Answering Natural Language Questions via Phrasal Semantic Parsing

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Peking University

December 9, 2014

Movie

Movie

1. What else movies did the director of the movie Interstellar direct ?

Movie

1. What else movies did the director of the movie Interstellar direct ?
2. How many awards did Anne Hathway win in 2013 ?

Movie

Interstellar (film)

From Wikipedia, the free encyclopedia

Interstellar is a 2014 science fiction film directed by Christopher Nolan. Starring Matthew McConaughey, Anne Hathaway, Jessica Chastain, Mackenzie Foy and Michael Caine, the film features a team of astronauts who travel through a wormhole in search of a new habitable planet. Brothers Christopher and Jonathan Nolan wrote the film, merging a script Jonathan developed in 2007 with Christopher's ideas. Christopher Nolan produced the film with his wife, Emma Thomas, and Lynda Obst. Theoretical physicist Kip Thorne, whose work inspired the film, acted as scientific consultant and executive producer.

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Interstellar

Theatrical release poster

Directed by	Christopher Nolan
Produced by	Emma Thomas Christopher Nolan Lynda Obst
Written by	Jonathan Nolan Christopher Nolan
Starring	Matthew McConaughey Anne Hathaway Jessica Chastain Bill Irwin Ellen Burstyn Michael Caine

Movie

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Interstellar

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Directed by	Christopher Nolan
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	Anne Hathaway
	Jessica Chastain
	Bill Irwin
	Ellen Burstyn
	Michael Caine

Movie

What else movies did the director of the movie Interstellar direct ?

Films directed /film/director/film

Films directed

Batman Begins

Insomnia

Memento

The Dark Knight

The Prestige

Following

Inception

The Dark Knight Rises

Doodlebug

Cinema 16: British Short Films

11 values total »

Movie

How many awards did Anne Hathway win in 2013 ?

Interstellar

Theatrical release poster

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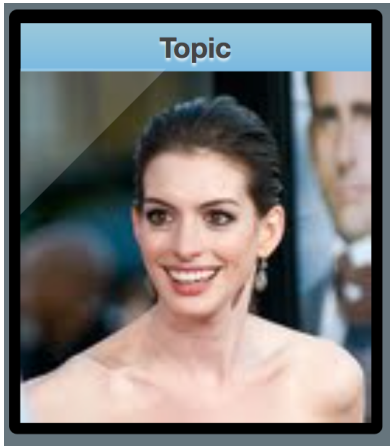
Movie



Anne Hathaway en

mid: /m/02vntj **notable type:** /celebrities/celebrity **on the web:** W wikipedia.org

Anne Jacqueline Hathaway is an American actress. After several stage roles, she ap
and in its 2004 sequel. Since then, Hathaway has starred in dramatic films such as H
Austen. In 2008, she won several awards for her performance in Rachel Getting Mar
in Wonderland, and Love and Other Drugs and won an Emmy Award for her voice-o
Nolan's The Dark Knight Rises and Fantine in Tom Hooper's Les Misérables. Her pe
BAFTA Award and the Academy Award for Best Supporting Actress. [-]

2012	Satellite Award for Best Supporting Actress – Motion Picture
2012	Golden Globe Award for Best Supporting Actress – Motion Picture
2012	Critics' Choice Movie Award for Best Supporting Actress
2013	Screen Actors Guild Award for Outstanding Performance by a Female Actor in a Supporting Role
2013	BAFTA Award for Best Actress in a Supporting Role
2013	Costume Designers Guild Award for Lacoste Spotlight Award

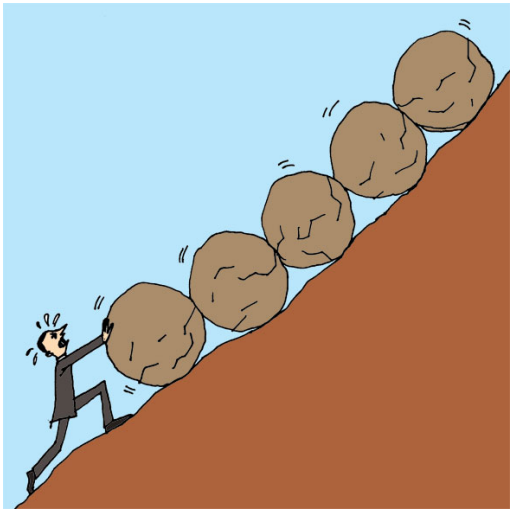
Goal

Answer Natural Language Questions against Structured Knowledge Base

Related Work

- Semantic Parsing Based Methods
  - PCCG based
    (Cai and Yates 2013; Kwiatkowski et al. 2013)
  - PCFG based
    (Berant et al. 2013)
- Paraphrase Based Method
  (Berant and Liang 2014)
- Machine Translation Based Method
  (Bao et al. 2014)
- Information Extraction Based Method
  (Yao and Van Durme 2014)

Semantic Parsing Based Method



Challenges:

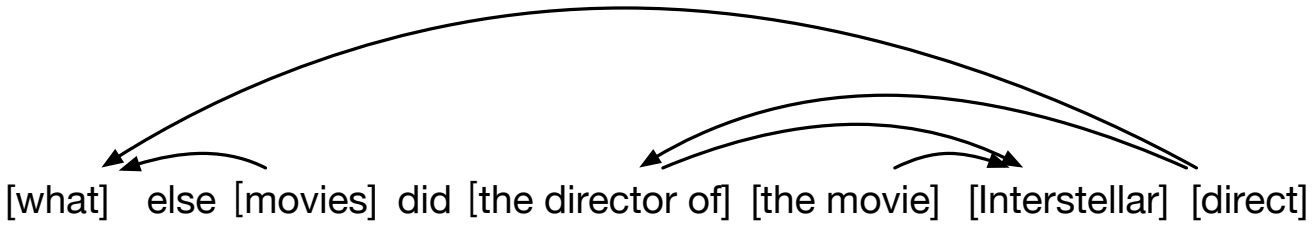
1. Convert the question into a meaning representation
2. Ground the meaning representation into a database query

Limits of Current Semantic Parsers:

1. Search space is huge
2. Difficult to adapt to other KBs

Motivation

1. Meaning representation is KB-independent



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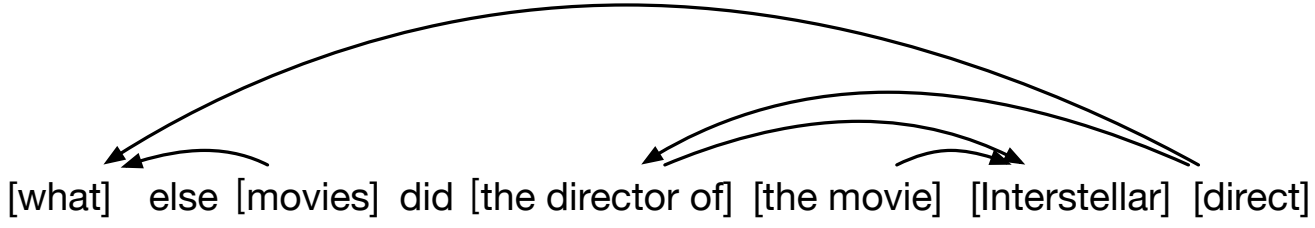

2. Separation of meaning representation and instantiation

Freebase

```
select ?y
[ fb:m.0fkf28   fb:object.type          fb:film.film
  fb:m.0fkf28   fb:film.film.directed_by ?x
  ?x            fb:film.director.fim    ?y
  ?y            fb:object.type          fb:film.film ]
```

DBpedia

```
select ?y
[ ns:Interstellar   dbo:type      dbo:film
  ns:Interstellar   dbp:director  ?x
  ?y                dbp:director  ?x
  ?y                dbo:type      dbo:film ]
```

Framework

what else movies did the director of the movie Interstellar direct

Framework

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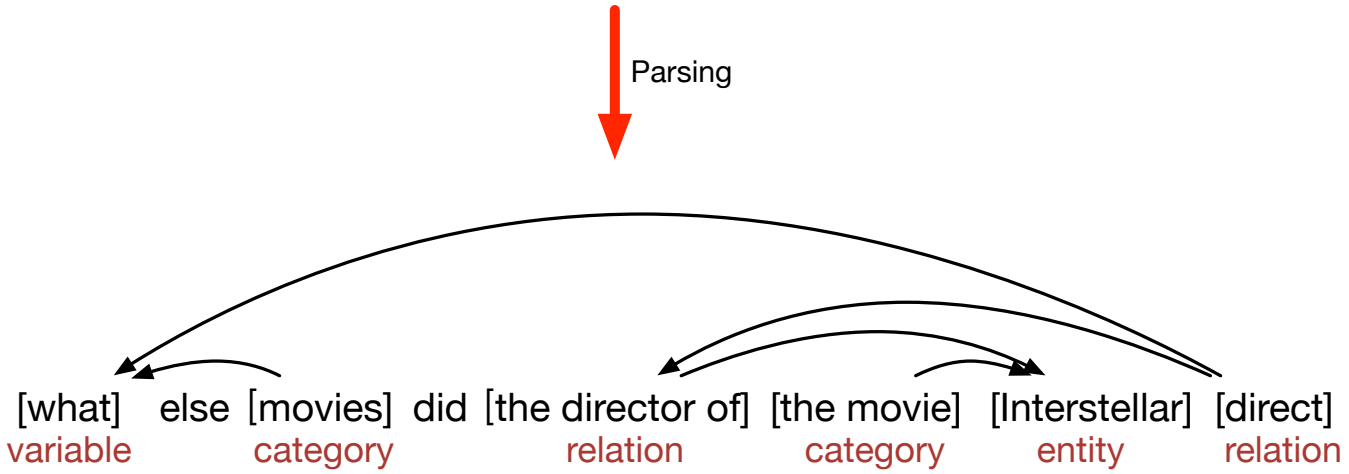
Framework

what else movies did the director of the movie Interstellar direct



Framework

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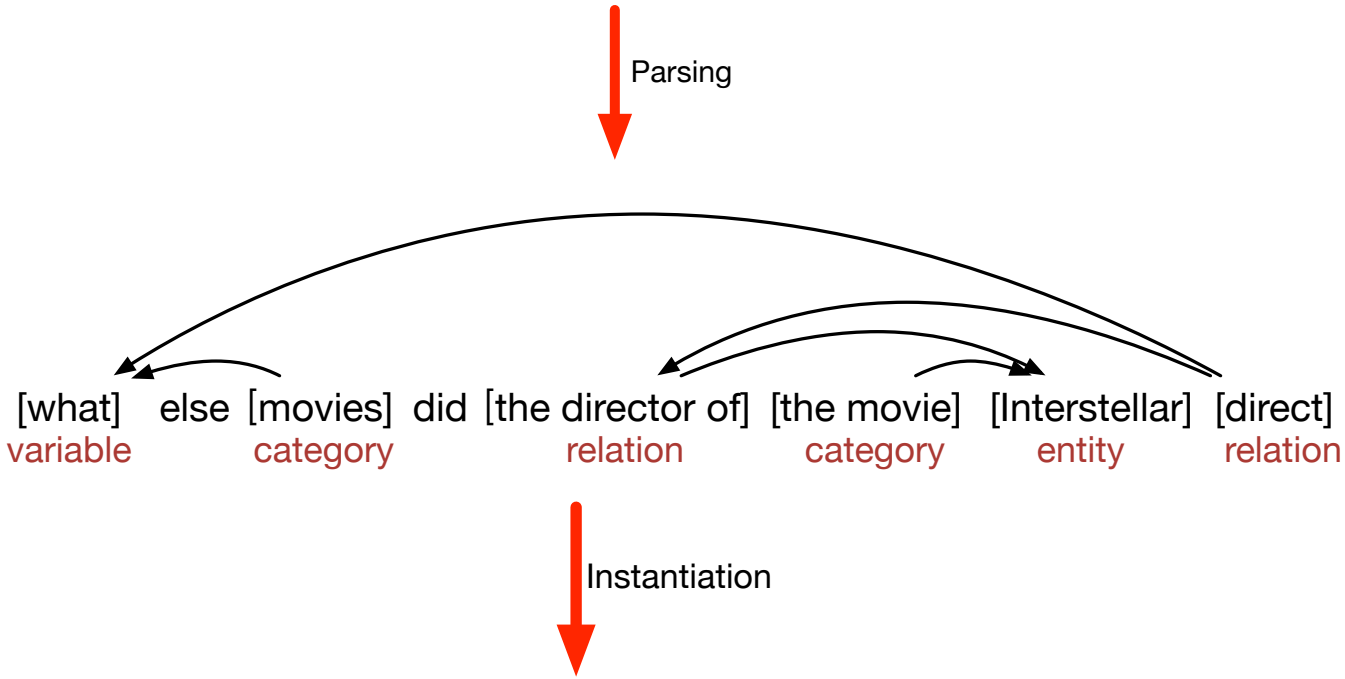

Framework

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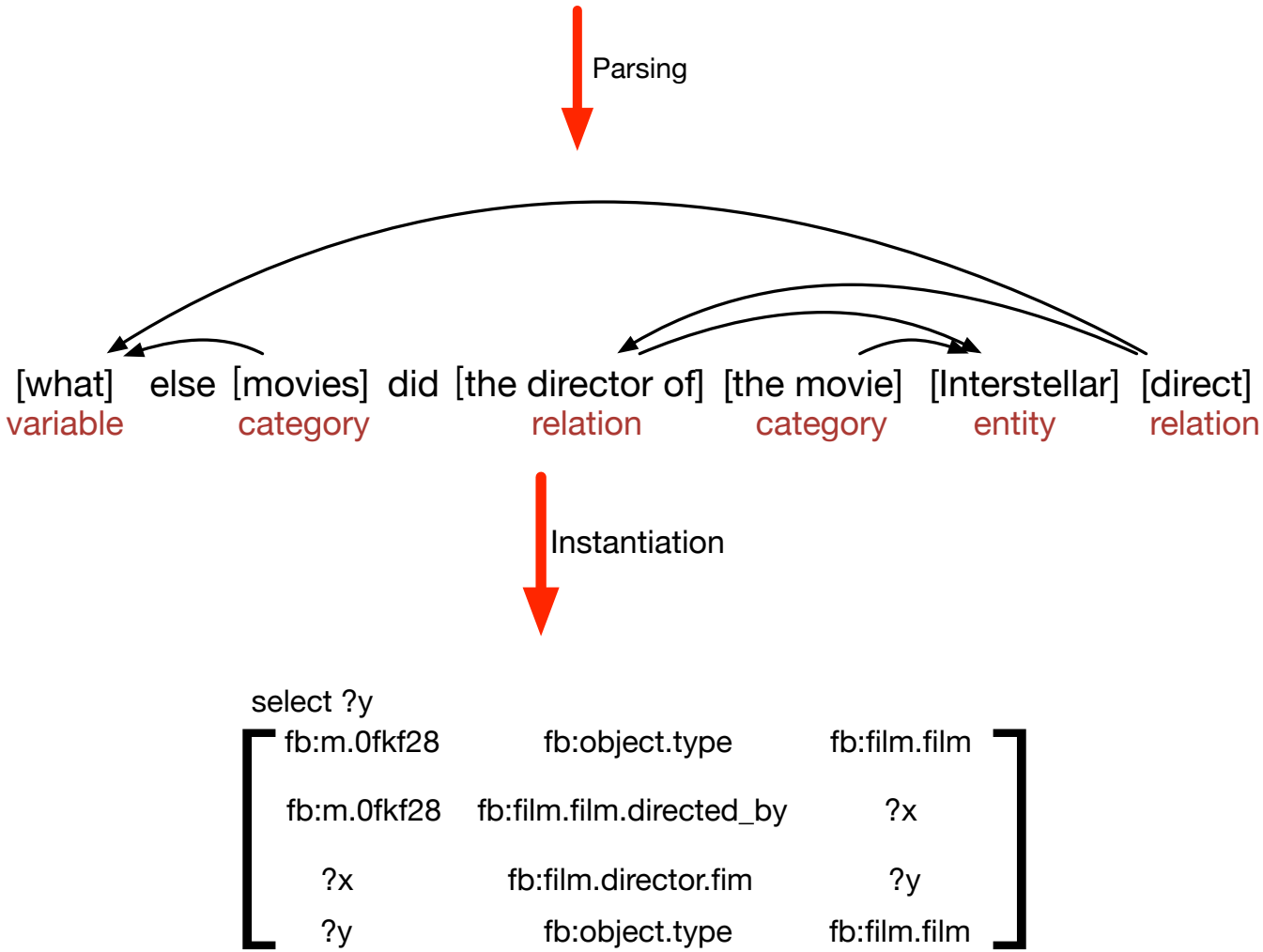
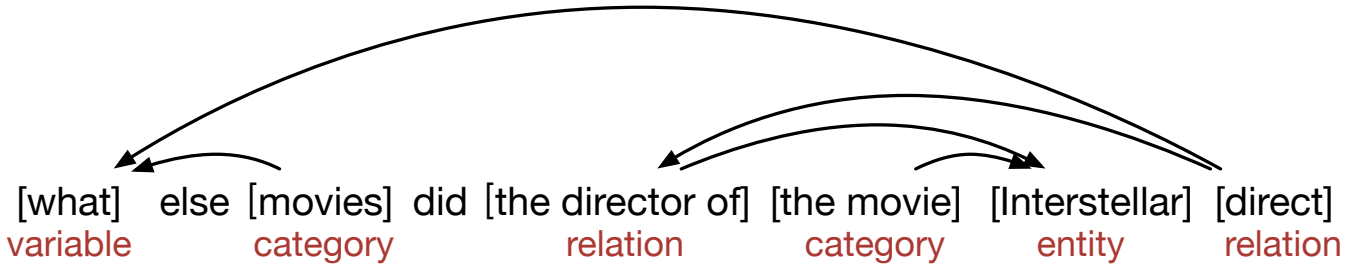


