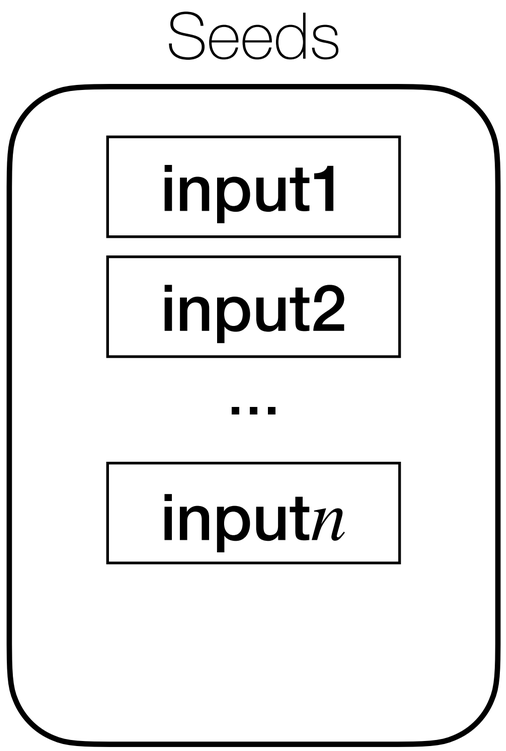
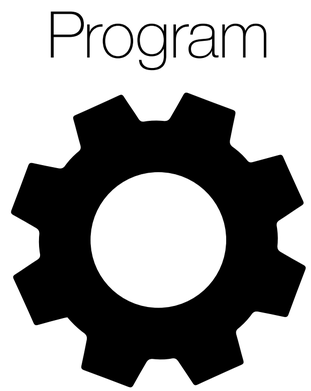
NEZHA:
Efficient Domain-Independent Differential Testing

Theofilos Petsios, Adrian Tang, Salvatore Stolfo, Angelos D. Keromytis, and Suman Jana (S&P '17)

Jaemin Hong 20203698

A fuzzer runs a program with random inputs.





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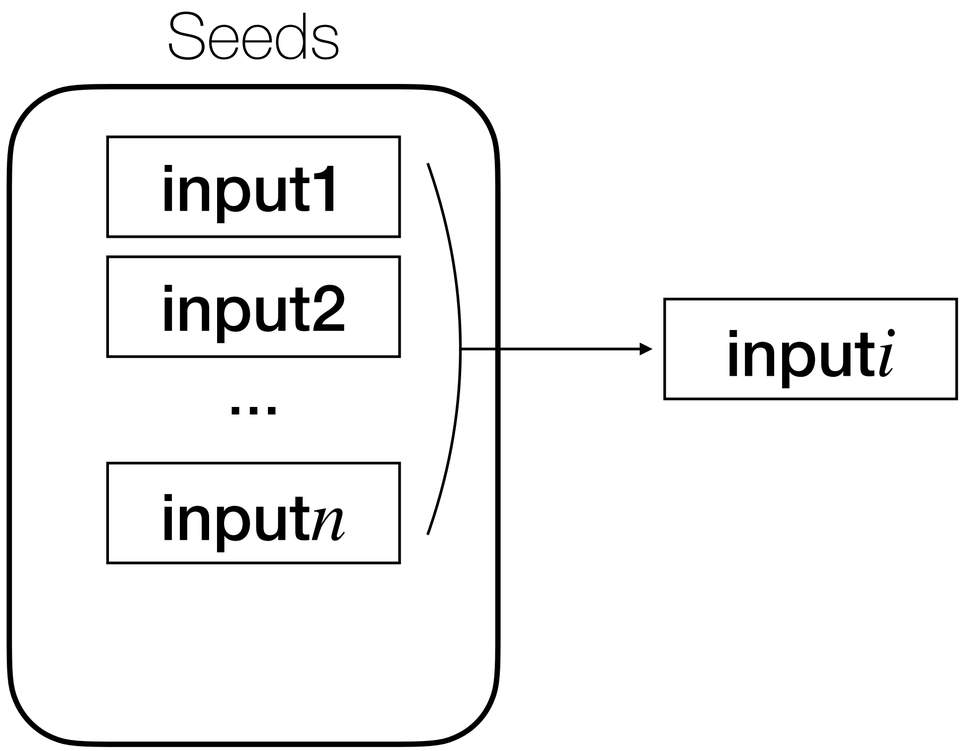

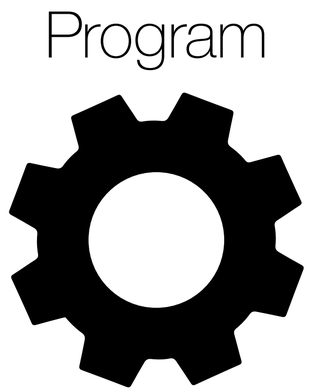

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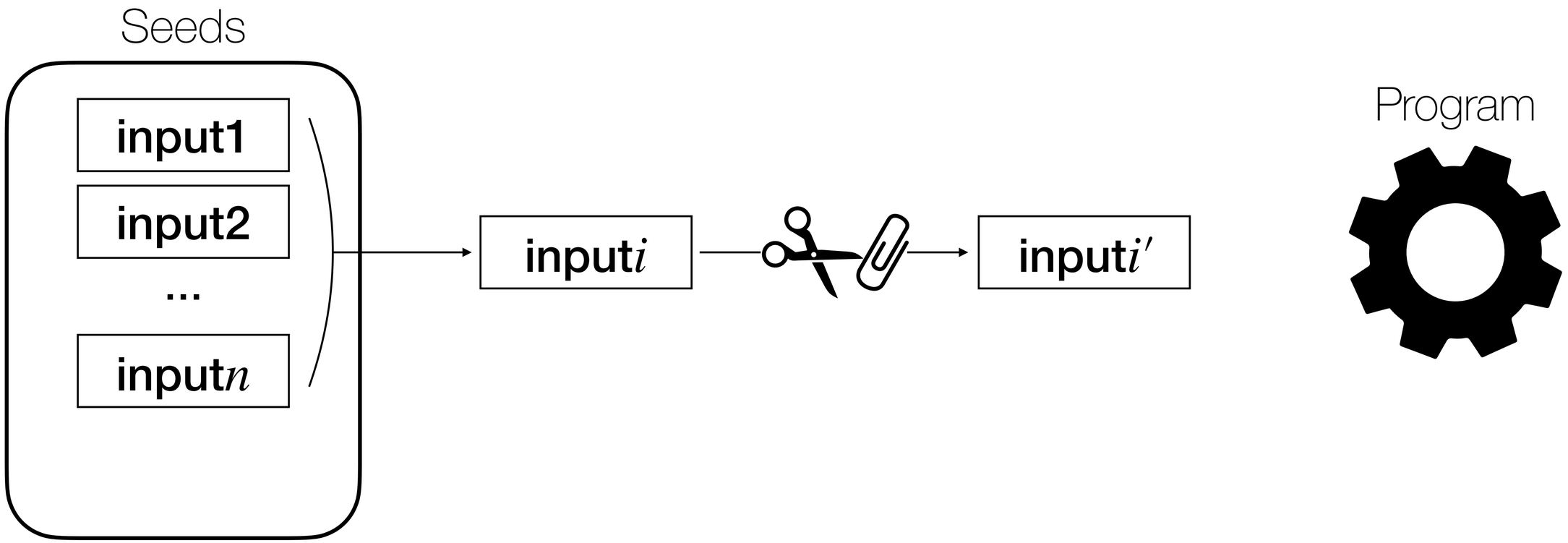

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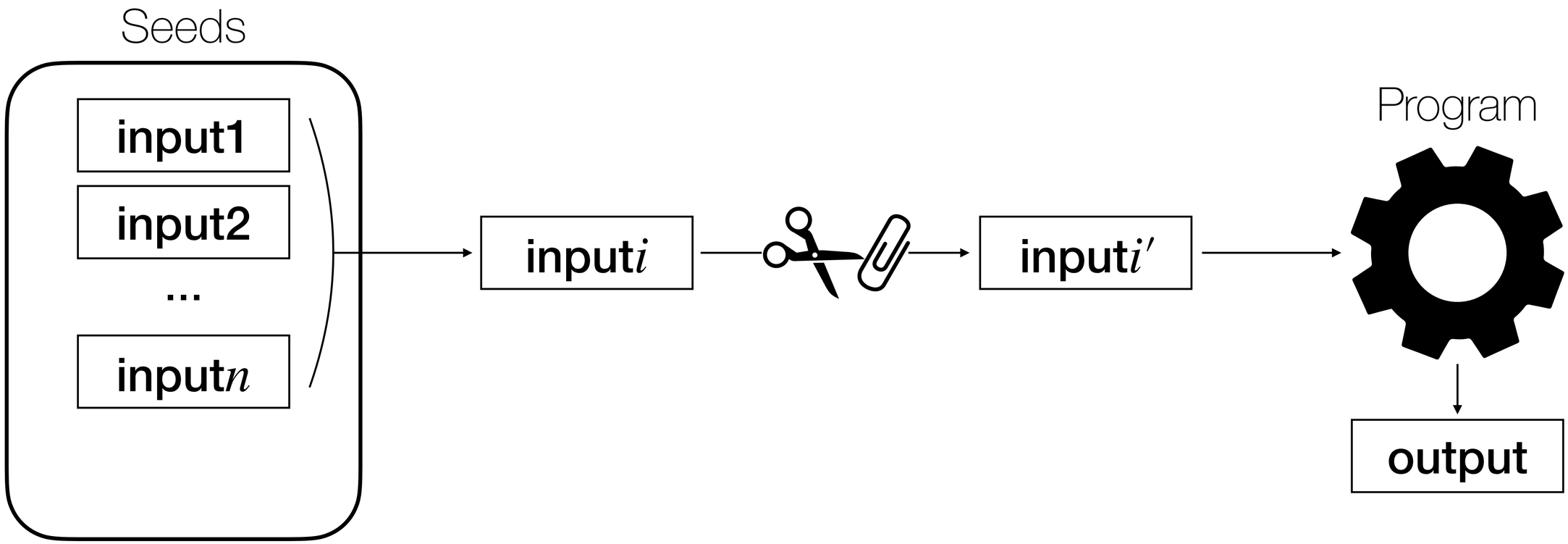

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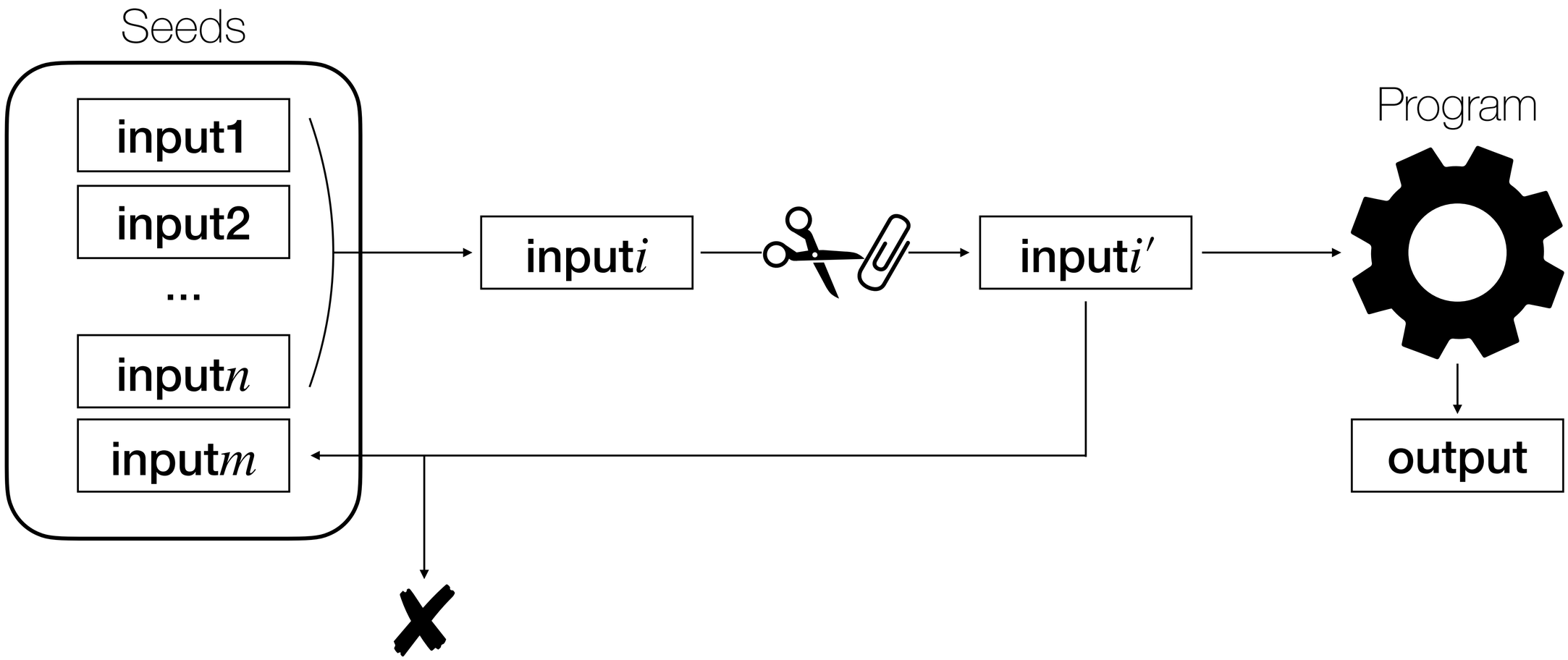

