NaCTeM at 2018 n2c2 Shared-Task

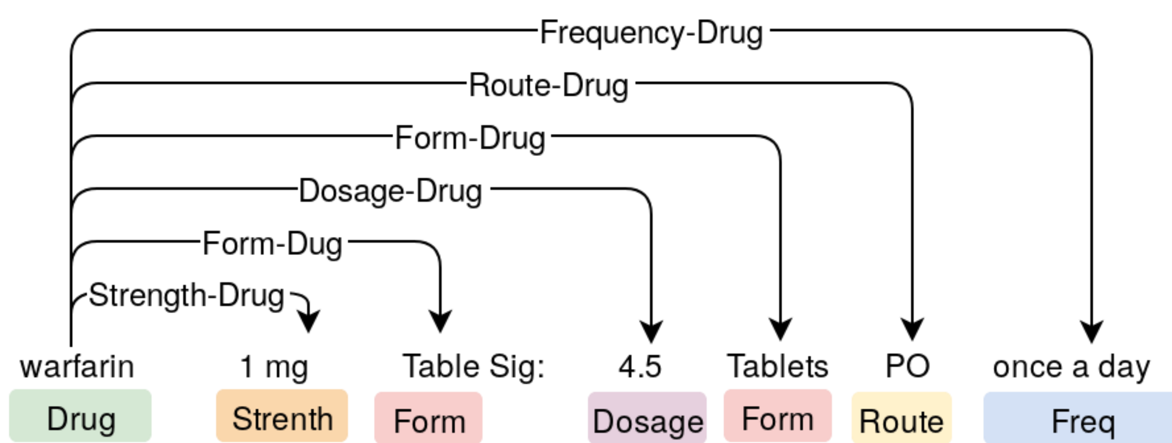
Extracting Adverse Drug Events and Medication in EHRs with Ensembles of Feature-based and Deep Learning Models

Nhung T.H. Nguyen, Fenia Christopoulou,
Thy Thy Tran, **Meizhi Ju**, Sunil Kumar Sahu,
Makoto Miwa, Sophia Ananiadou

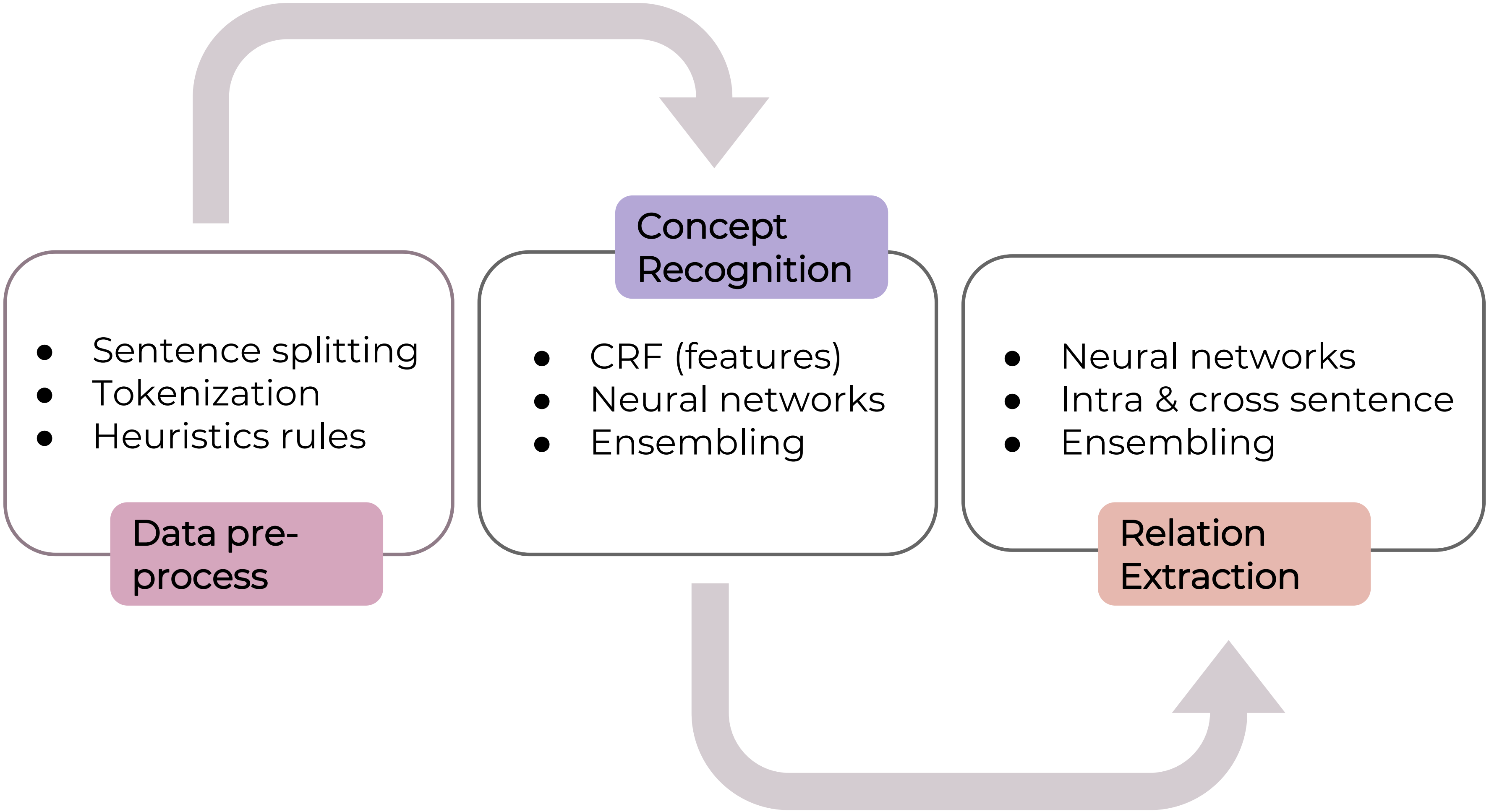
N2C2 Shared Task: Track 2

- Input: discharge summaries from electronic health records
- Tasks:
  1. Concept recognition
  2. Relation extraction: binary relations
  3. End-to-end system: identify concepts and relations from scratch

Entities	Ratio (%)	Relations	Ratio (%)
Duration	**1.1**	Duration-Drug	**1.7**
ADE	**1.8**	ADE-Drug	**3.0**
Reason	7.5	Reason-Drug	14.2
Dosage	8.28	Dosage-Drug	11.6
Route	10.7	Route-Drug	15.2
Frequency	12.3	Frequency-Drug	17.3
Form	12.9	Form-Drug	18.2
Strength	13.1	Strength-Drug	18.4
Drug	31.8		



