Research on NLP for RE at Università della Svizzera italiana: a Report

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Automatic generation of test cases

Test case =

Test case = input

Test case = input +

Test case = input + *expected* output

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- How to know inputs - valid, invalid, etc. ?

Test case = input + *expected* output

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- How to know the expected output given an input?

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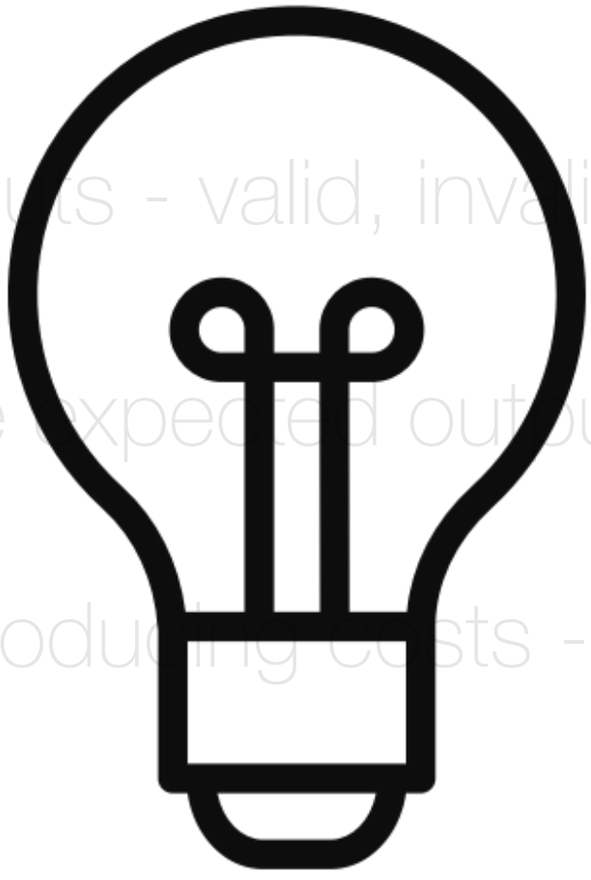
- How to know the expected output given an input?
- How to avoid introducing costs - e.g., human aid?

Test case = input + *expected* output



- How to know inputs - valid, invalid, etc. ?
- How to know the expected output given an input?
- How to avoid introducing costs - e.g., human aid?

Exploiting available information

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- How to know the expected output given an input?
- How to avoid introducing costs - e.g., human aid?

Exploiting available information

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- *Semantically relevant* information

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- Often expressed in Natural Language

Exploiting available information

- *Semantically relevant* information
- Often expressed in Natural Language
- ...code comments, documentation, requirements...

```java
// returns true if x is less than 0

public class SimpleMath {
    public boolean isNegative(int x){
        return x > 0;
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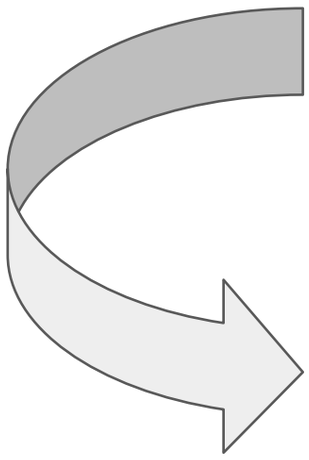

```java
public class SimpleMathTest {
    @Test
    public void testIsNegative(){
        SimpleMath simpleMathInstance = new SimpleMath();
        assertTrue(simpleMathInstance.isNegative(-1));
    }
}
```

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// returns true if x is less than 0

public class SimpleMath {
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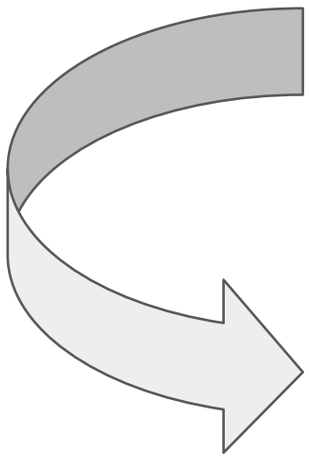

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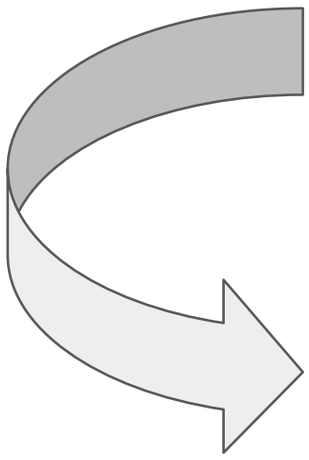

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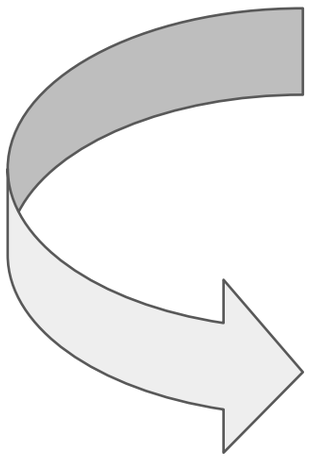

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public class SimpleMathTest {
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Test fails

```java
// returns true if x is less than 0

public class SimpleMath {
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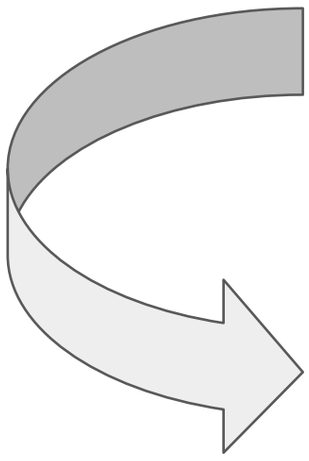
BUG!



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Test fails

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// returns true if x is less than 0

public class SimpleMath {
    public boolean isNegative(int x){
        return x < 0;
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FIXED!

```java
public class SimpleMathTest {
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Test passes

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// returns true if x is less than 0

public class SimpleMath {
    public boolean isNegative(int x){
        return x > 0;
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}
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FIXED!

Test cases help you detecting bugs!

```
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Test passes

Can we automatically translate natural language information into test cases?

