



中国科学技术大学  
University of Science and Technology of China



# NL4Opt: Natural Language for Optimizing Modeling Team Long Solution

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**Reporter: Yuting Ning**

# Outline

<b>1</b>	<b>Background</b>
<b>2</b>	<b>Subtask1 Solution</b>
<b>3</b>	<b>Subtask2 Solution</b>
<b>4</b>	<b>Conclusion</b>

# Self-introduction

## ➤ Team Long

### ➤ Team members

- Jiayu Liu, Longhu Qin, Yuting Ning, Tong Xiao, Shangzi Xue, Zhenya Huang, Qi Liu, Enhong Chen, Jinze Wu

### ➤ Affiliation

- University of Science and Technology of China

### ➤ Research Interest

- Our research mainly focuses on applying BigData and AI techniques to education and science.
- Some of the topics include: educational resource understanding, cognitive diagnosis and student modeling, personalized education services, etc.

# Background

## ➤ Background

- Many real-world decision-making problems can be formulated and solved as mathematical optimization problems.
- Modeling a problem into a proper formulation is a complex and time-consuming process.

## ➤ Research Problem

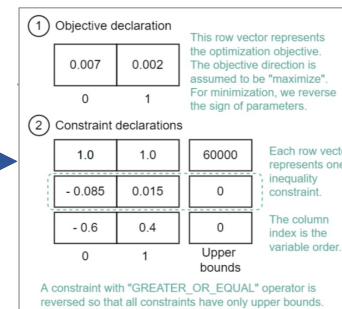
- Can learning-based natural language interfaces be leveraged to convert linear programming (LP) word problems into a format that solvers can understand?
  - Challenge 1: detect problem entities from the problem description
  - Challenge 2: generate a precise meaning representation of the optimization formulation

Your client has \$60,000 available to invest for a one-year term. The money can be placed in a trust yielding a 7% return or in a savings account yielding a 2% return. Based on your client's investment goals, you advise her that at least 15% of the investment be placed in the trust. Given her risk profile, she also requests that the money placed in savings should not exceed 60% of her total investment. How much should your client invest in each so as to maximize her return?

Subtask1

```
[{"text": "60,000", "label": "limit", "start_char": 17, "end_char": 23}, {"text": "available", "label": "constraint_direction", "start_char": 24, "end_char": 33}, {"text": "trust", "label": "variable", "start_char": 94, "end_char": 99}, {"text": "maximize", "label": "objective_direction", "start_char": 400, "end_char": 409}, {"text": "return", "label": "objective_name", "start_char": 413, "end_char": 433}]
```

Subtask2



# Outline

**1**

**Background**

**2**

**Subtask1 Solution**

**3**

**Subtask2 Solution**

**4**

**Conclusion**

# Subtask1 Solution

## ➤ Our Method

### ➤ Pre-processing

#### ➤ Data Augmentation

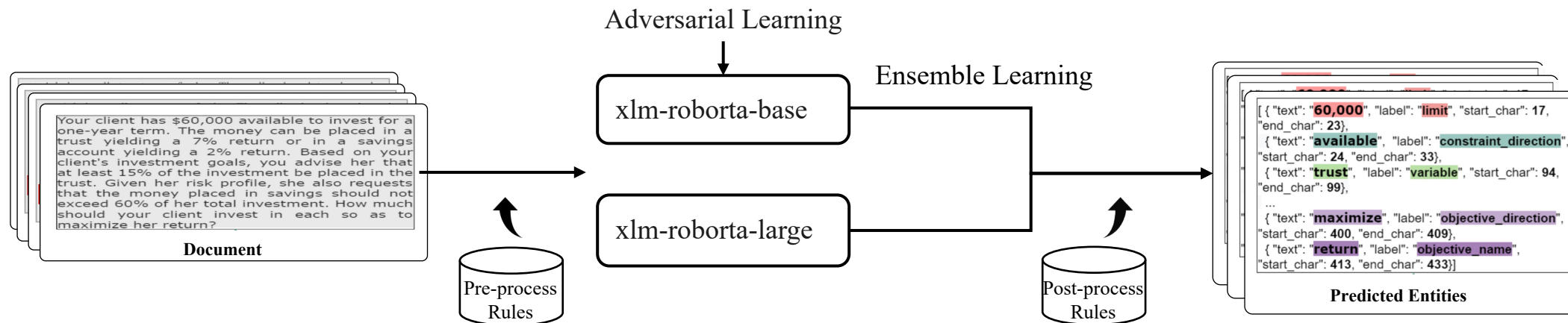
- Swap variables, synonym replace for OBJ\_NAME, randomly replace numbers

