Detecting Unseen Visual Relations Using Analogies

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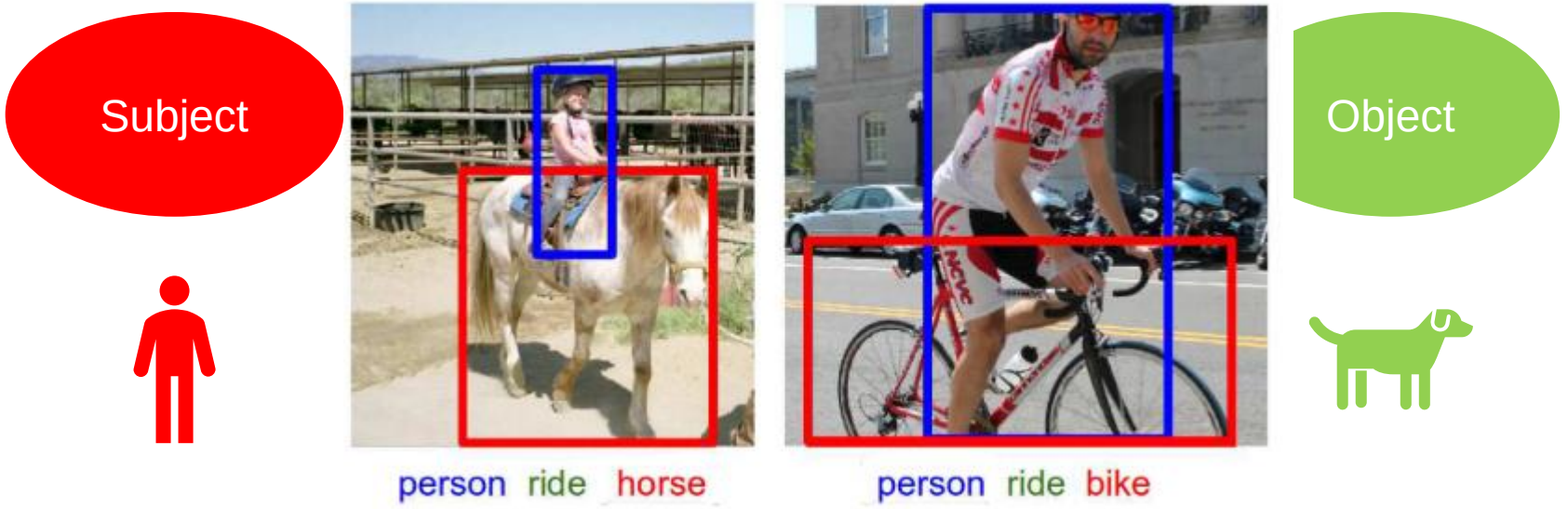
Introduction



Visual Relations - Triplets



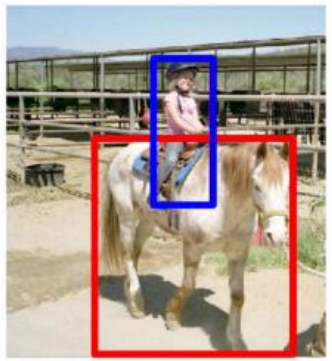
Recognize and **localize** unseen interactions in images

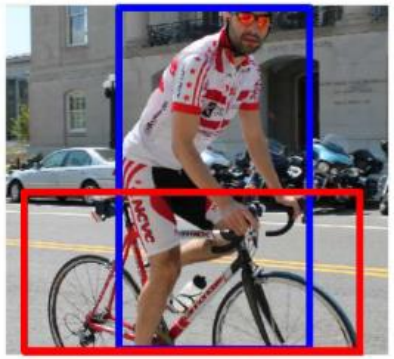
Problem

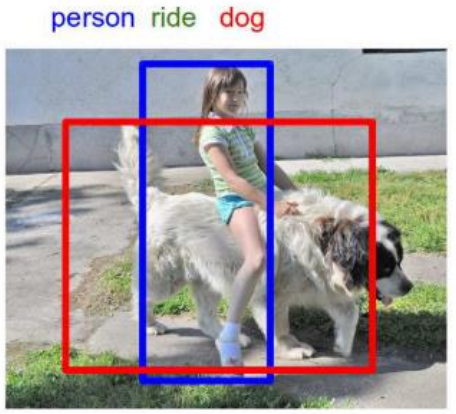
- The large variety of entities and possible relationships between them

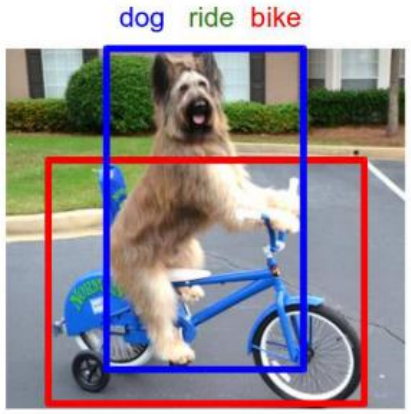
Person watch dog Person pet dog Person watch horse Dog watch horse

- Handle unseen visual triplets
  - Out of vocab unigram and unseen triplets









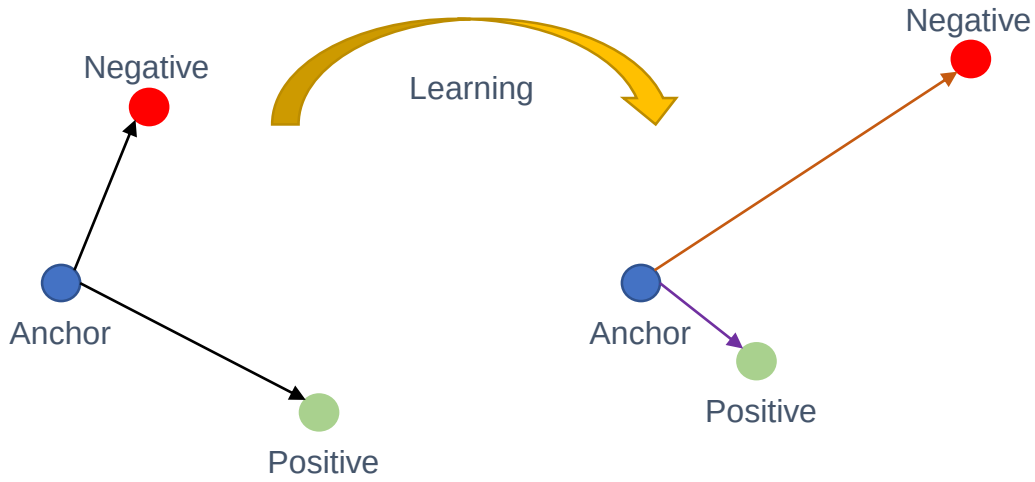
Triplet Loss

- At same time:
  - reduce the distance between similar things, p.
  - increase distance between different things, n.

