Position-aware Attention and Supervised Data Improve Slot Filling

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Knowledge Base Population

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Subject	**Relation/Slot**	**Object**
Mike Penner	per:spouse	Lisa Dillman
Lisa Dillman	per:title	Sportswriter
Lisa Dillman	per:employee_of	Los Angeles Times
…	…	…

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Key Problems

- Stanford routinely found DL models ineffective at slot filling task.

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1. **Existing models insufficiently tailored to relation extraction**
2. **Lack of a large-scale, fully supervised dataset for slot filling**

Overview

Model: A new position-aware attention model

+

Data: A new supervised dataset, TACRED

=

Result: Improved slot filling

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Relation Extraction

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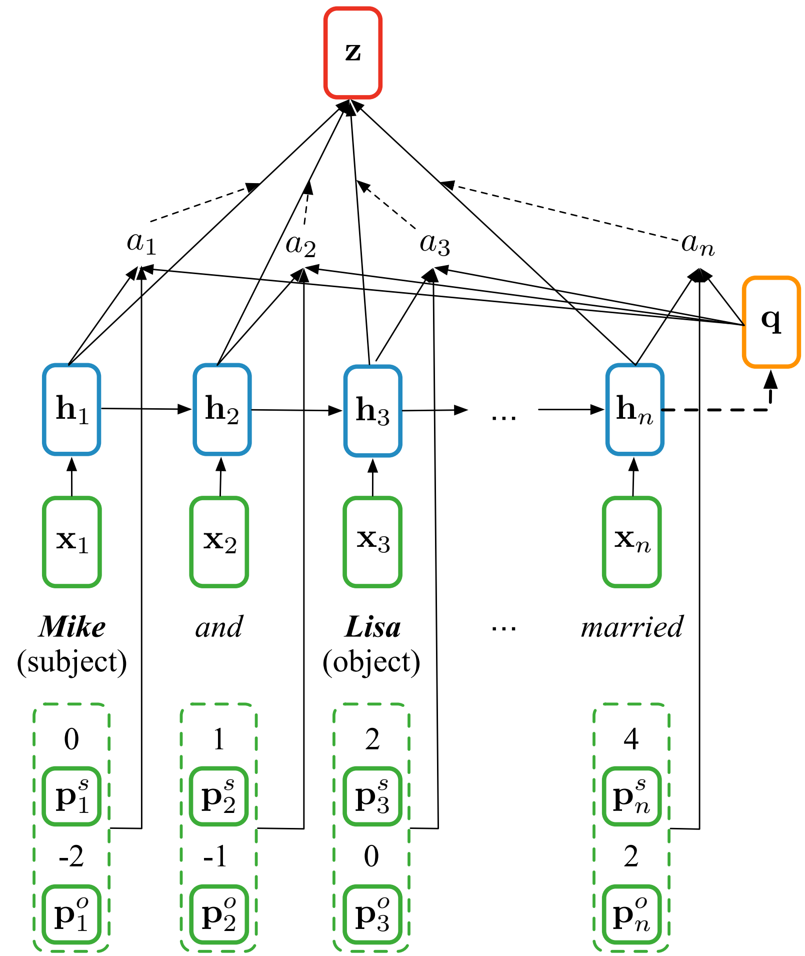
Key elements
- Context (relevant + irrelevant)
- Entities (types + positions)

