

Jointly Predicting **Predicates** and **Arguments** in Neural Semantic Role Labeling

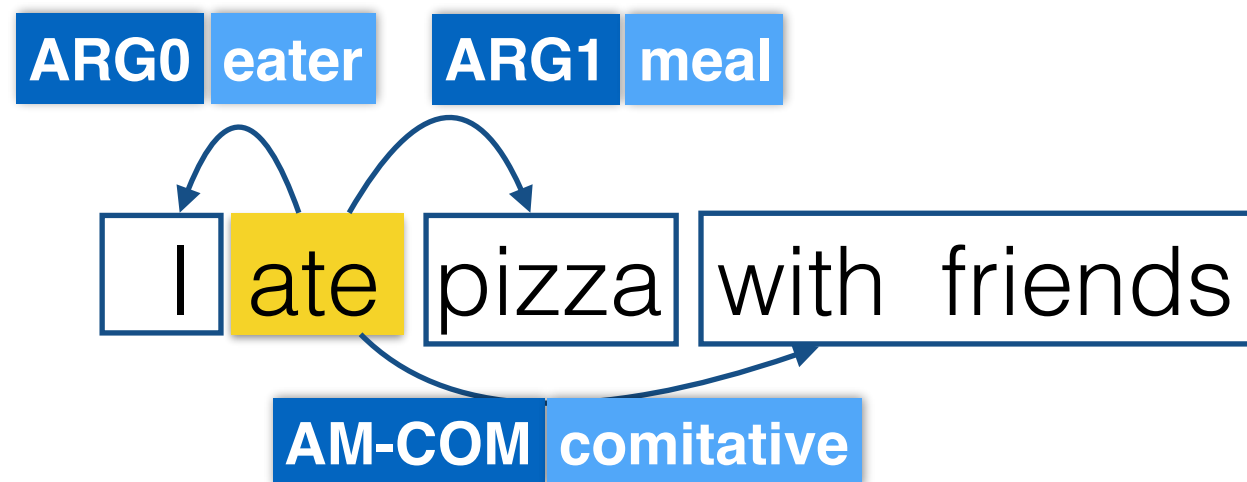
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University of Washington

*Now at Google

+Now at Facebook AI Research

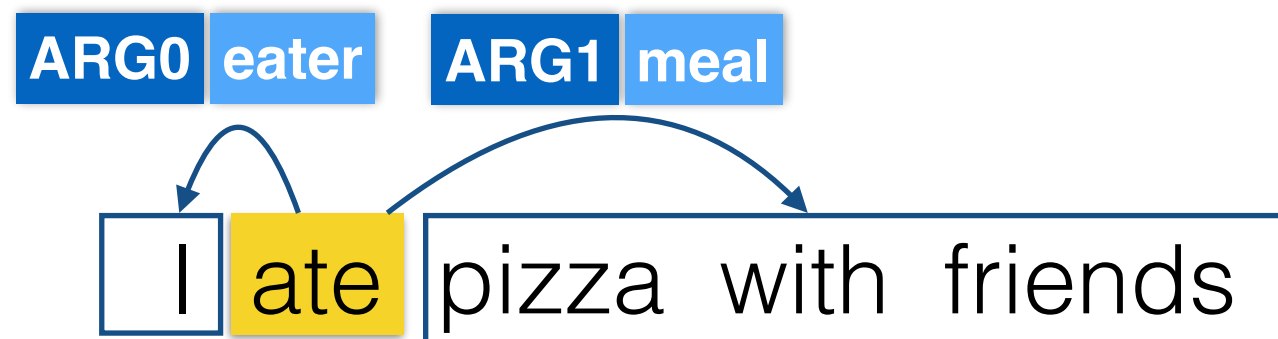
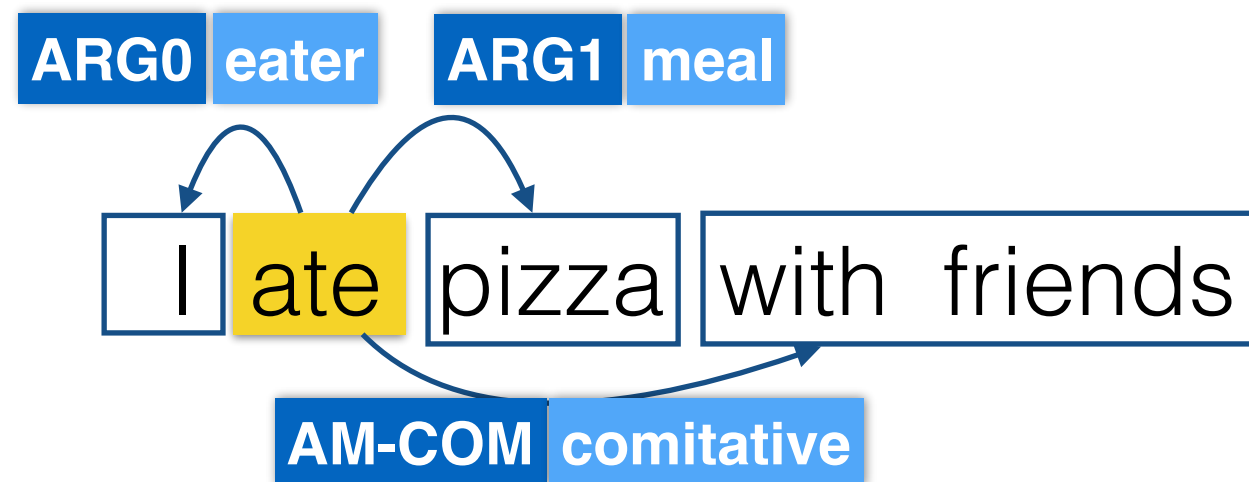
Semantic Role Labeling (SRL)

- Find out “**who did what to whom**” in text
- Capture **predicate-argument** structures

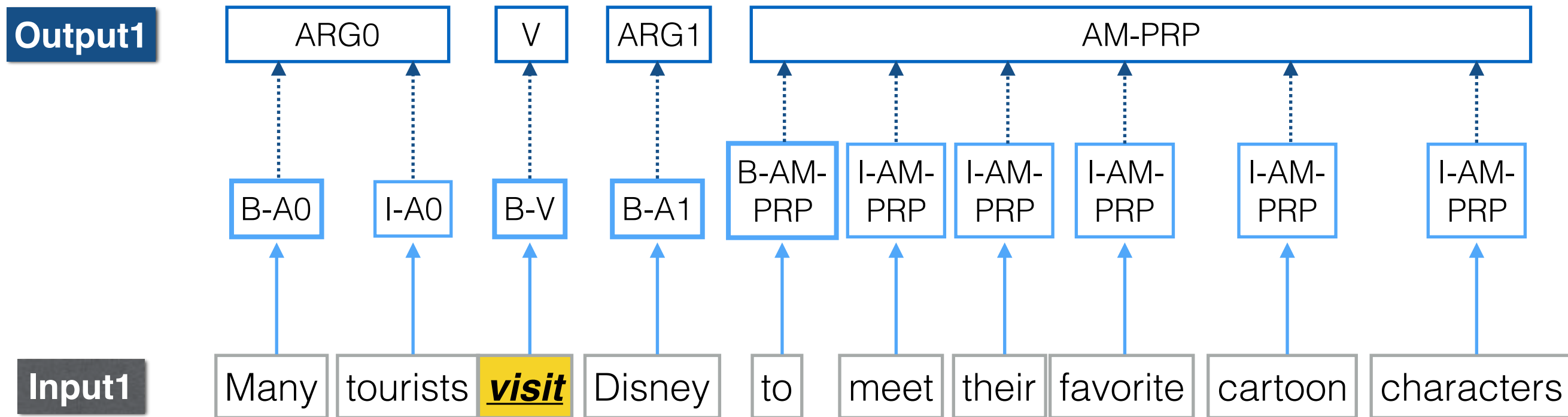


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- Capture **predicate-argument** structures



SRL as BIO Tagging

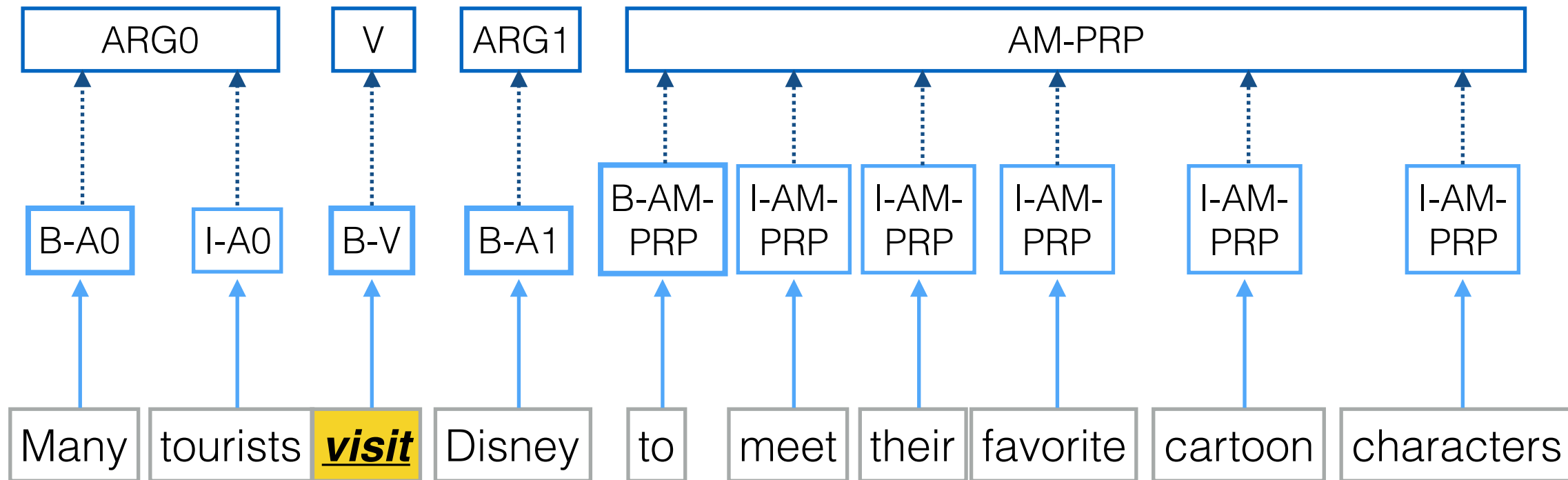


Needs target predicate as input!
(Prior works typically used gold predicates)

