Recognizing Lexical Inference

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Bar-Ilan University
Tradition of Excellence

Lexical Inference

- A directional semantic relation from one term (x) to another (y)

- Encapsulates various relations, for example:
  - Synonymy: $(elevator, lift)$
  - Is a / hypernymy: $(apple, fruit)$, $(Barack\ Obama, president)$
  - Hyponymy: $(fruit, apple)$
  - Meronymy: $(London, England)$, $(chest, body)$
  - Holonymy: $(England, London)$, $(body, chest)$
  - Causality: $(flu, fever)$

- Each relation is used to infer y from x ($x \rightarrow y$) in certain contexts:
  - I ate an $apple$ $\rightarrow$ I ate a $fruit$
  - I hate $fruit$ $\rightarrow$ I hate $apples$
  - I visited $London$ $\rightarrow$ I visited $England$
  - I left $London$ $\nrightarrow$ I left $England$ (What if I left to Manchester?)

Motivation

- Question answering:

  Question: “When was *Friends* first aired?”
  Text: “*Friends* was first broadcast in 1994”
  Knowledge: $broadcast \rightarrow air$
  Answer: 1994

Outline

- Learning to Exploit Structured Resources for Lexical Inference
- Improving Hypernymy Detection with an Integrated Path-based and Distributional Methods

Learning to Exploit Structured Resources for Lexical Inference

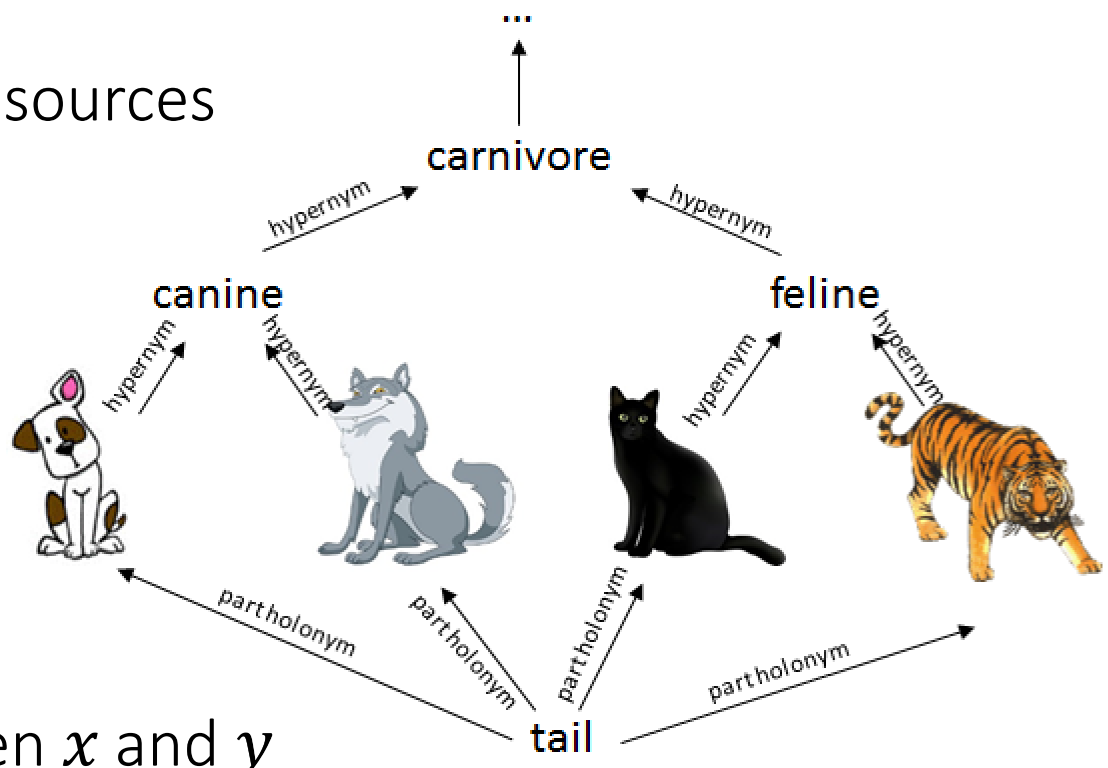
Vered Shwartz, Omer Levy, Ido Dagan and Jacob Goldberger

CoNLL 2015

Resource-based methods for lexical inference

- Based on knowledge from hand-crafted resources
  - Dictionaries
  - Taxonomies (e.g. WordNet)

- Resources specify the lexical-semantic relation between terms



- The decision is based on the paths between x and y
- Need to predefine which relations are relevant for the task

Resource-based methods for lexical inference

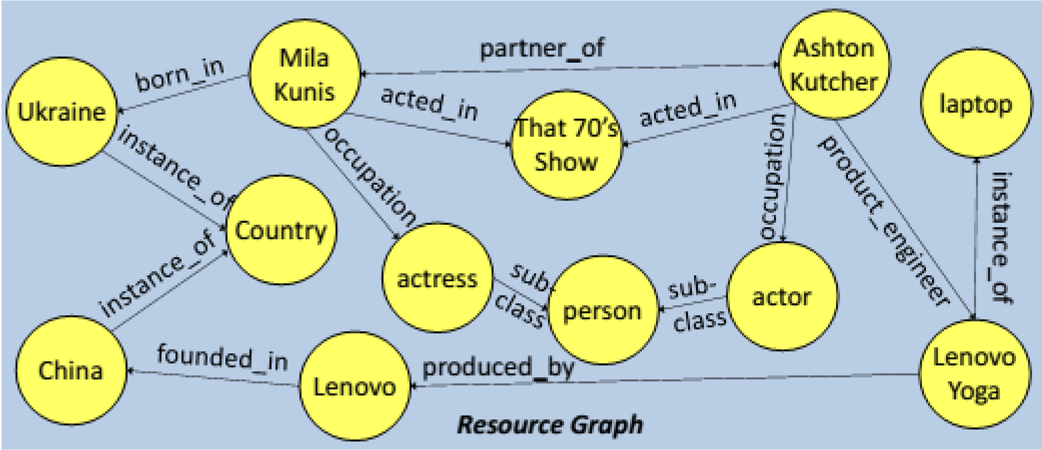
- High precision
- Limited recall:
  - WordNet is small
  - Not up-to-date