- The Transition-based Semantic Parser
  - Phrase Dependency Graph
  - The Transition-based Semantic Parsing
- Grounding the Dependency Graph to the Knowledge Base
- Experiments
- Conclusion



Node

A phrase with a semantic label $l \in$ {entity, category, variable, relation}

Edge

A predicate-argument dependency between phrases
unary predicate
binary predicate

Structure Prediction

Input: a natural language question

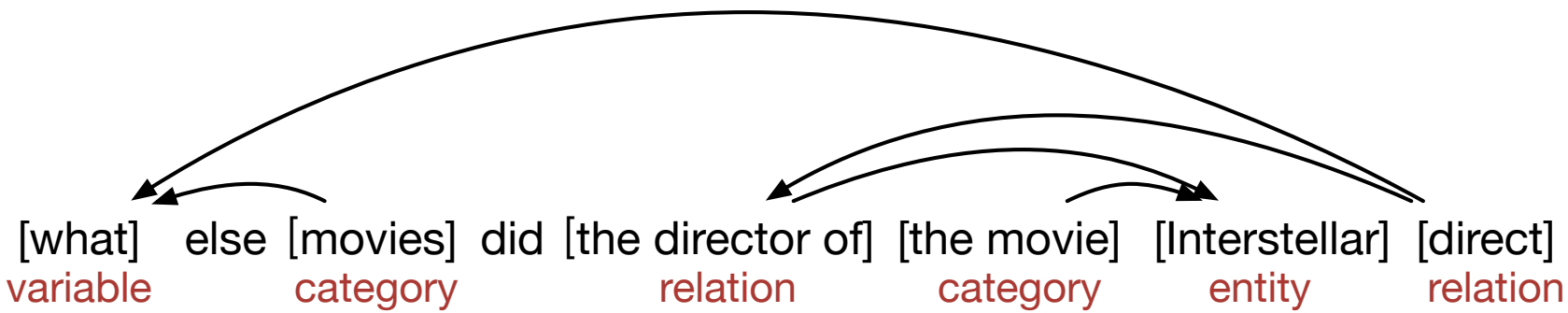
Output: a phrase dependency graph

A pipeline framework to predict the structure

1. Phrase Detection

what	else	movies	did	the director of	the movie	Interstellar	direct
variable		category		relation	category	entity	relation

2. Phrase Dependency Parsing

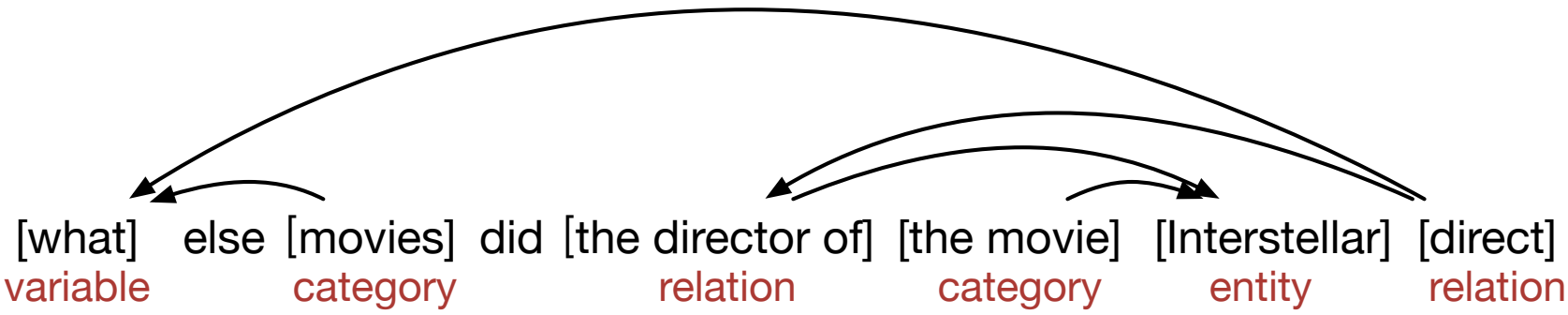


Phrase Detection

what	else	movies	did	the	director	of	the	movie	Interstellar	direct
V-B	O	C-B	O	R-B	R-I	R-I	C-B	C-I	E-B	R-B

- Sequence labeling problem
- Lexical Features

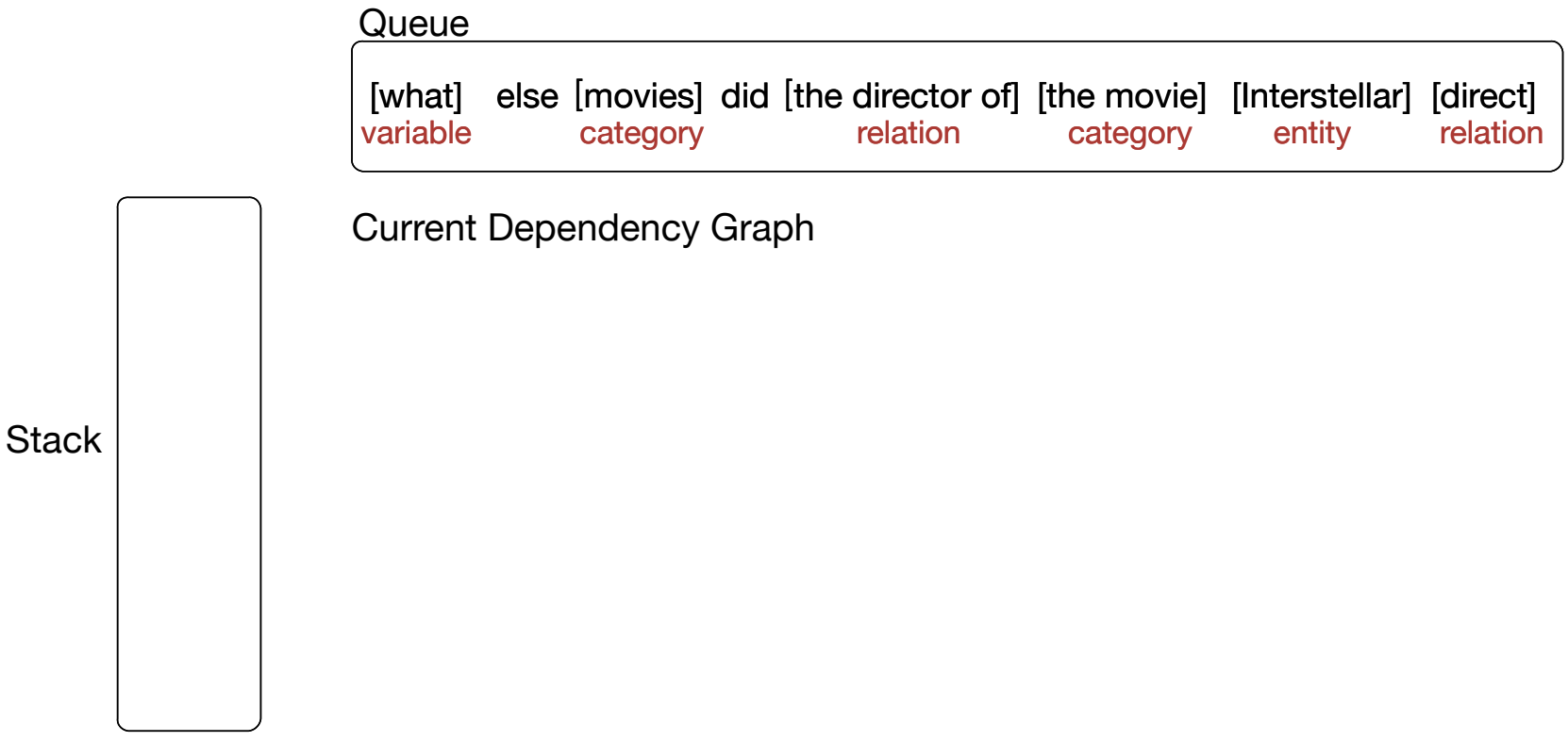
Phrase Dependency Parsing



Transition-based parsing

- A queue of incoming phrases
- A stack of processed phrases
- Four actions
- Multiple heads

Parsing Example



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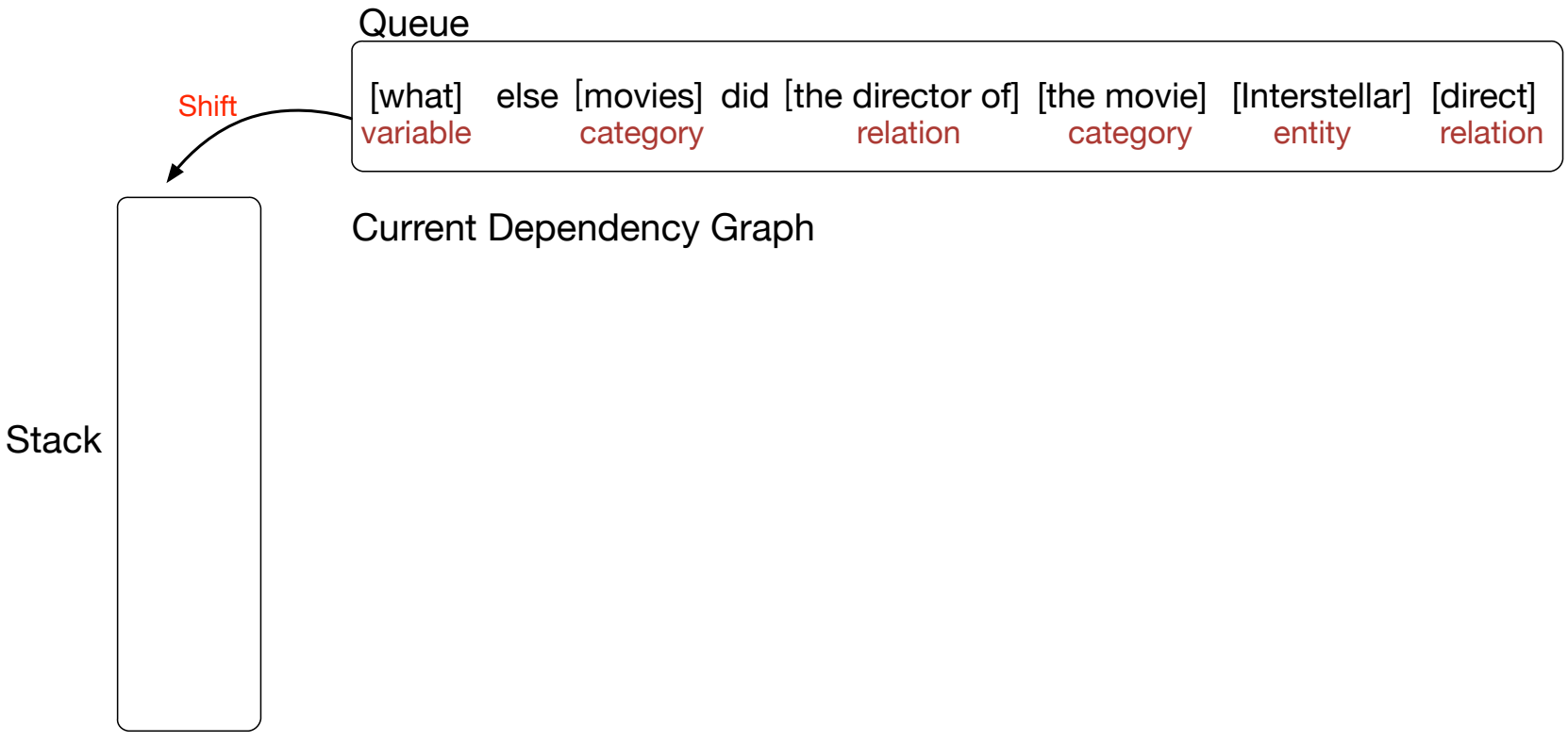

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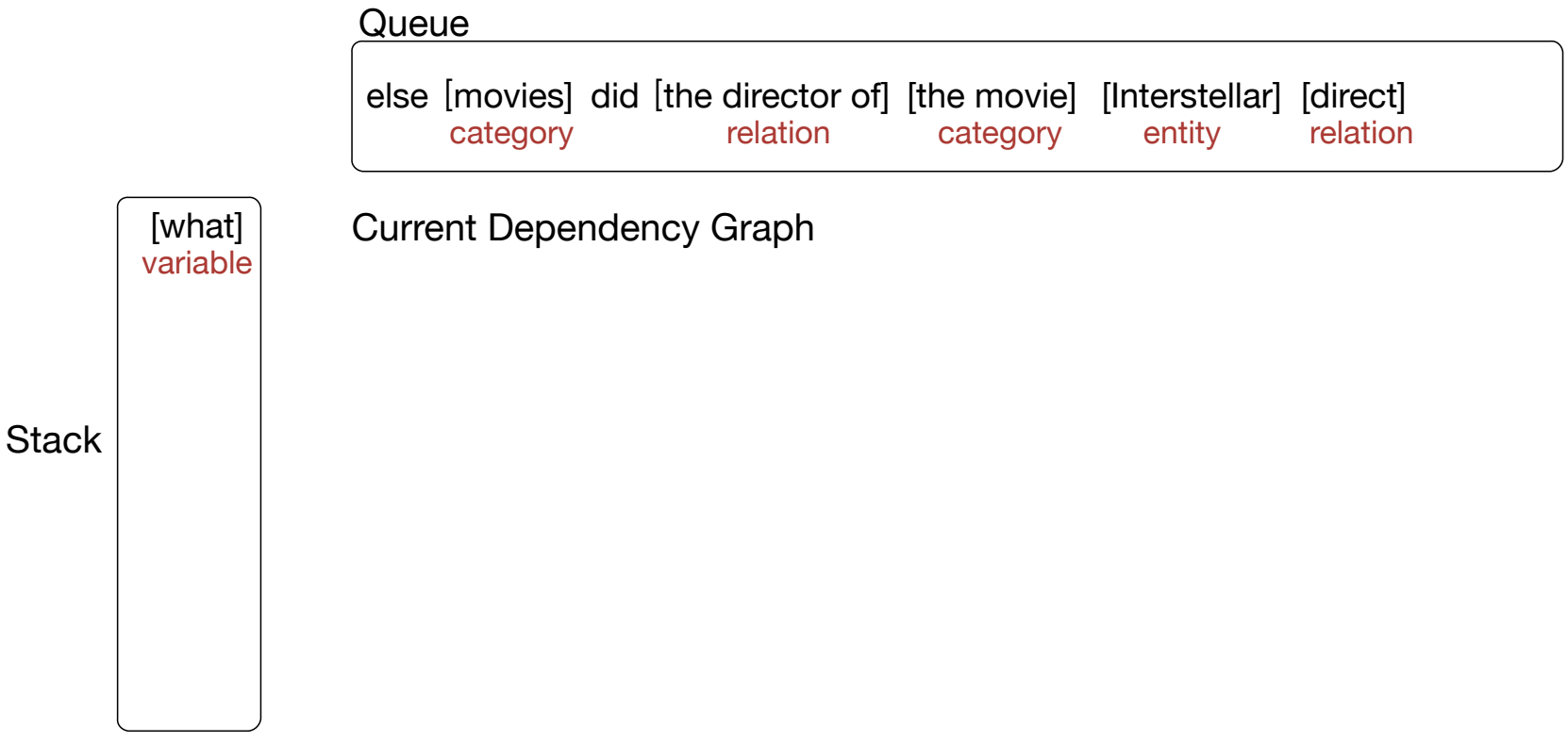