$$\sum_{i}^{N}\left[\left\|f(x_i^a)-f(x_i^{\textcircled{p}})\right\|_2^2-\left\|f(x_i^a)-f(x_i^{\textcircled{n}})\right\|_2^2+\alpha\right]$$

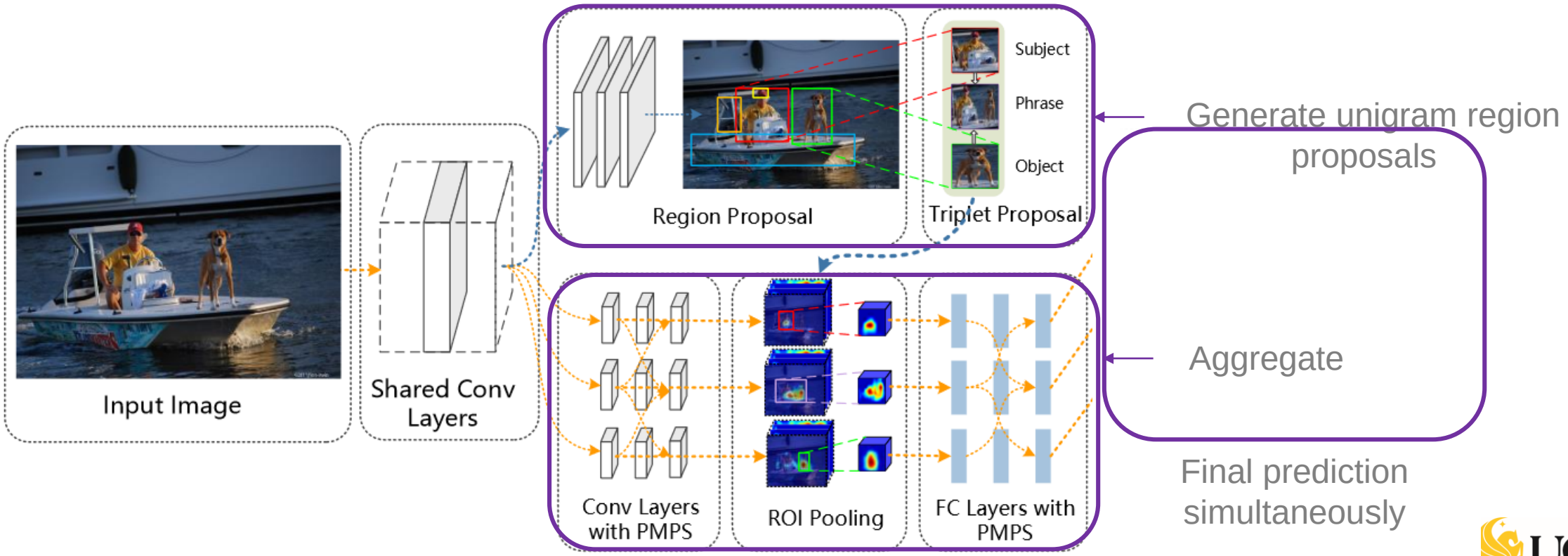
Minimize

Maximize



Compositional Approach

- Subject, predicate and object detected separately then aggregated together.



