Translating Code Comments to Procedure Specifications

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[♠]University of Washington Seattle, WA, USA

```
public static boolean removeAll(List myList){…}
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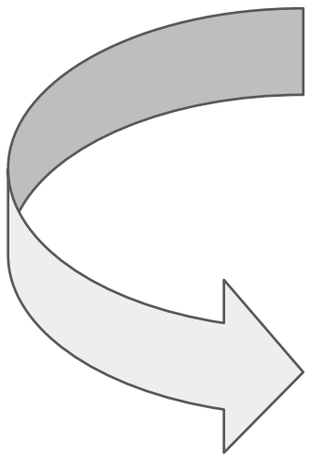

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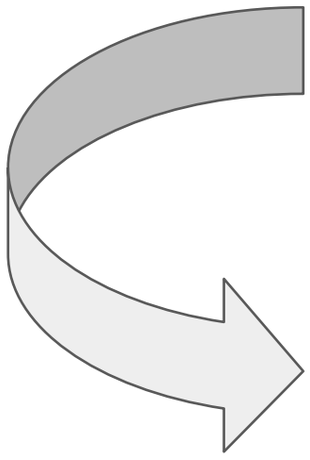

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public void testRemoveAll(){



}
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public static boolean removeAll(List myList){…}
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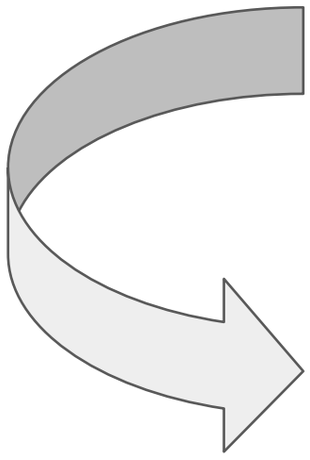

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public void testRemoveAll(){
    List<Integer> list = Arrays.asList(1, 2, 3);


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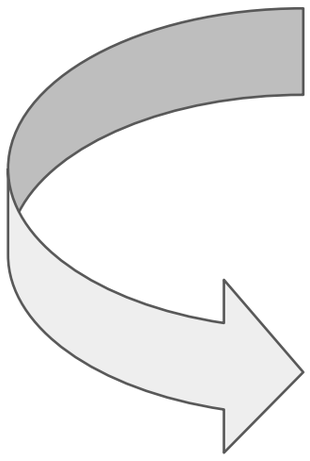

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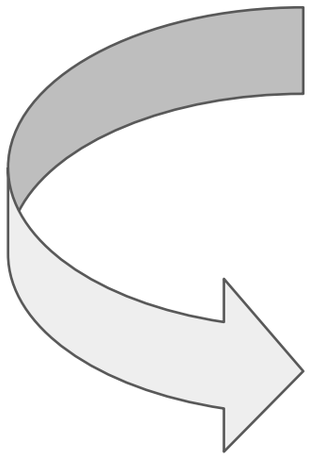

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    assert ?
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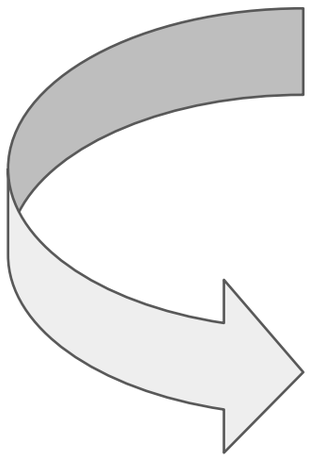

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EVOSUITE

Randoop

Automatic unit test generation for Java

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Automatic unit test generation for Java

Where is the oracle?

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Automatic unit test generation for Java

Where is the oracle?

Where is the specification?

Why not generating executable specifications automatically?

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Let’s rely on Javadoc comments!

Our solution

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/**
 * @return true if the list is empty
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public static boolean removeAll(List myList)
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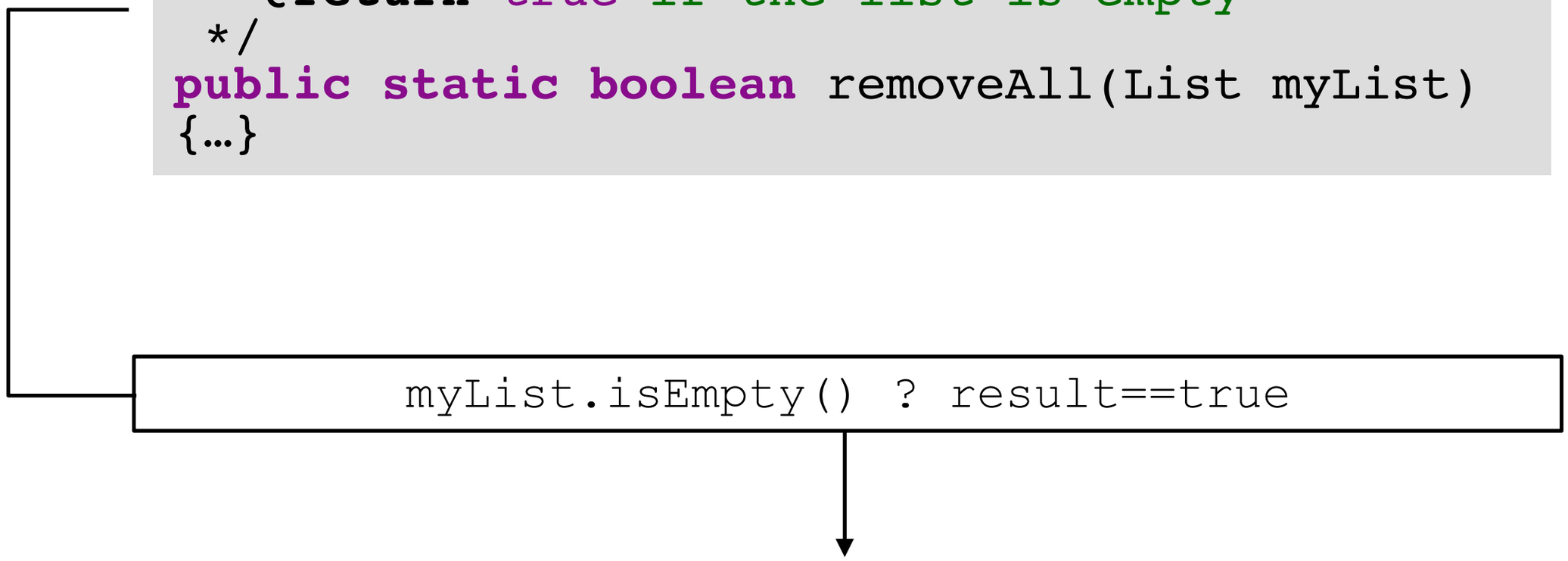

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    boolean result = removeAll(list);
    if(list.isEmpty()) assert result==true;
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ALICS

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Preconditions	Normal Postconditions	Exceptional Postconditions

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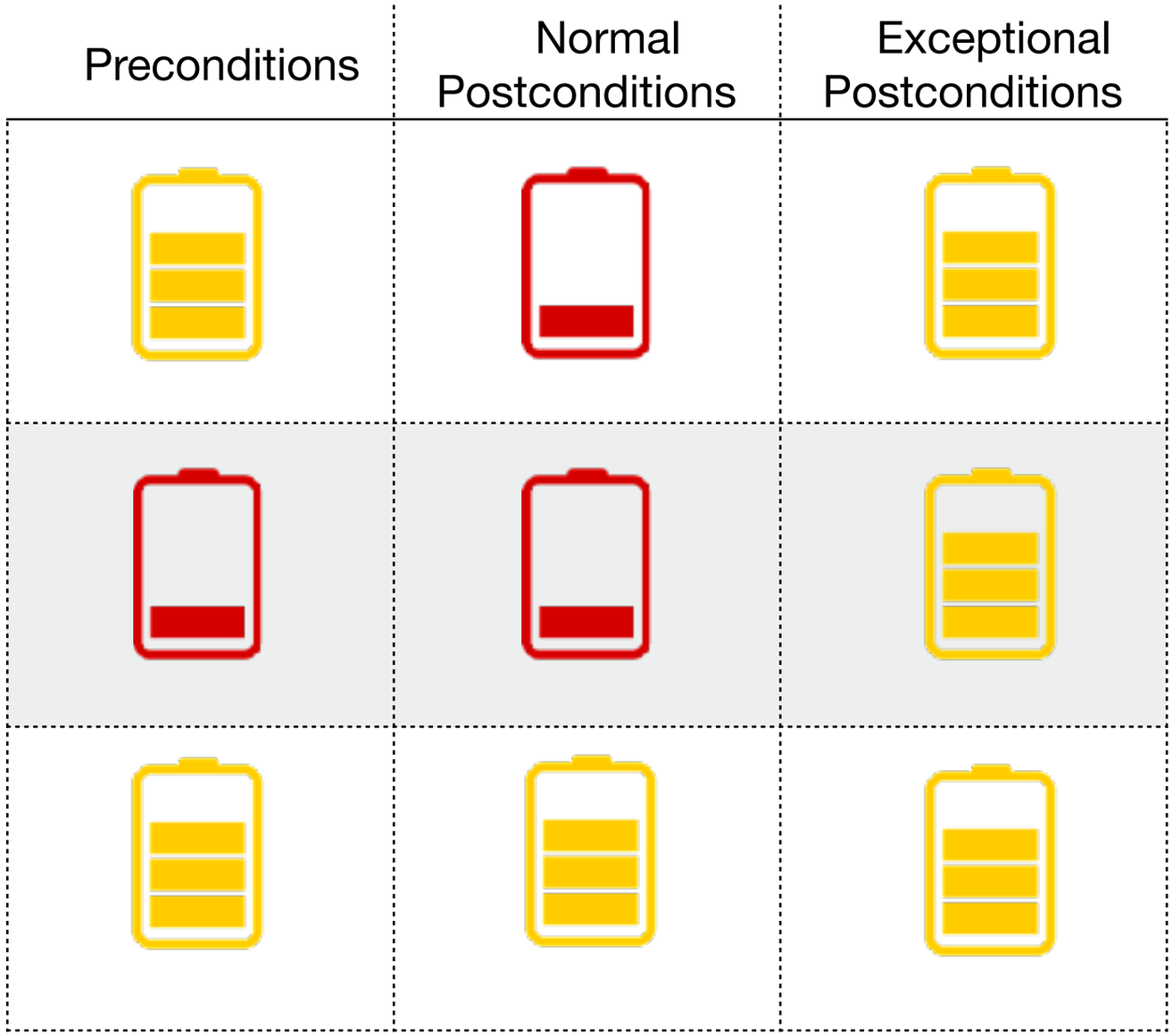

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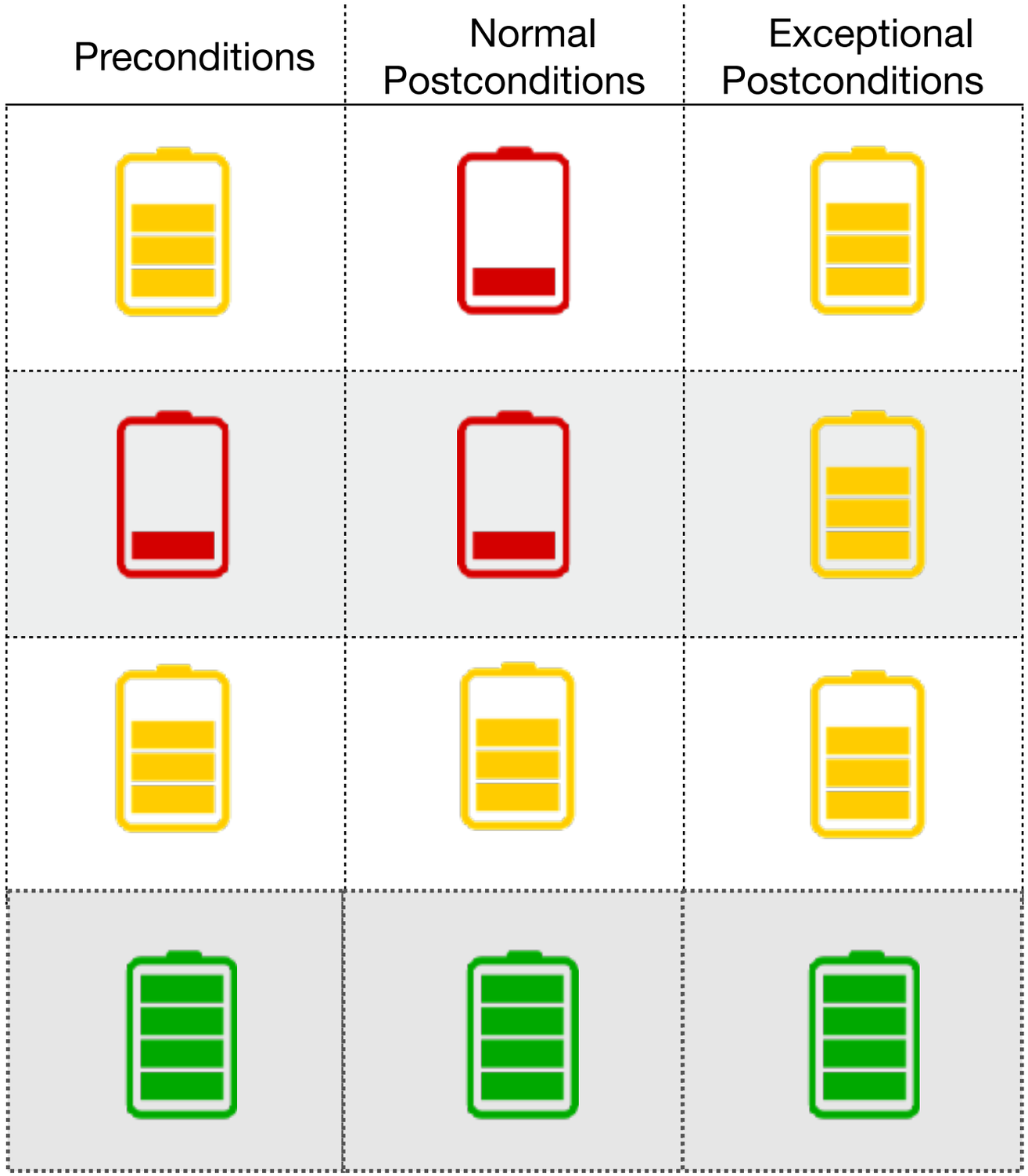
Jdoctor



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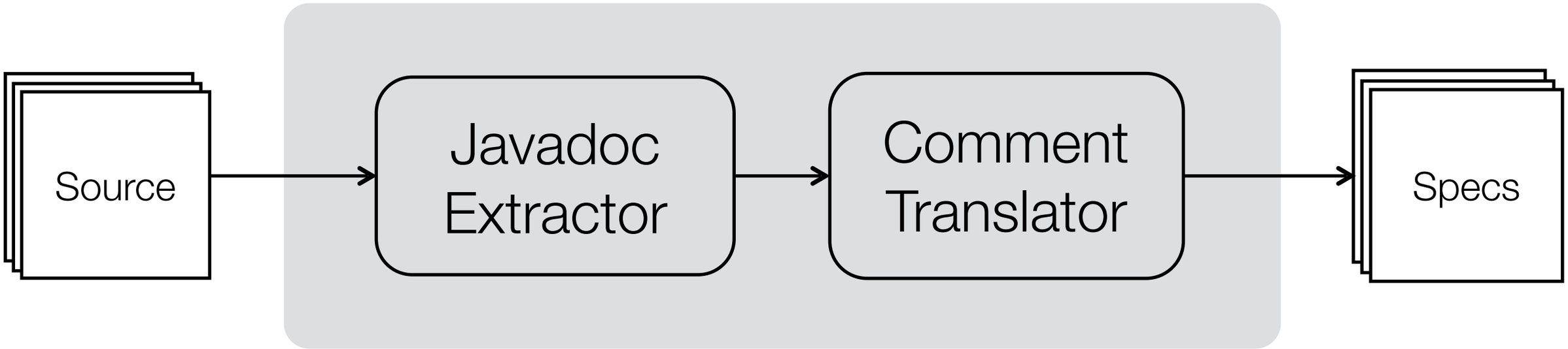
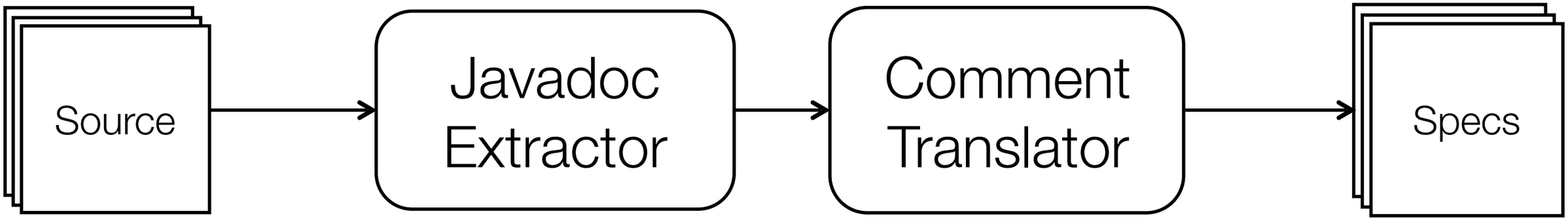
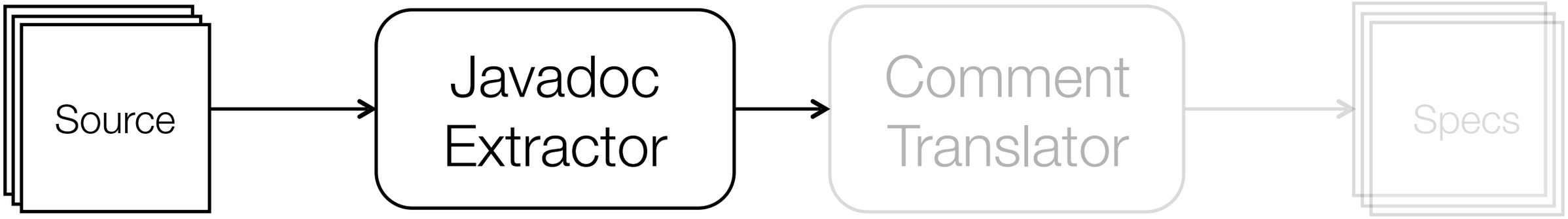



Source
Javadoc