Position-aware Attention Model



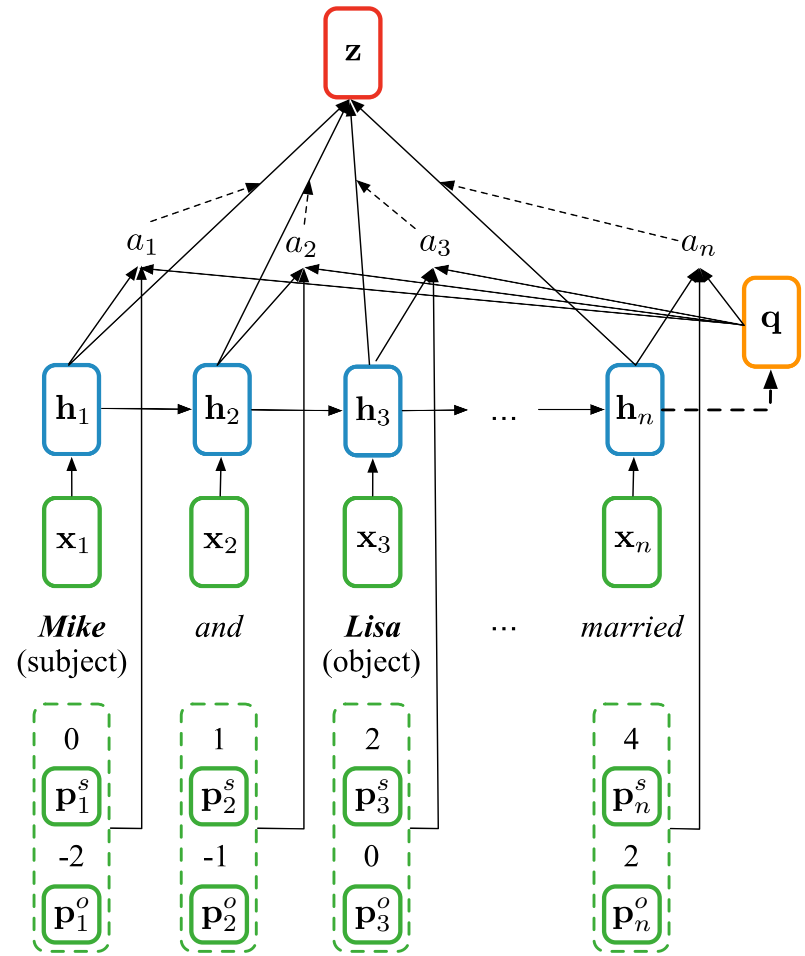
Position-aware Attention Model

Embedding Layers

Word: $\mathbf{x} = [\mathbf{x}_1, ..., \mathbf{x}_n]$

Position: $\mathbf{p}^s = [\mathbf{p}^s_1, ..., \mathbf{p}^s_n]$

$\mathbf{p}^o = [\mathbf{p}^o_1, ..., \mathbf{p}^o_n]$



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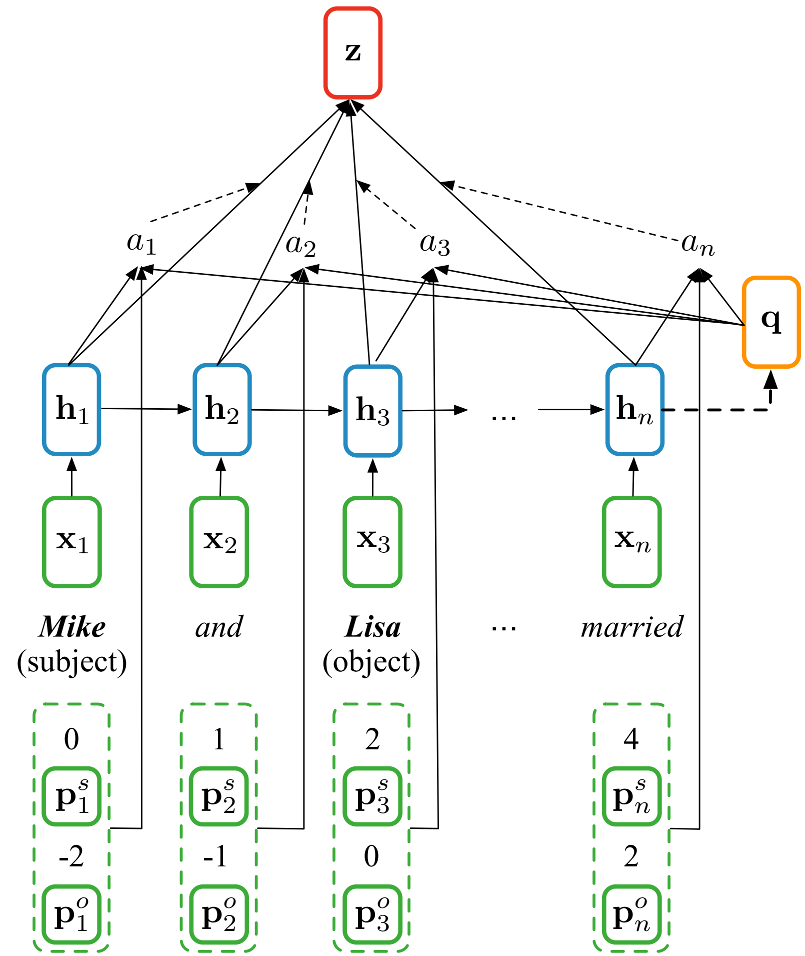
LSTM Layers

