Inferring Analogous Attributes

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Problem

Attributes: Visual properties that describe objects and transcend object and scene category boundaries

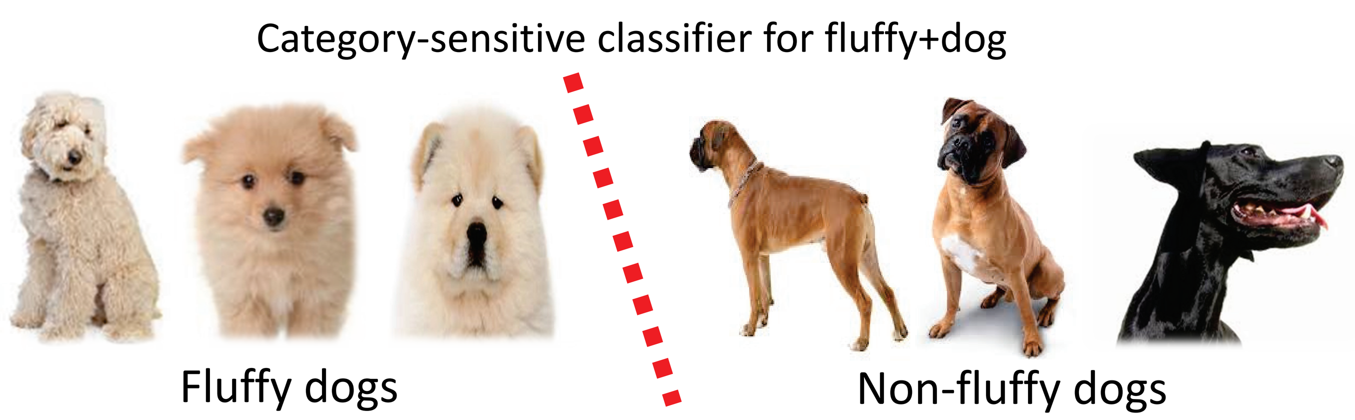
Status quo approach: Learn a single attribute classifier with data from all possible object/scene categories

[Kumar et al. 2009, Farhadi et al. 2009, Lampert et al. 2009, Russakovsky et al. 2010, Parikh & Grauman 2011, Patterson & Hays 2012,...]

But are attributes truly *category-independent*?

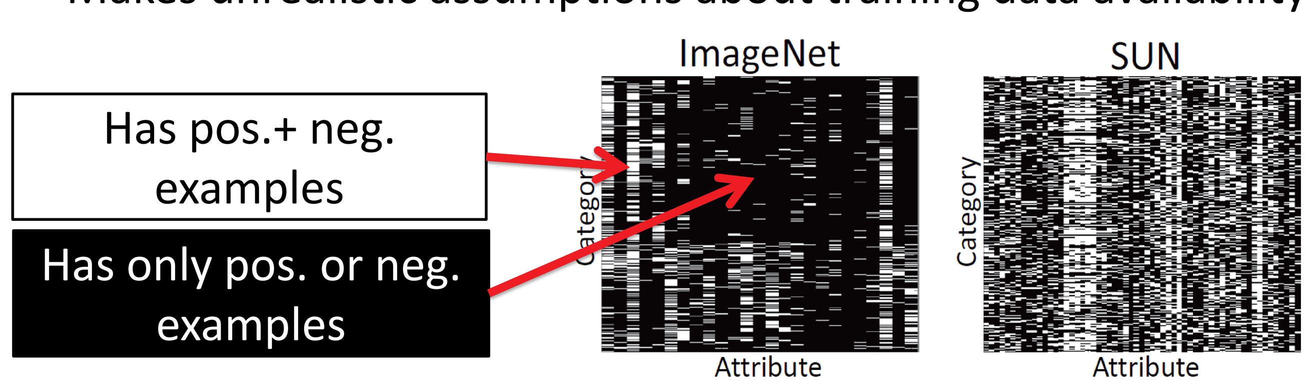
An intuitive *but impractical* solution…

Category-sensitive attributes: Learn a separate attribute classifier for each object category.