Extractor
Comment
Translator
Specs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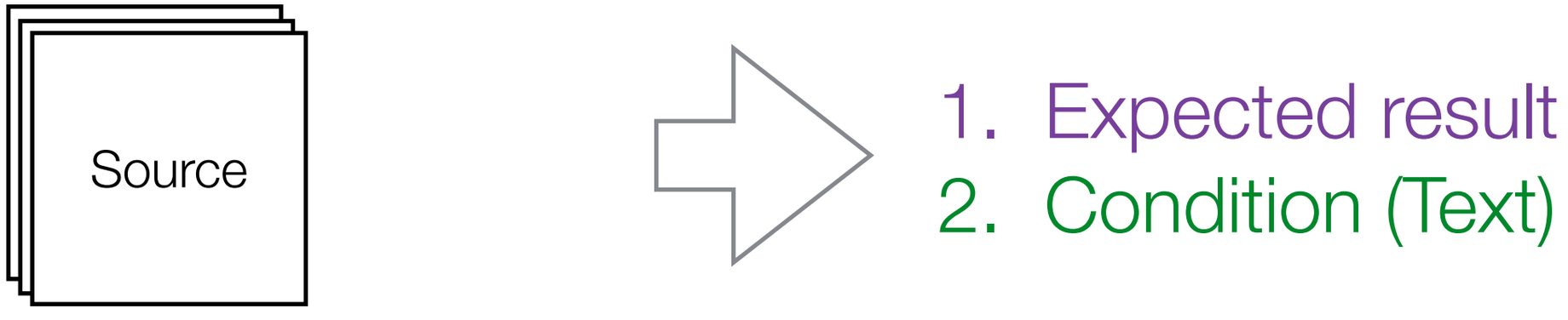
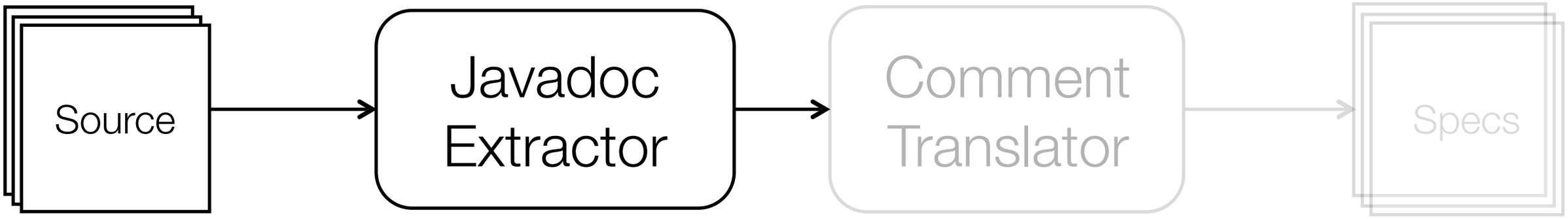
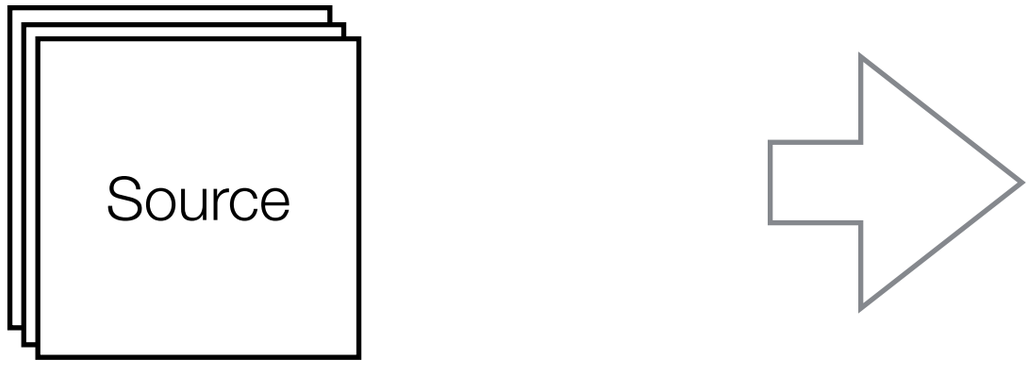

Source
1. Expected result
2. Condition (Text)



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public boolean removeAll(List
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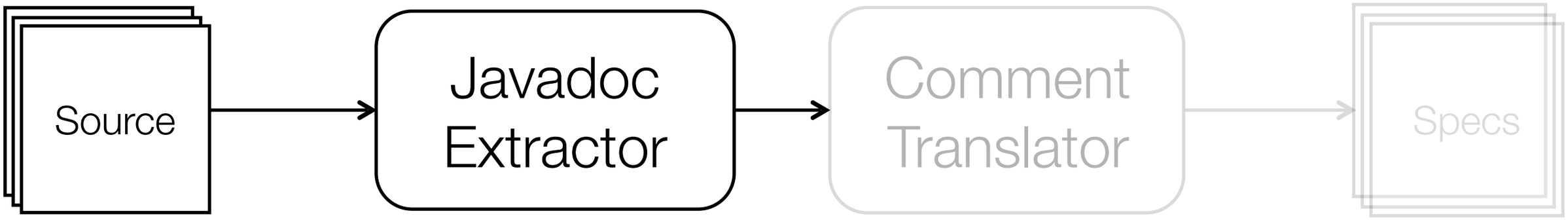

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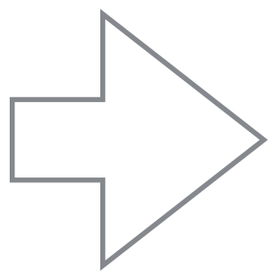

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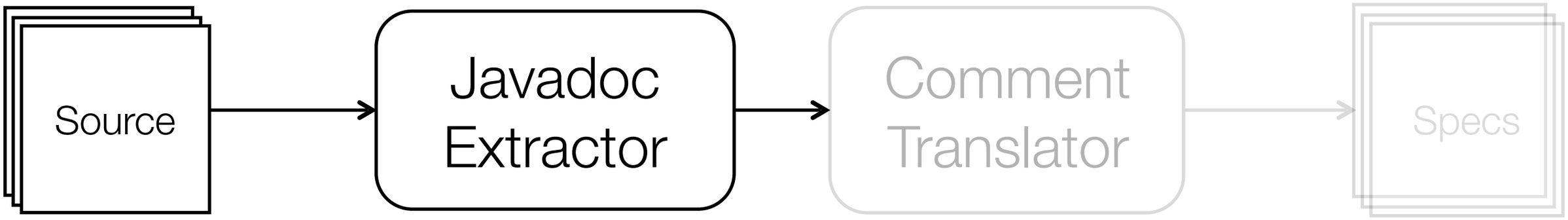

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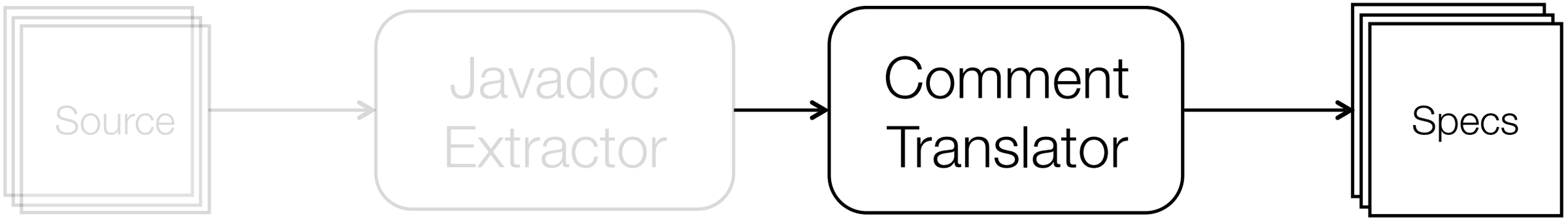

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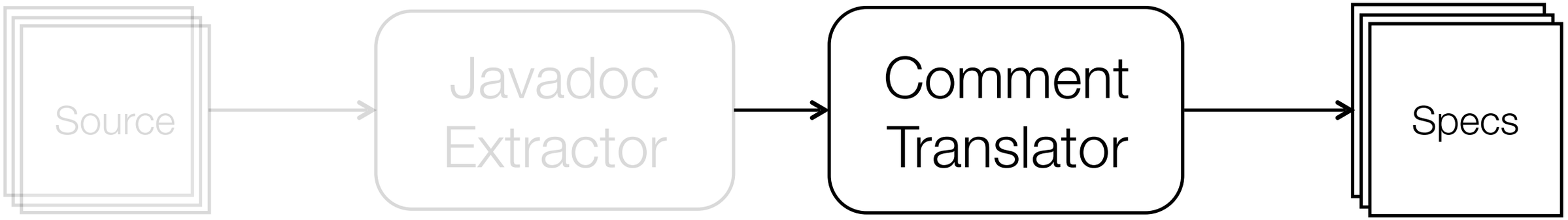

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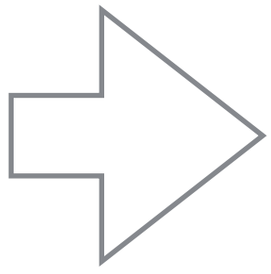

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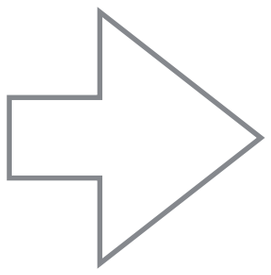

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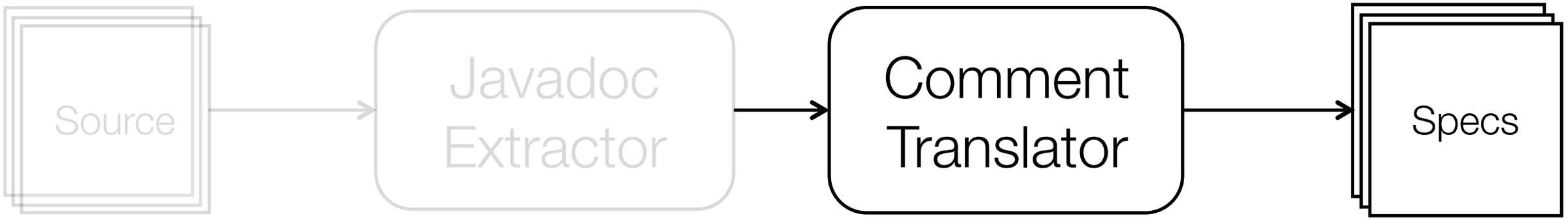

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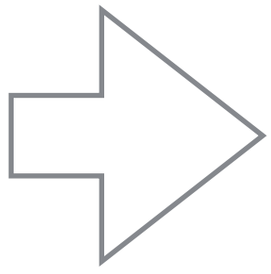

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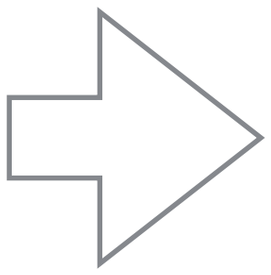

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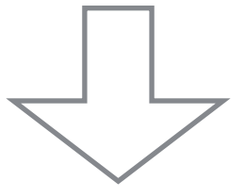
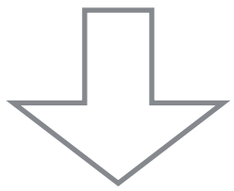
Natural Language Specification

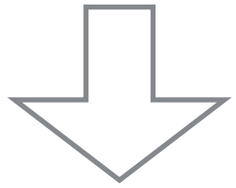


Comment Translator



Java Specification

Natural Language Specification



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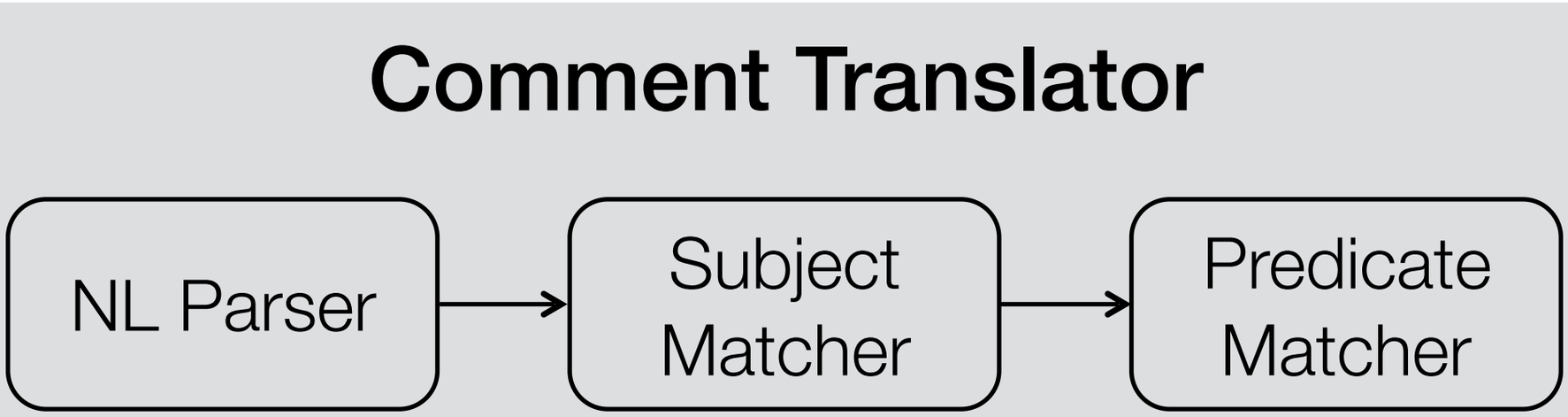

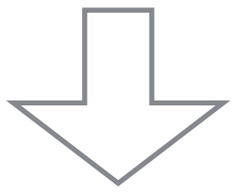

Java Specification


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“if the list is empty”
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Subject	Predicate
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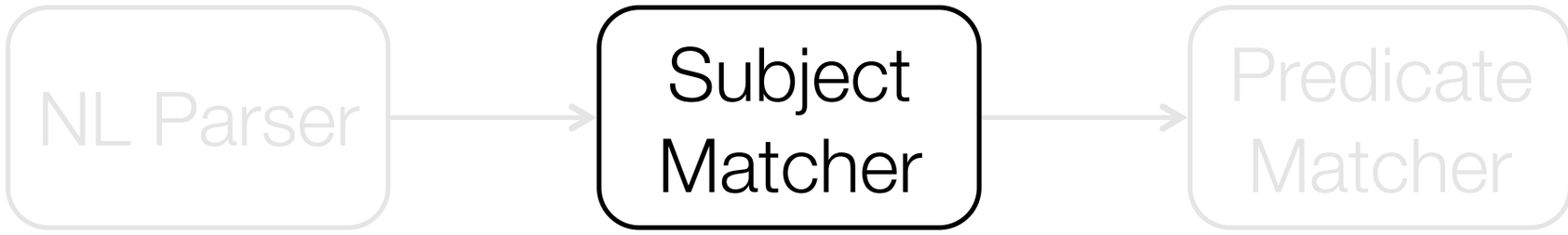

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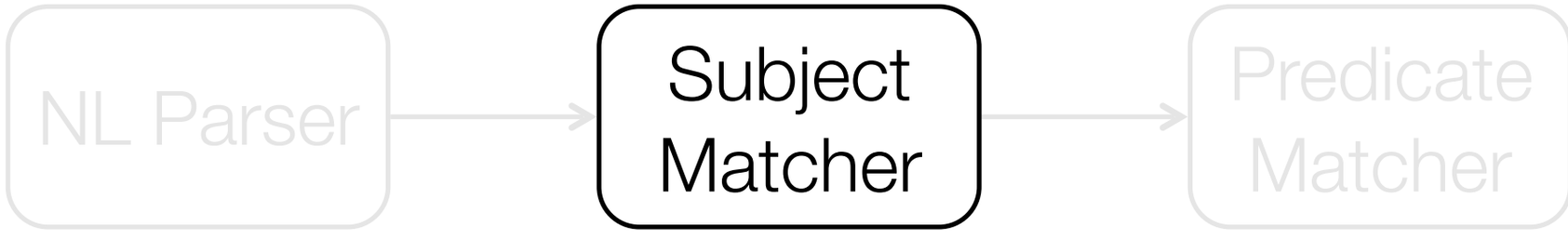


Subject: `“list”`

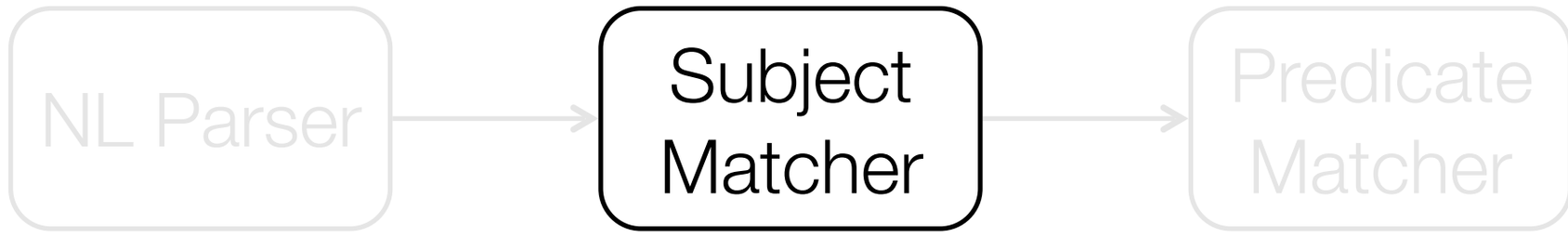
Candidates

Formal Parameters

Class Name

Methods

Fields

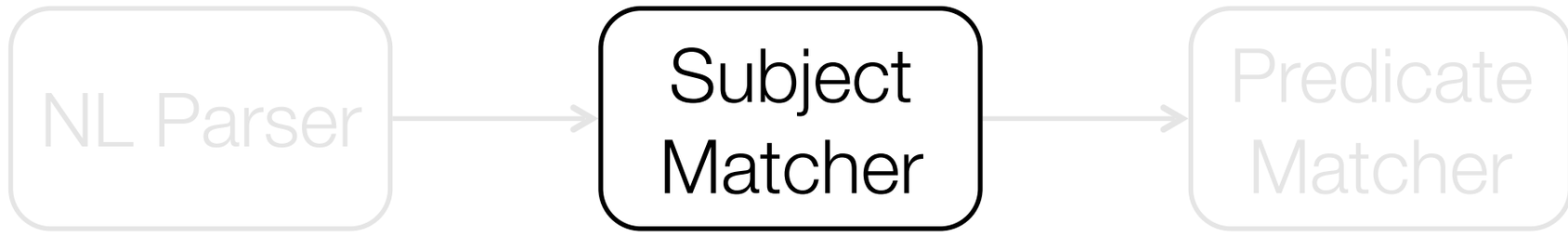


Subject: `"list"`

Candidates

Formal Parameters
Class Name
Methods
Fields

Candidate	Distance
`myList`	2
`isEmpty`	7
`iterator`	8
`size`	4
…	



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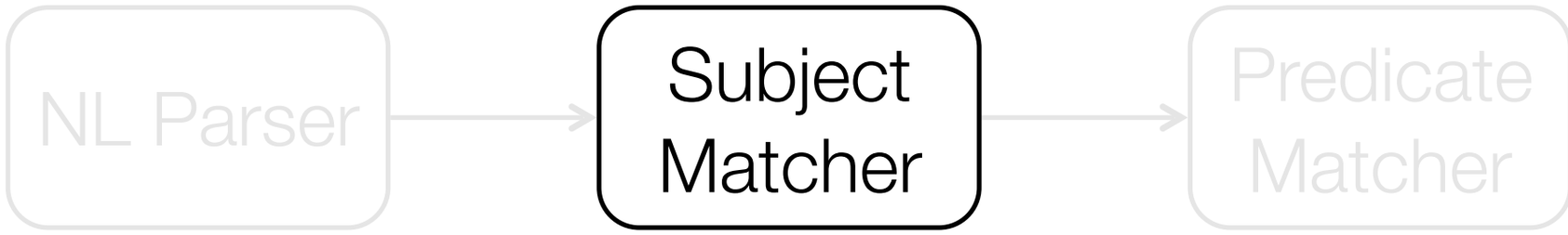

Subject: `"list"` => **`myList`**

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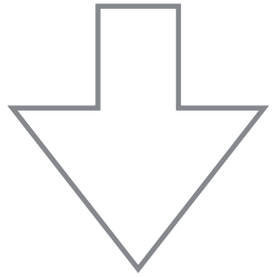

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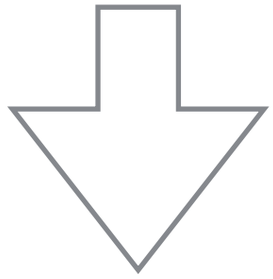