    Recent terminology is missing: Social Network
  - Contains mostly common nouns

    For example, it can’t tell us that *Lady Gaga* is a *singer*

Community-built Resources

- Huge
- Frequently updated
- Contain proper-names



WIKIDATA

6,000,000 entities in English
1,200 different properties

DBpedia

4,500,000 entities
1,367 different properties

yago select knowledge

10,000,000 entities in English
70 different properties

Utilizing Community-built Resources

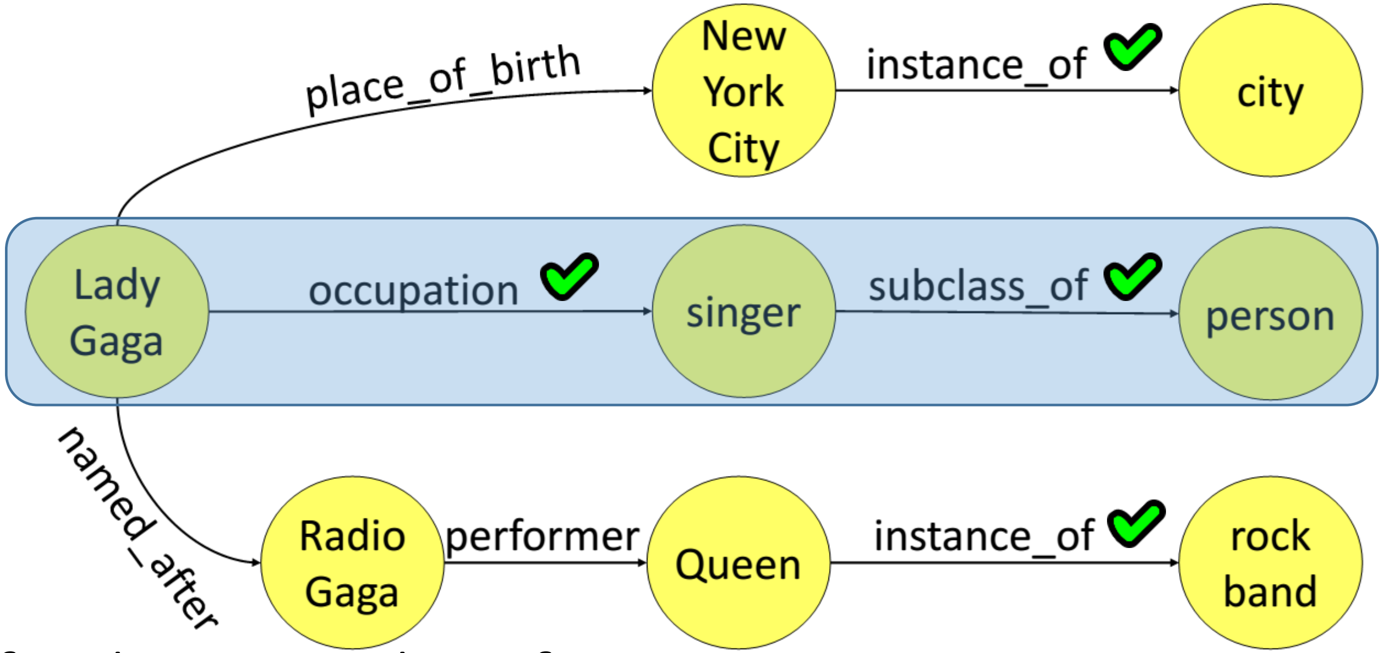
- Idea: extend WordNet-based method using these resources

- Problem: utilizing these resources manually is infeasible
    - thousands of relations to select from!

- Solution: learn to exploit these resources

Our Method

- Goal: learn which properties are indicative of given lexical inference relation (e.g. "is a")
- Approach: supervised learning