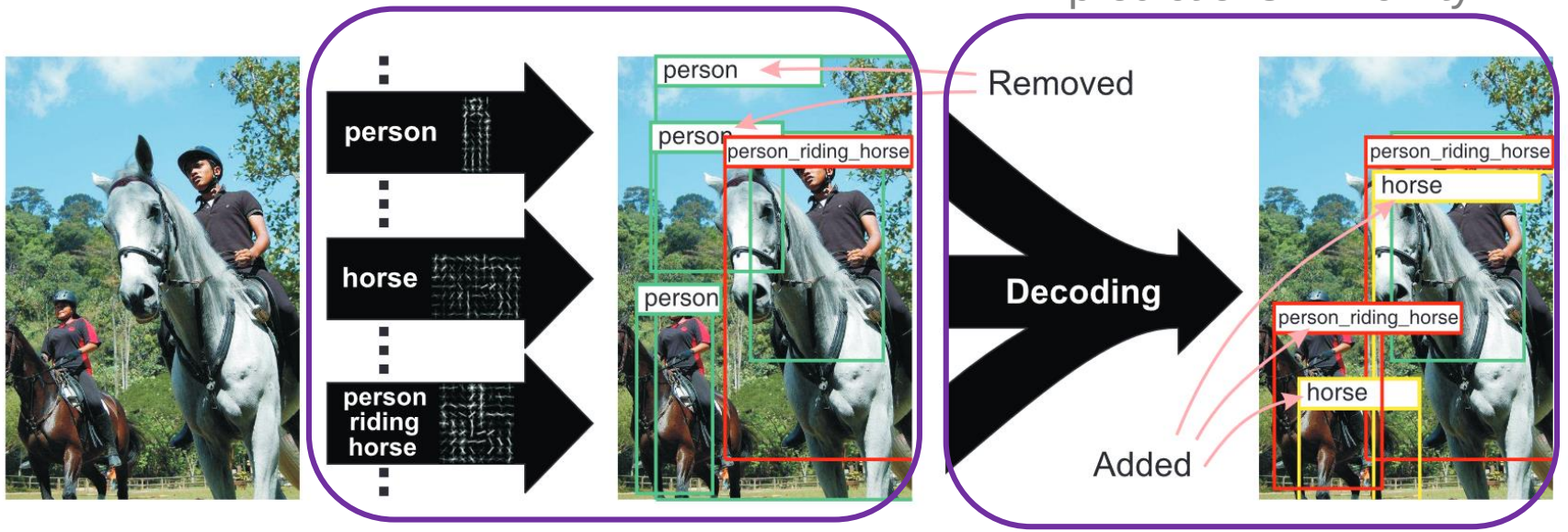
Visual Phrase Models

- Treat triplet as single entity
- Struggle with larger vocabulary



Correct predictions by looking at other predictions in vicinity

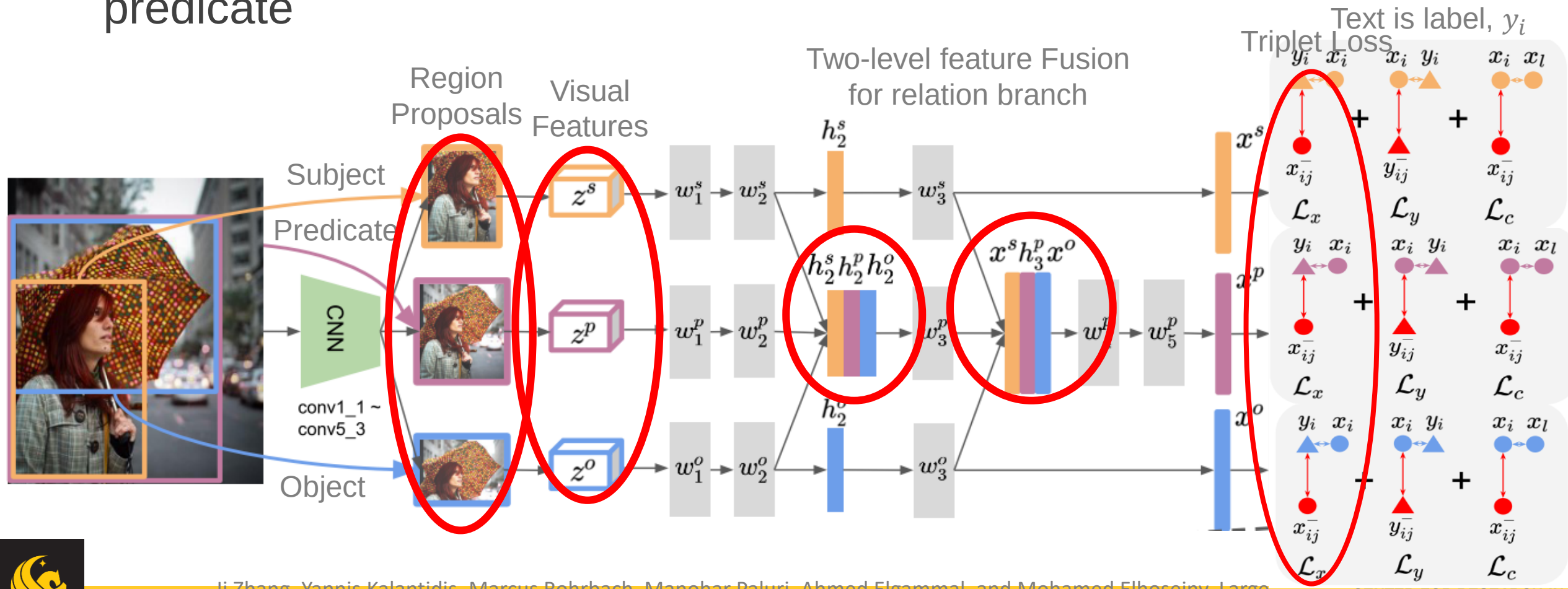
Predict VP region + objects



Mohammad Amin Sadeghi and Ali Farhadi. Recognition using visual phrases. In CVPR, 2011

Visual-Semantic Embeddings

- Learn separate visual-semantic spaces for subject, object, and predicate



Method

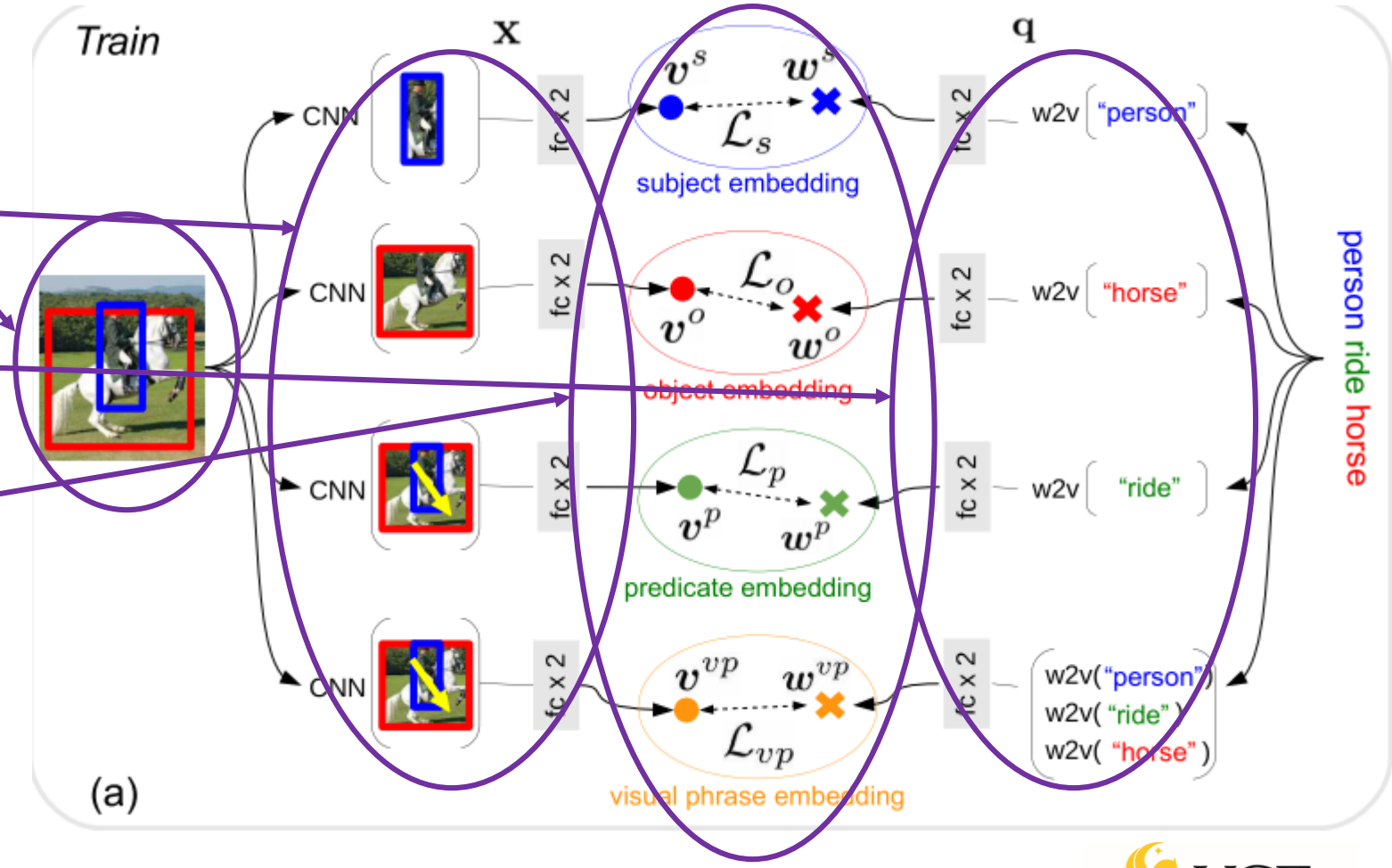
Phase 1

Pair of objects i

Visual Embeddings

Textual Embeddings

Final Embeddings



projection functions

Trained

$$v_i^b = f_v^b(x_i) \qquad f_v^b : \mathbb{R}^{d_v} \rightarrow \mathbb{R}^d$$

$$w_t^b = f_w^b(q_i) \qquad f_w^b : \mathbb{R}^{d_q} \rightarrow \mathbb{R}^d$$

Peyre, J., Sivic, J., Laptev, I., & Schmid, C. (2020). Detecting Unseen Visual Relations Using Analogies. ICCV, 2020.