Pipeline
Workflow

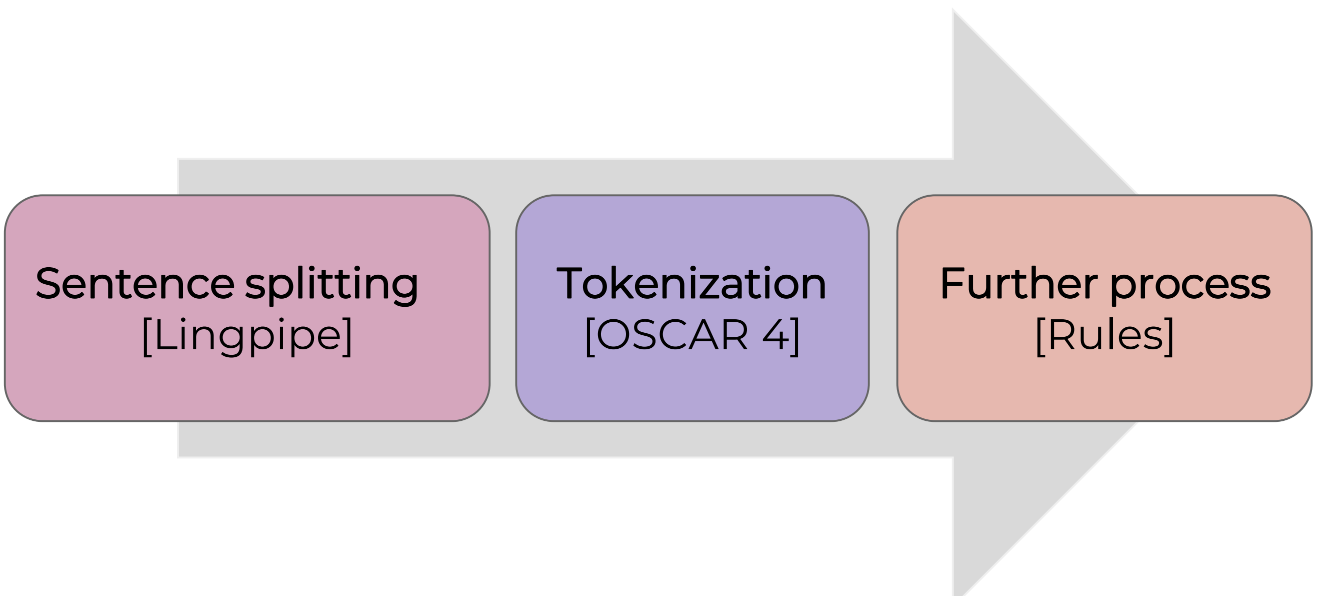


Data pre-process

- *Data splitting*
- *Existing tools*
- *Heuristics rules*

Pre-processing

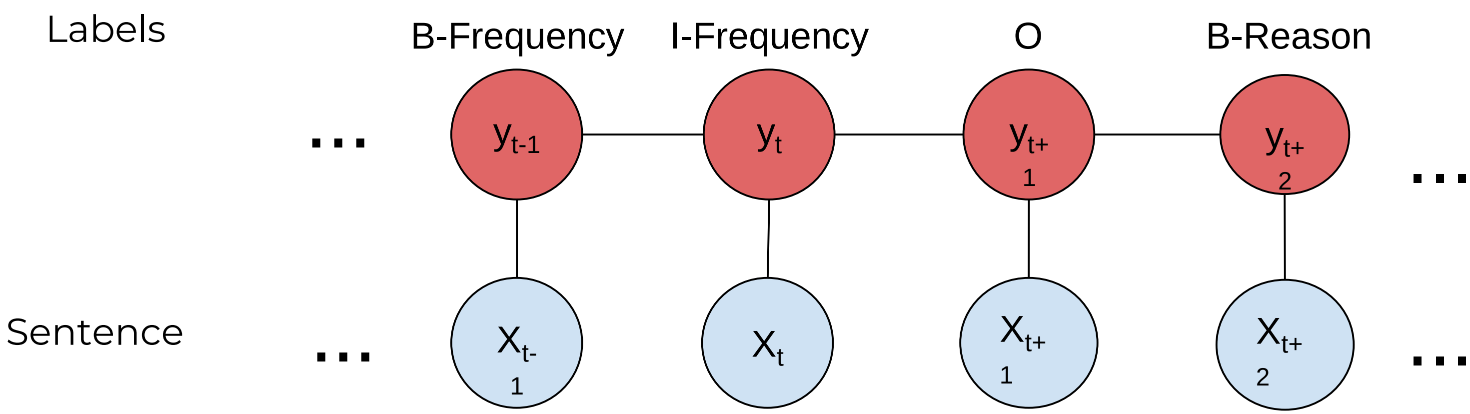
	Subset	Documents	Sentences
Training data	Train (80 %)	242	44932
	Dev (20 %)	61	11063
Testing data	Test	202	37390



Concept Recognition

- *CRF Model*
- *Neural Network Model*

Concept Recognition
CRF Model



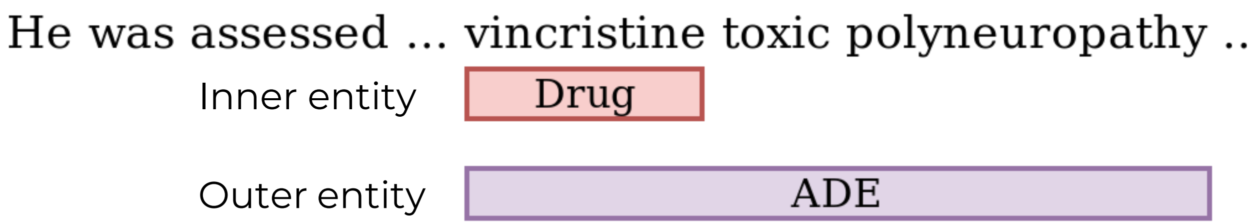
Features

Lexical, Syntactic, Orthographical	Token	as	needed	for	Constipation
	Base form	as	need	for	constipation
	Part of Speech	IN	VBN	IN	NNP
	Chunk tag	B-SBAR	B-VP	B-PP	B-NP
	Word shape	a	a	a	Aa
Dictionaries	In ADE terms	O	O	O	B-ADETerm
	In Disease terms	O	O	O	O
Clusters (Unlabelled MIMIC data, K-means)	128 Clusters, context=2	cluster92	cluster94	cluster92	cluster25
	256 Clusters, context=2	cluster94	cluster18	cluster200	cluster237
	512 Clusters, context=2	cluster471	cluster75	cluster142	cluster75
	128 Clusters, context=5	cluster42	cluster53	cluster42	cluster29
	256 Clusters, context=5	cluster42	cluster171	cluster42	cluster253
	512 Clusters, context=5	cluster264	cluster331	cluster264	cluster331

Use NERSuite (Cho et al., 2013): http://nersuite.nlplab.org

Motivation

- Nested entity: entities embedded in longer entities.