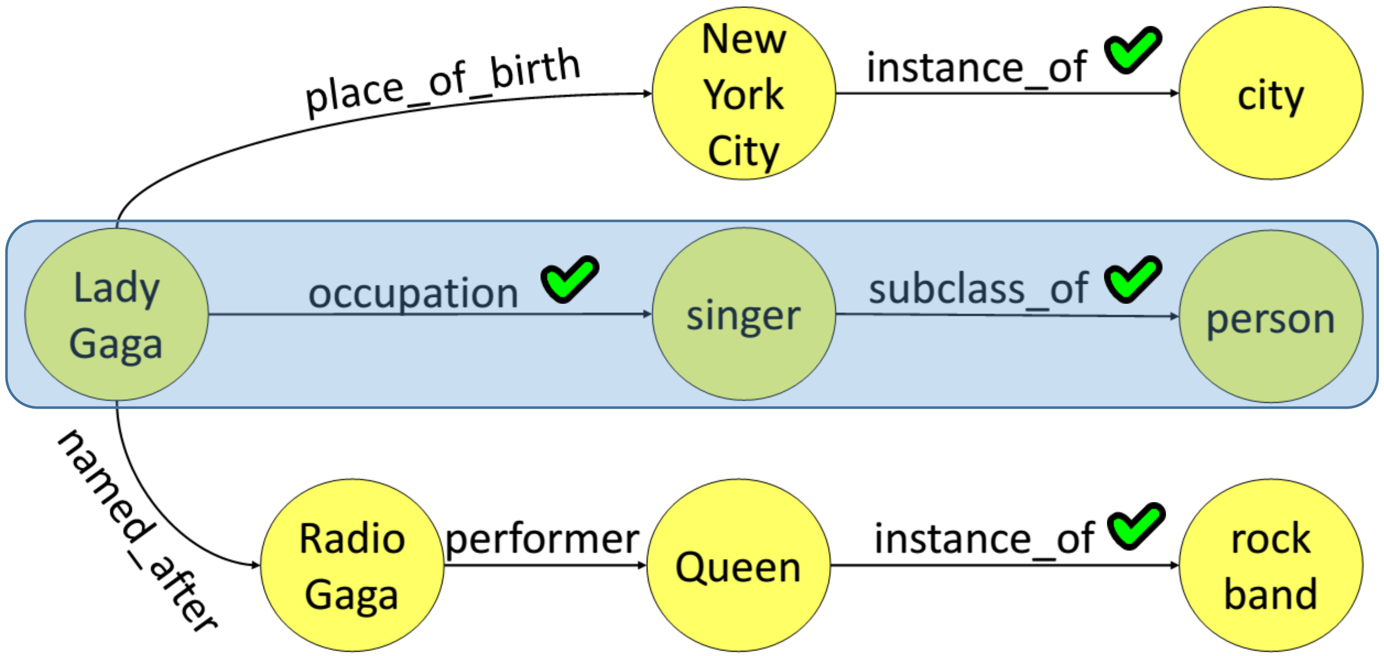


- $x \rightarrow y$ if there is a path of indicative edges from x to y

Results

- We replicate WordNet-based methods for common nouns
- We extract high-precision inferences including proper-names:

$Lady\ Gaga \rightarrow person$ ✔



Results

- Non-trivial resource relations are learned:

occupation	$Daniel\ Radcliffe \rightarrow actor$
gender	$Louisa\ May\ Alcott \rightarrow woman$
position in sports team	$Jason\ Collins \rightarrow center$

- We complement corpus-based methods in high-precision scenarios

Improving Hypernymy Detection with an Integrated Path-based and Distributional Method

Vered Shwartz, Yoav Goldberg, and Ido Dagan

Submitted to ACL 2016

Hypernymy Detection

- We focus on detecting hypernymy relations, which are common in inference:
  - $(apple, fruit)$
  - $(Barack\ Obama, president)$

Corpus-based methods for hypernymy detection

- Consider the statistics of term occurrences in a large corpus
- Roughly divided to two sub-approaches:
  - Distributional approach
  - Path-based approach

Distributional approach

- Distributional Hypothesis (Harris, 1954):
  Words that occur in similar contexts tend to have similar meanings
  - e.g. $elevator$ and $lift$ will both appear next to $\boldsymbol{down}$, $\boldsymbol{up}$, $\boldsymbol{building}$, $\boldsymbol{floor}$, and $\boldsymbol{stairs}$

- Measuring word similarity:
  - Represent words as distributional vectors

0	0	…	12	0	…	43	0	…	0
			↑ down			↑ up			

  - Measure the distance between the vectors (e.g. cosine similarity)

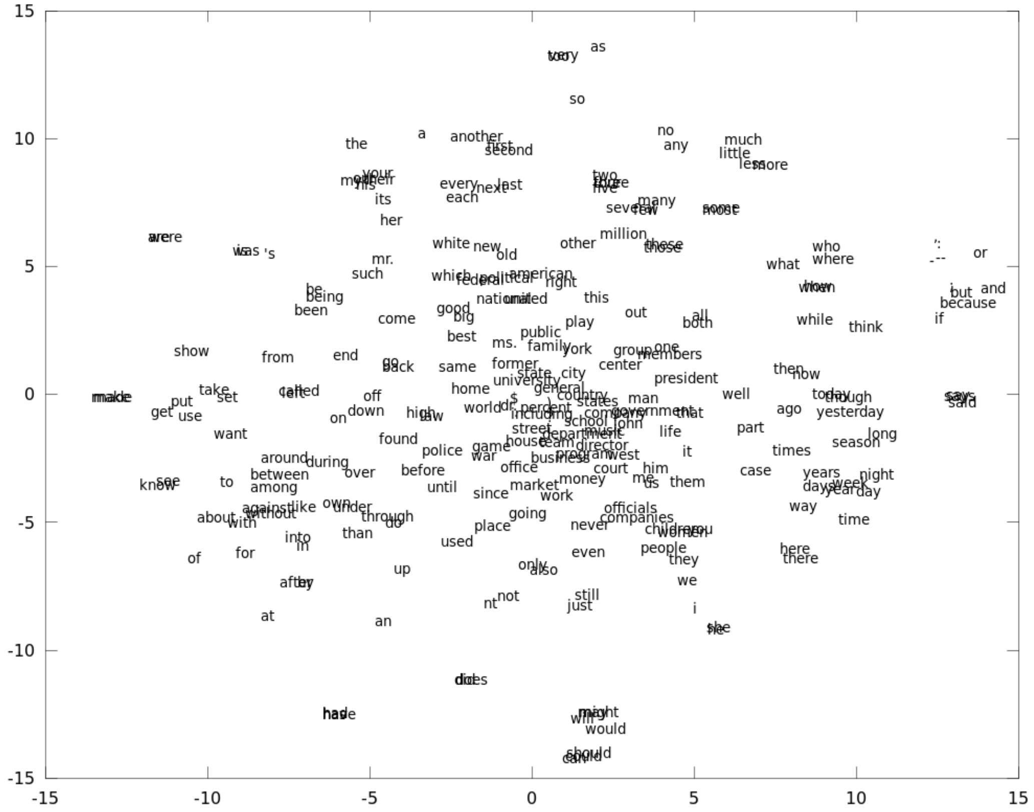
Unsupervised Distributional Methods

- But…
  - Word similarity != lexical inference
  - Antonyms are similar e.g. small, big
  - Mutually exclusive terms are also similar e.g. football, basketball

- Directional similarity
  - Inclusion: If $x \rightarrow y$, then the contexts of x are expected to be possible contexts for y (Weeds and Weir, 2003; Kotlerman et. al, 2010)
  - Generality: the most typical linguistic contexts of a hypernym are less informative than those of its hyponyms (Santus et al., 2014; Rimell, 2014).