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Let’s try with Javadoc comments!

```
/**
 * @param  v, the vertex, must not be null
 *
 * @param  nList, list of possible neighbors
 *
 * @return true if vertexes in nList are neighbors of
 *         vertex. Always false if the list is empty
 *
 * @throws IllegalArgumentException if vertex is not
 *         found in the graph
 */

public boolean neighborsOf(Vertex v, List nList){…}
```

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nList.isEmpty() ? returnValue==false

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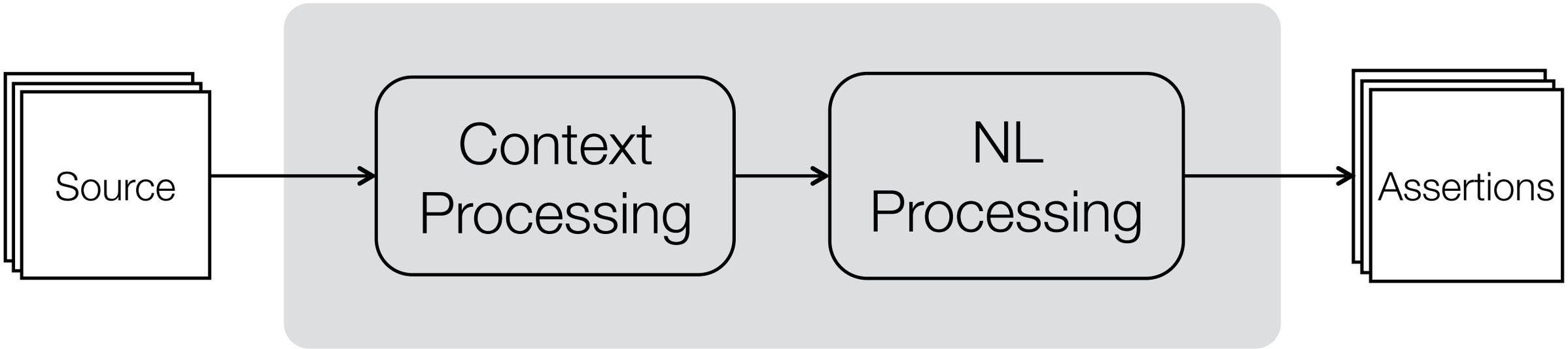
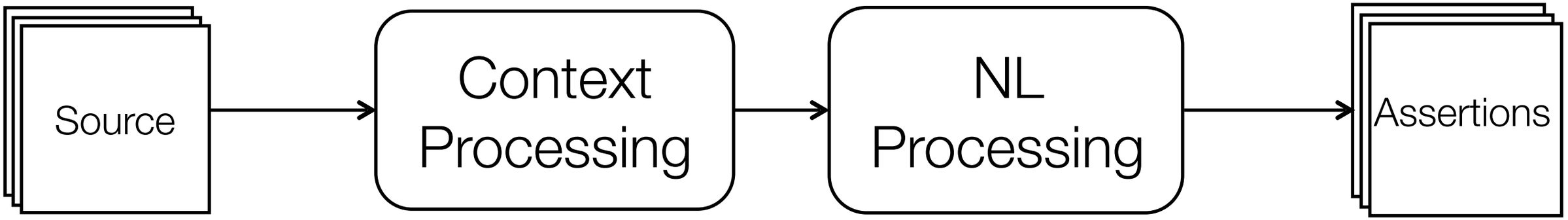
v != null

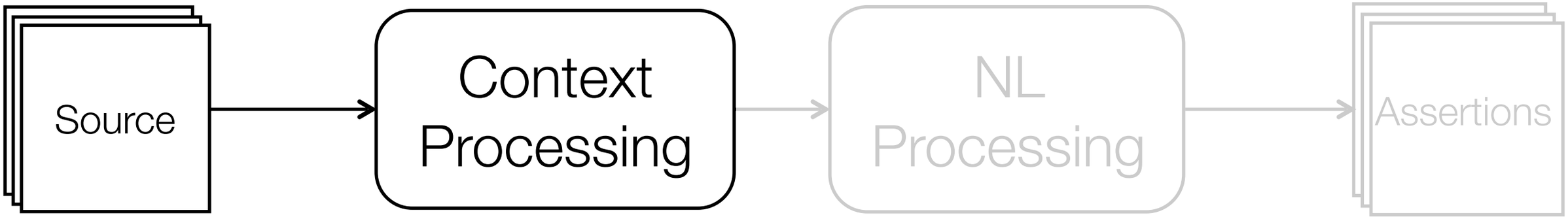
nList.isEmpty() ? returnValue==false

!graph.contains(v) -> IllegalArgumentException

Jdoctor




Source
Context Processing
NL Processing
Assertions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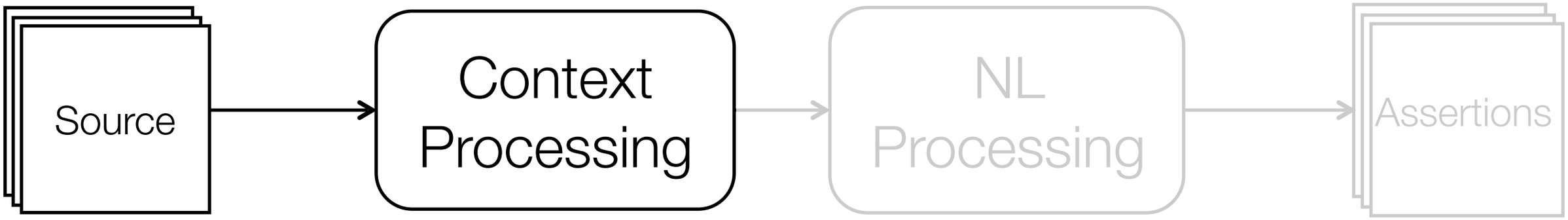
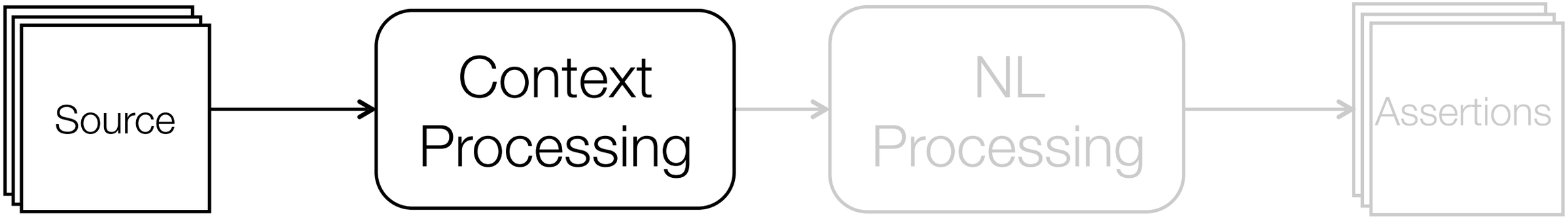


@param

1. Identifiers
2. Condition



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@param v, the vertex, must not
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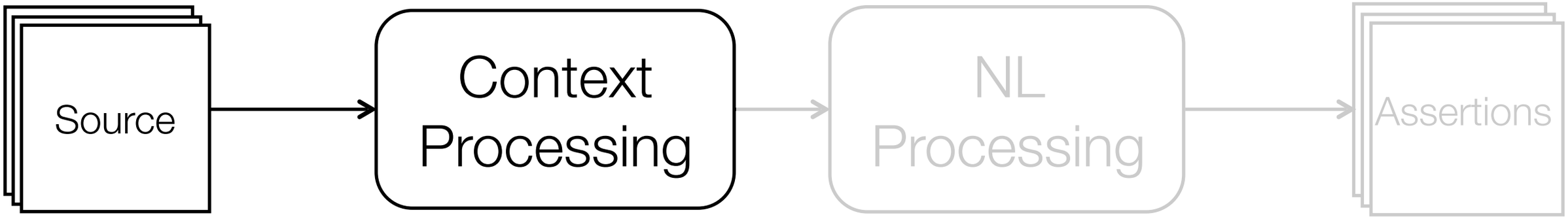