Phase 1 - Training

- $i \in \{1, \ldots, N\}$: Each (s, o) candidate bounding boxes
- $y_t^i = [0,1]$ if i^{th} pair of boxes can(not) be described as relation $t = (s, p, o)$
- Triplet loss

$$\mathcal{L}_b = \sum_{i=1}^{N} \sum_{t \in V_b} 1_{y_t^i = 1} \log\left(\frac{1}{1 + e^{-\mathbf{w}_t^{b\,T} \mathbf{v}_i^b}}\right) + \sum_{i=1}^{N} \sum_{t \in V_b} 1_{y_t^i = 0} \log\left(\frac{1}{1 + e^{-\mathbf{w}_t^{b\,T} \mathbf{v}_i^b}}\right)$$

For each input type b

$$\mathcal{L}_{joint} = \mathcal{L}_s + \mathcal{L}_o + \mathcal{L}_p + \mathcal{L}_{vp}$$

Peyre, J., Sivic, J., Laptev, I., & Schmid, C. (2020). Detecting Unseen Visual Relations Using Analogies. ICCV, 2020.

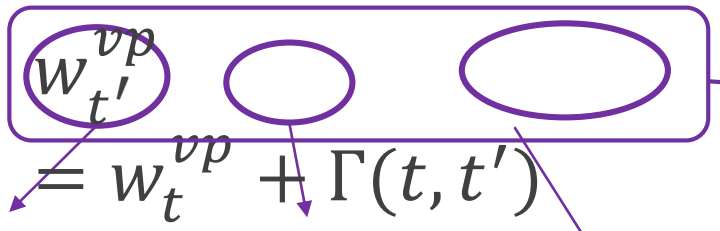
Phase 2

- *Transfer by Analogy* : transfer learned representation to unseen

Choosing Source Triplets:

$G(t,t') = \sum_{b\in(s,o,p)} \alpha_b w_t^{b\,T} w_{t'}^b$

where $G(t,t') \in [0,1]$ because $\sum_b \alpha_b = 1$

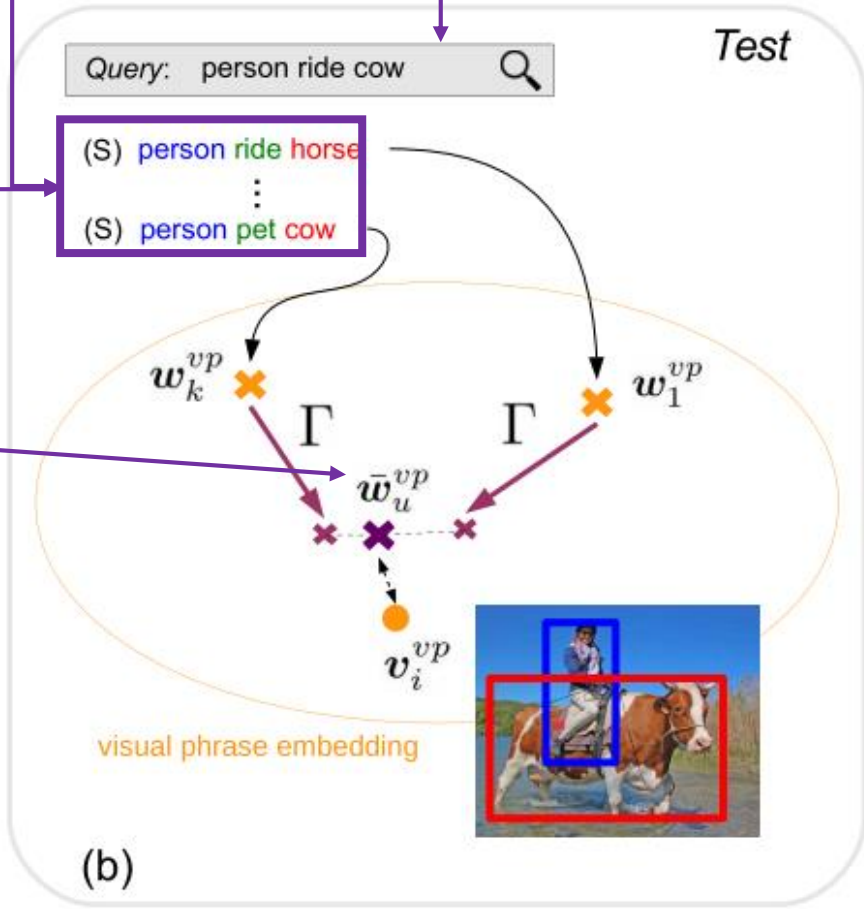


Embedding of target triplet

Embedding of source triplet

Transformation function, $t \rightarrow t'$

Aggregate



$$\Gamma(t,t') = \mathrm{MLP}\begin{bmatrix} \boldsymbol{w}_{s'}^{vp} - \boldsymbol{w}_s^{vp} \\ \boldsymbol{w}_{p'}^{vp} - \boldsymbol{w}_p^{vp} \\ \boldsymbol{w}_{o'}^{vp} - \boldsymbol{w}_o^{vp} \end{bmatrix}$$

$$w_s^{vp} = f_s^{vp}(\boldsymbol{q}_{[s,0,0]})$$
$$w_p^{vp} = f_p^{vp}(\boldsymbol{q}_{[0,p,0]})$$
$$w_o^{vp} = f_o^{vp}(\boldsymbol{q}_{[0,0,o]})$$

Peyre, J., Sivic, J., Laptev, I., & Schmid, C. (2020). Detecting Unseen Visual Relations Using Analogies. ICCV, 2020.

