Machine Translation based on Predicate-Argument Structure

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Outline

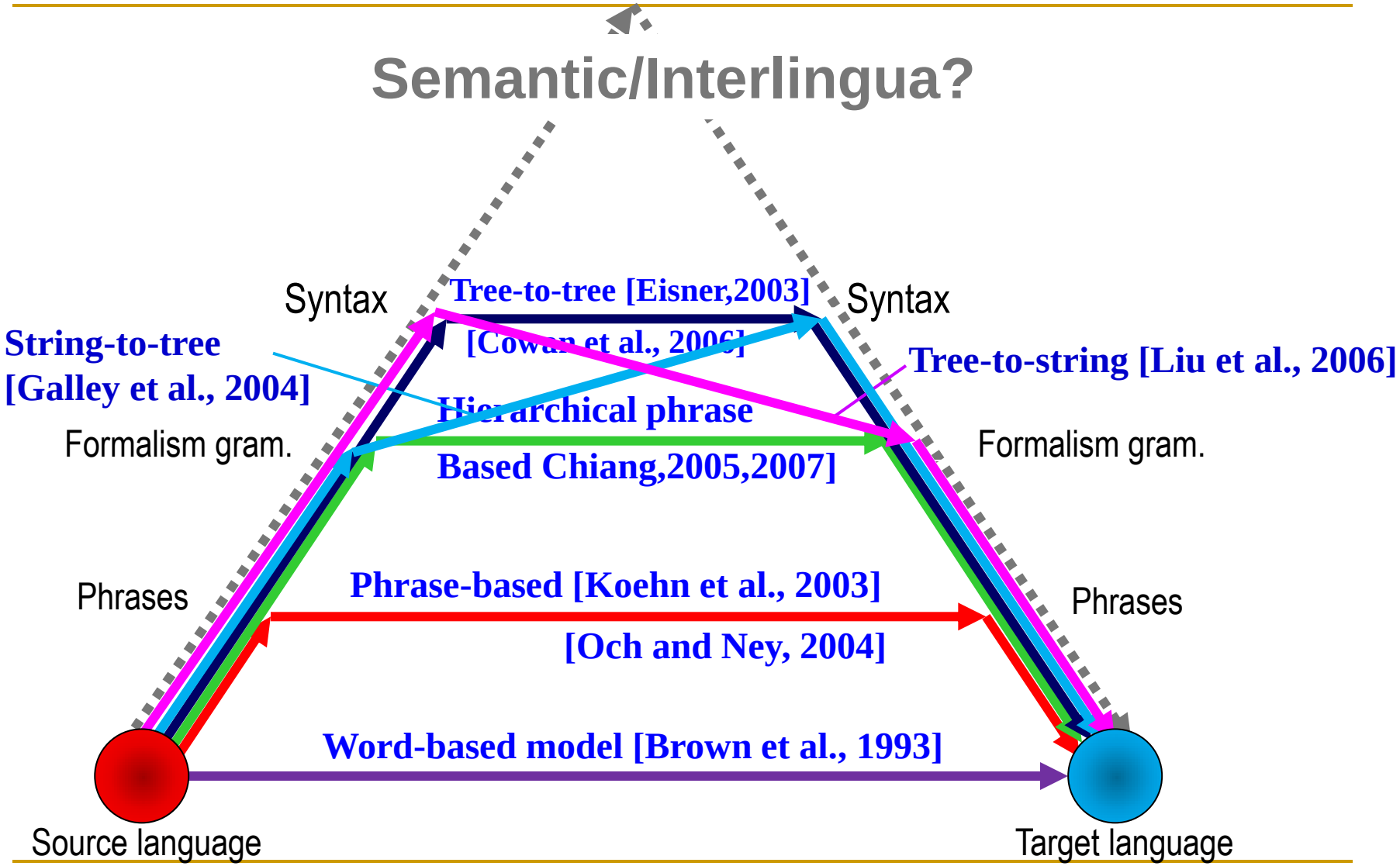
1. Introduction
2. Syntax-Complemented PAS
3. Transformation Rule Extraction
4. ATT Framework
5. Decoder
6. Experiment
7. Conclusion

1. Introduction

- Current Translation Models
  - Word-based Translation Model
    - Brown et al., 1993
  - Phrase-based Translation Model
    - Koehn et al., 2003
    - Och and Ney, 2004
  - Syntax-based Translation Model
    - Galley et al., 2006;
    - Liu et al., 2006;
    - Marcu et al., 2006

    …

1. Introduction



1. Introduction

◆ How to represent the meanings of a sentence?

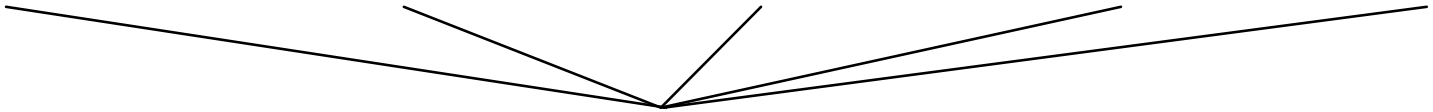
Predicate-Argument Structure (PAS)

- A **PAS** consists of a predicate and several associated arguments.
- The semantic relation between the predicate and its arguments is annotated.

This plan will provide tax concessions to the working masses.

此 项 计划 将 对 劳动 大众 提供 减税 优惠

[A0] [AM-ADV] [A2] [Pred] [A1]



PAS for Chinese predicate “提供”

1. Introduction

We can see:

- PAS Indicates the skeleton structure and shallow semantic information of sentence
- PAS of both source side and target side are more consistent with each other than syntactic structures[Fung et al., 2006; Wu and Fung, 2009]
- Compared with syntactic structure, PAS will be a better alternative for building translation models

1. Introduction

◆ Existing work on PAS for SMT

(1) Pre-process or post-process

- [Komachi and Matsumoto, 2006]
- [Wu and Fung, 2009]

■ The weakness:

- ➢ PAS is only used before or after decoding, rather than integrated into the decoder.
- ➢ Cannot handle the erroneous PAS, considering current PAS analysing system is not such satisfied.

1. Introduction

(2) Utilizing semantic role labeling tags to refine the non-terminals of syntax-based SMT

- [Liu and Gildea, 2008]
- [Gao and Vogel, 2011]

■ **The weakness:**

- ➢ Only utilize the semantic roles to refine the syntax tags.
- ➢ The core of PAS, i.e., its skeleton property and semantic property, is not effectively accessed during translation.

1. Introduction

(3) Design proper PAS-based features to constrain translation candidates

- [Liu and Gildea, 2010]
- [Xiong et al., 2012]

■ **The weakness:**

- Do not consider the PAS as an entire semantic structure in the decoder
- The property of structure consistency between languages in PAS is not effectively modeled
- Reordering is only based on partial PAS

1. Introduction

- **In summary:**

  The existing approaches just introduce some additional information for existing translation models. There is not a translation model built based on PAS.

1. Introduction

We propose an **A**nalysis-**T**ransformation-**T**ranslation(**ATT**) framework:

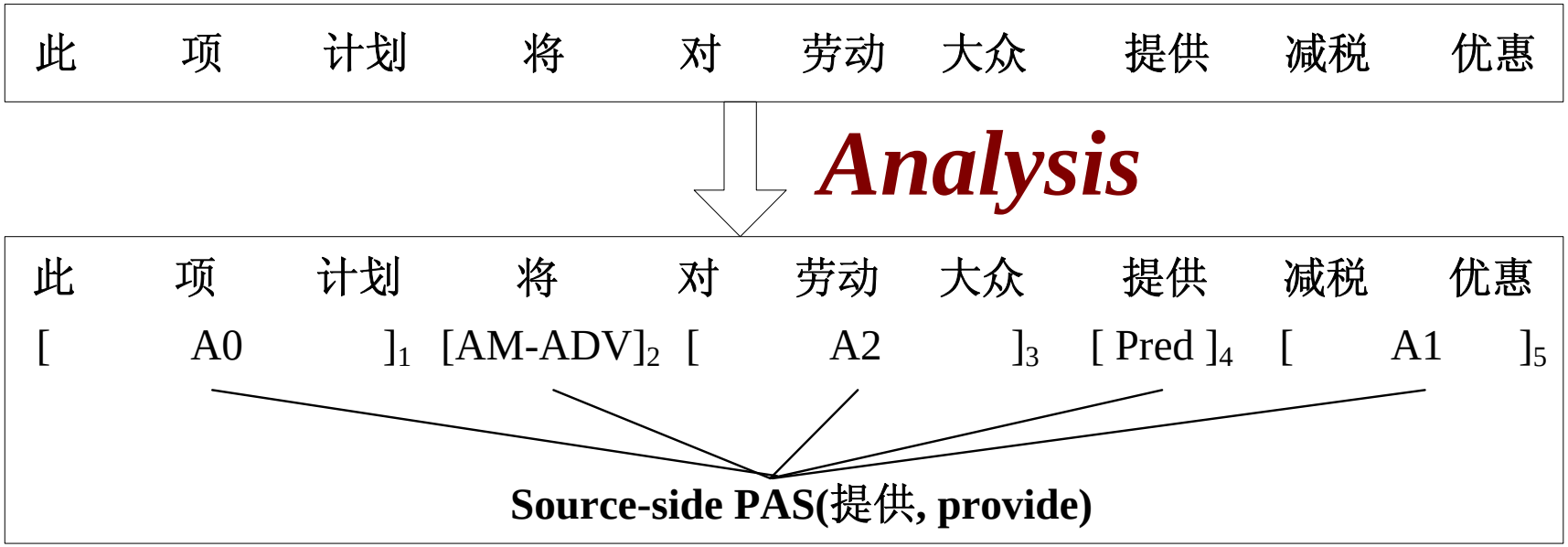
- **A**nalysis
- **T**ransformation
- **T**ranslation
  - Element translation
  - Translation by global reordering

1. Introduction

■ Step-1: Analysis

Semantic role labelling (SRL) on the input sentences to get **source-side PASs**

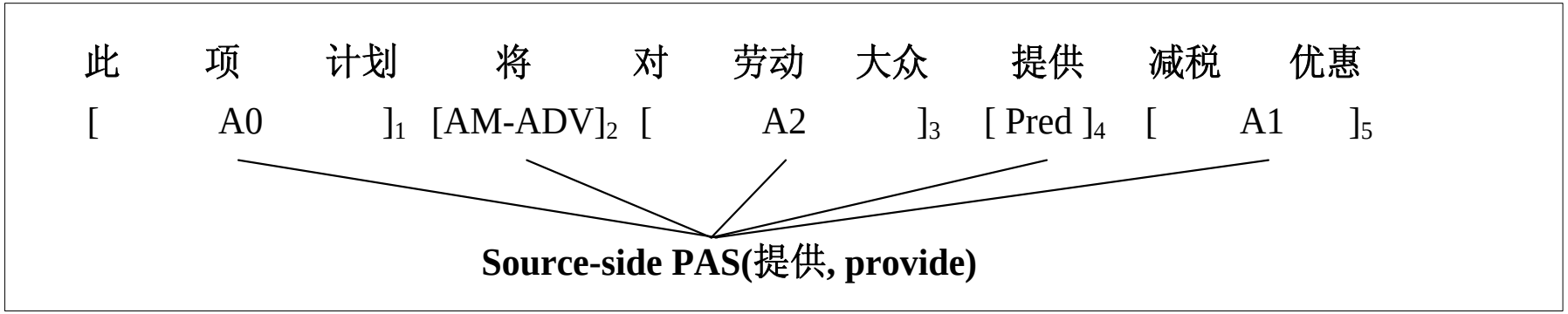
This plan will provide tax concessions to the working masses.

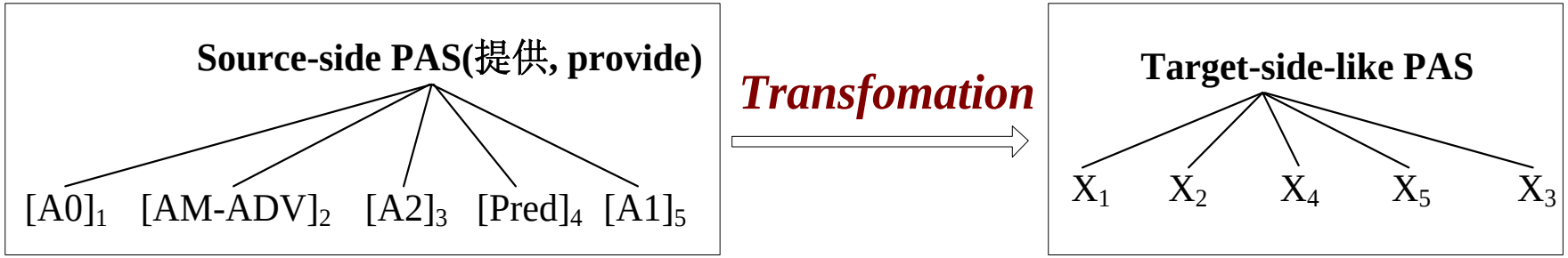


1. Introduction

■ Step-2: Transformation

Convert the source-side PASs to target-side-like PASs by **predicate-aware PAS transformation rules**





1. Introduction

■ Step-3: Translation

(a)Element translation: translate each source element (source predicate or argument) respectively

Source elements:

[A0]$_1$: 此 项 计划
[AM-ADV]$_2$: 将
[A2]$_3$: 对 劳动 大众
[Pred]$_4$: 提供
[A1]$_5$: 减税 优惠

Element translation

Translation candidates of source elements:

[A0]$_1$: this project / this plan / ...
[AM-ADV]$_2$: will / ...
[A2]$_3$: to public / to the working masses/...
[Pred]$_4$: provide / to provide / ...
[A1]$_5$: tax concessions / ...

1. Introduction

(b)Translation by global reordering: combine the translation candidates of source elements to get the final translation based on the target-side-like PAS

Translation candidates of source elements:

[A0]$_1$: this project / this plan / ...
[AM-ADV]$_2$: will / ...
[A2]$_3$: to public / to the working masses / ...
[Pred]$_4$: provide / to provide / ...
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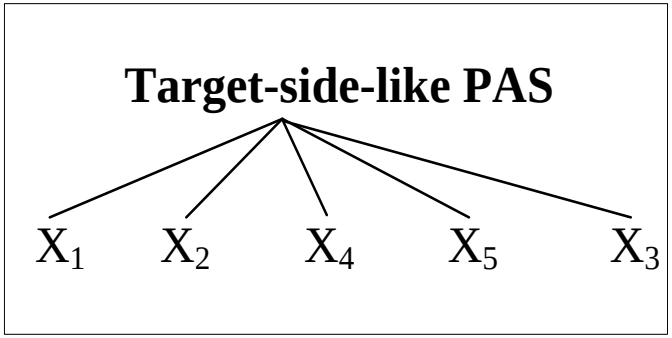

(b) Translation by global reordering

this plan / will / provide / tax concessions / to the working masses

1. Introduction

- **The strongpoints of ATT framework:**
  - The translation process transforms the skeleton structure of the source sentence into the skeleton of target language
  - It works similar to a human translator to some extent

  It is a big step towards semantics-based machine translation

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2. Syntax-Complemented PAS

◆ The problem of PAS

In a PAS representation, the adjacent elements are usually separated by gap strings.