1: Exact pattern match?

Subject	Predicate
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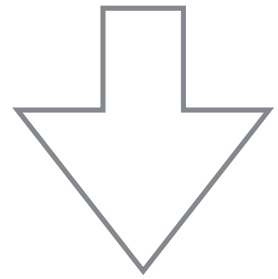

is null ⟶ `== null`

1: Exact pattern match?

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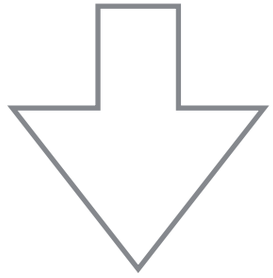

1: Exact pattern match?

is null ⟶ `== null`

is negative ⟶ `< 0`

Subject	Predicate
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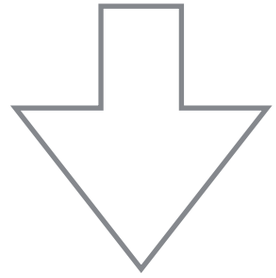

is null	→	`== null`
is negative	→	`< 0`
is positive	→	`> 0`

Subject	Predicate
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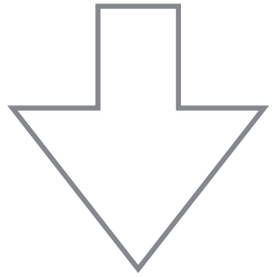

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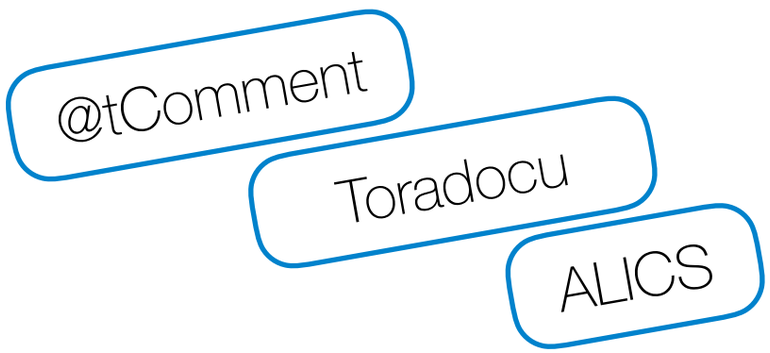

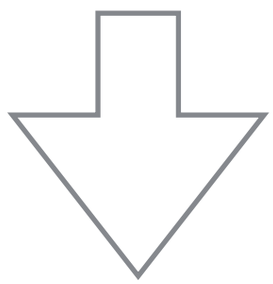

is null	→	`== null`
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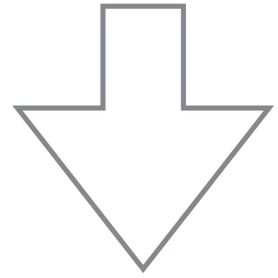
Subject	Predicate
`"list"`	`"is empty"`

"is empty" not found...



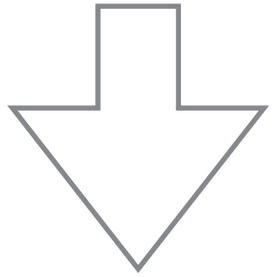
is null → `== null`

is negative → `< 0`

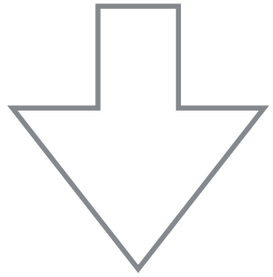
is positive → `> 0`

...

Subject	Predicate
`"list"`	`"is empty"`



Subject	Predicate
`"list"`	`"is empty"`



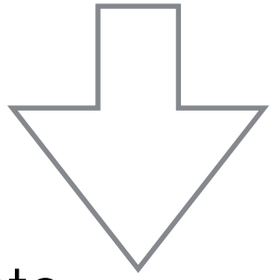
2: Syntax match?

Toradocu

Subject	Predicate
`"list"`	`"is empty"`

2: Syntax match?

Toradocu

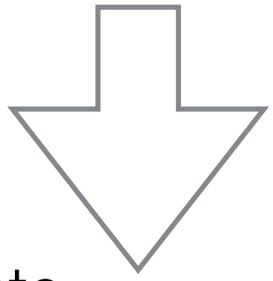


Candidate	Distance
`myList`	9
`isEmpty`	1
`iterator`	6
`size`	7
...	

Subject	Predicate
`"list"`	`"is empty"`

2: Syntax match?

Toradocu



Candidate	Distance
`myList`	9
`isEmpty`	**1**
`iterator`	6
`size`	7
...	

Pattern and syntax match are not enough

Pattern and syntax match are not enough

Return true if the list **is empty**

Pattern and syntax match are not enough

Return true if the list **is empty**

Candidate	Distance
`clear`	7
`isEmpty`	**1**
`iterator`	6
`size`	7
...	

Pattern and syntax match are not enough

Return true if the list **is empty**

contains no element

Pattern and syntax match are not enough

Return true if the list **is empty**

contains no element

has no content

Pattern and syntax match are not enough

Return true if the list **is empty**

contains no element

has no content

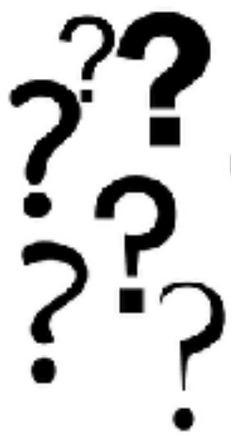
Candidate	Distance
`myList`	
`isEmpty`	
`iterator`	
`size`	
…	

Pattern and syntax match are not enough

Return true if the list **is empty**

contains no element

has no content

Candidate	Distance
`myList`	
`isEmpty`	
`iterator`	
`size`	
…	

Pattern and syntax match are not enough

Return true if the list **is empty**

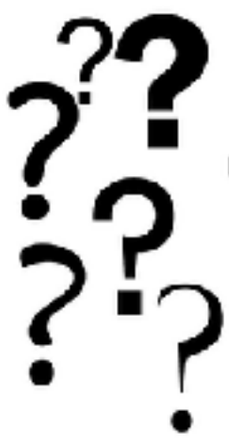
contains no element

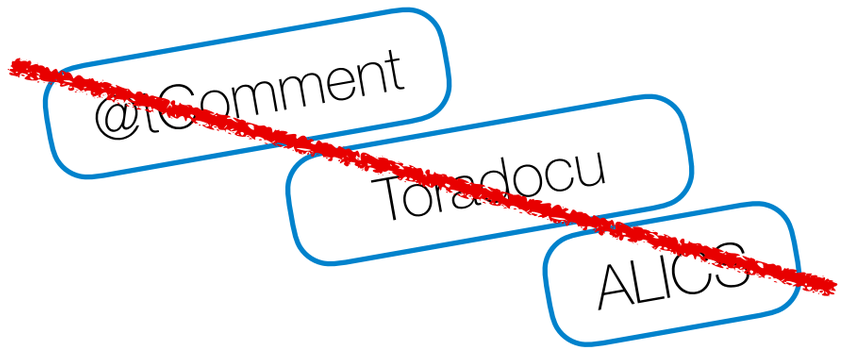
has no content

Candidate