Phase 2 Example

Intuition:
“person ride horse” – “horse” + “cow” = “person ride cow”

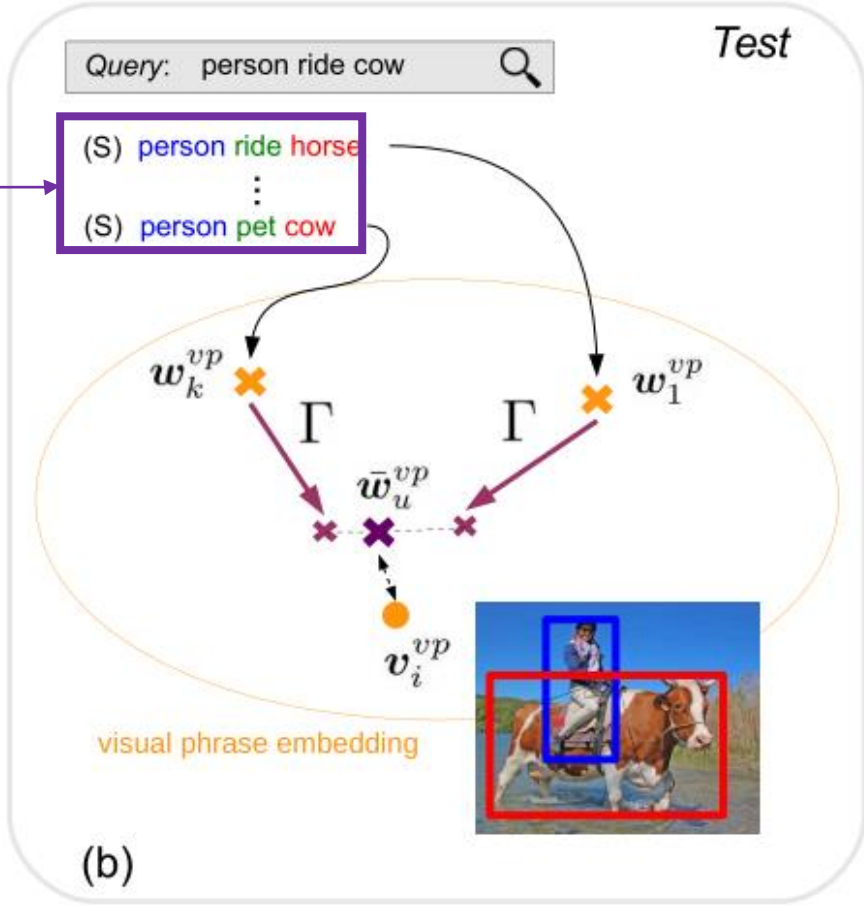
$$w_{t'}^{vp} = w_{t}^{vp} + \Gamma \begin{bmatrix} 0 \\ 0 \\ \boldsymbol{w}_{cow}^{vp} - \boldsymbol{w}_{horse}^{vp} \end{bmatrix}$$

Embedding of target triplet

Embedding of source triplet

Transformation function, $t \rightarrow t'$

Source Triplets



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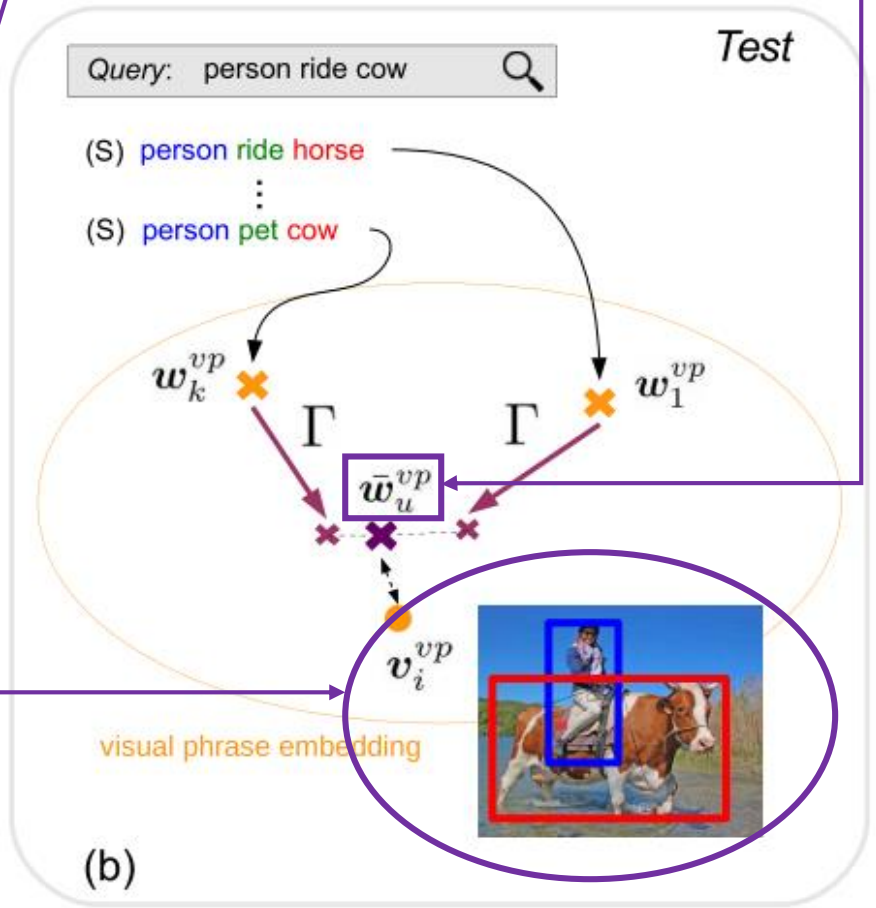
Phase 2 – Training

$$\mathcal{L}_\Gamma = \sum_{i=1}^{N} \sum_{(t,t')\in\mathcal{Q}} 1_{y_{t'}^i=1} \log\left(\frac{1}{1+e^{-(\boldsymbol{w}_t^{vp}+\Gamma(t,t'))^T \boldsymbol{v}_i^{vp}}}\right) + \sum_{i=1}^{N} \sum_{(t,t')\in\mathcal{Q}} 1_{y_{t'}^i=0} \log\left(\frac{1}{1+e^{-(\boldsymbol{w}_t^{vp}+\Gamma(t,t'))^T \boldsymbol{v}_i^{vp}}}\right)$$

- Optimize log-likelihood between pairs
  - Visual features are from target triplet
  - Language features from transformed training triplets

Visual Phrase Embedding of Unseen Triplet

$$\bar{\boldsymbol{w}}_u^{vp} = \sum_{t\in\mathcal{N}_u} G(t,u)\left(\boldsymbol{w}_t^{vp} + \Gamma(t,u)\right)$$