Flaws:

- Ignores semantic sharing that some attributes *do* possess
- Makes unrealistic assumptions about training data availability

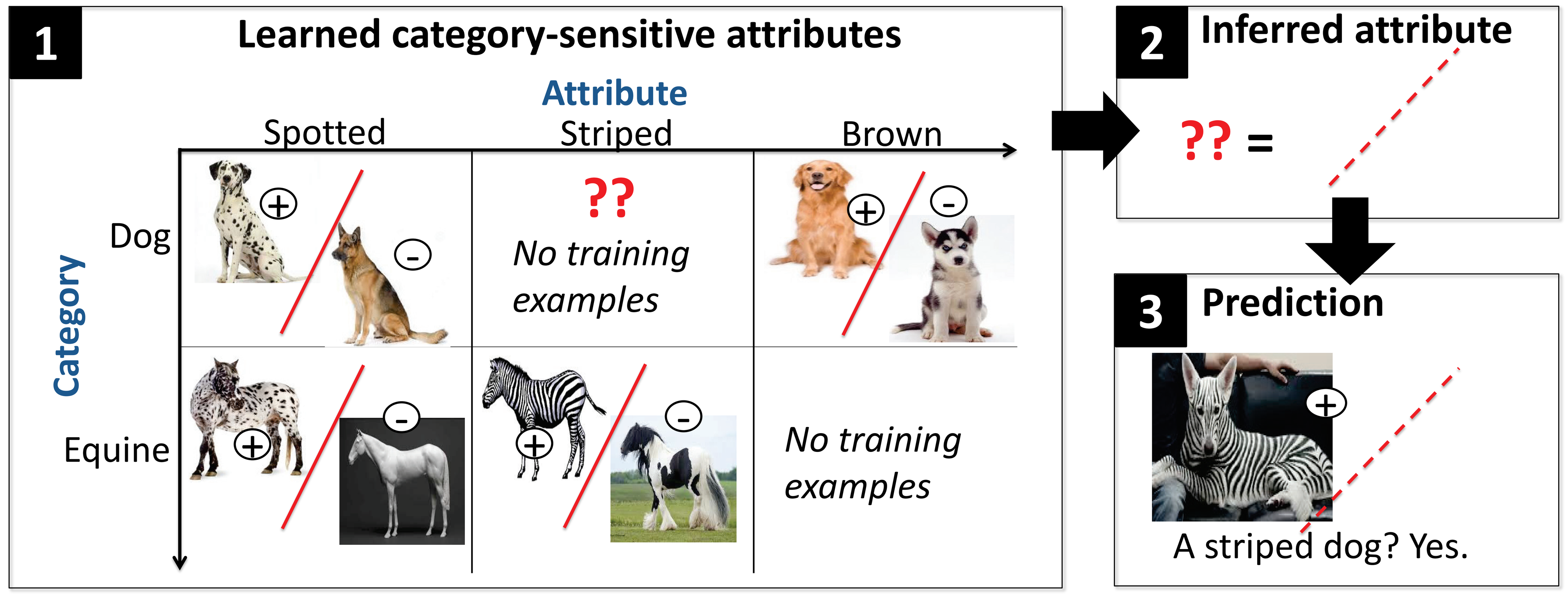


Our idea

1. **Learn category-sensitive attributes** for a sparse set of attribute+category pairs.
2. **Infer analogous attribute classifiers** by transferring knowledge from the trained category-sensitive attributes.

Novel form of transfer: Exploit 2D object-attribute label space to learn category-sensitive attributes with zero training images!

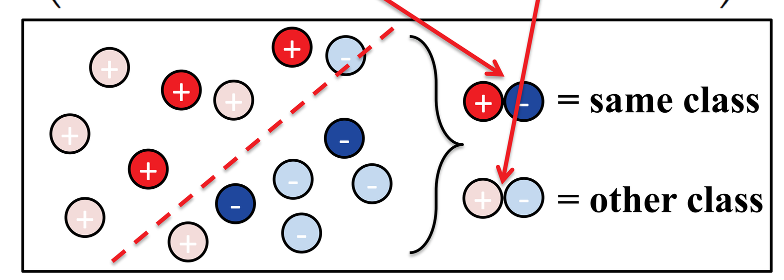
Approach



Learning category-sensitive attributes

minimize $\left(\frac{1}{2}||\boldsymbol{w}||^2 + C_s \sum_i \xi_i + C_o \sum_j \gamma_j\right)$