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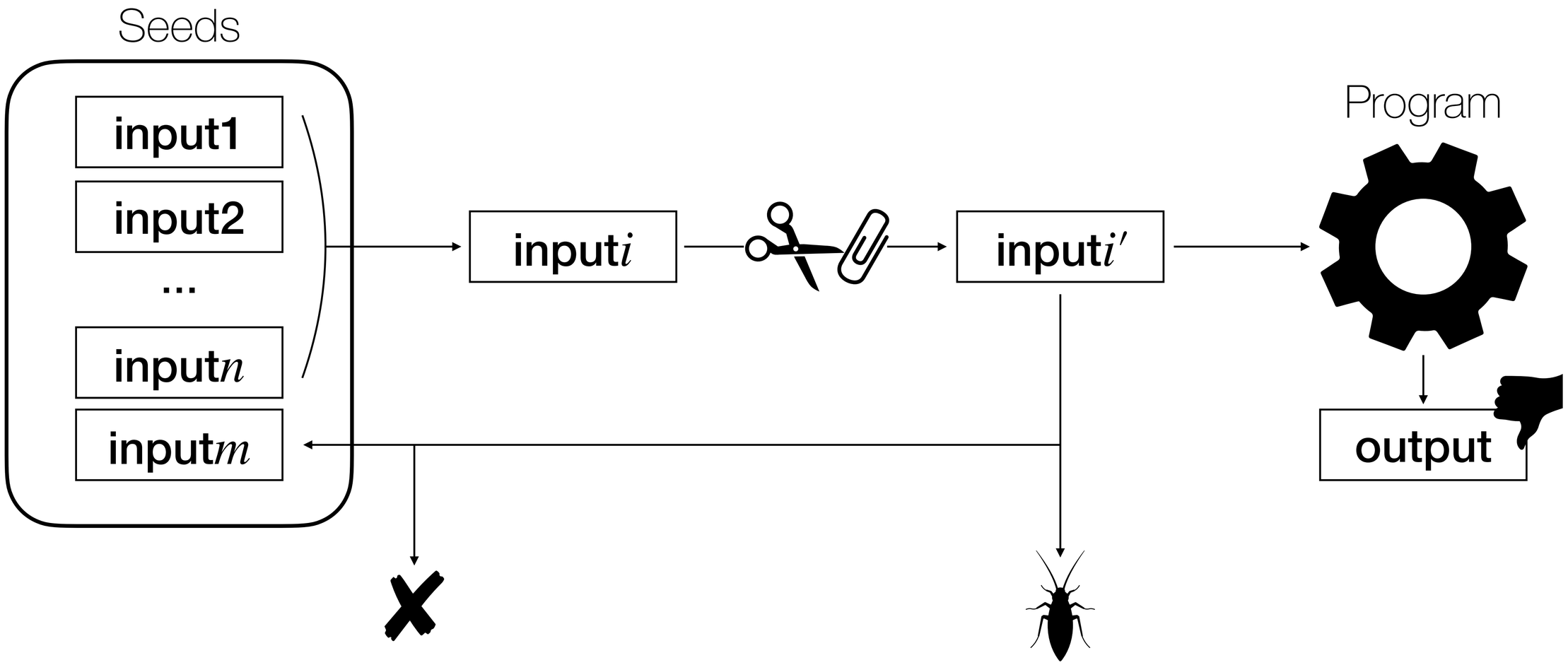
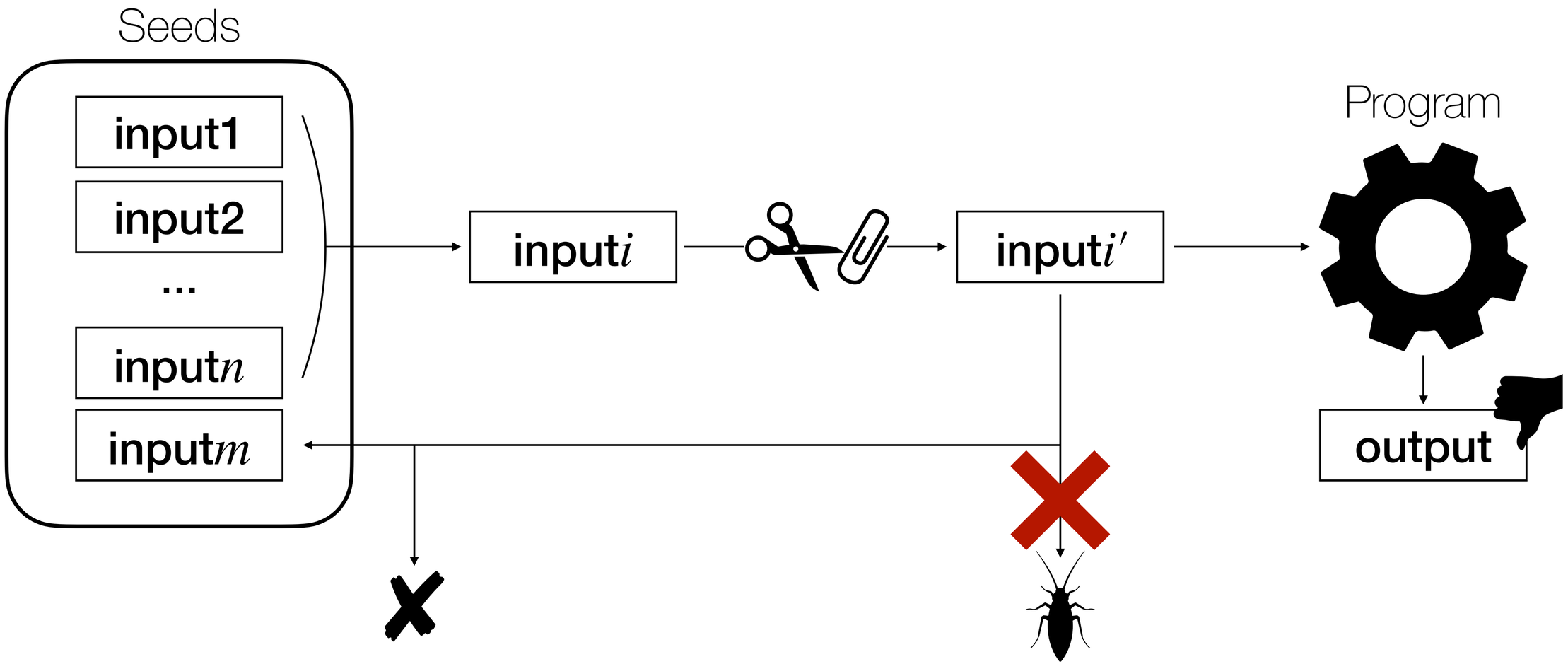
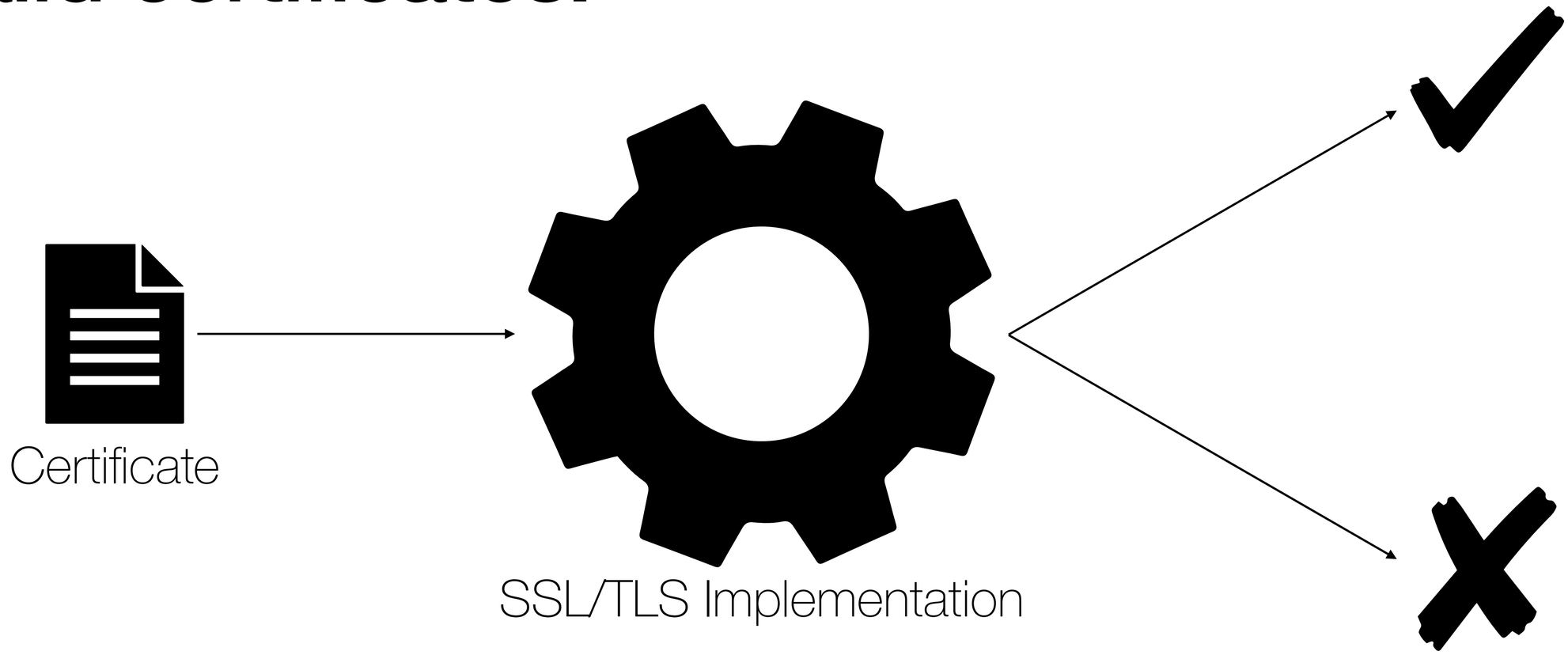


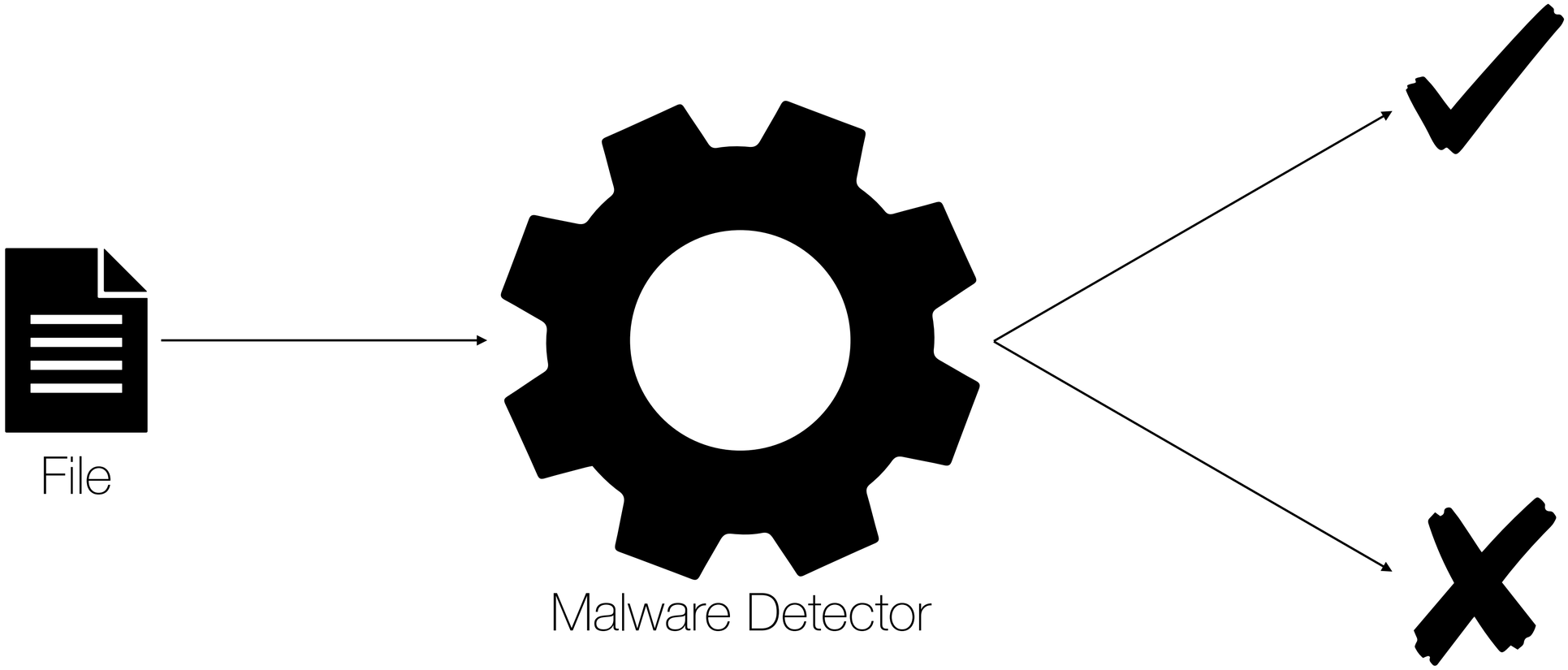
Most semantic bugs are silent.



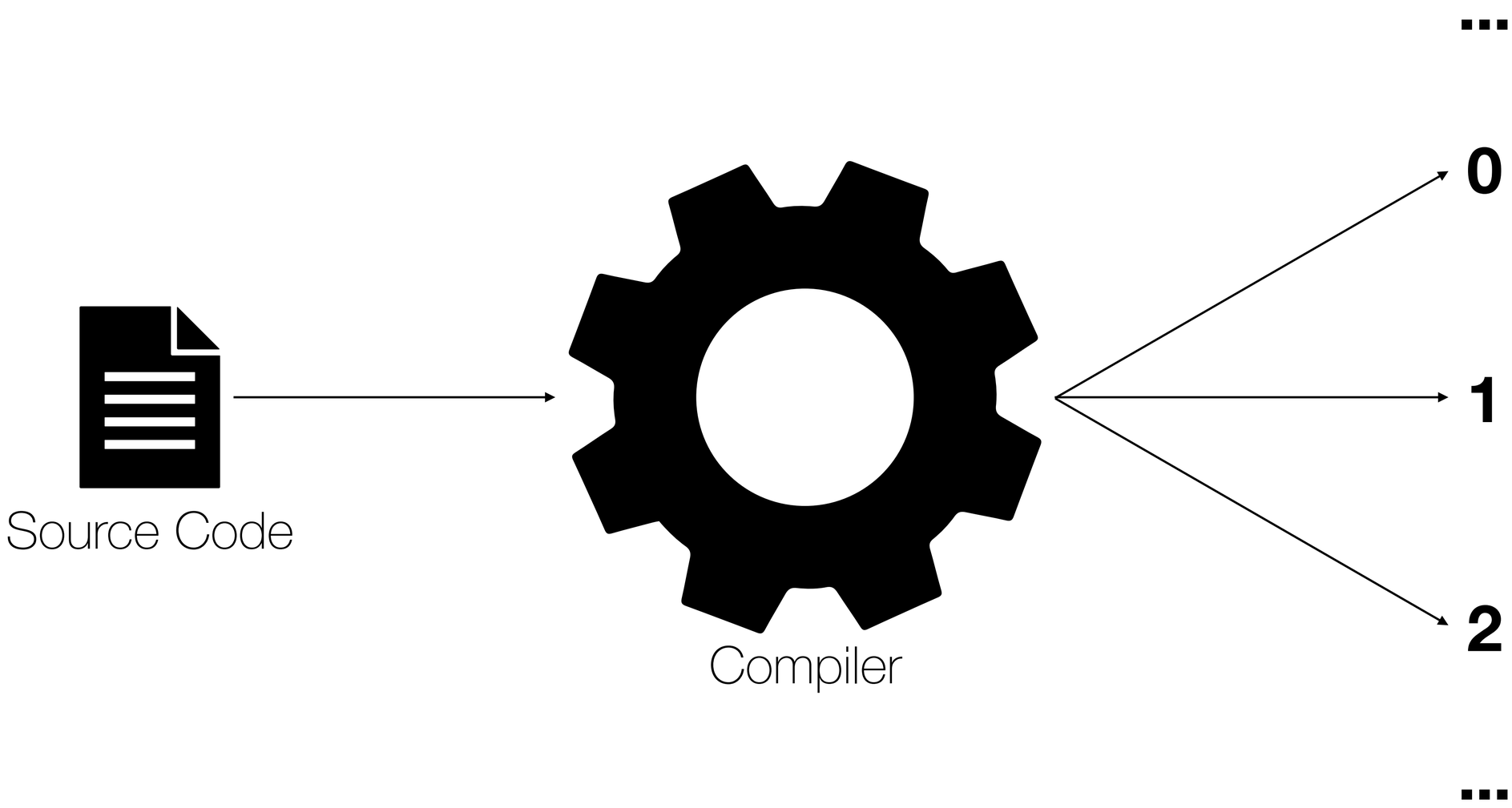
SSL/TLS implementations may accepts invalid certificates.



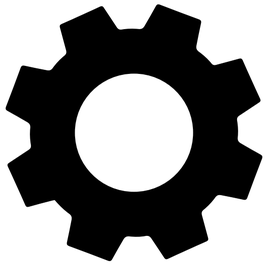
Malware detectors may miss malicious files.



Compilers may produce wrong binaries.

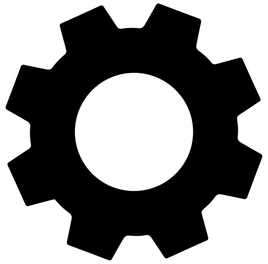


Various SSL/TLS implementations exist.



LibreSSL

Certificate



BoringSSL

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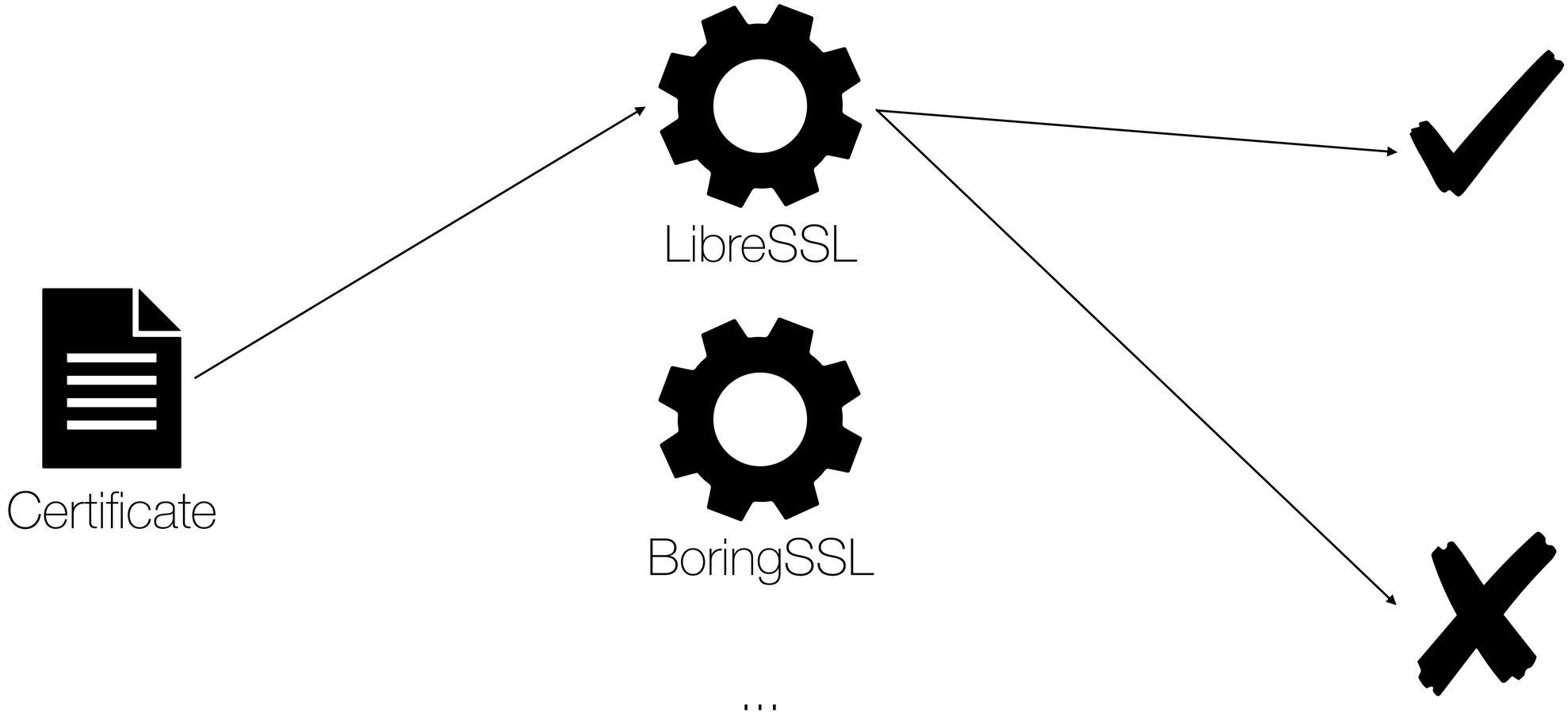