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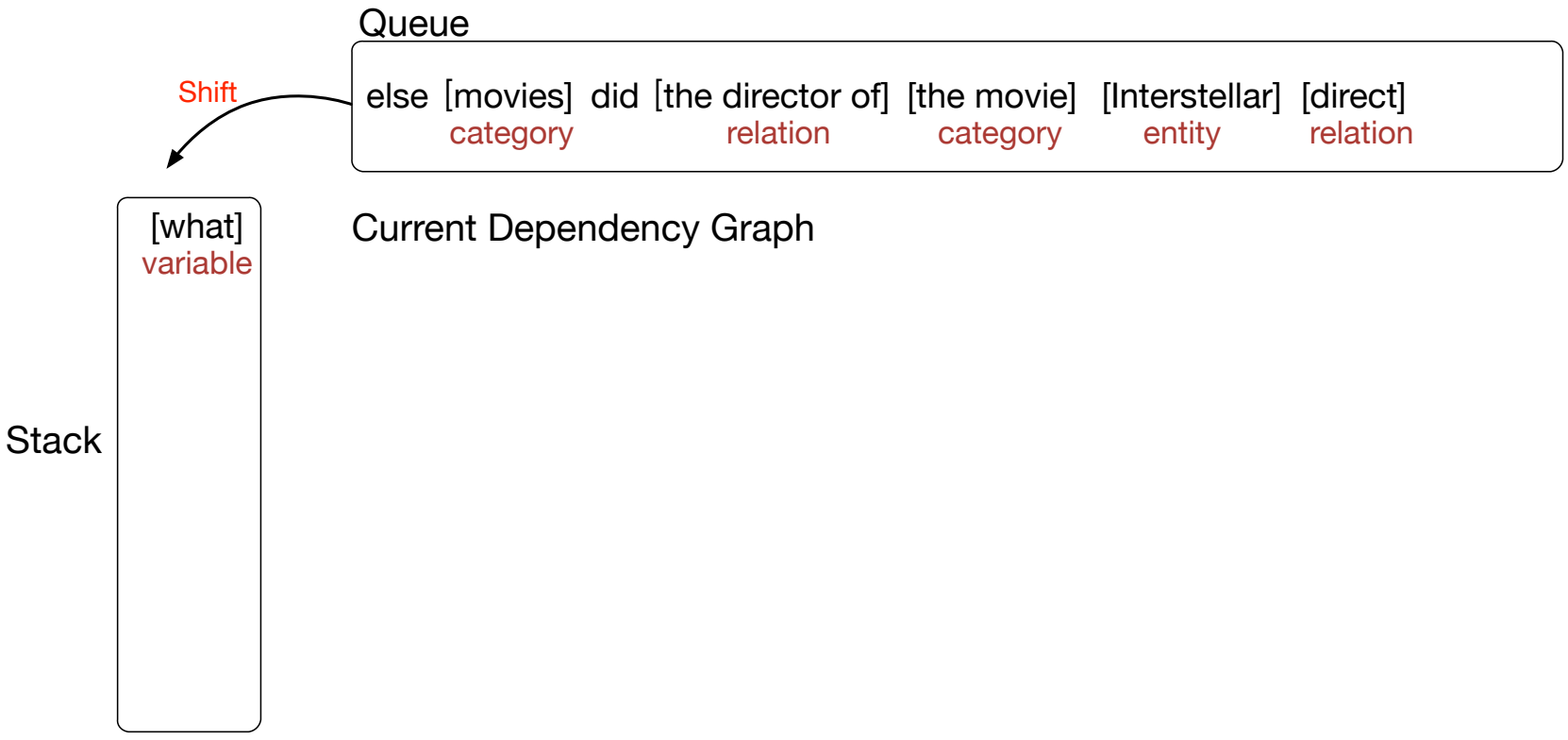


Parsing Example

Queue

[movies] category | did | [the director of] relation | [the movie] category | [Interstellar] entity | [direct] relation

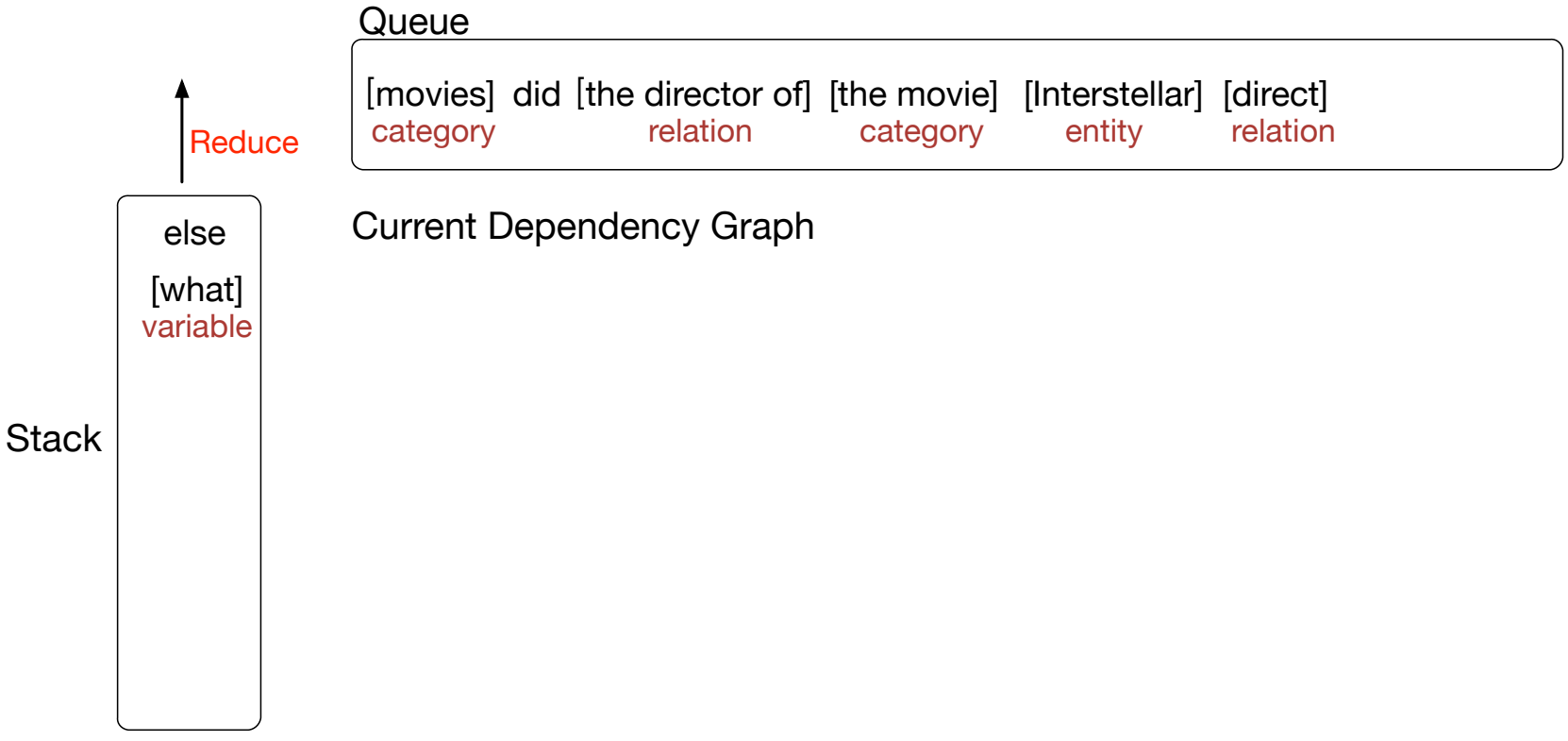
Current Dependency Graph

Stack

else

[what] variable

Parsing Example



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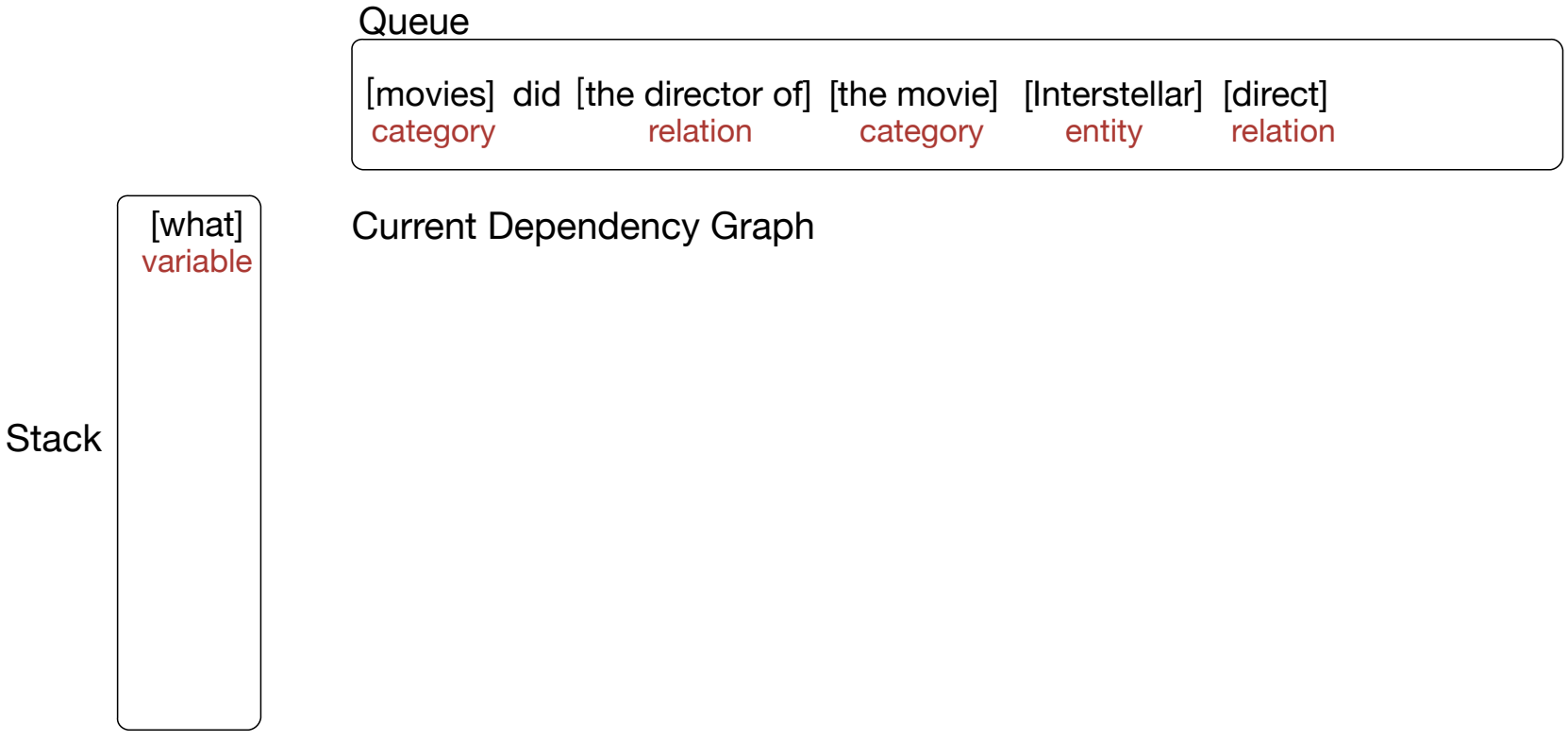

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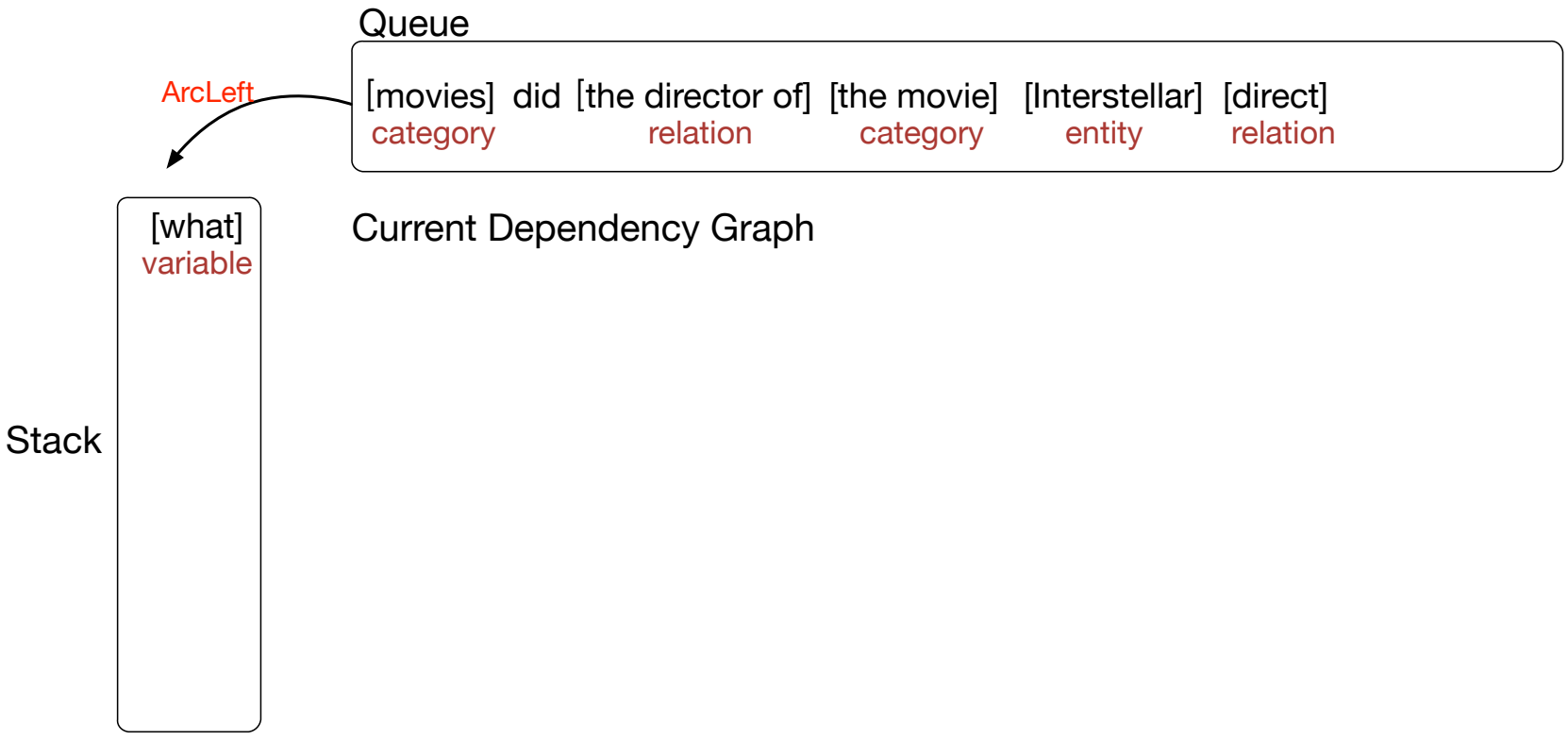

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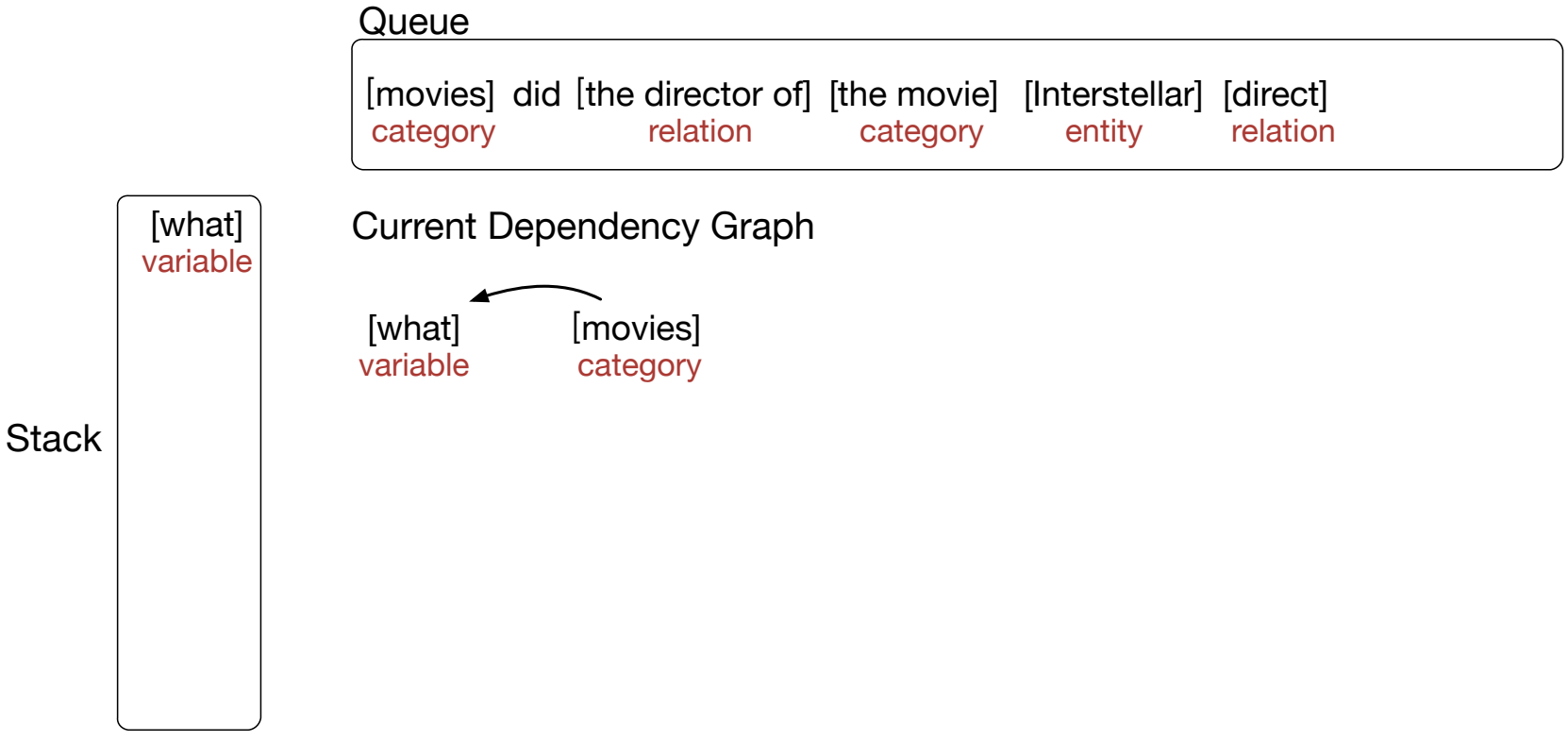