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ARG0		Pred	ARG1
奥运村 的 位置 the location of the olympic village	对 运动员 for athletes	是 is	最 好 的 the best

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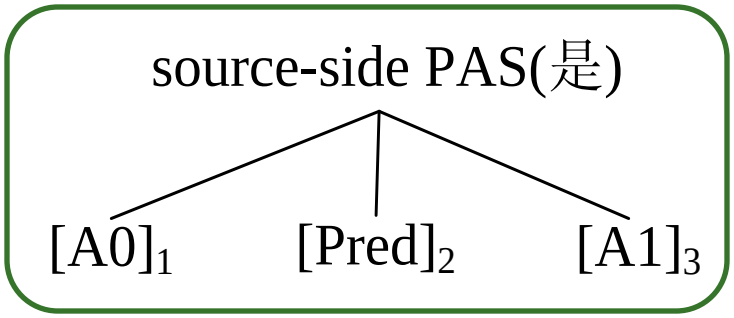

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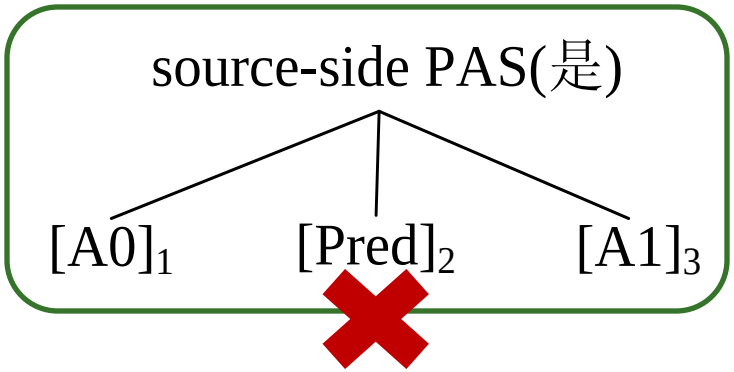

ARG0	AM-PRP	Pred	ARG1
奥运村 的 位置 the location of the olympic village	对 运动员 for athletes	是 is	最 好 的 the best

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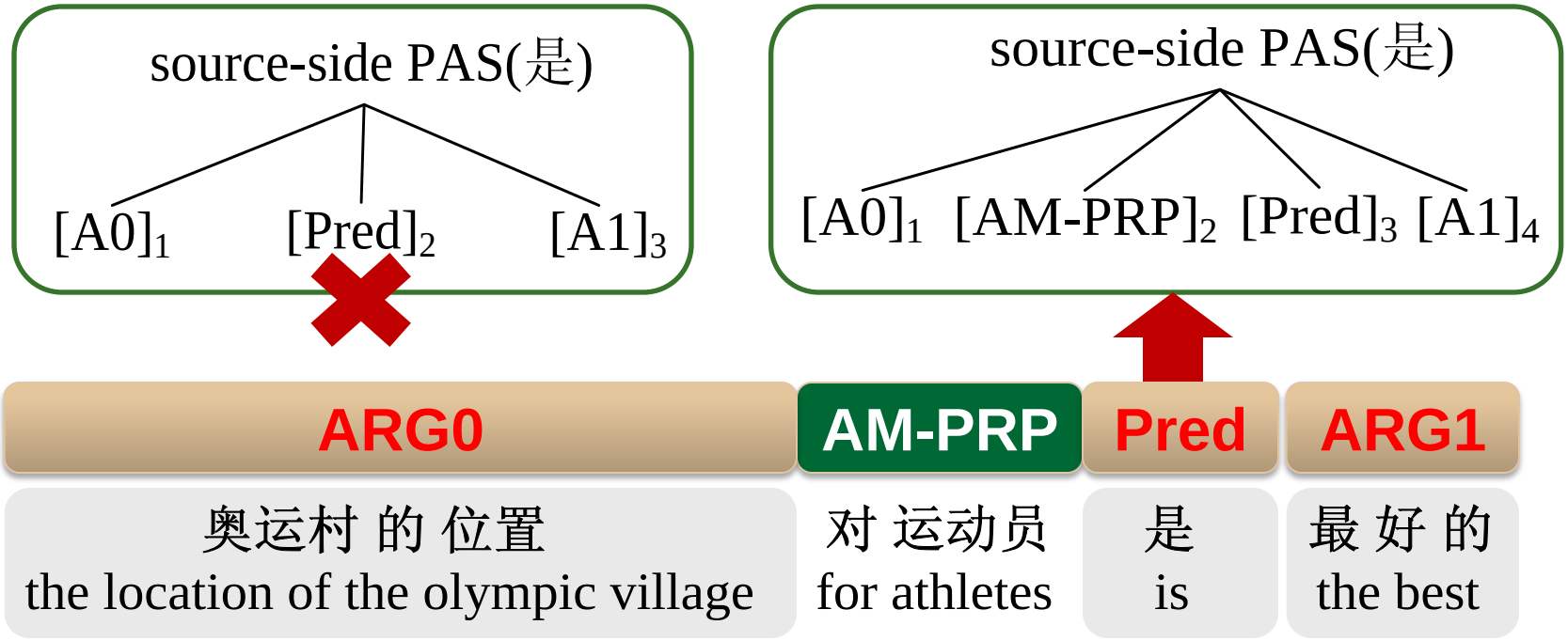

2. Syntax-Complemented PAS

◆ Syntax-Complemented PAS(SC-PAS)

- A combination of PAS and syntax. We employ syntax information to model the gap strings of PAS
- SC-PAS could effectively overcome the drawback of the prevalent gaps in PAS, and provides more useful knowledge for translation

2. Syntax-Complemented PAS

◆ Inside Context

奥运村 的 位置	对	运动员	是	最 好 的
ao-yun-cun de wei-zhi	dui	yun-dong-yuan	shi	zui hao de
ARG0			Pred	ARG1

2. Syntax-Complemented PAS

◆ Inside Context

奥运村 的 位置	对	运动员	是	最 好 的
ao-yun-cun de wei-zhi	dui	yun-dong-yuan	shi	zui hao de
ARG0			Pred	ARG1

closure_range

2. Syntax-Complemented PAS

◆ Inside Context

奥运村 的 位置 ao-yun-cun de wei-zhi	对 运动员 dui yun-dong-yuan	是 shi	最 好 的 zui hao de
ARG0	Inside Context	Pred	ARG1

closure_range

2. Syntax-Complemented PAS

- s-tag sequence: the sequence of the highest root categories that exactly dominates the tree fragments

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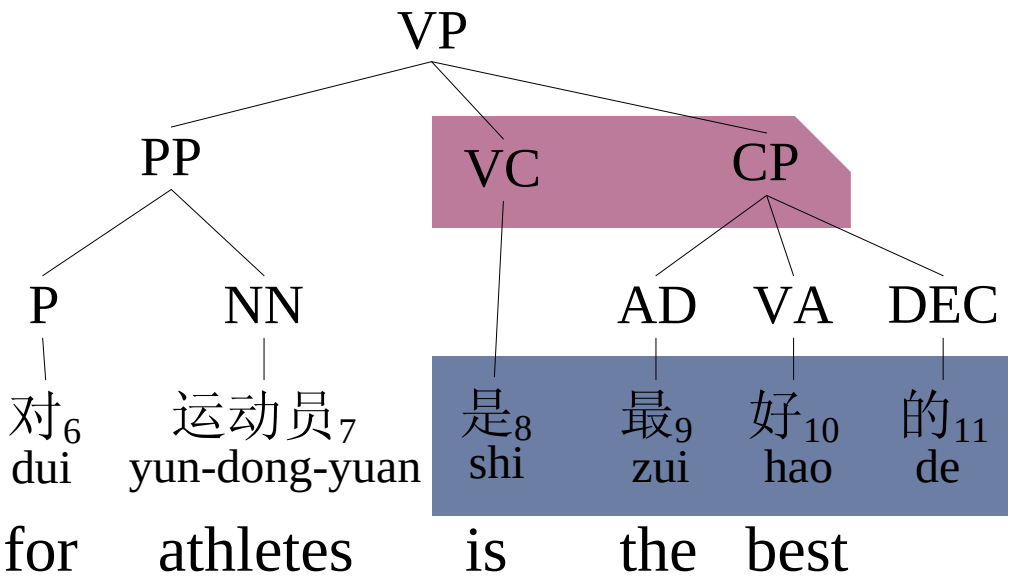
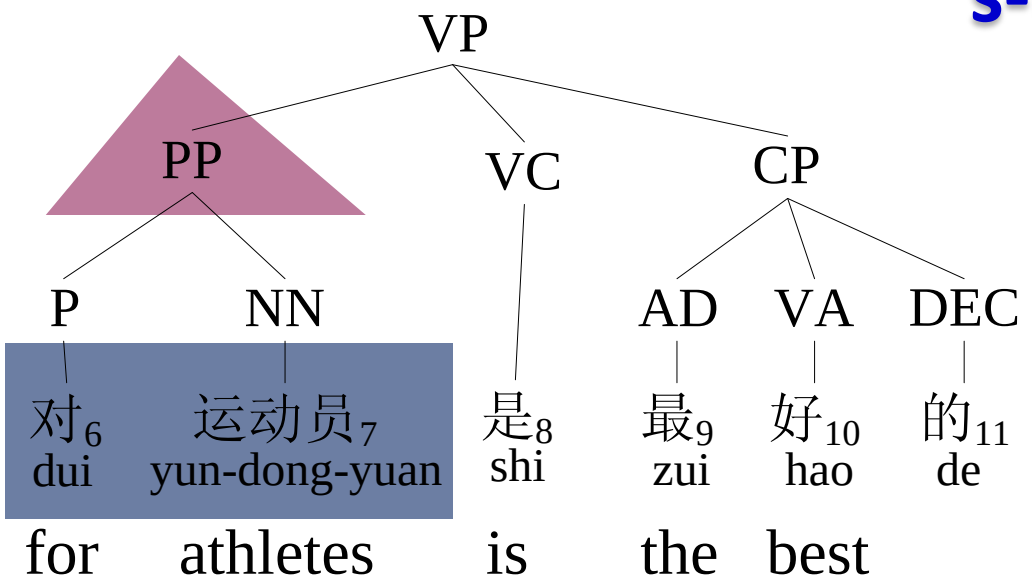
s-tag sequence: VC CP



2. Syntax-Complemented PAS

- s-tag sequence: the sequence of highest root categories that exactly dominates the tree fragments
- Abstract the **Inside Context (IC)** by the s-tag sequence of its corresponding span

s-tag sequence: PP



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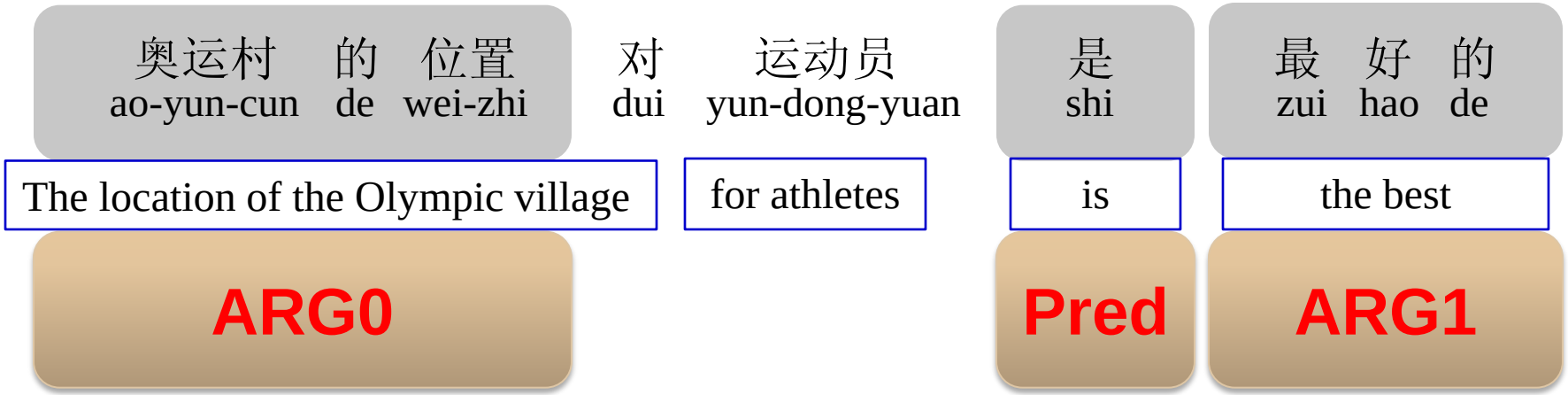

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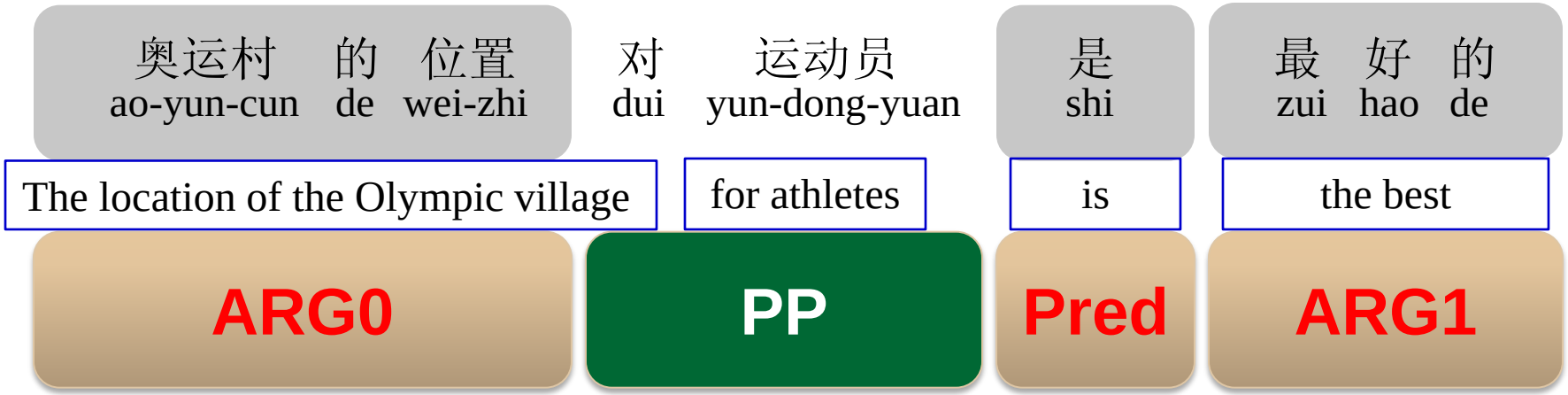