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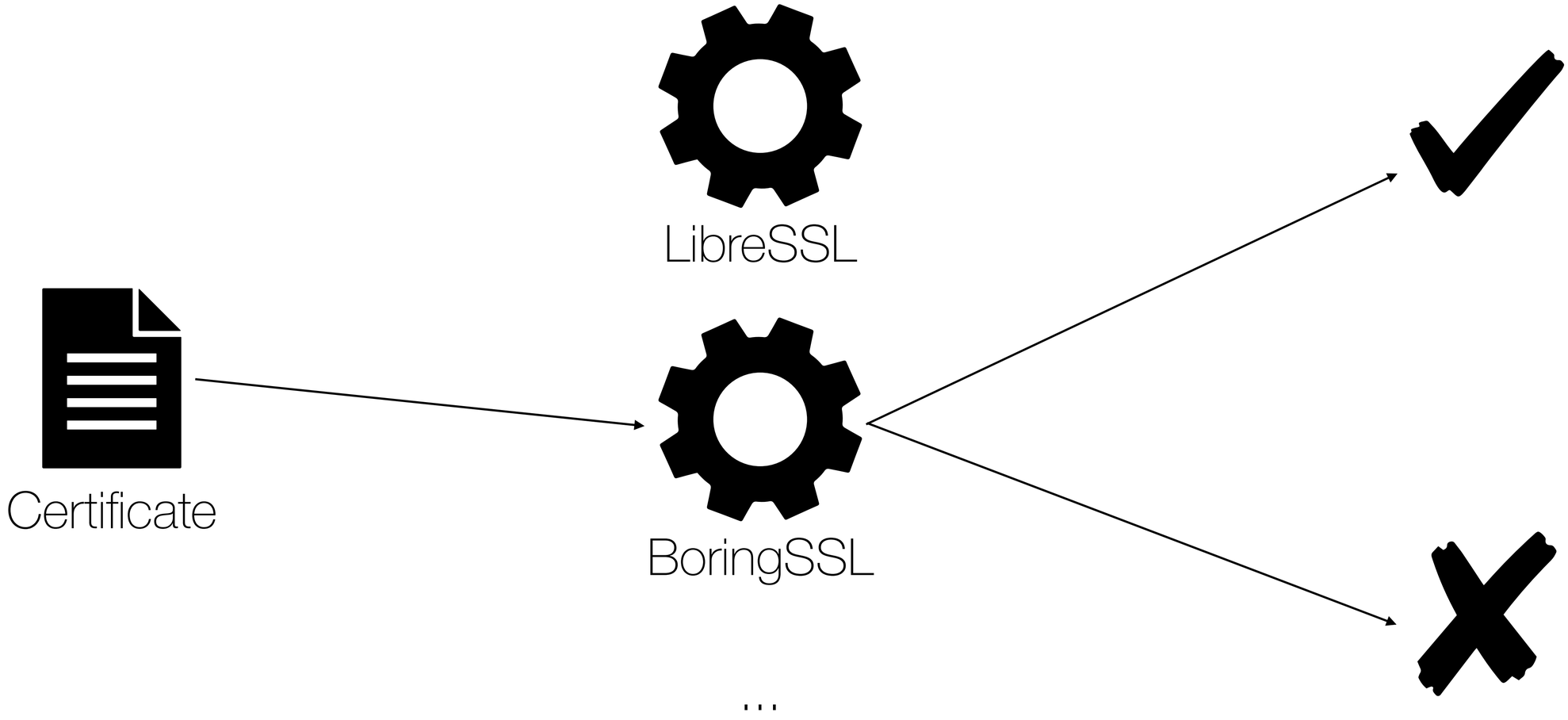

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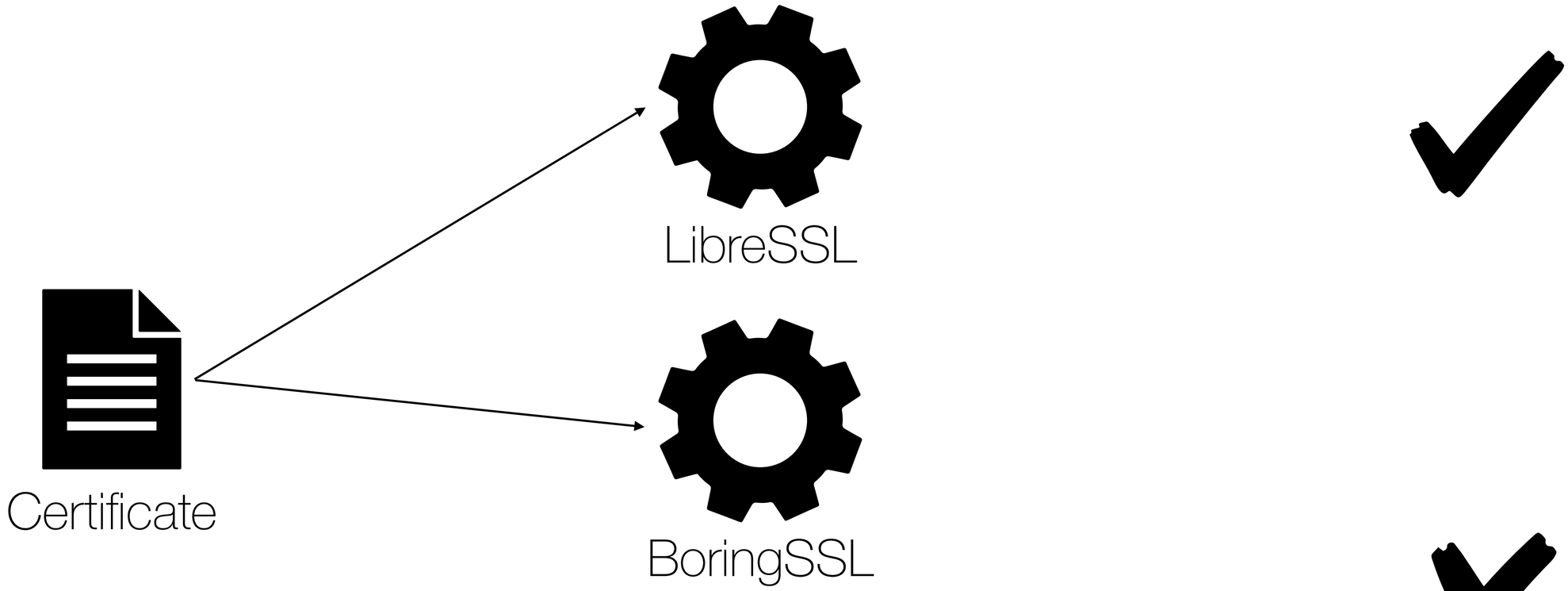

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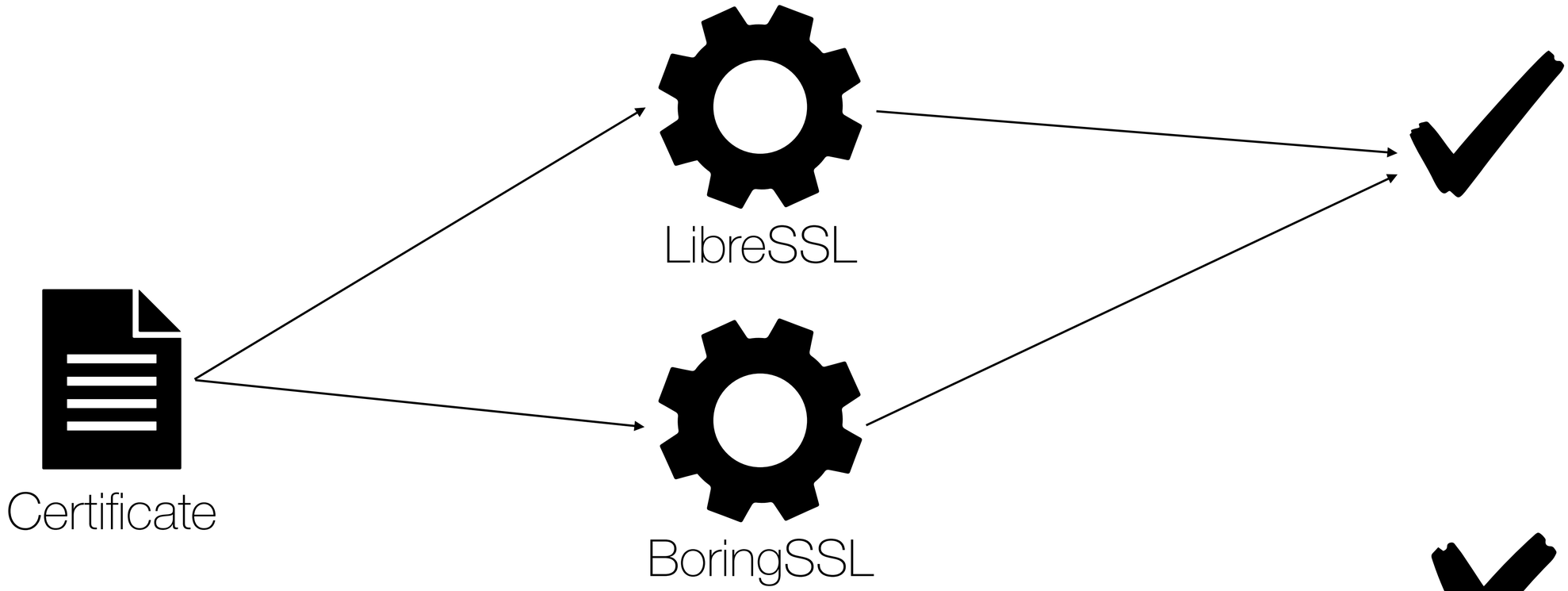

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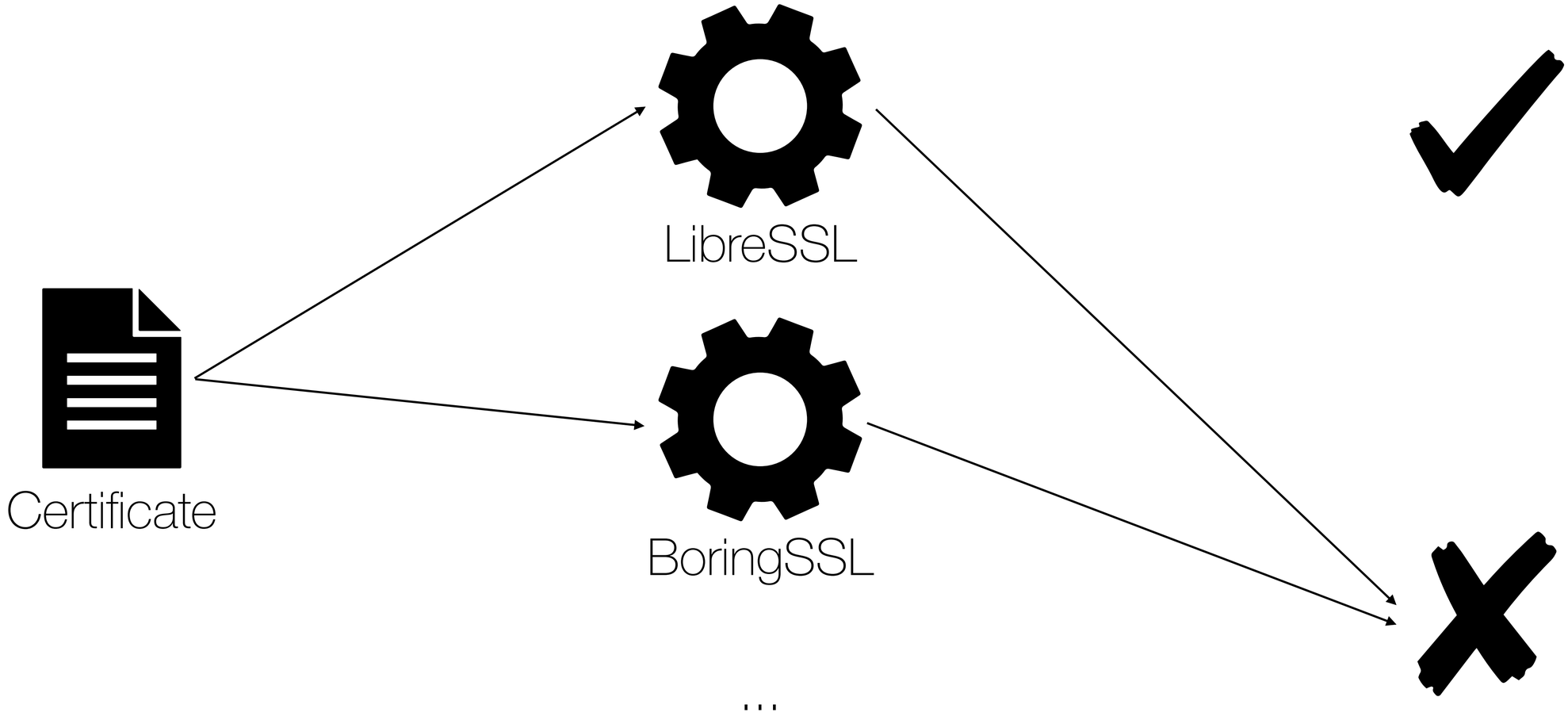

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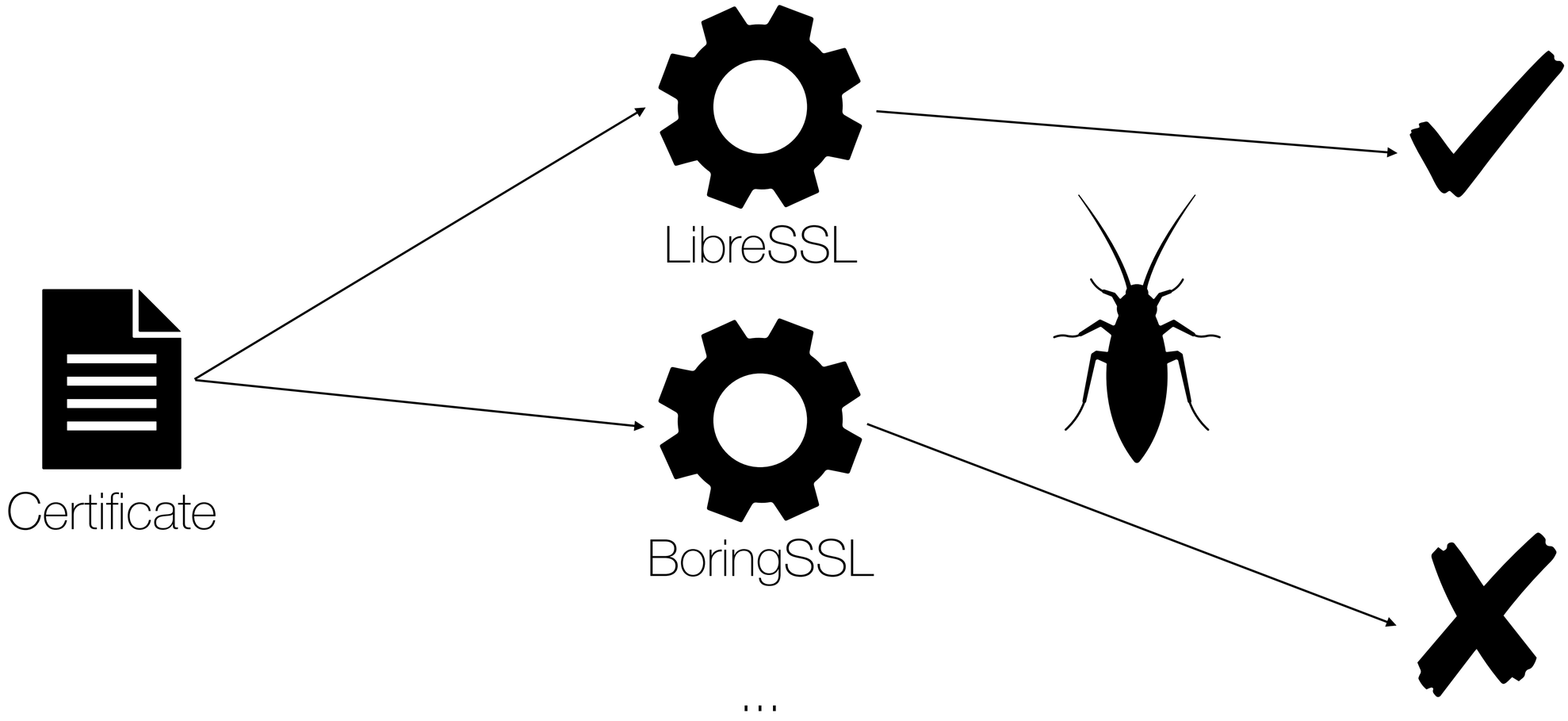
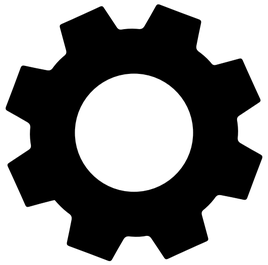
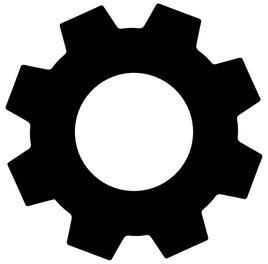


Various C compilers exist.