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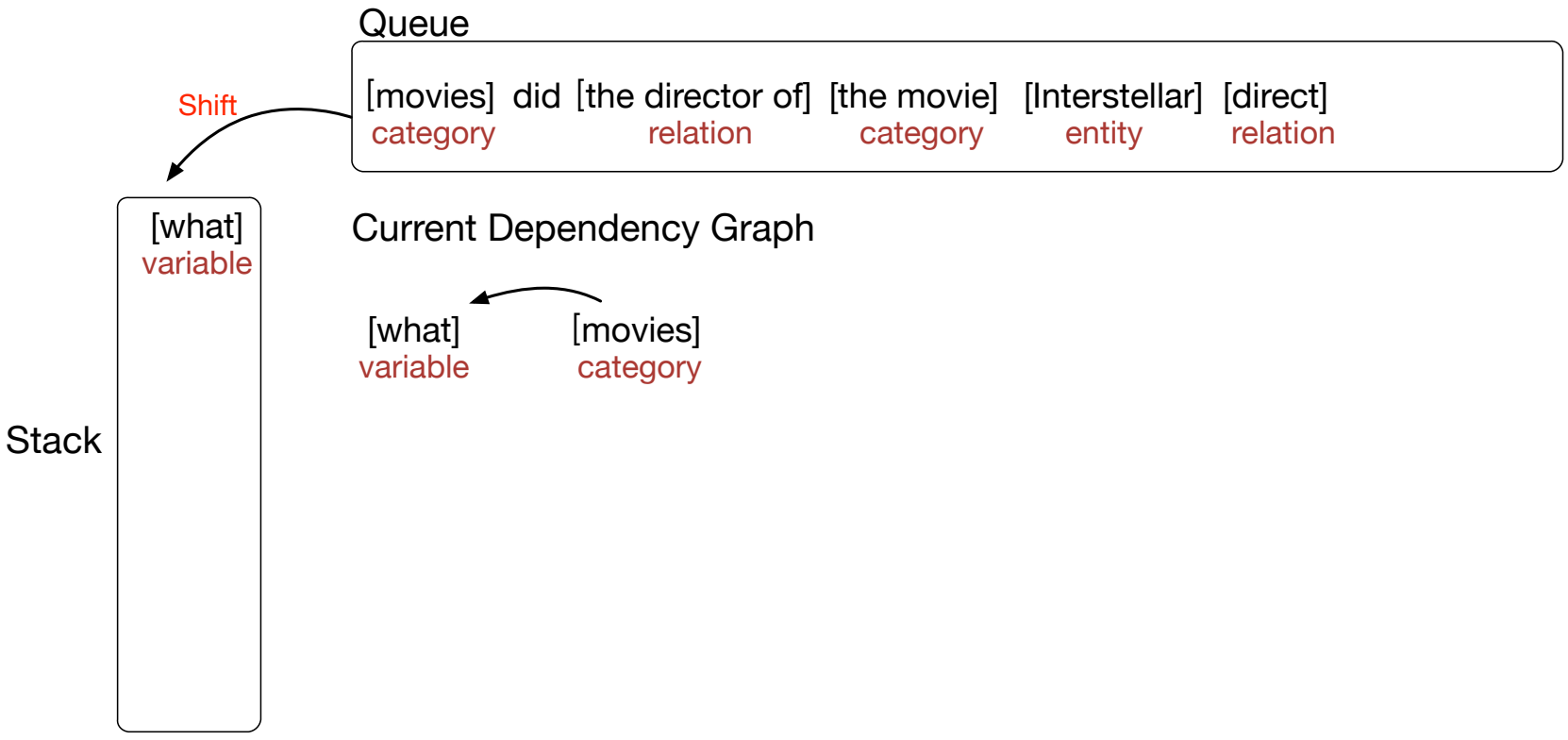

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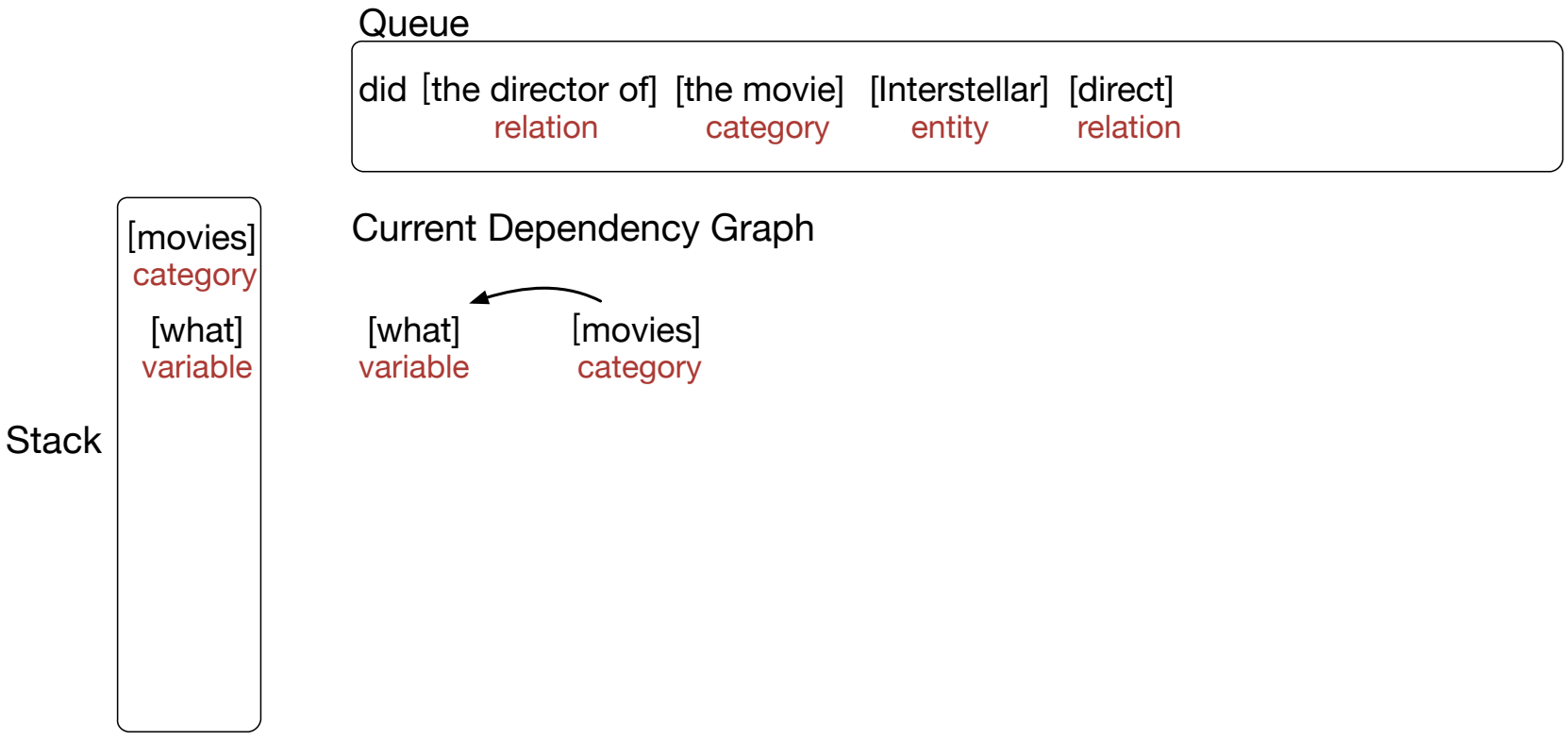

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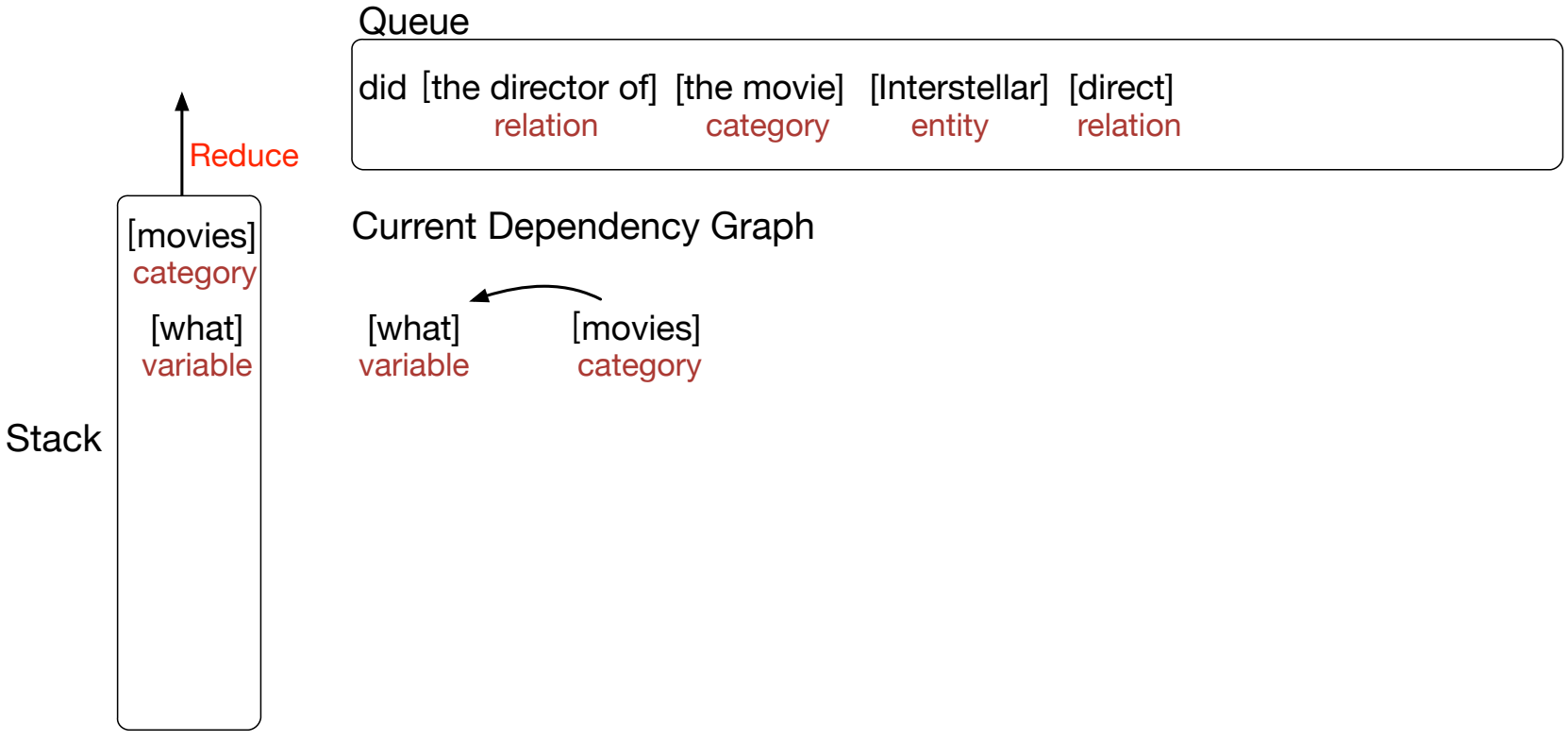

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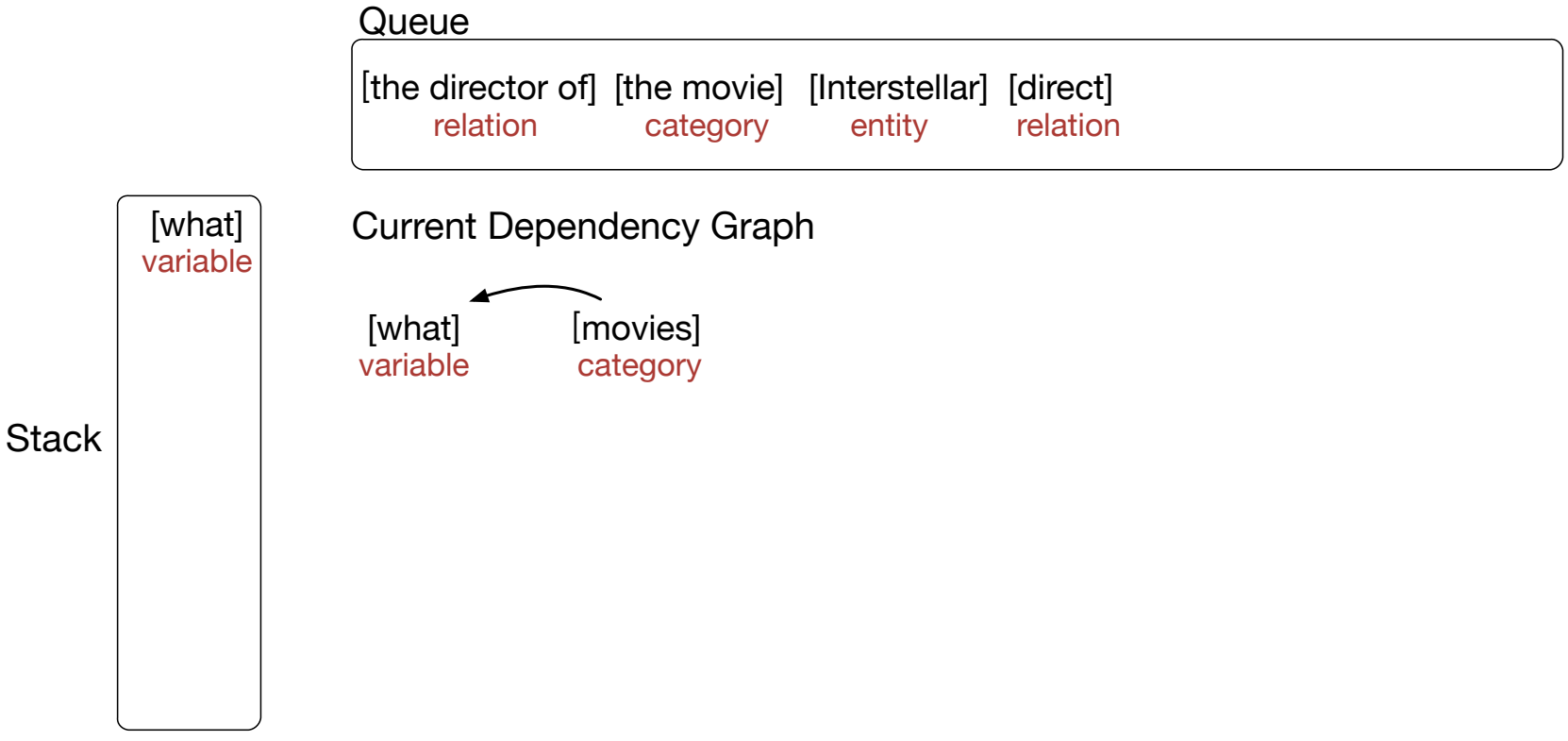