Collobert et al., 2011,
Zhou and Xu, 2015,
He et. al, 2017,
inter alia

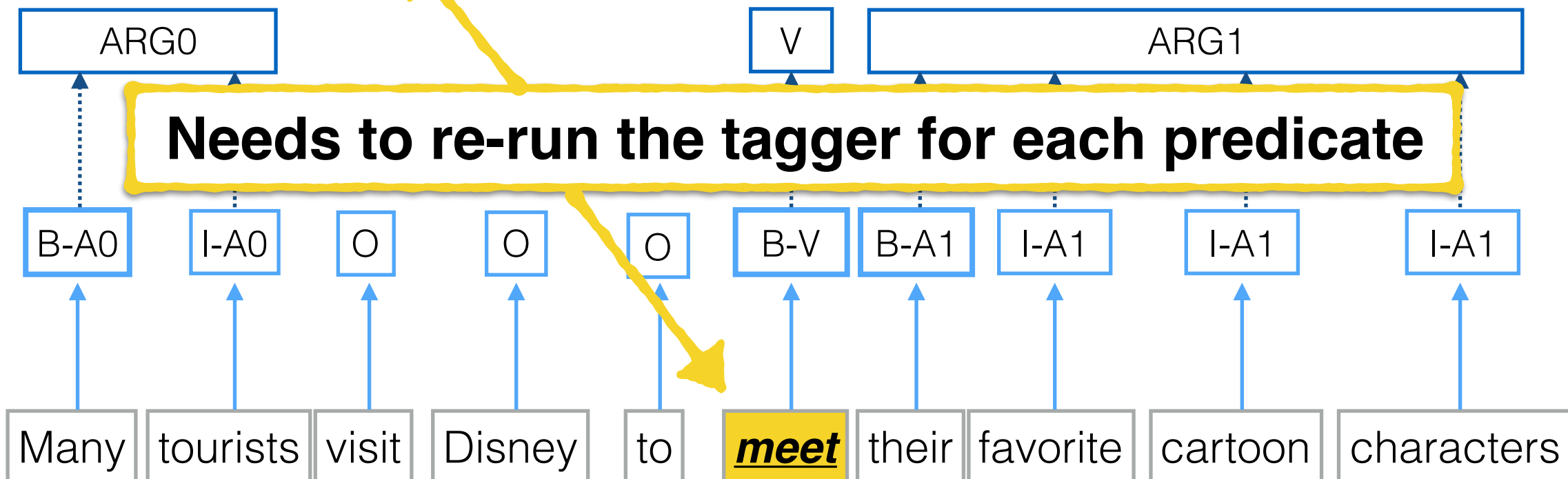
SRL as BIO Tagging

Output1



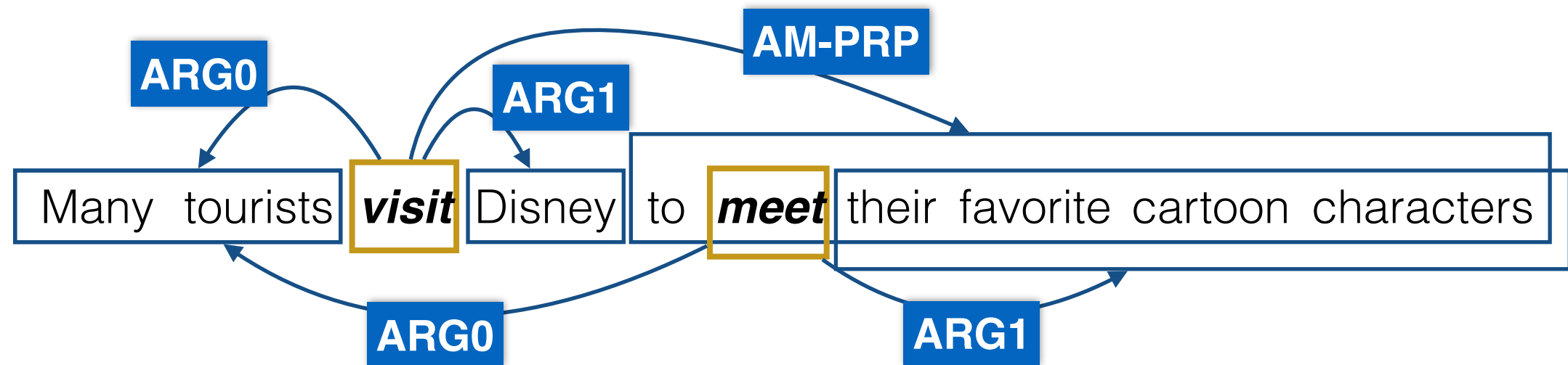
Input1

Output2

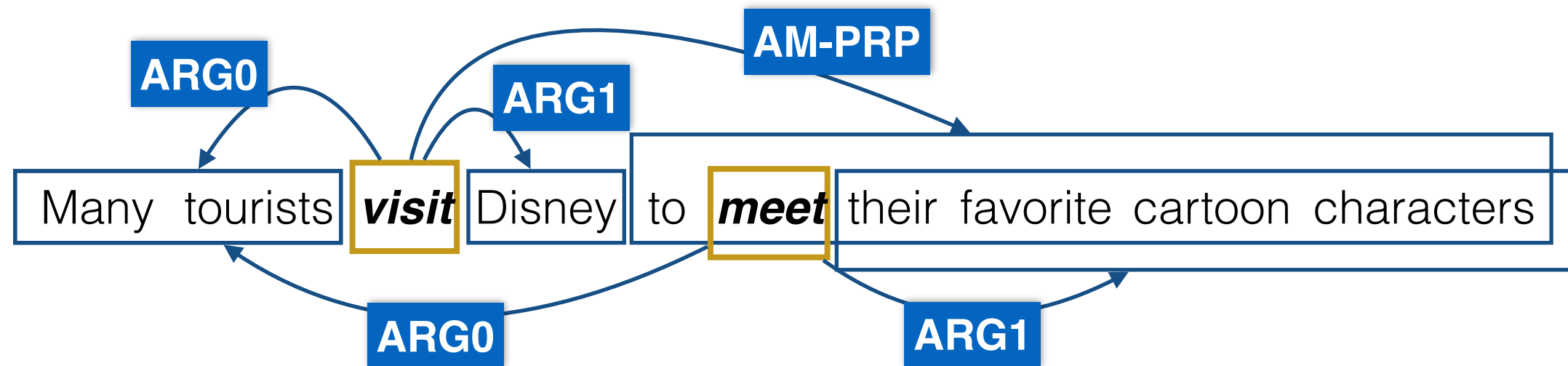


Input2

SRL as Predicting Word-Span Relations



SRL as Predicting Word-Span Relations



Advantages:

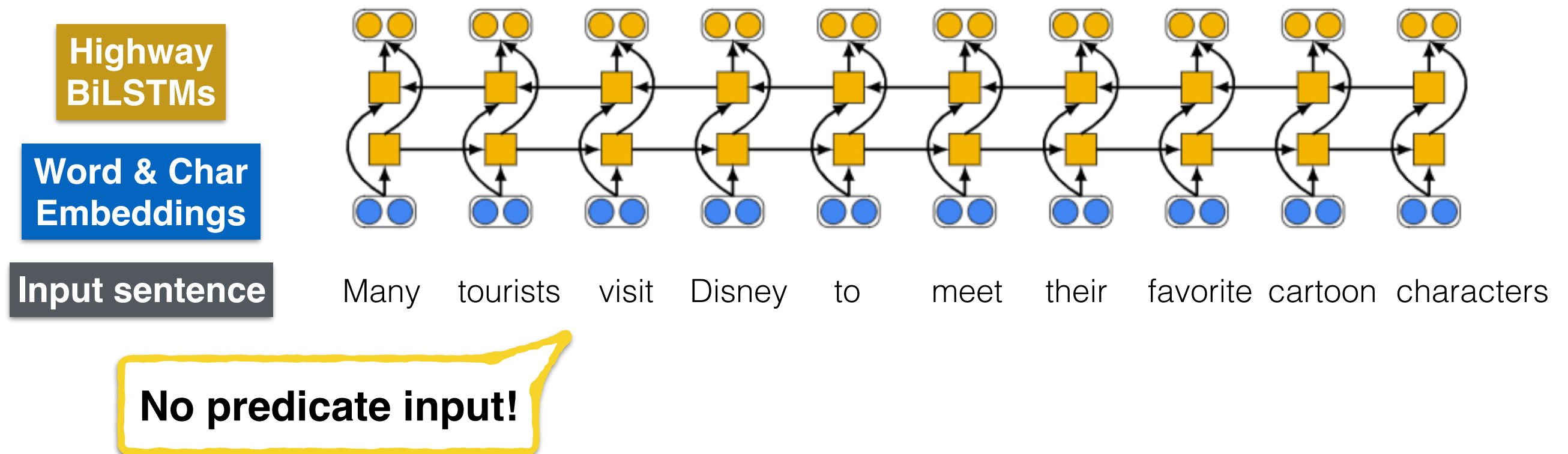
- * Jointly predict predicates
- * Span-level features
(similar to Punyakanok08, FitzGerald15, inter alia)

Challenge:

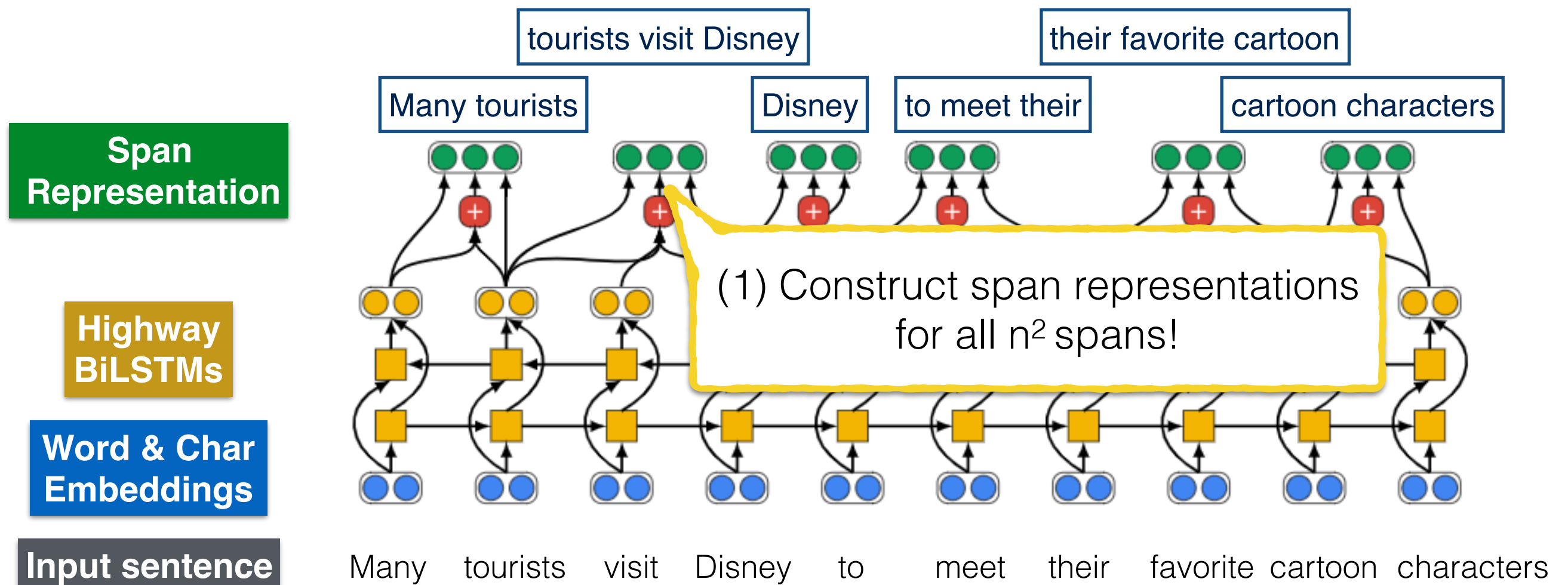
- * Too many possible edges (n^2 argument spans $\times$ n predicates)