C Source Code



GCC



Clang

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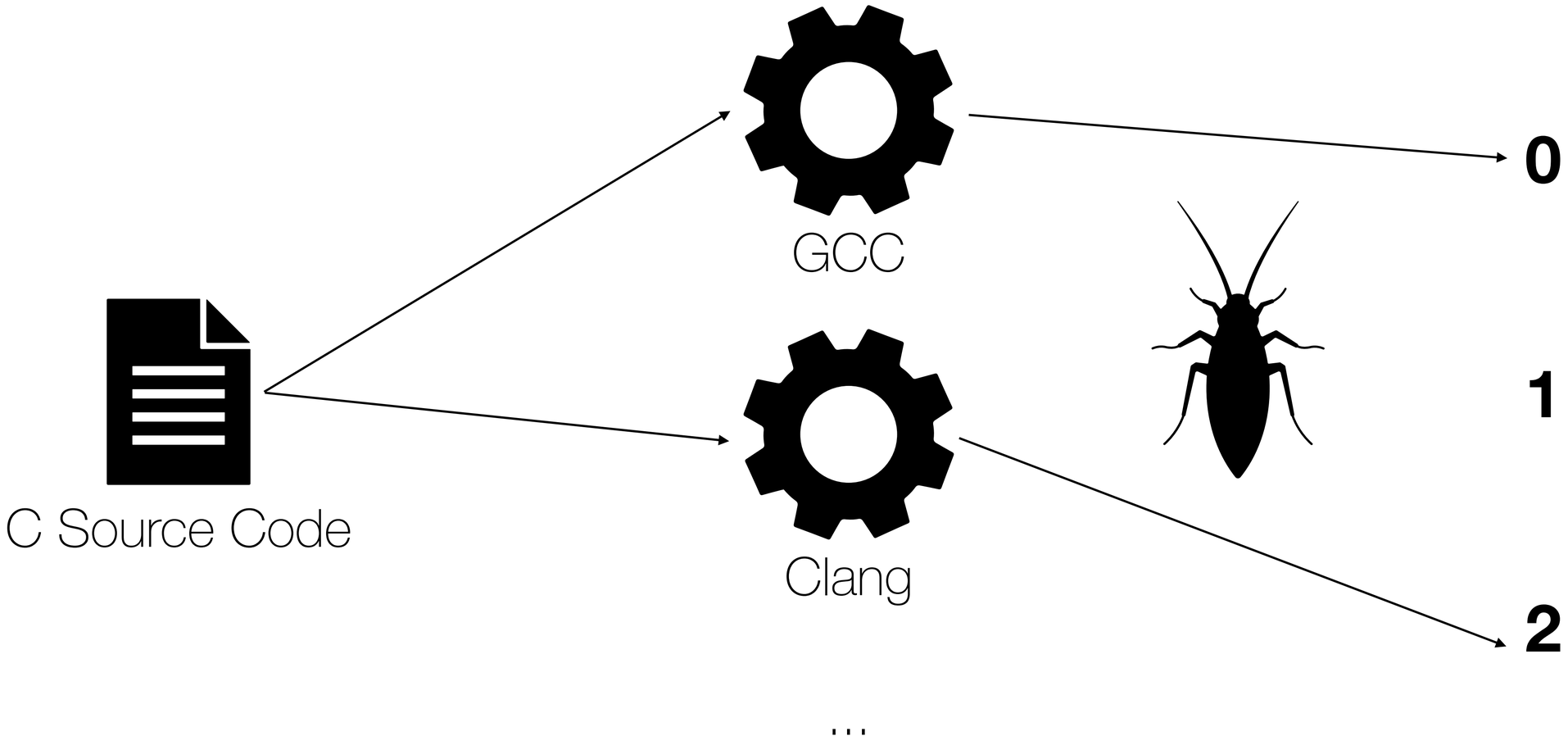
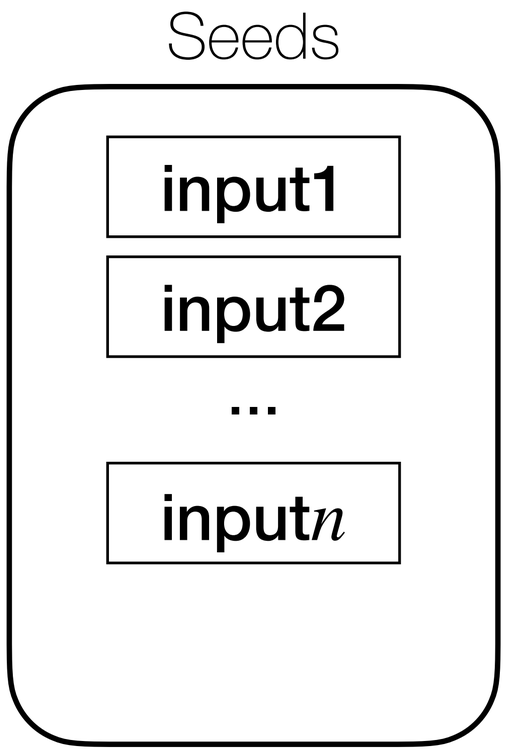
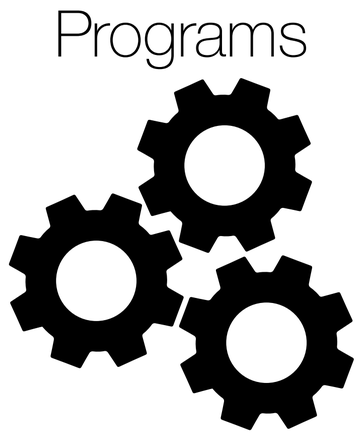


Differential testing runs multiple programs.





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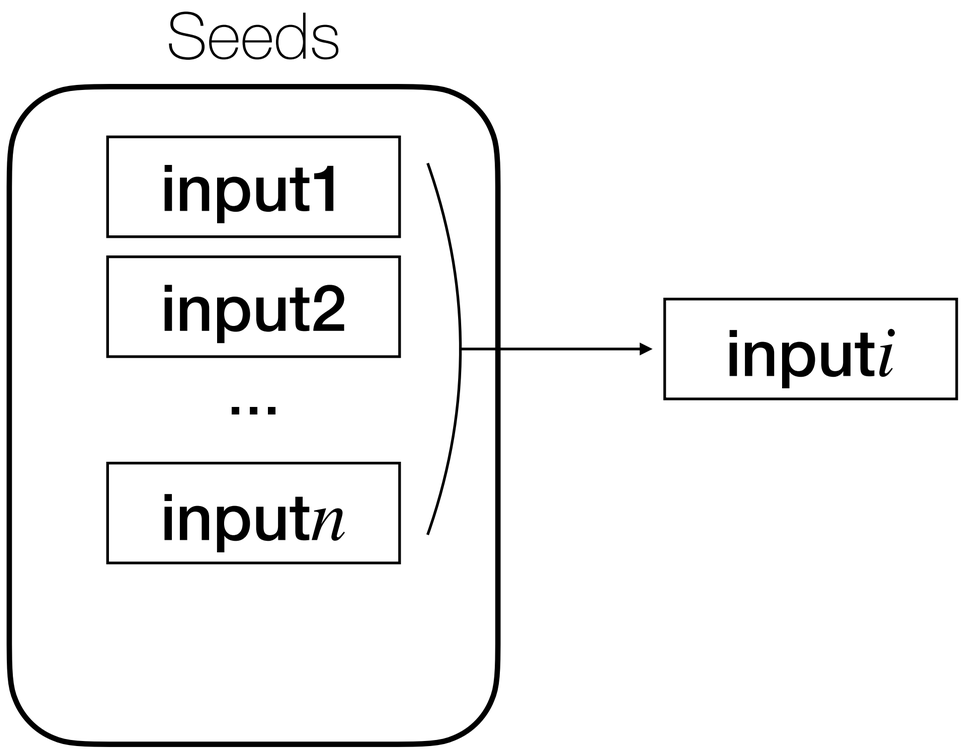

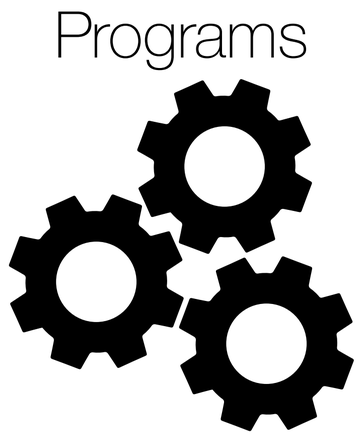

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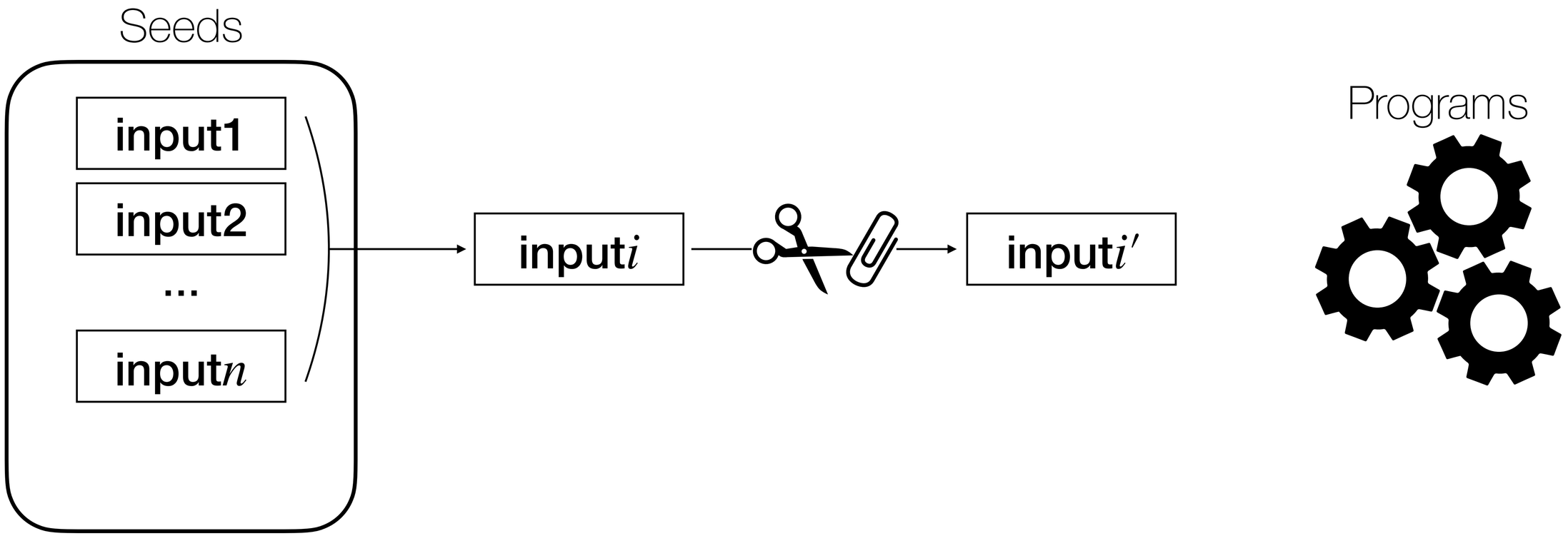

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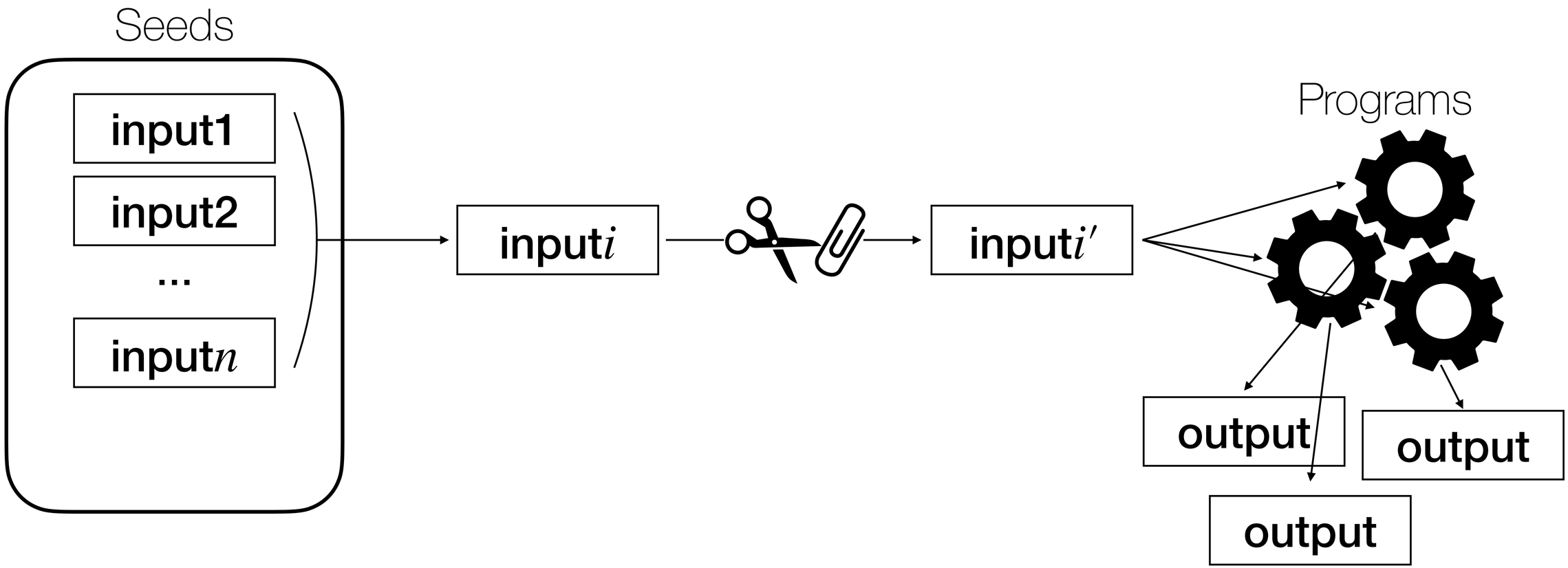

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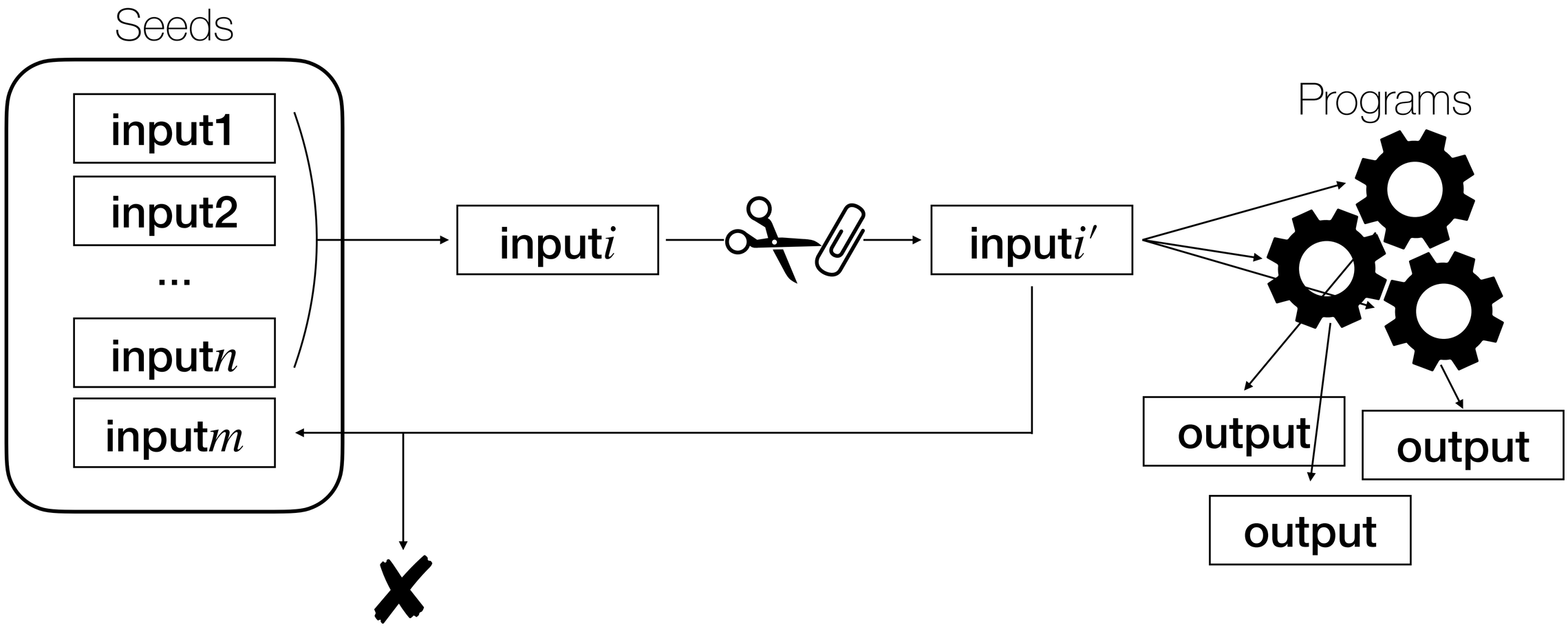