Supervised Distributional Methods

- Word Embeddings
  - Distributional vectors are high-dimensional and sparse
  - Word embeddings are dense and low-dimensional - more efficient
  - Similar words are still close to each other in the vector space
  - Bengio et al. (2003), word2vec (Mikolov et al., 2013), GloVe (Pennington et al., 2014)



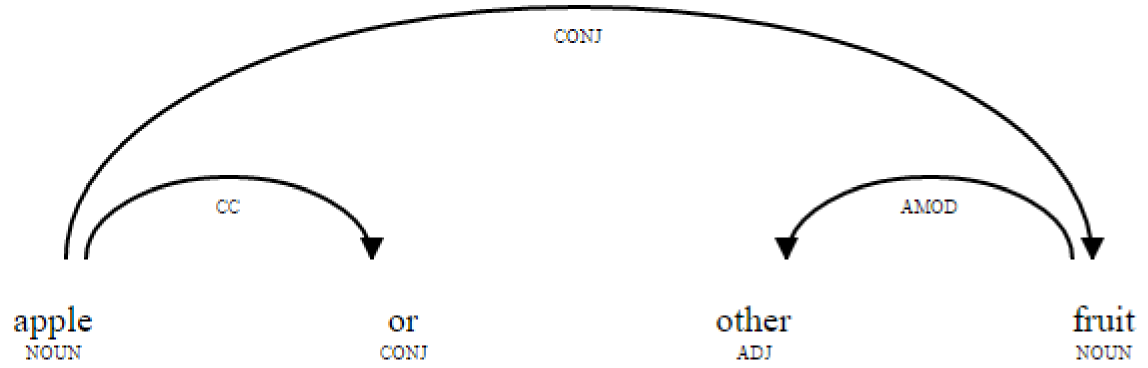
Supervised Distributional Methods

- Represent (x, y) as a combination of each term embeddings vector:
  - Concatenation $\vec{x} \oplus \vec{y}$ (Baroni et al., 2012)
  - Difference $\vec{y} - \vec{x}$ (Roller et al., 2014; Fu et al.,2014; Weeds et al., 2014)
  - Similarity $\vec{x} \cdot \vec{y}$

- Train a classifier over these vectors to predict entailment / hypernymy
- Achieved high performance
- However, these methods don’t learn anything about the relation between x and y – they only learn characteristics of each term (Levy et al., 2015).

Path-based approach

- **lexico-syntactic paths** = dependency paths or textual patterns, with POS tags and lemma
- Some patterns indicate semantic relations between terms:
  - e.g. X or other Y indicates that X is of type Y
- If x and y hold a certain semantic relation, they are expected to occur in the corpus as the arguments of such patterns
  - e.g. apple or other fruit



Hearst Patterns

- Hearst (1992) - automatic acquisition of hypernyms

- Found a few indicative patterns based on occurrences of known hypernyms in the corpus:

Y such as X

such Y as X

X or other Y

X and other Y

Y including X

Y, especially X

Snow et al. (2004)

- Supervised method to recognize hypernymy
  - Predict whether y is a hypernym of x
  - Supervision: set of known hyponym/hypernym pairs
  - Features: all dependency paths between x and y in a corpus

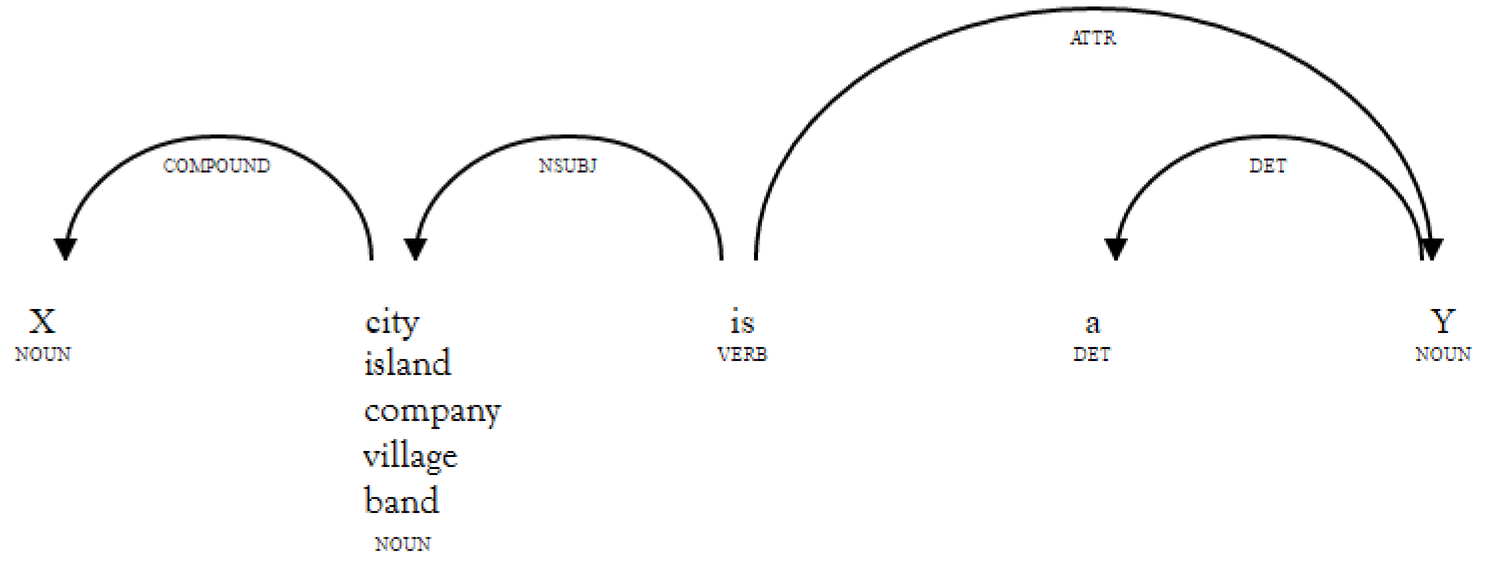
0	0	…	12	0	…	43	0	…	0

“x and other y” *“such y as x”*

- Successfully restores Hearst patterns (and adds many more)
- Used for analogy identification, taxonomy creation, etc.