Our Model

Our Model: Overview



Our Model: Overview



Our Model: Overview

Labeling
Softmax

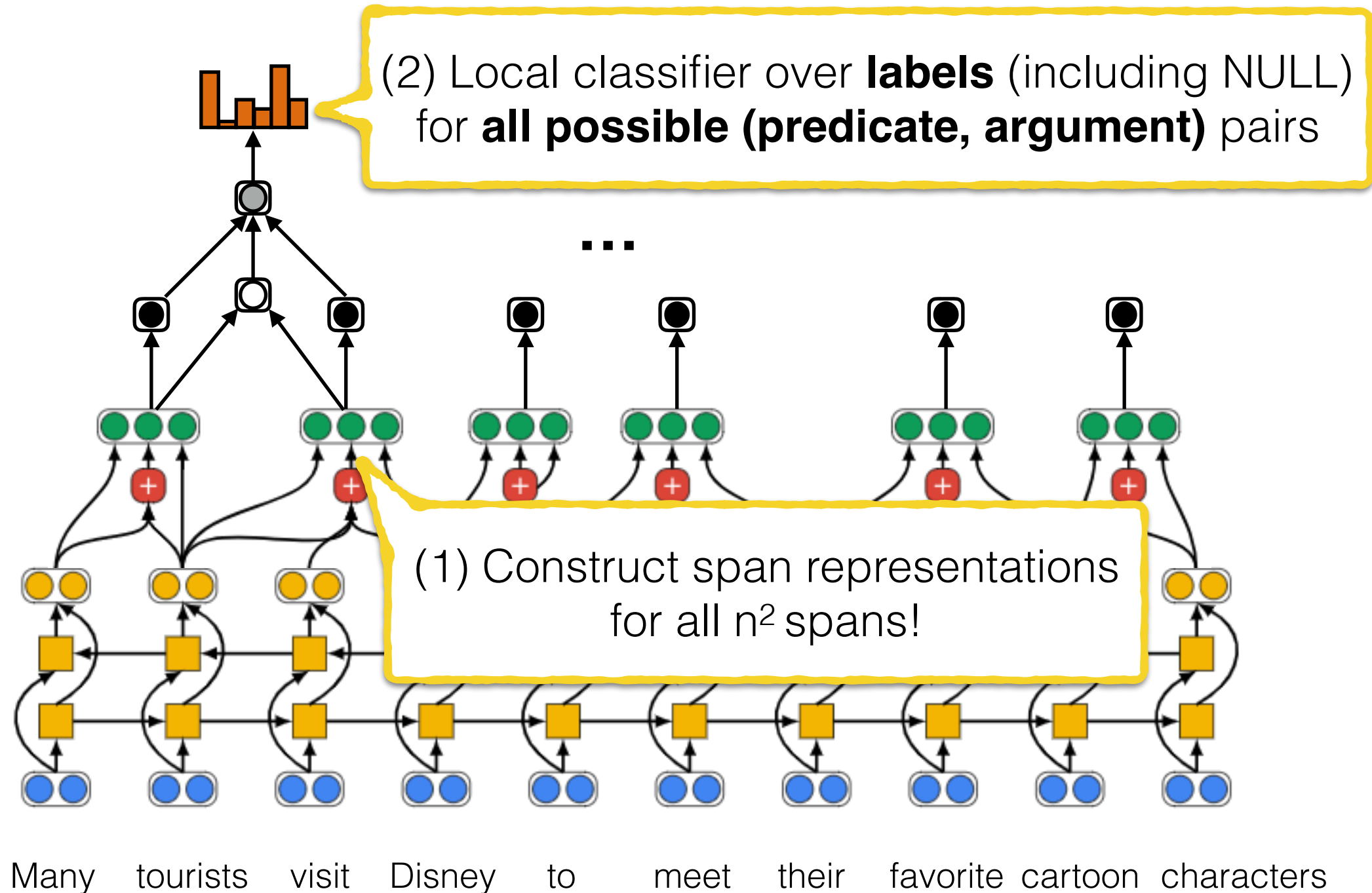
Node & Edge
Scores

Span
Representation

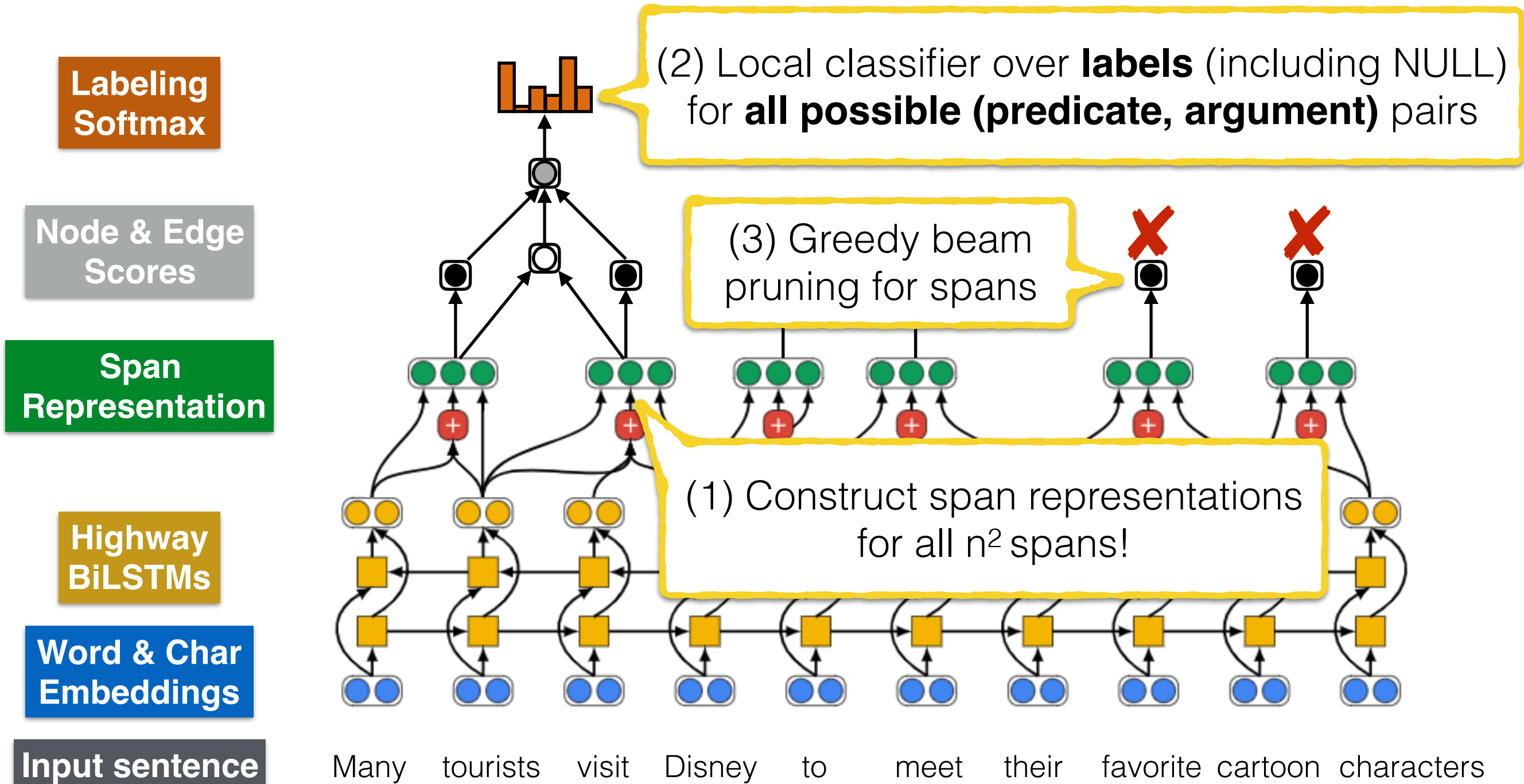
Highway
BiLSTMs

Word & Char
Embeddings

Input sentence



Our Model: Overview



(1) Span Representations

(2) Local Label
Classifiers

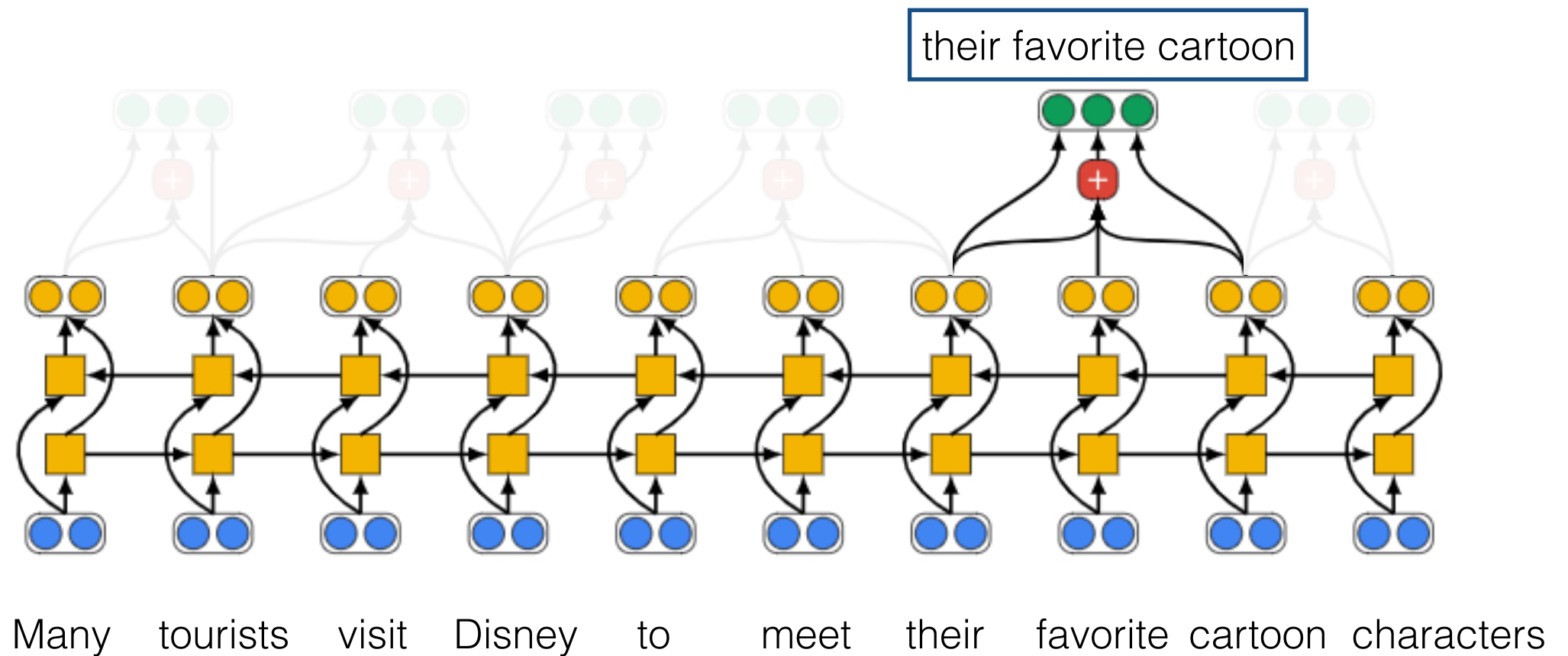
(3) Span
Pruning

Span
Representation

Highway
BiLSTMs

Word & Char
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Input sentence



(Same as Lee et al., 2017)