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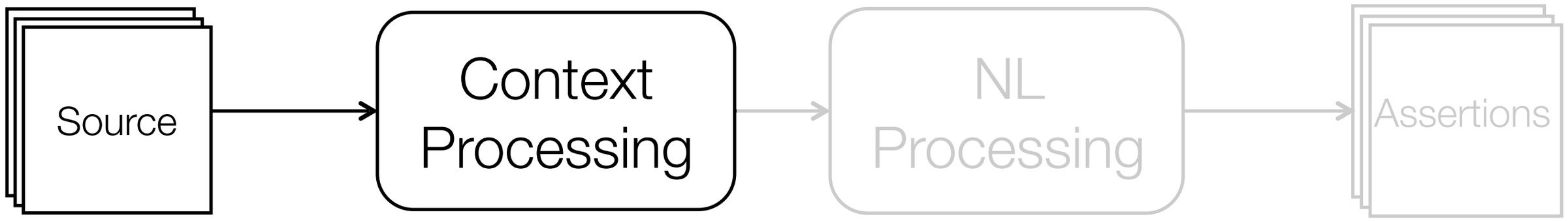

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@return always false if the
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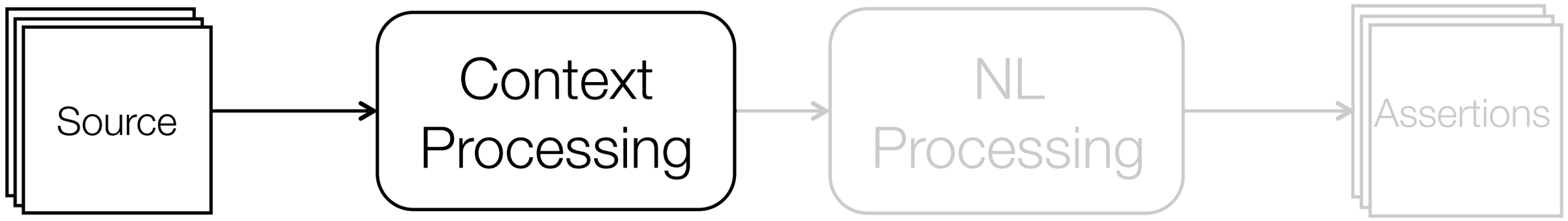

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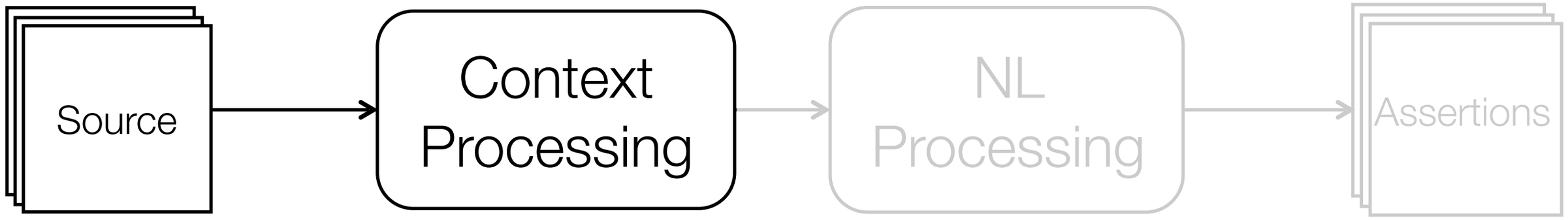

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@throws IllegalArgumentException
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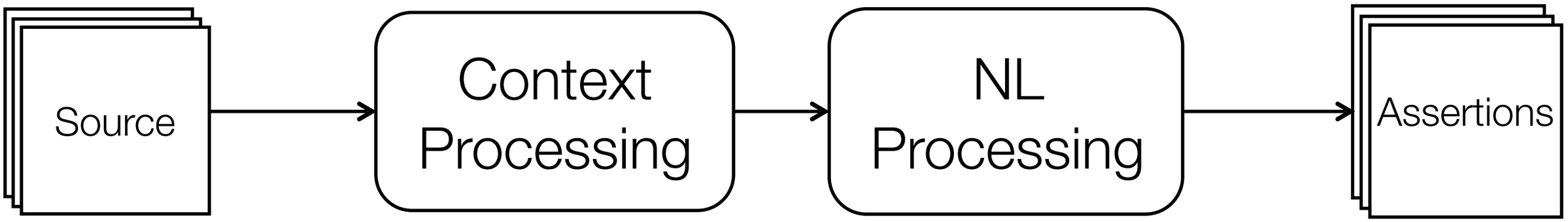

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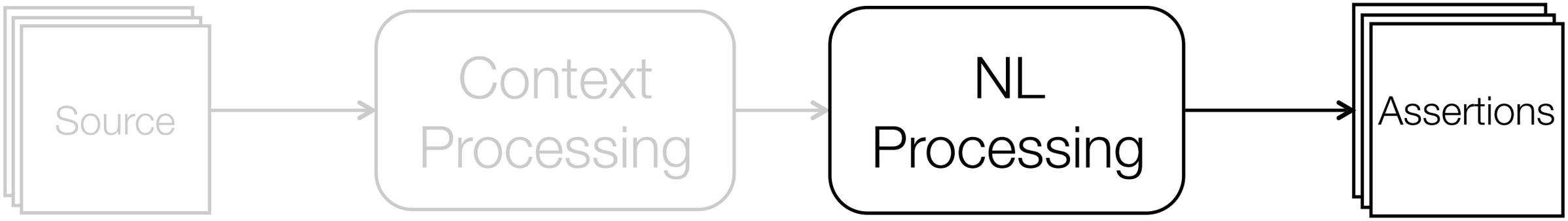


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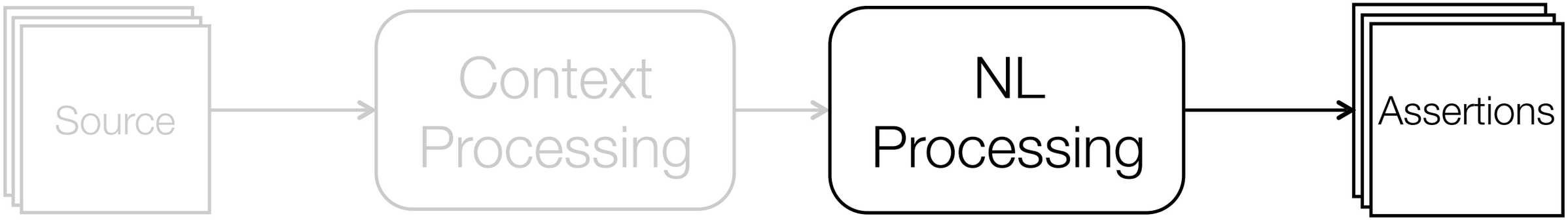