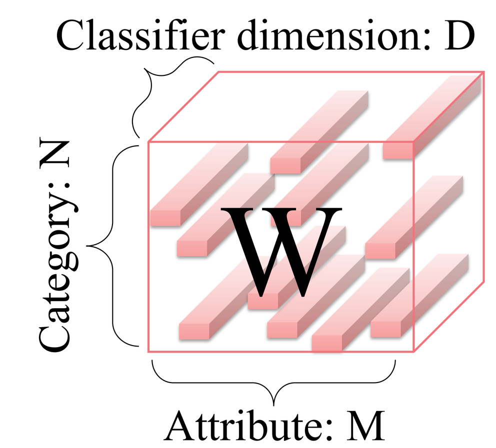
- Importance-weighted support vector machine (SVM) to train a category-sensitive attribute.
- Attributes' visual cues are shared among *some* objects, but the sharing is not universal.



Object-attribute classifier tensor

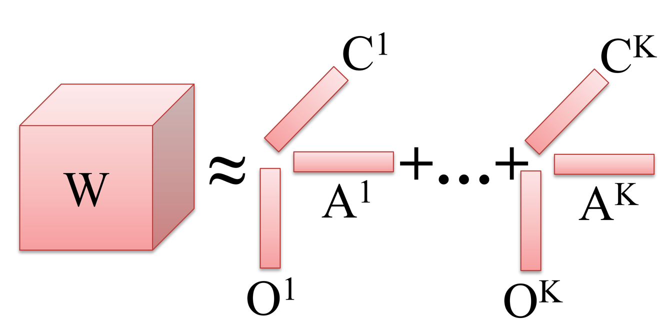
Construct a tensor comprised of the sparse set of explicitly trained category-sensitive attribute classifiers

- Each W(n,m,:) is a category-sensitive SVM weight vector trained for the n-th object and m-th attribute.
- Due to label availability, the tensor is sparse (75% missing values).
- For non-linear classifiers, we use explicit kernel maps.



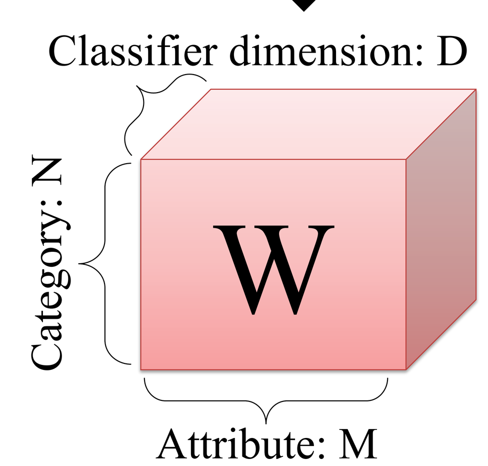
Inferring analogous attributes

- Apply Bayesian probabilistic tensor factorization [Xiong et al. 2010].
- Use recovered latent factors to impute unobserved classifier parameters.



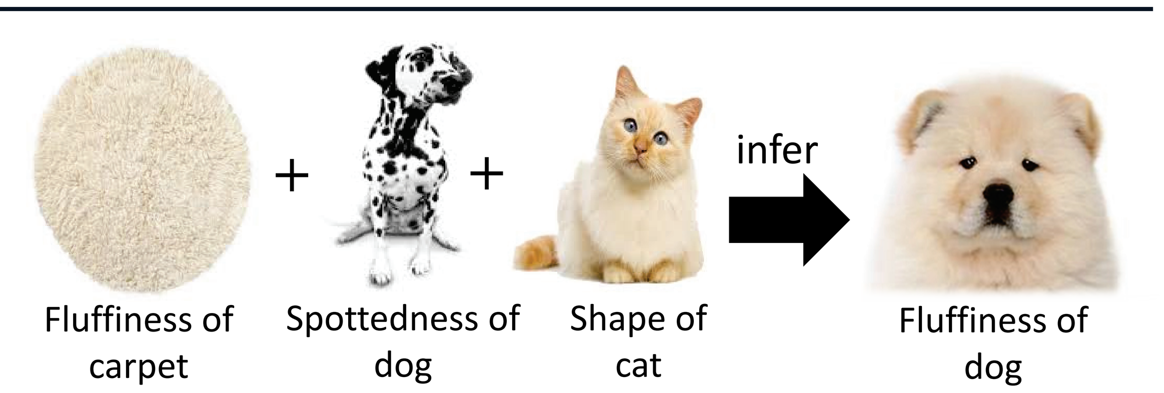
$$\mathbf{W} \approx \sum_{k=1}^{K} O^k \circ A^k \circ C^k$$