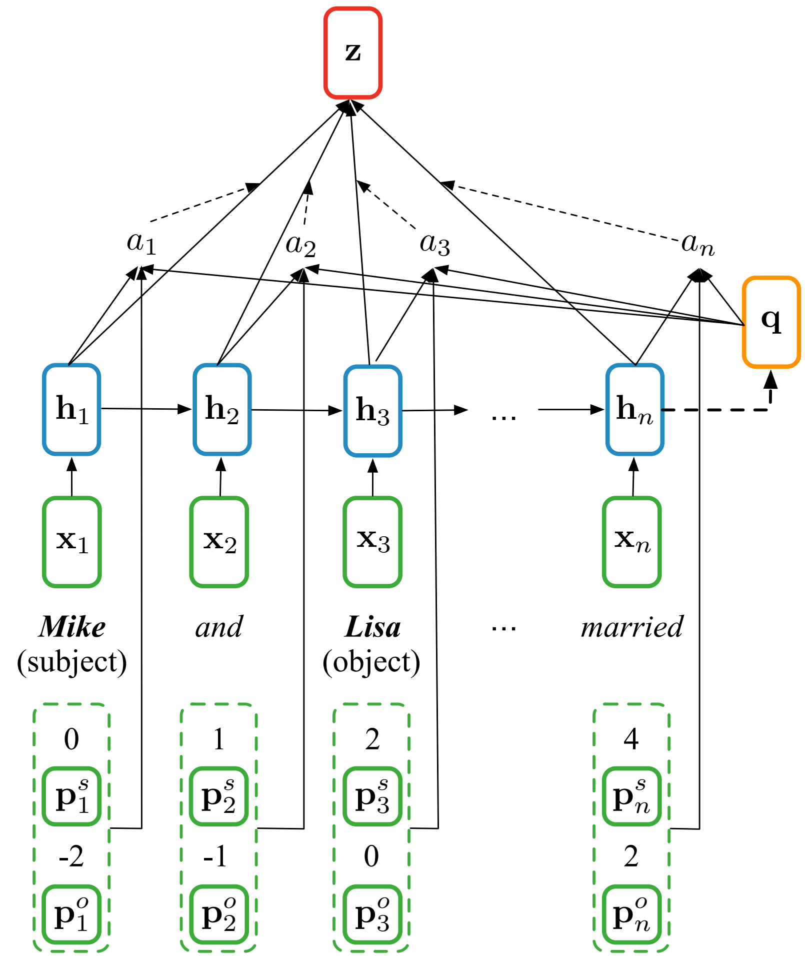
$$\{\mathbf{h}_1, ..., \mathbf{h}_n\} = \mathrm{LSTM}(\{\mathbf{x}_1, ..., \mathbf{x}_n\})$$



Position-aware Attention Model

Summary Vector

$$\mathbf{q} = \mathbf{h}_n$$



Position-aware Attention Model

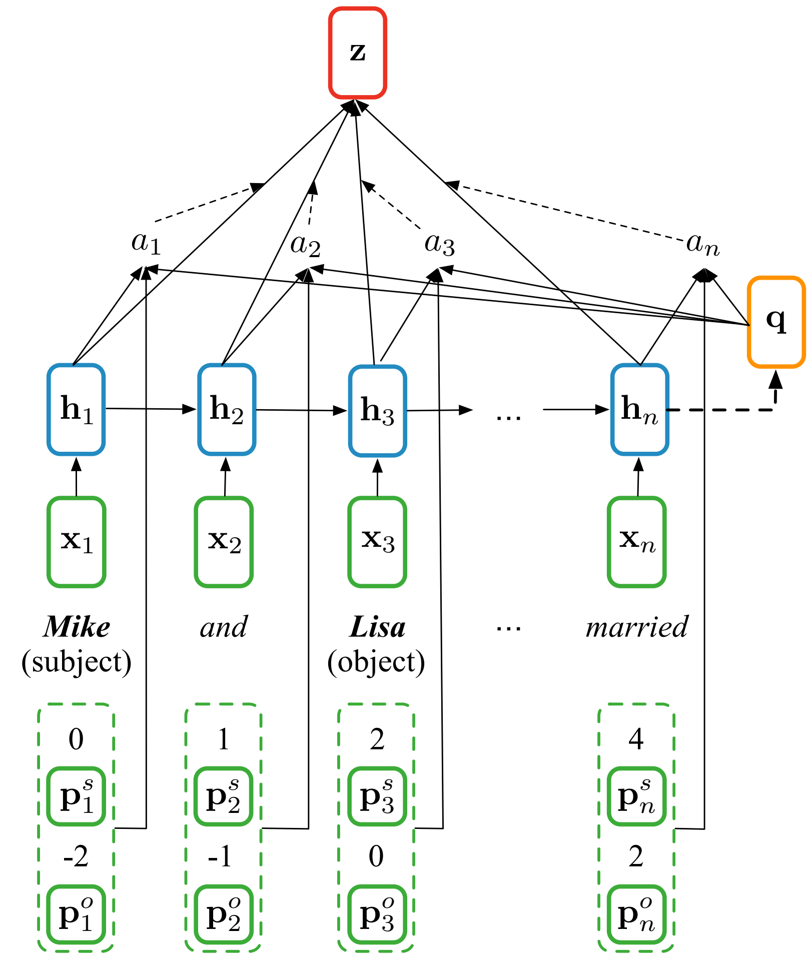
Summary Vector

$$\mathbf{q} = \mathbf{h}_n$$

Attention Layer

$$u_i = \mathbf{v}^\top \tanh(\mathbf{W}_h\mathbf{h}_i + \mathbf{W}_q\mathbf{q} + \mathbf{W}_s\mathbf{p}_i^s + \mathbf{W}_o\mathbf{p}_i^o)$$