- Inner entities are informative indicators for outer entities (Ju, et al. 2018).

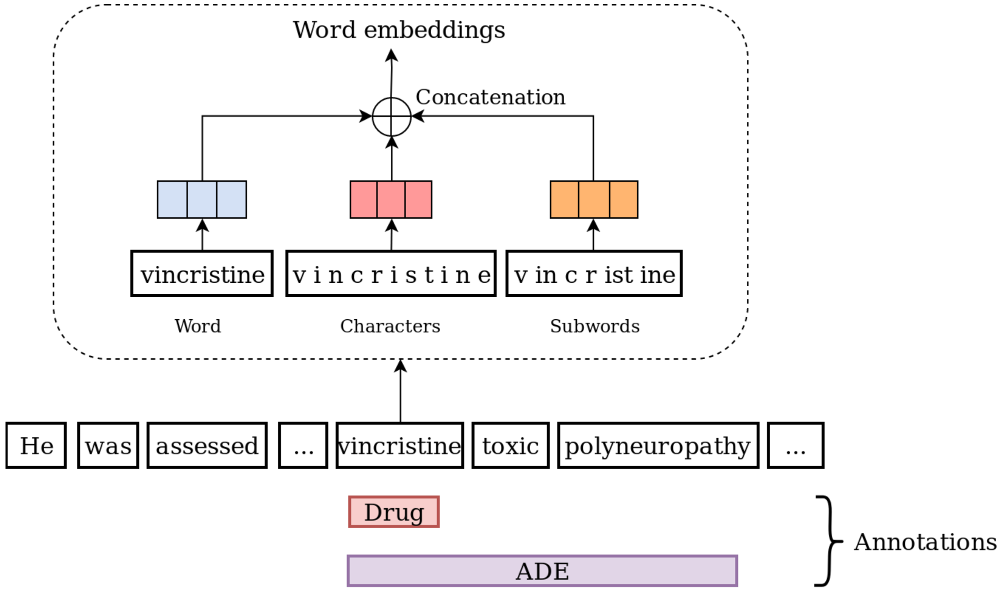
- Rare and unseen words can be well represented by re-tokenizing sentences into subwords based on frequencies. (Sennrich, et al. 2016).

Concept Recognition

Neural Network Model

Method

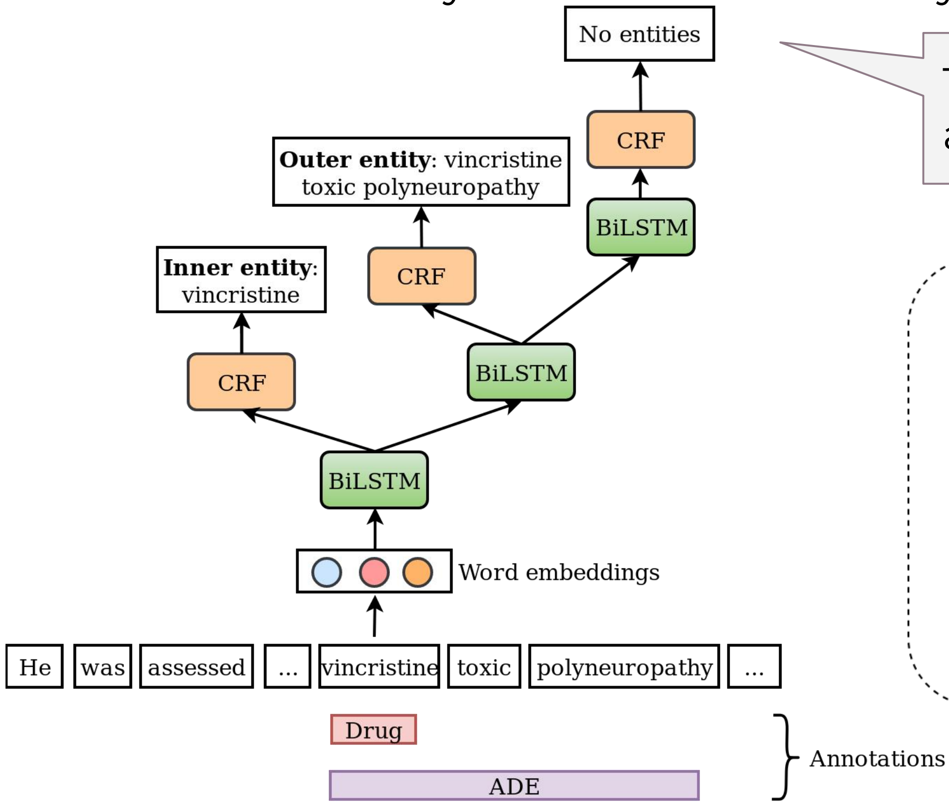
- Extract both nested entities and entities with multiple types
- Independent on linguistic features and external knowledge resources
- Automatically stacks BiLSTM-CRF layers.



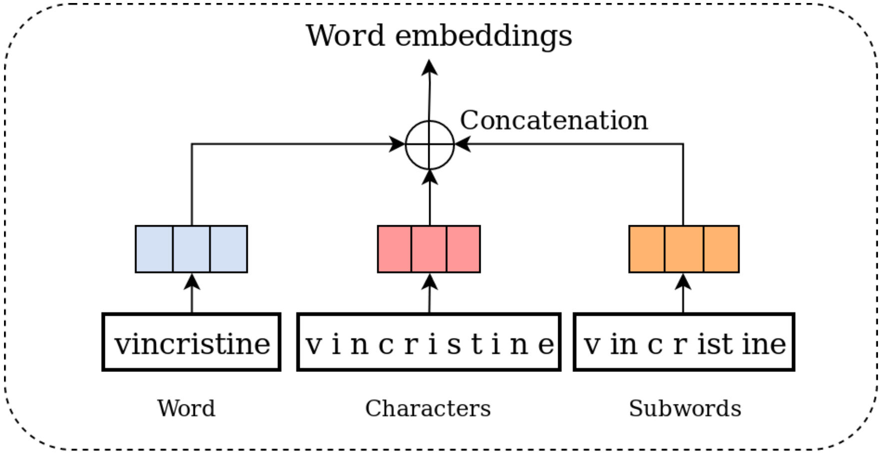
Concept Recognition
Neural Network Model

Method

- Extract both nested entities and entities with multiple types
- Independent on linguistic features and external knowledge resources
- Automatically stacks BiLSTM-CRF layers.