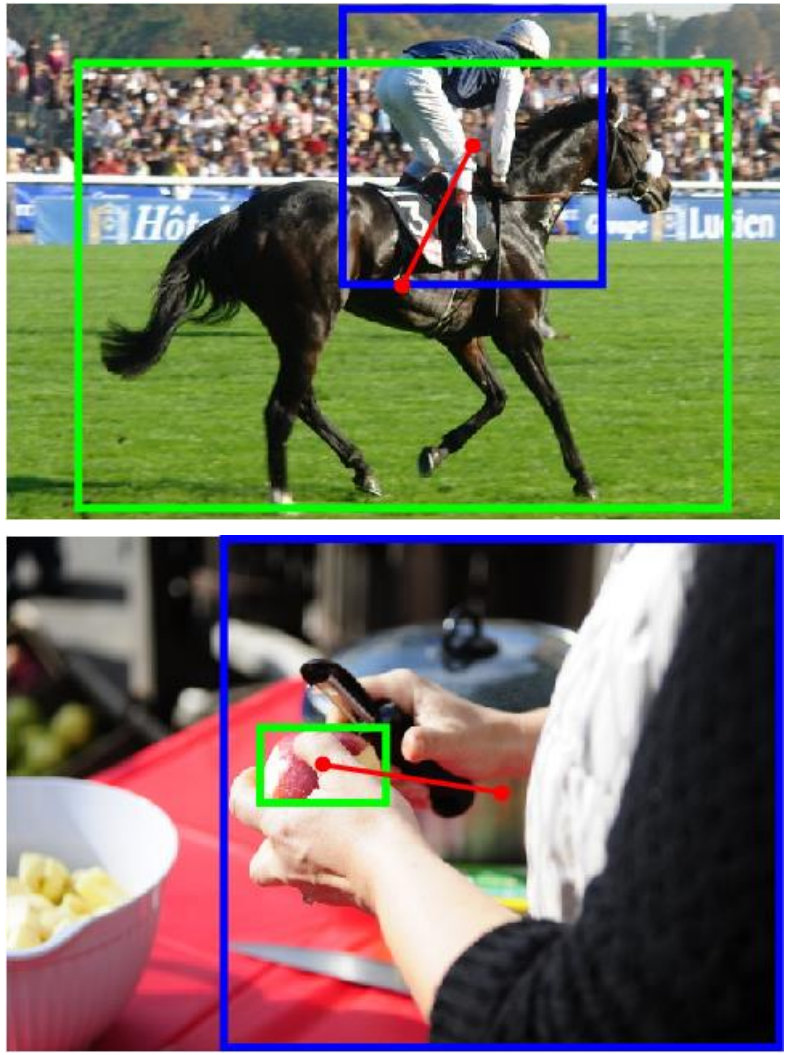


Peyre, J., Sivic, J., Laptev, I., & Schmid, C. (2020). Detecting Unseen Visual Relations Using Analogies. ICCV, 2020.

Experiments

Dataset – HICO-DET

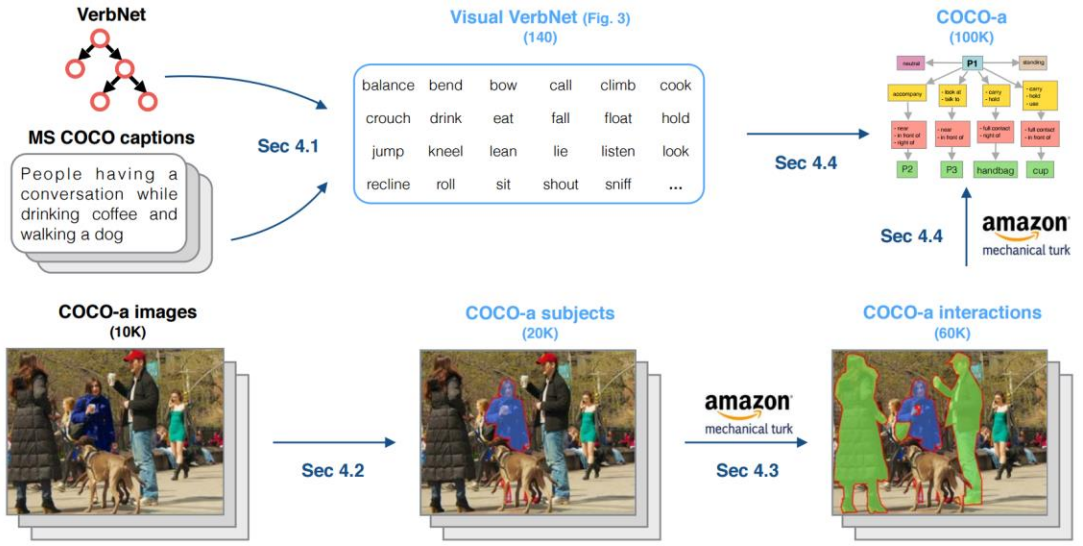
- Human-object interactions
  - 80 categories
- Human and object bounding box annotations
- Positive example of 600 triplets
- 9,360 possible triplets
- Use 25 non-rare triplets as unseen during test time



Yu-Wei Chao, Zhan Wang, Yugeng He, Jiaxuan Wang, and Jia Deng. HICO: A Benchmark for Recognizing Human-Object Interactions in Images. IEEE International Conference on Computer Vision (ICCV), 2015.