Problem with lexico-syntactic paths

- The feature space is too sparse:

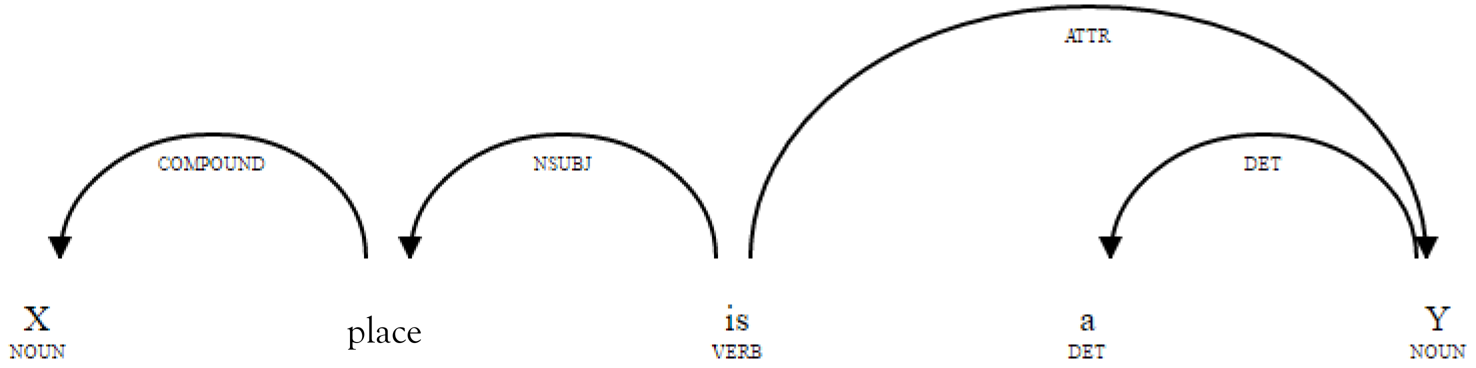


- Some words along the path don’t change the meaning

PATTY

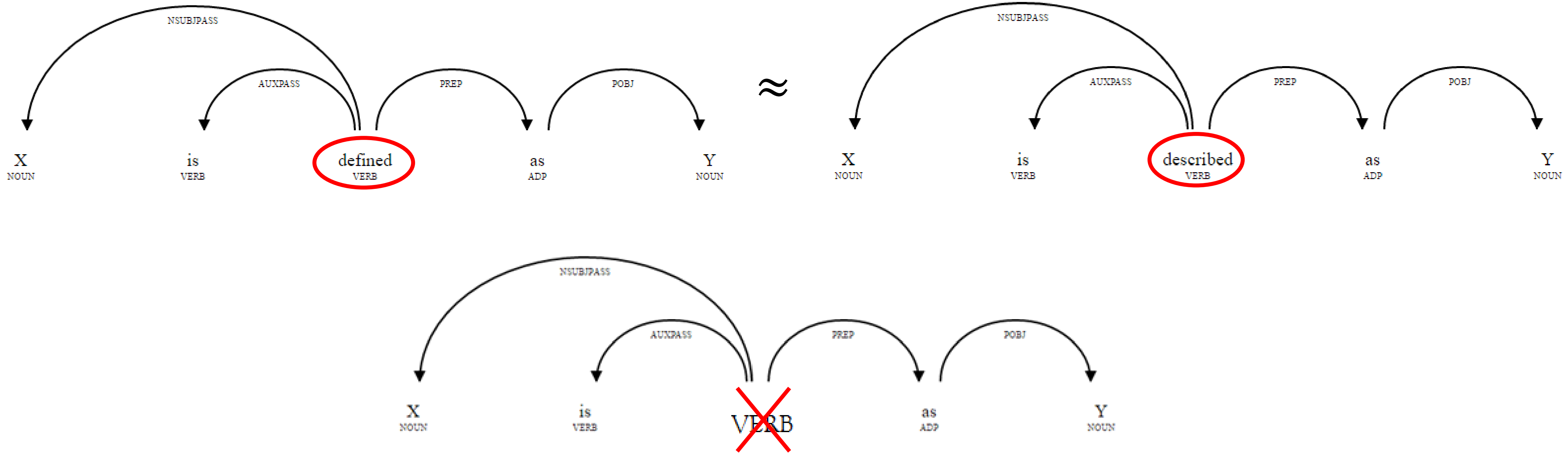
- A taxonomy created from free text (Nakashole et al., 2012)
- The relation between terms is based on the dependency paths between them

- Paths are generalized – a word might be replaced by:
  - its POS tag
  - a wild card
  - its ontological type

