Consistent CCG Parsing over Multiple Sentences for Improved Logical Reasoning

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Masashi Yoshikawa● Koji Mineshima◆ Hiroshi Noji★ Daisuke Bekki◆

●Nara Institute of Science and Technology, ◆Ochanomizu University, ★Artificial Intelligence Research Center AIST

Ochanomizu University

National Institute of Advanced Industrial Science and Technology

AIST

▶ Background

👉 **Parse failures** are harmful for logic-based RTE systems since they derive inconsistent pred-arg structure. We solve this by modeling explicitly the **consistency** of CCG parses for multiple sentences using Markov Random Field (MRF) model of (Rush+, 2012).

▶ Method

👆 We adopt **locally-factored** A* CCG model of (Yoshikawa+ 2017) that decomposes the probability of a CCG tree into those of its supertags and dependency arcs.

1 Locally-factored Model for CCG

For a sentence: $p(\boldsymbol{y}|\boldsymbol{x}) = \prod p_{dep}(h_i|\boldsymbol{x})p_{cat}(c_i|\boldsymbol{x})$

For sentences: $P(Y|X) = \prod p(\boldsymbol{y}_i|\boldsymbol{x}_i)$

👉 **Supertags** are the key of our method; they determine the most part of a parse structure. We encourage consistent parsing by rewarding **consistent assignment of supertags across sentences** using MRF.

3 Joint Decoding via Dual Decomposition

$$(Y^*, \boldsymbol{z}^*) = \underset{Y \in \mathcal{Y}(X), \boldsymbol{z} \in \mathcal{Z}(X)}{\arg\max} P(Y|X) + g(\boldsymbol{z})$$

$$\text{s.t.} \forall (s,t) \ z_{s,t} = c_{s,t}$$

🏆 **efficient**: Our A* decoder runs very fast in DD iterations when having computed $p_{dep|tag}$ probs once.

🏆 **accurate**: Our method constantly contributes to the improvement in RTE performance, solving challenging parsing problems; cf. **Parsing Results**.

0 Motivating Example

premise:

hypothesis:

Wrong!

Proof fails!

$\forall x.\text{outside}(x) \rightarrow \text{outdoors}(x),$

$\exists x.\text{man}(x) \land \exists e.\text{run}(e,x) \land \text{outside}(e) \nvdash$

$\exists x.\text{man}(x) \land \exists y.\text{outdoors}(y) \land \exists e.\text{run}(e,x,y)$

2 Global Consistency Modeling

s_1: **a few men** are **running** outside

s_2: **a few men** are **running** outdoors

$$\text{MRF}: g(\boldsymbol{z}) \approx \sum_{((s,t),c) \in \text{edges}} \text{sim}(z_{(s,t)}, z_c)$$

$\text{sim}(\cdot)$: similarity between categories, tuned by human

👉 Jointly decode both CCG parser and MRF so that **they assign the same supertags**.

4 Result

Voila!

▶ RTE Experiments

Pipelines of ccg2lambda (Mineshima+, 2015) and LangPro (Abzianidze, 2017):

Premise & Hypothesis → **CCG Parsing** → Semantic Parsing → Theorem Proving → Yes, No, Unknown

English experiment on SICK

Method	Accuracy	Precision	Recall
LangPro (Abzianidze, 2017)			
baseline	81.53	97.51	58.81
+MRF	**81.61**	**97.52**	**59.00**
ccg2lambda (Martínez-Gómez+, 2017)			
baseline	81.95	**97.19**	59.98
+MRF	**82.86**	97.14	**62.18**

English settings:
- SICK (Marelli+, 2014)
- LangPro:
  - tableau-based system
- ccg2lambda:
  - higher-order logic
- Reward the consistent supertag assignment for words with the same surface forms

Japanese experiment on JSeM

Method	Accuracy	Precision	Recall
baseline	67.87	88.34	56.77
+MRF	**71.31**	**88.88**	**62.24**

Japanese settings:
- JSeM (Kawazoe+, 2017)
- ccg2lambda (ja)

▶ Parsing Results

★ Coordination Solved Before ➝ After

T: `The girl is sitting on the couch and is [`S_{ng}`\NP crocheting]`
H: `The girl is sitting on the sofa and` **`crocheting`**

`crocheting`: N ➝ S_{ng}\NP

Fixes coordination with `sofa` to that with `sitting`

★ PP Attachment Solved

T: `A veteran shows different things` **`from`** `a war` **`to`** `some people`
H: `Different things [(NP\NP)/NP from] a war are being shown [(VP\VP)/NP to] some people by a veteran`

`from`: (VP\VP)/NP ➝ (NP\NP)/NP
`to`: (NP\NP)/NP ➝ (VP\VP)/NP

Solves two PP attachments at the same time!

✳ Some Error

T: `A man is [(`S_{ng}`\NP)/NP eating] some food`
H: `The person is` **`eating`**

`eating`: S_{ng}\NP ➝ (S_{ng}\NP)/NP

Wrongly forces into a category for transitive verb