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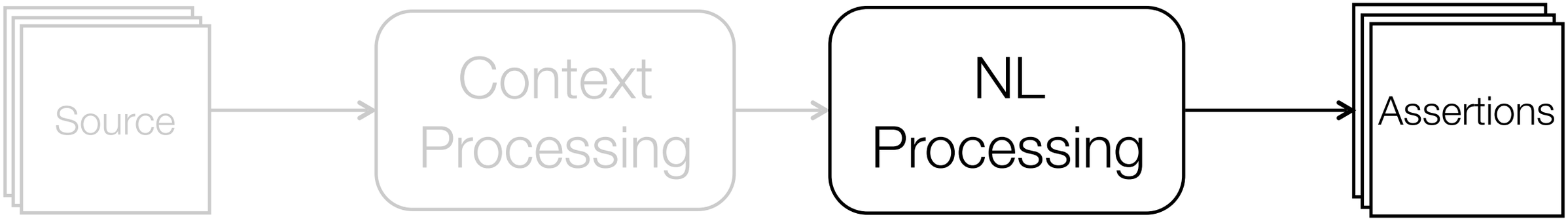


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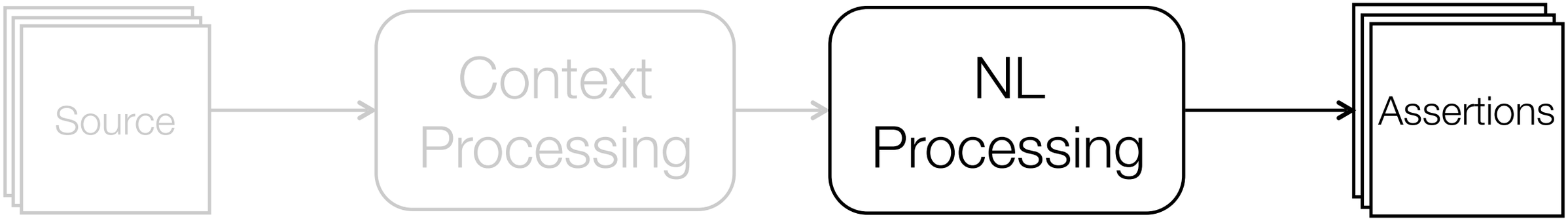


```
@param v, the vertex, must not
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PATTERN MATCH

"vertex not null"

`v != null`

```
@return always false if the
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```
@throws IllegalArgumentException
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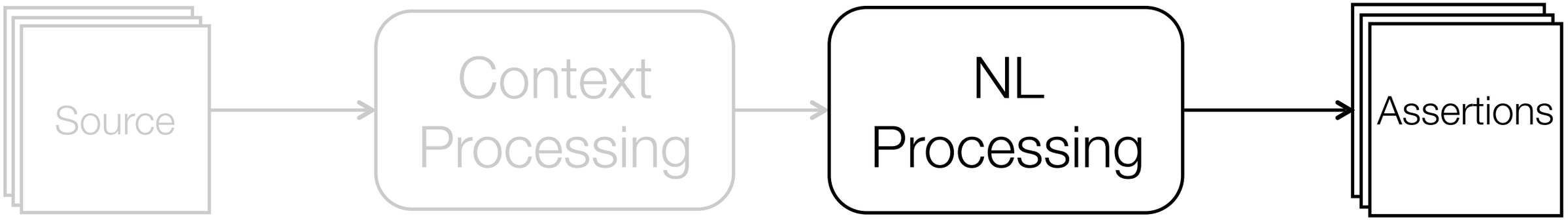


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PATTERN MATCH

"vertex not null"

`v != null`

```
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SYNTAX MATCH

"list is empty"

`nList.isEmpty()`

```
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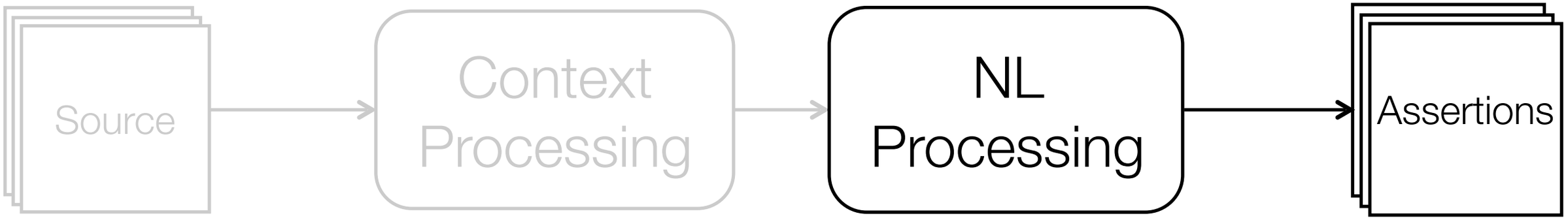


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SYNTAX MATCH

"list is empty"

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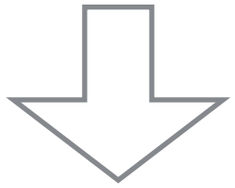
SEMANTIC MATCH

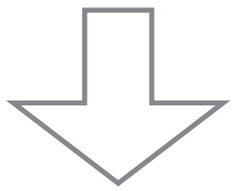
"vertex not found in graph"