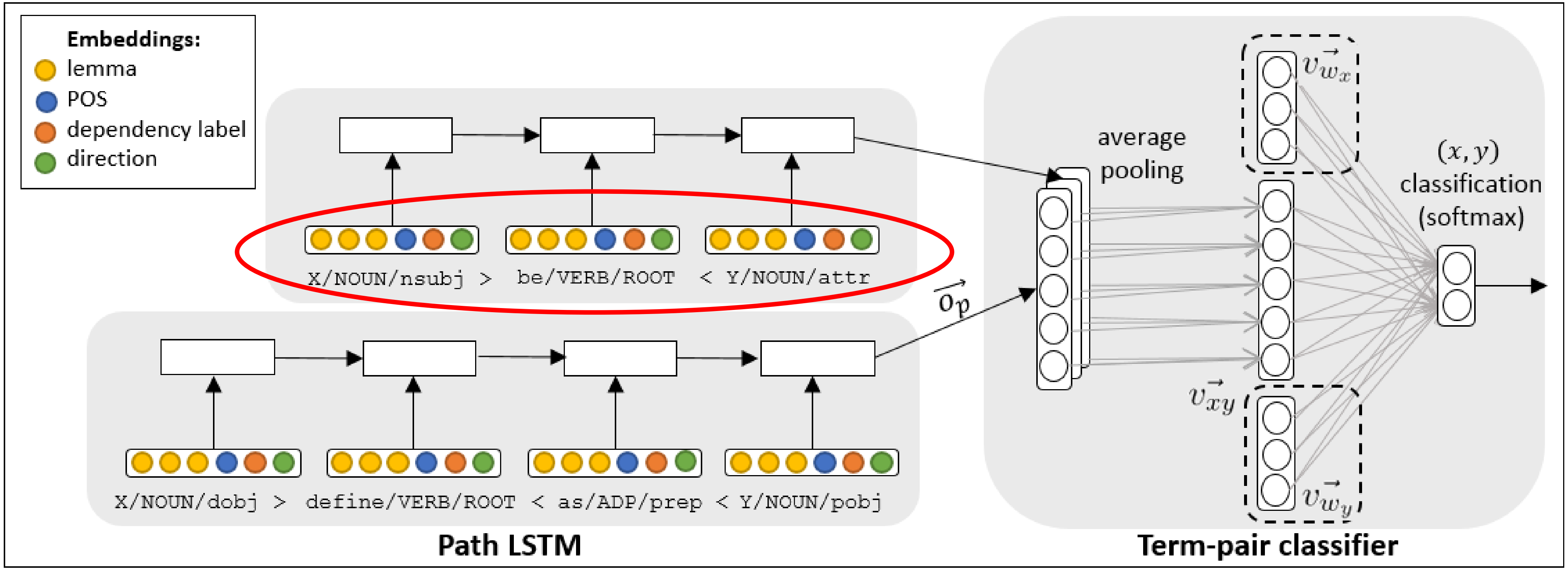


LSTM-based path representation

- Idea: learn “smarter” generalizations

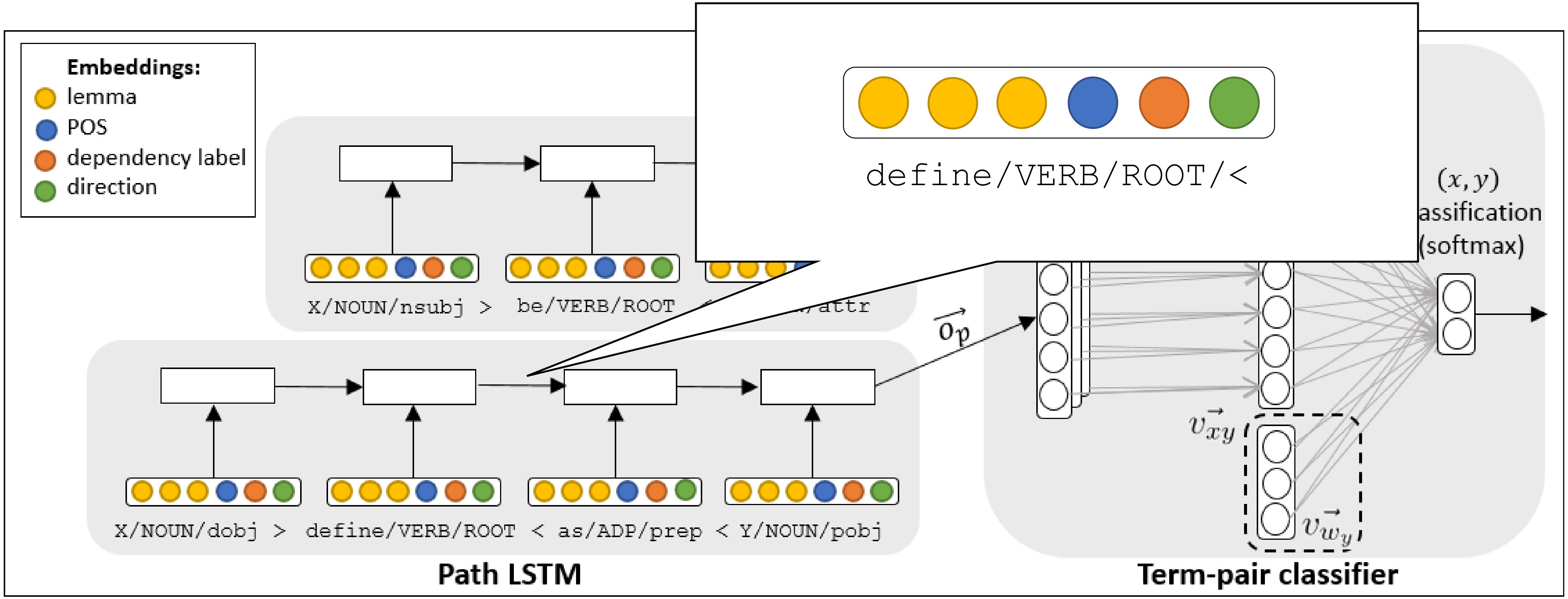


LSTM-based hypernymy detection



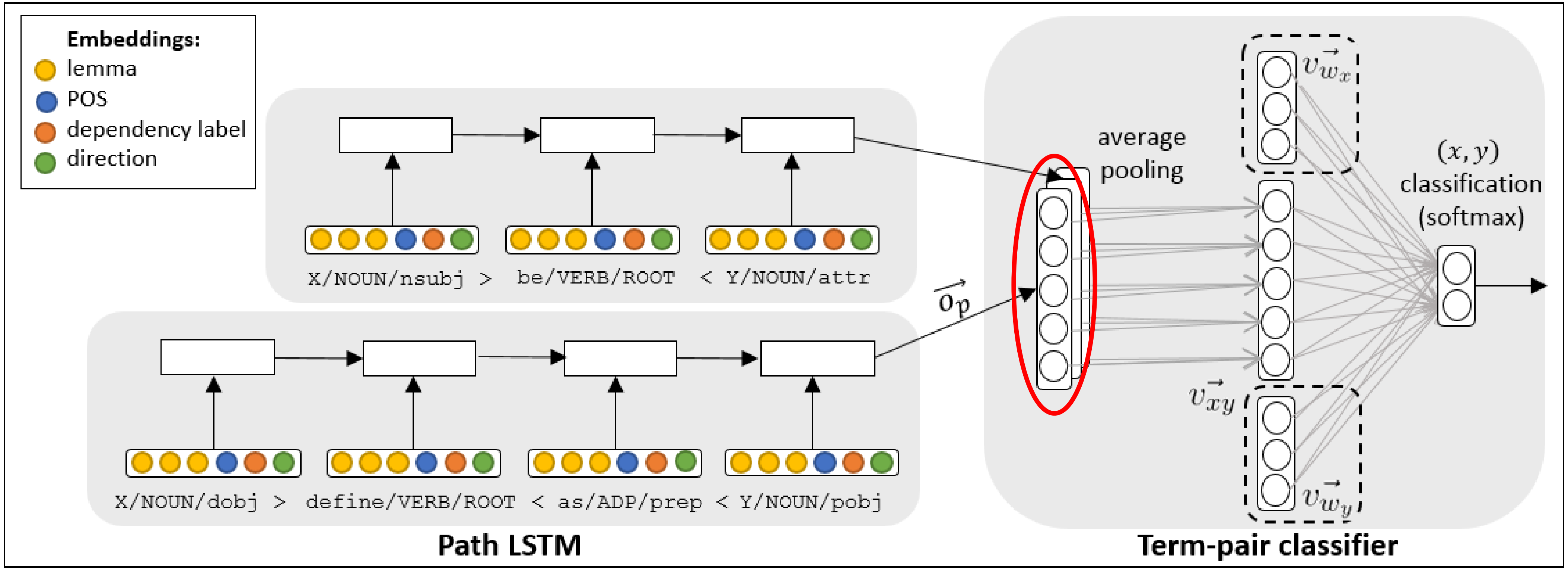
- Process each path edge-by-edge, using an LSTM