```
myList
isEmpty
iterator
size
...
```

Distance





Analyzing complex comments

```
/**
* Checks if there is a credible threatening unit to
* this unit within a range of moves.
*
* @param moves list of moves
* @return True if a threat was found.
*/
public boolean isInDanger(List<Object> moves)
```

Analyzing complex comments

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Analyzing complex comments

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* this unit within a range of moves.
*
* @param moves list of moves
* @return True if a threat was found.
*/
public boolean isInDanger(List<Object> moves)
```

searchForDanger(*List<Object>*)

PRINCETON UNIVERSITY

WordNet

A Lexical Database for English

threat was found

search for **danger**

PRINCETON UNIVERSITY

WordNet

A Lexical Database for English

Verb

- S: (v) find, happen, chance, bump, encounter (come upon, as if by accident; meet with)
- S: (v) detect, observe, find, discover, notice (discover or determine the existence, presence, or fact of)
- S: (v) find, regain (come upon after searching; find the location of something that was missed or lost)
- S: (v) determine, find, find out, ascertain (establish after a calculation, investigation, experiment, survey, or study)
- S: (v) find, feel (come to believe on the basis of emotion, intuitions, or indefinite grounds)
- S: (v) witness, find, see (perceive or be contemporaneous with)
- S: (v) line up, get hold, come up, find (get something or somebody for a specific purpose)
- S: (v) discover, find (make a discovery, make a new finding)
- S: (v) discover, find (make a discovery)
- S: (v) find (obtain through effort or management)

Verb

- S: (v) find, happen, chance, bump, encounter (come upon, as if by accident; meet with)
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- S: (v) find, regain (come upon after searching; find the location of something that was missed or lost)
- S: (v) determine, find, find out, ascertain (establish after a calculation,

"*search*" is **not** displayed as a result

- S: (v) witness, find, see (perceive or be contemporaneous with)
- S: (v) line up, get hold, come up, find (get something or somebody for a specific purpose)
- S: (v) discover, find (make a discovery, make a new finding)
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- S: (v) determine, find, find out, ascertain (establish after a calculation,

We need more than semantic **equivalence**

- S: (v) witness, find, see (perceive or be contemporaneous with)
- S: (v) line up, get hold, come up, find (get something or somebody for a specific purpose)
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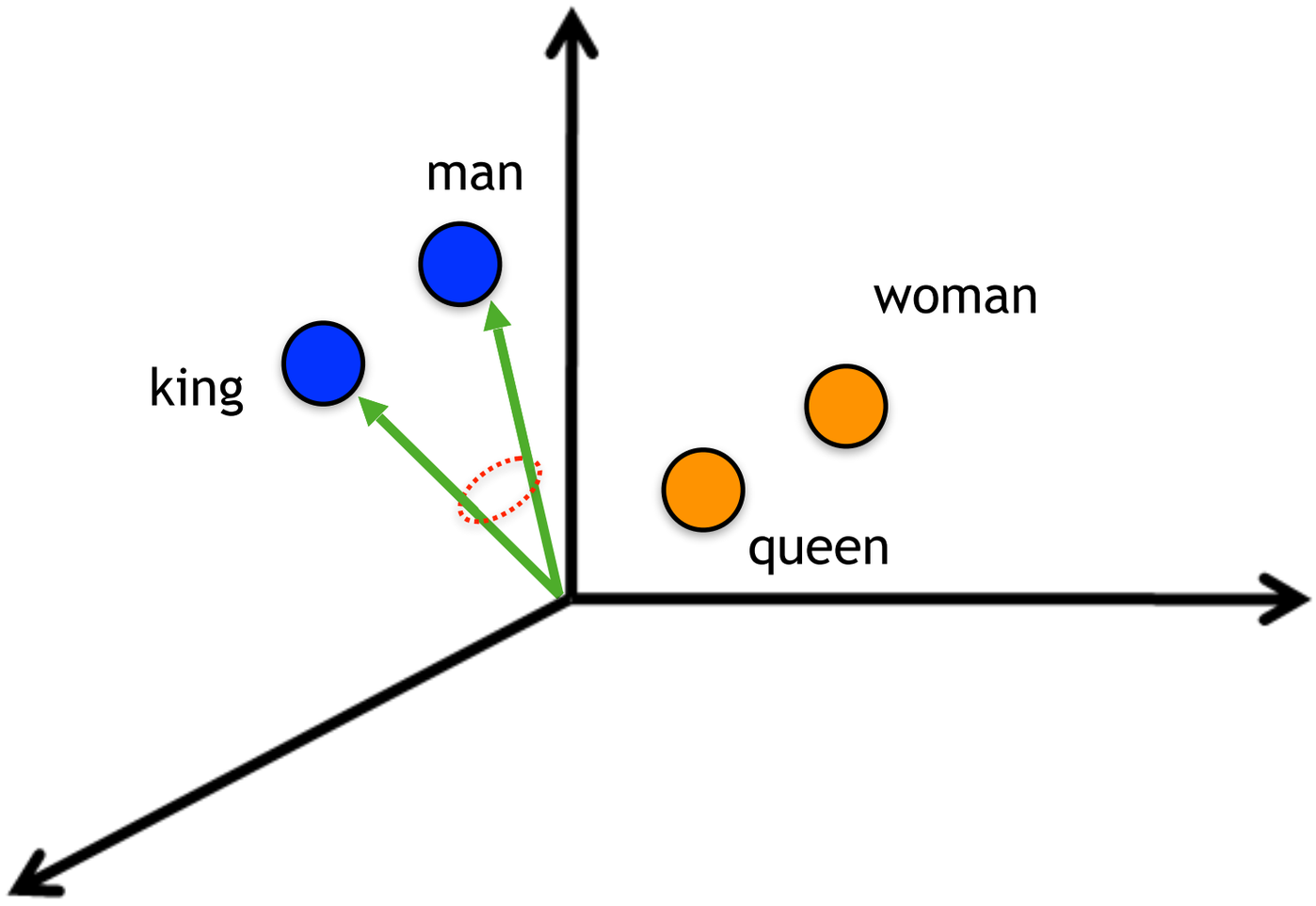
- S: (v) find (obtain through effort or management)