#### ➤ Label Standardization

- Remove *times* after numbers in PARAM and LIMIT entity

### ➤ Adversarial Training

- Use Projected Gradient Descent<sup>[1]</sup> to improve the robustness and generalization ability of the model



[1] Aleksander Madry et al. Towards Deep Learning Models Resistant to Adversarial Attacks. ICLR 2018.

# Outline

**1**

**Background**

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**Subtask1 Solution**

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**Subtask2 Solution**

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**Conclusion**

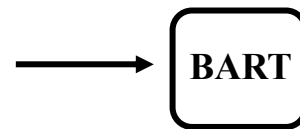
# Subtask2 Solution

- Framework
  - Following the provided baseline
    - Prompt-guided input
    - Encoder-decoder model
    - Intermediate Representation
    - Canonical Formulation

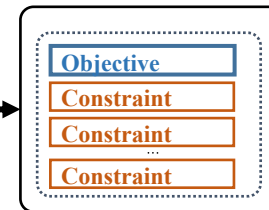
**Prompt-guided Input**

`<CONST_DIR>at most</CONST_DIR>` s>A bakery sells two types of cakes. They sell a chocolate cake and a vanilla cake. Let's say they make  $x_1$  chocolate cakes, at a profit of \$10 each, and  $x_2$  vanilla cakes, at a profit of \$11 each ( $x_1$  and  $x_2$  are unknowns both greater than or equal to 0). The daily demand for these cakes is at most 50 chocolate cakes and at most 30 vanilla cakes. The bakery is short staffed and can make a maximum of 50 cakes of either type per day. How much of each cake should the bakery make in order to maximize profit?</s>

**Prompt-guided Input**



**Encoder-Decoder Model**



**Intermediate Representation**

Parser

① Objective declaration

0.007	0.002	
0	1	

This row vector represents the optimization objective. The objective direction is assumed to be "maximize". For minimization, we reverse the sign of parameters.

② Constraint declarations

1.0	1.0	60000
-0.085	0.015	0
-0.6	0.4	0
0	1	Upper bounds

Each row vector represents one inequality constraint.

The column index is the variable order.

A constraint with "GREATER\_OR\_EQUAL" operator is reversed so that all constraints have only upper bounds.