LSTM-based hypernymy detection



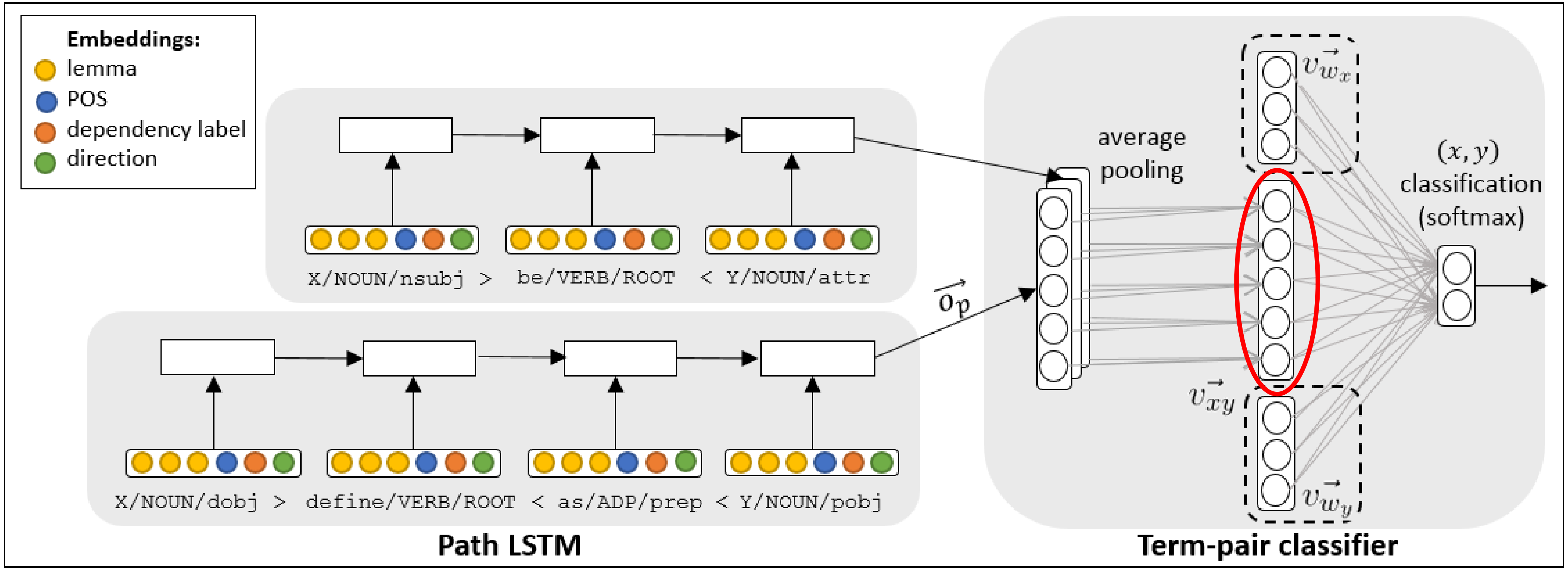
- Represent each edge as a concatenation of:
  - Lemma vector
  - Part-of-speech vector
  - Dependency label vector
  - Direction vector