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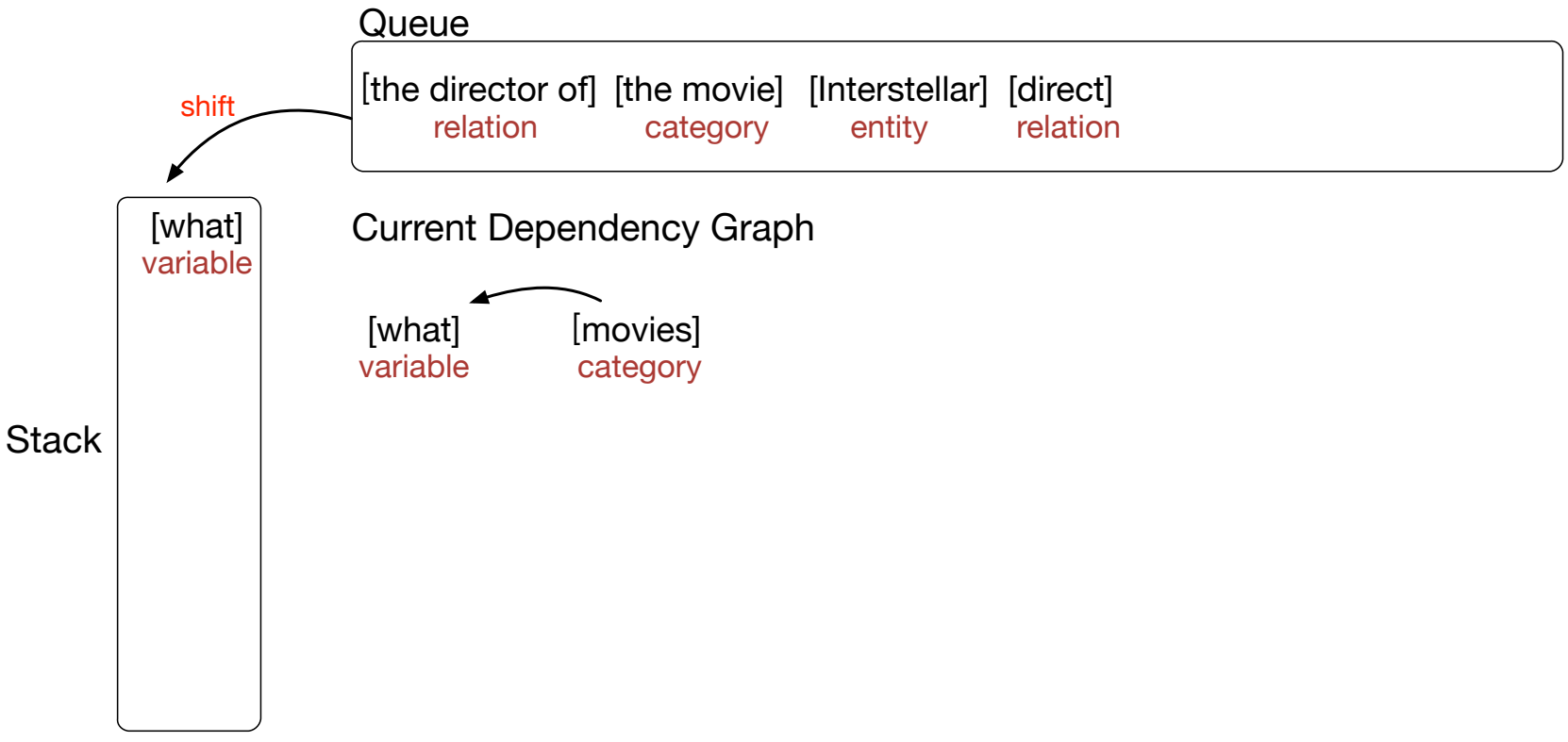

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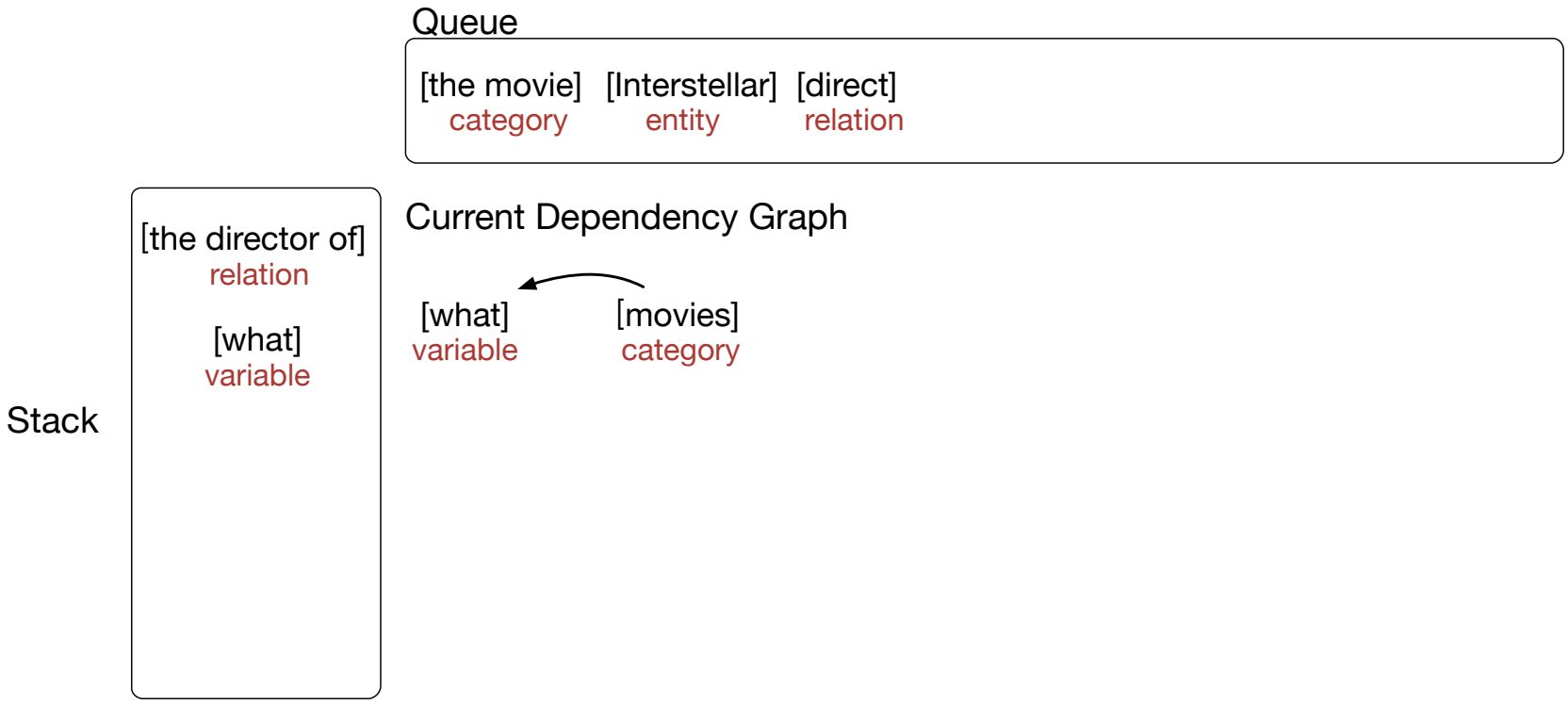

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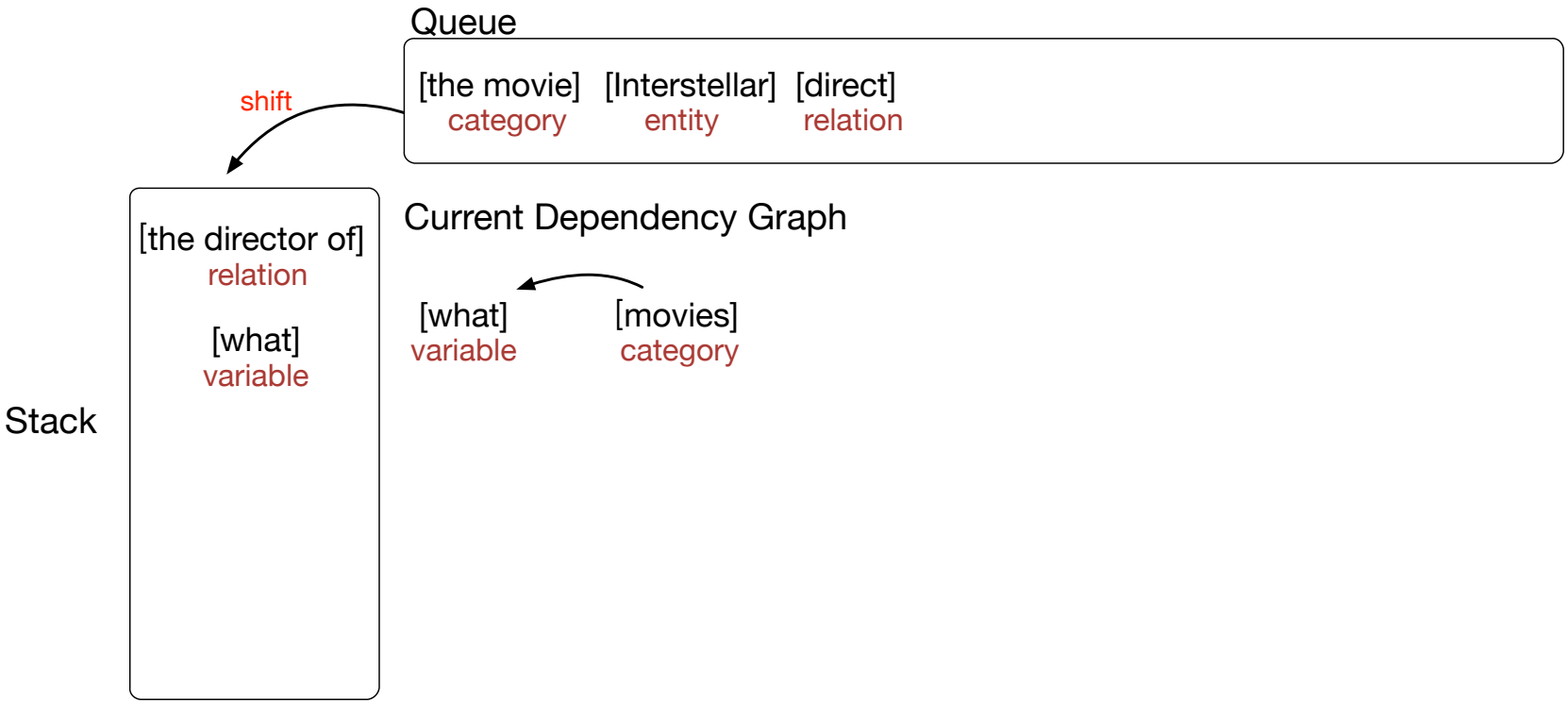

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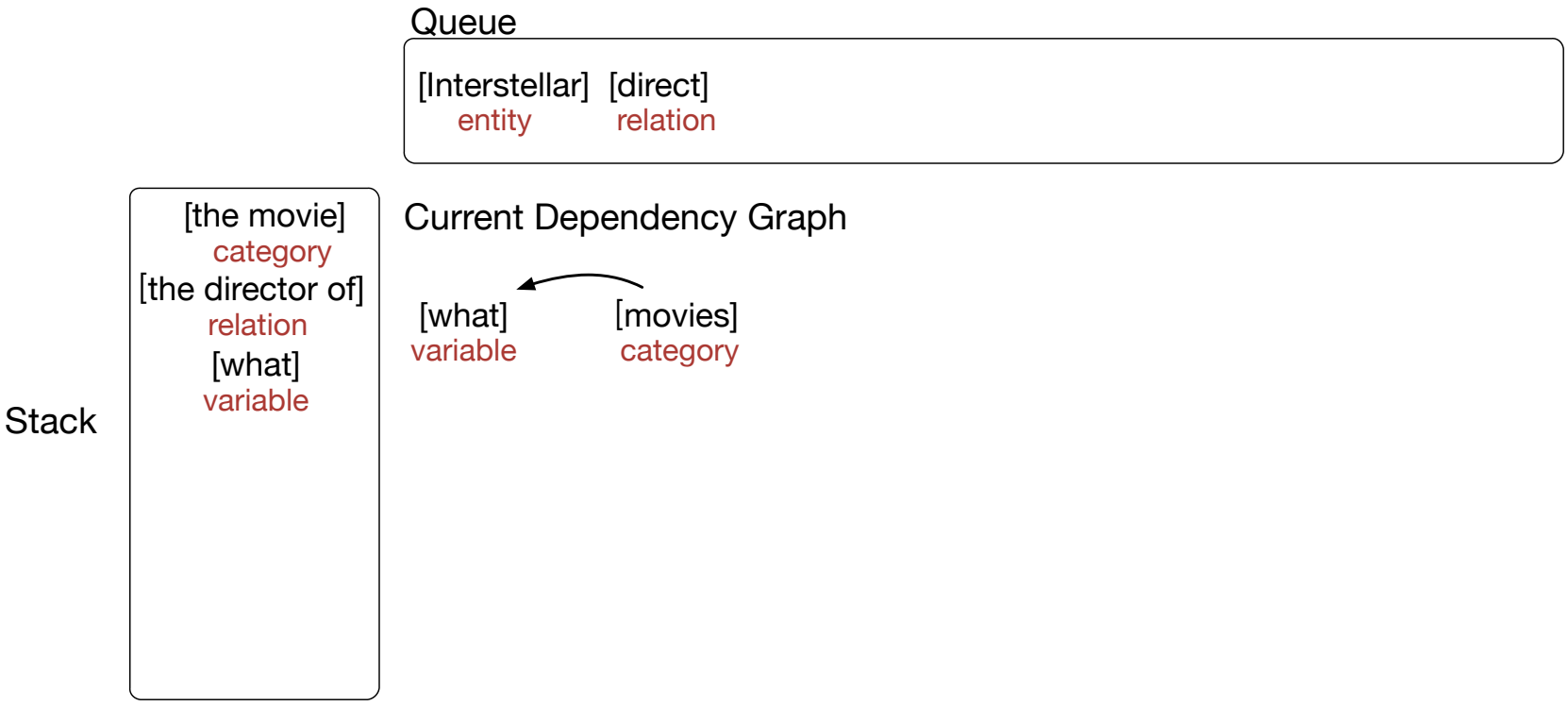

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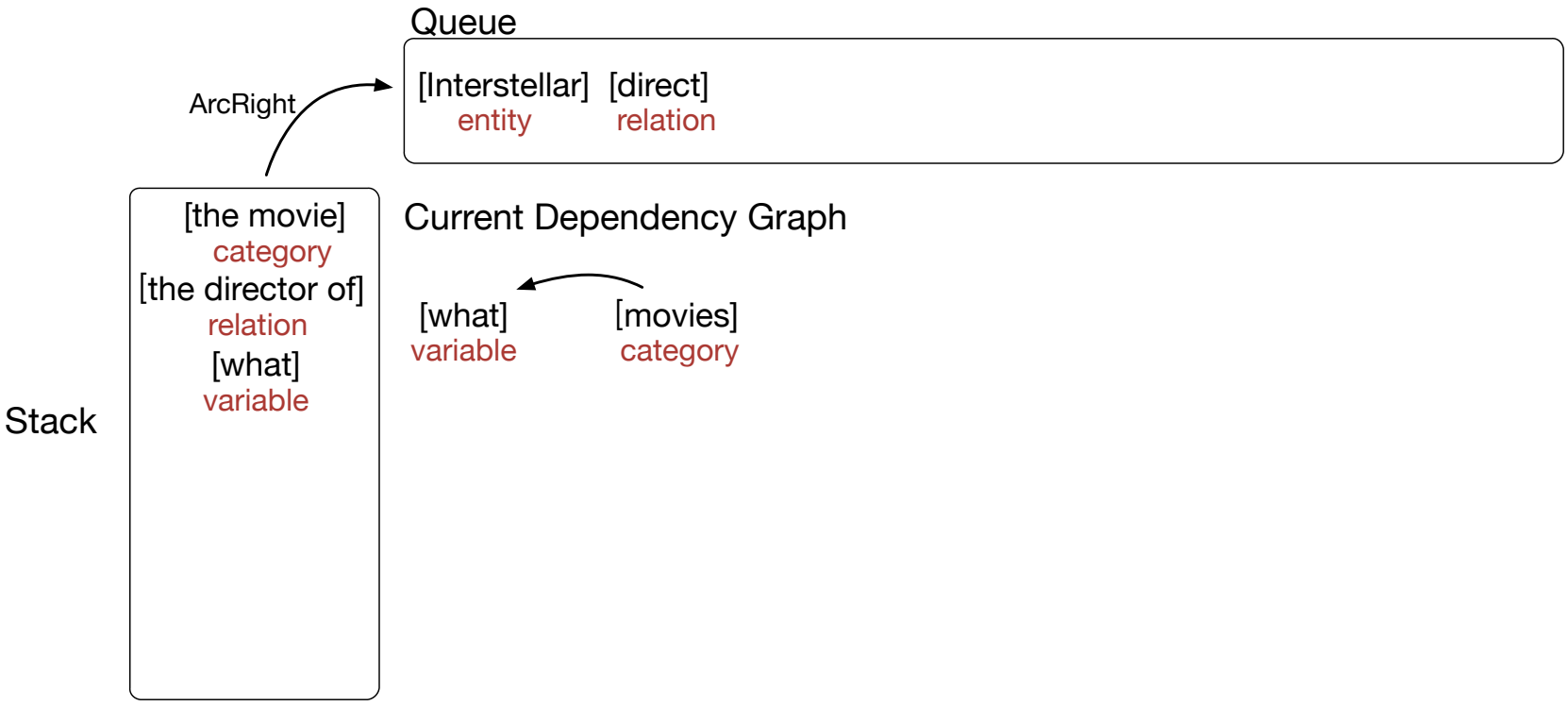