**Canonical Formulation**

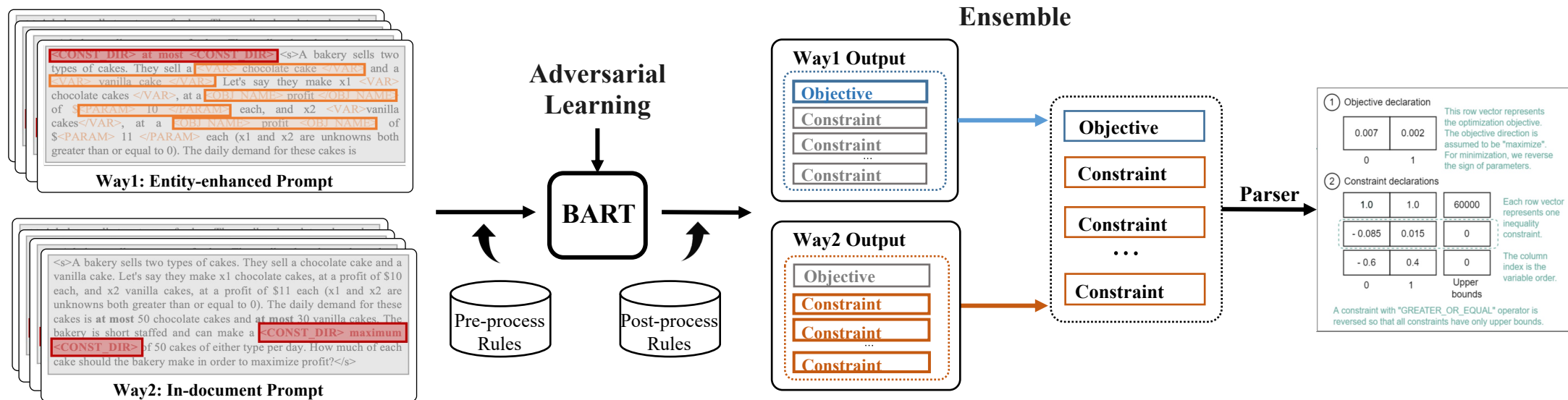


# Subtask2 Solution

## ➤ Framework

### ➤ Following the provided baseline

- Prompt-guided input ← **Prompt re-design**
- Encoder-decoder model ← **Adversarial Training**
- Intermediate Representation ← **Ensemble & Post-processing**
- Canonical Formulation

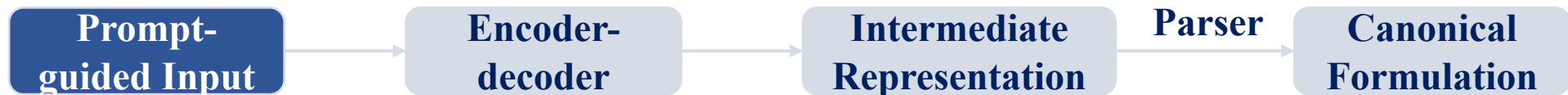


# Subtask2 Solution

- Prompt-guided input
  - Prompt re-design
    - Original prompt of baseline
    - Re-designed prompt
      - Version1: Insert the prompt in the document
      - Version2: Entity-enhanced prompt
  - Repeat CONST\_DIR

**<CONST\_DIR>at most</CONST\_DIR>**<s>A bakery sells two types of cakes. They sell a chocolate cake and a vanilla cake. Let's say they make  $x_1$  chocolate cakes, at a profit of \$10 each, and  $x_2$  vanilla cakes, at a profit of \$11 each ( $x_1$  and  $x_2$  are unknowns both greater than or equal to 0). The daily demand for these cakes is **at most** 50 chocolate cakes and **at most** 30 vanilla cakes. The bakery is short staffed and can make a maximum of 50 cakes of either type per day. How much of each cake should the bakery make in order to maximize profit?</s>

Original prompt of baseline



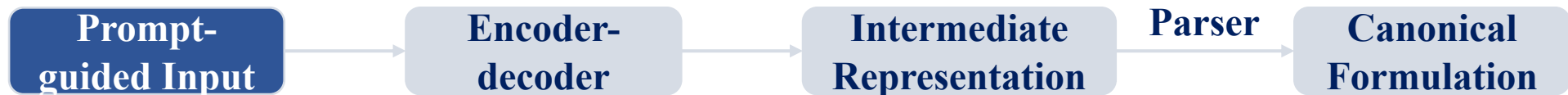
# Subtask2 Solution

- Prompt-guided input
  - Prompt re-design
    - Original prompt of baseline
    - Re-designed prompt
      - Version1: Insert the prompt in the document
      - Version2: Entity-enhanced prompt
  - Repeat CONST\_DIR