Terminates stacking when no entities are extracted



Experimental Results

Concept

Model	Precision	Recall	F1-score
CRF			
Lexical and syntactic features (Baseline)	0.9525	0.8825	0.9162
Baseline + word shape (ws)	0.9527	0.8815	0.9157
Baseline + dictionary features (df)	0.9511	0.8829	0.9157
Baseline + cluster features (cf)	0.9504	0.8902	**0.9193**
Baseline + ws + df + cf	0.9486	0.8900	0.9184
Neural network			
Baseline (word + characters)	0.9385	0.9143	0.9262
Baseline (subword + characters)	0.9352	0.9115	0.9232
Baseline (word + subword)	0.9353	0.9224	**0.9288**
Baseline (word + subword + characters)	0.9507	0.9066	0.9281

Relation Extraction

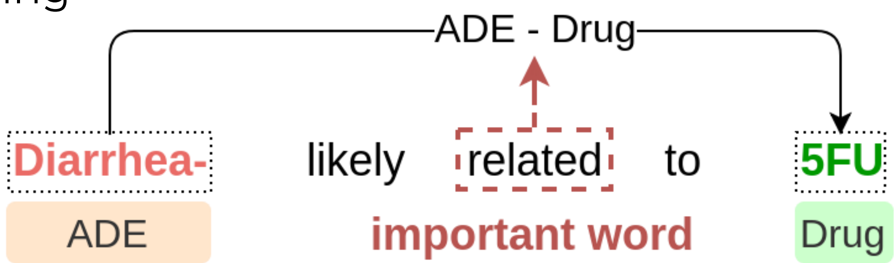
- *Weighted LSTM Model*
- *Walk-based Model*
- *Cross-sentence Model*

Relation Extraction
Weighted LSTM

Motivation

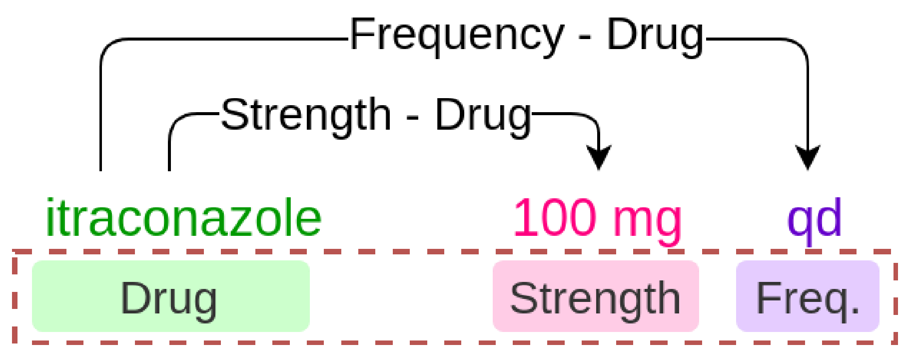
- Context-based word meaning

Sentence



- EHRs contain latent relation patterns e.g. Drug-Form-Frequency

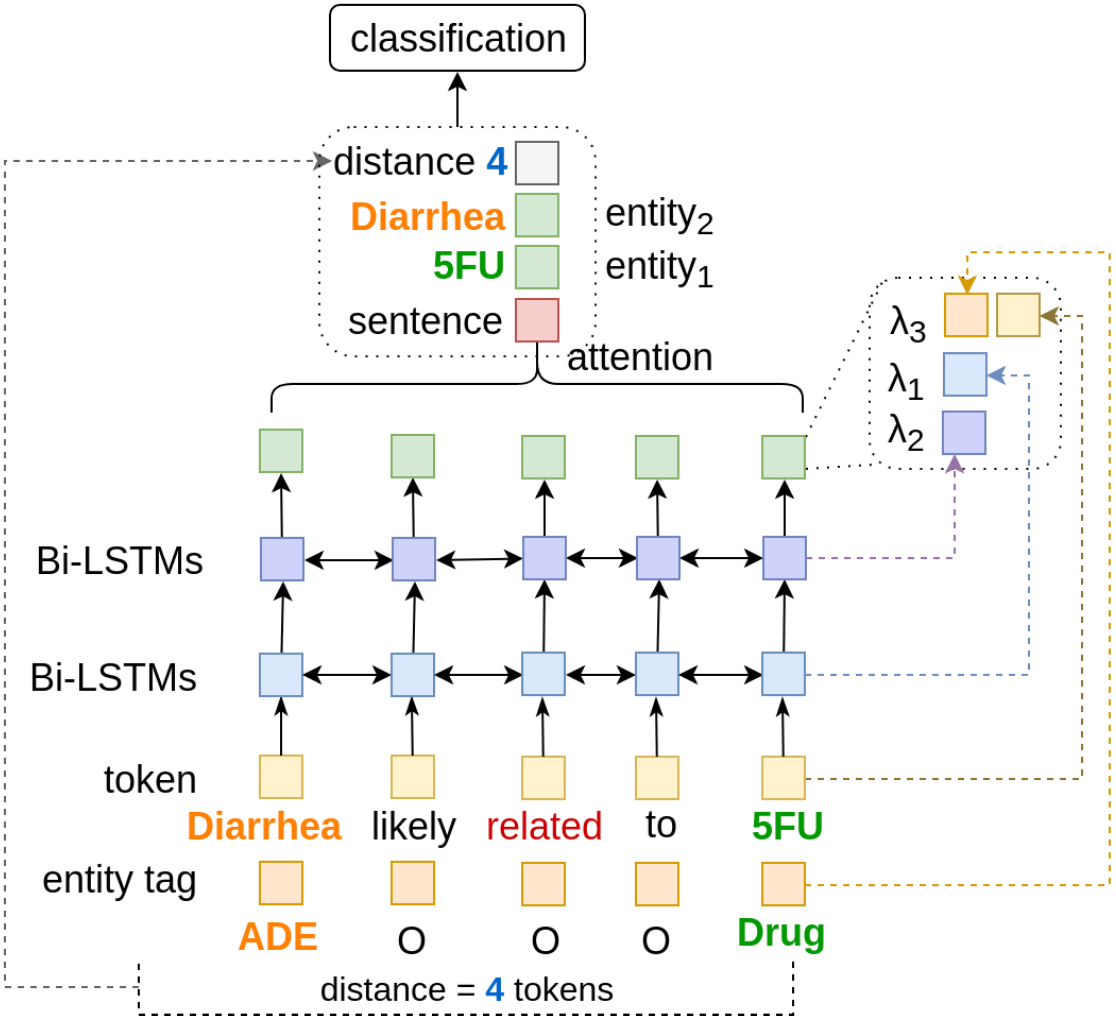
Pattern



Method

- Attention layer: different emphasis on each word
- Entity tags as input: learn relation patterns