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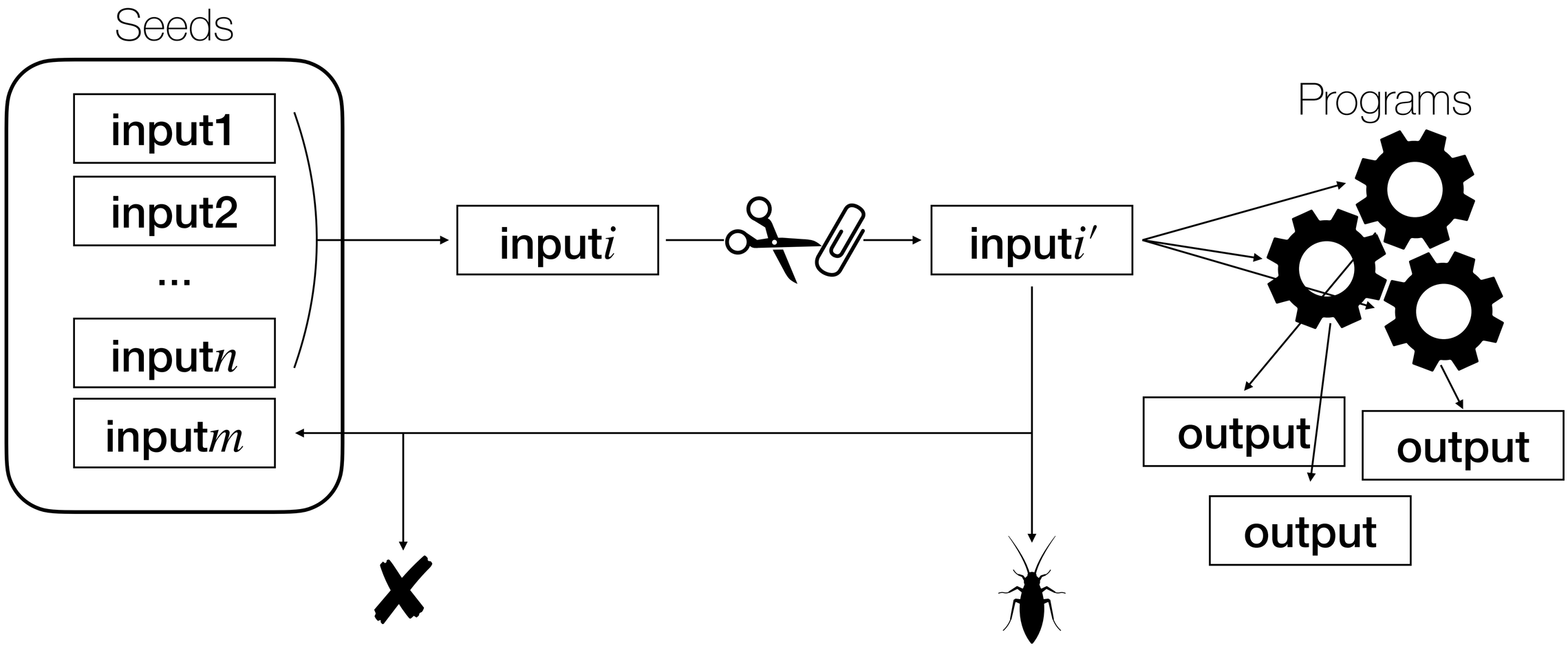
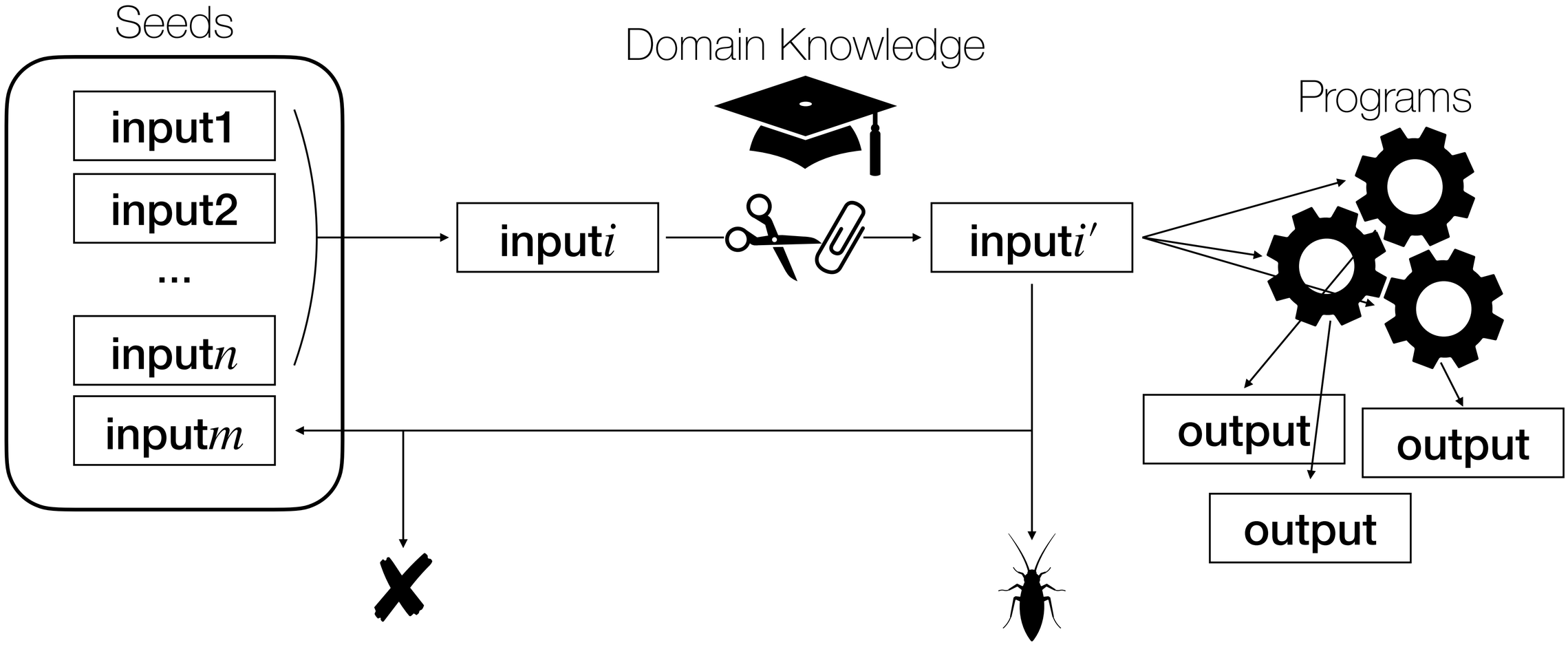


Existing differential testing frameworks are domain-specific.



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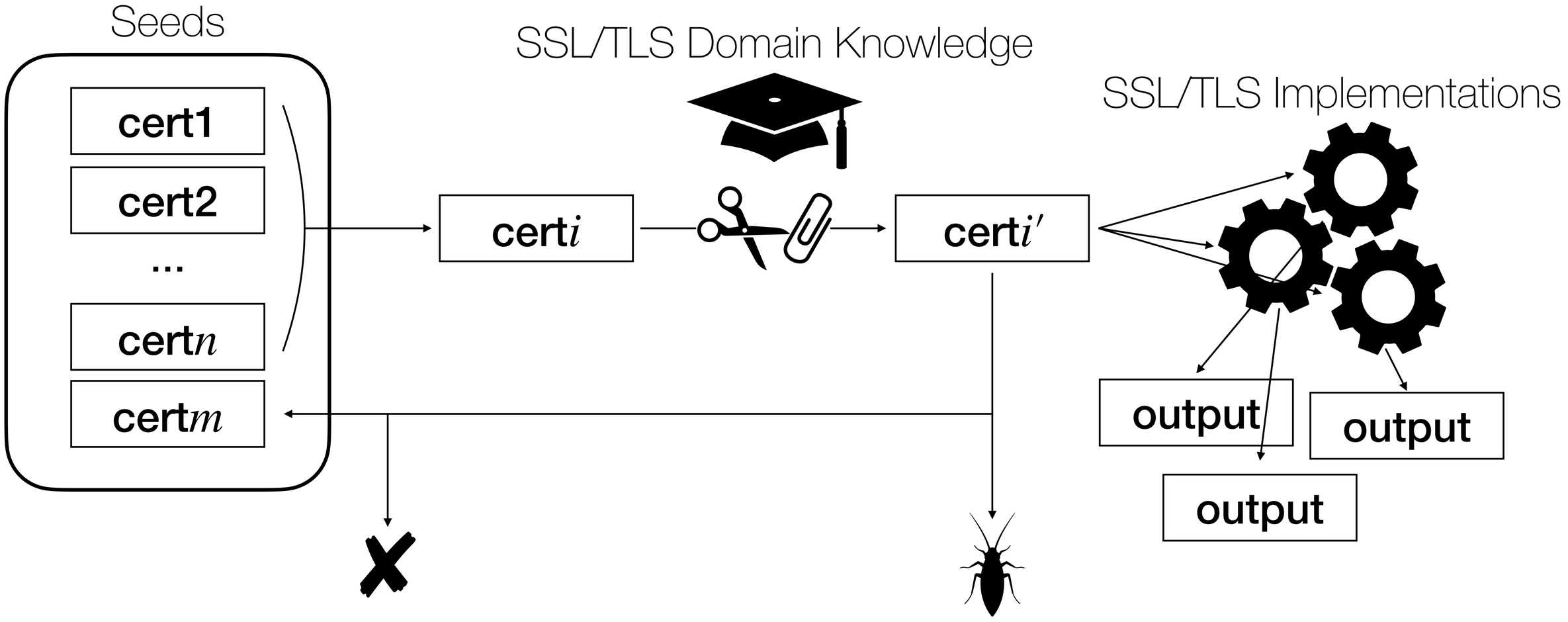

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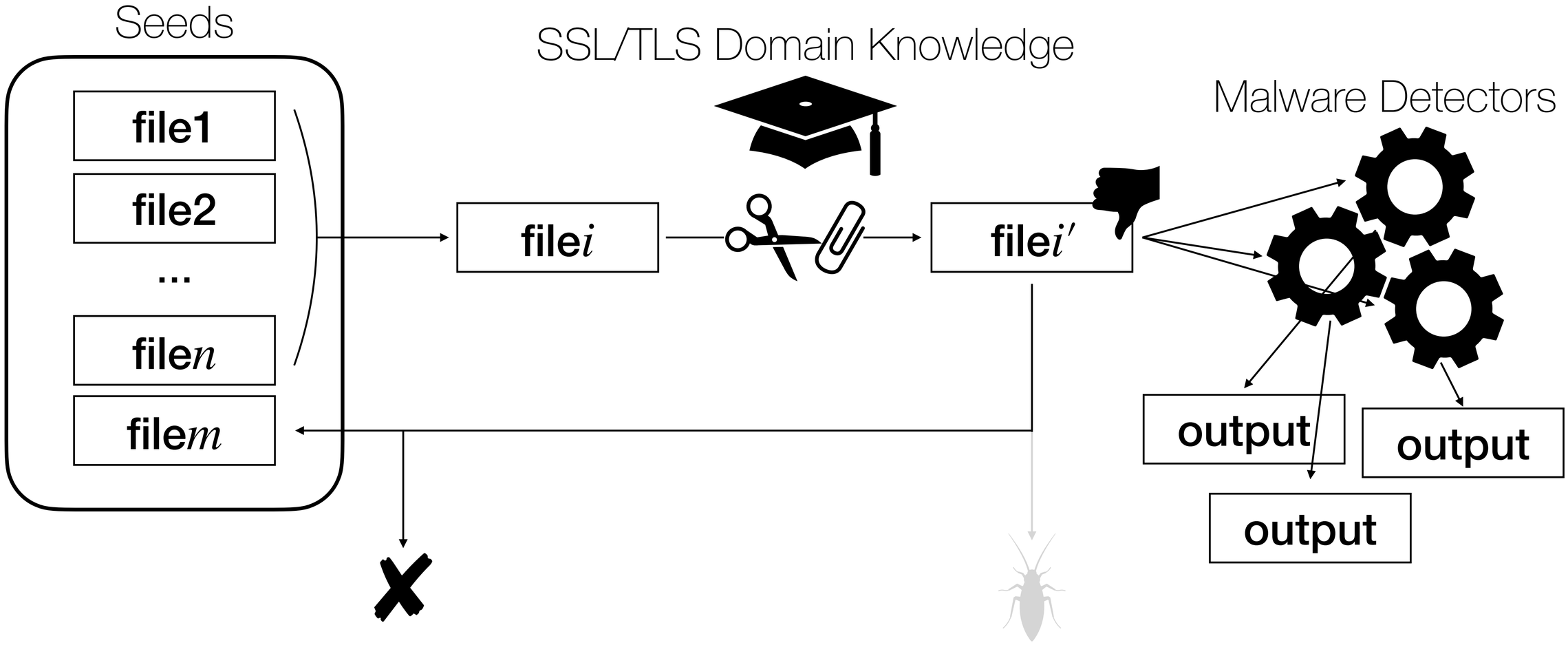
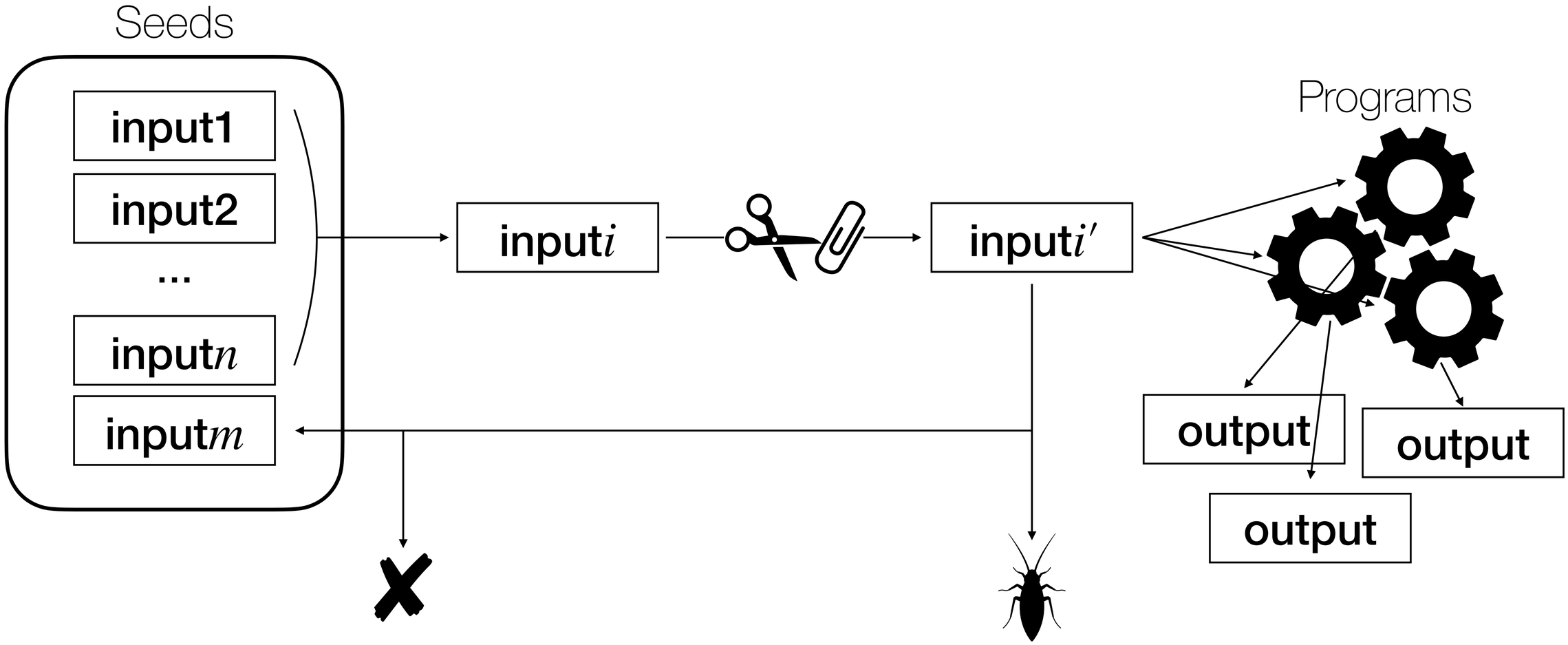
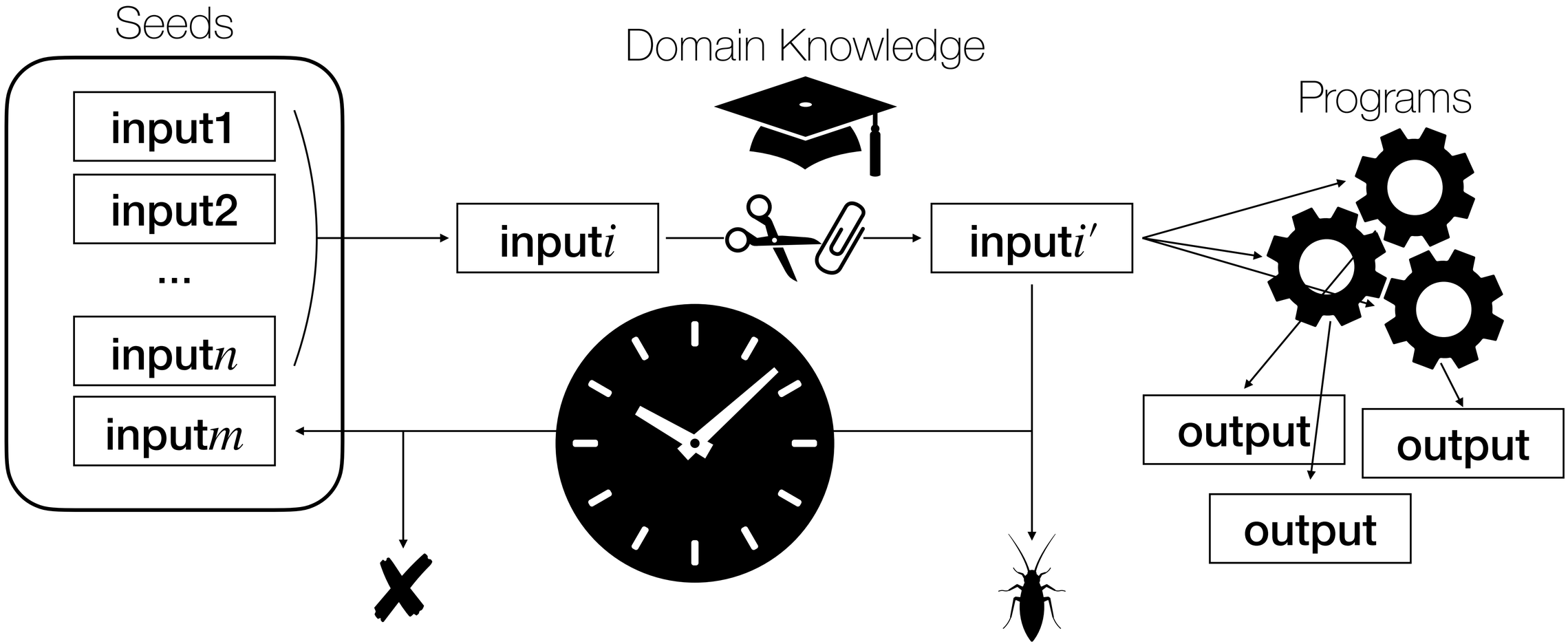


A domain-independent differential testing framework is required.



Existing domain-specific differential testing frameworks are inefficient.



