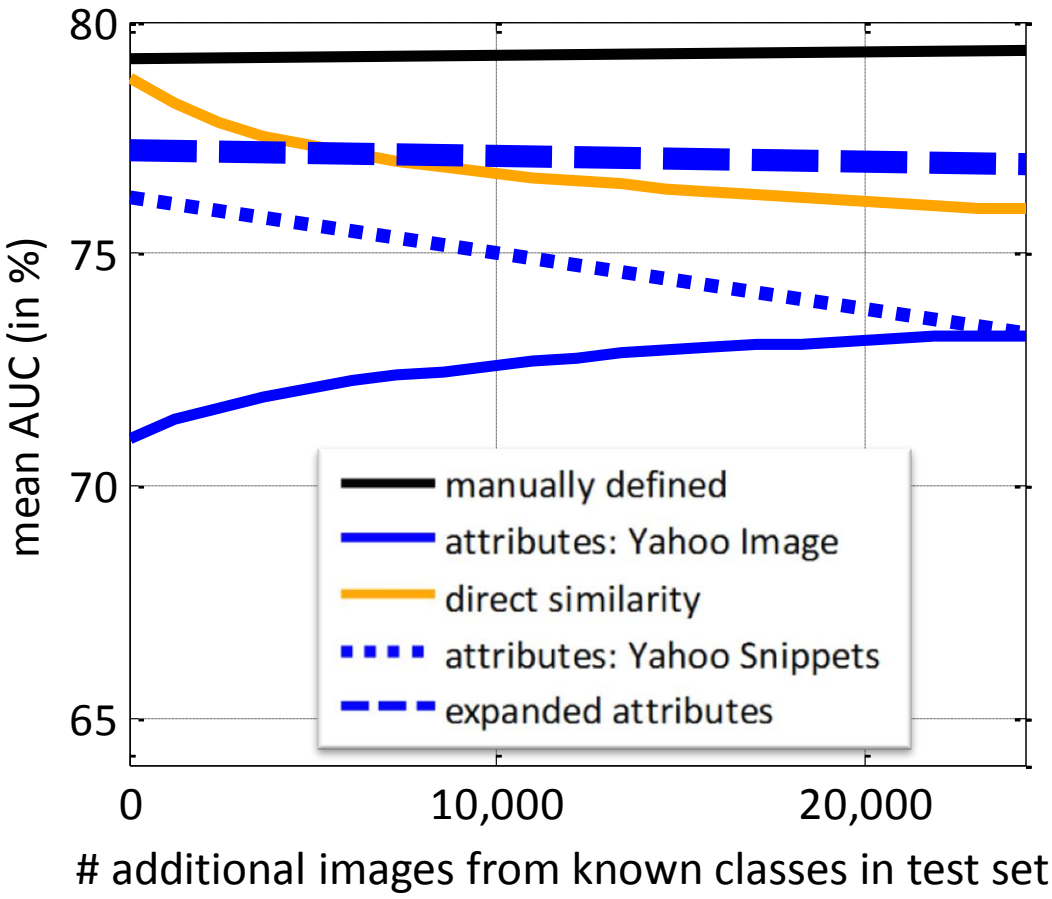
1. New measures



# Conclusion

Improvements by

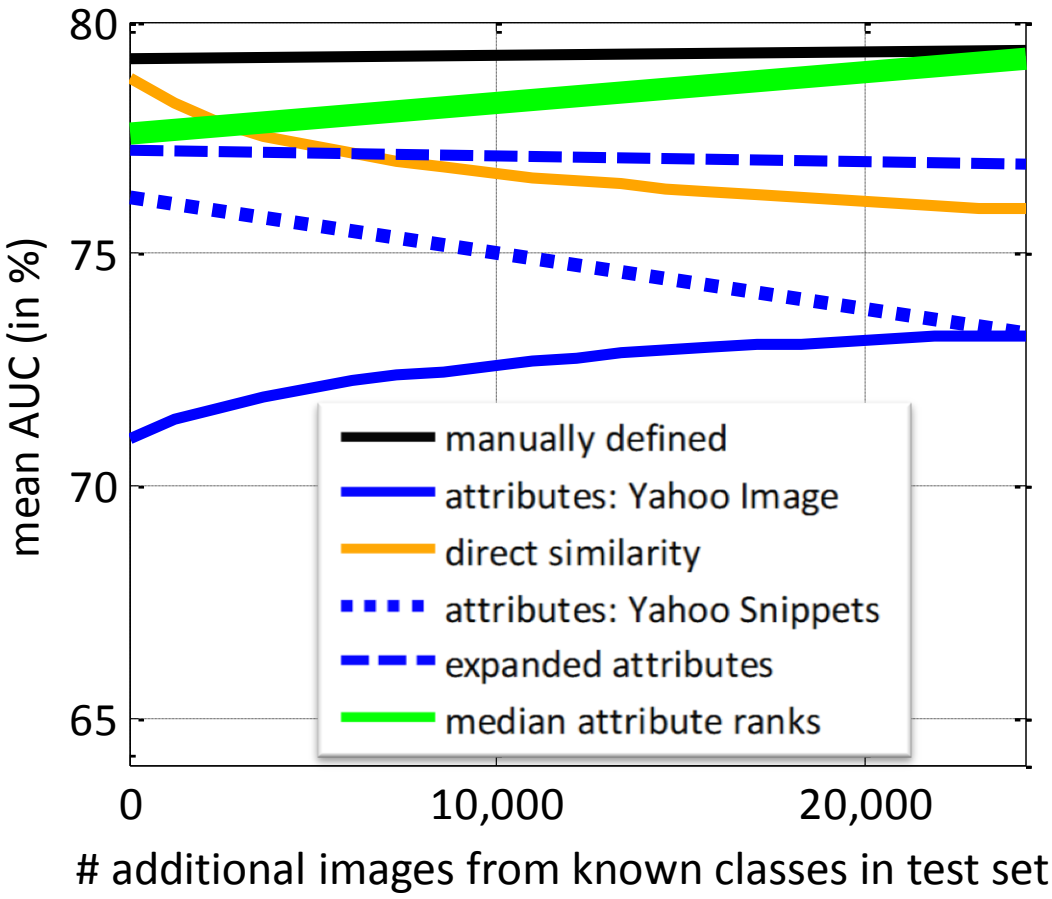
1. New measures
2. Expanded attributes



# Conclusion

Improvements by

1. New measures