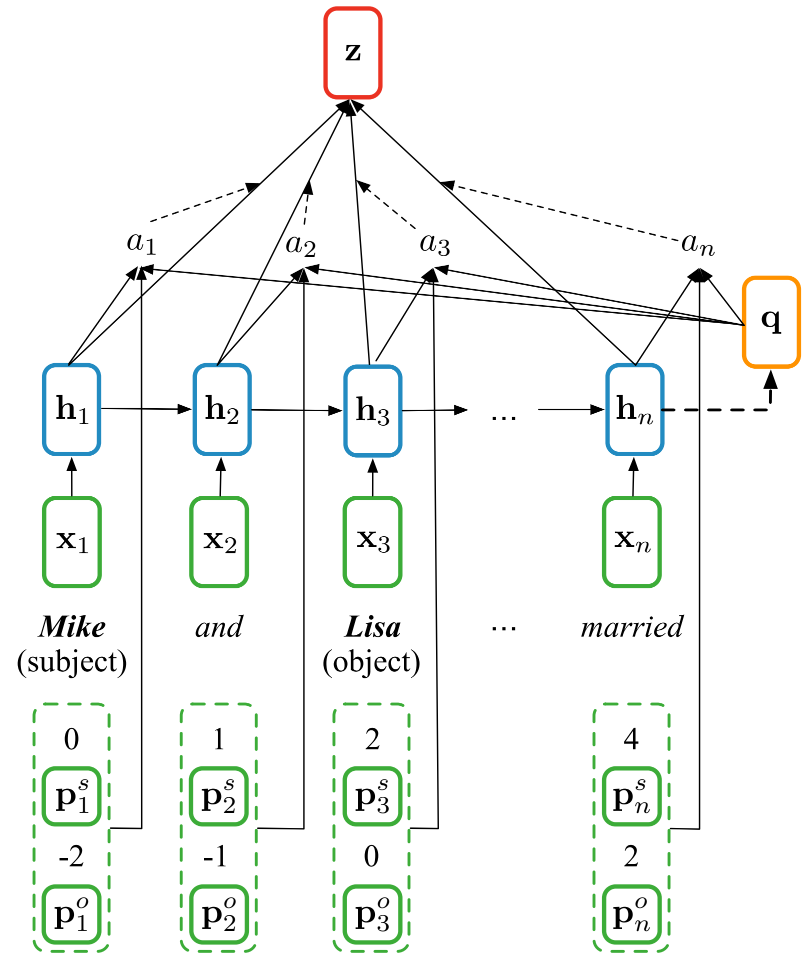
$$a_i = \frac{\exp(u_i)}{\sum_{j=1}^{n}\exp(u_j)}$$



Position-aware Attention Model

Relation Representation

$$\mathbf{z} = \sum_{i=1}^{n} a_i \mathbf{h}_i$$



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Relation Representation

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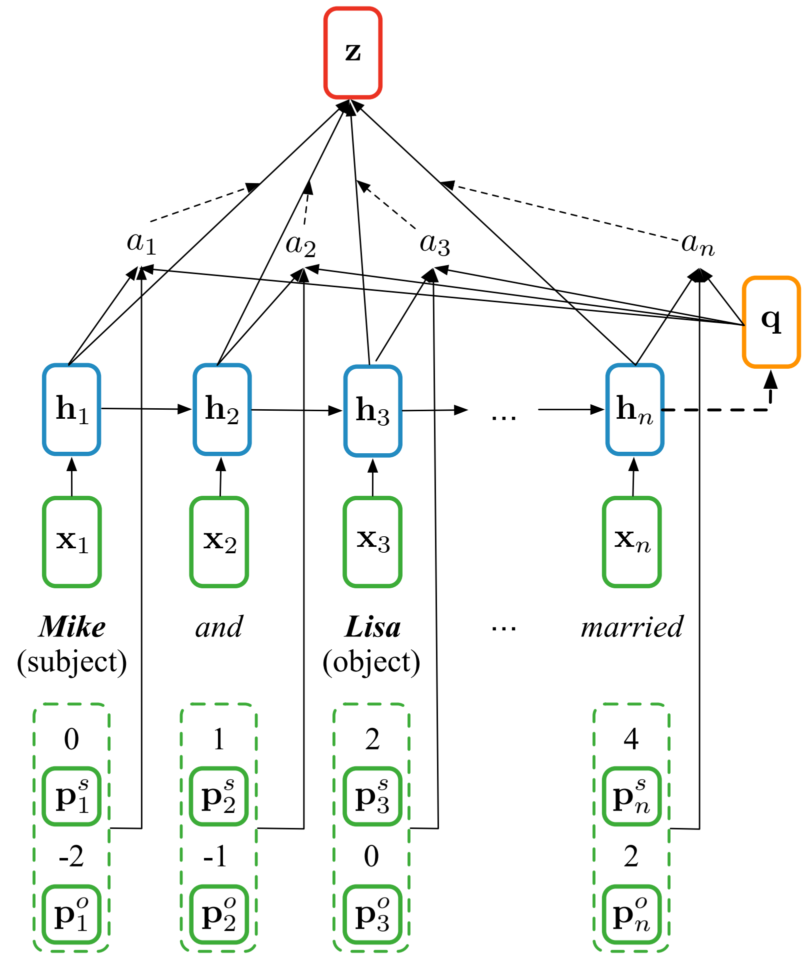
Softmax Layer