Relation Extraction
Weighted LSTM



(Peters et al. 2018; Christopoulou, et al. 2018)

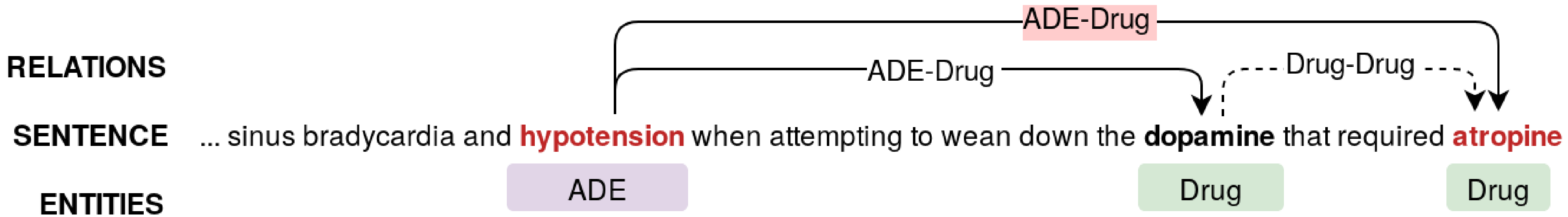
Relation Extraction
Walk-based Neural Network

Motivation

A potentially related entity pair can be supported by co-existing related pairs in the same sentence (Christopoulou, et al. 2018)

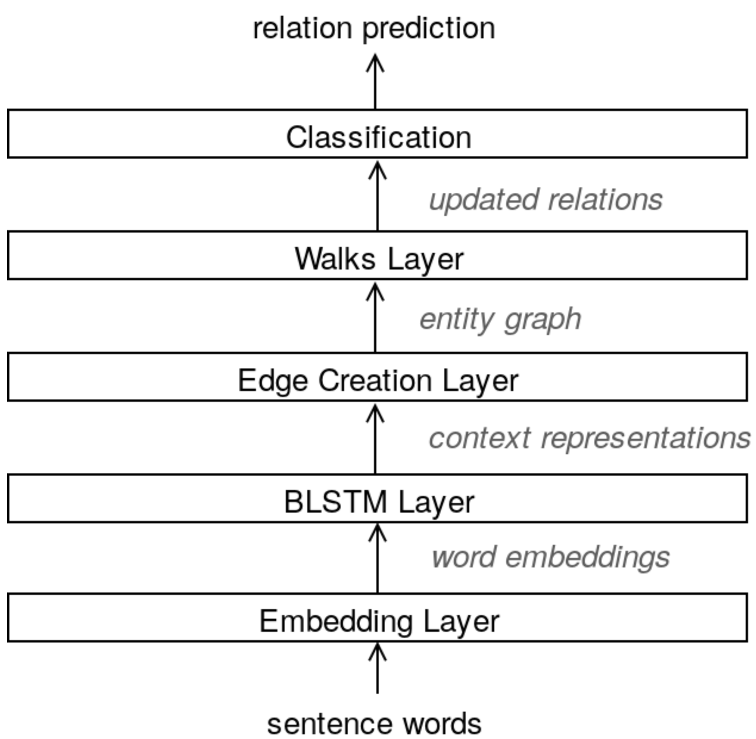
Method

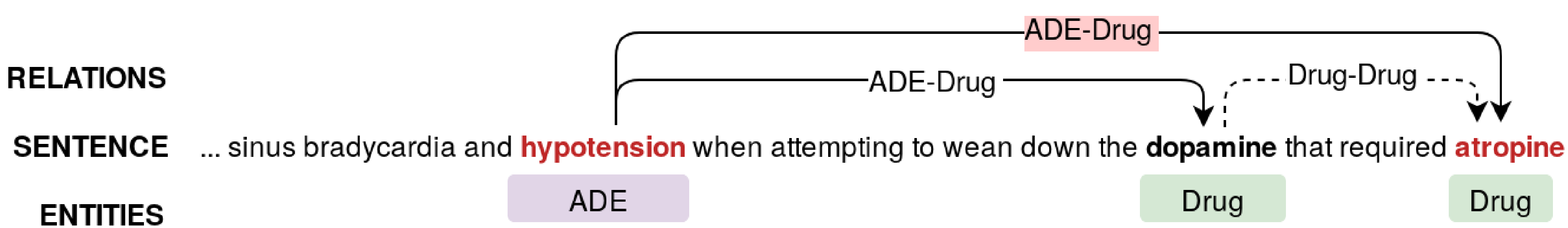
- Map a sentence into a directed graph structure
- Nodes = Entities
- Edges
  - representation of the relation between them
  - building block for 1-to-*l* length walks between the pair entities
- Consider only X-Drug pairs
- Keep Drug-Drug pairs, even without annotation