`!graph.contains(v)`

Natural Language Specification

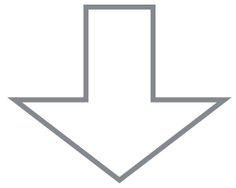


NL
Processing

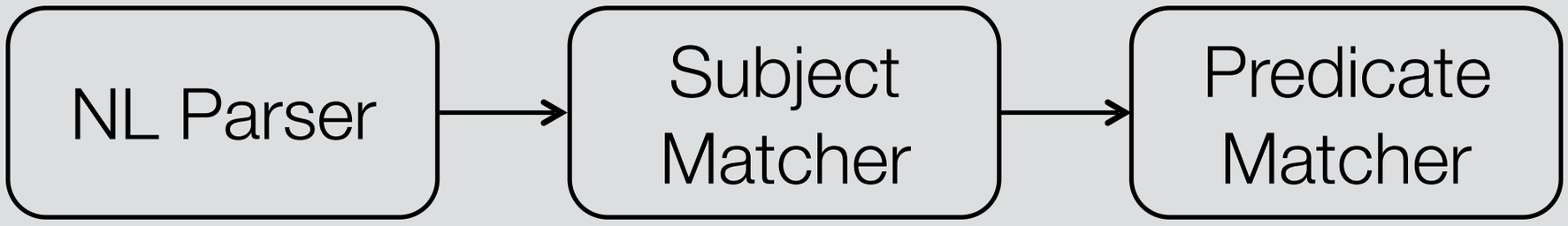


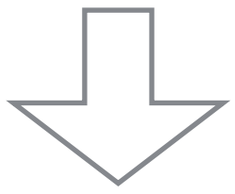
Code Translation

Natural Language Specification



Natural Language Processing





Code Translation

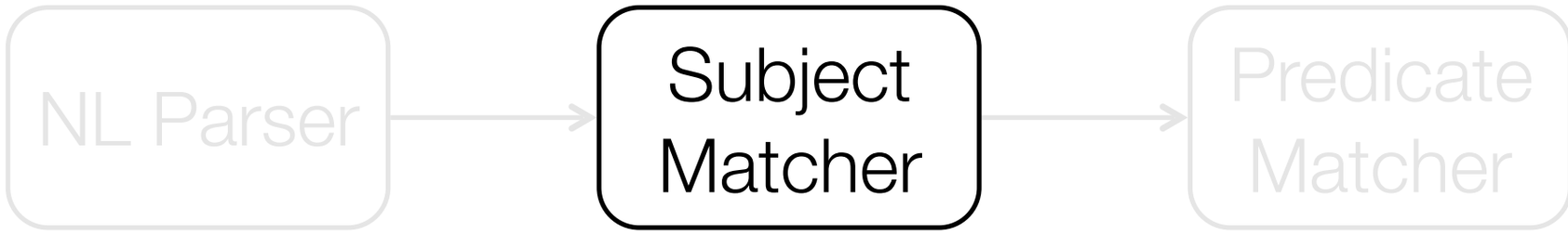
@return

“ *(false)* if the list is empty ”

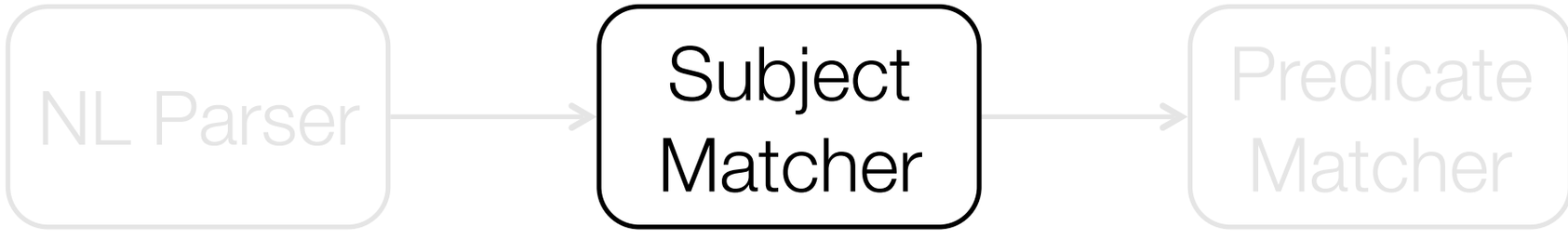
@return

`" (false) if the list is empty "`

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



Subject: `“list”`



Subject: `“list”`

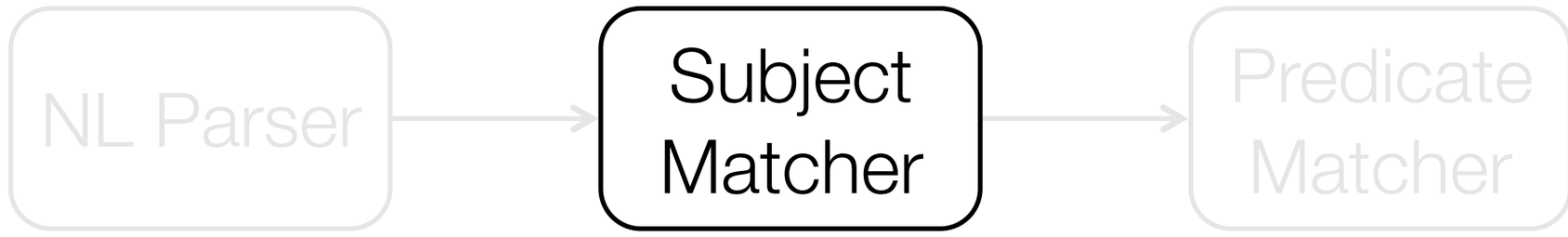
Candidates

Formal Parameters

Class Name

Methods

Fields

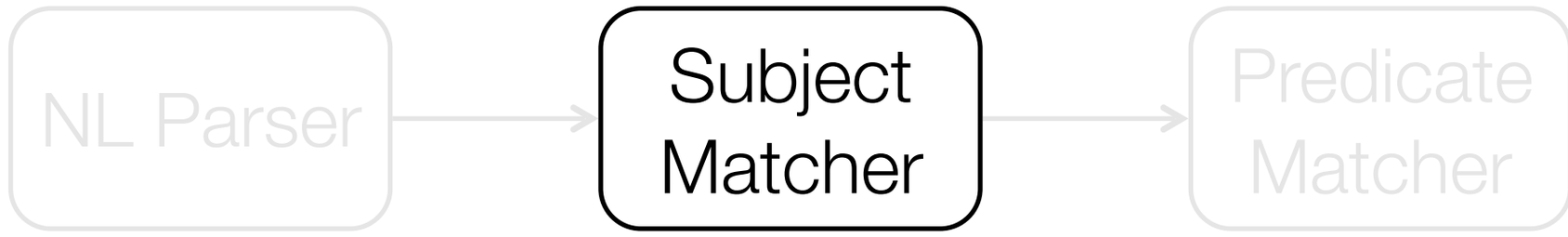


Subject: `"list"`

Candidates

Formal Parameters
Class Name
Methods
Fields

Candidate	Edit Distance
`nList`	1
`isEmpty`	7
`iterator`	8
`size`	4
...	



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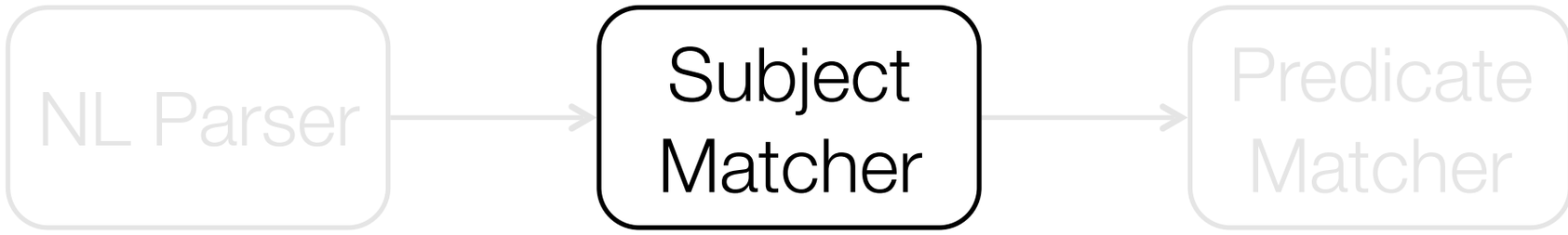

Subject: `"list"` => **`nList`**

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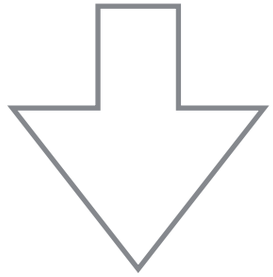
Subject	Predicate
`"list"`	`"is empty"`



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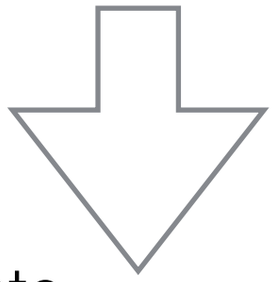

Candidate	Edit Distance
`nList`	8
`isEmpty`	1
`iterator`	6
`size`	7
...	