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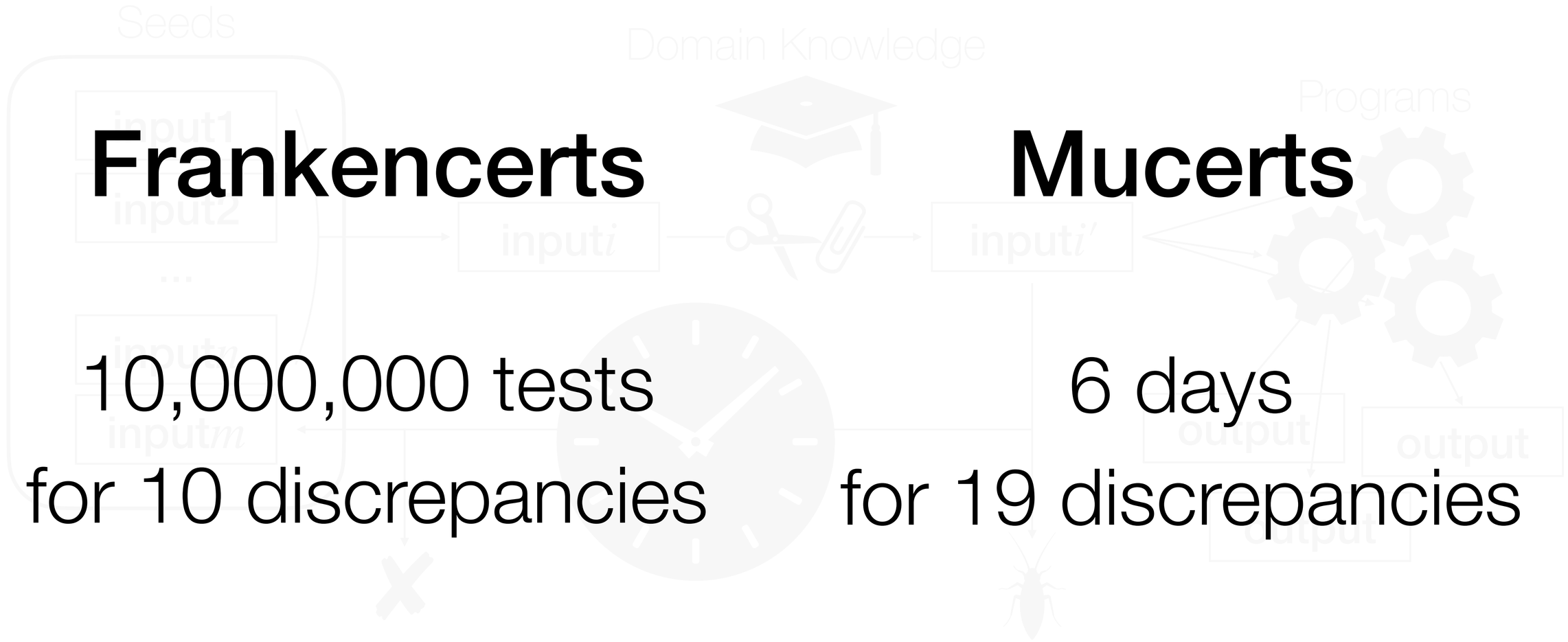


Frankencerts

10,000,000 tests
for 10 discrepancies

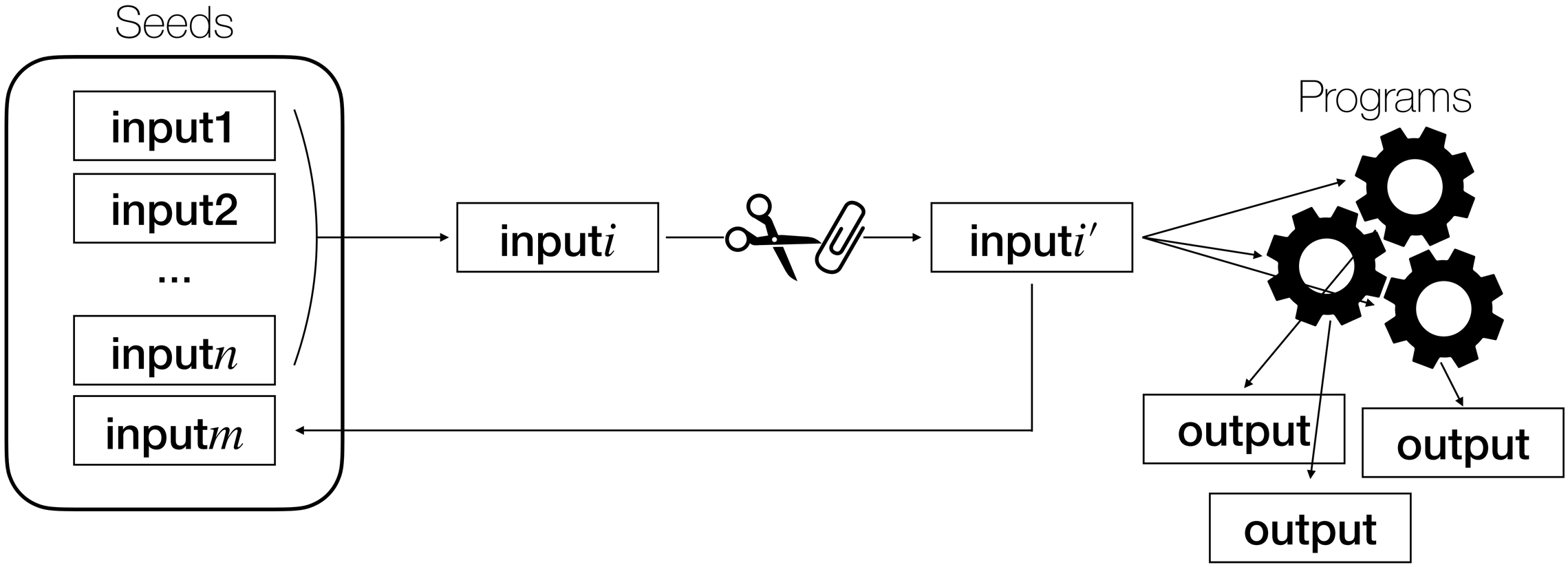
Mucerts

6 days
for 19 discrepancies

Nezha

is a domain-independent differential testing framework outperforming existing frameworks.

Existing differential testing frameworks ignore asymmetry across programs.



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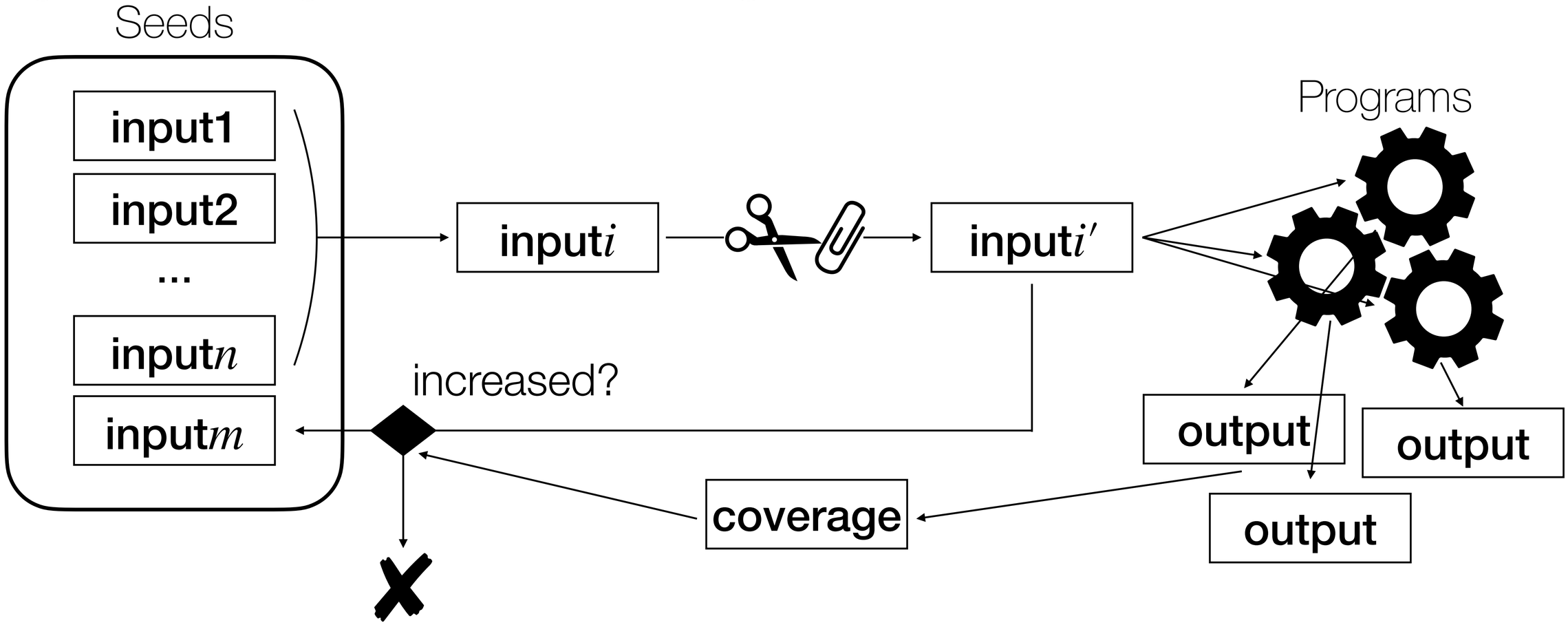

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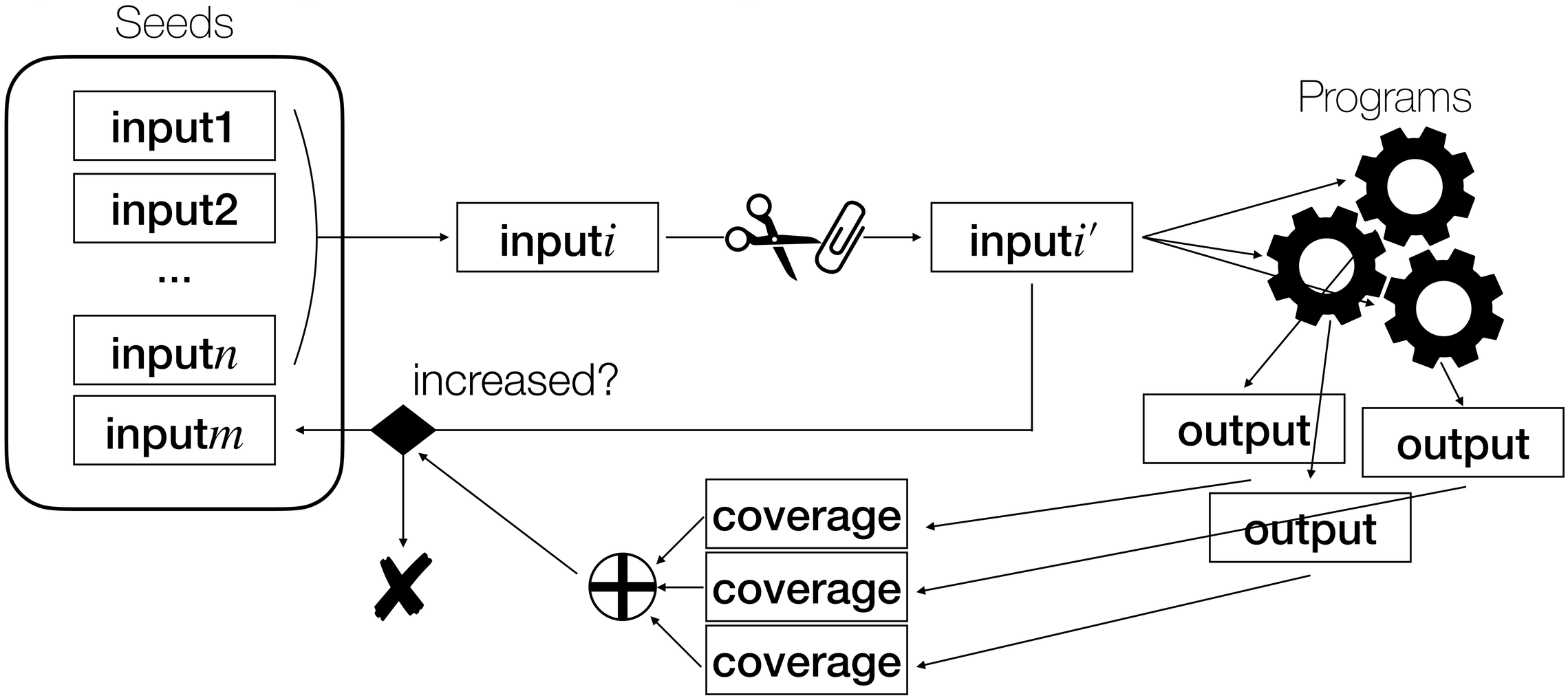
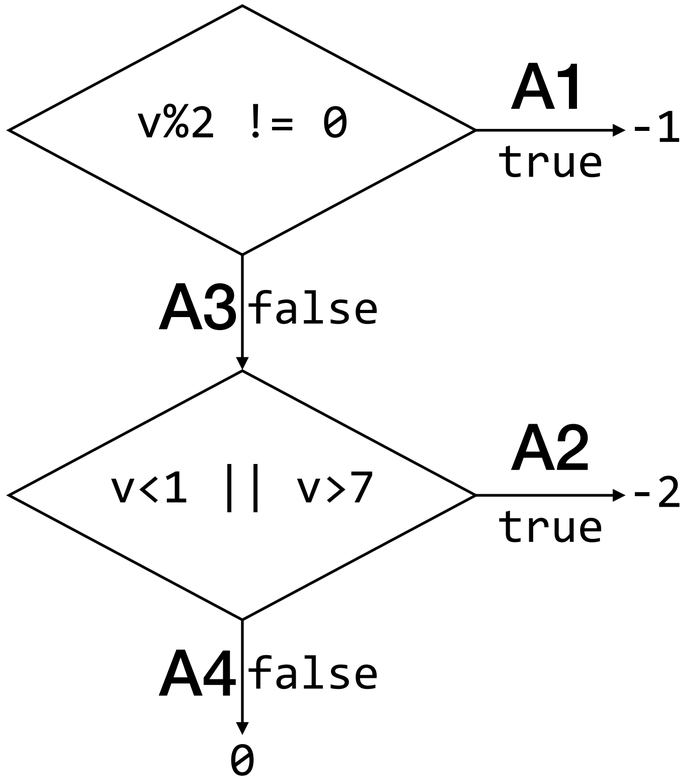
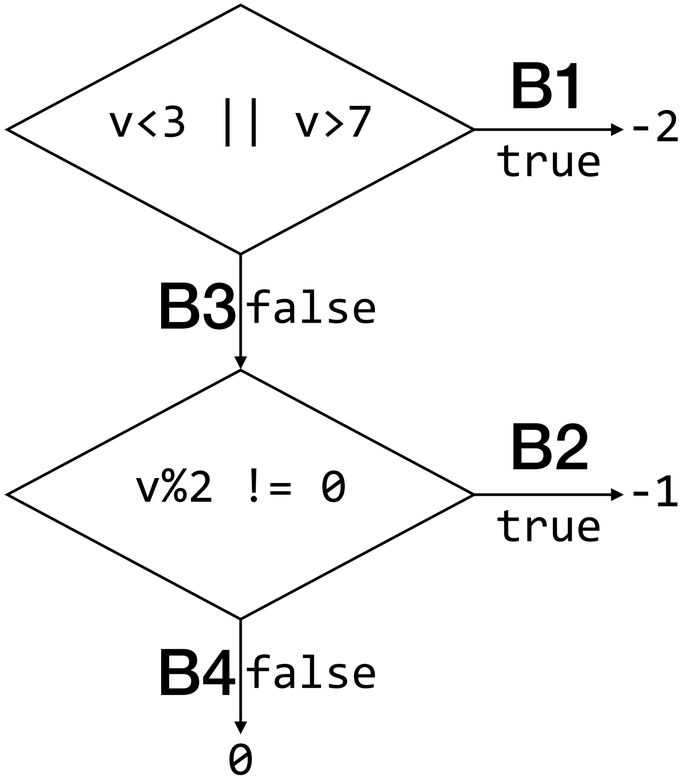
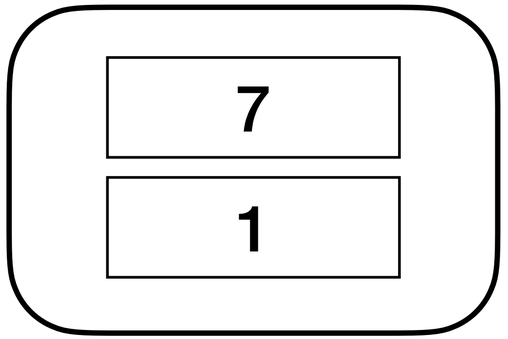
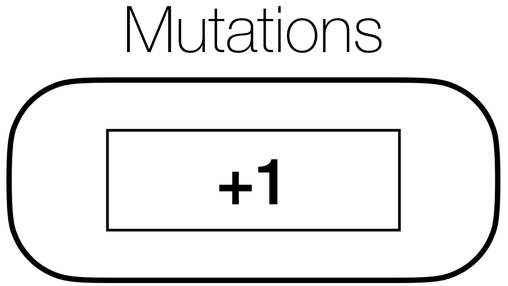


The strategy maximizing the global coverage often misses interesting inputs.