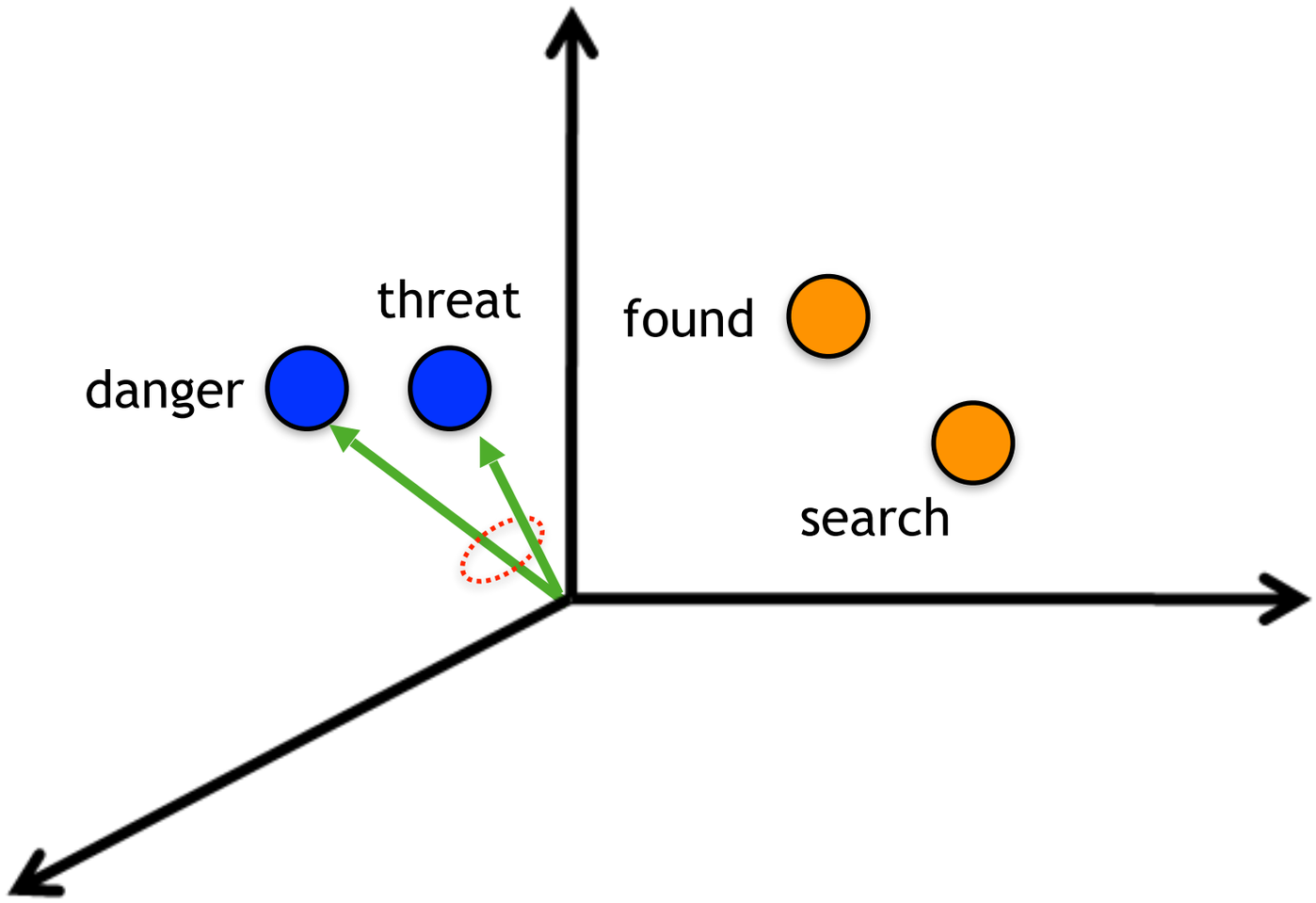
Word embedding

Word embedded in vector space: GloVe, Word2Vec



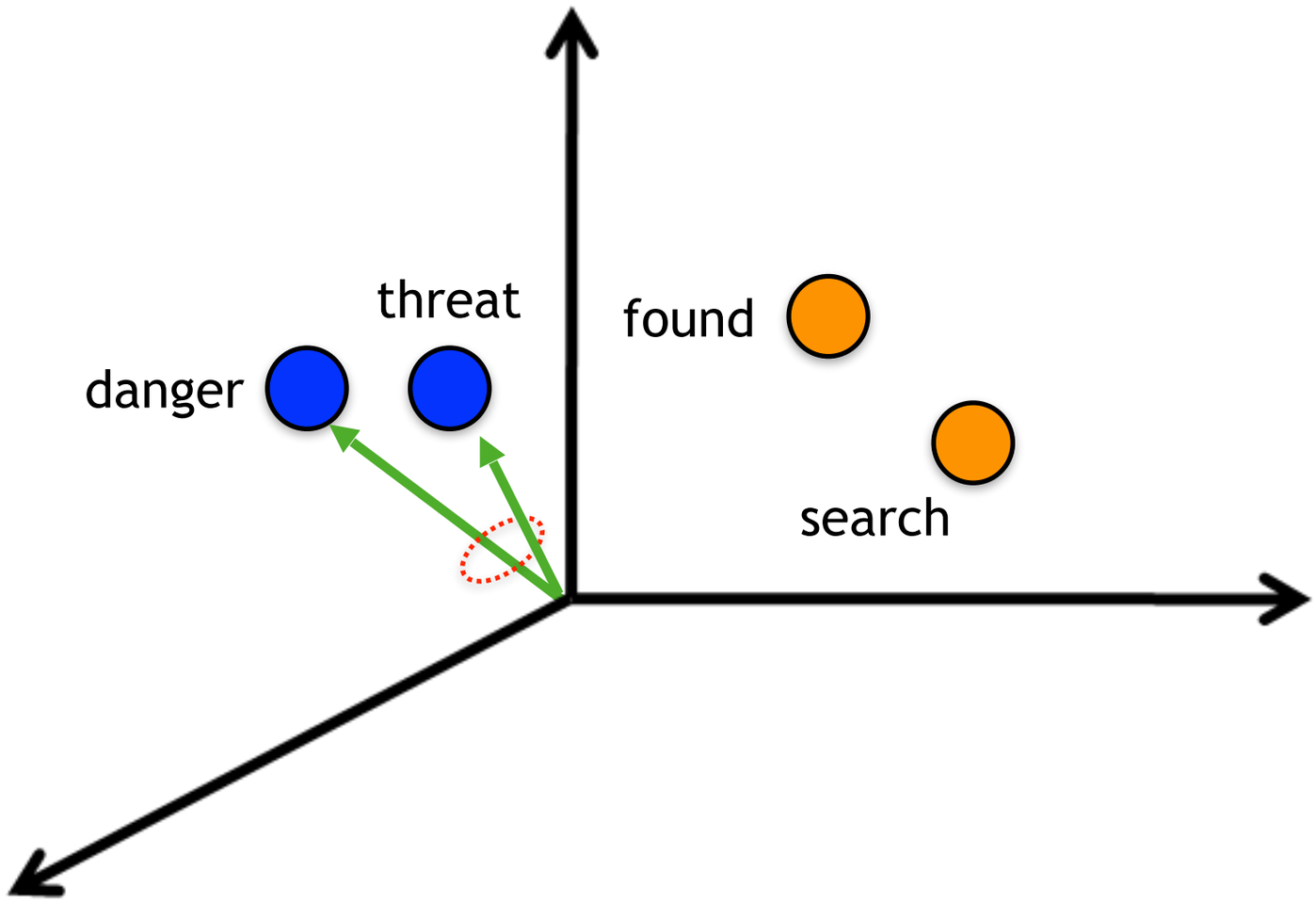
Word embedding

Word embedded in vector space: GloVe, Word2Vec



Word embedding

Word mover's distance (Matt J. Kusner et al., 2015)



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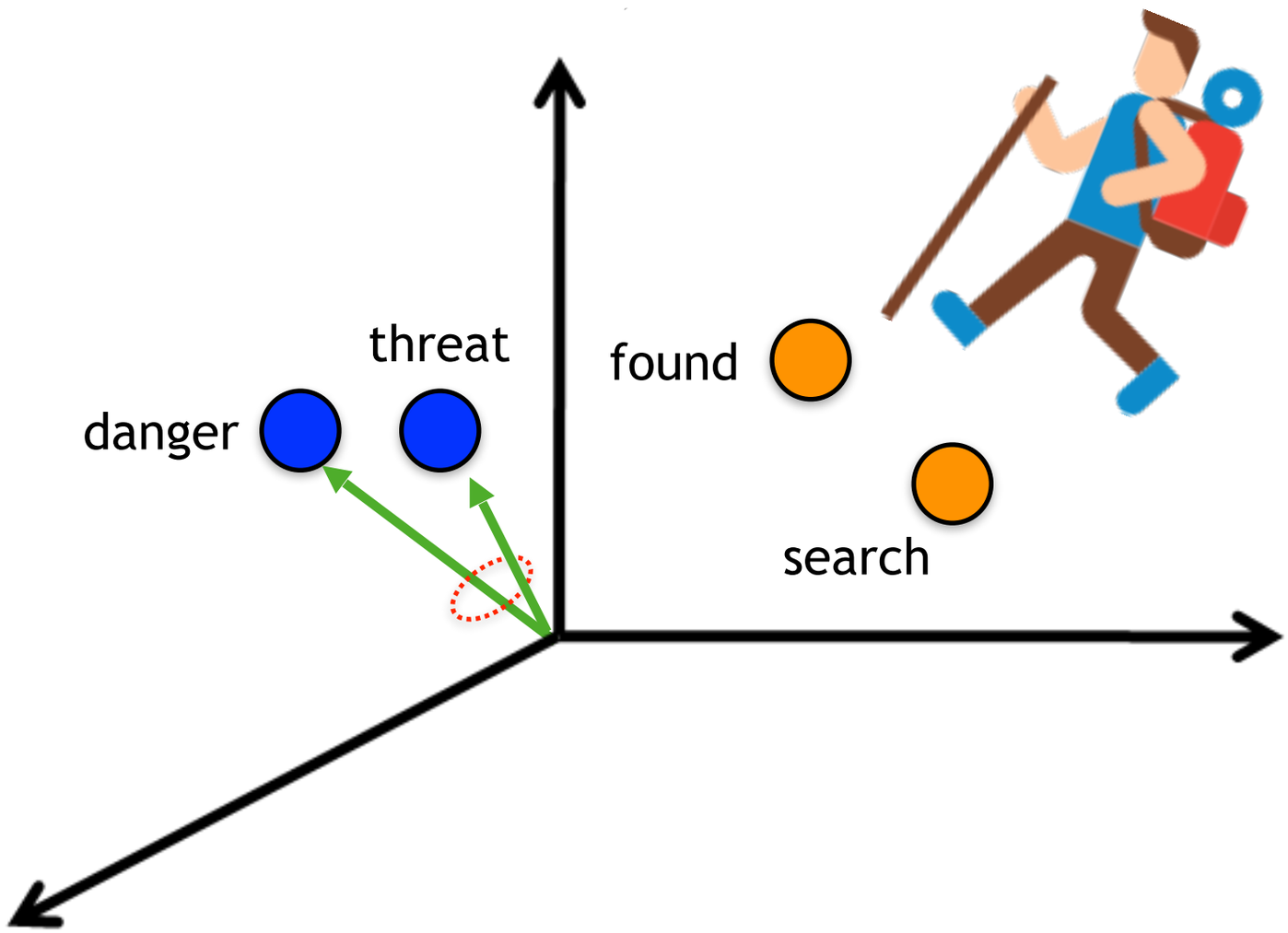
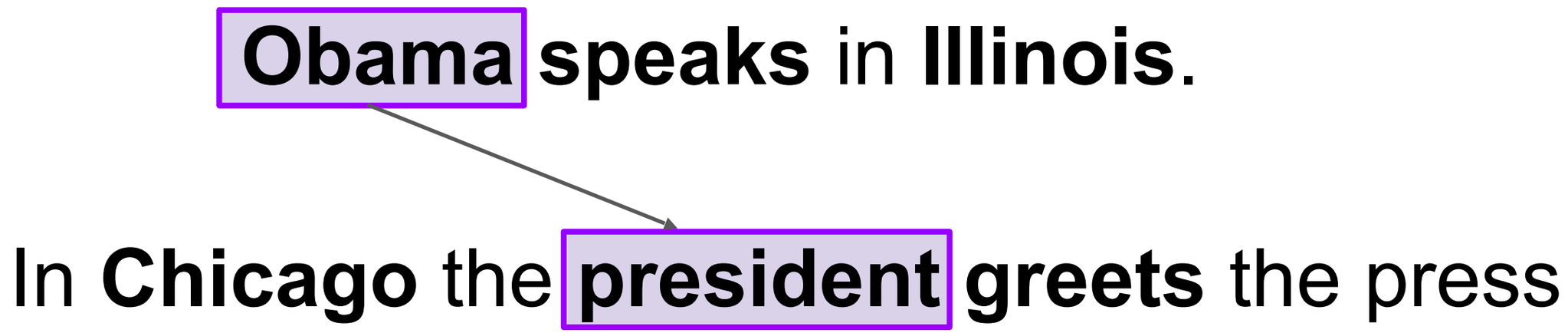


Word Mover's distance

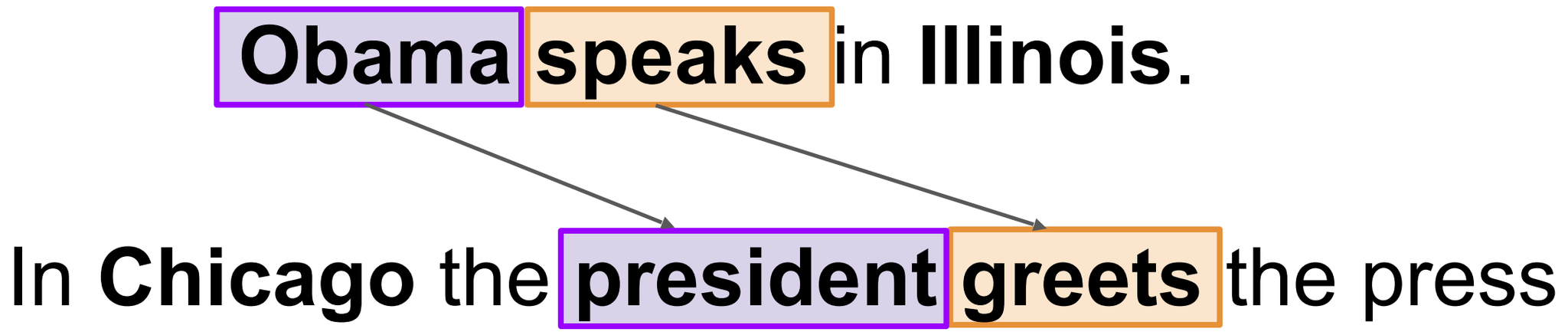
Obama speaks in **Illinois**.

In **Chicago** the **president greets** the press

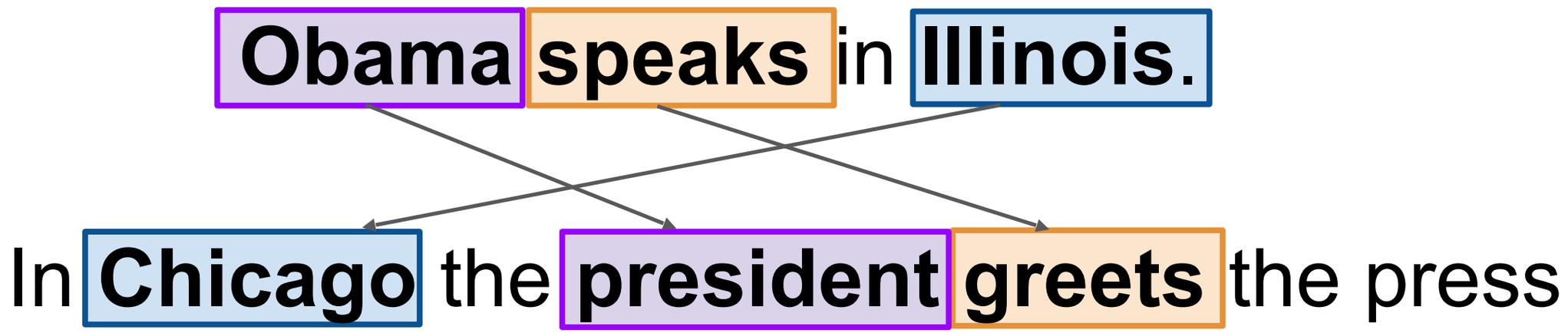
Word Mover's distance



Word Mover's distance



Word Mover's distance



Word Mover's distance

Threat was **found**

Search For Danger

Word Mover's distance

Threat was **found**

Search For Danger

Word Mover's distance

Threat was **found**

Search For Danger

How accurate is Jdoctor?