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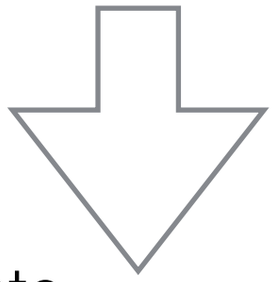

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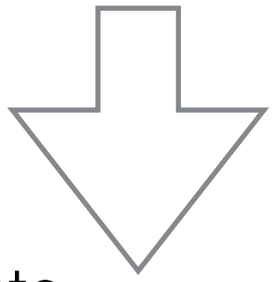
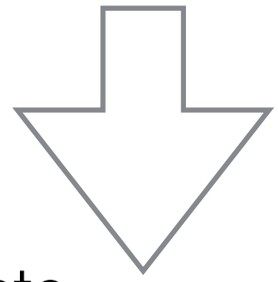
Subject	Predicate
`"list"`	`"is empty"`



Candidate	Edit Distance
`nList`	8
`isEmpty`	**1**
`iterator`	6
`size`	7
...	

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

Syntax match



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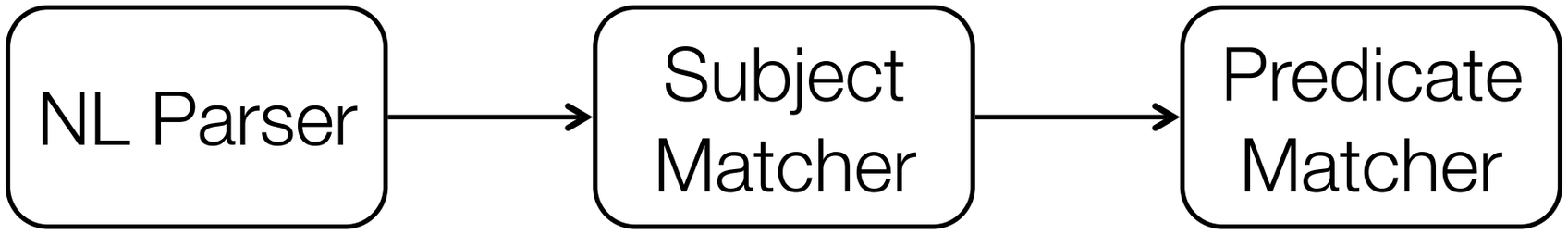

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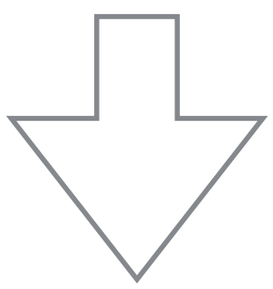

```
nList.isEmpty()
```