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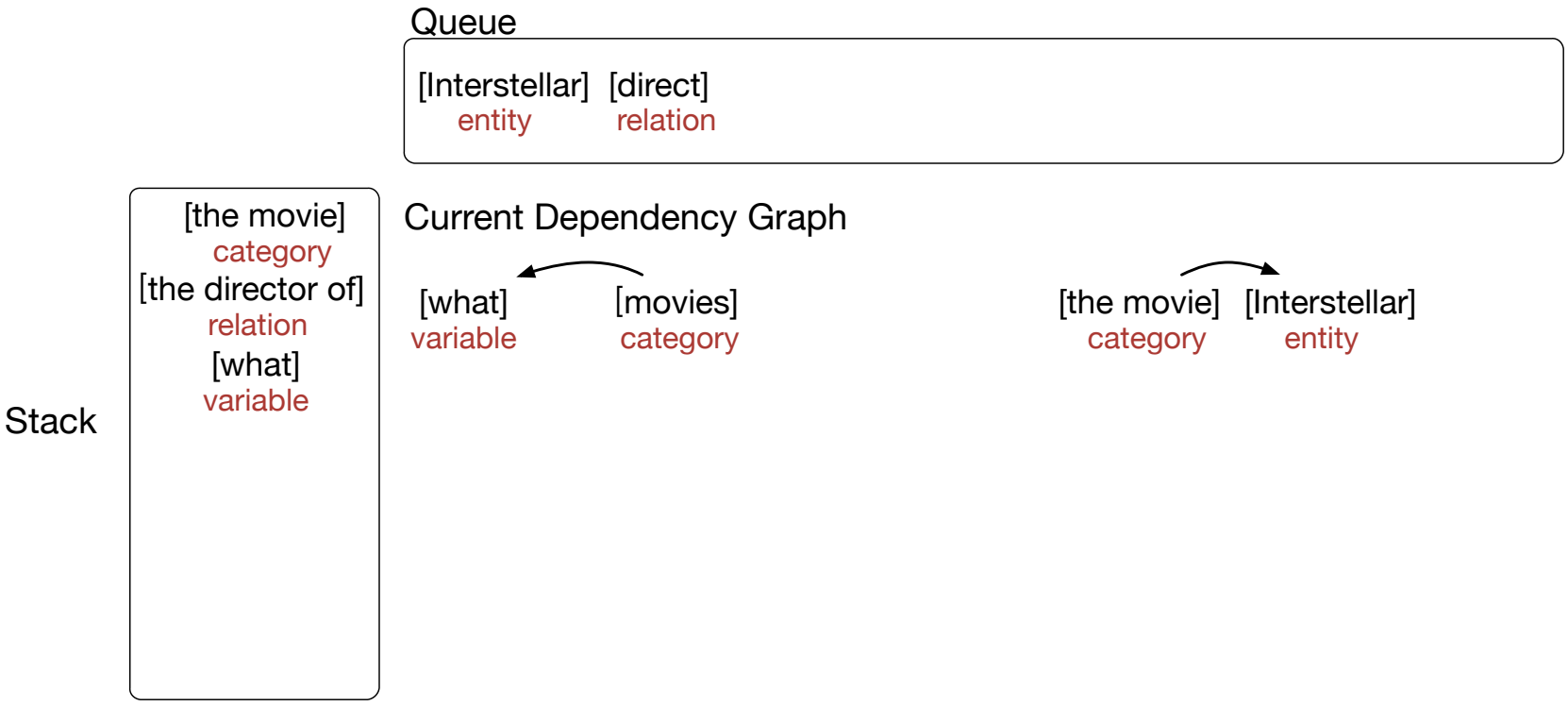

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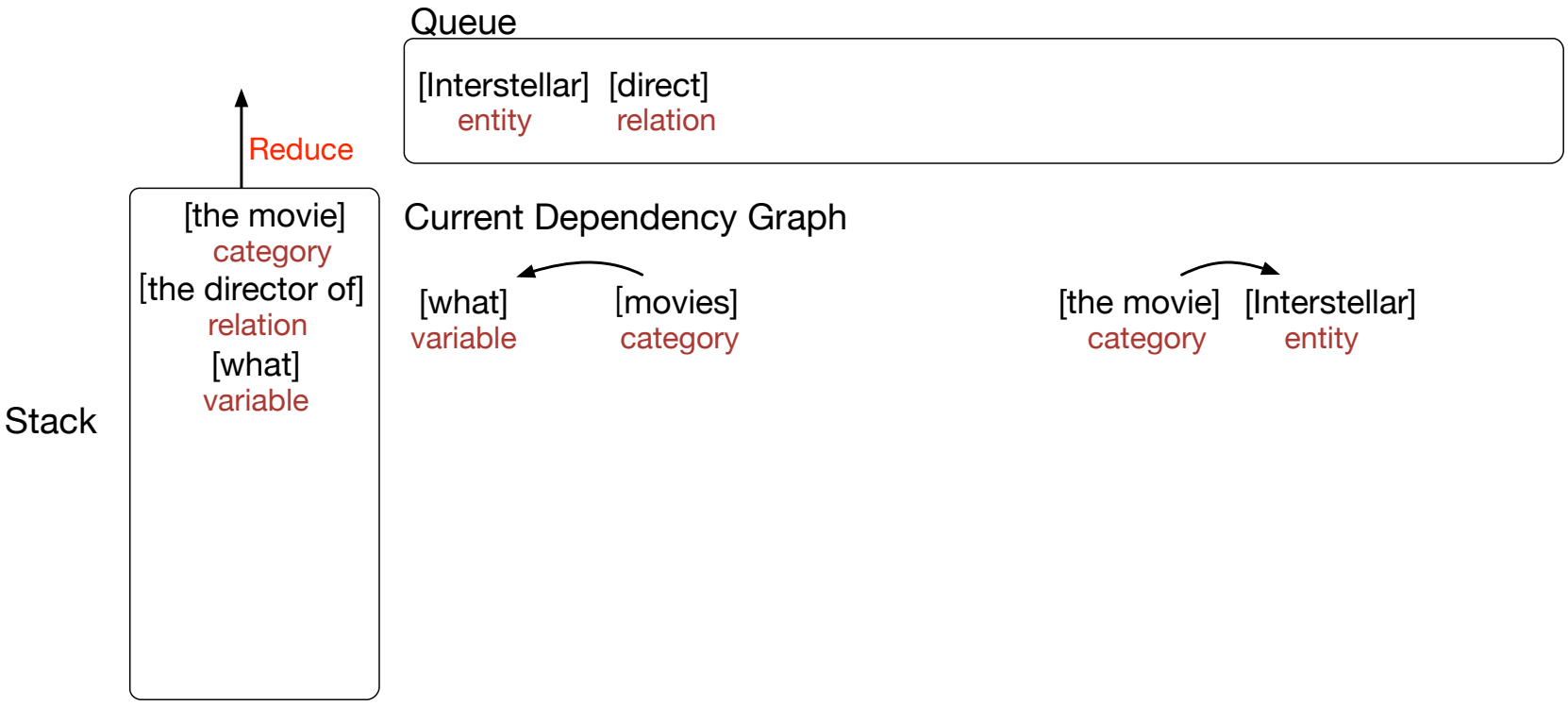

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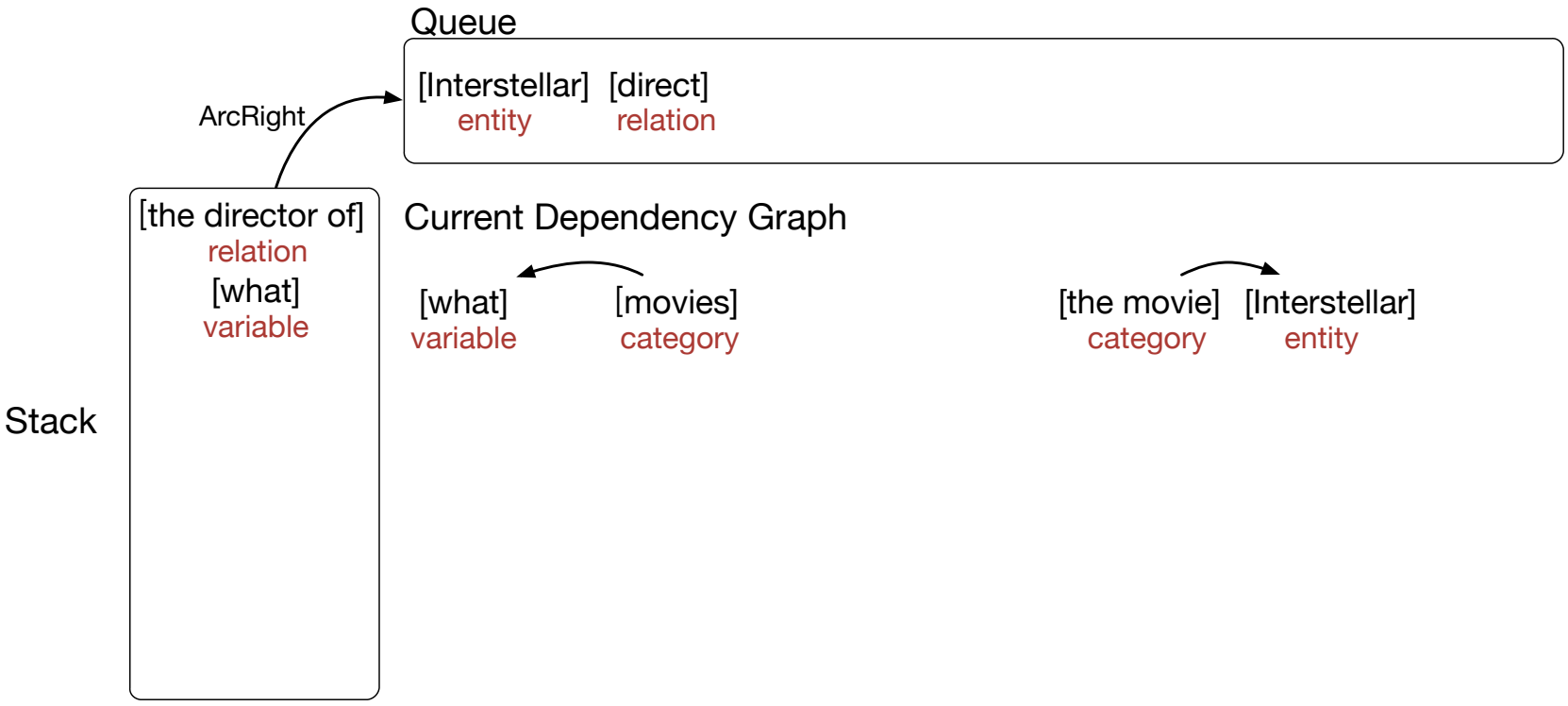

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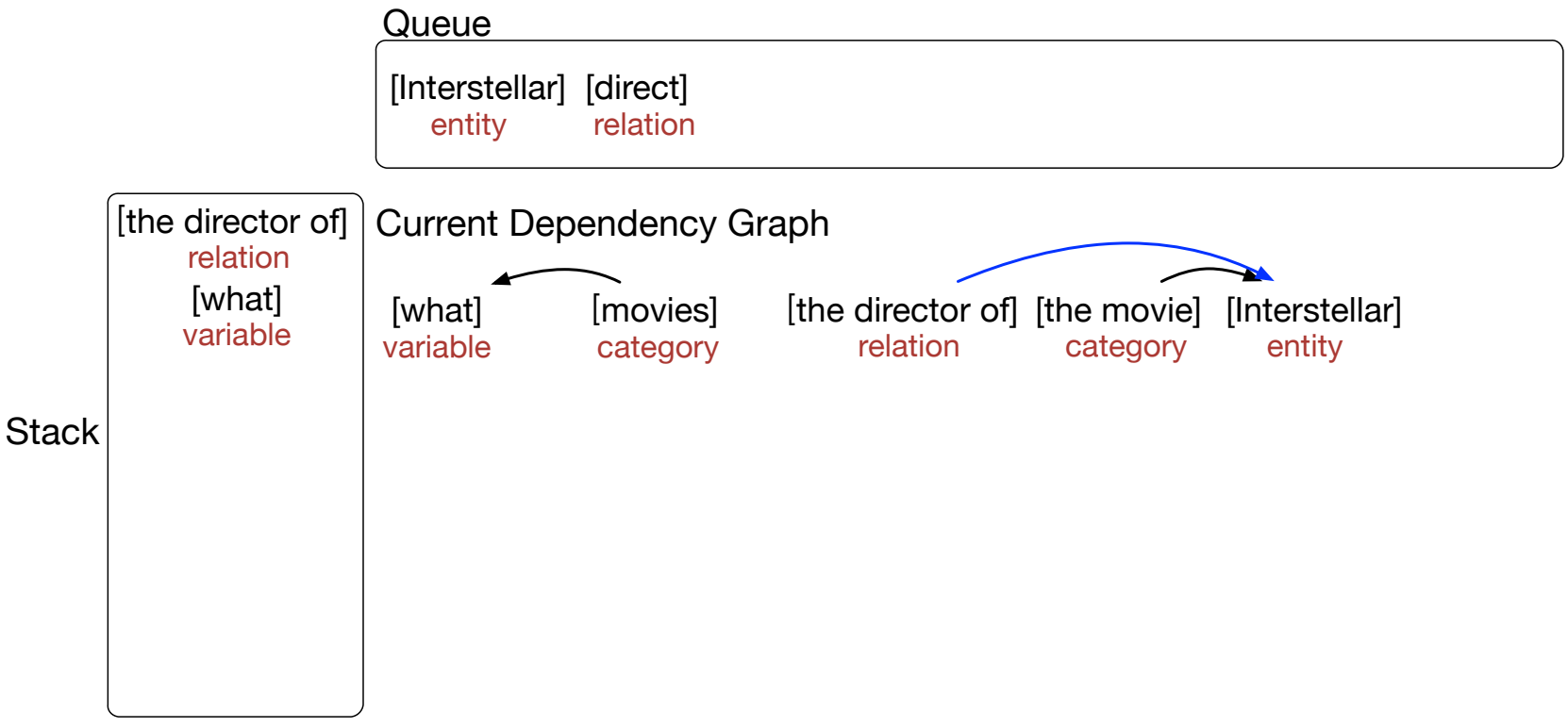

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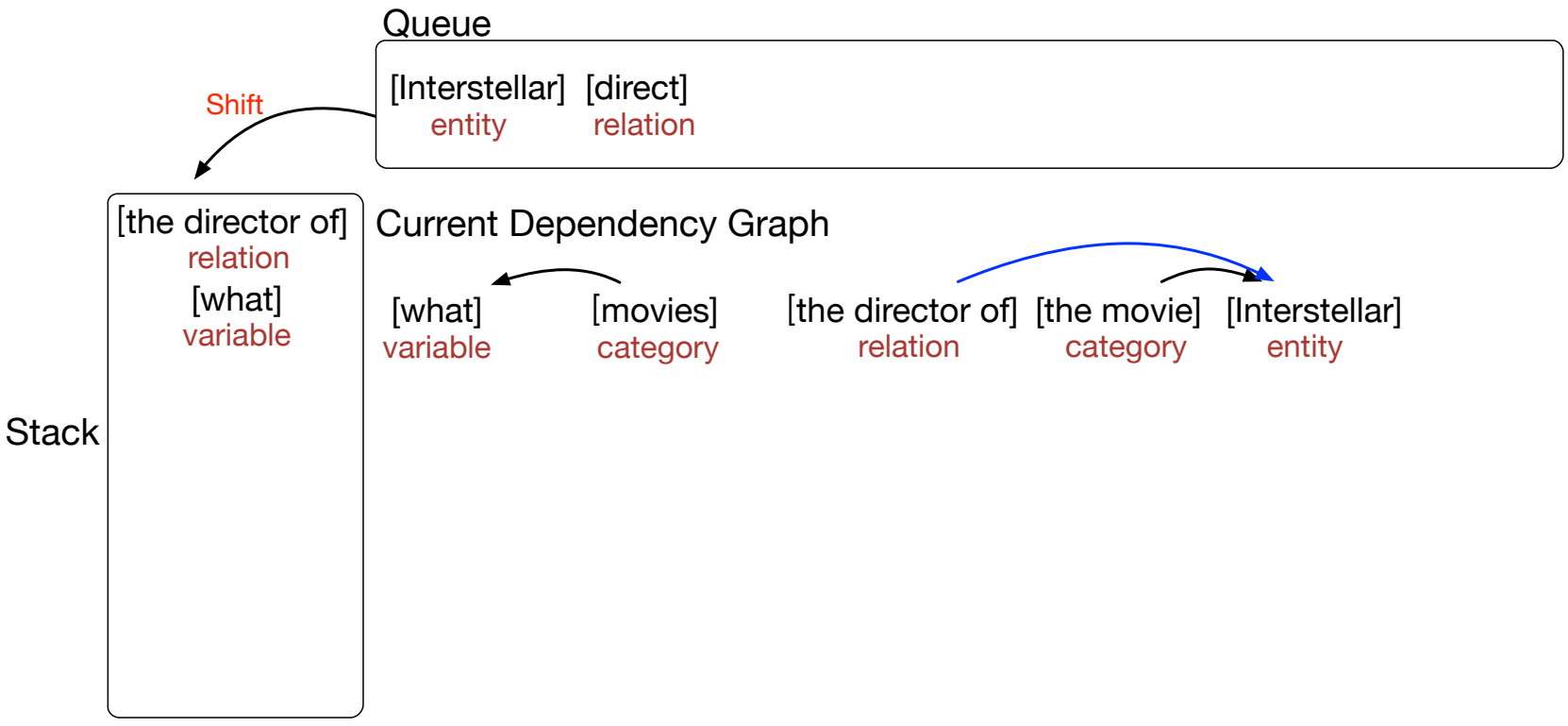