(1) Span Representations

(2) Local Label
Classifiers

(3) Span
Pruning

LSTM boundary points

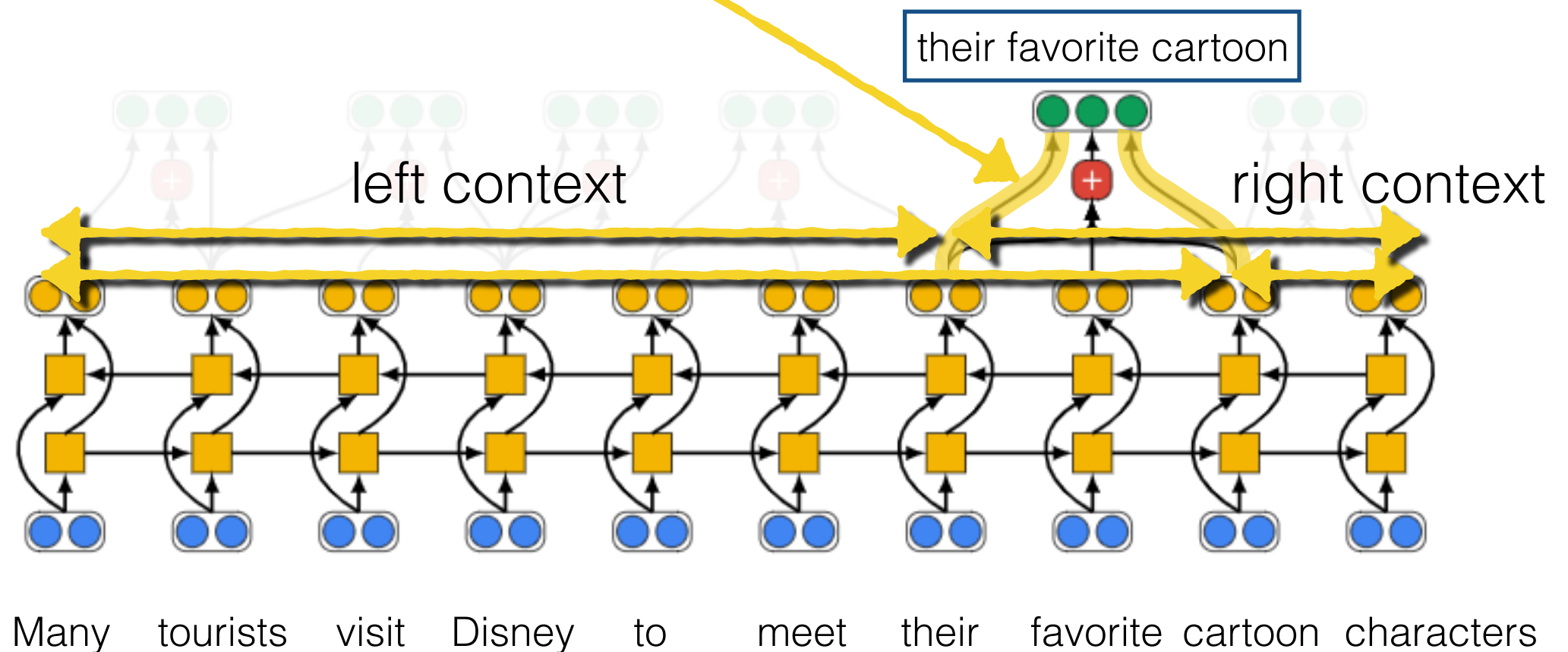
$$[\text{BiLSTM}(w_1 : w_n)_{\text{START}}, \text{BiLSTM}(w_1 : w_n)_{\text{END}}]$$

**Span
Representation**

**Highway
BiLSTMs**

**Word & Char
Embeddings**

Input sentence



(Same as Lee et al., 2017)

(1) Span Representations

(2) Local Label
Classifiers

(3) Span
Pruning

LSTM boundary points

Attention over words

$$[\text{BiLSTM}(w_1 : w_n)_{\text{START}}, \text{BiLSTM}(w_1 : w_n)_{\text{END}}]$$

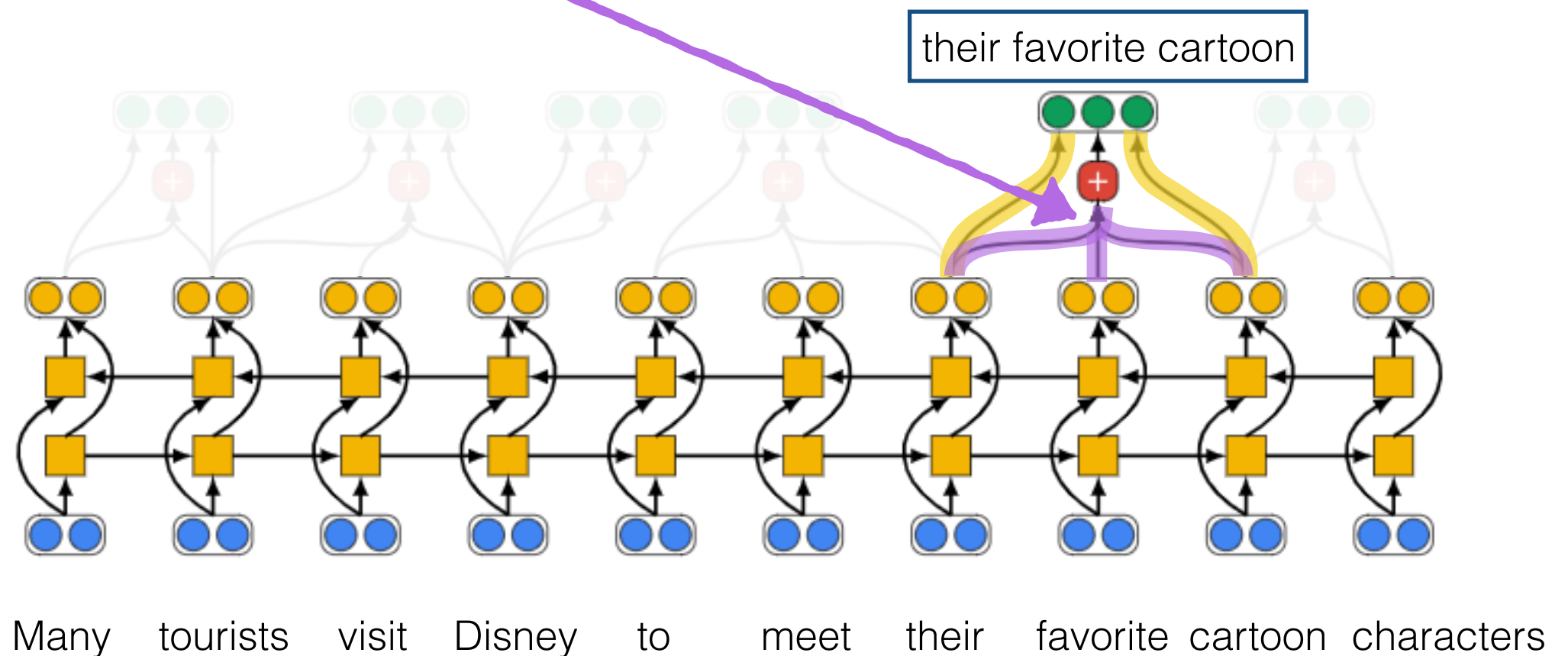
$$\sum_{i=\text{START}}^{\text{END}} \text{SOFTMAX}(a_{\text{START}} : a_{\text{END}})_i w_i$$

Span
Representation

Highway
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Input sentence



(Same as Lee et al., 2017)