Experimental setup

6 Popular open-source Java systems

Experimental setup

829 Manually-written Java conditions

92

%

Precision

92%

Precision

83%

Recall

92%

Precision

83%

Recall

Translating Code Comments to Procedure Specifications, Blasi et al., ISSTA'18

Past

Past

```
/**
 * @return always false if the list is empty
 * @param  v, the vertex, must not be null
 * @throws IllegalArgumentException if vertex is not found in the graph
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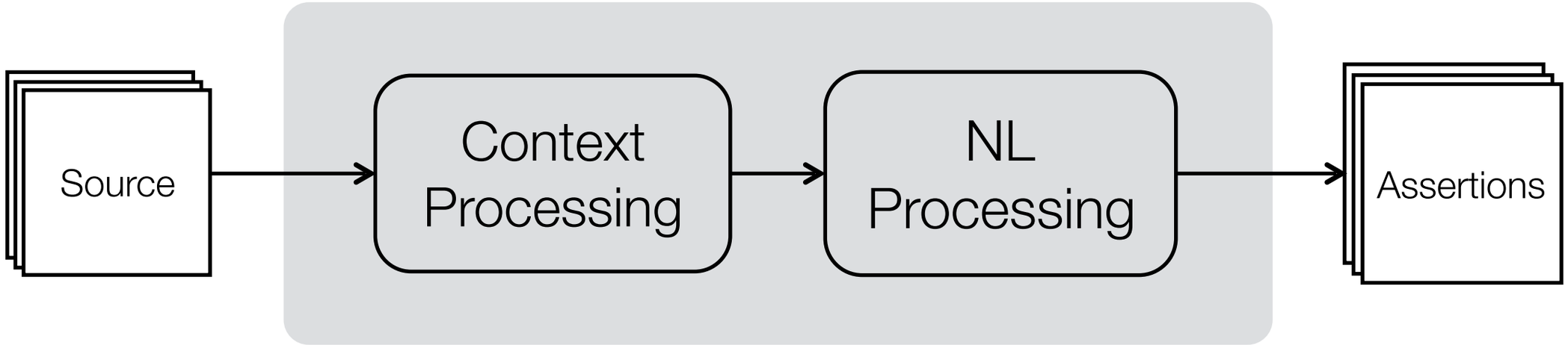

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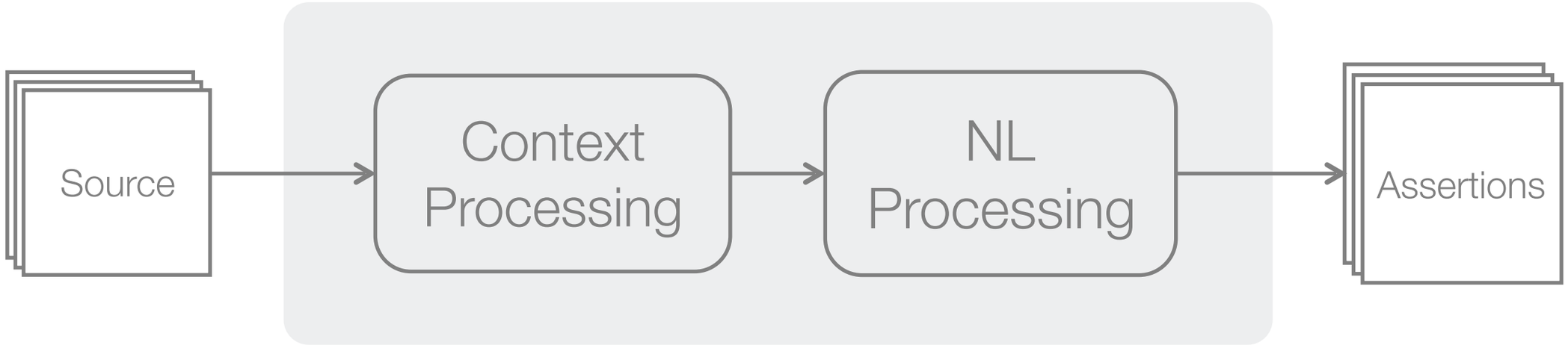

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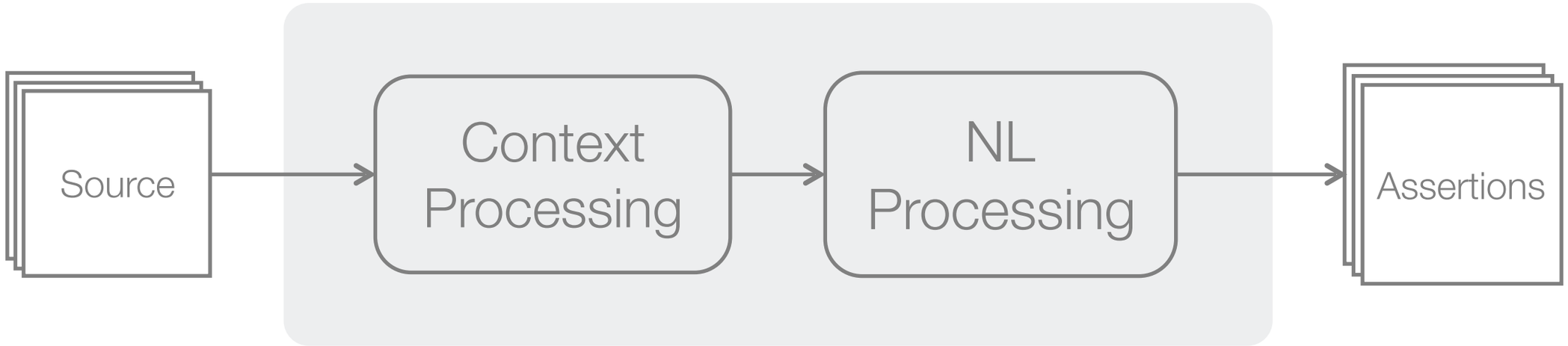

- Exploiting **semi-structured** natural language information

Past

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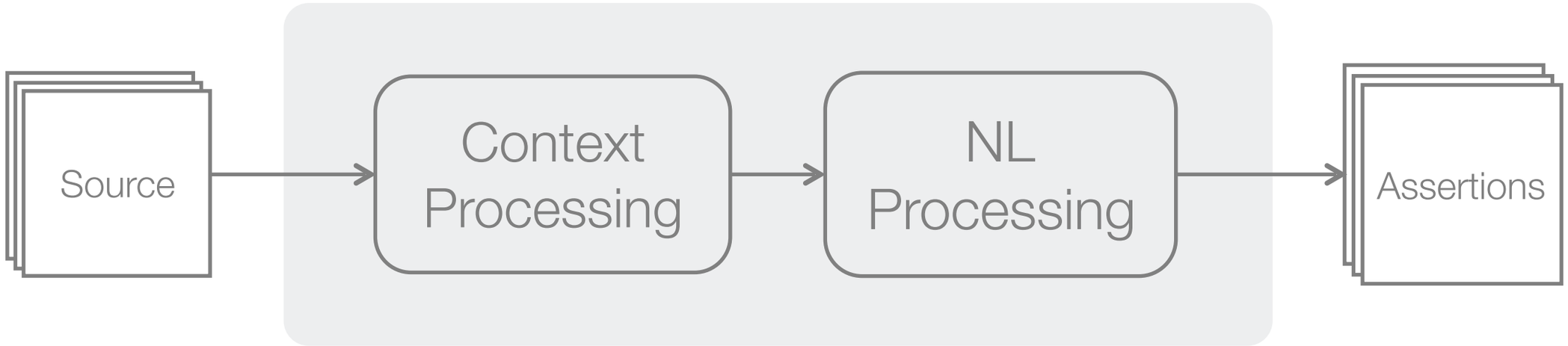

- Exploiting **semi-structured** natural language information
- For generating test cases at the **unit** level

Past

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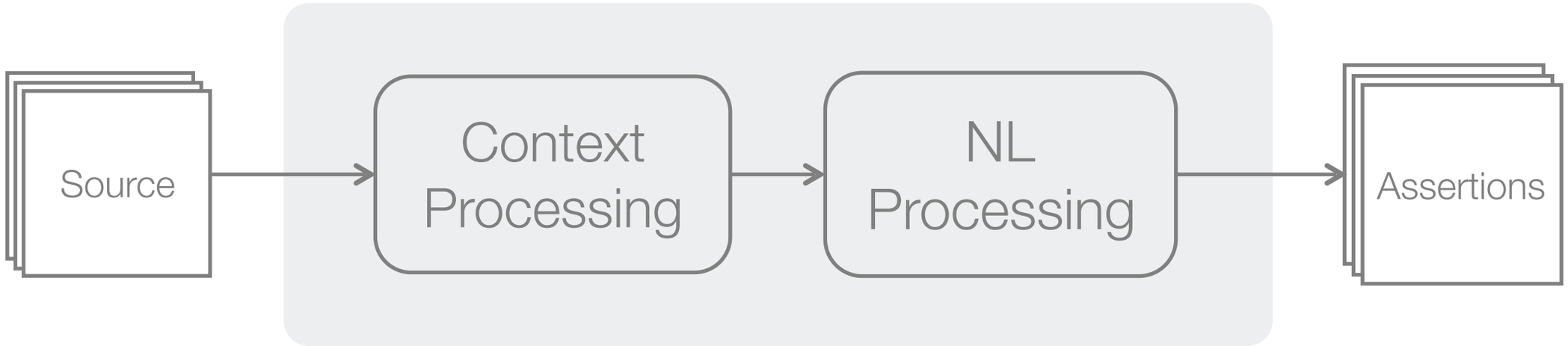
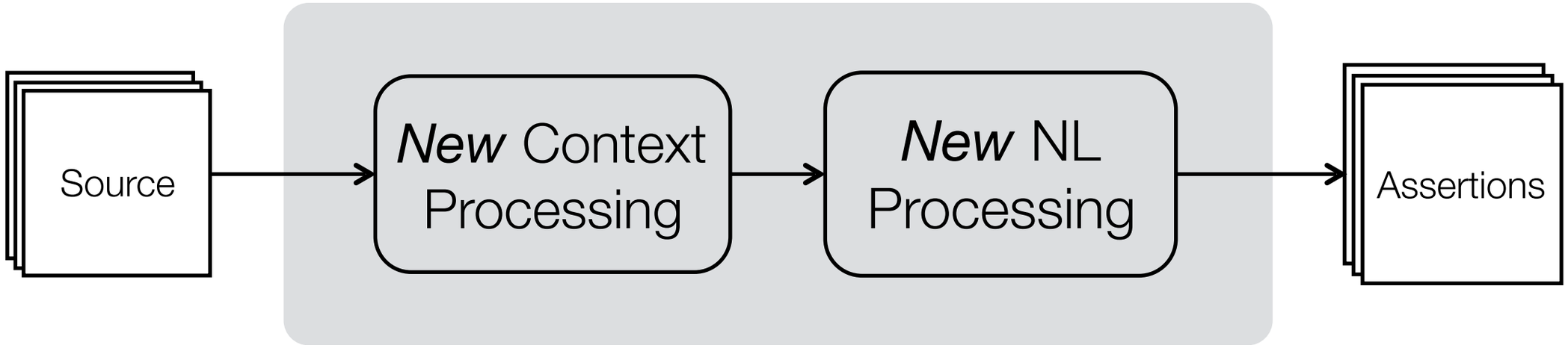


- Exploiting **semi-structured** natural language information
- For generating test cases at the **unit** level
- Testing **functional** properties only

Present