<s>A bakery sells two types of cakes. They sell a chocolate cake and a vanilla cake. Let's say they make x1 chocolate cakes, at a profit of \$10 each, and x2 vanilla cakes, at a profit of \$11 each (x1 and x2 are unknowns both greater than or equal to 0). The daily demand for these cakes is **<CONST\_DIR> at most <CONST\_DIR>** 50 chocolate cakes and **at most** 30 vanilla cakes. The bakery is short staffed and can make a maximum of 50 cakes of either type per day. How much of each cake should the bakery make in order to maximize profit?</s>

Version1: Insert the prompt in the document

Method	VAL_ACC	CONST_ACC	OBJ_ACC	TEST_ACC
baseline	0.6149	0.5502	0.7778	0.641
Version1 Prompt	0.7586	0.7149	0.8687	0.803



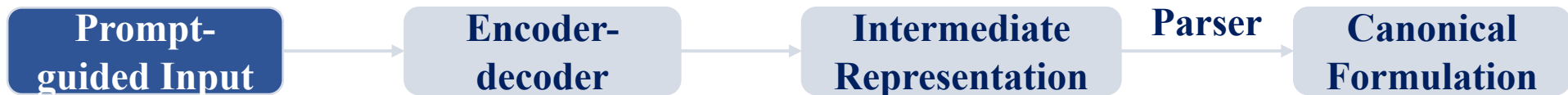
# Subtask2 Solution

- Prompt-guided input
  - Prompt re-design
    - Original prompt of baseline
    - Re-designed prompt
      - Version1: Insert the prompt in the document
      - Version2: Entity-enhanced prompt
  - Repeat CONST\_DIR

**<CONST\_DIR> at most <CONST\_DIR>** <s>A bakery sells two types of cakes. They sell a <VAR> chocolate cake </VAR> and a <VAR> vanilla cake </VAR>. Let's say they make x1 <VAR> chocolate cakes </VAR>, at a <OBJ\_NAME> profit </OBJ\_NAME> of \$<PARAM> 10 </PARAM> each, and x2 <VAR>vanilla cakes</VAR>, at a <OBJ\_NAME> profit <OBJ\_NAME> of \$<PARAM> 11 </PARAM> each (x1 and x2 are unknowns both greater than or equal to 0). The daily demand for these cakes is <CONST\_DIR> at most <CONST\_DIR> <LIMIT> 50 </LIMIT>...

Version2: entity-enhanced prompt

Method	VAL_ACC	CONST_ACC	OBJ_ACC	TEST_ACC
baseline	0.6149	0.5502	0.7778	0.641
Version1 Prompt	0.7586	0.7149	0.8687	0.803
Version2 Prompt	0.6667	0.5542	0.9394	0.708



# Subtask2 Solution

- Prompt-guided input
  - Prompt re-design
    - Original prompt of baseline
    - Re-designed prompt
      - Version1: Insert the prompt in the document
      - Version2: Entity-enhanced prompt
  - Repeat CONST\_DIR

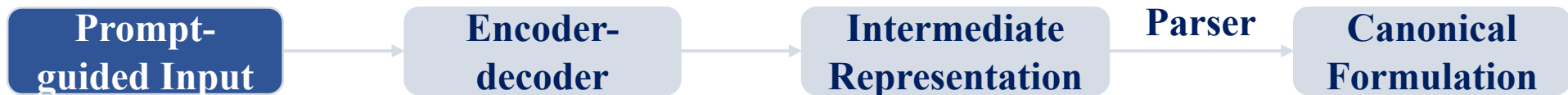
Avian would like the commercials to be seen by **at least 86** million young girls and **72** million middle-aged women.

**2** LIMIT entities are related to **1** CONST\_DIR.  
**2** declarations are generated by **1** CONST\_DIR entity.



Avian would like the commercials to be seen by **at least 86** million young girls and **at least 72** million middle-aged women.