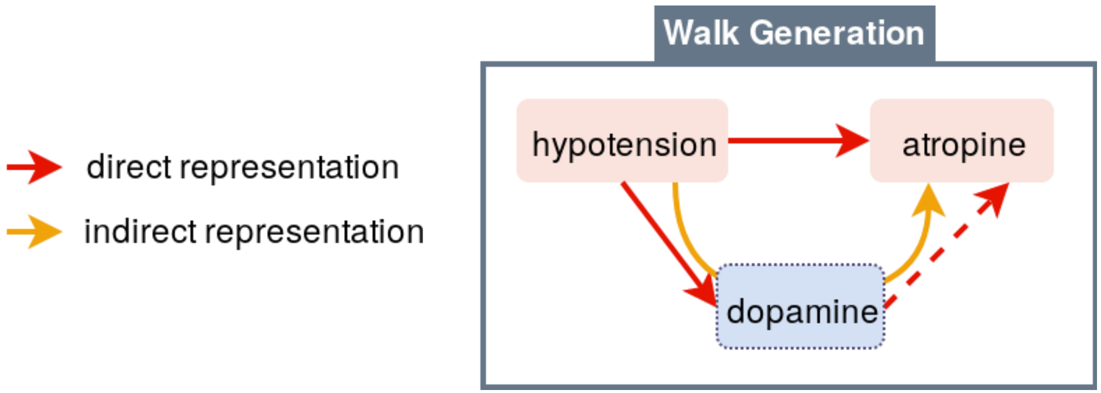
Relation Extraction

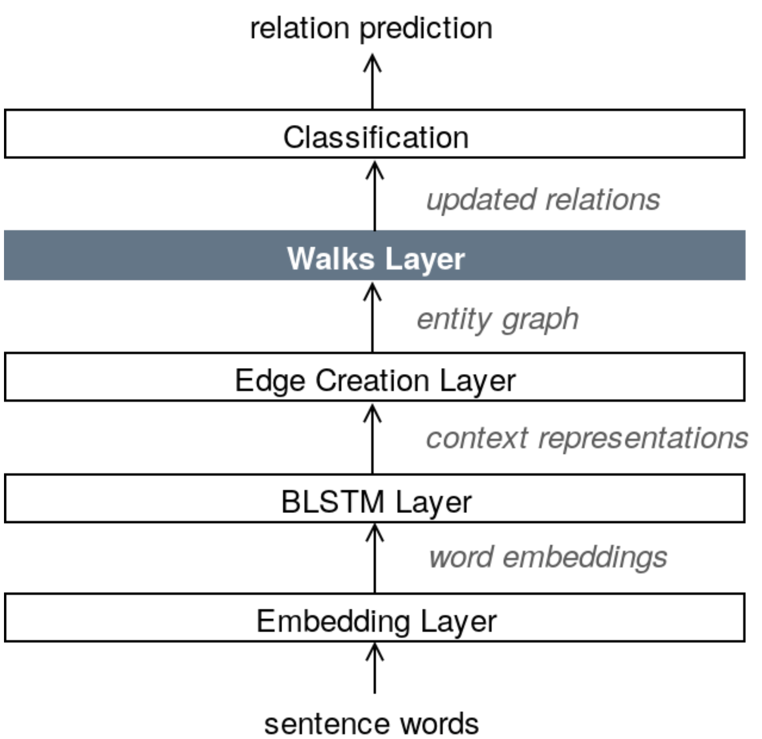
Walk-based Neural Network

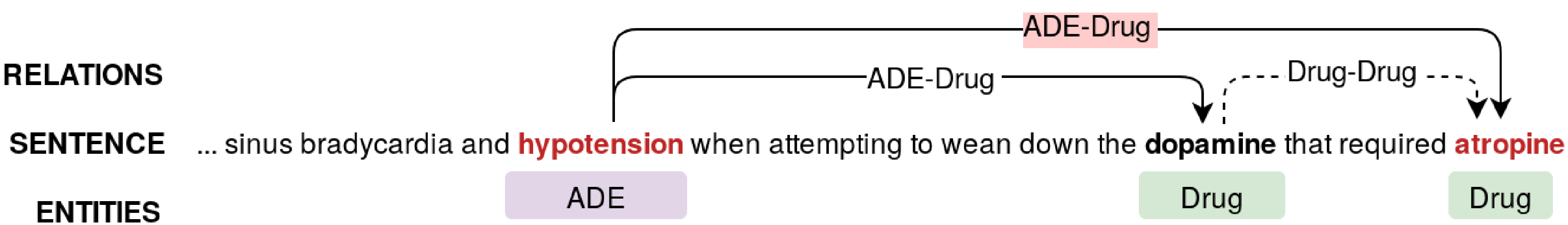




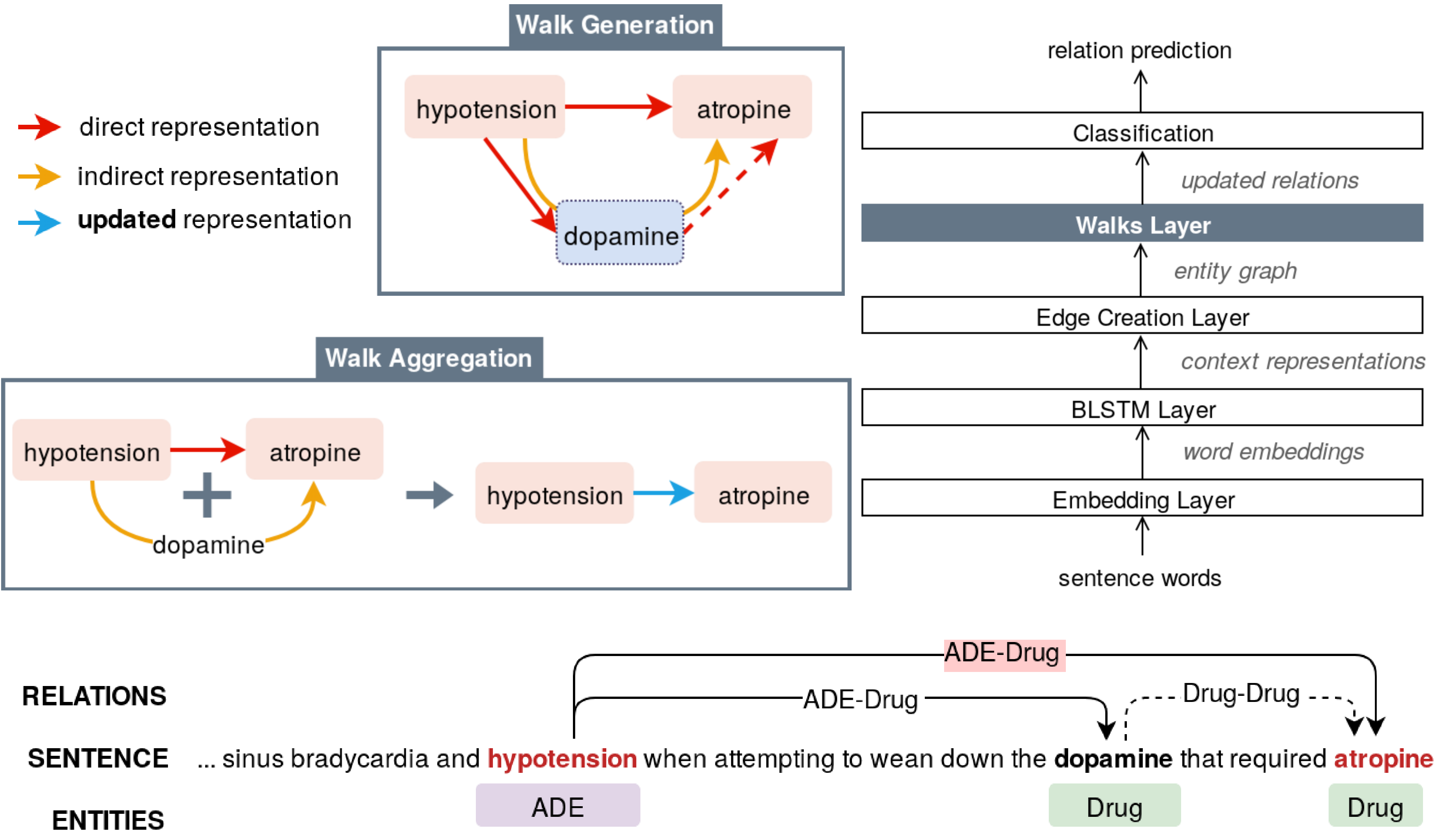
Relation Extraction
Walk-based Neural Network