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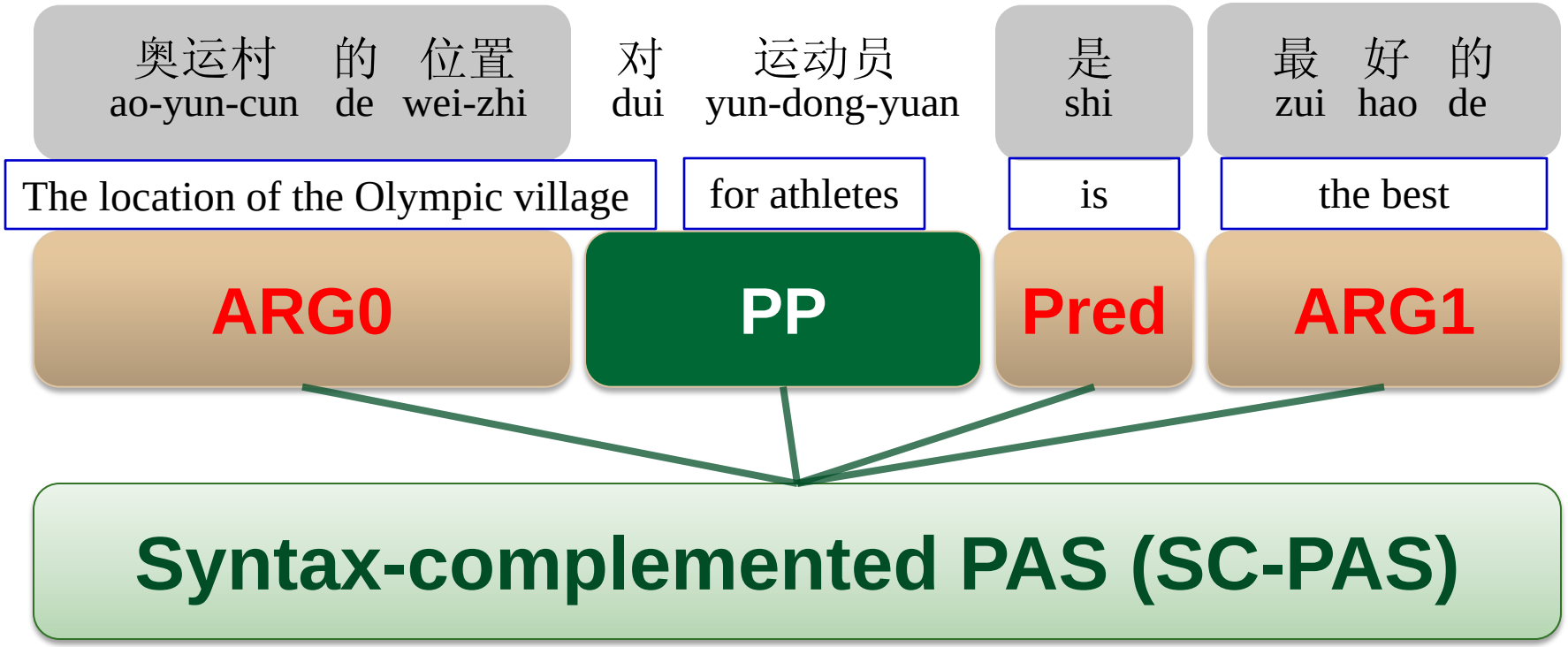

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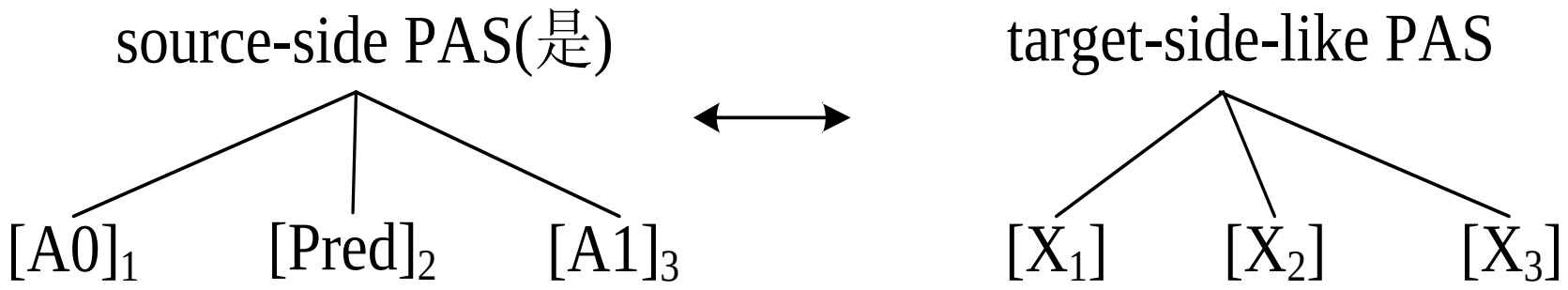
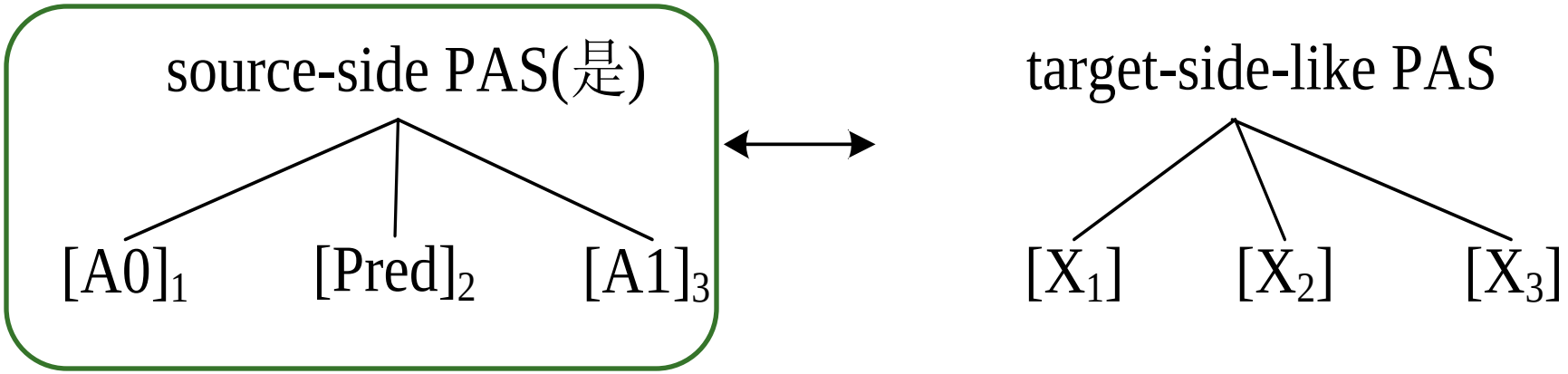
3. Transformation Rule Extraction

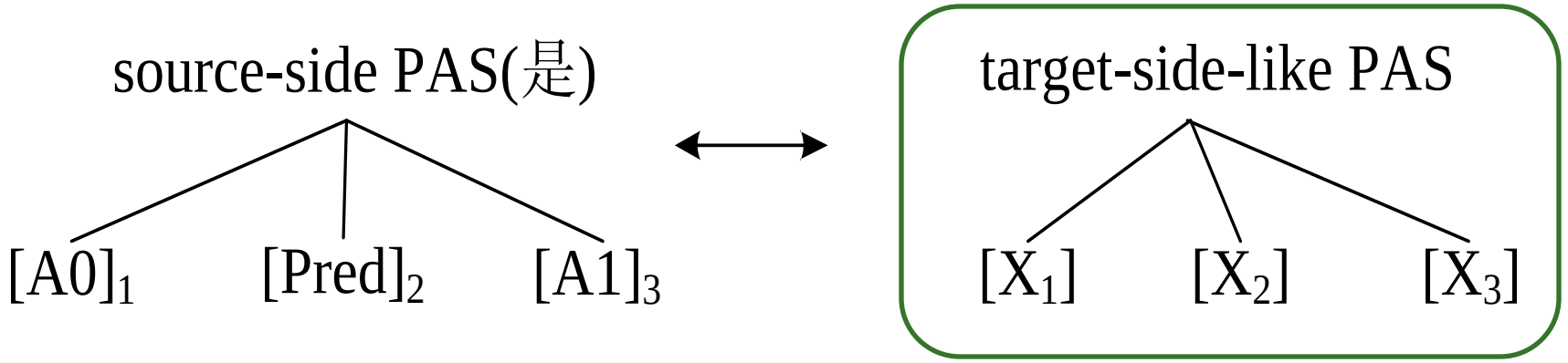


3. Transformation Rule Extraction



- ***Pred***: the predicate where the rule is extracted
- ***SP***: the source-side PAS, i.e., the list of source elements in source language order

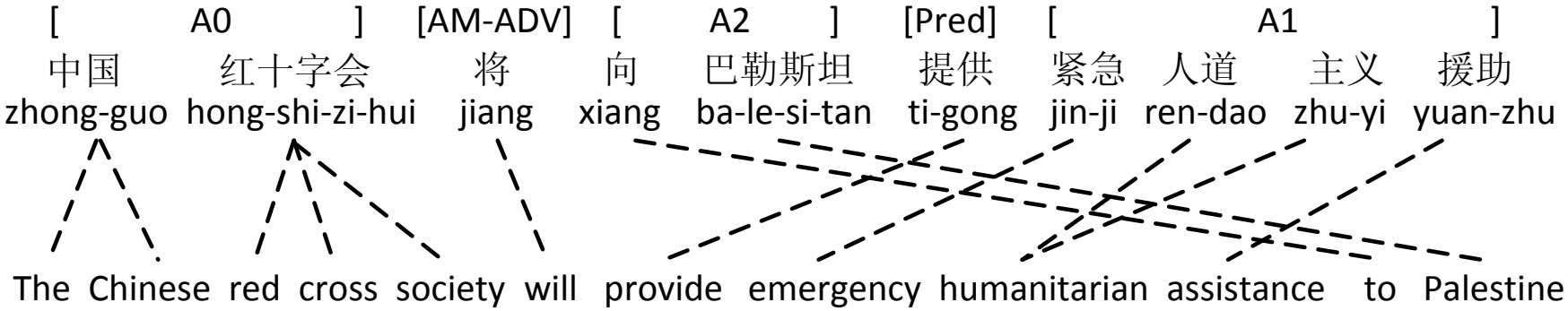
3. Transformation Rule Extraction



- ***Pred***: the predicate where the rule is extracted
- ***SP***: the source-side PAS, i.e., the list of source elements in source language order
- ***TP***: the target-side-like PAS, i.e., a list of general non-terminals in target language order.

3. Transformation Rule Extraction

◆ Example ①



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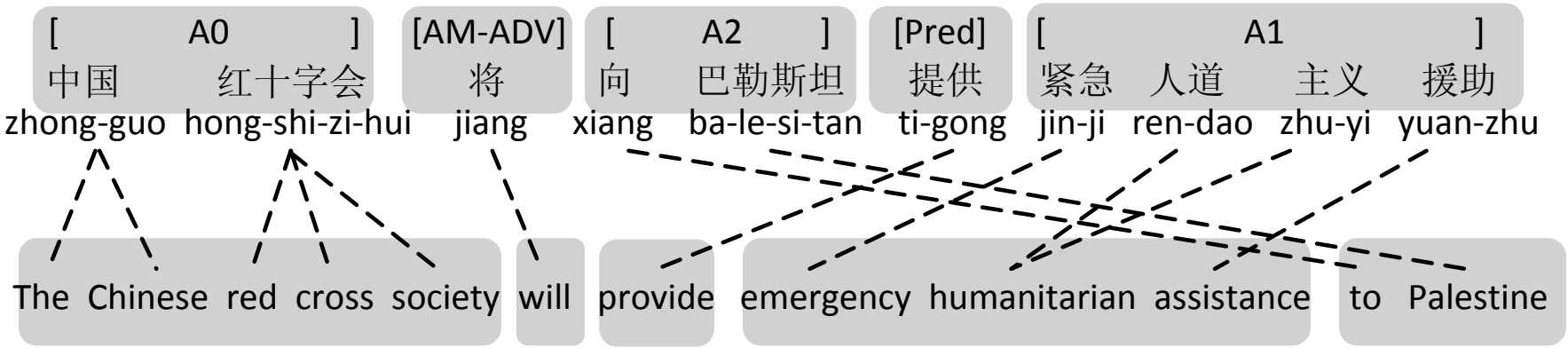
◆ Example ①



3. Transformation Rule Extraction

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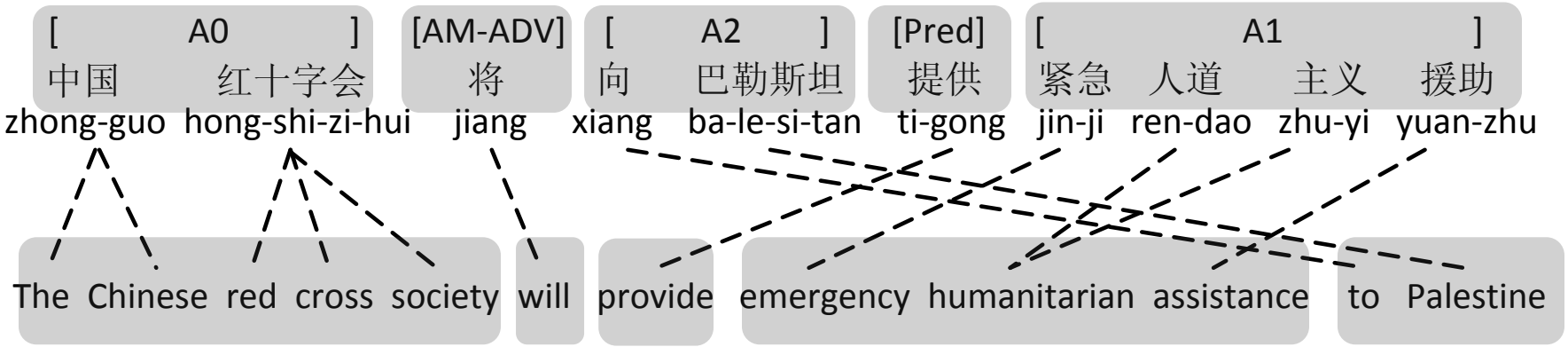