(1) Span
Representations

(2) Local Label Classifiers

(3) Span
Pruning

Labeling
Softmax

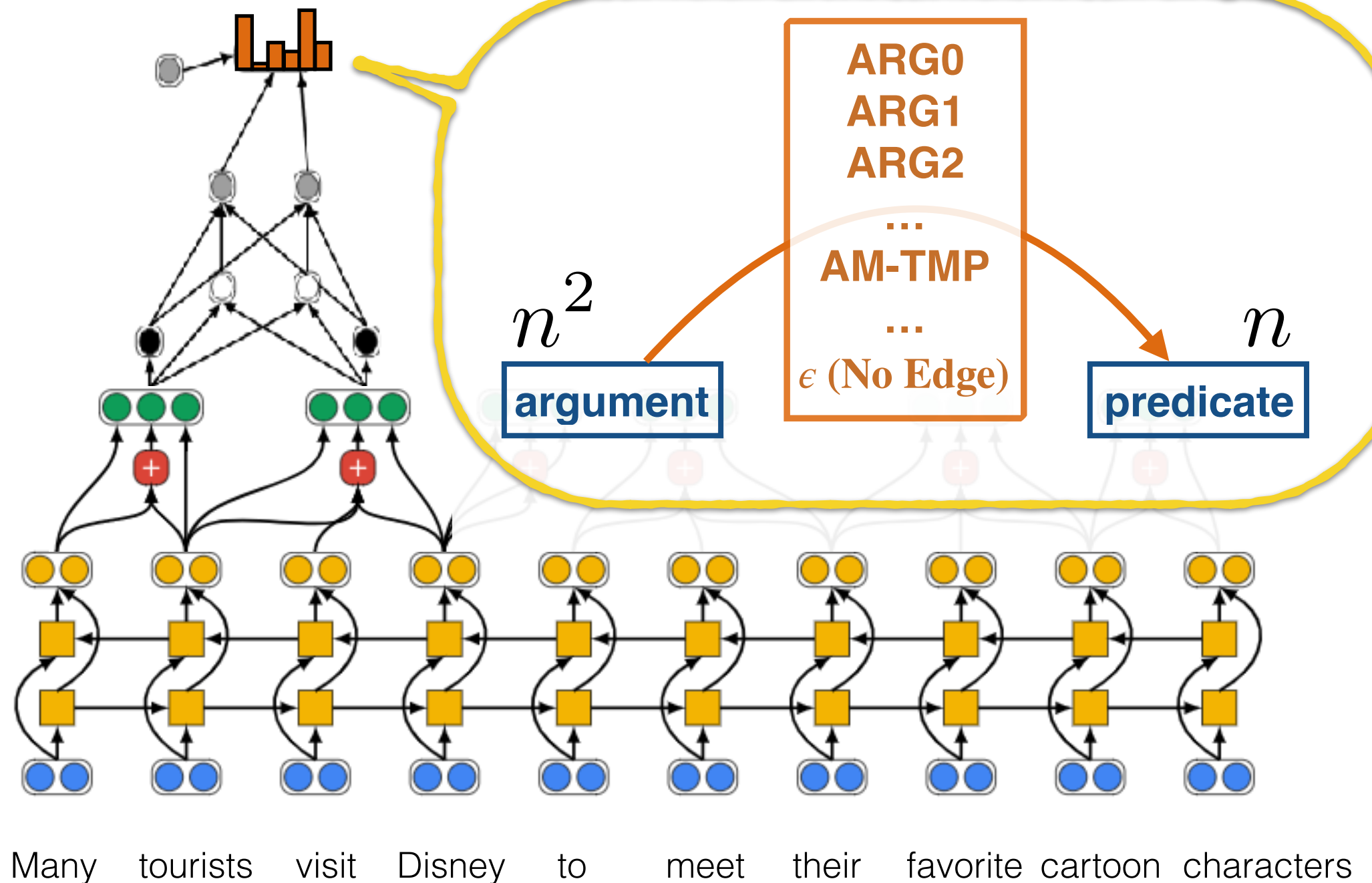
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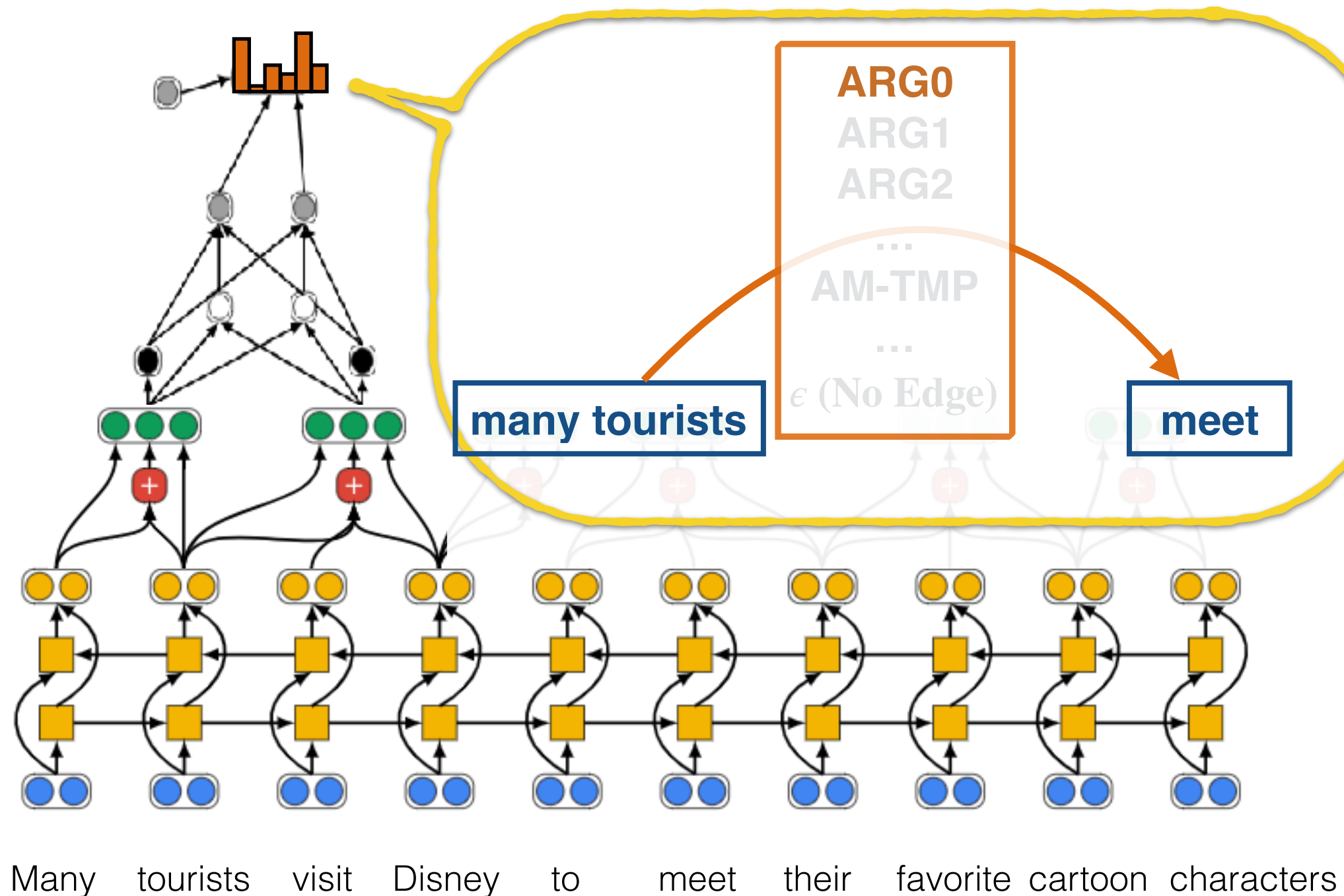
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Input sentence



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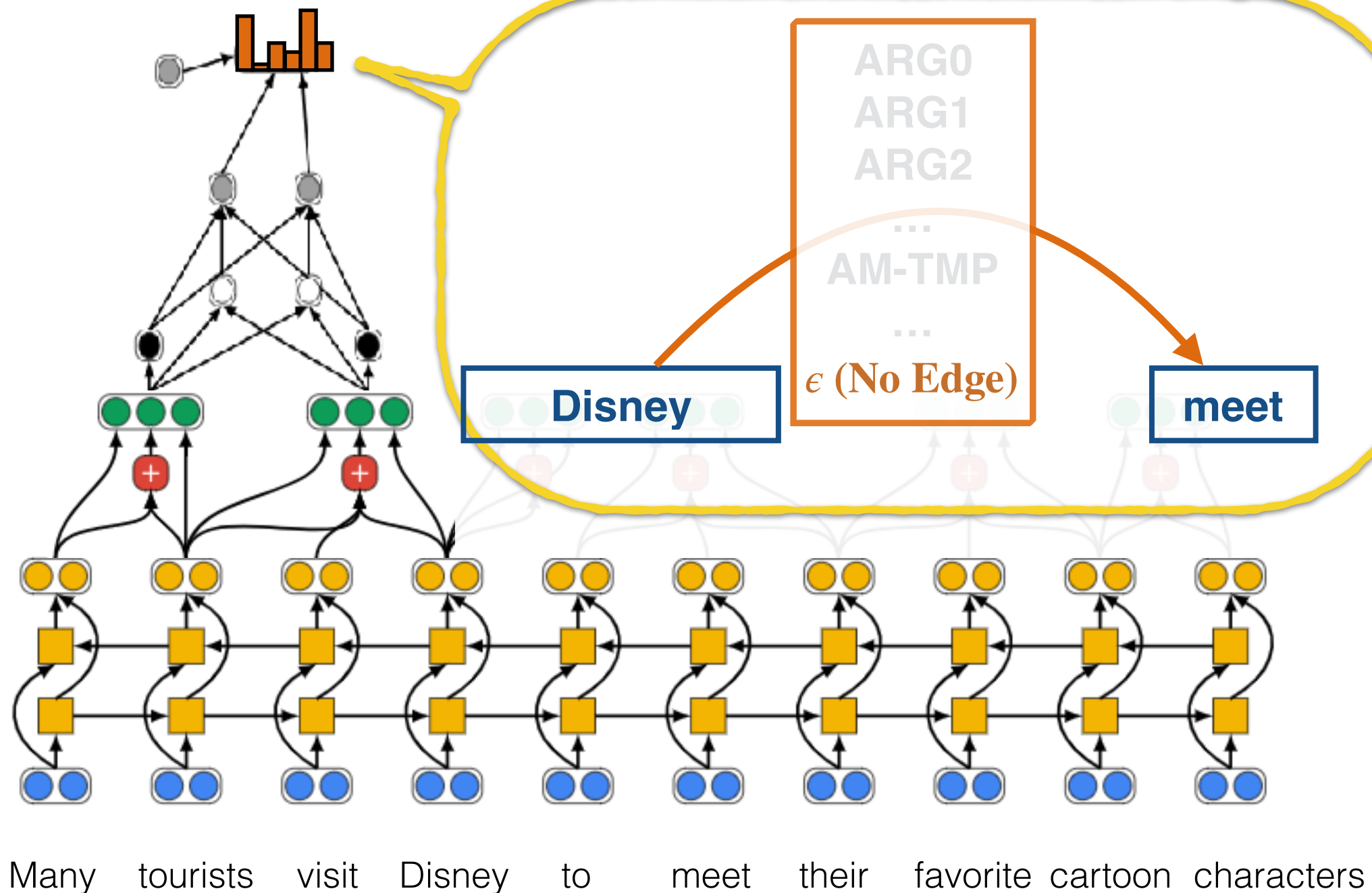
Node & Edge
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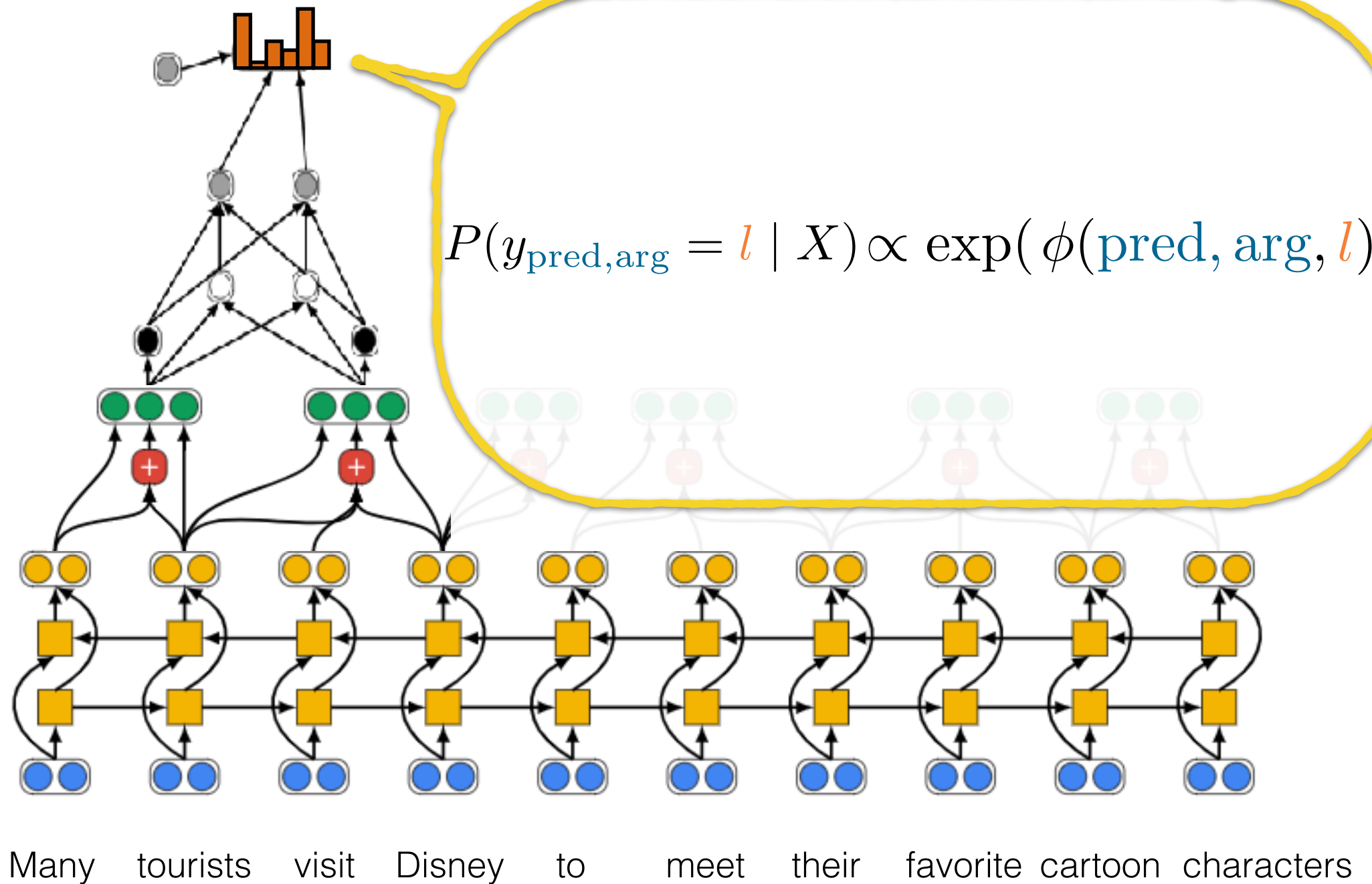
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(1) Span
Representations