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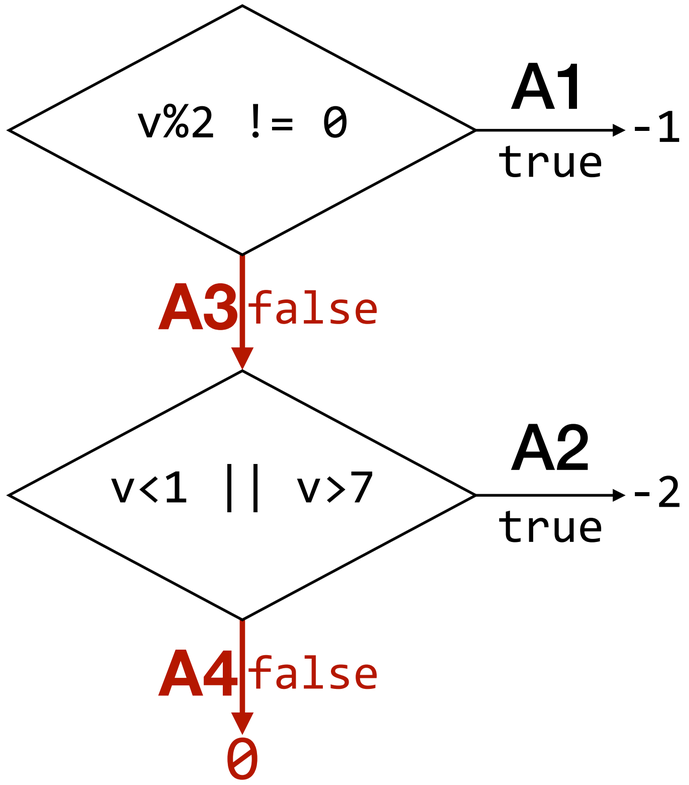
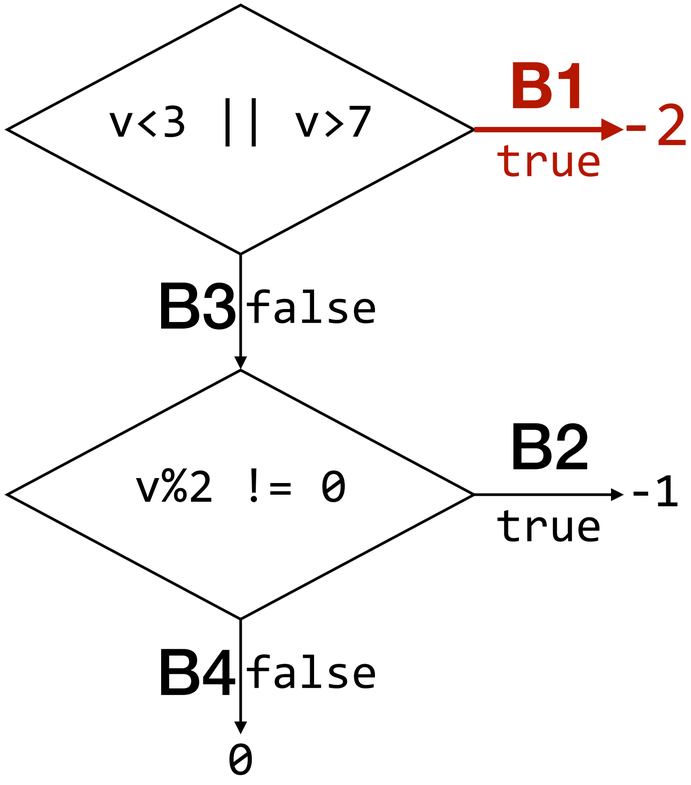
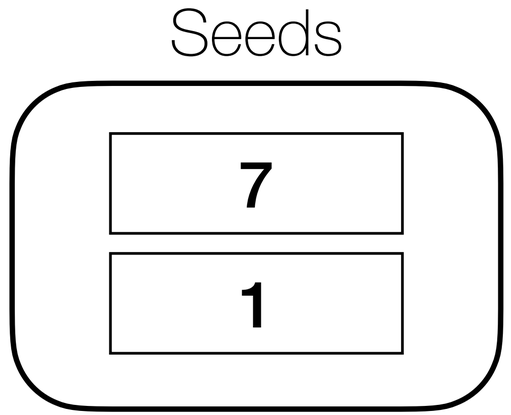
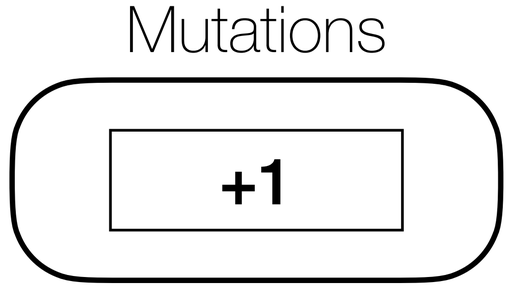


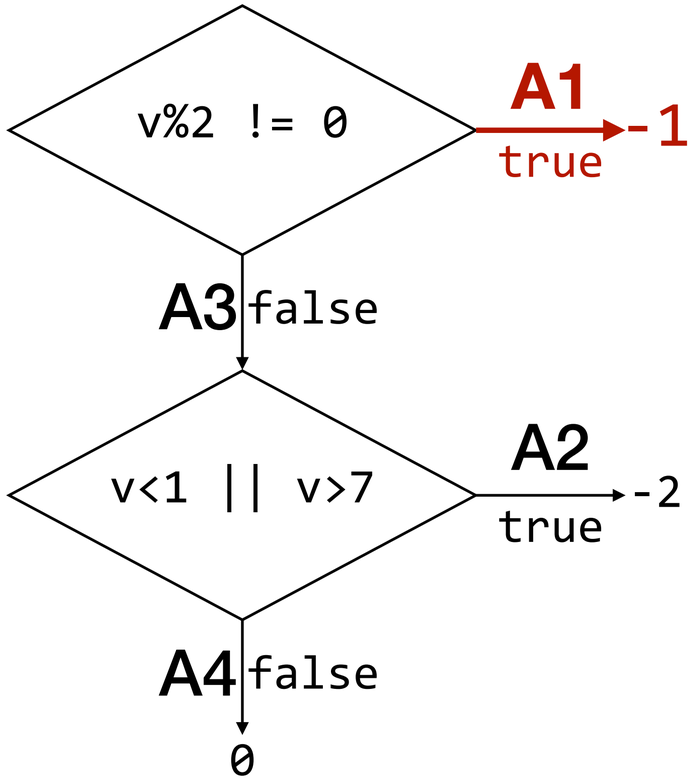


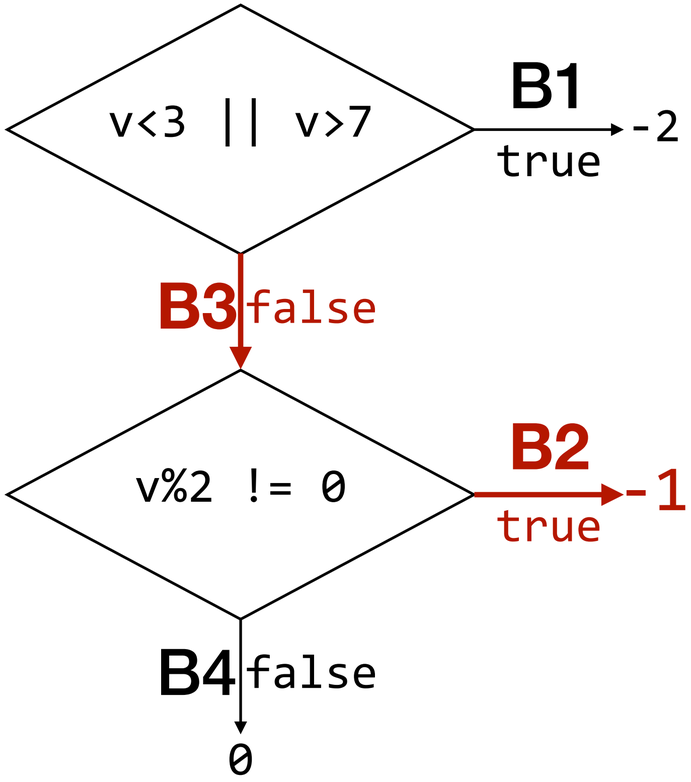


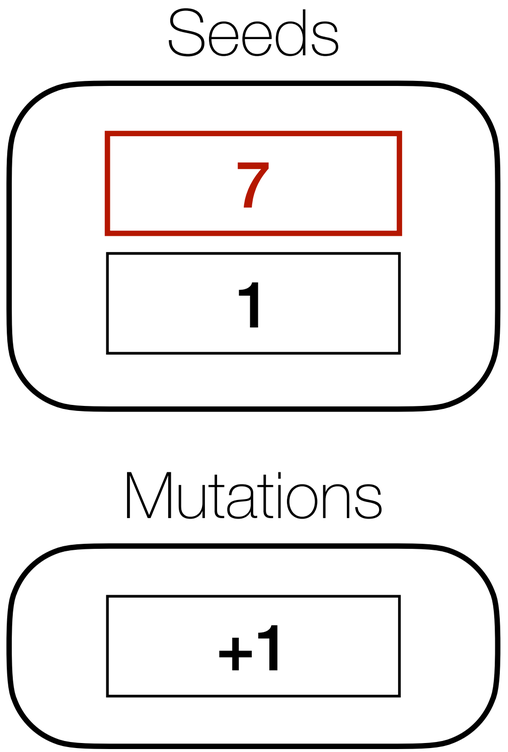


Differs on input 2

The strategy maximizing the global coverage often misses interesting inputs.

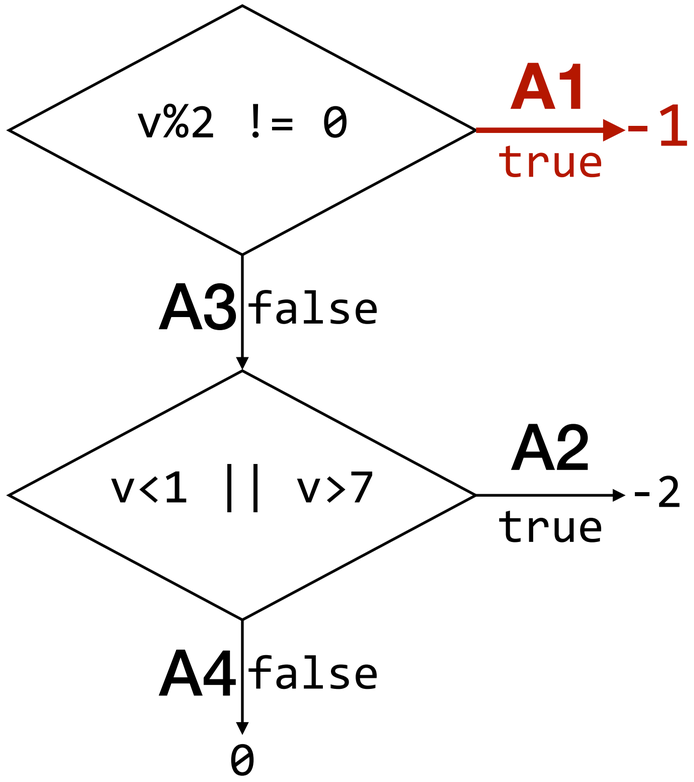


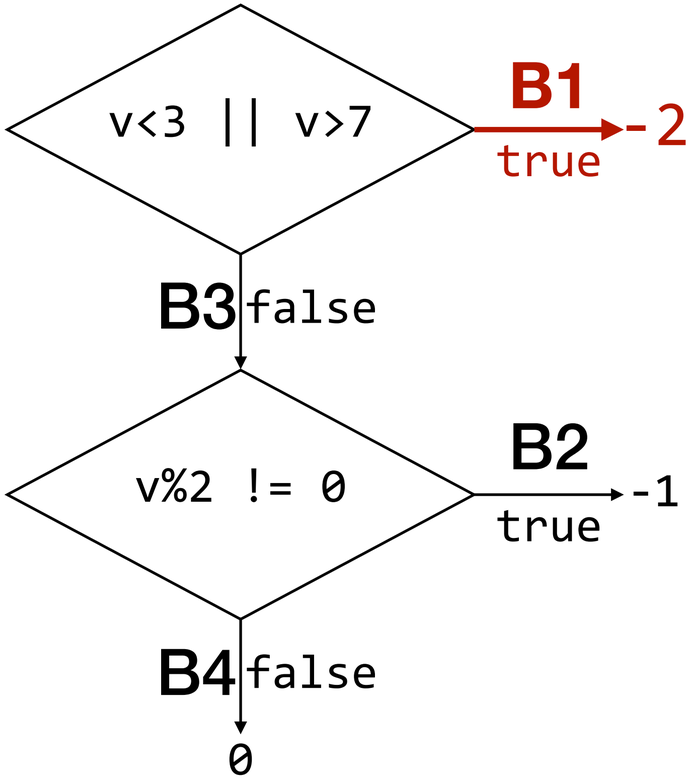


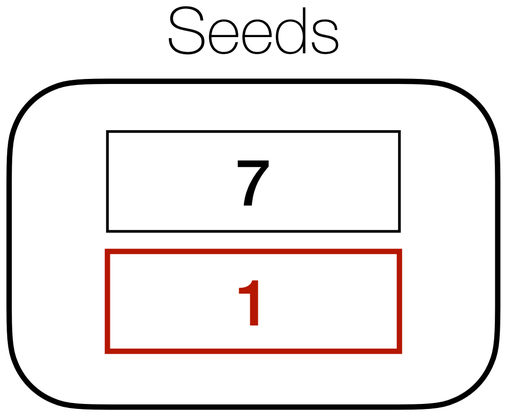


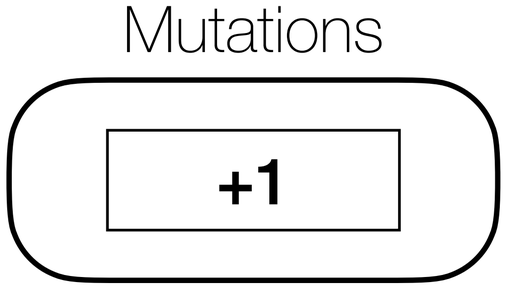
coverage = 3

The strategy maximizing the global coverage often misses interesting inputs.



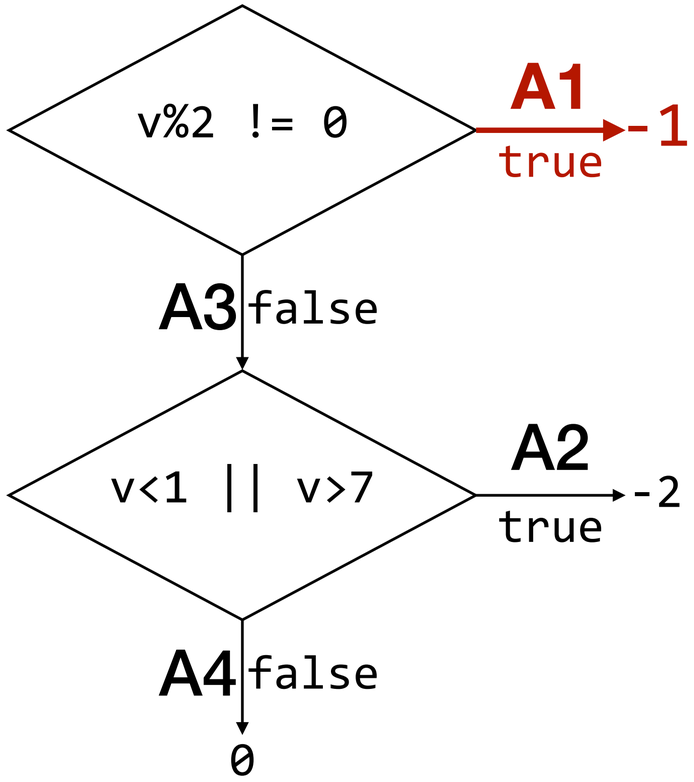


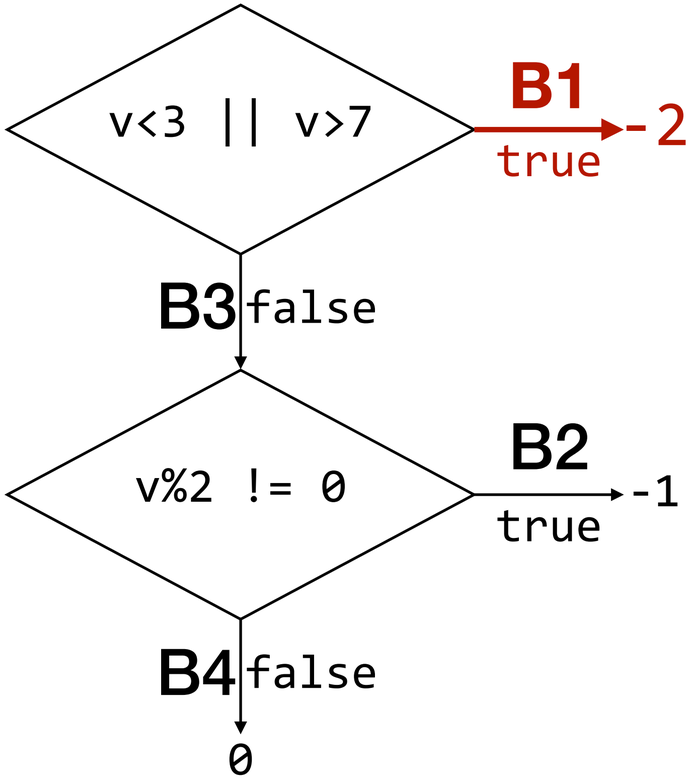


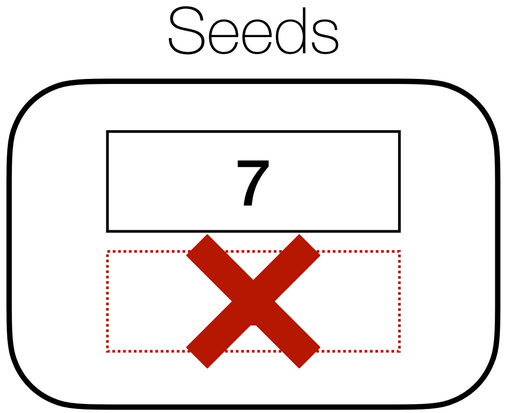


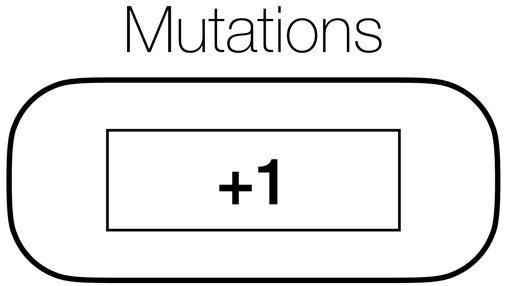
coverage = 2

The strategy maximizing the global coverage often misses interesting inputs.