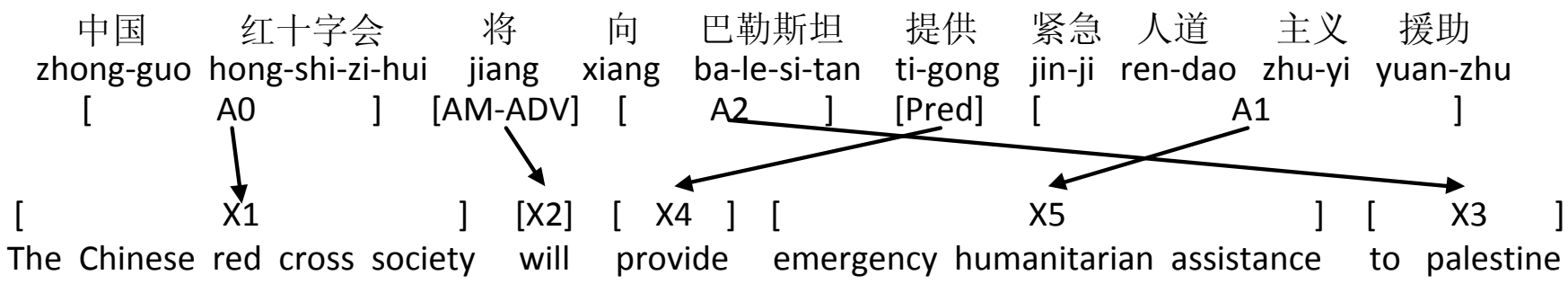

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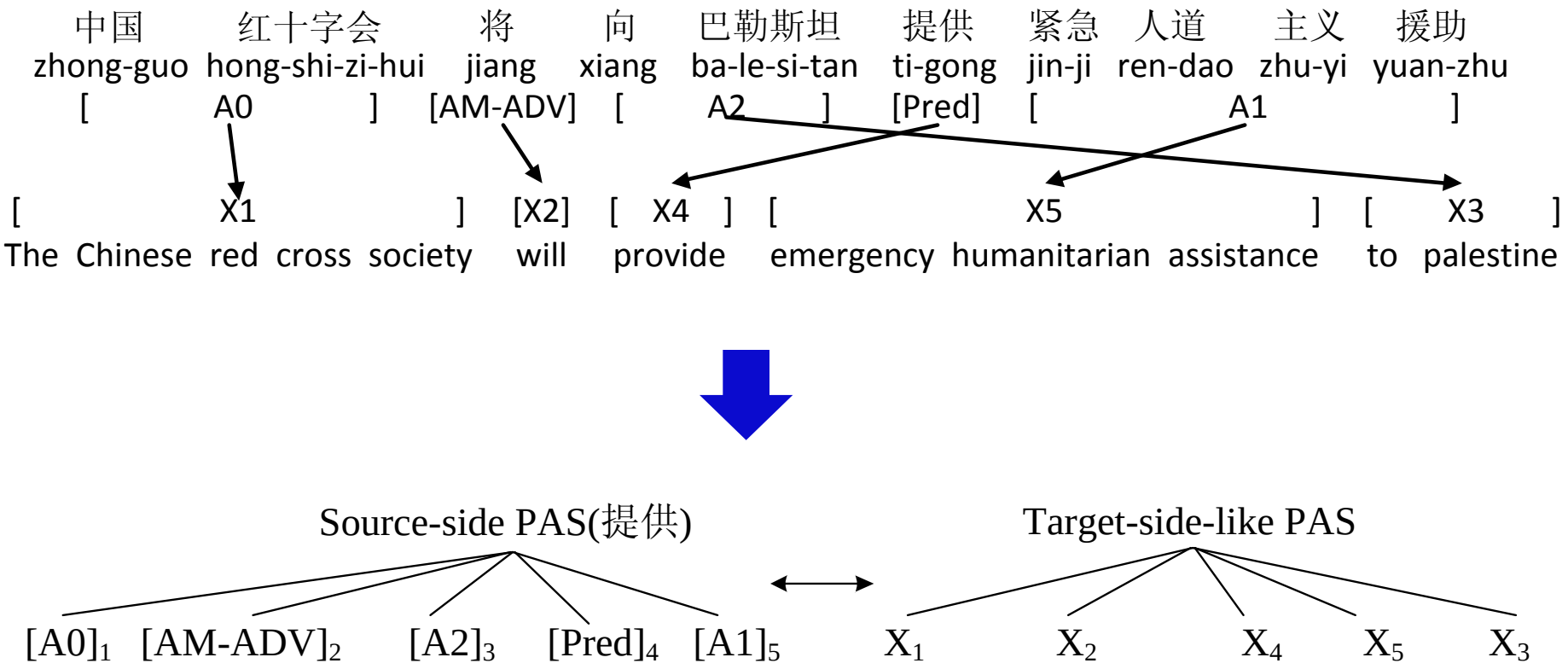
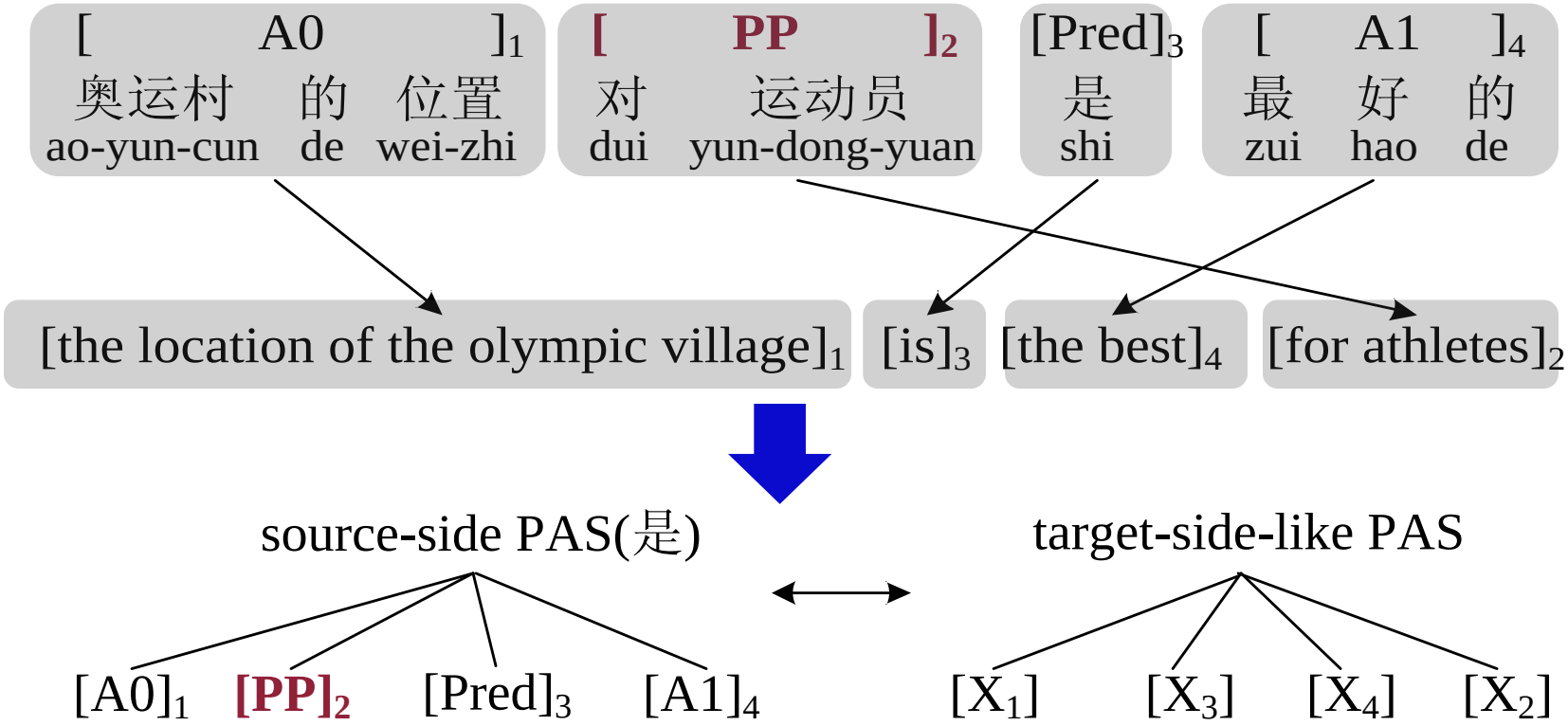
◆ Example ①



3. Transformation Rule Extraction

◆ Example ②



SC-PAS-based Transformation Rule

3. Transformation Rule Extraction

◆ Examples of PAS transformation rule

Reordering PAS Transformation Rules		
Pred	SP	TP
关心(concern)	$[AM\text{-}ADV]_2\ [Pred]_3\ [A1]_1$	$X_3\ X_1\ X_2$
提供(provide)	$[A0]_1\ [A2]_2\ [Pred]_3\ [A1]_4$	$X_1\ X_3\ X_4\ X_2$

Monolingual PAS Transformation Rules		
Pred	SP	TP
是(is)	$[A0]_1\ [Pred]_2\ [A1]_3$	$X_1\ X_2\ X_3$
希望(hope)	$[A0]_1\ [Pred]_2\ [A1]_3$	$X_1\ X_2\ X_3$

3. Transformation Rule Extraction

◆ Example SC-PAS Transformation Rule

Reordering SC-PAS Transformation Rules		
Pred	SP	TP
是(is)	$[A0]_1$ **$[PP]_2$** $[Pred]_3$ $[A1]_4$	X_1 X_3 X_4 X_2
举行(hold)	$[AM\text{-}TMP]_1$ **$[PP]_2$** $[Pred]_3$	X_3 X_2 X_1

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4. ATT Framework

Step 1: Analysis

SRL on the test sentences

- 3 parse trees (Berkeley Parser: 3-best)

P_1:	[	A0	]	[AM-ADV]	[	A2	]	[Pred]	[	A1	]	
P_2:	[AM-ADV]	[A0]		[AM-ADV]	[	A2	]	[Pred]	[	A1	]	
P_3:	[AM-ADV]	[A0]		[AM-ADV]	[	A2	]	[Pred]		[A1]		

布什$_1$ 说$_2$ 此$_3$ 项$_4$ 计划$_5$ 将$_6$ 对$_7$ 劳动$_8$ 大众$_9$ 提供$_{10}$ 减税$_{11}$ 优惠$_{12}$

Bush said this plan will provide tax concessions to the working masses.

4. ATT Framework

Step 2: Transformation

- Match the source-side PASs from the **analysis** step with the PAS transformation rules and get the target-side-like PASs

P_1:	[	A0	]	[AM-ADV]	[	A2	]	[Pred]	[	A1	]	
P_2:	[AM-ADV]	[A0]		[AM-ADV]	[	A2	]	[Pred]	[	A1	]	
P_3:	[AM-ADV]	[A0]		[AM-ADV]	[	A2	]	[Pred]		[A1]		

布什$_1$ 说$_2$ 此$_3$ 项$_4$ 计划$_5$ 将$_6$ 对$_7$ 劳动$_8$ 大众$_9$ 提供$_{10}$ 减税$_{11}$ 优惠$_{12}$

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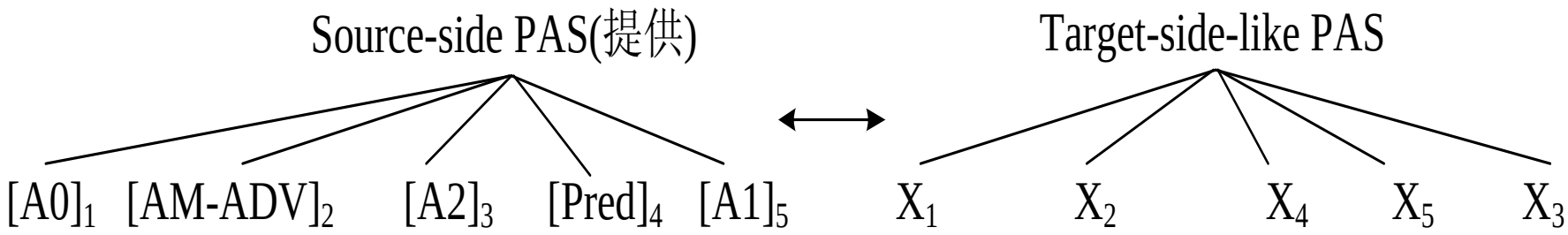
P_1:	[	A0	]	[AM-ADV]	[	A2	]	[Pred]	[	A1	]												
P_2:	[AM-ADV]	[A0]		[AM-ADV]	[	A2	]	[Pred]	[	A1	]												
P_3:	[AM-ADV]	[A0]		[AM-ADV]	[	A2	]	[Pred]	[	A1	]												
布什$_1$	说$_2$	此$_3$	项$_4$	计划$_5$	将$_6$	对$_7$	劳动$_8$	大众$_9$	提供$_{10}$	减税$_{11}$	优惠$_{12}$												



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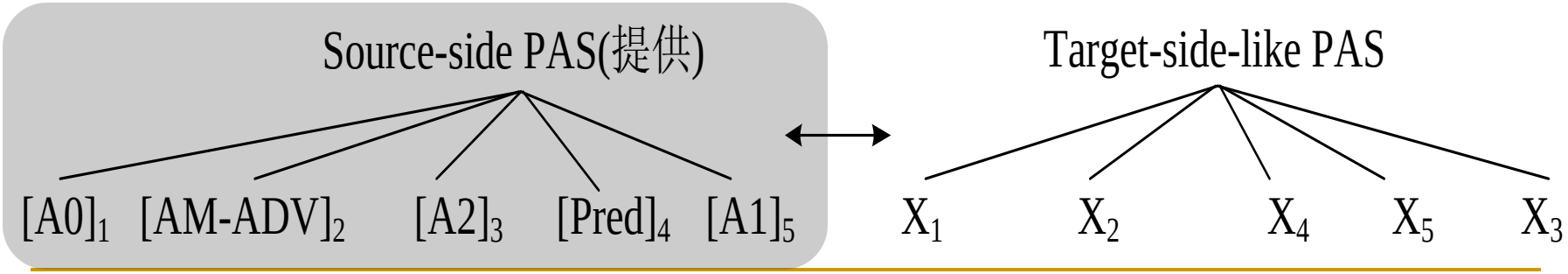
P_1:	[	A0	]	[AM-ADV]	[	A2	]	[Pred]	[	A1	]	
P_2:	[AM-ADV]	[A0]		[AM-ADV]	[	A2	]	[Pred]	[	A1	]	
P_3:	[AM-ADV]	[A0]		[AM-ADV]	[	A2	]	[Pred]			[	A1]
	布什$_1$	说$_2$	此$_3$	项$_4$	计划$_5$	将$_6$	对$_7$	劳动$_8$	大众$_9$	提供$_{10}$	减税$_{11}$	优惠$_{12}$



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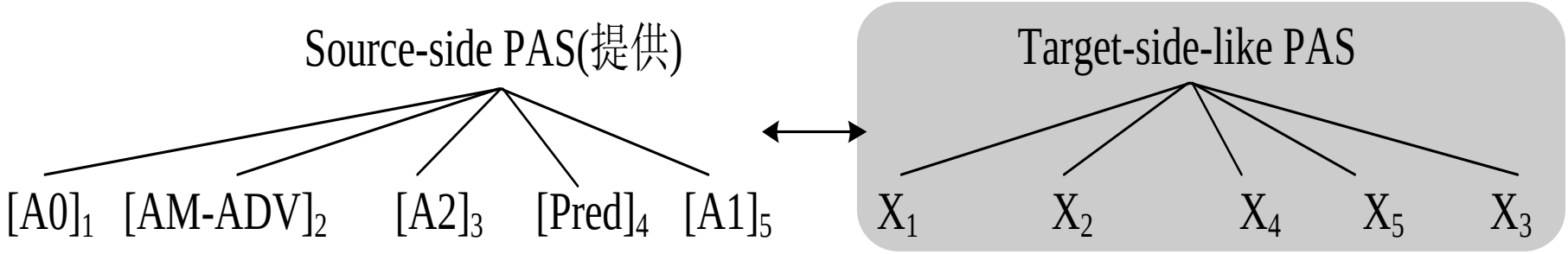
Step 2: Transformation

- Match the source-side PASs from the **analysis** step with the PAS transformation rules and get the target-side-like PASs

P_1:	[	A0	]	[AM-ADV]	[	A2	]	[Pred]	[	A1	]	
P_2:	[AM-ADV]	[A0]		[AM-ADV]	[	A2	]	[Pred]	[	A1	]	
P_3:	[AM-ADV]	[A0]		[AM-ADV]	[	A2	]	[Pred]			[	A1]
	布什$_1$	说$_2$	此$_3$	项$_4$	计划$_5$	将$_6$	对$_7$	劳动$_8$	大众$_9$	提供$_{10}$	减税$_{11}$	优惠$_{12}$



4. ATT Framework

◆How to select target-side-like PASs ?