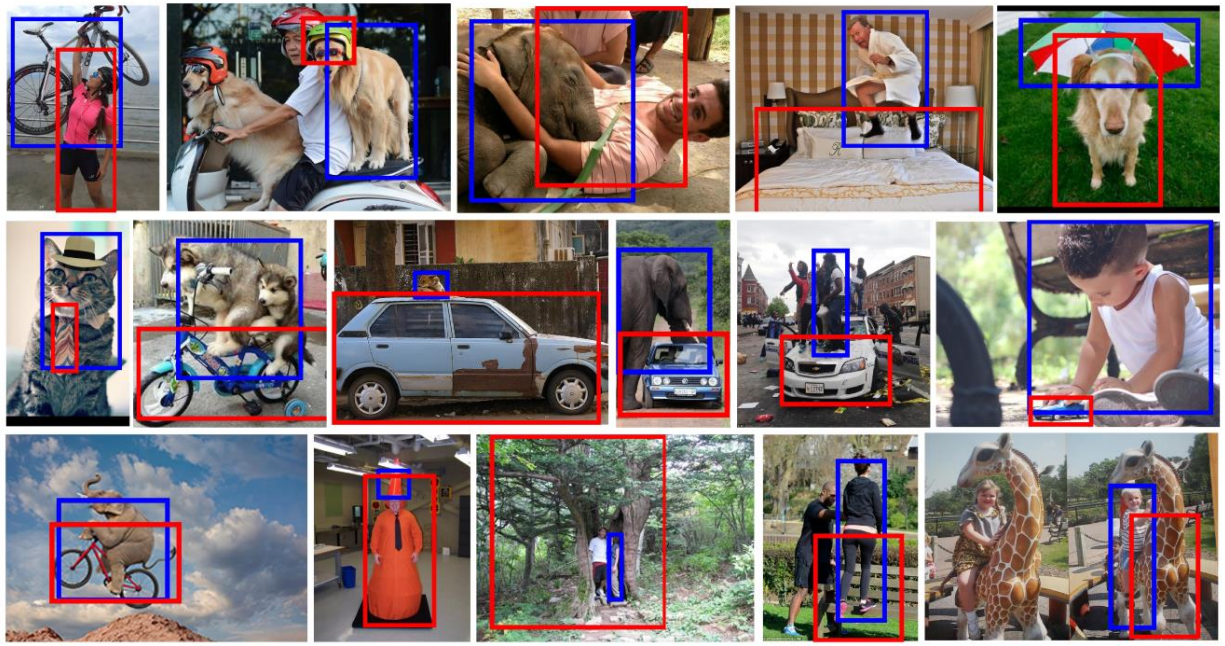
Dataset – COCO-a

- Subset of COCO with human object interactions
  - 80 categories
- Positive examples of 140 triplets
- 1,681 possible triplets
- Used for evaluation on HICO-DET trained model
  - 71% unseen involve out-of-vocabulary *predicate* not seen at training



Dataset – UnRel

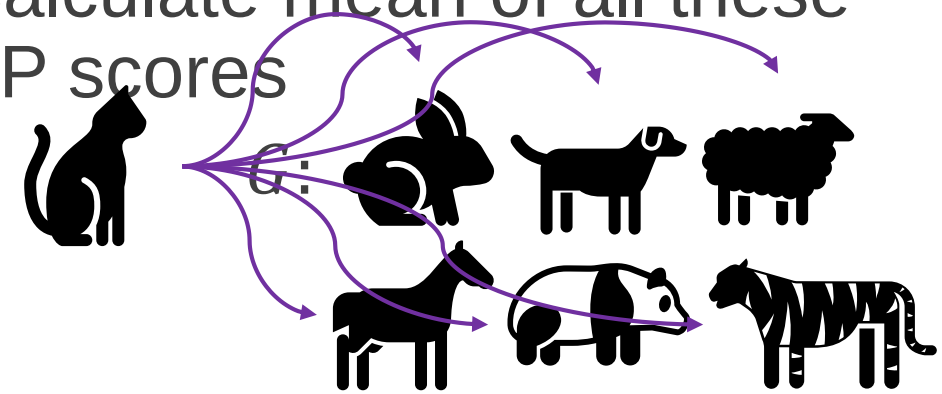
- Triplets but not necessarily involving a human
- Predicates not necessarily actions
- Positive examples of 76 *unusual* triplets
- Used for evaluation only



Peyre, Julia, et al. "Weakly-supervised learning of visual relations." Proceedings of the IEEE International Conference on Computer Vision. 2017.

Mean Average Precision for Image Retrieval

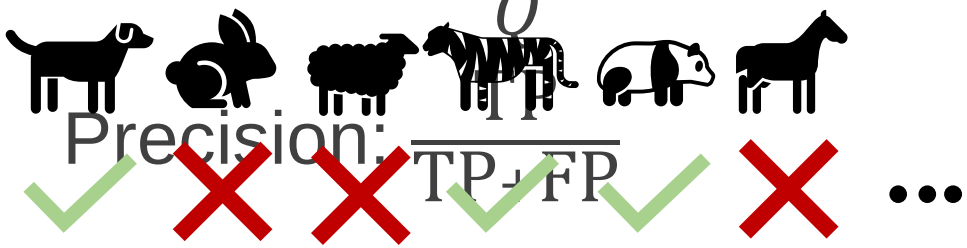
- for a given query, $q \in Q$:
  - calculate average precision, $\text{AveP}(q)$:
- Calculate mean of all these AP scores



- Measure similarity between Q and each G and sort by most similar.

$$\text{MAP} = \frac{\sum_{q=1}^{Q} \text{AveP}(q)}{Q}$$

Precision: $\frac{TP}{TP+FP}$

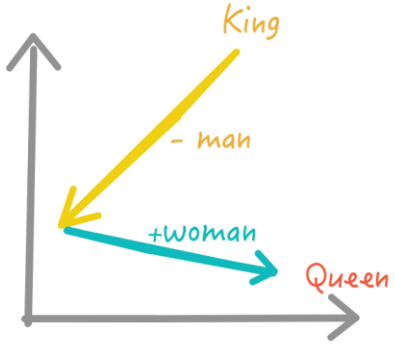


$\frac{TP}{Total}$ $\frac{1}{1}$ $\frac{2}{4}$ $\frac{3}{5}$

$$Overall\ AP = \frac{1}{3}\left(\frac{1}{1} + \frac{2}{4} + \frac{3}{5}\right) = .7$$

Implementation Details

- Evaluation is mAP over set of triplet queries
- Word embeddings from Word2Vec trained on Google news
  - Triplet is aggregated vectors



a) Learns Analogy



b) Similar Words have same angles

- Projection functions are 2 FCs + 1 ReLU
- Pre-extracted candidate pairs
- Visual representation of candidate pair is 1000-dimensional vector
  - Aggregate visual and spatial of objects
  - Subject is only appearance

Peyre, J., Sivic, J., Laptev, I., & Schmid, C. (2020). Detecting Unseen Visual Relations Using Analogies. ICCV, 2020.

Seen Triplets

- mAP results on HICO-DET
- **s+o+p**: the compositional part using all unigram terms
- **s+o+vp**: visual phrase part combined with object scores
- **s+o+p+vp:** visual phrase representation on top of the compositional baseline