$$\mathbf{y} = \mathrm{softmax}(\mathbf{W}\mathbf{z})$$

$$c = \underset{i}{\mathrm{argmax}}(y_i);$$

$$c \in \{\textit{per:spouse}, \textit{org:founded}, \ldots\}$$



Other Augmentations

- **Word dropout**: balance OOV distribution

Penner is survived by his brother, John

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Penner is <UNK> by his brother, John

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SUBJ-PER is survived by his brother, OBJ-PER

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- **Linguistic information**: POS and NER embeddings from Stanford CoreNLP

Penner is survived by …

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Penner	is	survived	by	…
NNP	VPZ	VBN	IN	…
PER	O	O	O	…

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Try out these tricks!

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SemEval 2010: Popular But Suboptimal

- Small in size (10.7k)
- Different and vague relations

A New York Times food **writer** fries the potatoes in a **mixture** of peanut oil and duck fat with bacon added.

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The **TAC R**elation **E**xtraction **D**ataset

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- Crowdsourced
- Tailored for TAC KBP slot filling

- Four explicit goals
  - Large-scale
  - Real-world corpus
  - Negative examples
  - Fully supervised

Goal 1: Large-scale

Split	# examples
Train	68,124
Dev	22,631
Test	15,509
Total	**106,264**

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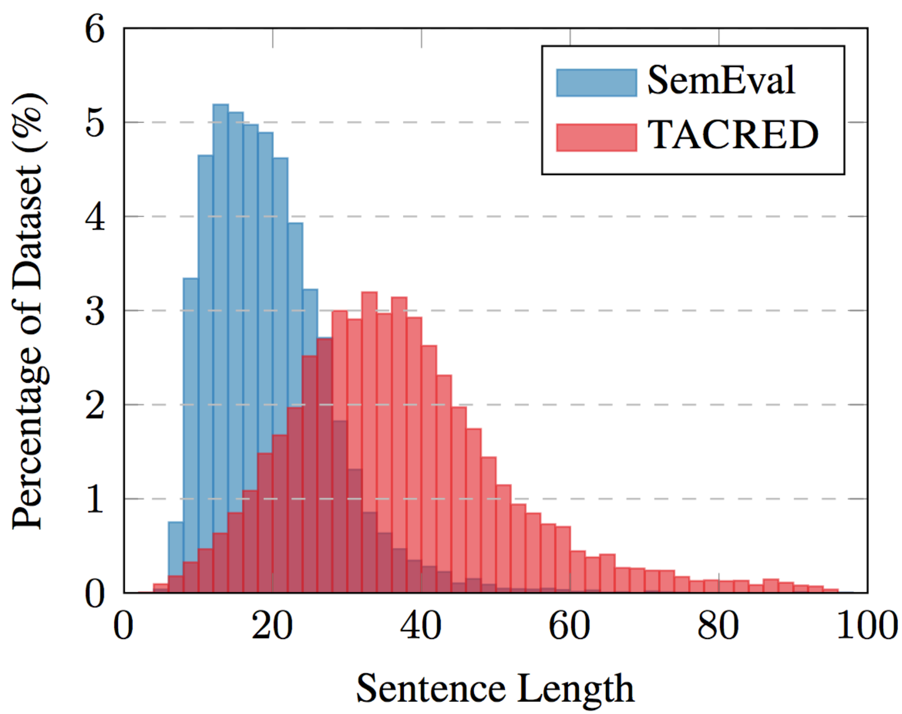
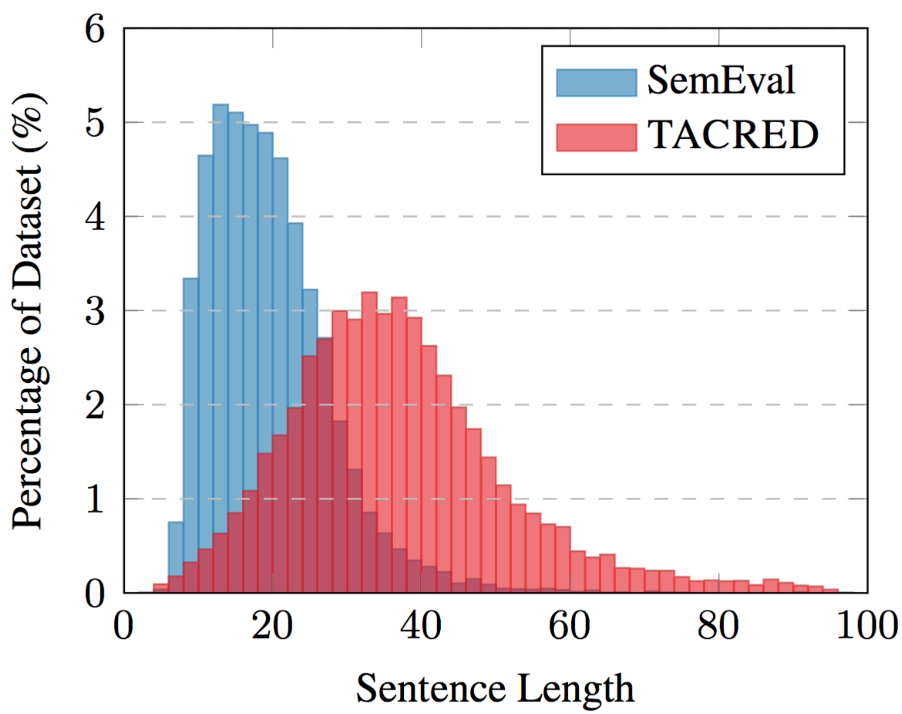
An order of magnitude larger!