- The same source-side PAS might play different roles or indicate different meaning in their corresponding sentences.
- One source-side PAS may correspond to several different target-side-like PASs.

4. ATT Framework

❶

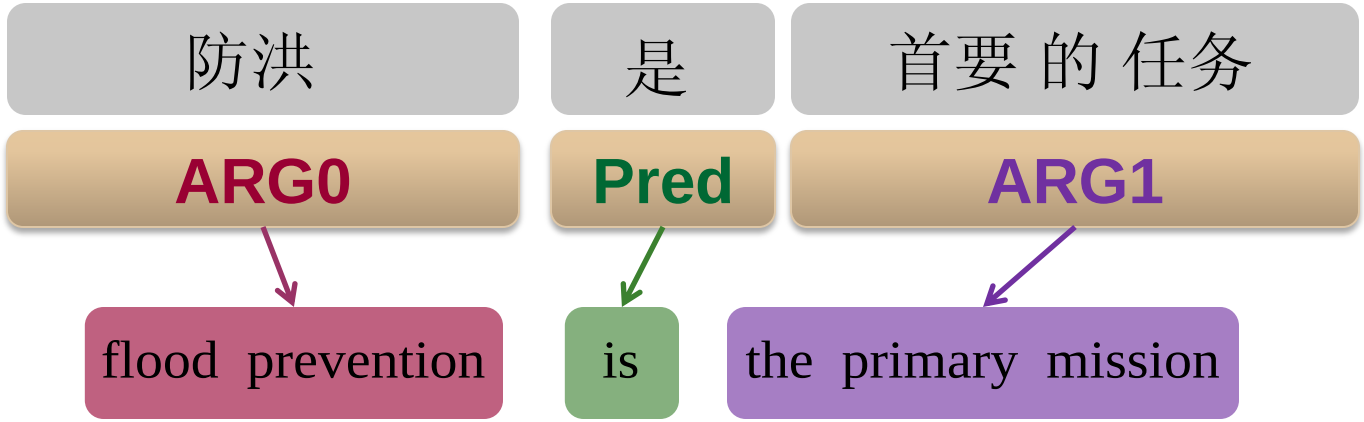
防洪	是	首要 的 任务
ARG0	Pred	ARG1

❷

ARG0	Pred	ARG1	
中国 和 俄罗斯	是	两个 大国	， 应 …

4. ATT Framework

❶



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4. ATT Framework

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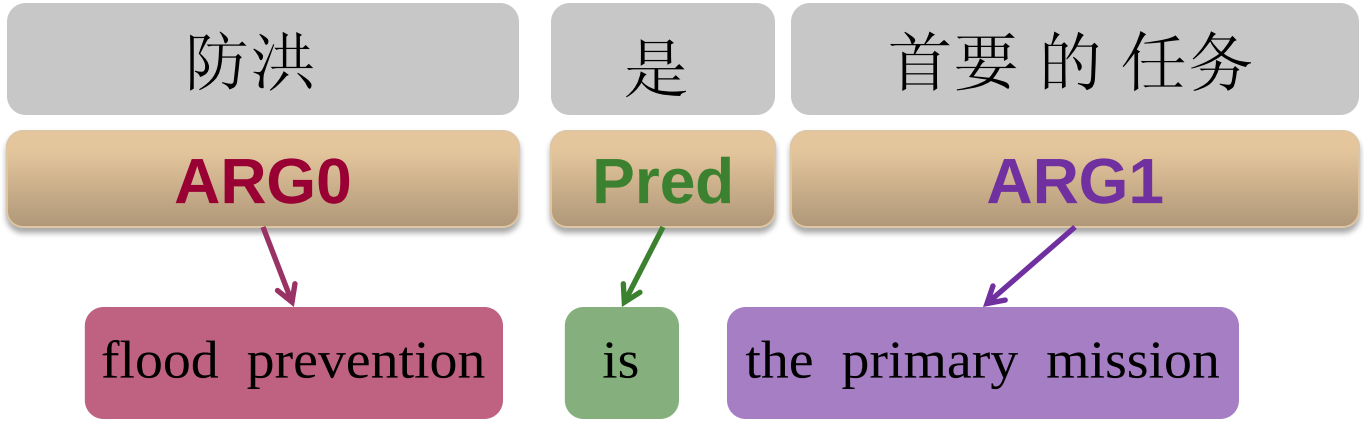

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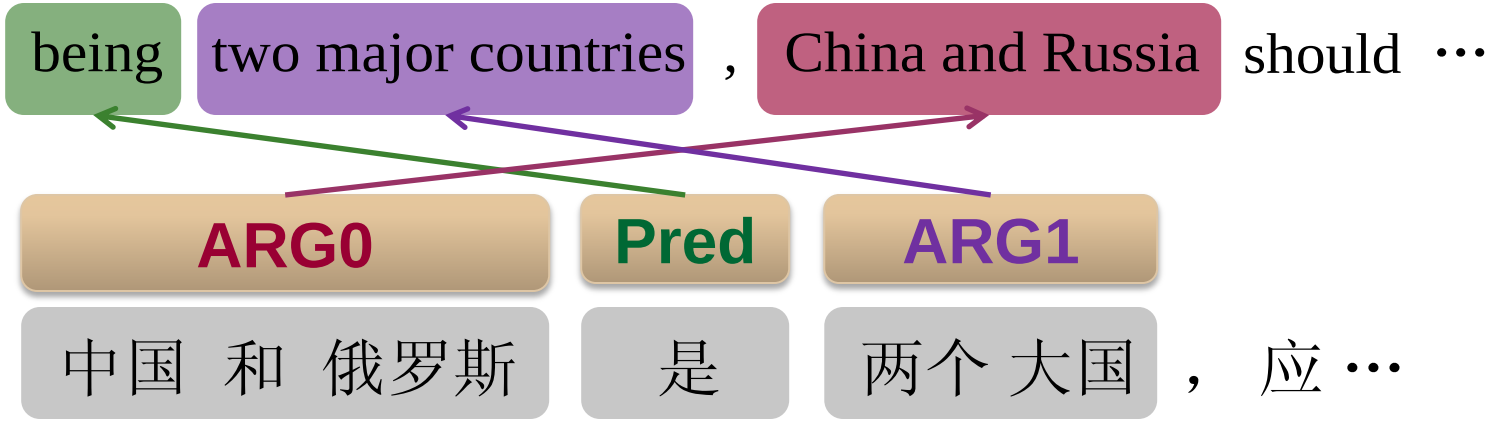
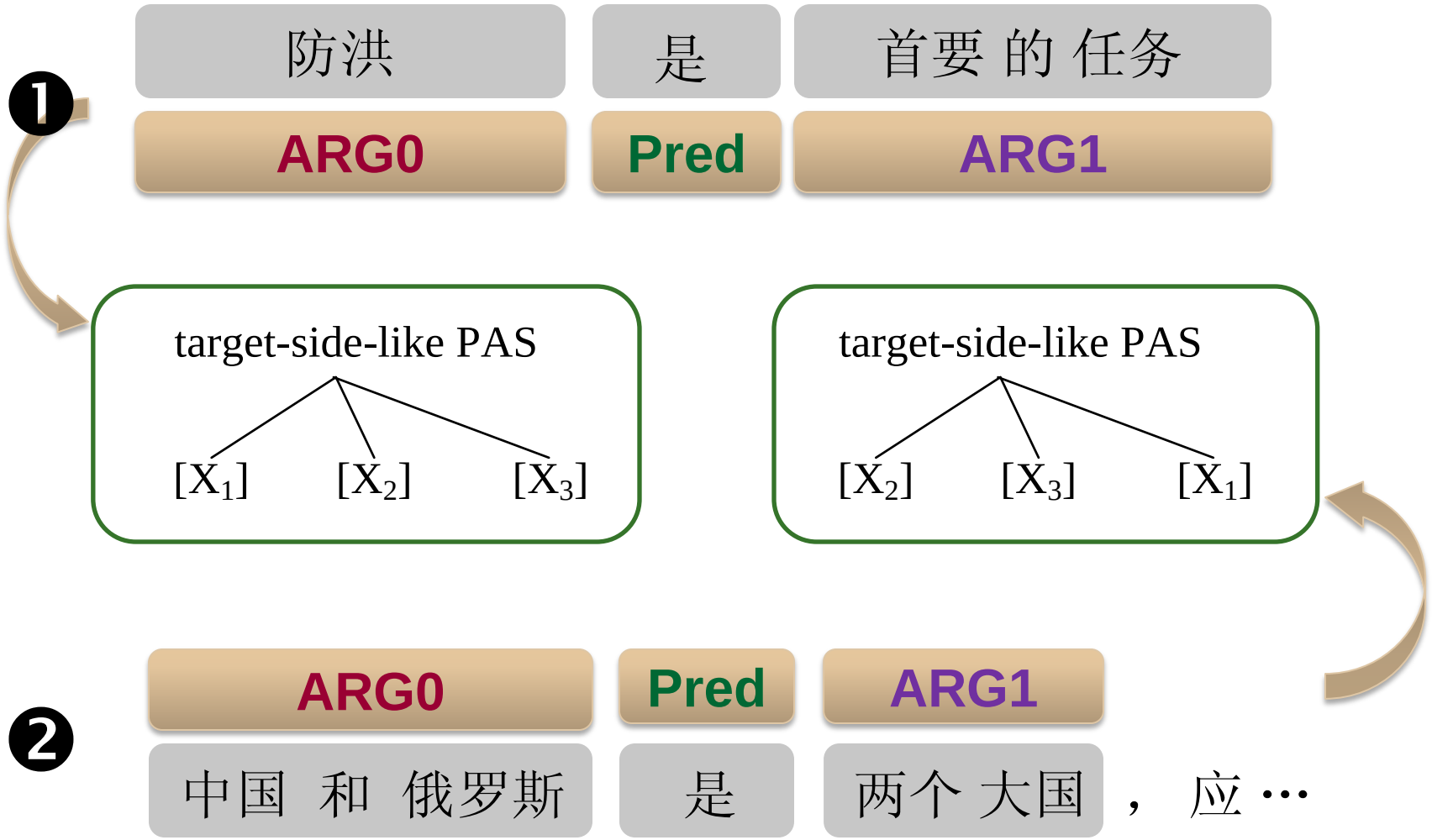