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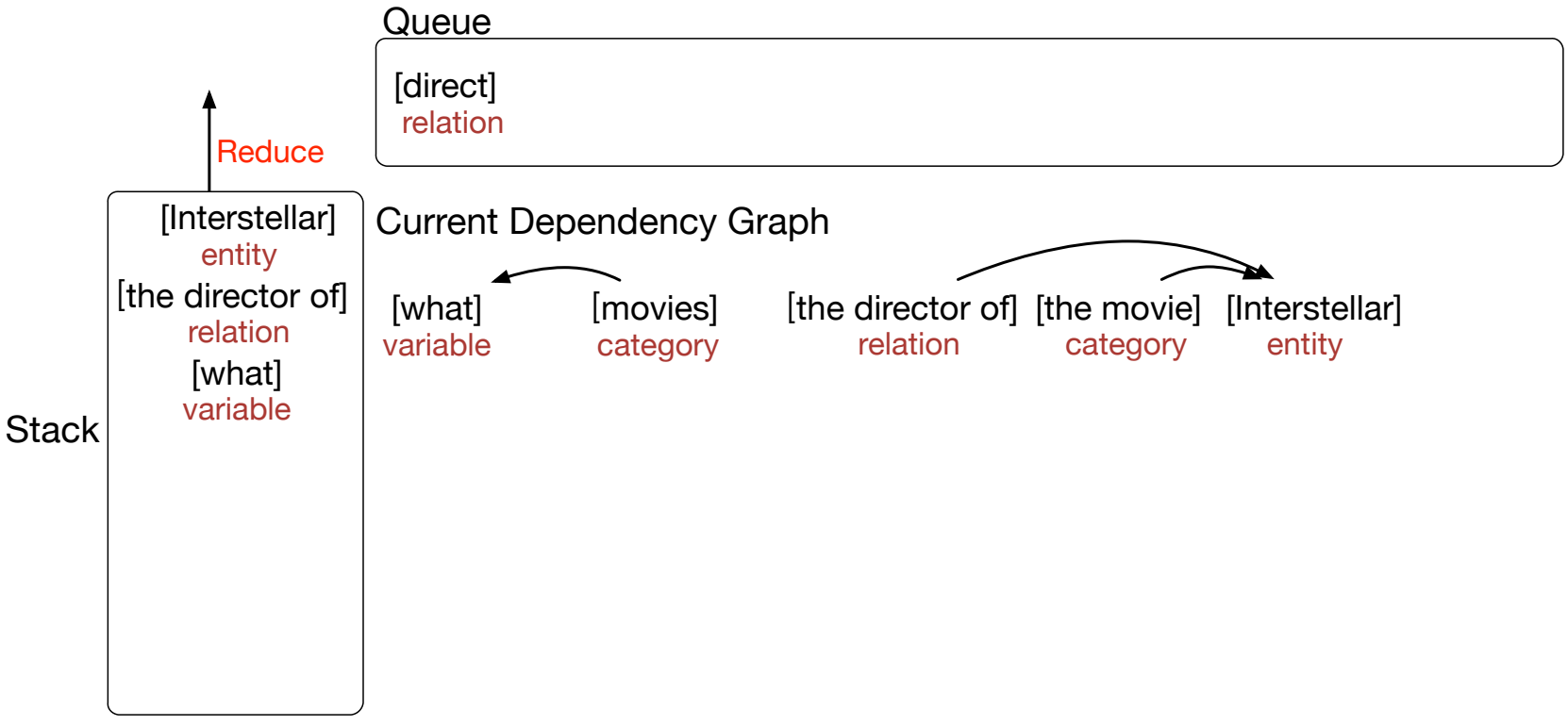

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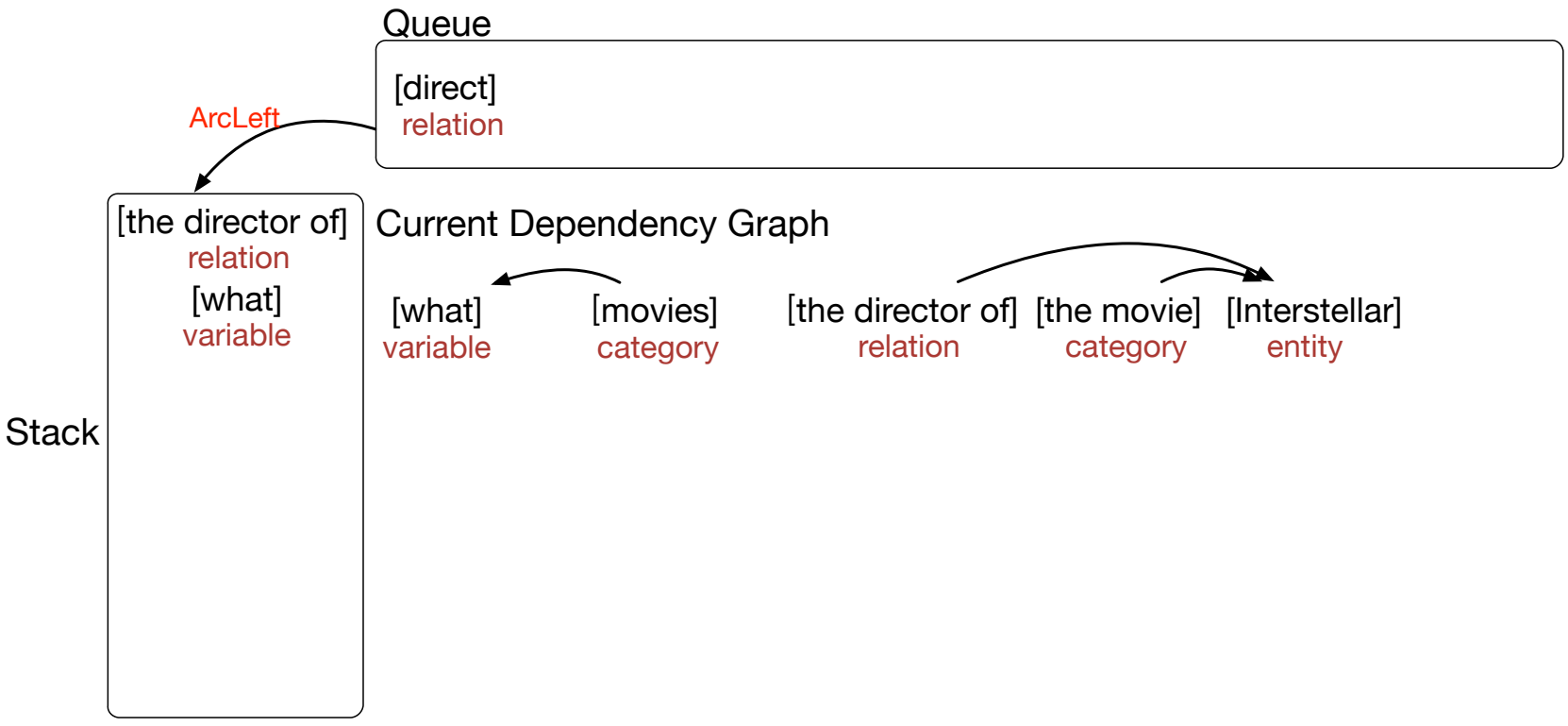

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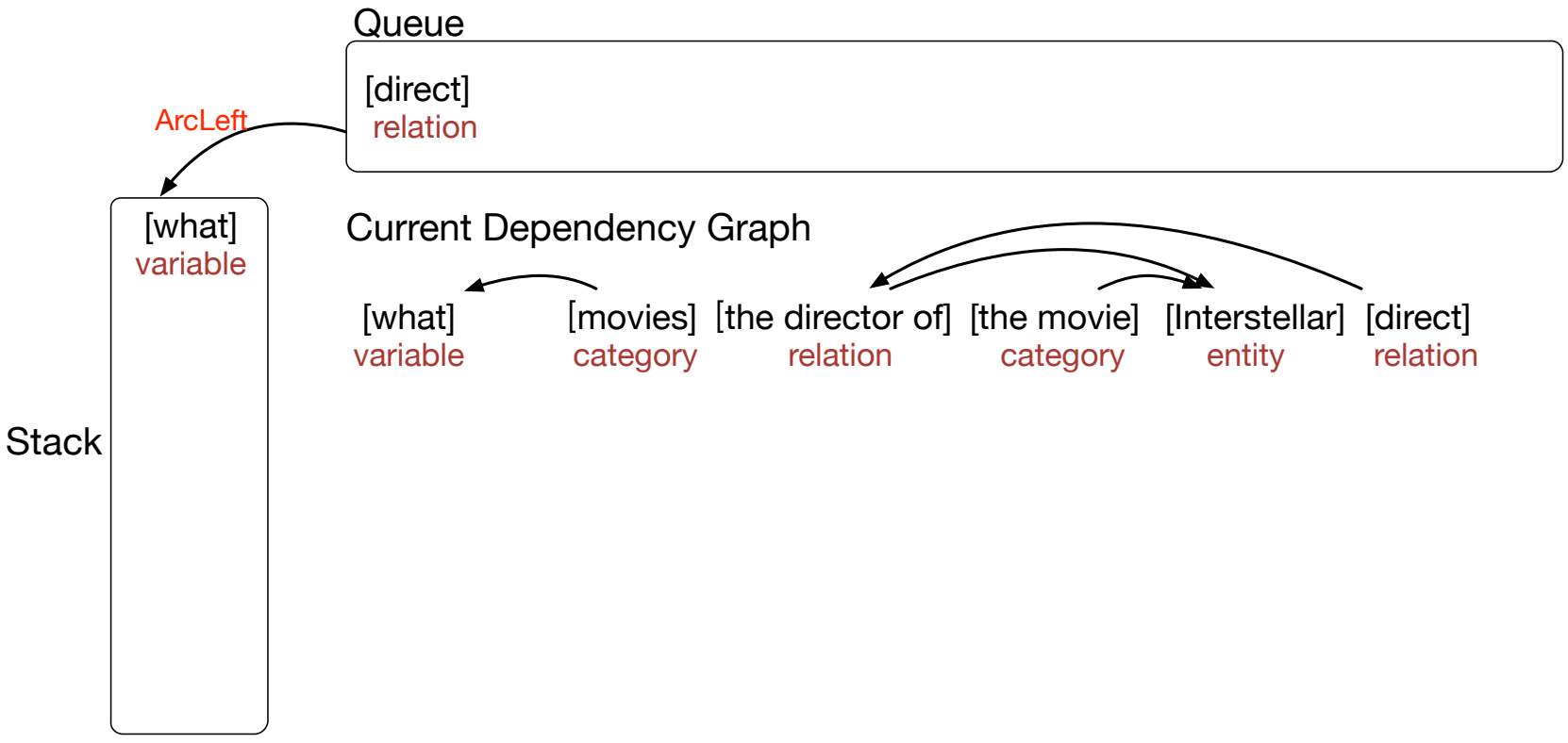

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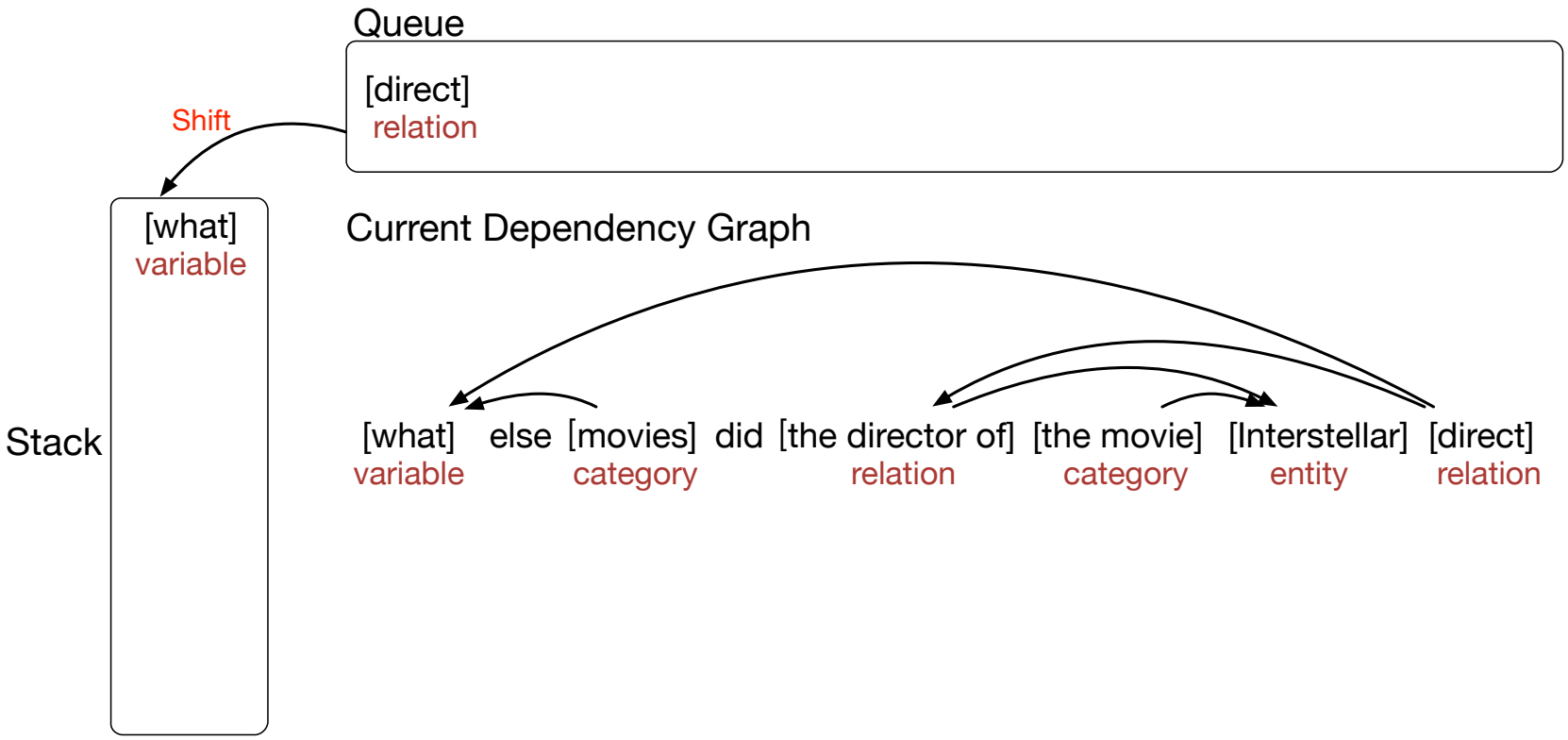

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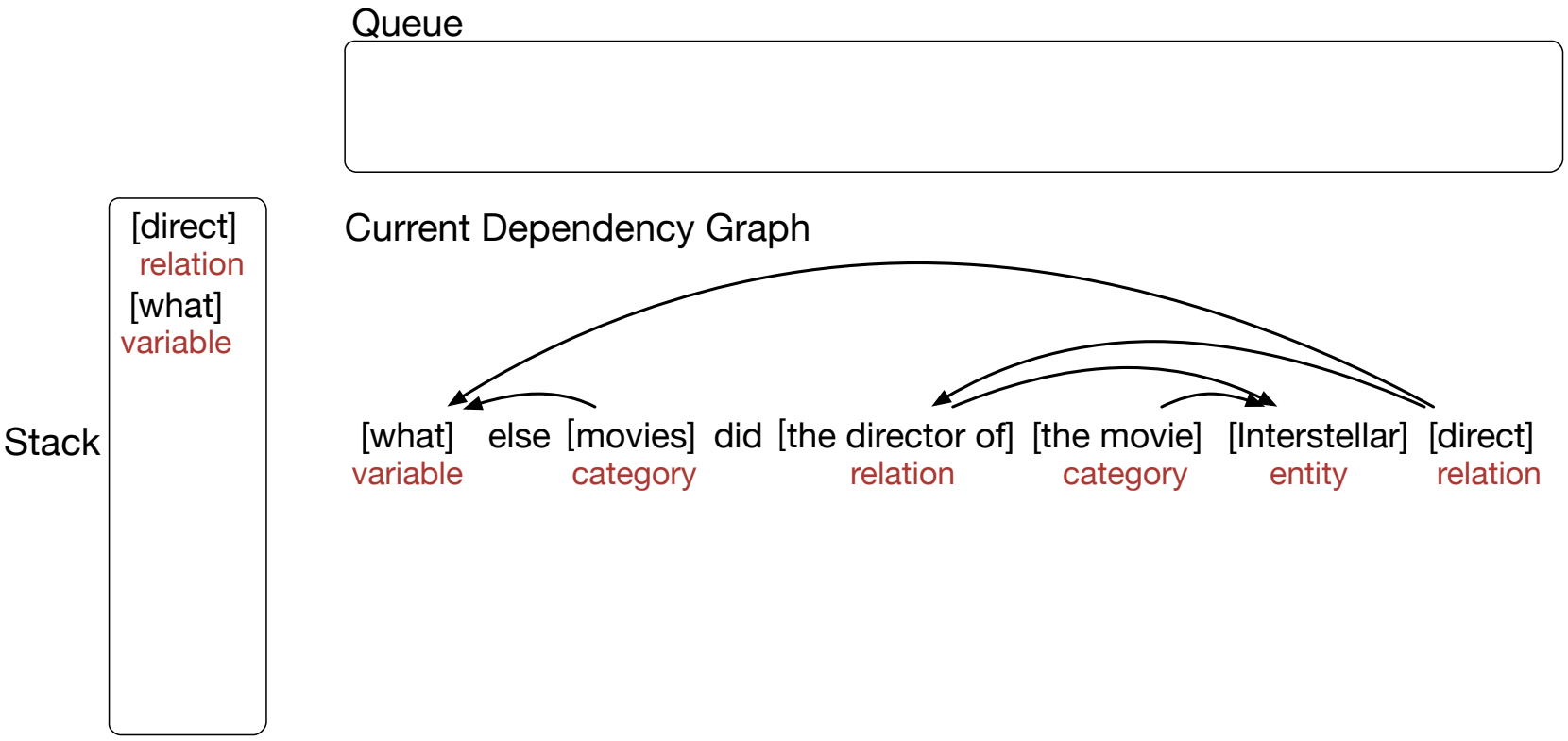
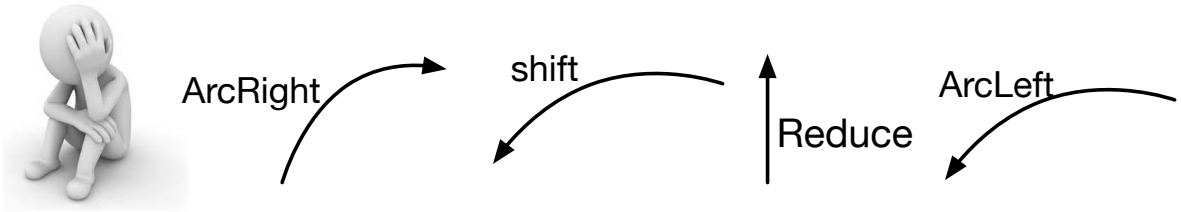