$$w_{nm}^d \approx \langle O_n, A_m, C_d \rangle$$



Discussion

- **Analogous attributes** transfer information from *multiple* objects *and* attributes.
- **Novel transfer idea**: tensor completion to infer classifiers "untrainable" from data.
- **Assume** some common structure among the explicitly trained category-sensitive models.



Dog+brown: Dog+spotty = Equine+brown: Equine+spotted

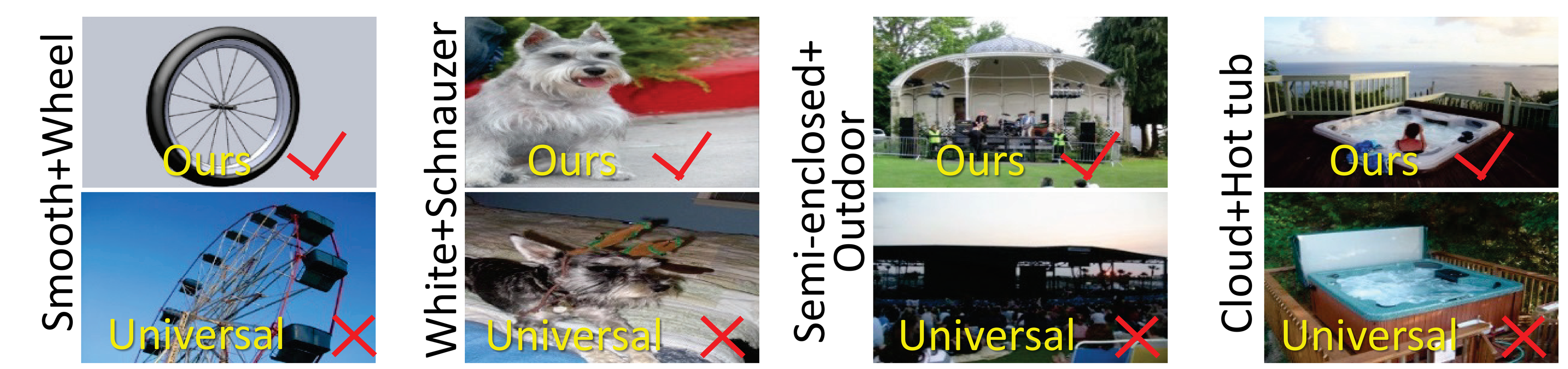
Results

Accuracy (mAP) of attribute prediction: Total 664 categories x 84 attributes

	Trained explicitly		Trained via transfer		
	Category-sens.	Universal	Inferred (Ours)	Adopt similar	One-shot
ImageNet	**0.7304**	0.7143	**0.7259**	0.6194	0.6309
SUN	**0.6505**	0.6343	**0.6429**	N/A	N/A

We infer classifiers for 26K attributes. Category-sensitive baseline impossible for 70% of them!
Our gains over Universal average 0.13 in AP for 79% of cases.

Example predictions



Discovered analogous attributes

Which categories are found to be analogous for an attribute?

Each example shows nearby category in latent space and the most similar attributes.

Focusing on semantically close data

Could side information about relatedness further help ease transfer?

Yes. If we restrict tensor to closely related objects and closely related attributes, obtain even better results.

Subset	Category-sensitive	Inferred (subset)	Inferred (all)
Categories (dogs)	0.7478	0.7358	0.7173
Attributes (colors)	0.7665	0.7631	0.7628

Conclusions

- Attributes are not strictly category-independent → Need category-sensitive attributes.
- Infer *analogous classifiers* from observed classifiers organized by inter-related label spaces.
- Enables category-sensitive training, even when category-specific labeled data not possible.