2. Expanded attributes
3. Combining semantic relatedness

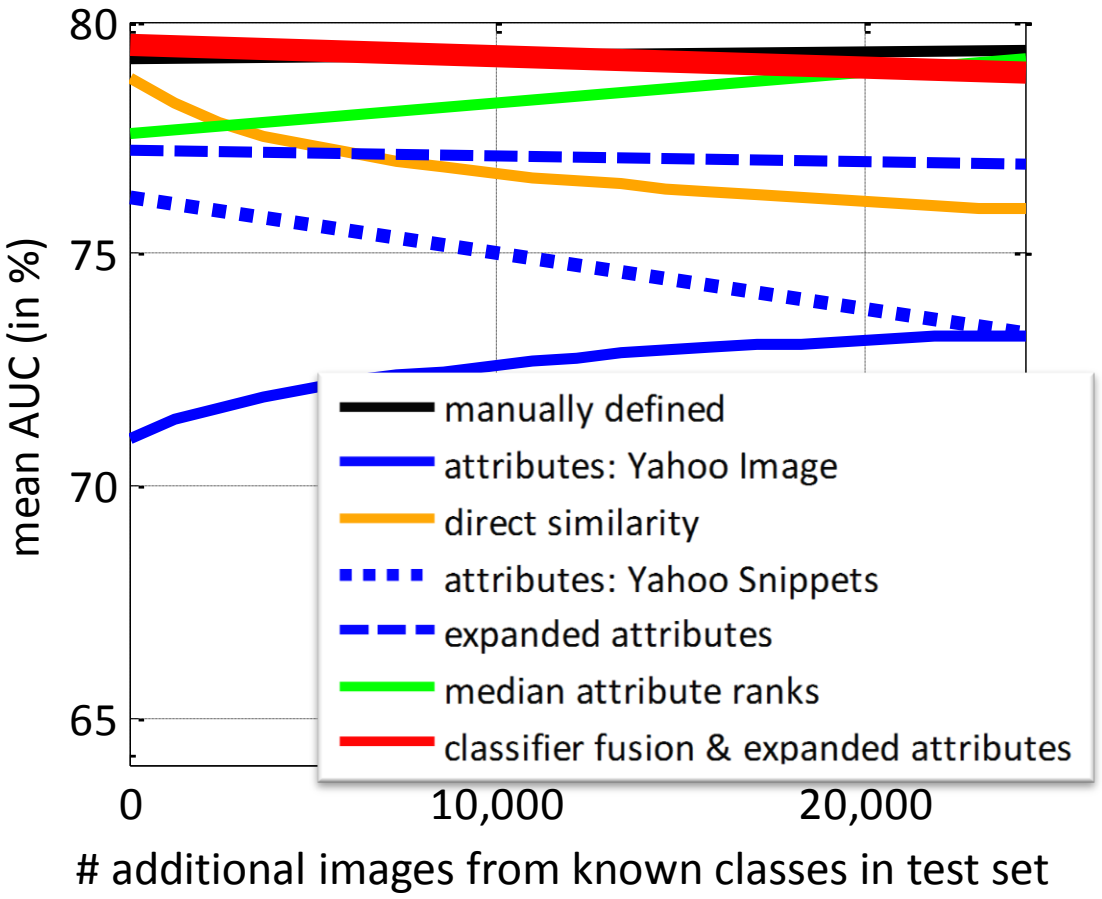


# Conclusion

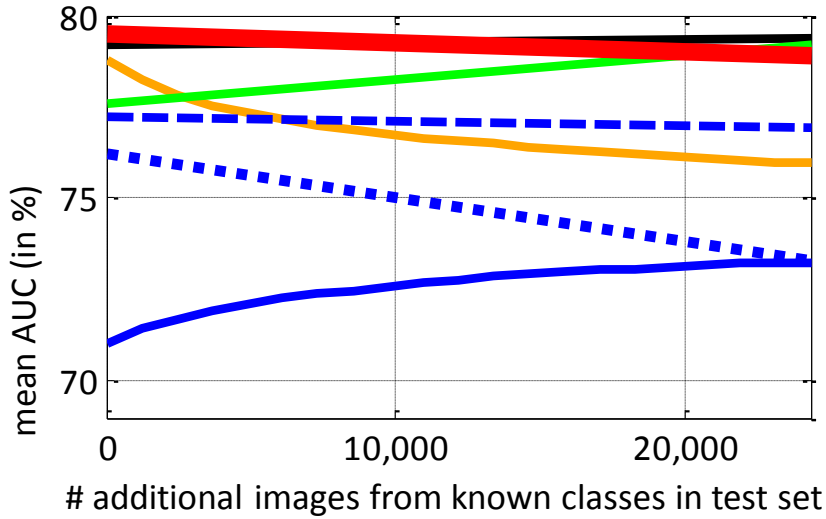
Improvements by

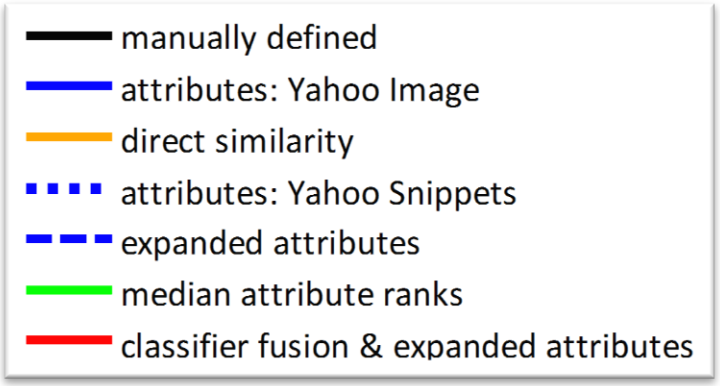
1. New measures
2. Expanded attributes
3. Combining semantic relatedness
4. Fusion on classifier level

⇨ **Performance on par with manual defined associations**



# Thank you!




# Questions?

Software?

**http://www.mpi-inf.mpg.de/~rohrbach/**