Experimental setup

6 Popular open-source Java systems

Experimental setup

563 Analyzed Java methods

Experimental setup

829 Manually-written Java conditions

92

%

Precision

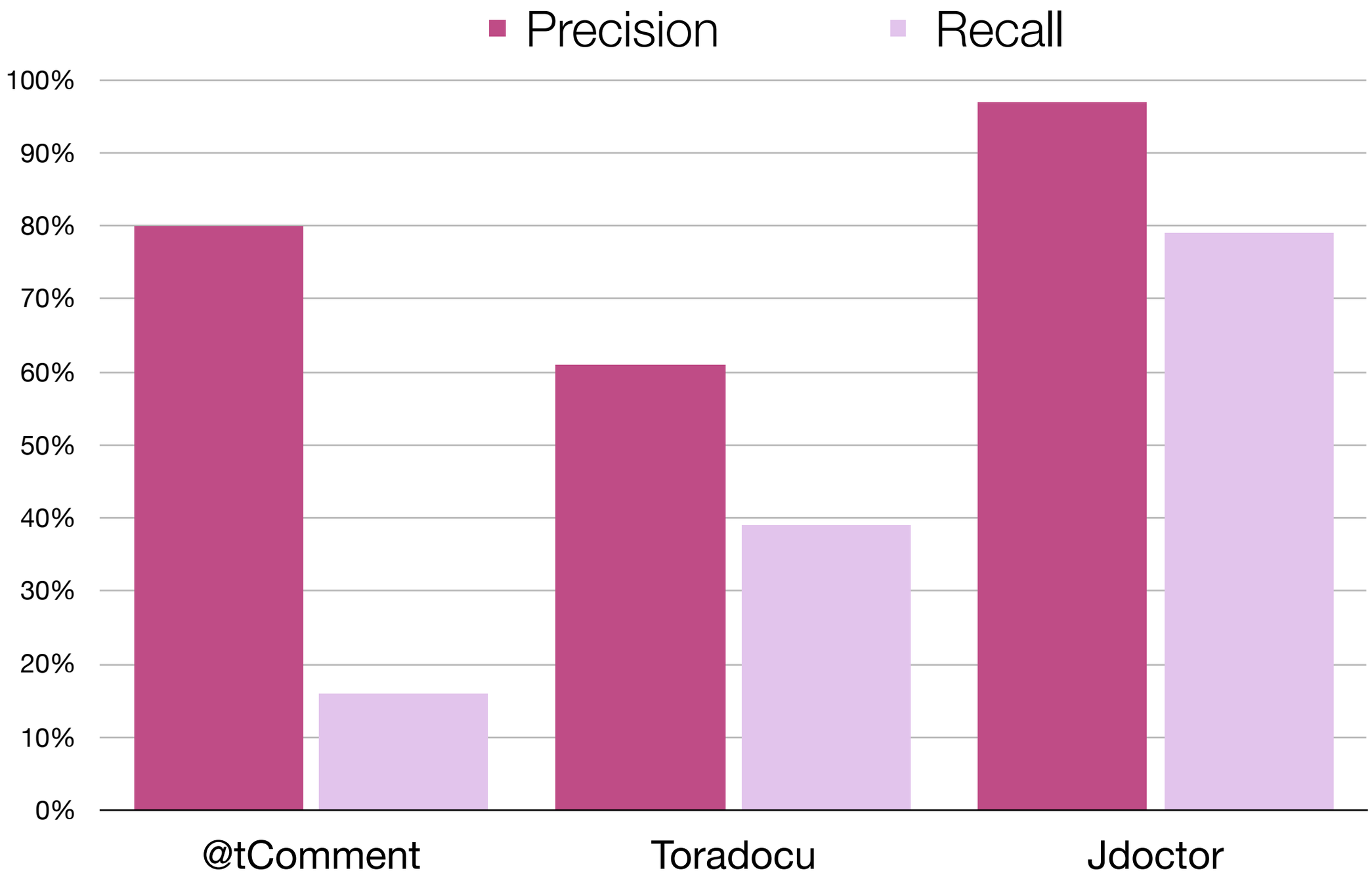
92%

Precision

83%

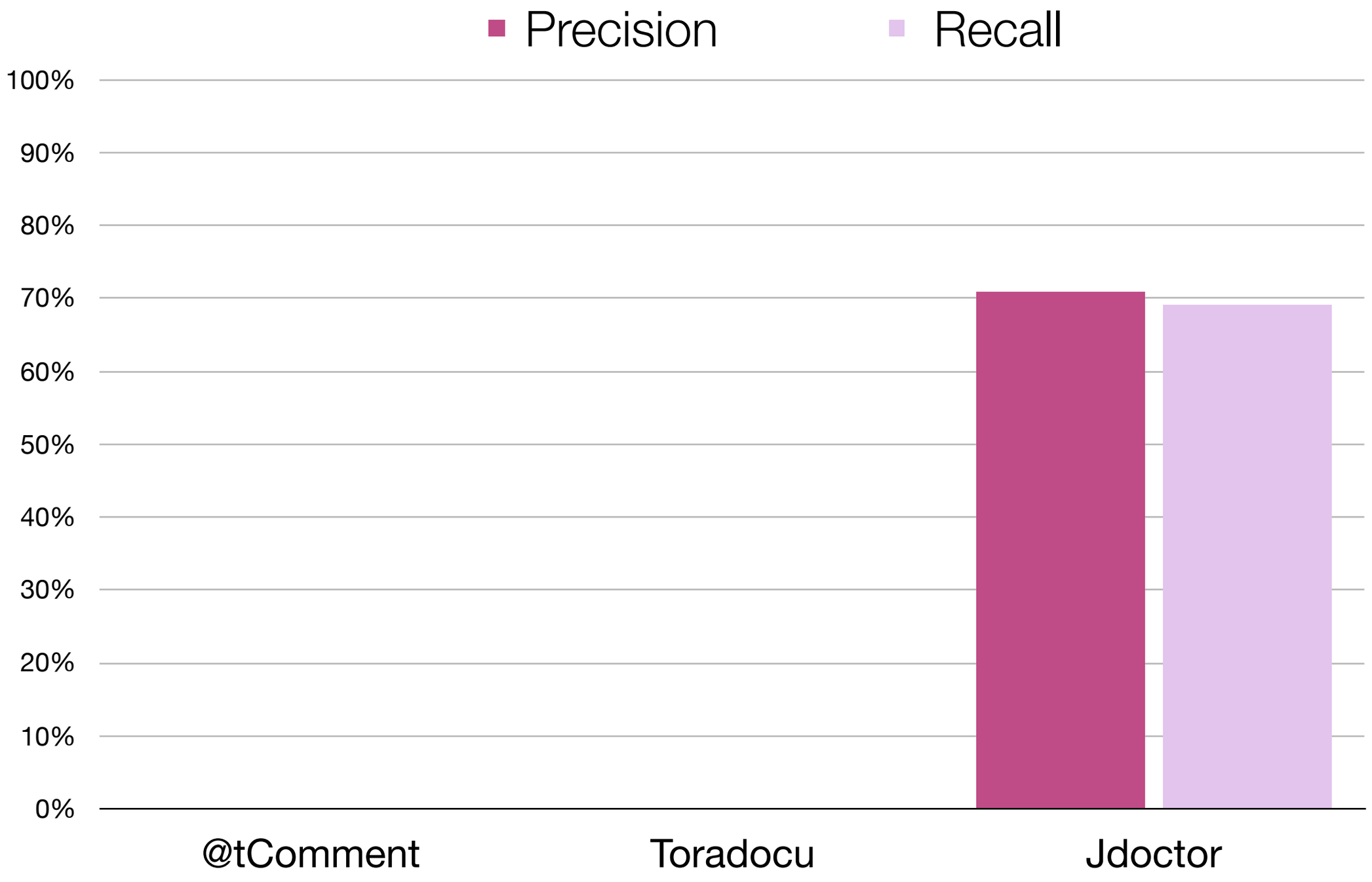
Recall

Exceptional Postconditions

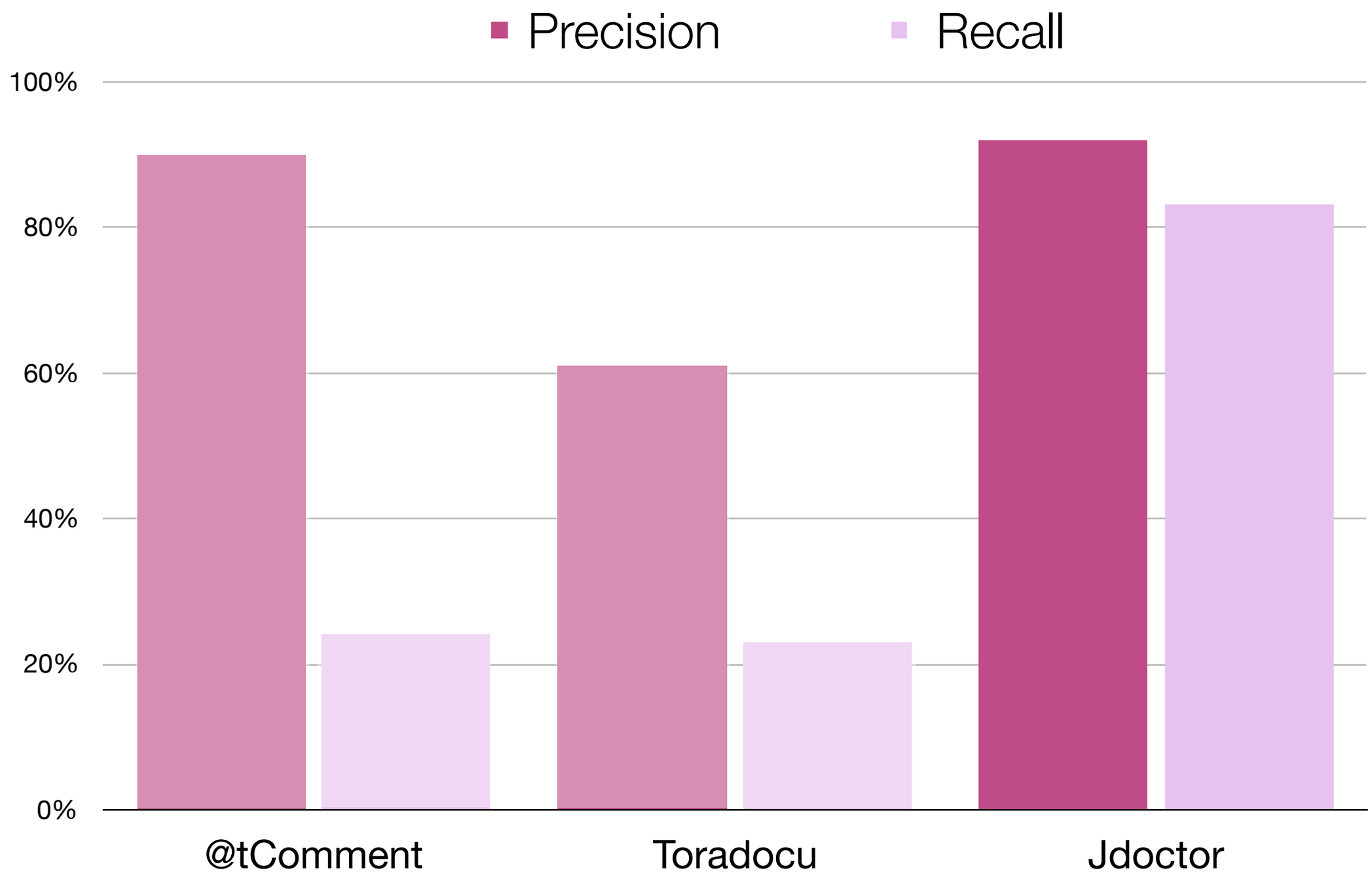


Preconditions

Normal Postconditions



Overall accuracy



How can you use Jdoctor?