Relation Extraction
Walk-based Neural Network



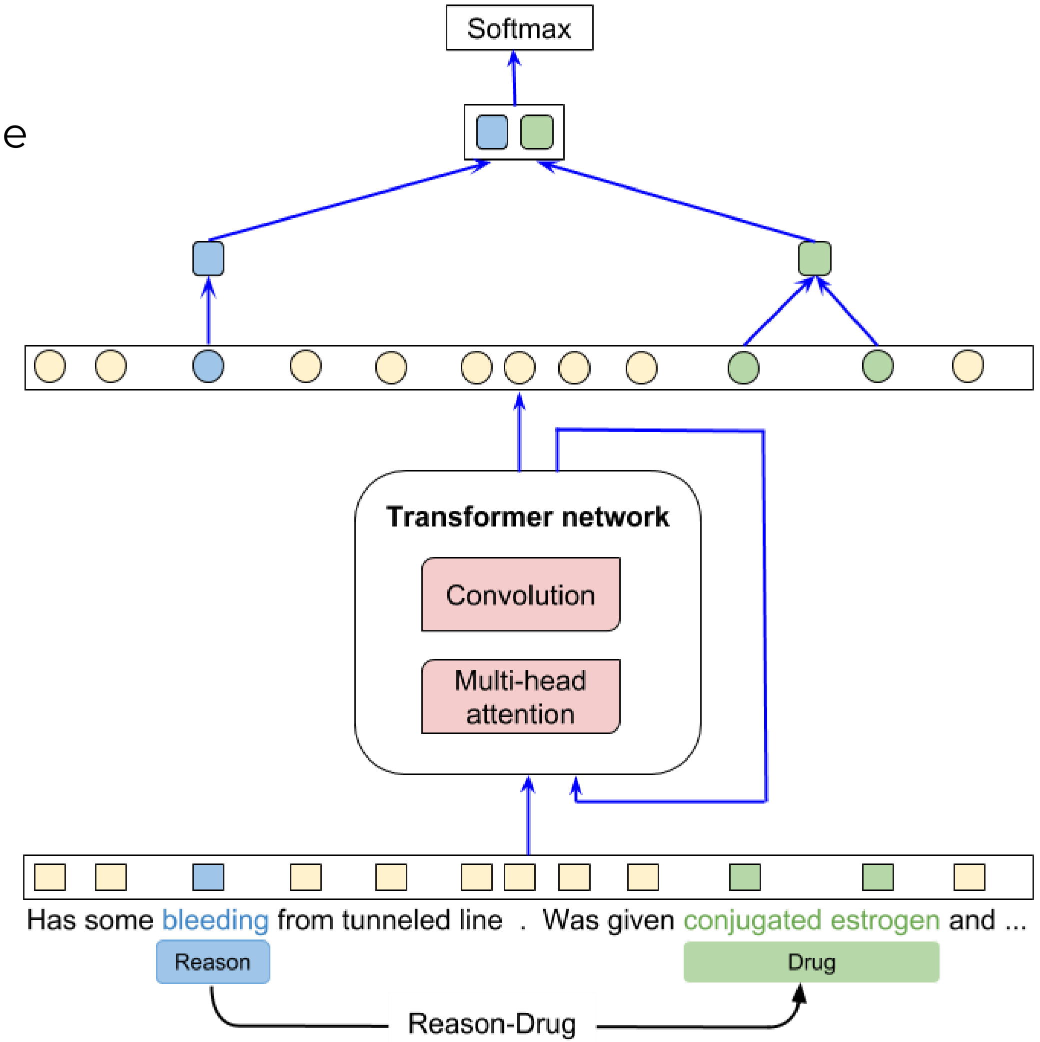
Relation Extraction
Cross-sentence Model

Motivation

- In the dataset, approx. 8 % of the relations are cross-sentence.

Method

- Only drug, non-drug pairs
- Only consider up to two span of sentences
- Employ transformer network (Vaswani et al, 2017)
  - RNN: low time efficient in longer sequence computation