LSTM-based hypernymy detection



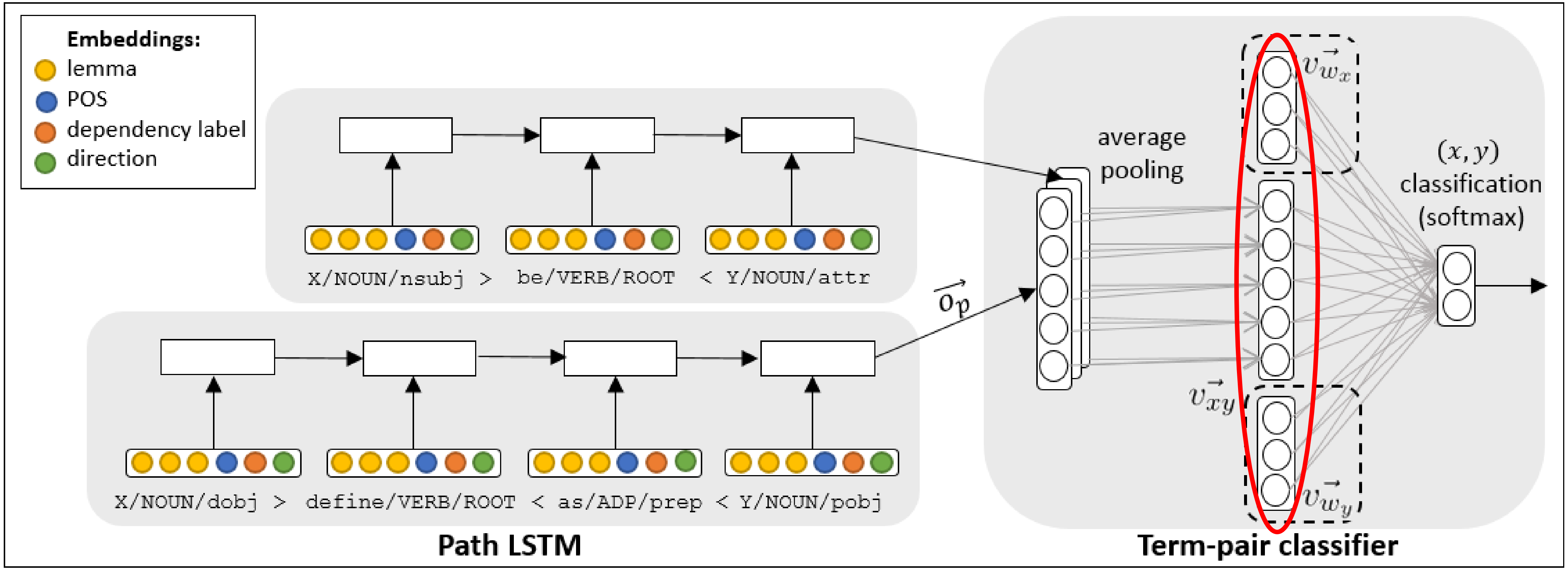
- Use the LSTM output as the path vector
- Each term-pair has multiple paths

LSTM-based hypernymy detection



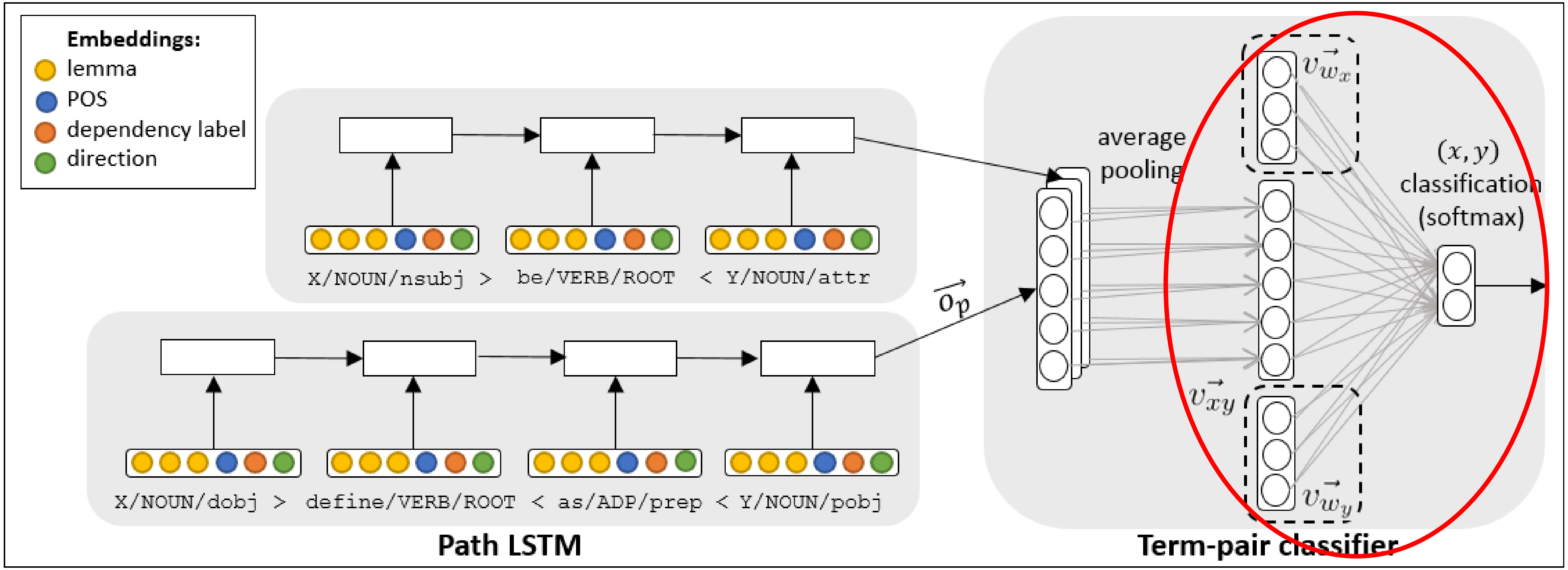
- Use the LSTM output as the path vector
- Each term-pair has multiple paths
  - Compute the averaged path embedding

LSTM-based hypernymy detection



- Each pair (x, y) is represented using the concatenation of:
  - x's embedding vector
  - the averaged path vector
  - y's embedding vector

LSTM-based hypernymy detection



- This vector is used as the input of a network that predicts whether y is a hypernym of x

Results

		random split			lexical split		
method		precision	recall	F_1	precision	recall	F_1
Path-based	Snow	0.843	0.452	0.589	0.760	0.438	0.556
	Snow + Gen	0.852	0.561	0.676	0.759	0.530	0.624
	LSTM (this paper)	0.811	0.716	0.761	0.691	**0.632**	0.660
Distributional	SLQS (Santus et al., 2014)	0.246	0.213	0.228	0.270	0.222	0.243
	Best supervised (concatenation)	0.901	0.637	0.746	0.754	0.551	0.637
Combined	LSTM-Integrated (this paper)	**0.913**	**0.890**	**0.901**	**0.809**	0.617	**0.700**

- Path-based:
  - Our method outperforms the baselines
  - The generalizations yield improved recall
- The combined method outperforms both path-based and distributional methods

Analysis – Path Representation

- Snow’s method finds certain common paths:
  X company is a Y
  X ltd is a Y
- PATTY-style generalizations find very general, possibly noisy paths:
  X NOUN is a Y
- Our method makes fine-grained generalizations:
  X (association|co.|company|corporation| foundation|group|inc.|international|limited|ltd.) is a Y

Thanks!

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