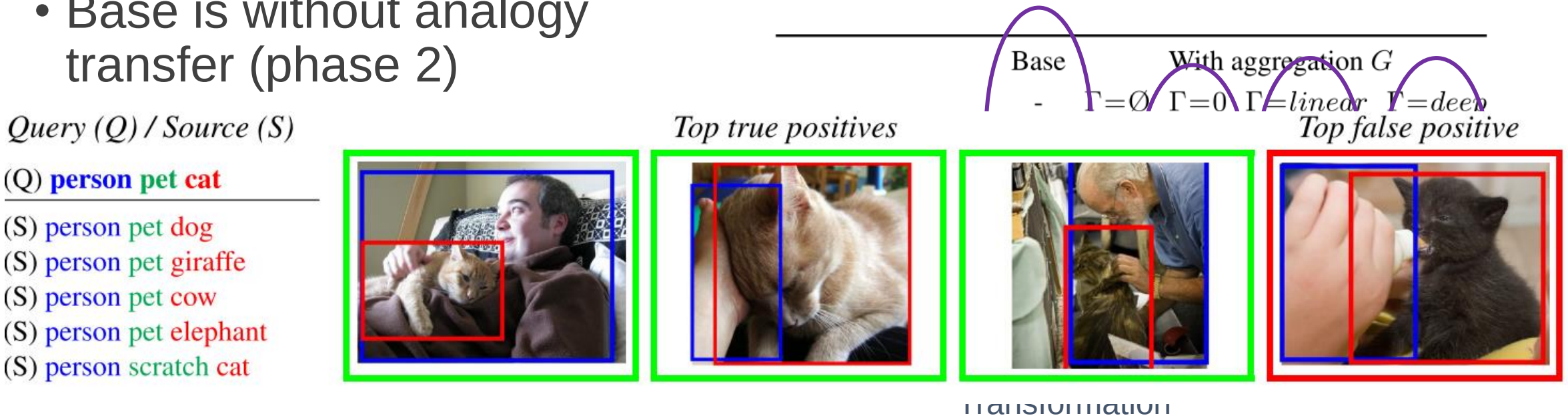
	full	rare	non-rare
Chao [6]	7.8	5.4	8.5
Gupta [13]	9.1	7.0	9.7
Gkioxari [12]	9.9	7.2	10.8
GPNN [34]	13.1	9.3	14.2
iCAN [10]	14.8	10.5	16.1
s+o+p	18.7	13.8	20.1
s+o+vp	17.7	11.6	19.5
s+o+p+vp	**19.4**	**14.6**	**20.9**

Table 1: Retrieval results on HICO-DET dataset (mAP).

Peyre, J., Sivic, J., Laptev, I., & Schmid, C. (2020). Detecting Unseen Visual Relations Using Analogies. ICCV, 2020.

Transfer by Analogy Unseen Triplets

- 25 zero- shot triplets of HICO-DET
- Base is without analogy transfer (phase 2)



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Transfer by Analogy Unseen, Unusual Triplets

- UnRel dataset
- Used $\Gamma = deep$

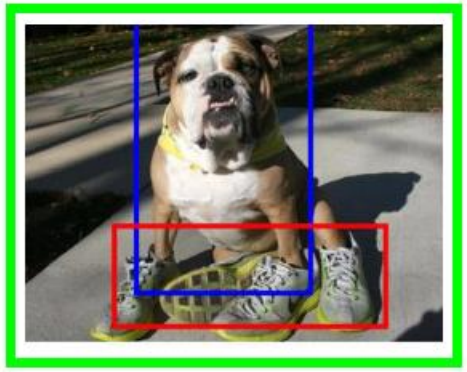
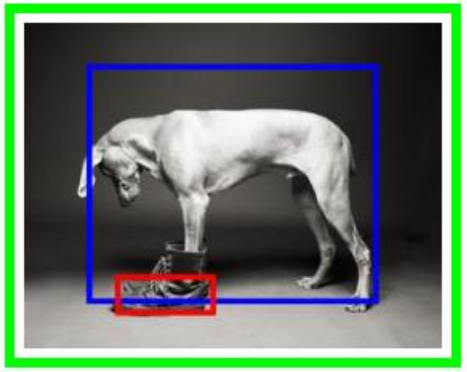
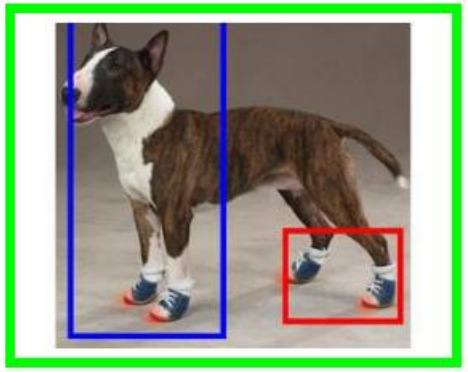
	With GT	With candidates		
	-	union	subj	subj/obj

Query (Q) / Source (S)

(Q) **dog wear shoes**

(S) person wear shoes
(S) person wear shoe
(S) person wear skis
(S) person wear pants
(S) person wear jeans

Top true positives

Top false positive



Table 3: Retrieval on UnRel (mAP) with IoU=0.3.

Peyre, J., Sivic, J., Laptev, I., & Schmid, C. (2020). Detecting Unseen Visual Relations Using Analogies. ICCV, 2020.

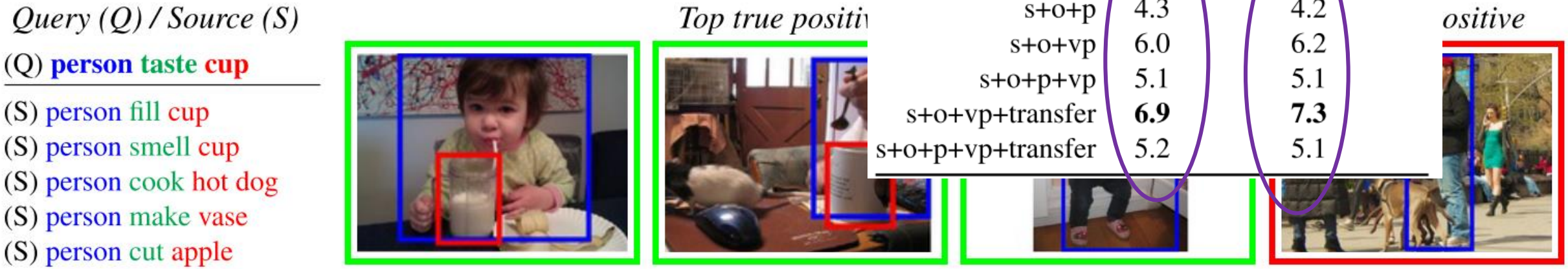
Transfer by Analogy Unseen (out-of-vocabulary) Triplets

- Trained on HICO-DET, evaluated on Coco-a Daaset

All Unseen

Unseen Out-of-vocabulary only

	all	out of vocabulary
s+o+p	4.3	4.2
s+o+vp	6.0	6.2
s+o+p+vp	5.1	5.1
s+o+vp+transfer	**6.9**	**7.3**
s+o+p+vp+transfer	5.2	5.1



Peyre, J., Sivic, J., Laptev, I., & Schmid, C. (2020). Detecting Unseen Visual Relations Using Analogies. ICCV, 2020.

Conclusion

Conclusion

- Authors propose combined method to detect visual relations:
  - Compositional representations
  - Visual phrase representations
- Method involves:
  - Visual and text embeddings
  - Triplet Loss
  - Transfer learning via transformation function

- Their method outperforms existing models in:
  - Seen triplets
  - Unseen triplets
  - Out-of-Vocabulary unseen triplets

Peyre, J., Sivic, J., Laptev, I., & Schmid, C. (2020). Detecting Unseen Visual Relations Using Analogies. ICCV, 2020.

Thank you