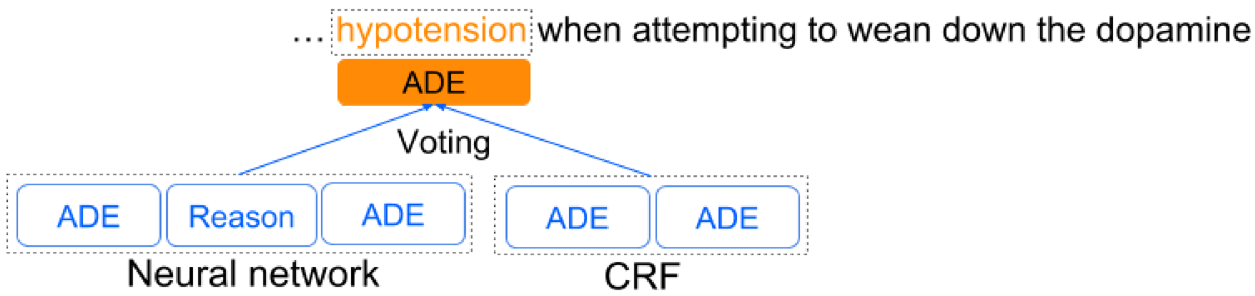


Experimental Results
Relation

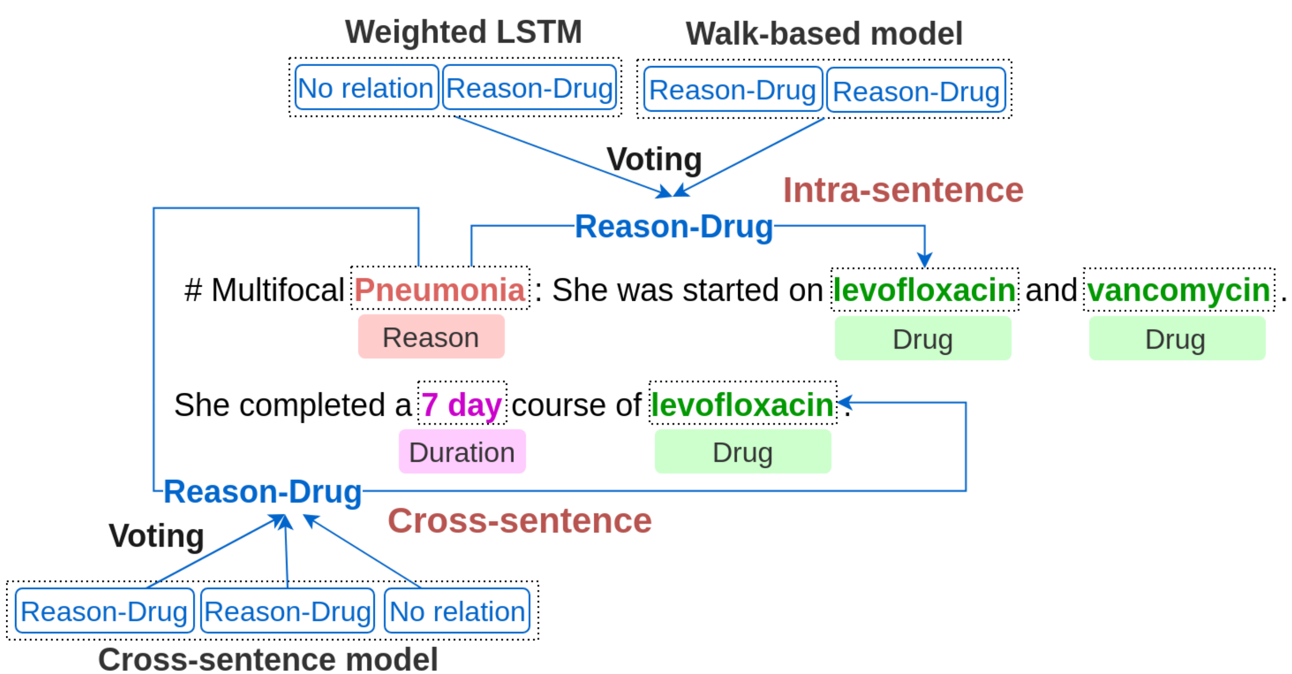
Model	Precision	Recall	F1-score
Weighted LSTM			
Weighted-one-BLSTM	0.9729	0.9108	0.9408
Weighted-stack-BLSTM-hyperparam-set1	0.9751	0.9102	**0.9416**
Weighted-stack-BLSTM-hyperparam-set2	0.9693	0.9146	0.9411
Walk-based Model			
Walks-L2-random_embeddings	0.9792	0.9041	0.9402
Walks-L4-pubmed_embeddings	0.9723	0.9112	0.9408
Walks-L8-pubmed_embeddings	0.9782	0.9086	0.9421
Walks-L8-random_embeddings	0.9721	0.9208	**0.9457**
Cross-sentence Model			
Transformer-span-1	0.9663	0.9077	0.9361
Cross-sentence-transformer-span-2	0.9538	0.9423	**0.9480**
Cross-sentence-transformer-span-3	0.9115	0.9536	0.9321

Ensemble Methods
Majority Voting

Concept



Relation



Submission Results

Track 2

Task	System	P	R	F1
Concept	(1) NN ensemble	0.9664	0.8875	0.9253
	(2) CRF ensemble	0.9532	0.8797	0.9150
	(3) Ensemble of NN and CRF	0.9444	0.9073	**0.9255**
Relation	(1) Walked-based (BEST) + Cross sentence	0.9420	0.9517	0.9468
	(2) Ensemble: Walked-based + Cross sentence	0.9463	0.9467	0.9465
	(3) Ensemble: Weighted LSTM + Walked-based + Cross sentence	0.9463	0.9480	**0.9472**
End-to-end	Concept (1) + Relation (1)	0.9463	0.8091	0.8723
	Concept (3) + Weighted LSTM + Cross sentence	0.9264	0.8318	**0.8765**
	Concept (3) + Relation (3)	0.9284	0.8289	0.8759

Submission Results
Best Concept Ensemble

Category	P	R	F
Drug	0.9567	0.9533	0.9550
Strength	0.9815	0.9804	0.9810
Duration	0.8875	0.7513	0.8138
Route	0.9662	0.9445	0.9552
Form	0.9653	0.9436	0.9543
ADE	0.4697	0.1984	0.2790
Dosage	0.9356	0.9433	0.9395
Reason	0.7254	0.5470	0.6237
Frequency	0.9788	0.9666	0.9727
Overall (micro)	**0.9444**	**0.9073**	**0.9255**
Overall (macro)	0.9397	0.8932	0.9144

Submission Results

Best Relation Ensemble

Category	P	R	F
Strength -> Drug	0.9879	0.984	0.986
Dosage -> Drug	0.9814	0.9777	0.9796
Duration -> Drug	0.8968	0.9178	0.9072
Frequency -> Drug	0.9772	0.9655	0.9713
Form -> Drug	0.9921	0.9792	0.9856
Route -> Drug	0.9804	0.9729	0.9766
Reason -> Drug	0.8080	0.8182	0.8131
ADE -> Drug	0.7029	0.8458	0.7678
Overall (micro)	**0.9462**	**0.9479**	**0.9472**
Overall (macro)	0.9408	0.9449	0.9420

Submission Results

Best End2End Ensemble

Category	P	R	F
Strength -> Drug	0.974	0.9621	0.968
Dosage -> Drug	0.9311	0.9124	0.9217
Duration -> Drug	0.7983	0.6784	0.7335
Frequency -> Drug	0.9672	0.9286	0.9475
Form -> Drug	0.9588	0.9264	0.9423
Route -> Drug	0.9516	0.9140	0.9324
Reason -> Drug	0.7179	0.4463	0.5505
ADE -> Drug	0.502	0.1678	0.2515
Overall (micro)	**0.9264**	**0.8318**	**0.8765**
Overall (macro)	0.9072	0.7954	0.8423

Conclusions

Concept Recognition

- Detect nested and multi-label entities
- NN-based model does not dependent on any external knowledge resources and hand-crafted features

Relation Extraction

- Independence of external syntactic tools and dictionaries
- Detect both intra and cross-sentence relations

THANK YOU FOR YOUR ATTENTION!

Questions?