Repeat the CONST\_DIR entity before the second LIMIT entity

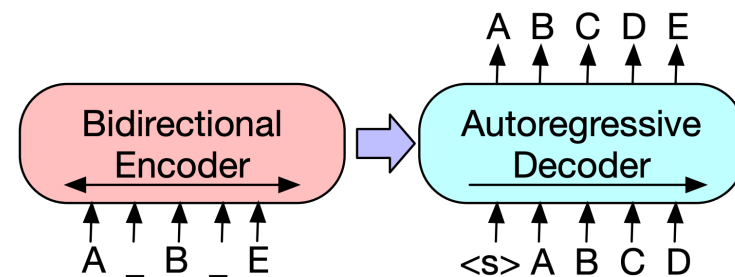


# Subtask2 Solution

## ➤ Encoder-decoder model

### ➤ Model

#### ➤ BART<sup>[2]</sup>



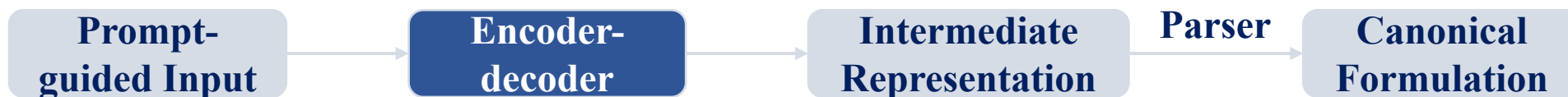
BART model

### ➤ Adversarial Training

➤ A training method that introduces noise and improve the robustness and generalization ability of model

➤ We use Fast Gradient Method<sup>[3]</sup> here

Method	VAL_ACC	CONST_ACC	OBJ_ACC	TEST_ACC
baseline	0.6149	0.5502	0.7778	0.641
Version1 Prompt	0.7586	0.7149	0.8687	0.803
+ fgm	0.7845			0.825
+ repeat const_dir	0.8649			0.856



[2] Mike Lewis et al. BART: Denoising Sequence-to-Sequence Pre-training for Natural Language Generation, Translation, and Comprehension

[3] Takeru Miyato, Andrew M. Dai, Ian Goodfellow. Adversarial Training Methods for Semi-Supervised Text Classification. ICLR 2017.

# Subtask2 Solution

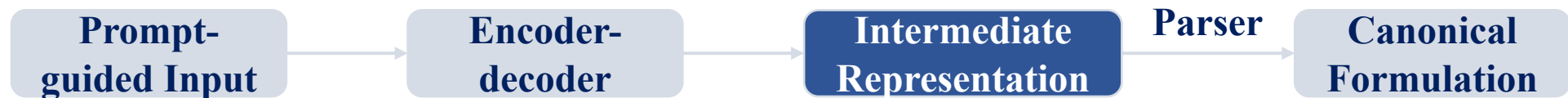
## ➤ Intermediate Representation

### ➤ Ensemble

- obj\_declaration: version2 prompt-guided input
- const\_declarations: version1 prompt-guided input + CONST\_DIR repeat + adversarial training

### ➤ Post-processing

- Rule1: correct wrong operator direction
- Rule2: correct wrong unseen numbers



# Subtask2 Solution

## ➤ Intermediate Representation

### ➤ Ensemble

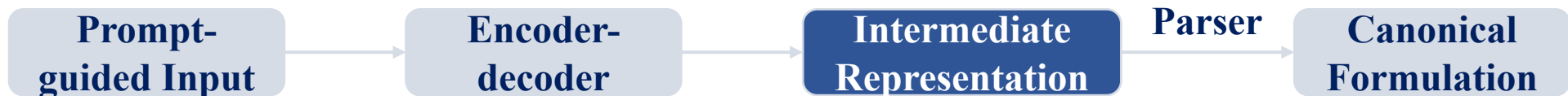
- obj\_declaration: version2 prompt-guided input
- const\_declarations: version1 prompt-guided input + CONST\_DIR repeat + adversarial training