4. ATT Framework



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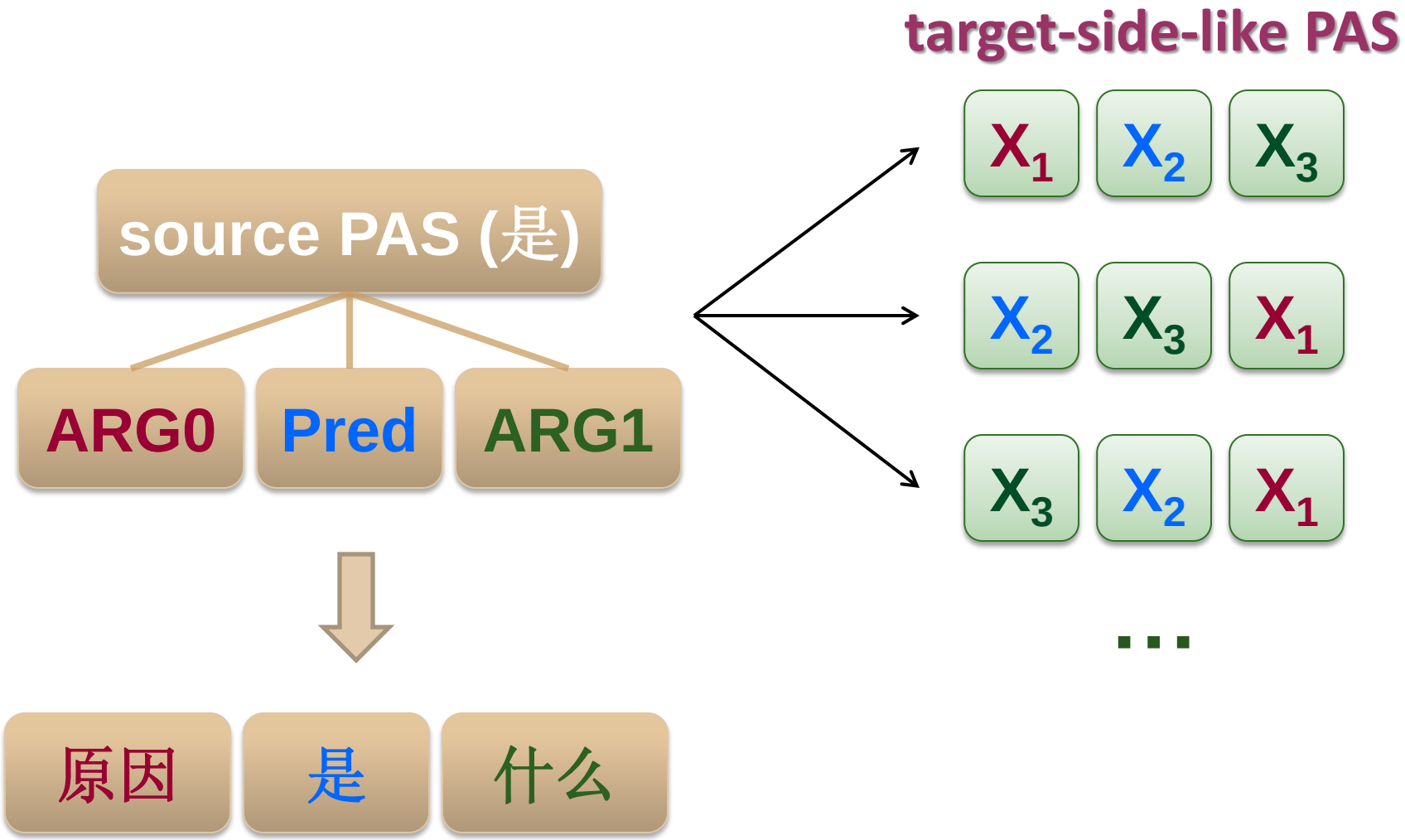
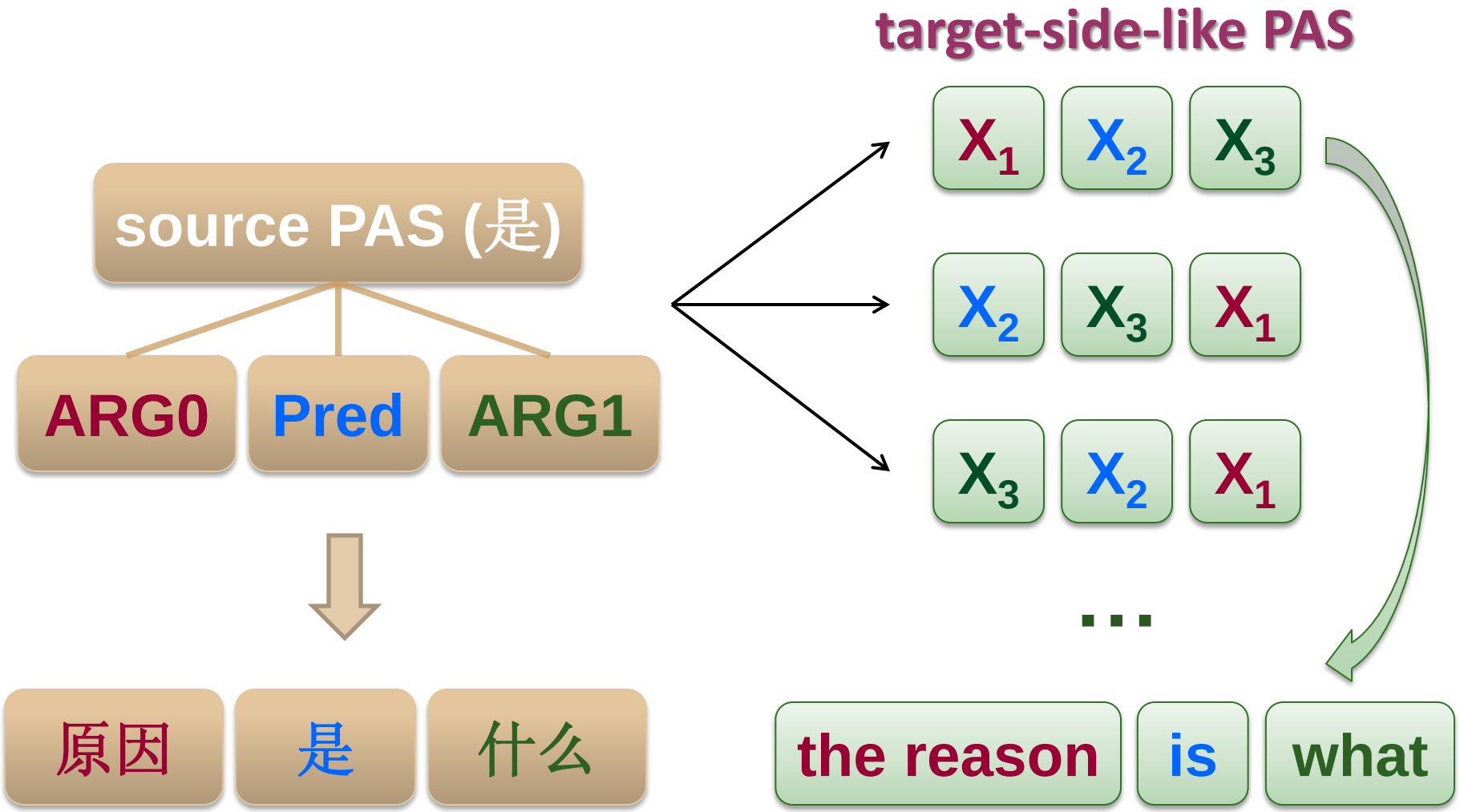
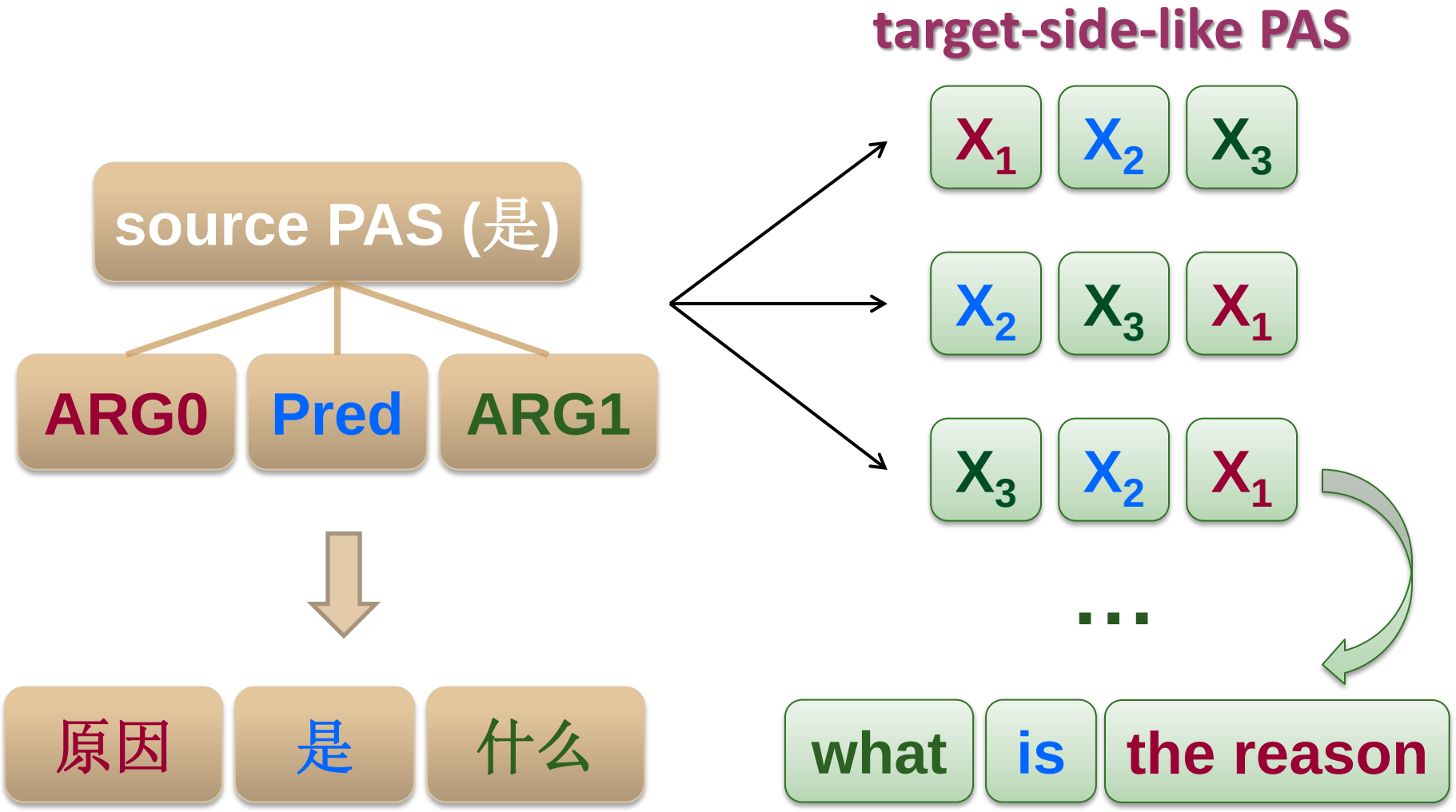


4. ATT Framework

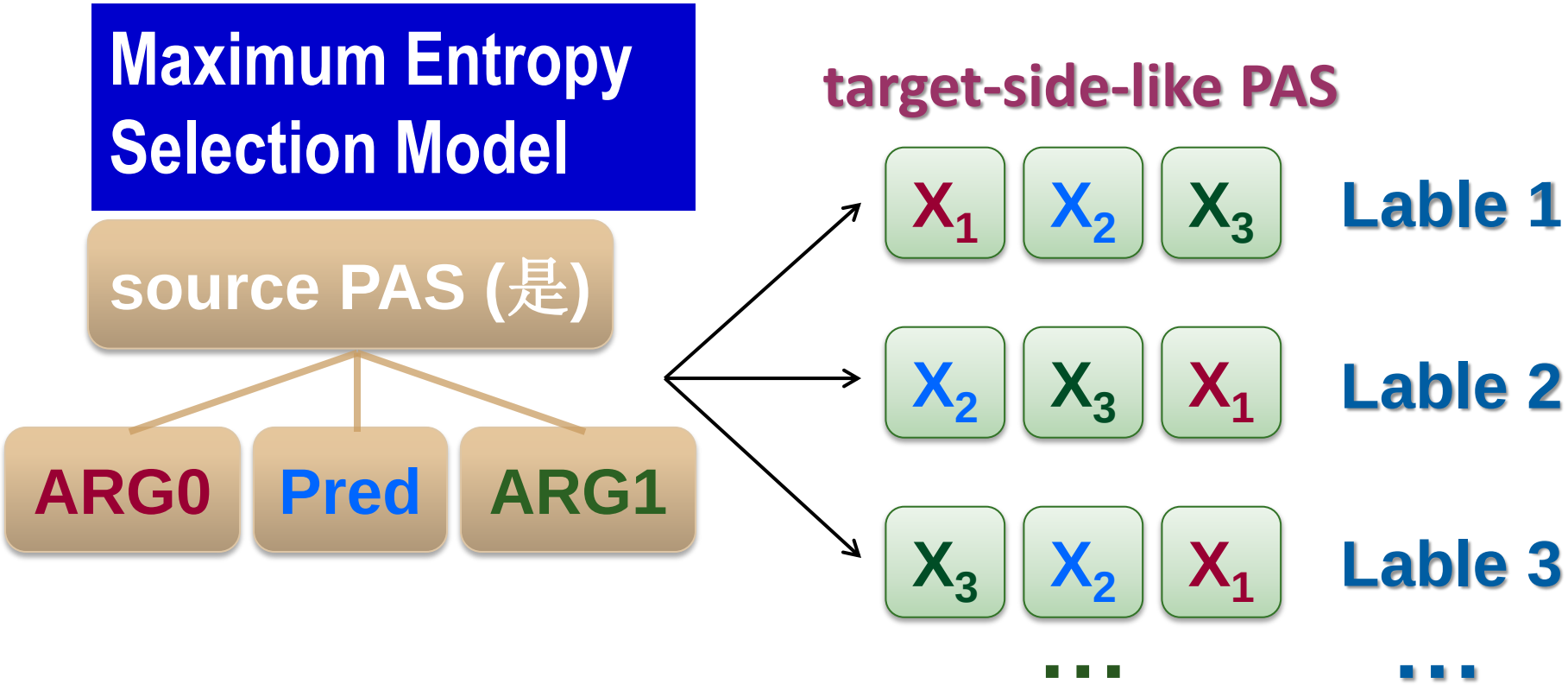


4. ATT Framework



4. ATT Framework

◆**The problem of selecting proper target-side-like PAS can be considered as a multi-class classification task.**



4. ATT Framework

◆ Maximum Entropy Selection Model

$$P_\theta(tp \mid sp, c(sp), c(tp)) = \frac{\exp(\sum_i \theta_i h_i(sp, tp, c(sp), c(tp)))}{\sum_{tp'} \exp(\sum_i \theta_i h_i(sp, tp, c(sp), c(tp)))}$$

4. ATT Framework

◆ Maximum Entropy Selection Model

$$P_\theta(tp \mid sp, c(sp), c(tp)) = \frac{\exp(\sum_i \theta_i h_i(sp, tp, c(sp), c(tp)))}{\sum_{tp'} \exp(\sum_i \theta_i h_i(sp, tp, c(sp), c(tp)))}$$

- sp: source-side PAS
- tp: target-side-like PAS
- $c(sp)$, $c(tp)$: context information on the two sides

4. ATT Framework

◆ The features

- **Lexical and POS features**
  - ➢ the words immediately to the left and right of ***sp***
  - ➢ The head word of each argument also serves as a lexical feature
  - ➢ The corresponding POS tags of the above words

4. ATT Framework

- **Predicate feature**
  - The pair of source predicate and its corresponding target predicate

$$t\text{-}pred = \arg\max_{j \in t\_range(PAS)} p(t_j \mid s\text{-}pred)$$

  - ✓ $s\text{-}pred$ is the source predicate
  - ✓ $t\text{-}pred$ is the corresponding target predicate.
  - ✓ $t\_range(PAS)$ refers to the target range covering all the words that are reachable from the PAS via word alignment.

4. ATT Framework

- **Syntax features**
  - The highest syntax tag for each argument
  - The lowest father node of ***sp*** in the parse tree.

4. ATT Framework

Step 3: translation

1. **Element translation: Get translation candidates for each element from any translation system (BTG etc.).**

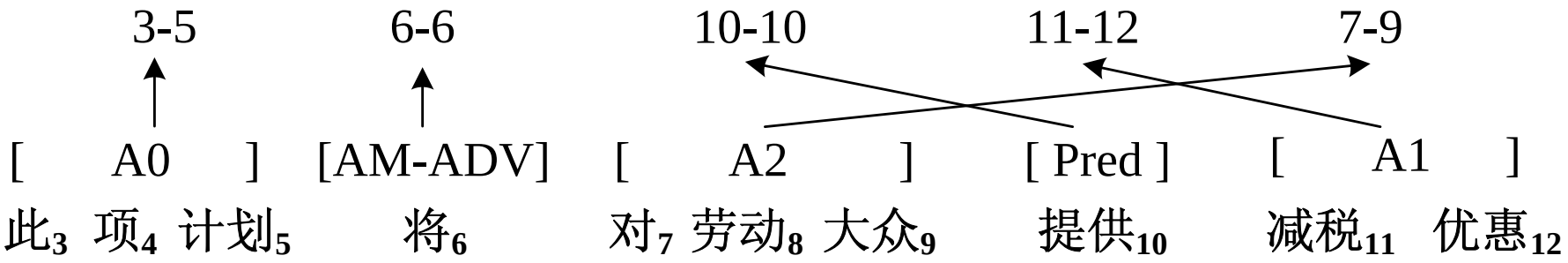
[A0] [AM-ADV] [A2] [Pred] [A1]

此$_3$ 项$_4$ 计划$_5$ 将$_6$ 对$_7$ 劳动$_8$ 大众$_9$ 提供$_{10}$ 减税$_{11}$ 优惠$_{12}$

This plan will provide tax concessions to the working masses.