Decoding



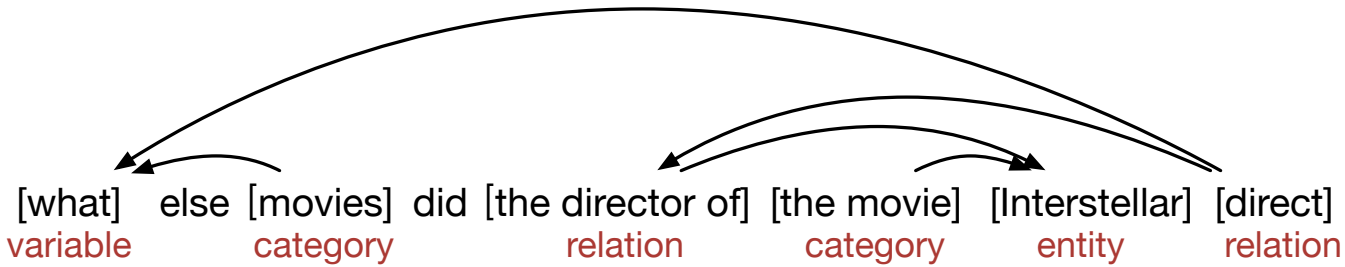
- incremental processing

$$z = \arg\max_{a \in A} w \cdot f(S, Q, a)$$

where A = {`Shift`, `Reduce`, `ArcLeft`, `ArcRight`}

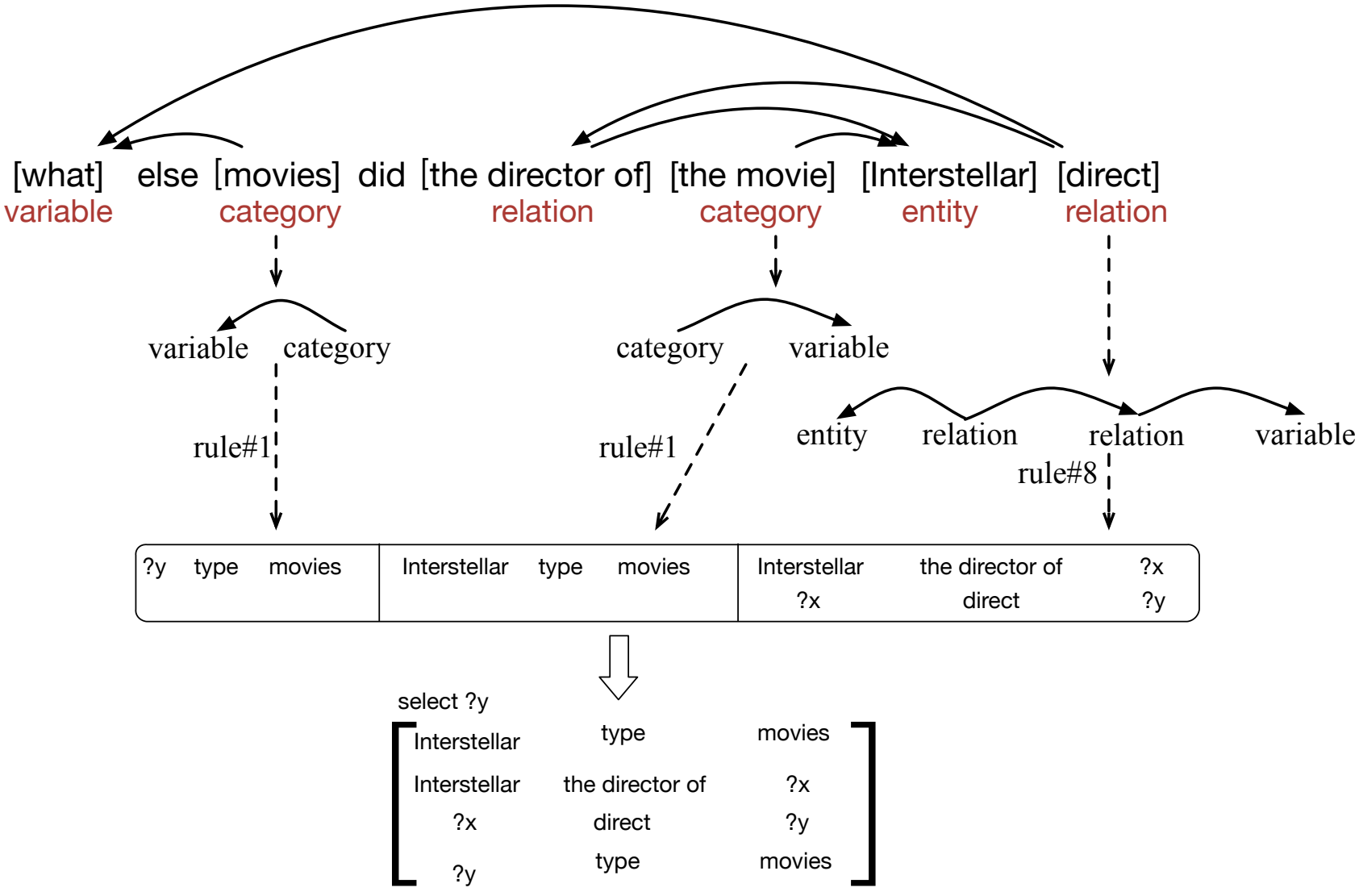
- features
  - lexical features
  - semantic features
  - structural features

Instantiation

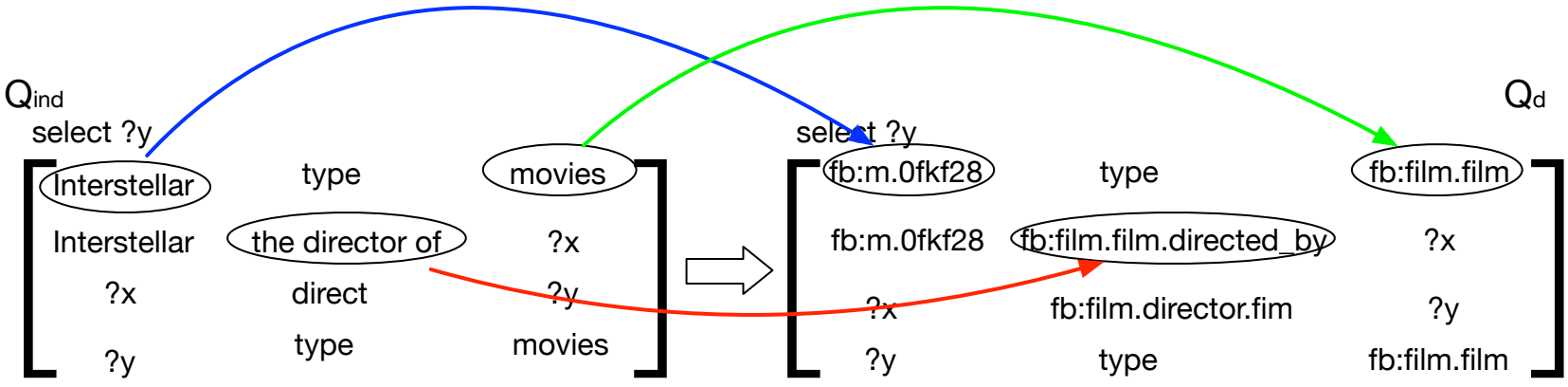


1. Converting Phrase Dependency Graph into Structured Queries
2. Instantiating Structured Query against KB

Applying Rules

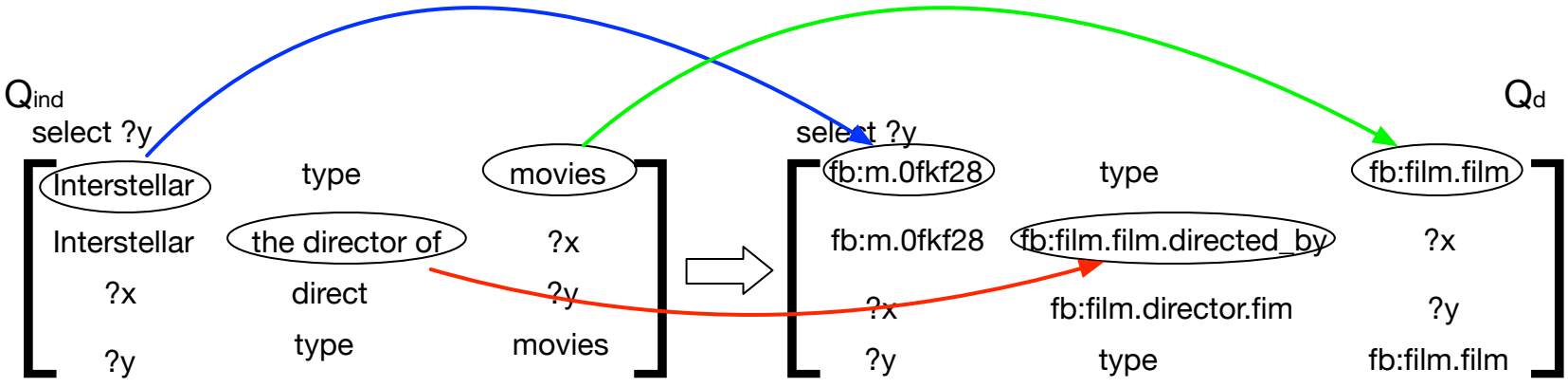


Probablity Model



$$Q_d^* = \arg\max P(Q_d | Q_{ind})$$

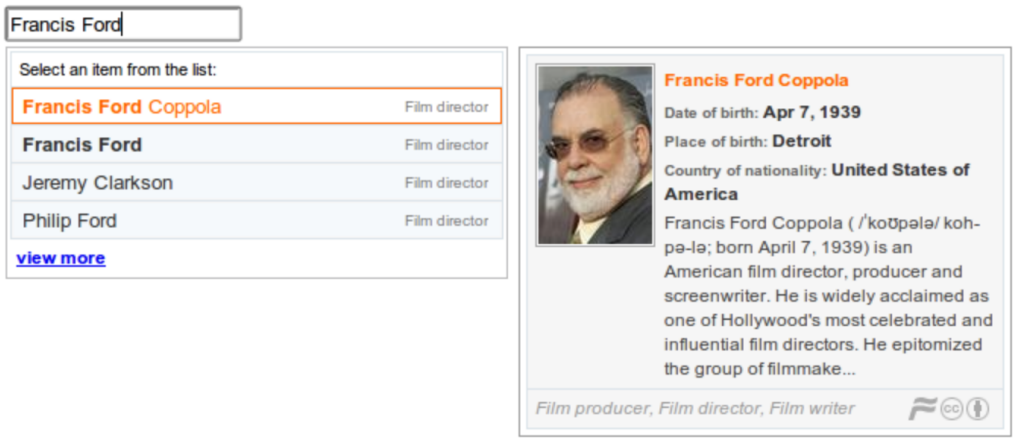
Probablity Model



$$Q_d^* = \arg\max P(Q_d|Q_{ind})$$

$$\overline{P}(Q_d|Q_{ind}) = \prod_{i=1}^{n} \overline{P}(s_{d_i}|s_{ind_i})\overline{P}(o_{d_i}|o_{ind_i})\overline{P}(p_{d_i}|p_{ind_i})$$

- $\overline{P}(s_{d_i}|s_{ind_i})\overline{P}(o_{d_i}|o_{ind_i})$
  Freebase Search API



- $\overline{P}(p_d|p_{ind})$
  Co-occurrence Matrix contributed by Yao

Experiment

Datasets

- Free917
  (917 questions with annotated phrase dependency graph, 30% of the data for the final test)
- WebQuestions
  (5,810 question-answer pairs, with the same test split with previous work)

Dataset	Question
Free917	How many legal offences has lindsey lohan committed ?
	At what institutions was marshall hall a professor ?
	How many games did donovan mcnabb play in the 2008 nfl season ?
	For what country did bernard lagat play in the 2000 summer olympics ?
	What percentage of the grapes in a 1966 chateau latour grand vin are merlot ?
WebQuestions	What is the most common language in norway ?
	What currency do they use in switzerland ?
	When olympic games 2012 opening ceremony ?
	What type of government system does saudi arabia have ?
	What countries does queen elizabeth ii reign ?

Results

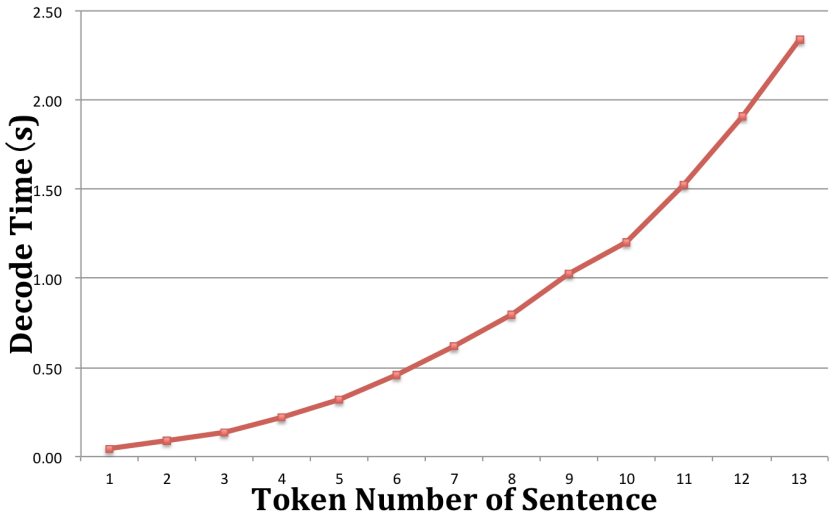
- System Accuracy

	Free917	WebQuestions
CY13	59.0%	-
BCFL13	62.0%	35.7%
KCAZ13	68.0%	-
BCFL14	68.5%	**39.9%**
Our work	**69.0%**	39.1%

BCFL13 and BCFL14 train the parser on Free917 and WebQuestions, respectively.
Our parser is only trained on Free917.

Results

- Training Time
  Our parser takes 40 minutes to train
  PCFG-based semantic parser takes 5 days to train
- Decode Time
  Time complexity of our parser is O(n)
  Time complexity of PCFG-based parser is $O(n^3)$



Results

Dataset	Question	Answer
Free917	Who said that one small step for man one giant leap for mankind ?	Neil Armstrong
	What sport did scott anderson play in the 1992 summer olympics ?	field hockey
	when was the construction of new steubenville bridge began ?	1979
WebQuestions	When did liverpool fc last win the champions league ?	2006 FA Cup Final
	Who does jeremy shockey play for in 2012 ?	Carolina Panthers
	What college did deion sanders jr go to ?	Florida State University
	What was queen elizabeth ii childhood nickname ?	Lillibet

Error Analysis

1. The detection errors
   "harry potter and the global of fire"
2. Fail to answer the questions that imply aggregation operations.
   "where do most of people live in russia"
3. Unable to handle temporal information
   "what kind of government did the united states have after the revolution"

Conclusions

- A novel pipeline framework
  - Separate KB-independent meaning representation and KB-related instantiation
  - Easily adapt to new KBs
- A transition-based parser
  - Efficient shift-reduce parser

Future Work

- A joint model
  - simultaneously detects phrases and dependency relations
- the function phrase
  - introduce the aggregation operation

Questions?