Compositional Semantics and Inference System for Temporal Order based on Japanese CCG

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Introduction

- NLI involving temporal expressions is crucial and challenging
  - **Temporal adverbs**, **temporal expressions**, **verb tenses** and **temporal order** are difficult to represent
    - e.g. "4月3日 (April 3rd)", "以前 (before)", "到着する/した (arrive/arrived)"
- We realize **compositional semantics** and a **logical inference system for temporal inference** in **Japanese** based on **Combinatory Categorial Grammar (CCG)** [Steedman 2000, Bekki 2010]

Inference Examples

P　午後7時以降ロビンは両親を訪ねた。　(After 7 p.m. Robin visited her parents.)
H　16時以降ロビンは両親を訪ねた。　(After 16:00 Robin went to visit her parents.)
Gold answer: Yes (PLMUTE_ja Section: time_multi, No. 11)

P_1　1992年以来、ITELはバーミンガムにある。　(Since 1992 ITEL has been in Birmingham.)
P_2　現在、1996年である。　(It is now 1996.)
H　ITELは1993年にはバーミンガムにあった。　(ITEL was in Birmingham in 1993.)
Gold answer: Yes (JSeM No. 645)

Proposed System

1. Convert the premise and hypothesis into a CCG tree
2. Transform the obtained CCG tree
   - Temporal expressions are treated as a **multi-word expression**
3. Convert a modified CCG tree into a logical formula using **ccg2lambda** [Mineshima+ 2016]
4. Convert logical formulas and axioms into a certain format
5. Determine whether or not a hypothesis is provable from premises
   - Entailment: Yes, Contradiction: No, Neutral: Unknown
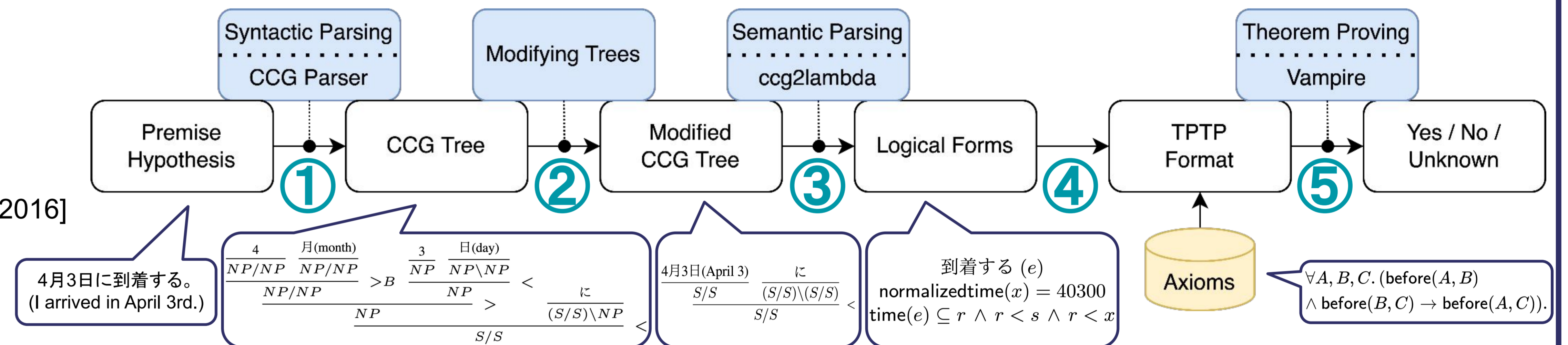
Experiments–Datasets

- **JSeM** [Kawazoe+ 2015]: Japanese version of FraCaS [Cooper+ 1006], the **semantically challenging inferences dataset** involving various linguistic phenomena
  - We use 23 problems involving **temporal order** in temporal reference section
- **PLMUTE_ja**: The dataset that we translated into Japanese from PLMUTE [Thukral+ 2021], a English dataset consisting of temporal inferences involving **various temporal adverbs**

Experiments–Comparison Systems

- **Logic-based system**: Japanese logical inference system for **temporal clauses** [Onishi+ 2020]
- **Deep learning-based systems**
  - **BERT_JSNLI**: Japanese BERT fine-tuned on JSNLI [Yoshikoshi+, 2020] (533,005 examples)
  - **BERT_few**: Japanese BERT fine-tuned on the minimal PLMUTE_ja training set (360 examples)
  - **BERT_all**: Japanese BERT fine-tuned on the entire PLMUTE_ja training set (11,220 examples)

Experiments–Results

- Our system outperformed all models except BERT_all on PLMUTE_ja

Accuracy on JSeM

System		Accuracy
BERT	JSNLI	.522
	few	.217
	all	.435
Onishi et al. (2020)		.478
Our system		**.783**

Accuracy on PLMUTE_ja

System		year	month	date	date_dmy	date_my	day	time_12	time_24	time_multi
Majority		.382	.421	.425	.403	.379	.396	.368	.415	.418
BERT	JSNLI	.394	.413	.382	.400	.400	.380	.378	.415	.368
	few	.509	.517	.509	.491	.476	.518	.440	.453	.515
	all	.997	1.000	.998	.985	.982	1.000	1.000	.998	.960
Onishi et al. (2020)		.238	.265	.239	.206	.244	.291	.290	.225	.253
Our system		1.000	1.000	.980	.971	.974	.984	.943	.970	.953

Analysis

- Our system did not solve the problems involving **comparative deletion** and **temporal connectives** such as "より先 (before)" and "より後 (after)"

P_1　ジョーンズが契約書を修正した。
(Jones revised the contract.)
P_2　スミスが契約書を修正した。
(Smith revised the contract.)
P_3　ジョーンズがスミスより先に契約書を修正した。
(Jones revised the contract after Smith did.)
H　スミスはジョーンズより後に契約書を修正した。
(Smith revised the contract before Jones did.)
Gold answer: yes (JSeM No. 659)

Conclusion and Future Work

- We developed a logic-based NLI system for temporal order in Japanese
  - Our system performed **more robustly** than previous logic-based systems as well as current deep learning-based models
- In the future, we plan to cover various temporal inferences (e.g. comparative deletion and temporal anaphora)
  - We also plan to construct inference test sets for these challenging inferences