Goal 2: Real-world TAC KBP corpus



Goal 2: Real-world TAC KBP corpus



Longer and more complex context!

Goal 3: Negative examples annotated

Label	Ratio (%)
Positive	20.5
Negative	79.5

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Beat false positives in slot filling!

Goal 4: Fully supervised

Pandit worked at the brokerage Morgan Stanley for about 11 years until 2005, when he and some 106 Morgan Stanley colleagues quit and later founded the hedge fund **Old Lane Partners**.	**org:founded_by**

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41 TAC KBP slot types + no_relation!

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Experiments

Experiments

- Task 1: Relation Extraction on TACRED

  Q: How well can we do on relation extraction?

  VS: Baseline traditional and neural models.

- Task 2: End-to-end TAC KBP Slot Filling Task

  Q: Does it improve slot filling?

  VS: SOTA slot filling system.

Models Compared Against

Non-Neural

- Stanford's TAC KBP 2015 winning system
  - **Patterns**
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Neural

- **CNN** with positional encodings (Nguyen and Grishman, 2015)
- **Dependency-based RNN** (Xu et al., 2015)
- **LSTM**: 2-layer Stacked-LSTM

Relation Extraction Results

	Model	**P**	**R**	**F1**
Traditional	Patterns	**86.9**	23.2	36.6
	LR	73.5	49.9	59.4
	LR + Patterns	72.9	**51.8**	**60.5**

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- Patterns: high precision
- LR: high recall

Relation Extraction Results

	Model	P	R	F1
Traditional	LR + Patterns	72.9	51.8	60.5
Neural	CNN	**75.6**	47.5	58.3
	CNN-PE	70.3	54.2	61.2
	SDP-LSTM	66.3	52.7	58.7
	LSTM	65.7	**59.9**	**62.7**

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- CNN higher precision; LSTM higher recall
- CNN-PE and LSTM outperform traditional

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Neural	LSTM	65.7	59.9	62.7
	Our model	65.7	**64.5**	**65.1**
	Ensemble (5)	70.1	**64.6**	**67.2**

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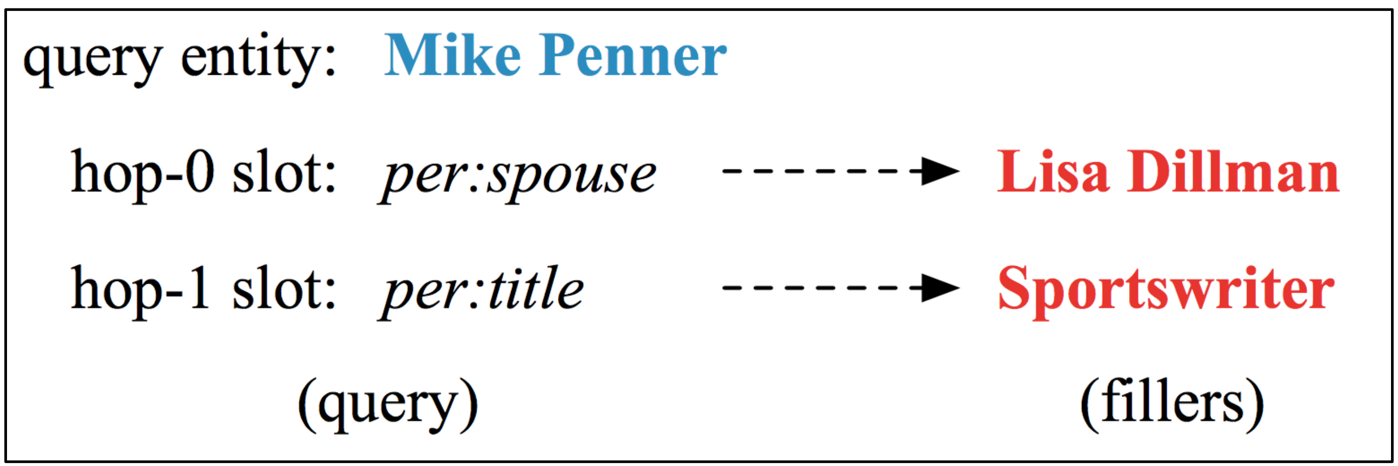
- Our model: +2.4 improvement on F1