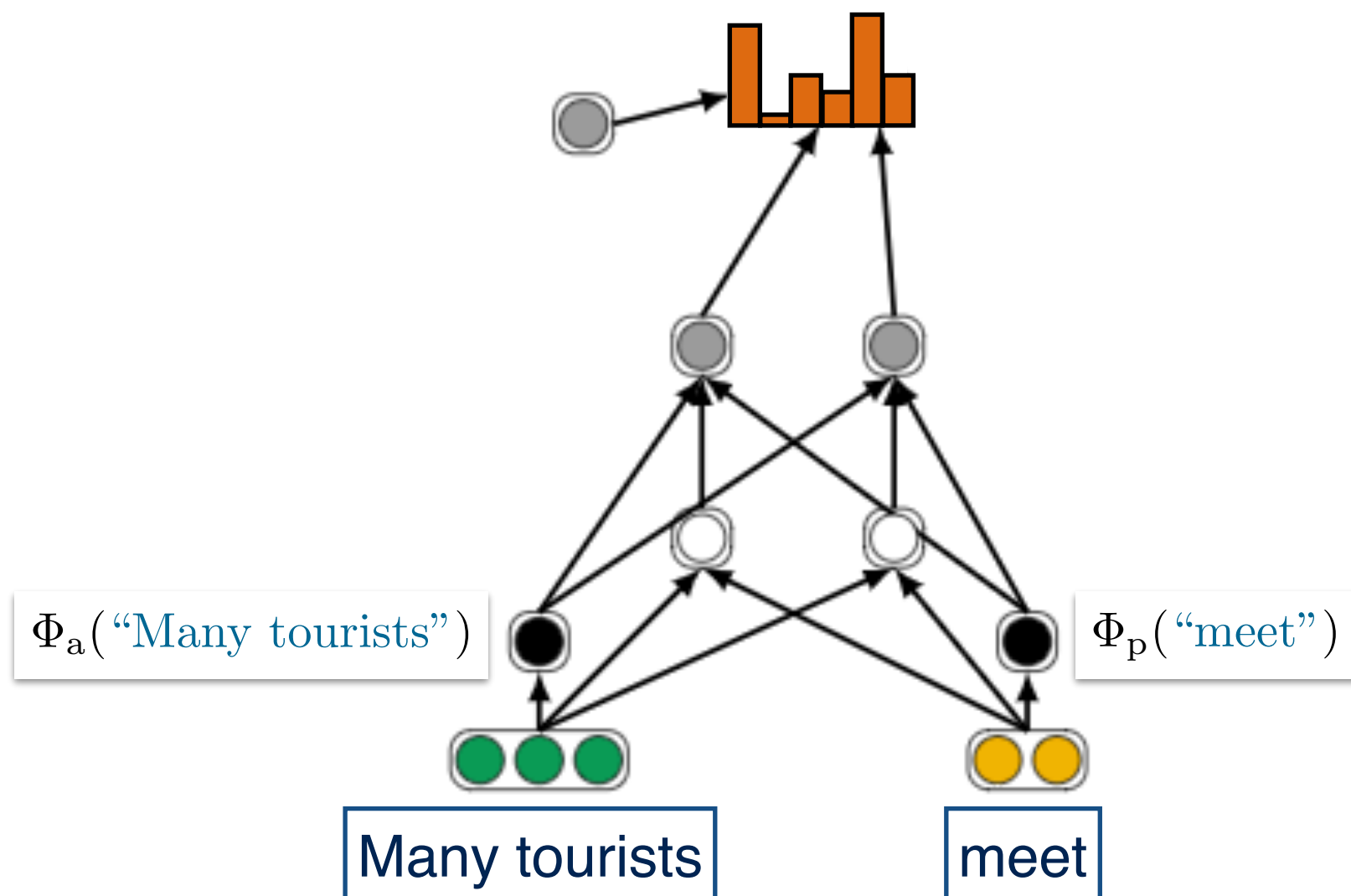
(2) Local Label Classifiers

(3) Span
Pruning

$$\phi(\text{pred}, \text{arg}, l) = \Phi_a(\text{arg}) + \Phi_p(\text{pred}) + \Phi_{\text{rel}}^{(l)}(\text{arg}, \text{pred})$$

**Pred./Arg.
score**

**Span
Representation**



(1) Span
Representations

(2) Local Label Classifiers

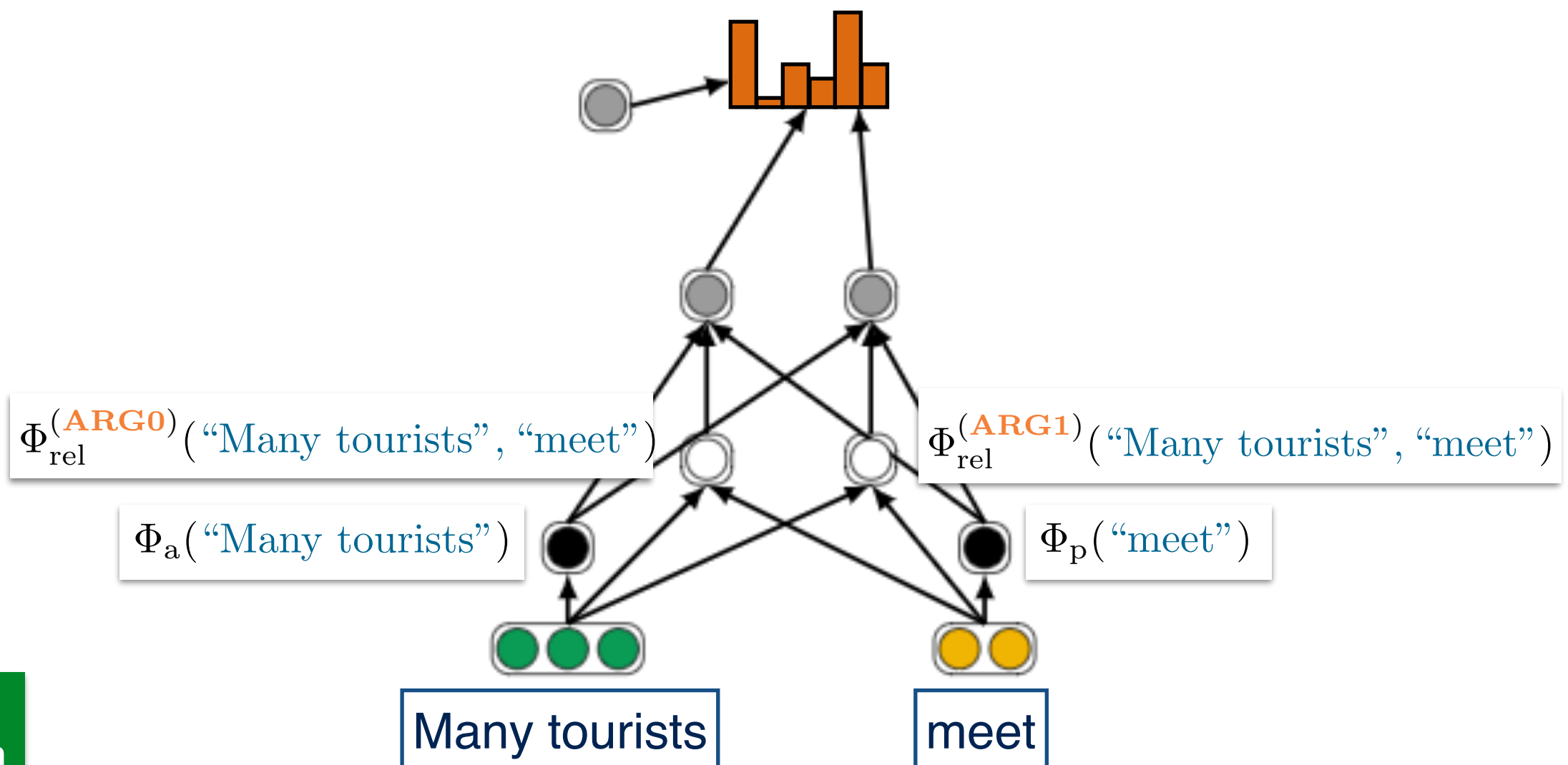
(3) Span
Pruning

$$\phi(\text{pred}, \text{arg}, l) = \Phi_a(\text{arg}) + \Phi_p(\text{pred}) + \Phi_{\text{rel}}^{(l)}(\text{arg}, \text{pred})$$