Automatic Test Case Generator

+

Jdoctor

Randoop

Automatic unit test generation for Java

+

Jdoctor

Randoop+Jdoctor reclassification

passing

passing

failing

invalid

Randoop+Jdoctor reclassification

passing

passing

failing

invalid

Randoop+Jdoctor reclassification

+ Jdoctor

passing

passing

failing

invalid

Randoop+Jdoctor reclassification

+ Jdoctor

passing → invalid

passing

failing

invalid

Randoop+Jdoctor reclassification

+ Jdoctor

passing → invalid **= invalid**

passing

failing

invalid

Randoop+Jdoctor reclassification

+ Jdoctor

passing → invalid **= invalid**

passing → failing

failing

invalid

Randoop+Jdoctor reclassification

+ Jdoctor

passing	→	invalid	**= invalid**
passing	→	failing	**= missed alarm**
failing			
invalid			

Randoop+Jdoctor reclassification

+ Jdoctor

passing	→	invalid	**= invalid**
passing	→	failing	**= missed alarm**
failing	→	passing	
invalid			

Randoop+Jdoctor reclassification

+ Jdoctor

passing	→	invalid	**= invalid**
passing	→	failing	**= missed alarm**
failing	→	passing	**= false alarm**
invalid			

Randoop+Jdoctor reclassification

+ Jdoctor

passing	→	invalid	**= invalid**
passing	→	failing	**= missed alarm**
failing	→	passing	**= false alarm**
invalid	→	passing	

Randoop+Jdoctor reclassification

+ Jdoctor

passing	→	invalid	**= invalid**
passing	→	failing	**= missed alarm**
failing	→	passing	**= false alarm**
invalid	→	passing	**= new test**

Missed alarm

```
public static boolean removeAll(List myList){…}
```

Missed alarm

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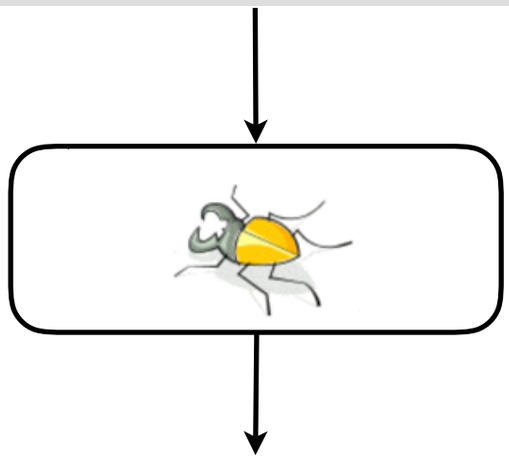
public static boolean removeAll(List myList){…}
```

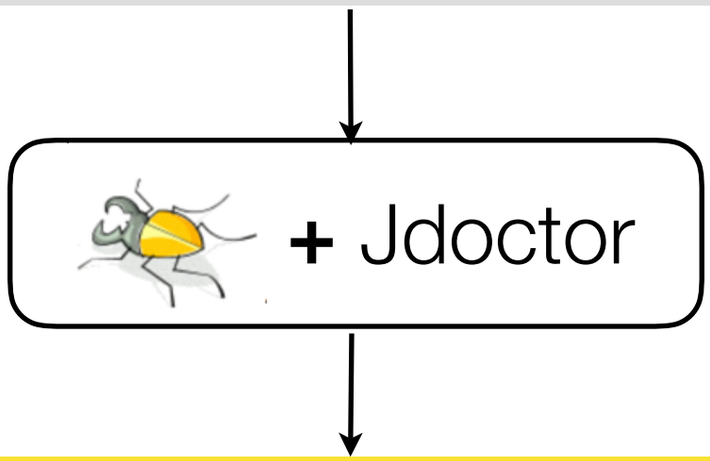


```
@Test
public void testRemoveAll(){
     List<Integer> list = Arrays.asList(1, 2, 3);
     boolean result = removeAll(list);

}
```

Missed alarm

```
/**
 * @return true if the list is empty
 */
public static boolean removeAll(List myList){…}
```

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Missed alarm

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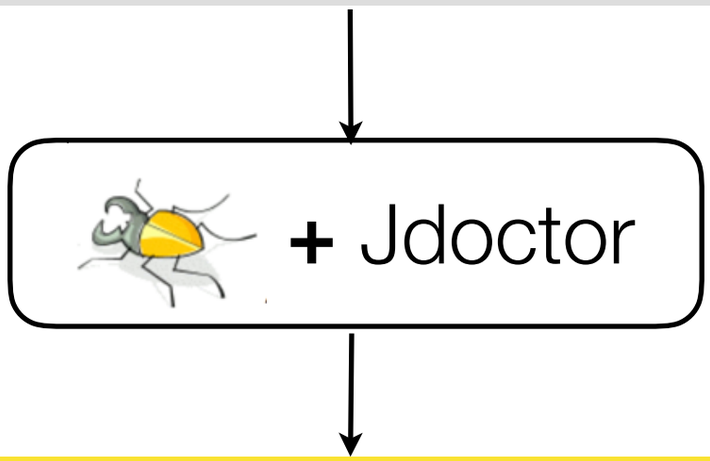


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@Test
public void testRemoveAll(){
     List<Integer> list = Arrays.asList(1, 2, 3);
     boolean result = removeAll(list);
     if(list.isEmpty()) assert result==true;
}
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Missed alarm

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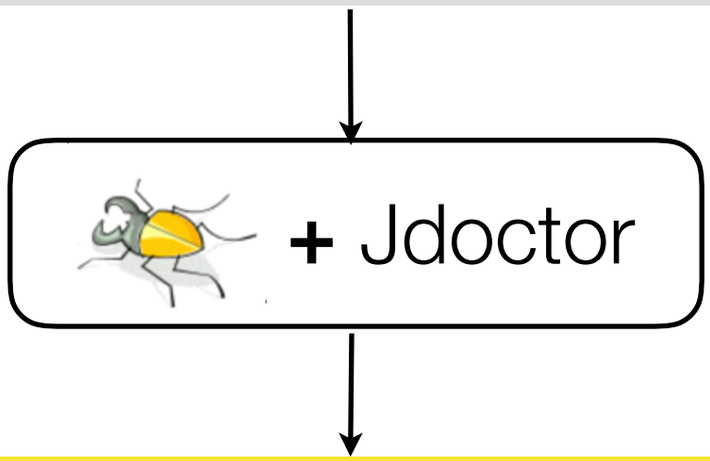


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Invalid test

```
public static float max(float[] floatArray){…}
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Invalid test

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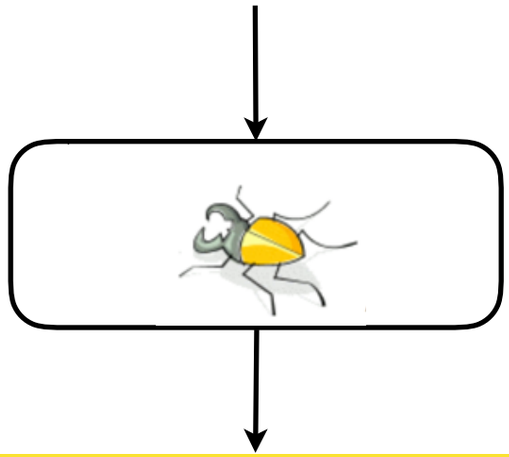
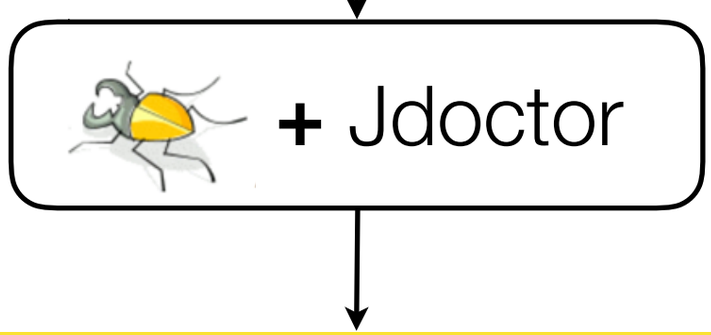


```
@Test
public void testRemoveAll(){
        float[] floatArray0 = null;
        float float1 = max(floatArray0);
}
```

Invalid test

```
/**
 * @param floatArray array of floats, not null
 */
public static float max(float[] floatArray){…}
```

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Invalid test

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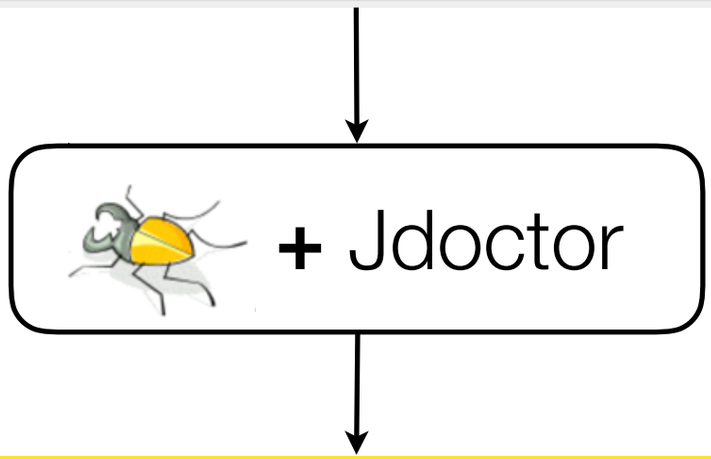
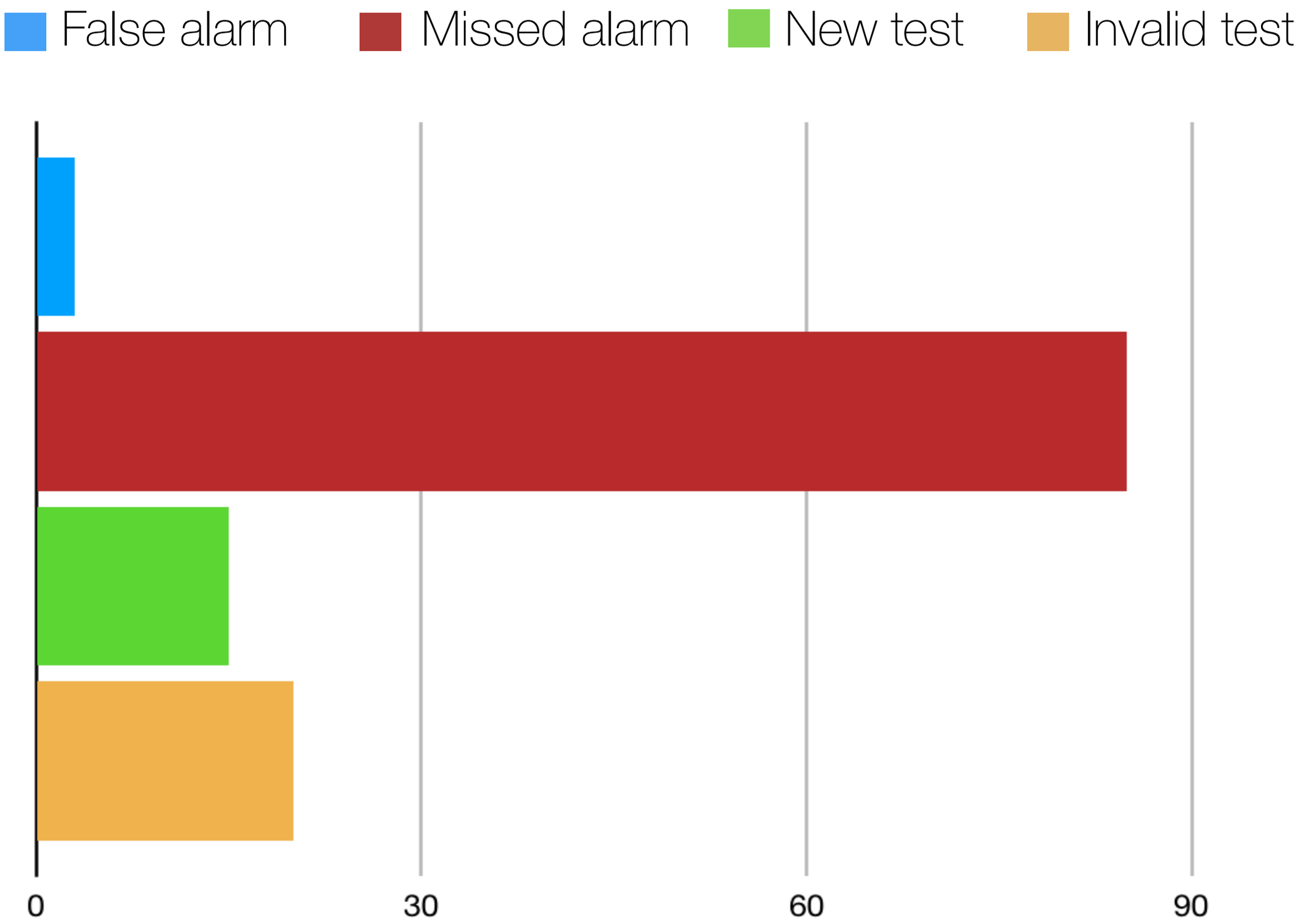


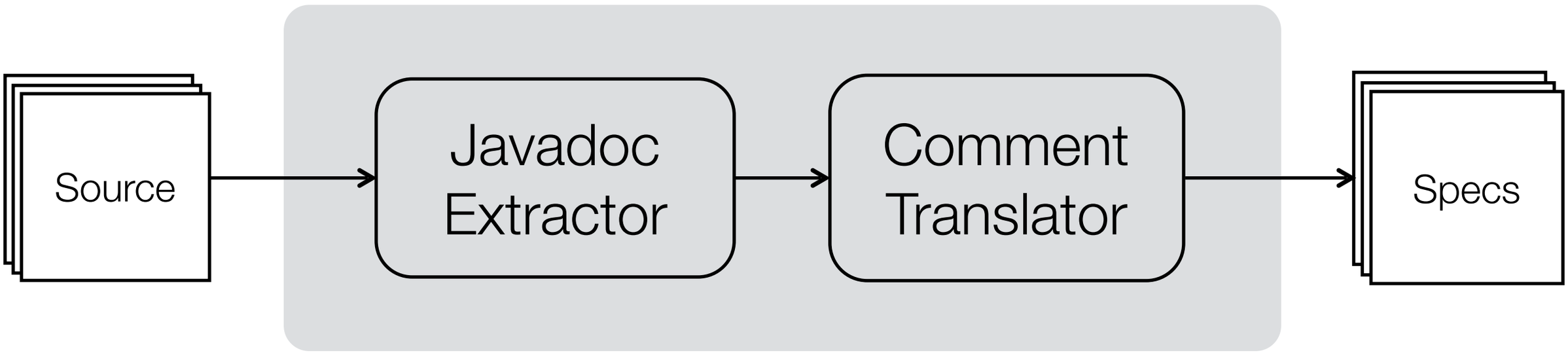

```java
@Test
public void testRemoveAll(){
        float[] floatArray0 = null;
        float float1 = max(floatArray0);
}
```