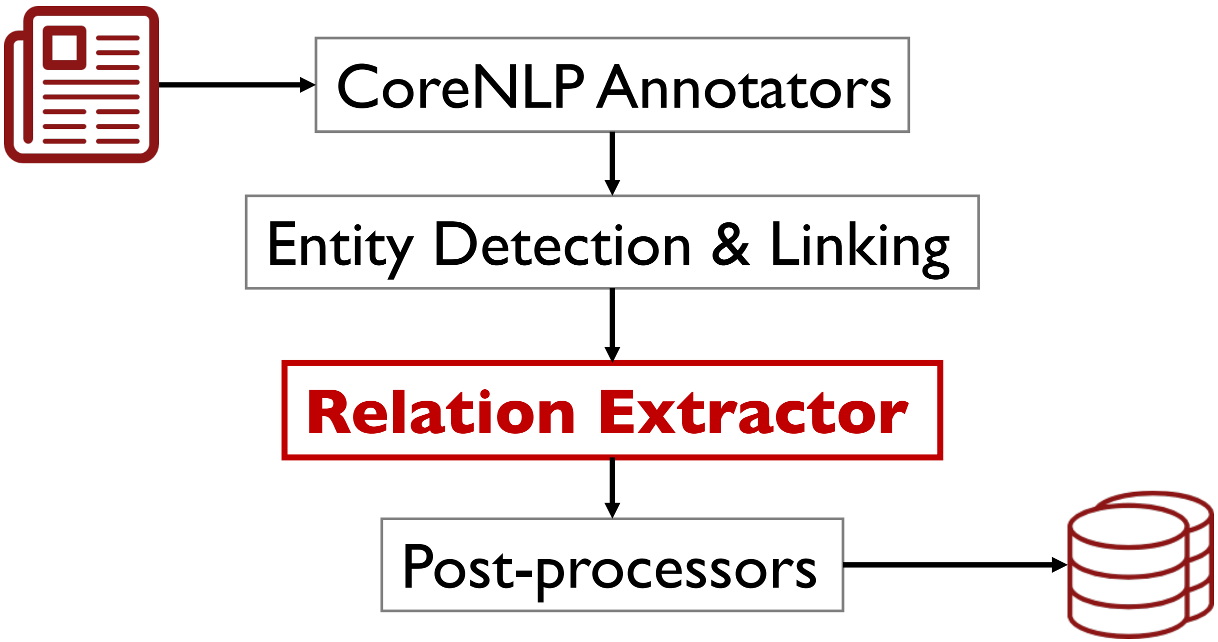
Slot Filling Evaluation

- **Input**: 50k docs + 2-hop queries
- **Output**: slot fillers



Slot Filling Evaluation

- Stanford's 2015 winning system + new extractor



Slot Filling Results

	Hop-0			Hop-all		
Model	**P**	**R**	**F1**	**P**	**R**	**F1**
Patterns	**63.8**	17.7	27.7	**58.9**	13.3	21.8
LR	36.6	21.9	27.4	25.6	16.3	19.9
+ Patterns (2015 winning)	37.5	24.5	29.7	26.6	19.0	**22.2**
LR trained on TACRED	32.7	20.6	25.3	16.8	15.3	16.0
+ Patterns	36.5	**26.5**	**30.7**	20.1	**21.2**	20.6

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- Close results when trained on TACRED only

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Our model	39.0	28.9	33.2	28.2	21.5	24.4
+ Patterns	**40.2**	**31.5**	**35.3**	**29.7**	**24.2**	**26.7**

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- Neural vs LR: **+7.9** hop-0, **+8.4** hop-all!
- Best vs 2015 winning: **+5.6** hop-0, **+4.5** hop-all!