Edge score

Pred./Arg.
score

Span
Representation



(1) Span
Representations

(2) Local Label Classifiers

(3) Span
Pruning

$$\phi(\text{pred}, \text{arg}, l) = \Phi_a(\text{arg}) + \Phi_p(\text{pred}) + \Phi_{\text{rel}}^{(l)}(\text{arg}, \text{pred})$$

Softmax

$$\phi(\text{"Many tourists"}, \text{"meet"}, \epsilon) = 0$$

Combined
score

$$\phi(\text{"Many tourists"}, \text{"meet"}, \text{ARG0})$$

$$\phi(\text{"Many tourists"}, \text{"meet"}, \text{ARG1})$$

Edge score

$$\Phi_{\text{rel}}^{(\text{ARG0})}(\text{"Many tourists"}, \text{"meet"})$$

$$\Phi_{\text{rel}}^{(\text{ARG1})}(\text{"Many tourists"}, \text{"meet"})$$

Pred./Arg.
score

$$\Phi_a(\text{"Many tourists"})$$

$$\Phi_p(\text{"meet"})$$

Span
Representation

Many tourists

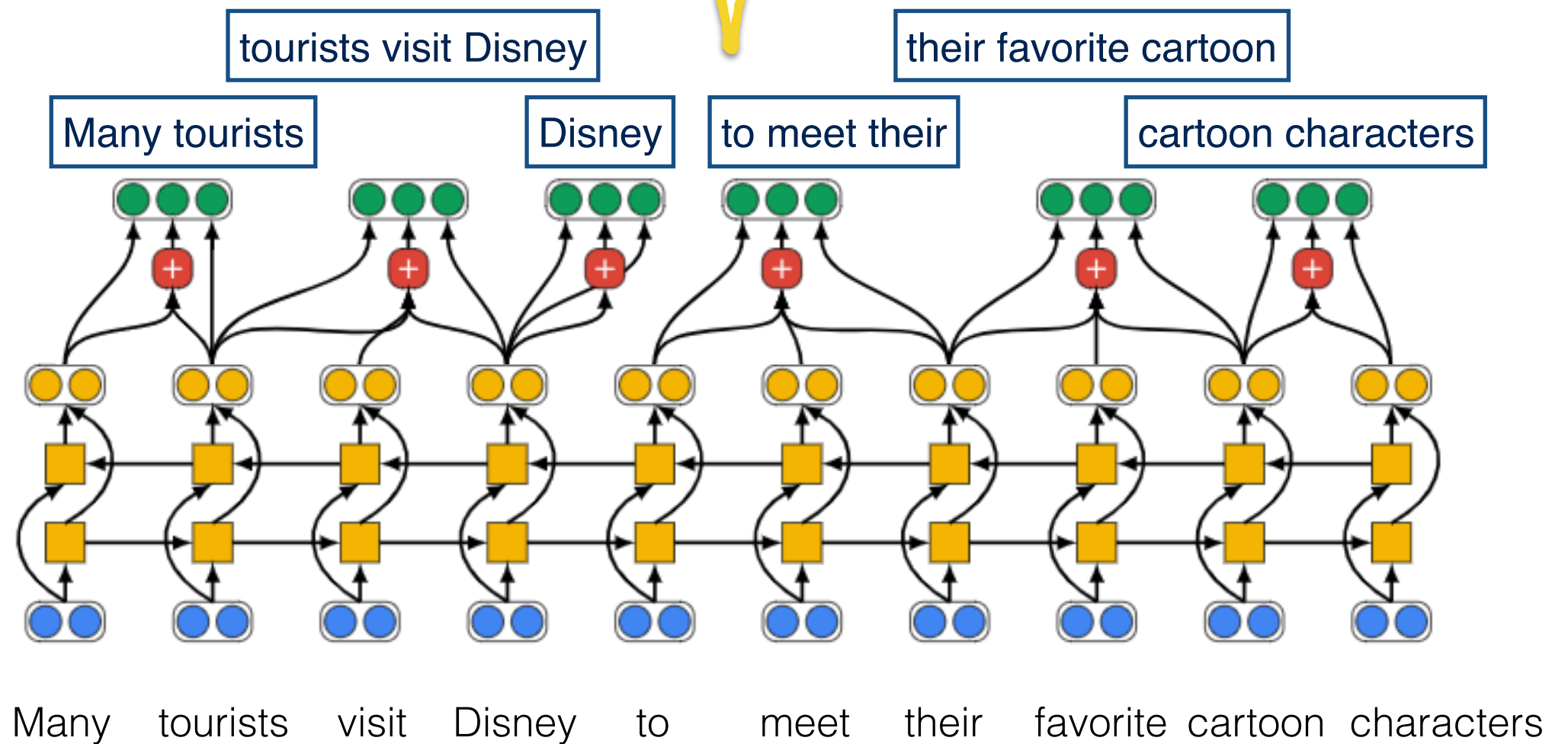
meet

(1) Span
Representations

(2) Local Label
Classifiers

(3) Span Pruning

$O(n^2)$ arguments, $O(n)$ predicates,
—> **$O(n^3)$ edges!**



Span
Representation

Highway
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Input sentence

(1) Span
Representations

(2) Local Label
Classifiers

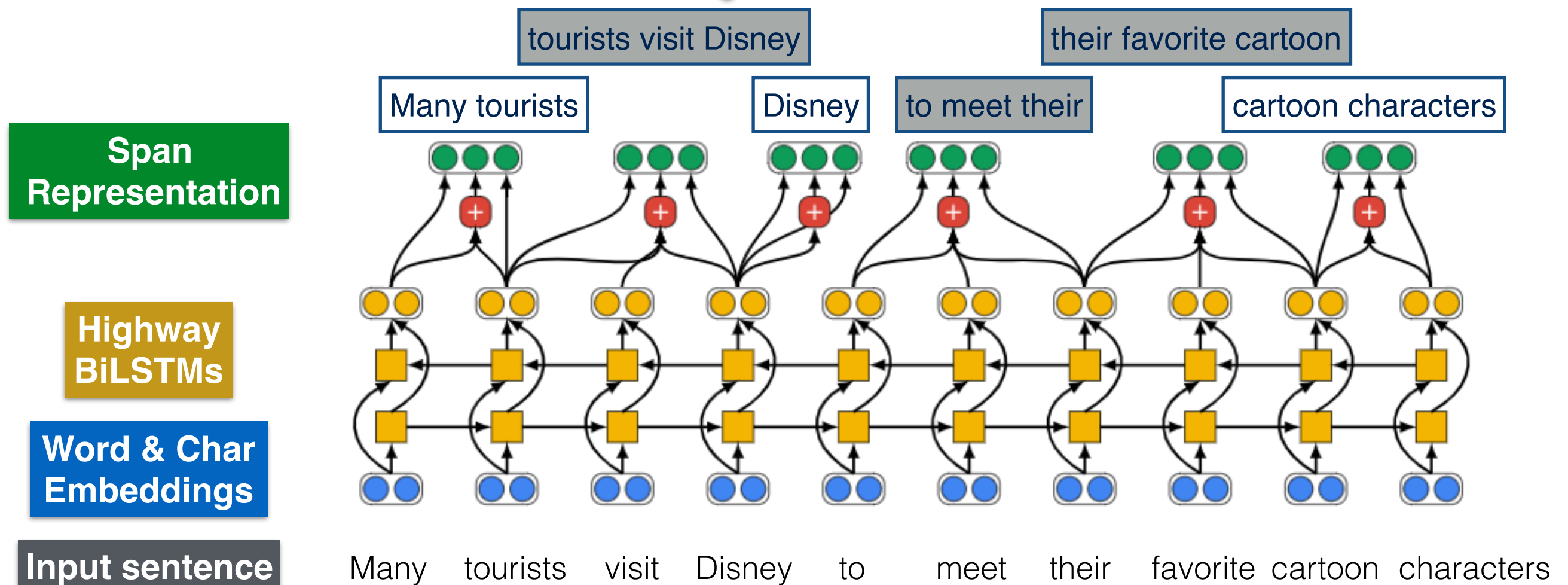
(3) Span Pruning

Only keep top **O(n)** spans
using their unary scores

$$\Phi_a(\text{"many tourists"}) = 2.5$$

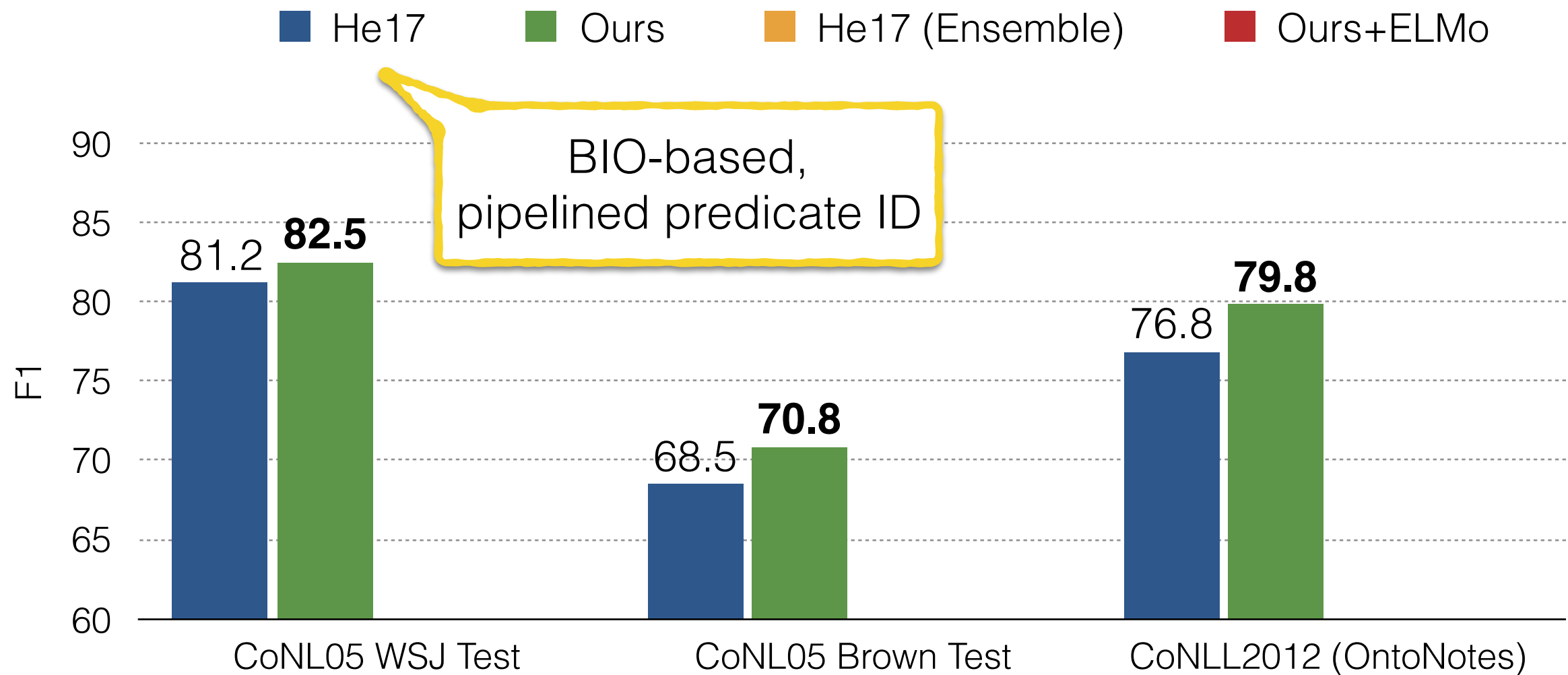
$$\Phi_a(\text{"tourists visit Disney"}) = -0.8$$

...