```
/**
 * Note that it is not possible to delete the last element by
 * immediately calling remove() on the iterator, as a call to remove()
 * before a call to next() will result in an illegal state.
 */
```



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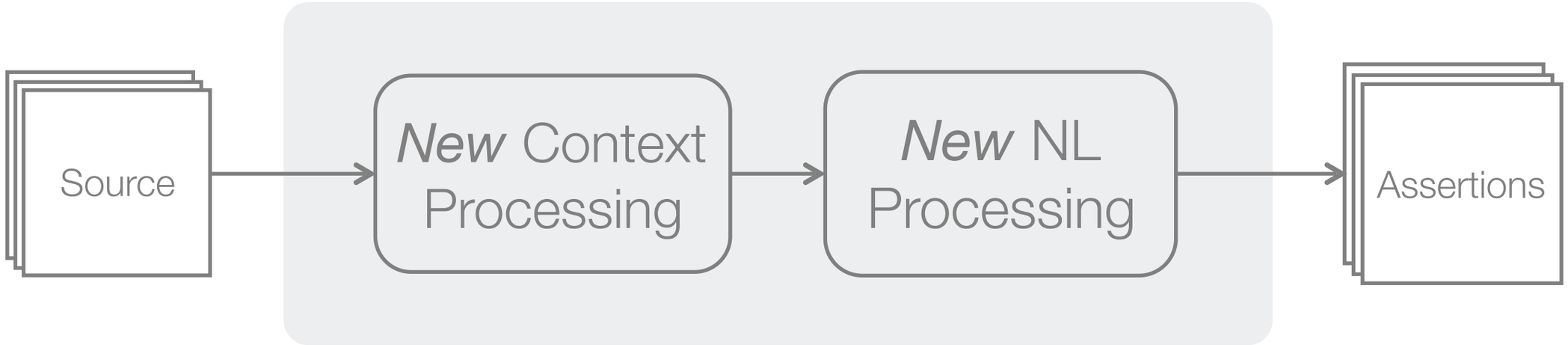

- Exploiting **unstructured** natural language information

Present

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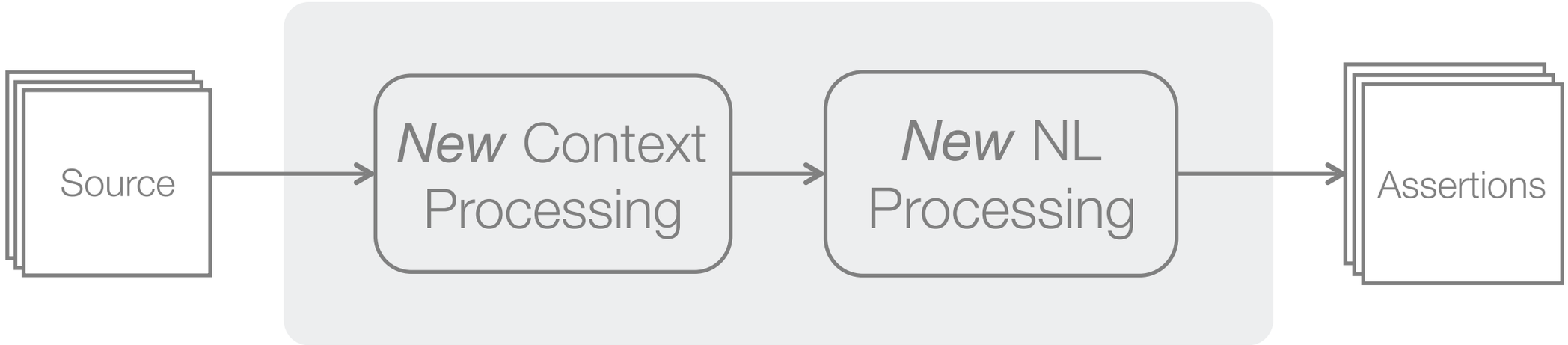
```



- Exploiting **unstructured** natural language information
- For testing both at the unit and the **integration** level

Present

```
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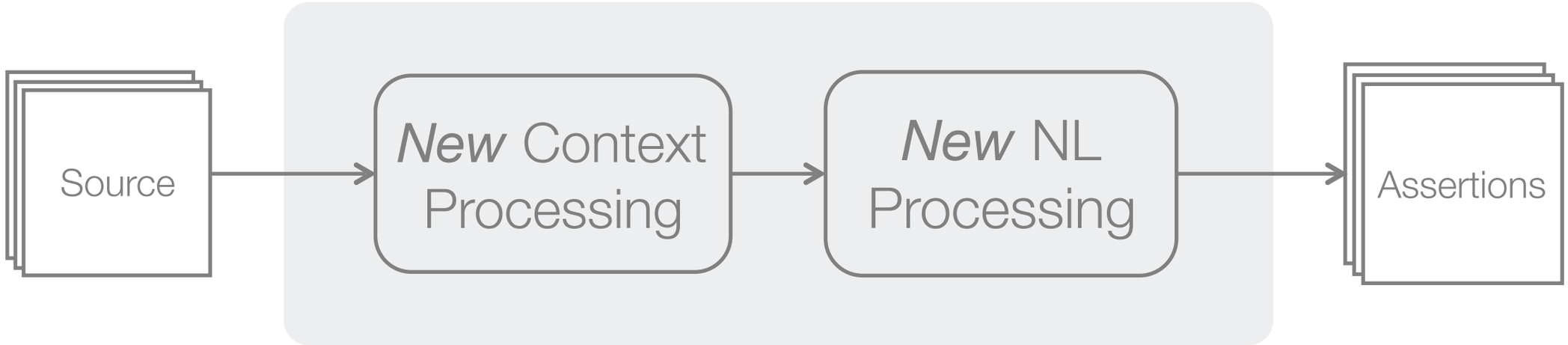

- Exploiting **unstructured** natural language information
- For testing both at the unit and the **integration** level
- Testing functional properties only

Future

Future

- Testing at the **system** level for complex systems

Future

- Testing at the **system** level for complex systems
- Testing both functional and **non-functional properties**

Future

- Testing at the **system** level for complex systems
- Testing both functional and **non-functional properties**
- Exploiting **any kind** of natural language information