Further Analysis

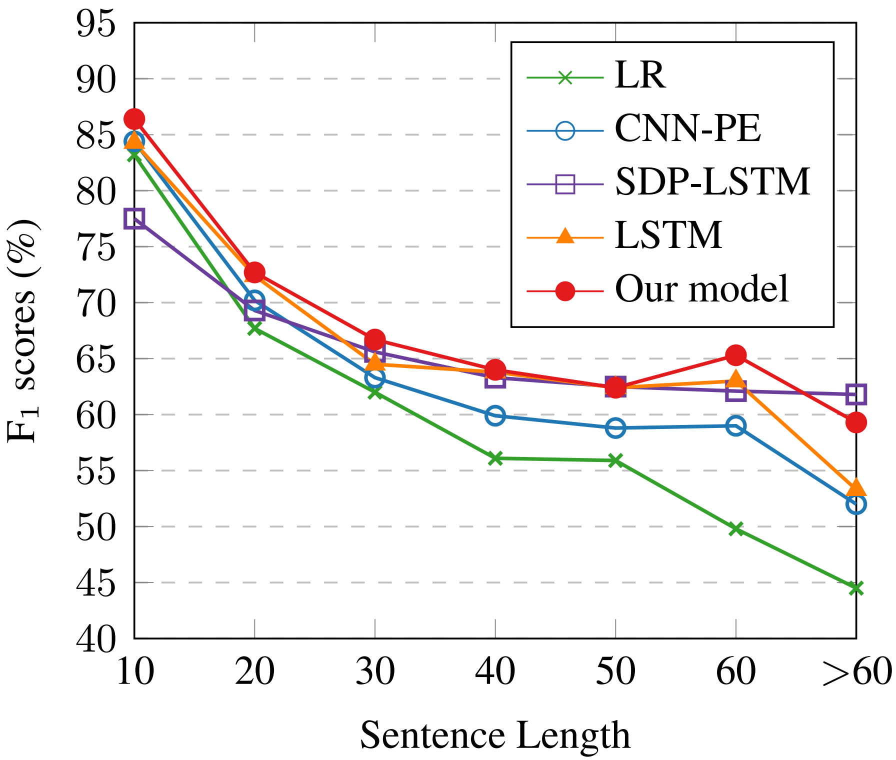
- Model Ablation

Model	Dev F1
Our model (single)	**66.0**
- Position-aware attention	65.2
- All attention	64.1
- Word dropout	65.4
- All Above	62.2

Attention plays an important role!

Further Analysis

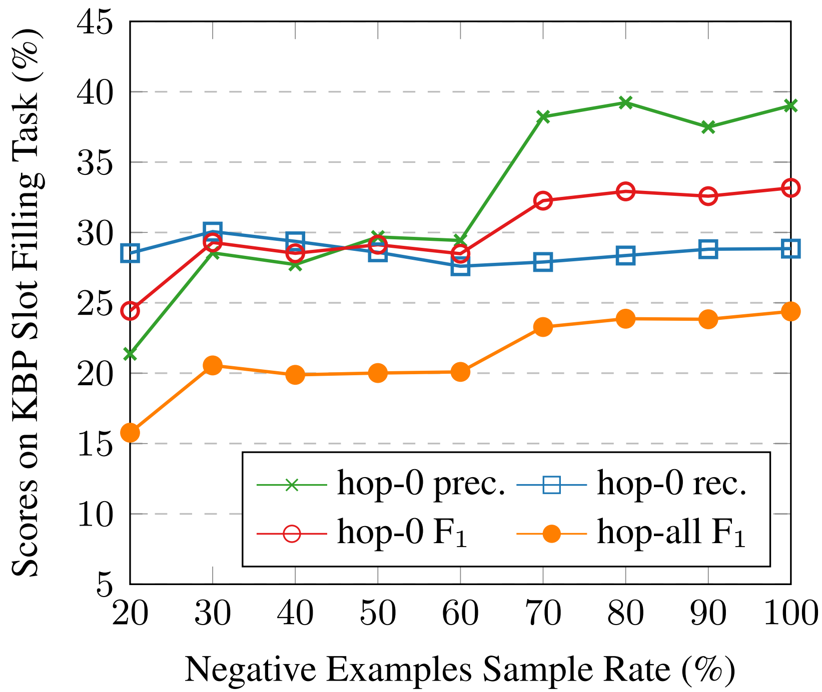
- Performance by sentence length



- LR and CNN drops drastically
- SDP-LSTM least sensitive to lengths
- Our model achieves best performance

Further Analysis

- Impact of negative examples



- Hop-0 precision increases
- Hop-0 recall stays
- Hop-0 and hop-all F1 increases

Further Analysis

- Attention visualization

PER-SUBJ graduated from North Korea 's elite Kim Il Sung University and ORG-OBJ ORG-OBJ .

per:schools_attended

The cause was a heart attack following a case of pneumonia , said PER-SUBJ 's niece , PER-OBJ PER-OBJ .

per:other_family

Independent ORG-SUBJ ORG-SUBJ ORG-SUBJ (ECC) chairman PER-OBJ PER-OBJ refused to name the three , saying they would be identified when the final list of candidates for the august 20 polls is published on Friday .

org:top_members/employees

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