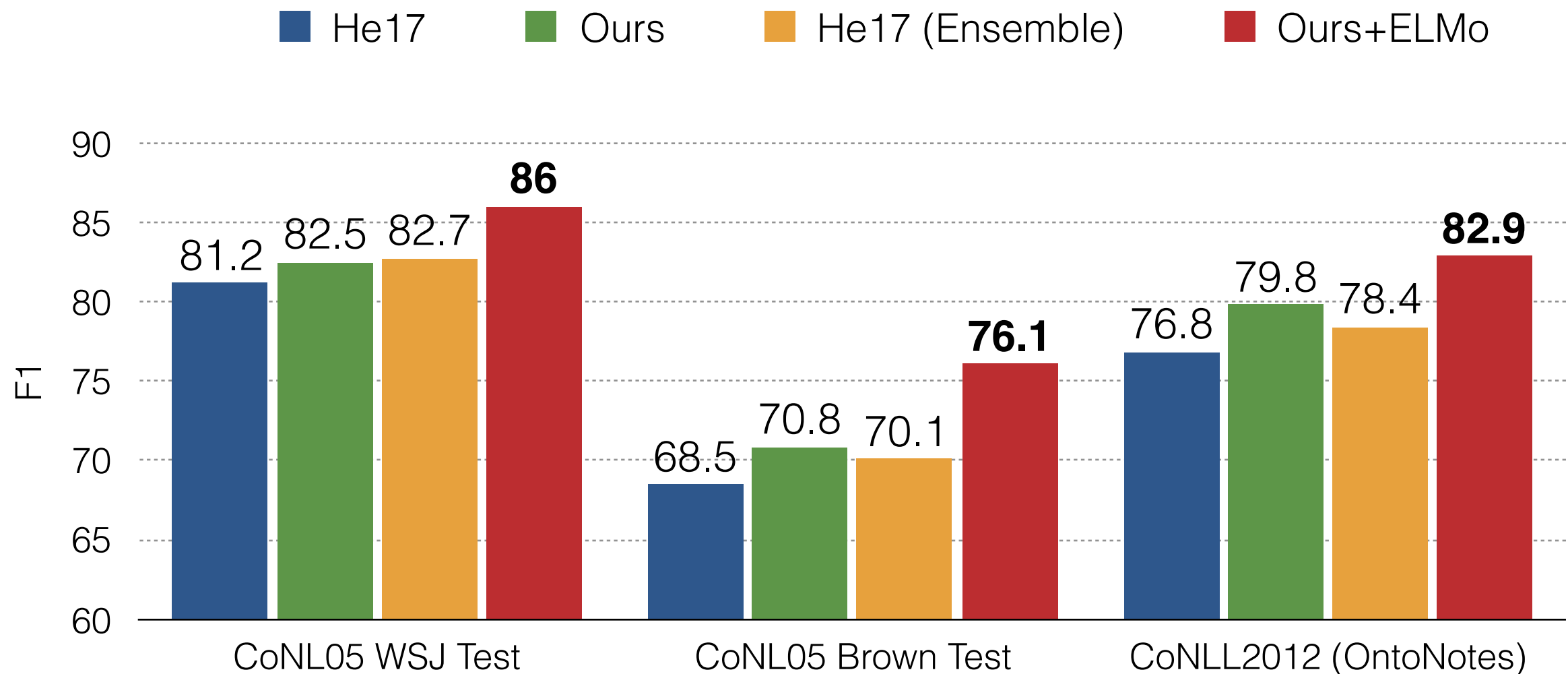


Results & Analysis

End-to-End SRL Results



End-to-End SRL Results



With **ELMo**, over 3 points improvement over SotA ensemble!

*ELMo: Deep Contextualized Word Representations, Peters et al., 2018

Span-based vs. BIO

	BIO (He17)	Span-based (this work)
Inputs	(Sentence, Predicate)	Sentence
Predicate Identification	Pipelined	Joint
Global Consistency		
Long-range Dependency		

Span-based vs. BIO

	BIO (He17)	Span-based (this work)
Inputs	(Sentence, Predicate)	Sentence
Due to the strong independence assumption we make.	Pipelined	Joint
Global Consistency		

Long-range Dependency

Span-based vs. BIO

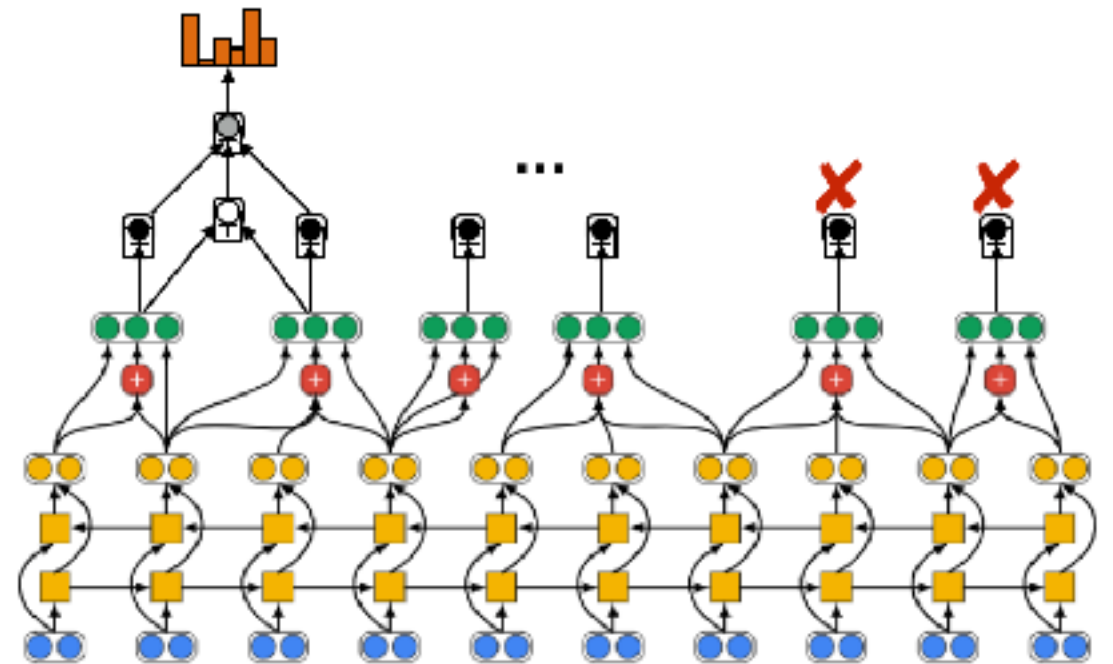
	BIO (He17)	Span-based (this work)
Inputs	(Sentence, Predicate)	Sentence
Processing	Due to the strong independence assumption we make. pipelined	Joint
Global Context	By allowing direct interaction between predicates and arguments	
Long-range Dependency		

Conclusion

- Joint prediction of predicates and arguments

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- Our recipe:
 1. Contextualized span representations
 2. Local label classifiers
 3. Greedy span pruning

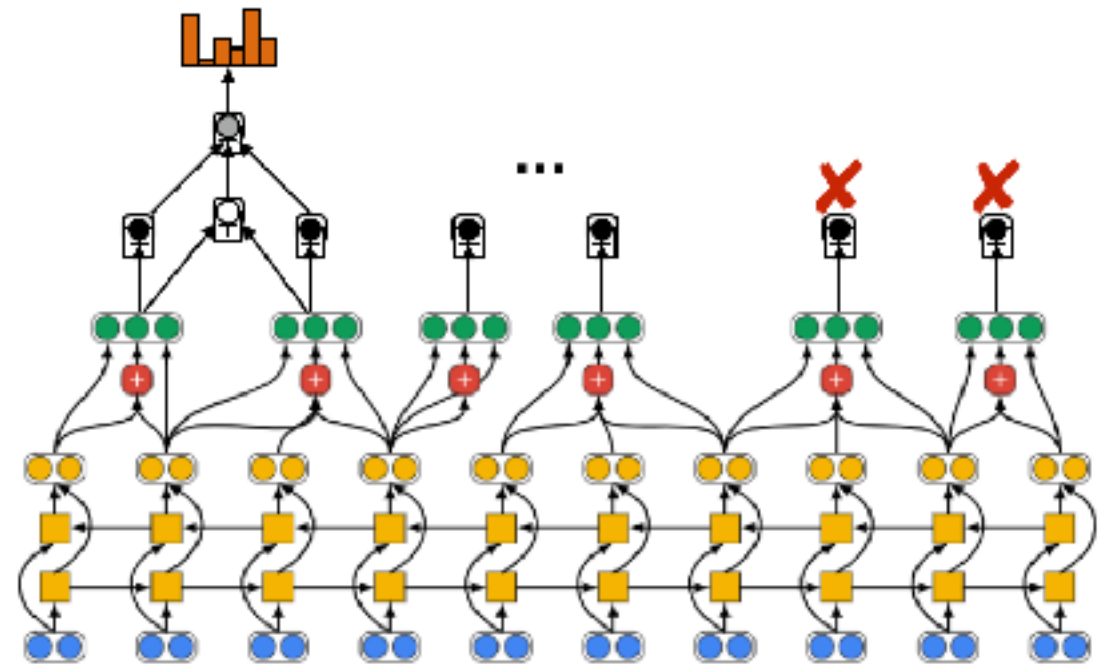


Conclusion

- Joint prediction of predicates and arguments

- Our recipe:

1. Contextualized span representations
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- Future work: Improve global consistency, use span representations for downstream tasks, etc.

THANK YOU!

Code and pertained models:
<https://github.com/luheng/lsgn>