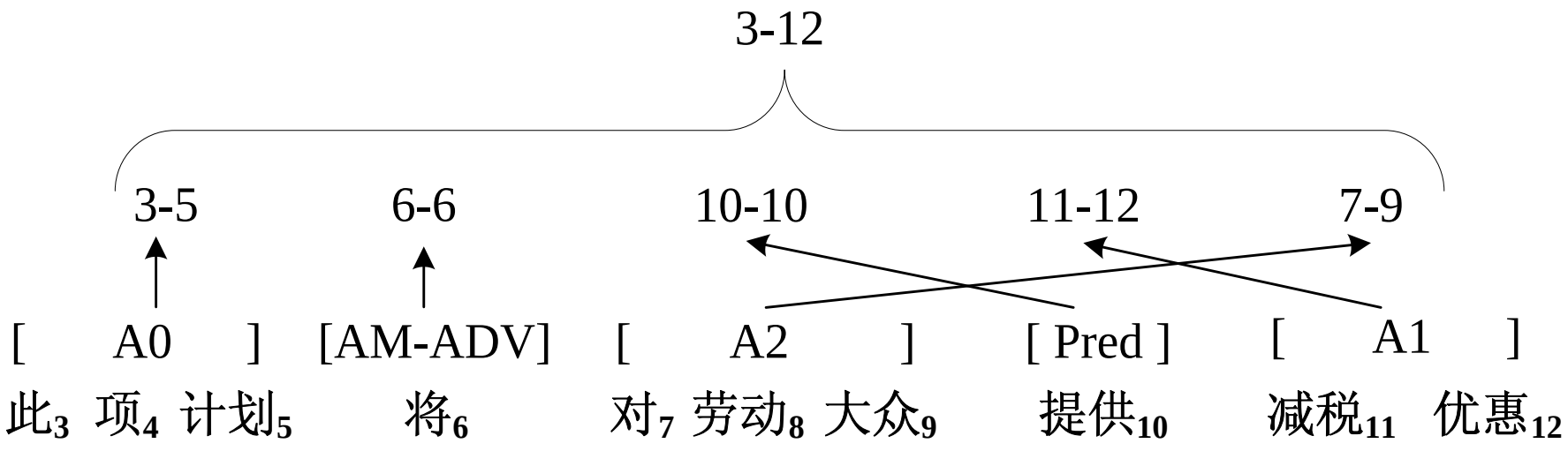
4. ATT Framework

2. **Reorder the translation candidates of elements according to the achieved target-side-like PAS.**



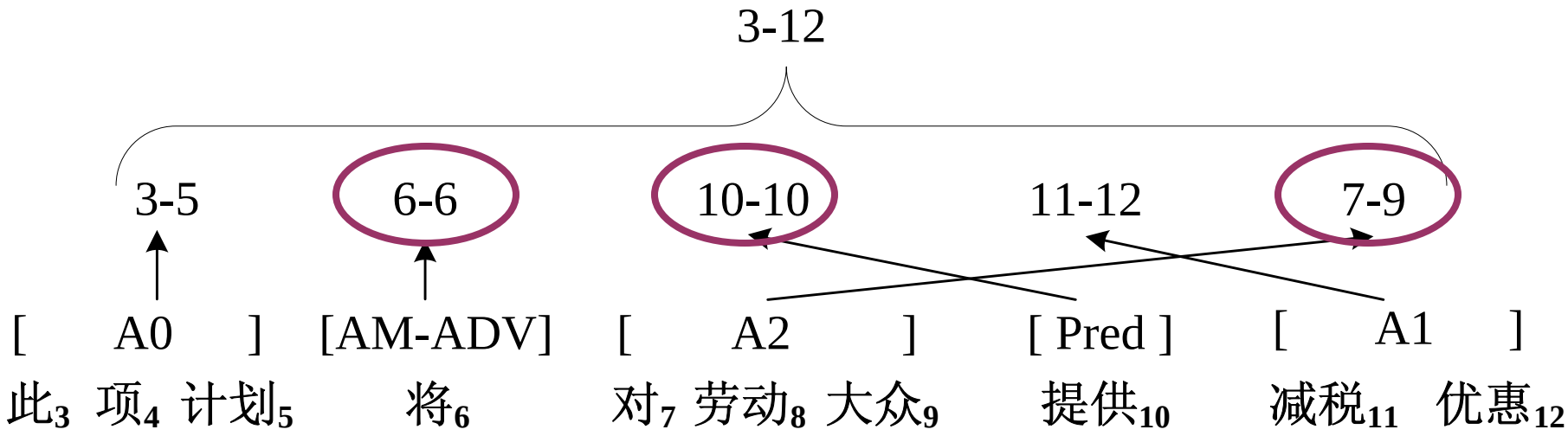
4. ATT Framework

3. Combine the candidates of elements by cube pruning.



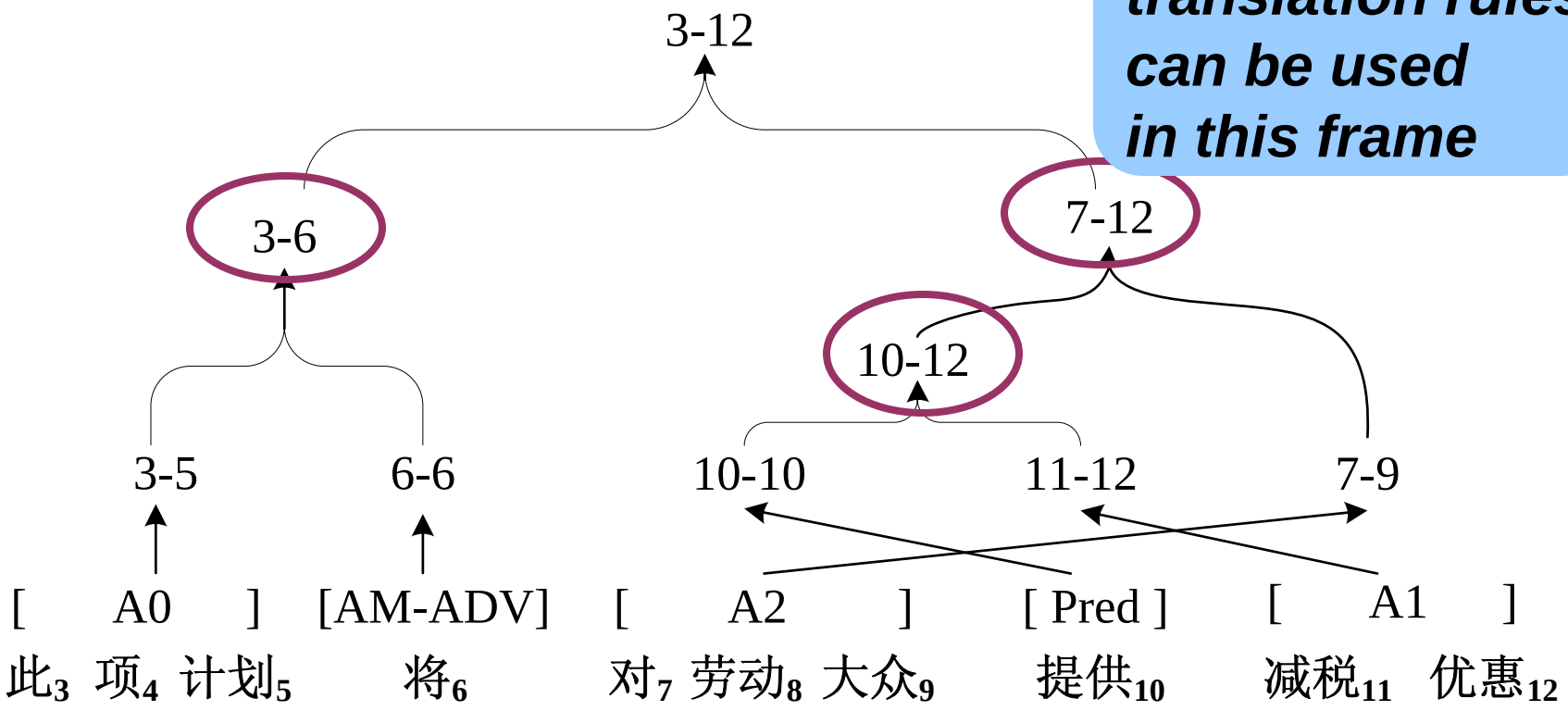
4. ATT Framework

However, many source elements' spans are very short, numerous phrase translation rules are ignored during translation !!!



4. ATT Framework

◆ CKY style decoding strategy



More phrase translation rules can be used in this frame

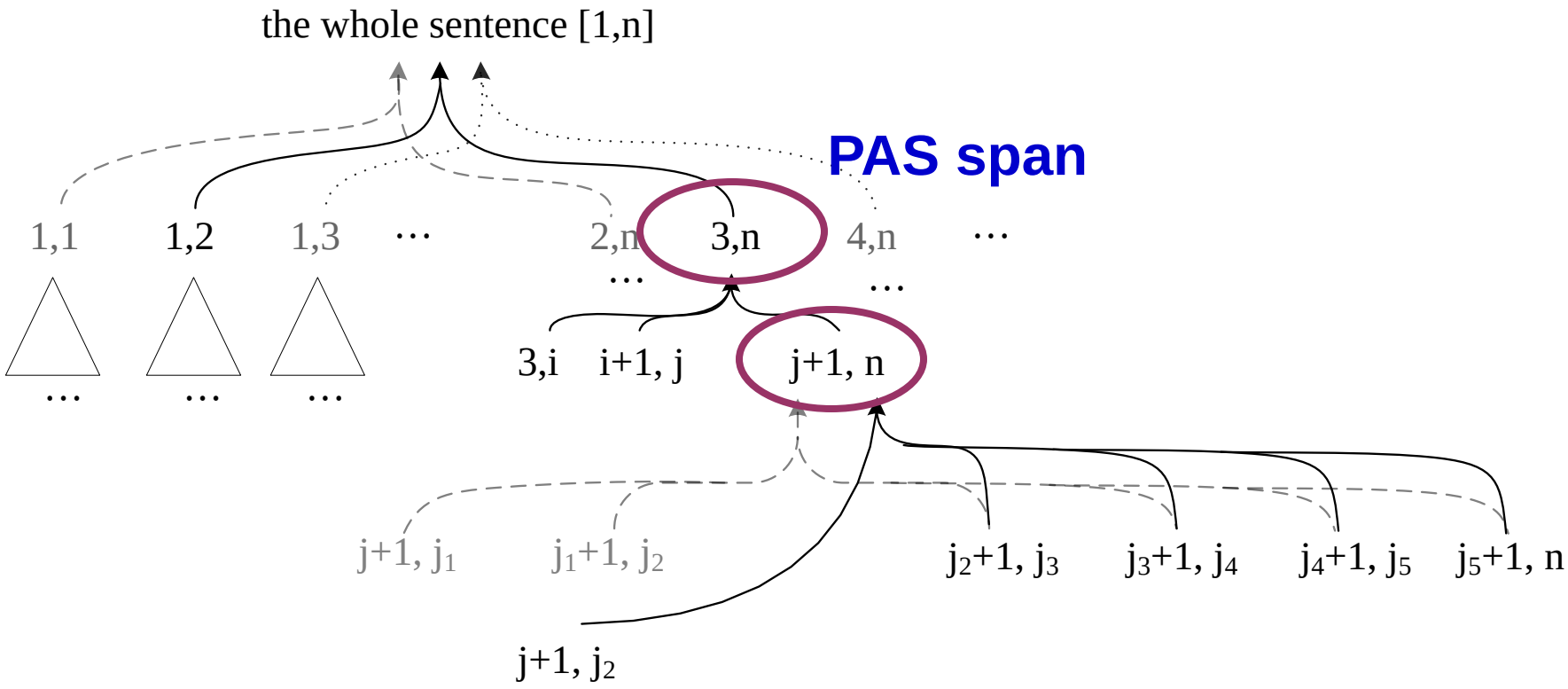
Outline

1. Introduction
2. Syntax-Complemented PAS
3. Transformation Rule Extraction
4. ATT Translation Framework
5. Decoder
6. Experiment
7. Conclusion

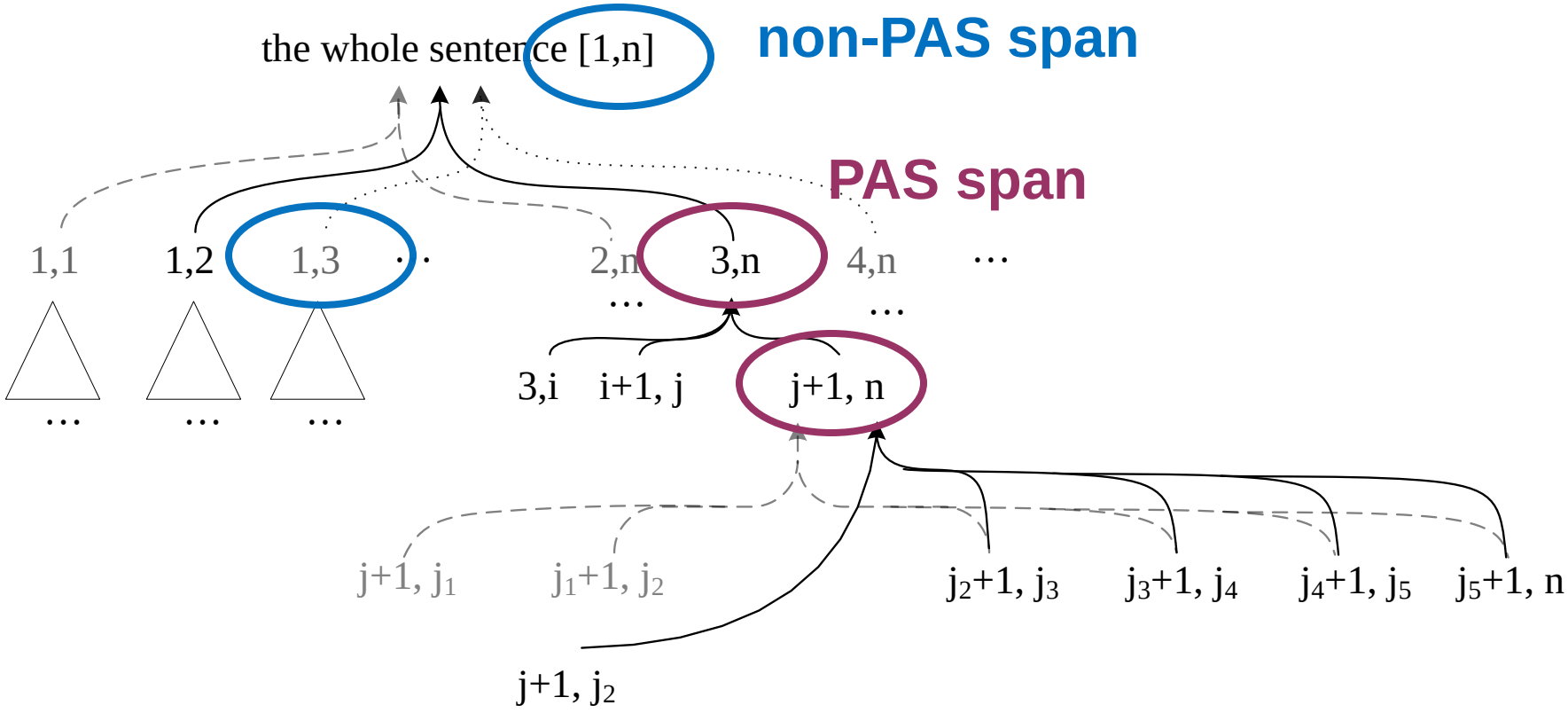
5. Decoder

- Construct a decoding hypergraph for the whole sentence
- PAS span: the span covered by a PAS.
  - use a multiple-branch hyperedge to connect that span to the PAS's elements
- non-PAS span: the span not covered by PAS
  - consider all the binary segmentations of that span and use binary hyperedges to link them

5. Decoder


the whole sentence [1,n]
PAS span
1,1
1,2
1,3
…
2,n
3,n
4,n
…
…
…
3,i
i+1, j
j+1, n
j+1, j1
j1+1, j2
j2+1, j3
j3+1, j4
j4+1, j5
j5+1, n
j+1, j2

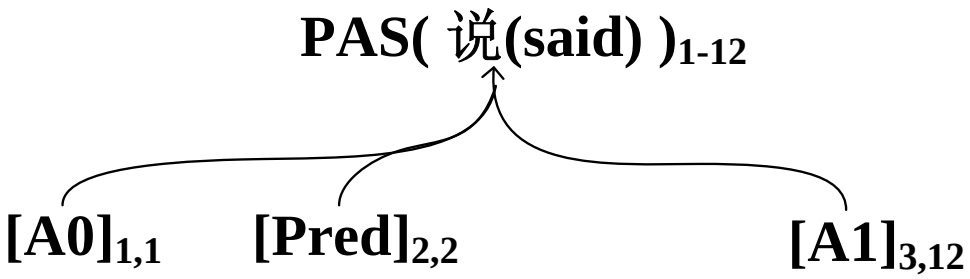
5. Decoder


the whole sentence [1,n]
non-PAS span
PAS span
1,1
1,2
1,3
2,n
3,n
4,n
3,i
i+1, j
j+1, n
j+1, j1
j1+1, j2
j2+1, j3
j3+1, j4
j4+1, j5
j5+1, n
j+1, j2