INVALID

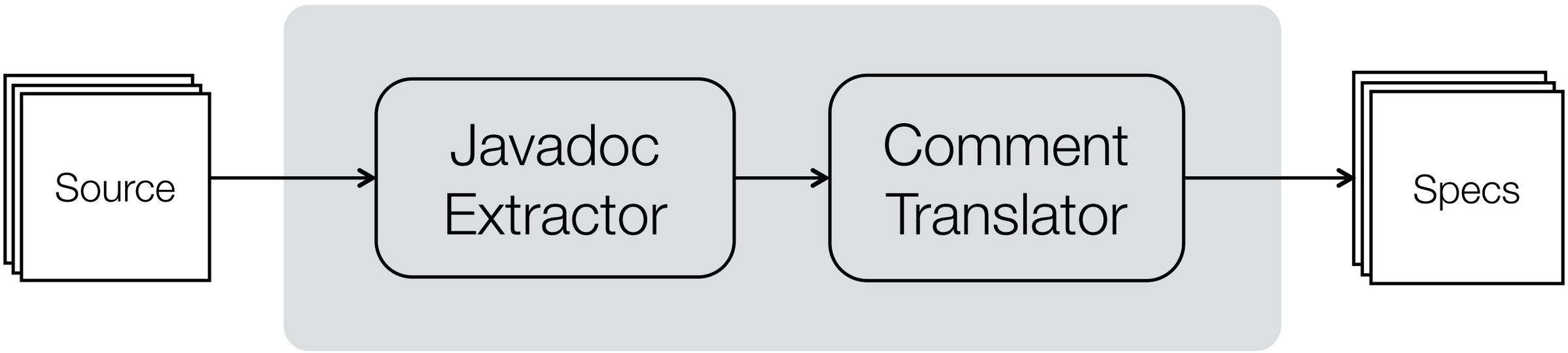
Reclassification



Jdoctor

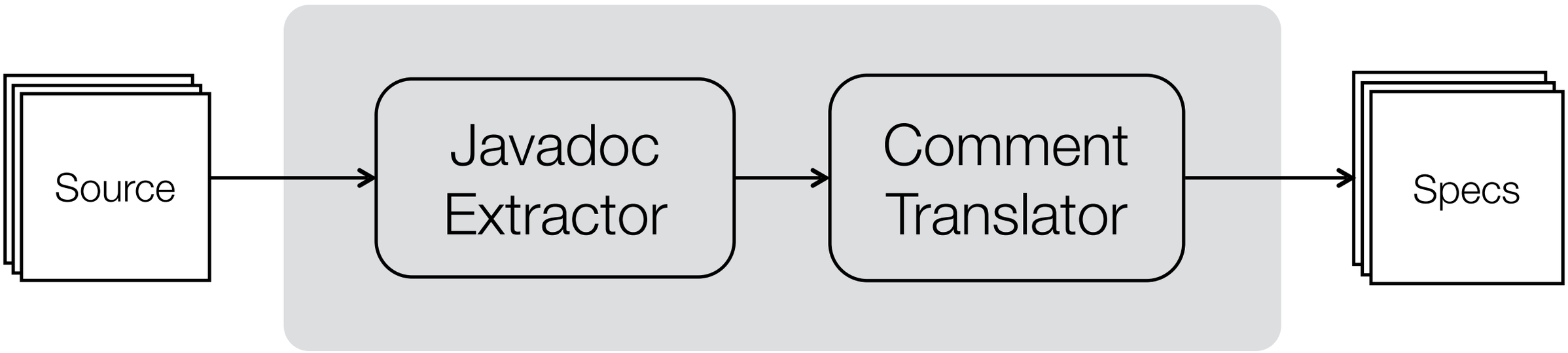


Jdoctor



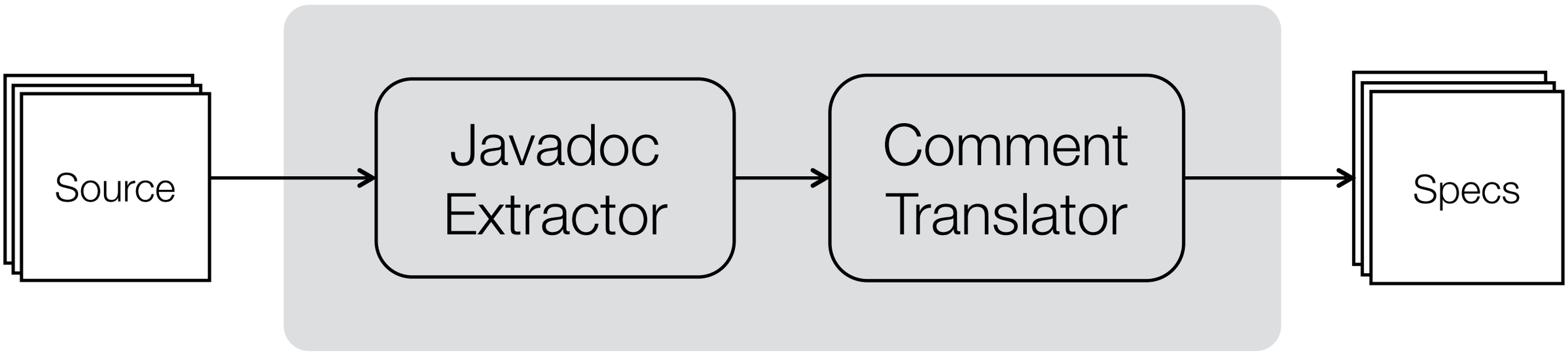
- ✓ Preconditions

Jdoctor



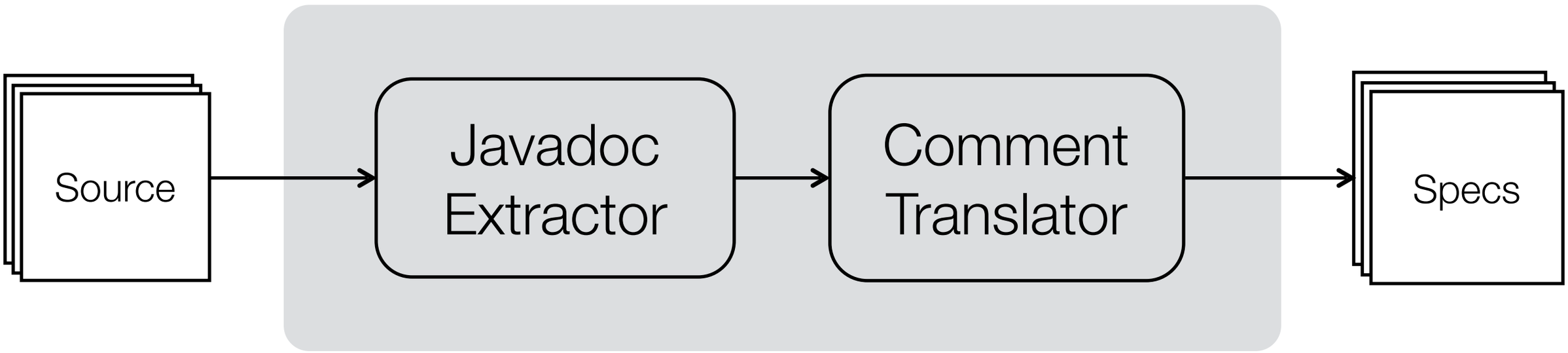
- ✓ Preconditions
- ✓ Normal Postconditions

Jdoctor



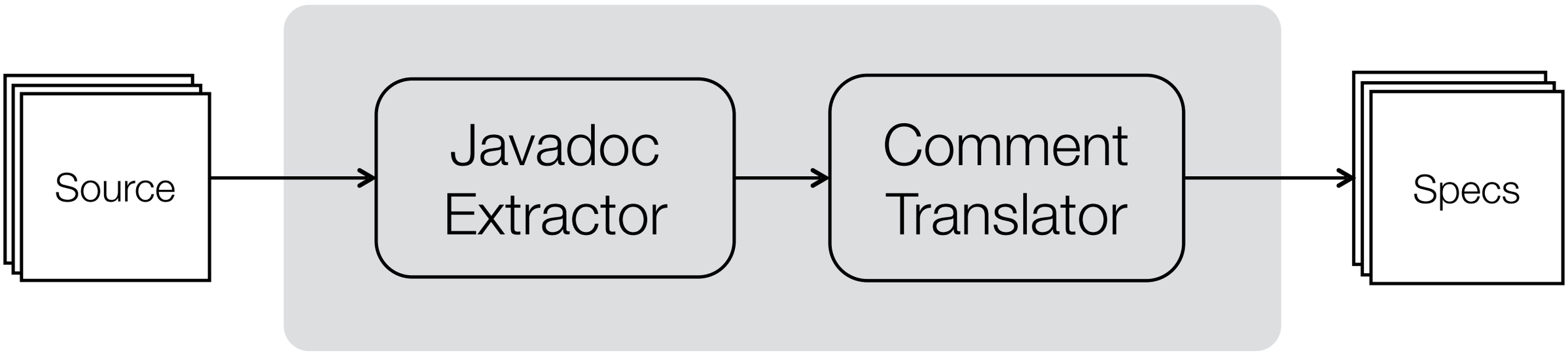
- ✓ Preconditions
- ✓ Normal Postconditions
- ✓ Exceptional Postconditions

Jdoctor



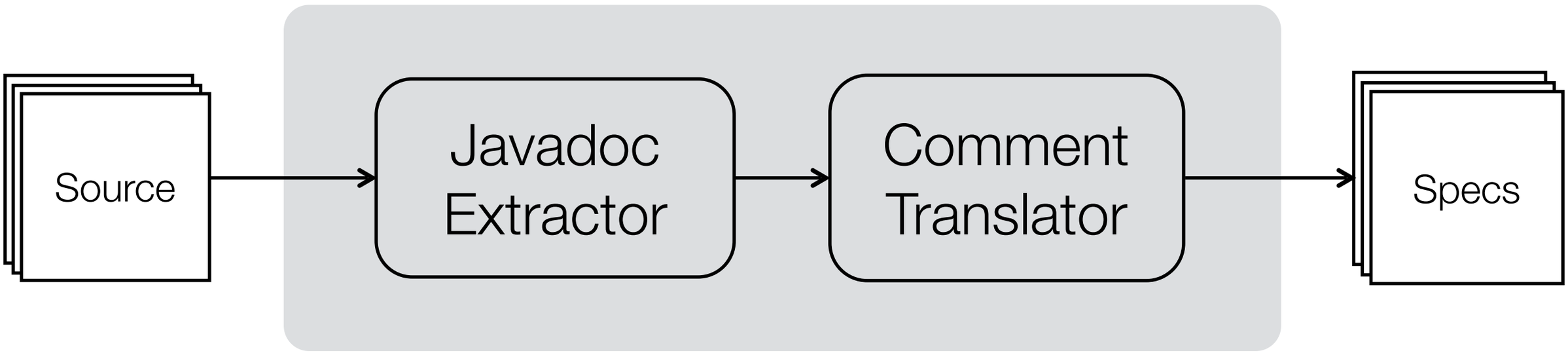
- ✓ Preconditions
- ✓ Normal Postconditions
- ✓ Exceptional Postconditions
- ✓ Pattern Match

Jdoctor



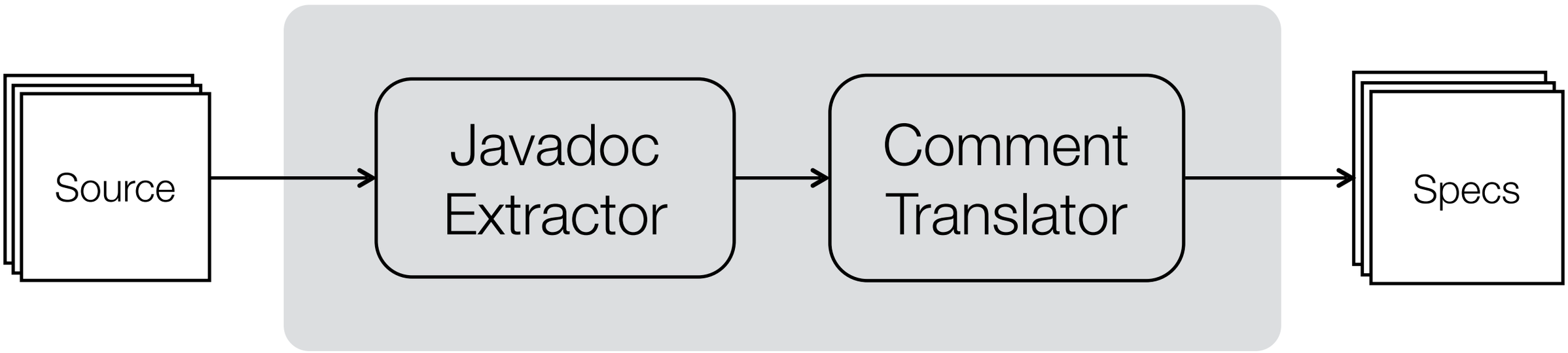
- ✓ Preconditions
- ✓ Normal Postconditions
- ✓ Exceptional Postconditions
- ✓ Pattern Match
- ✓ Syntax Match

Jdoctor



- ✓ Preconditions
- ✓ Normal Postconditions
- ✓ Exceptional Postconditions
- ✓ Pattern Match
- ✓ Syntax Match
- ✓ Semantic Match

Jdoctor



- ✓ Preconditions
- ✓ Normal Postconditions
- ✓ Exceptional Postconditions
- ✓ Pattern Match
- ✓ Syntax Match
- ✓ Semantic Match

https://github.com/albertogoffi/toradocu