### ➤ Post-processing

- Rule1: correct wrong operator direction
- Rule2: correct wrong unseen numbers

```
<DECLARATION>
<CONST_DIR> larger than </CONST_DIR>
<OPERATOR> LESS_OR_EQUAL </OPERATOR>
<CONST_TYPE> [XBY_CONSTRAINT] </CONST_TYPE>
<VAR> “puff of air </VAR> [TIMES] <PARAM> 0.02 </PARAM>
<VAR> tonometer test </VAR> [TIMES] <PARAM> 0.05 </PARAM>
</DECLARATION>
```

Wrong operator direction





# Subtask2 Solution

## ➤ Intermediate Representation

### ➤ Ensemble

- obj\_declaration: version2 prompt-guided input
- const\_declarations: version1 prompt-guided input + CONST\_DIR repeat + adversarial training

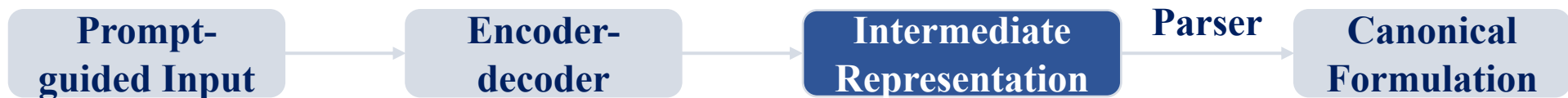
### ➤ Post-processing

- Rule1: correct wrong operator direction
- Rule2: correct wrong unseen numbers

**Document:** ...If there is a budget of \$**6500**, how many of each type of employee should the firm schedule to work to minimize the total number of shifts?

**Intermediate Representation:** ...OPERATOR> LESS\_OR\_EQUAL  
</OPERATOR><LIMIT> **6500** </LIMIT>...

Wrong unseen numbers



# Subtask2 Solution

- Experimental Result
  - Prompt re-design significantly improves the performance
    - Introducing the position of CONST\_DIR is necessary.
    - Introducing rich information in provided entities is necessary.
    - Repeating CONST\_DIR which is followed by two LIMIT alleviates the mismatch between the number of the ground truth and predicted declarations.
  - It is useful to integrate different models to predict different types of declaration

Method	VAL_ACC	CONST_ACC	OBJ_ACC	TEST_ACC
baseline	0.6149	0.5502	0.7778	0.641
Version1 Prompt	0.7586	0.7149	0.8687	0.803
+ fgm	0.7845			0.825
+ repeat const_dir*	0.8649			<b>0.856</b>
Version2 Prompt*	0.6667	0.5542	0.9394	<b>0.708</b>
+ fgm	0.6810			0.693
Ensemble				0.867
+ post-processing				<b>0.880</b>

# Subtask2 Solution

- Future Direction
  - Constraint the prefix of intermediate representation
  - Data augmentation or more pre-processing rules
  - More attempts of prompt design

```
<DECLARATION>  
<CONST_DIR> larger than </CONST_DIR>  
<OPERATOR> LARGE_OR_EQUAL </OPERATOR>  
<CONST_TYPE> [XBY_CONSTRAINT] </CONST_TYPE>  
<VAR> puff of air </VAR> [TIMES] <PARAM> 0.02 </PARAM>  
<VAR> tonometer test </VAR> [TIMES] <PARAM> 0.05 </PARAM>  
</DECLARATION>
```

# Outline

**1**

**Background**

**2**

**Subtask1 Solution**

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**Subtask2 Solution**

**4**

**Conclusion**

# Conclusion

- Conclusion
  - Subtask1 Solution
    - Ensemble learning with adversarial training and pre&post-processing
  - Subtask2 Solution
    - Prompt re-design
    - Adversarial training
    - Ensemble
    - Post-processing

# Q & A



## Thanks!

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