5. Decoder

[A0] [Pred] [A1]

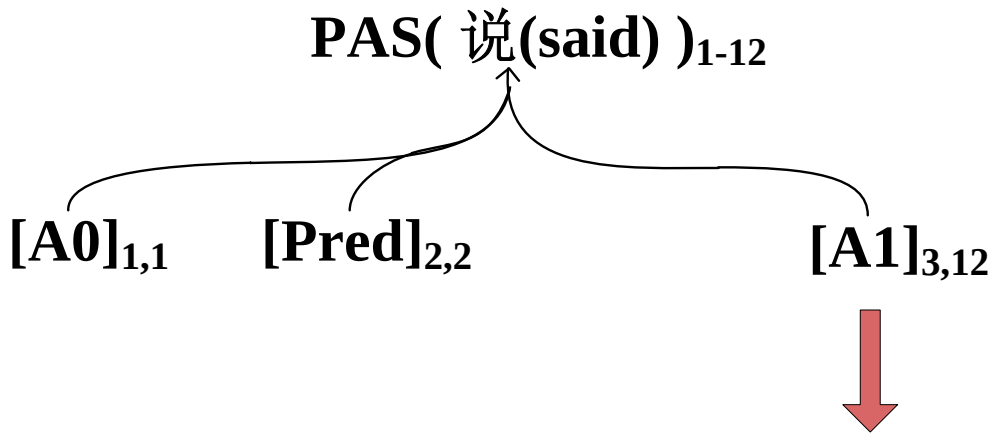
布什$_1$ 说(said)$_2$ 此$_3$ 项$_4$ 计划$_5$ 将$_6$ 对$_7$ 劳动$_8$ 大众$_9$ 提供$_{10}$ 减税$_{11}$ 优惠$_{12}$



5. Decoder

[A0] [Pred] [A1]

布什$_1$ 说(said)$_2$ 此$_3$ 项$_4$ 计划$_5$ 将$_6$ 对$_7$ 劳动$_8$ 大众$_9$ 提供$_{10}$ 减税$_{11}$ 优惠$_{12}$



P1: [A0] [AM-ADV] [A2] [Pred] [A1]

P2: [AM-ADV] [A0] [AM-ADV] [A2] [Pred] [A1]

此$_3$ 项$_4$ 计划$_5$ 将$_6$ 对$_7$ 劳动$_8$ 大众$_9$ 提供(provide)$_{10}$ 减税$_{11}$ 优惠$_{12}$

5. Decoder

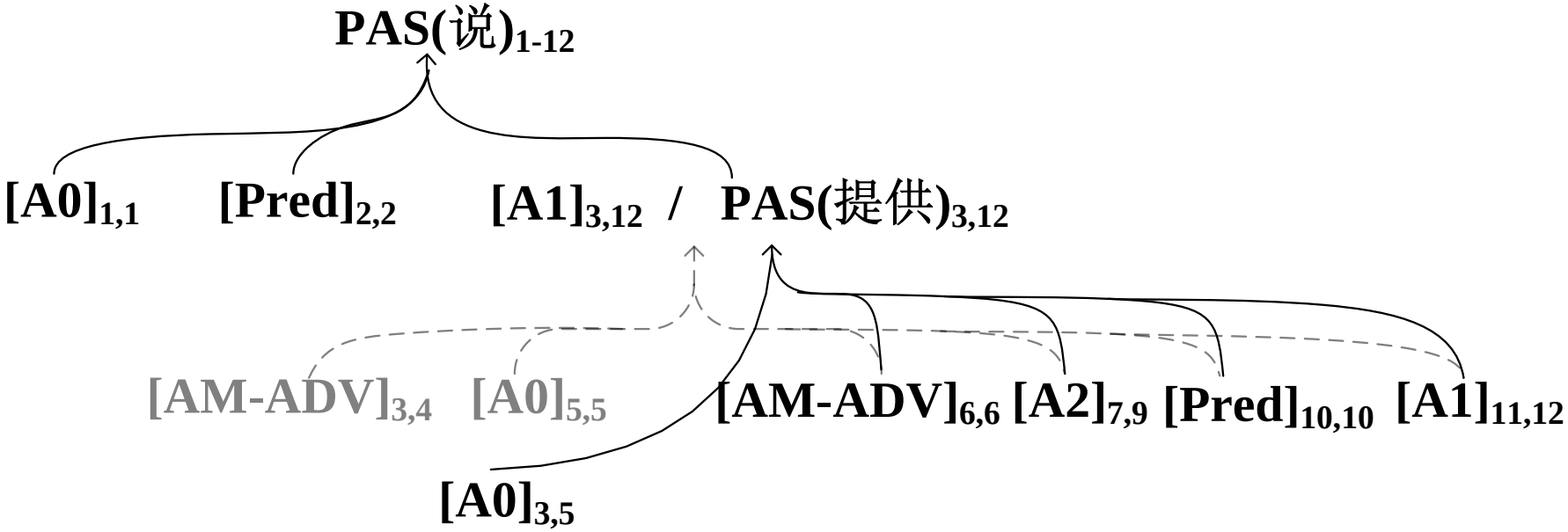
布什$_1$ 说(said)$_2$ 此$_3$ 项$_4$ 计划$_5$ 将$_6$ 对$_7$ 劳动$_8$ 大众$_9$ 提供$_{10}$ 减税$_{11}$ 优惠$_{12}$

[A0] [Pred] [A1]

P1: [A0] [AM-ADV] [A2] [Pred] [A1]

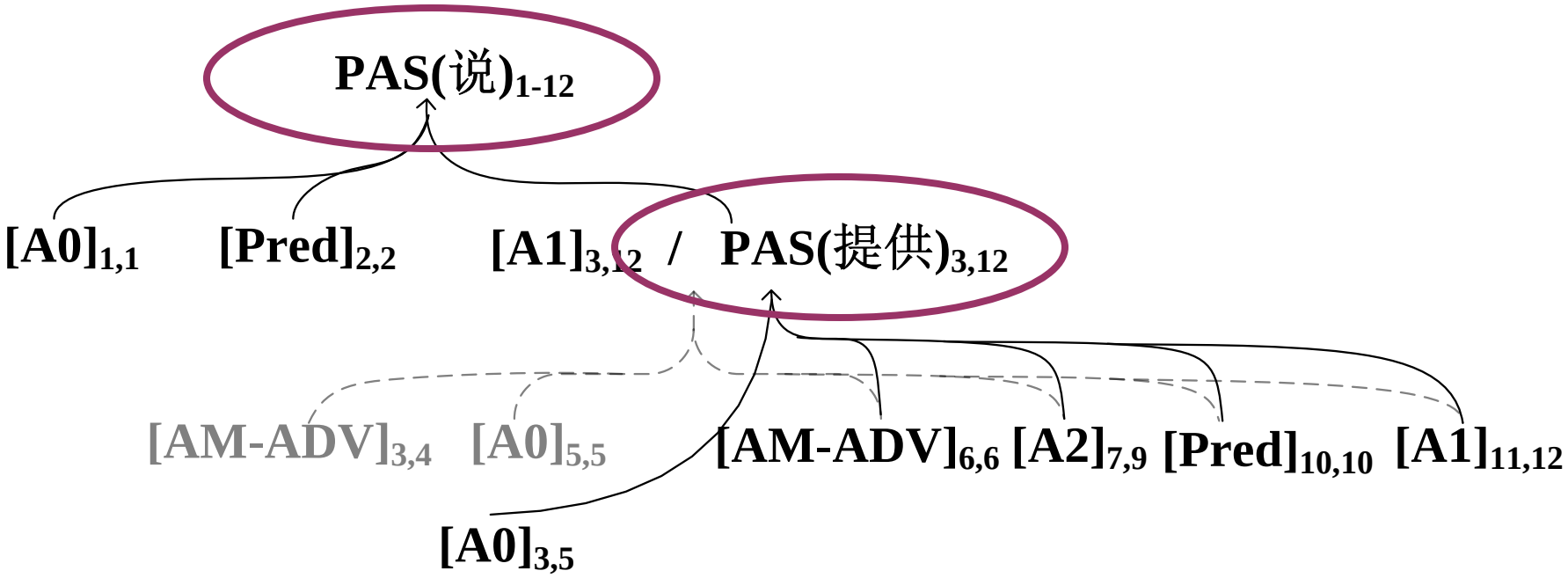
P2: [AM-ADV] [A0] [AM-ADV] [A2] [Pred] [A1]

此$_3$ 项$_4$ 计划$_5$ 将$_6$ 对$_7$ 劳动$_8$ 大众$_9$ 提供(provide)$_{10}$ 减税$_{11}$ 优惠$_{12}$



5. Decoder

- PAS span : The ATT translation framework
- non-PAS span: BTG system



5. Decoder

①

BTG

[甲烷] [的 温室效应] [是] [二氧化碳 的 21倍]

[methane] [is] [21 times that of carbon dioxide] [, greenhouse gas emissions]

PAS-ATT

甲烷 的 温室效应 是 二氧化碳 的 21倍

[A0] [Pred] [A1]

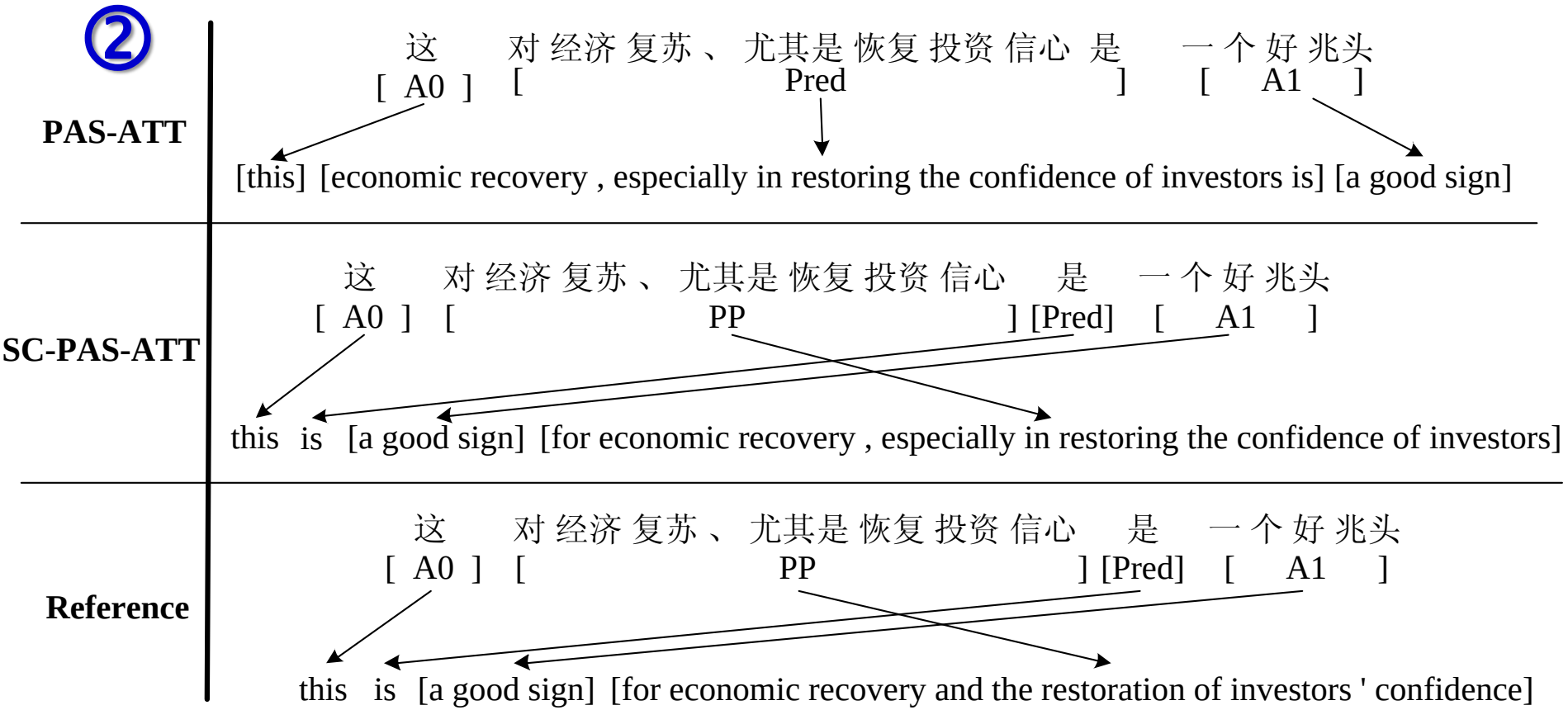
[greenhouse gas emissions of methane] [is] [21 times that of carbon dioxide]

Reference

[甲烷 的 温室效应] [是] [二氧化碳 的 21倍]

[the greenhouse effect of methane] [is] [21 times that of carbon dioxide]

5. Decoder


②
PAS-ATT
这 对 经济 复苏 、 尤其是 恢复 投资 信心 是 一 个 好 兆头
[A0] [Pred] [A1]
[this] [economic recovery , especially in restoring the confidence of investors is] [a good sign]
SC-PAS-ATT
这 对 经济 复苏 、 尤其是 恢复 投资 信心 是 一 个 好 兆头
[A0] [PP] [Pred] [A1]
this is [a good sign] [for economic recovery , especially in restoring the confidence of investors]
Reference
这 对 经济 复苏 、 尤其是 恢复 投资 信心 是 一 个 好 兆头
[A0] [PP] [Pred] [A1]
this is [a good sign] [for economic recovery and the restoration of investors ' confidence]

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6. Experiment

◆ Experimental Setup

- Chinese-to-English translation
- **Training set:** about 2.1M sentence pairs
- **Language model:** 5-gram trained on Xinhua portion of GIGA WORD corpus and training set
- **Development set:** NIST03 (919)
- **Test set:** NIST04 (1788) and NIST05 (1082)
- **Baseline Translation System:** Moses, BTG

6. Experiment

- PAS-ATT : The ATT framework using PAS
- SC-PAS-ATT : The ATT framework using SC-PAS

Systems	BLEU	
	MT04	MT05
Moses	36.21	33.85
BTG	37.20	34.86
PAS-ATT	37.50*	35.33*
SC-PAS-ATT	37.81*#	35.82*#

Outline

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7. Conclusion

- We have built an ATT framework to model predicate-argument structure in translation model:
  - We analyze the weakness of PAS and propose a concept of syntax-complemented PAS (SC-PAS).
  - We extract structure transformation rule to model the intrinsic relation between the source-side and the target-side-like PASs
  - We divide the translation process into 3 steps: ***Analysis; Transformation; Translation.***

7. Conclusion

- The predicate-argument structure helps to improve the translation quality in the following aspects:
  - Taking advantage of PAS, the translation model keeps structure consistency well across languages.
  - Using the transformation rules, the translation model performs global reordering in a skeleton scenario.
  - Reasonable strategies are designed to exert the merit of PAS to segment sentences for translation.

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Thank-!

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