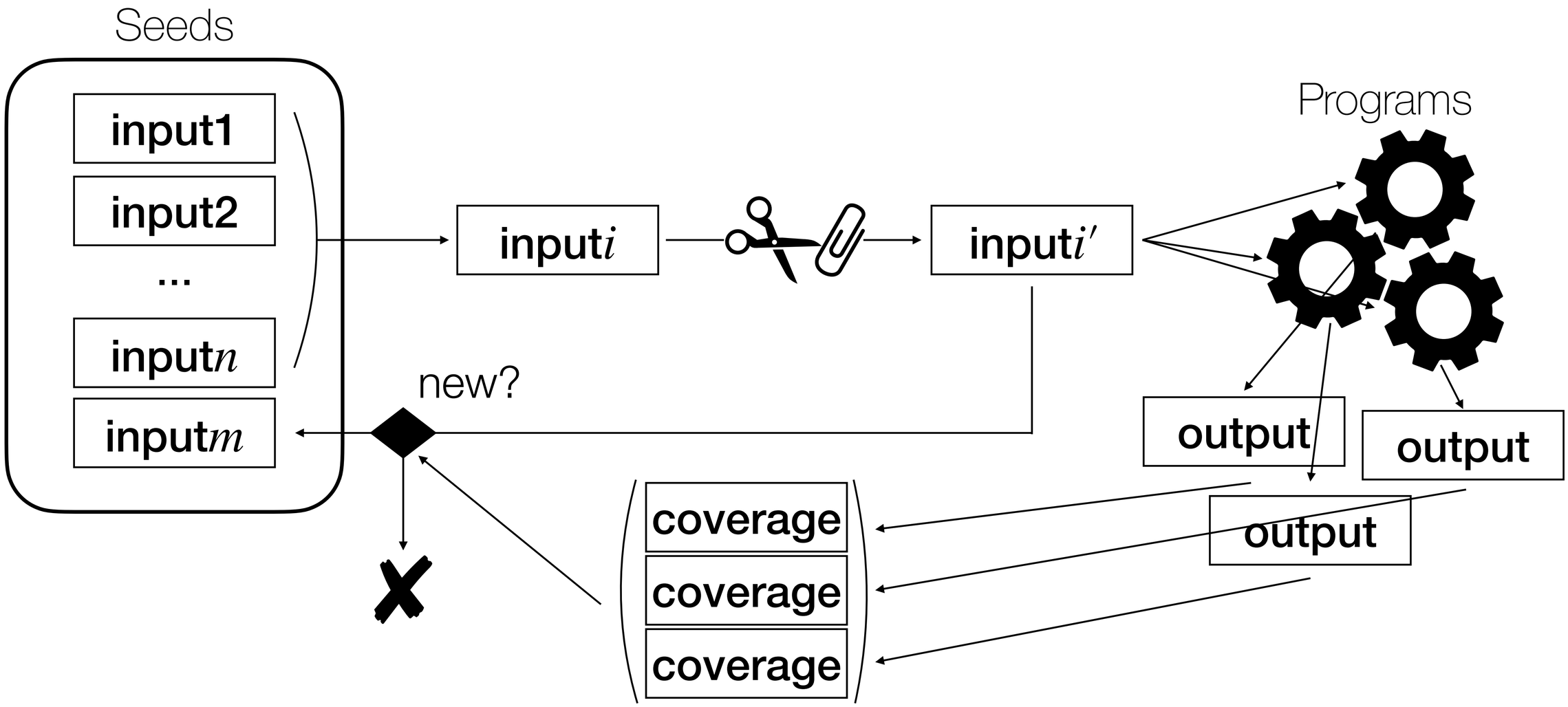






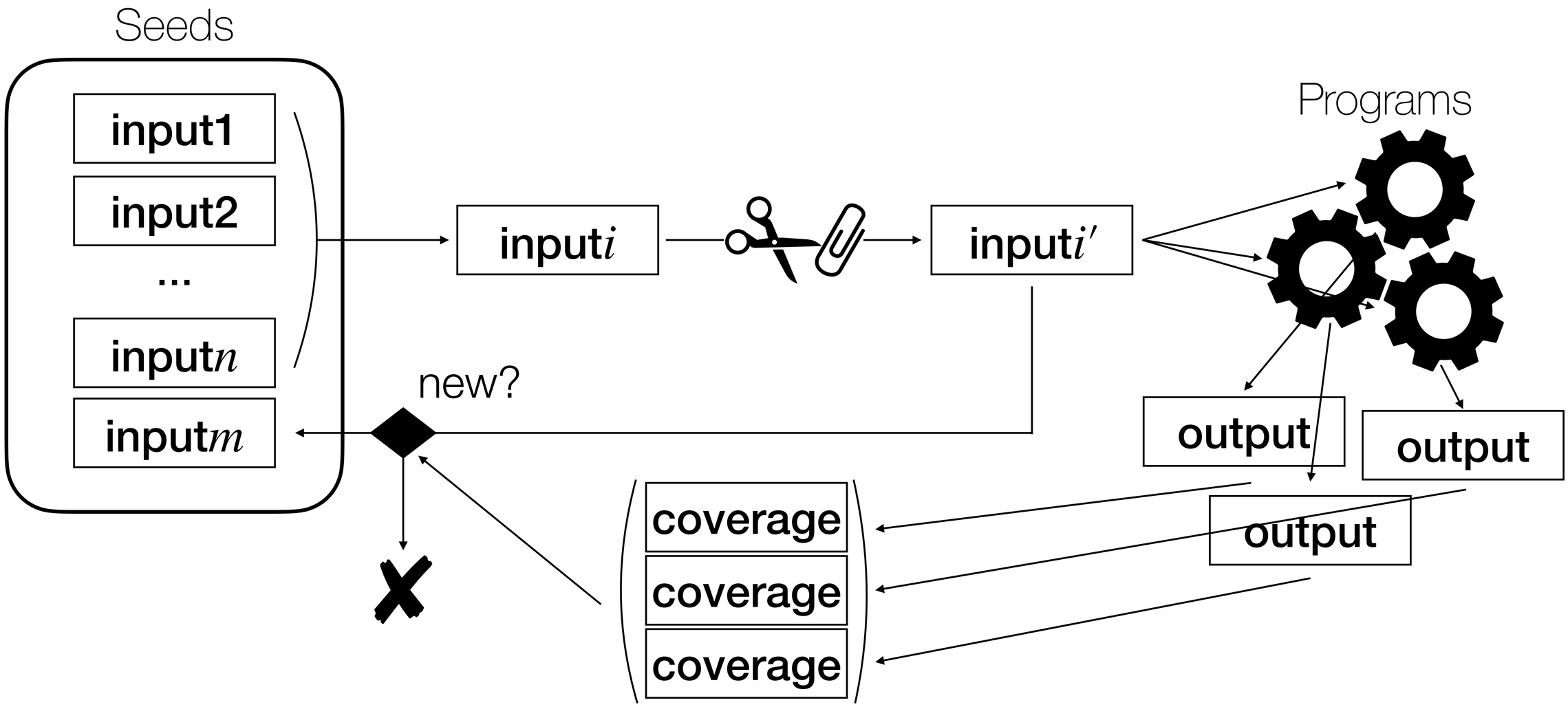
coverage = 2 < 3

NEZHA introduces δ-diversity.

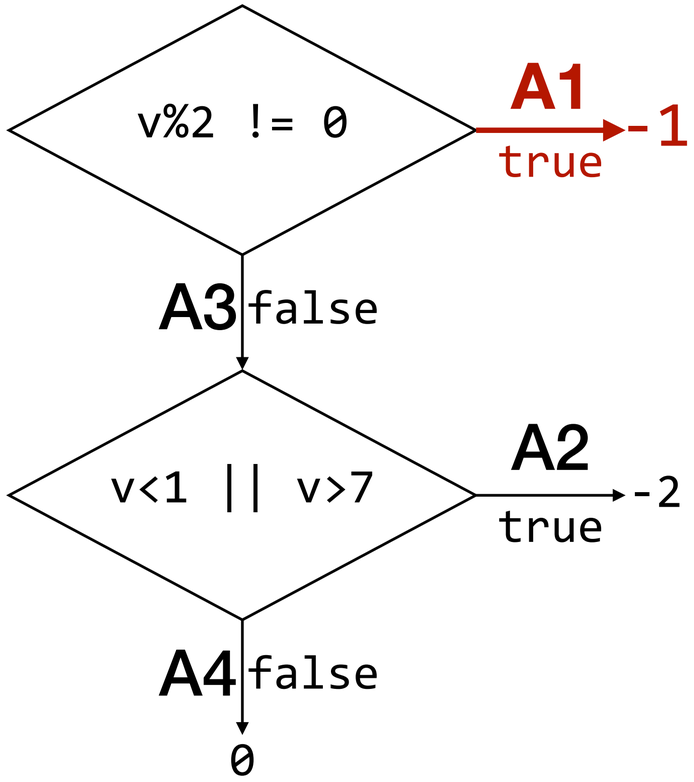


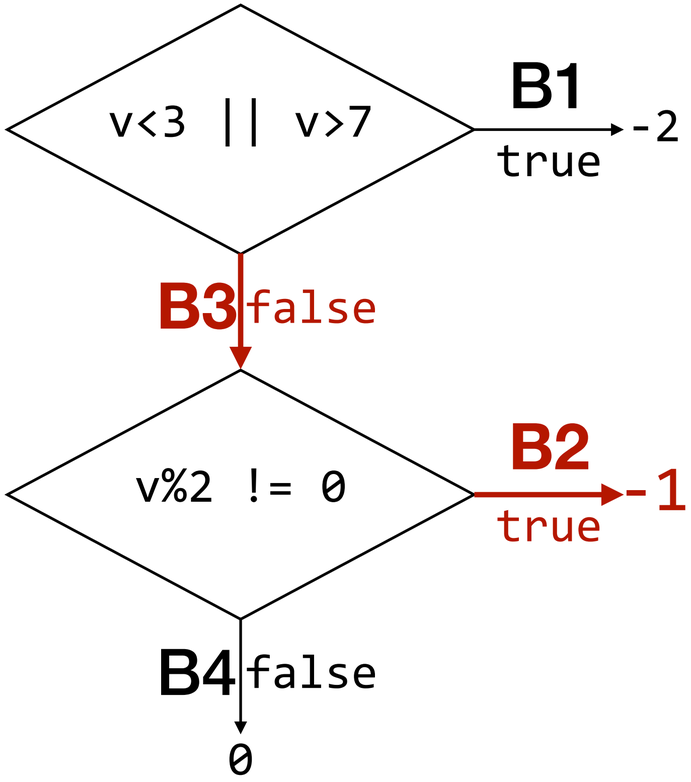
NEZHA introduces δ-diversity.

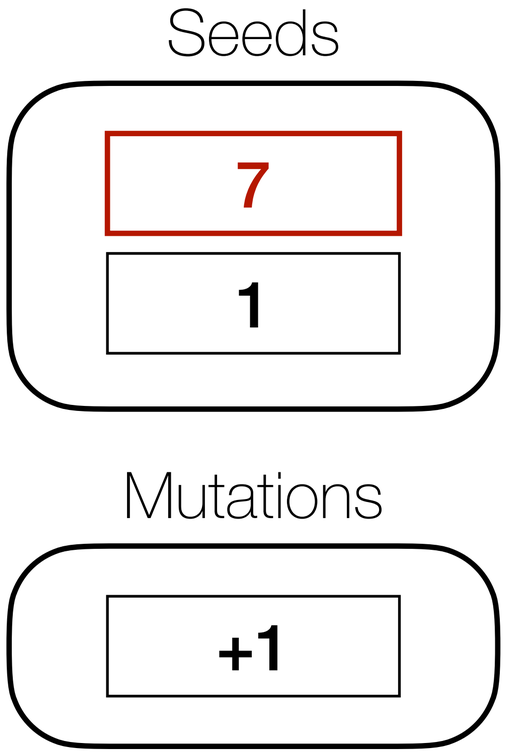
- Fine path δ-diversity
- Coarse path δ-diversity
- Output δ-diversity



Fine path δ-diversity considers tuples of sets.

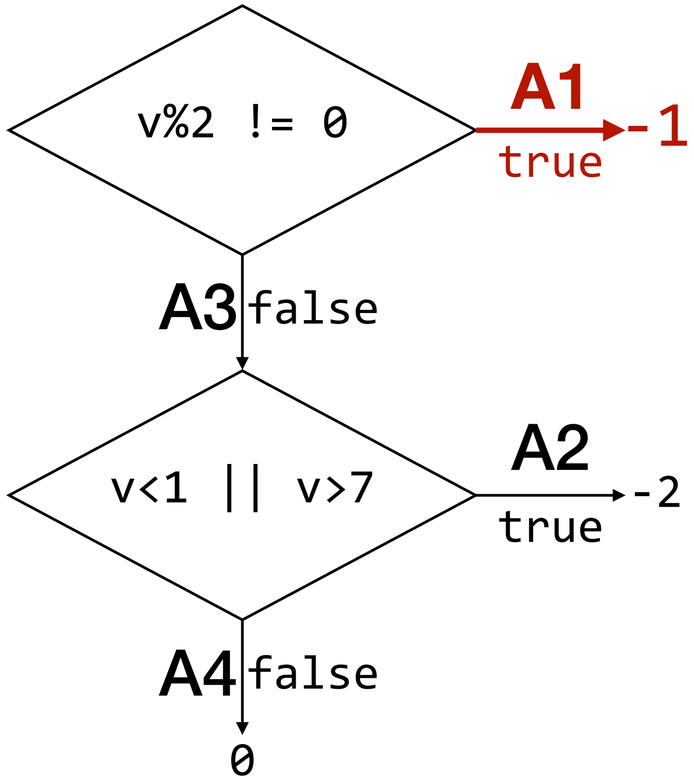


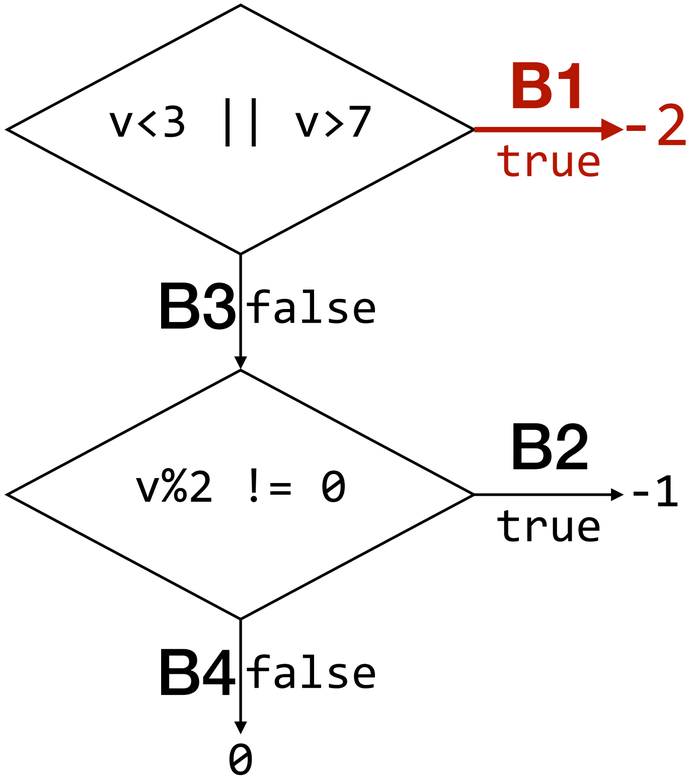


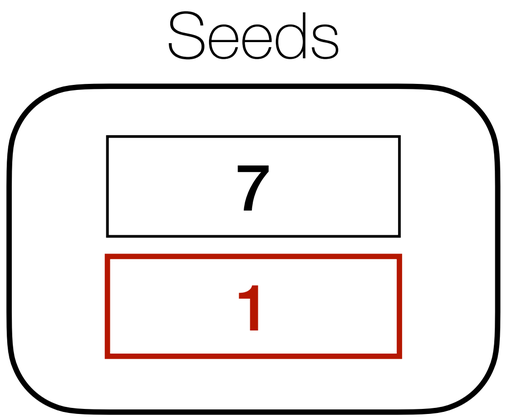


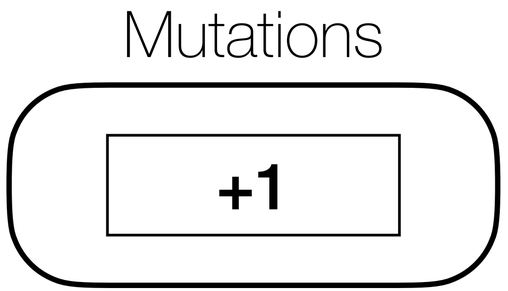
tuple = ({A1}, {B2, B3})

Fine path δ-diversity considers tuples of sets.



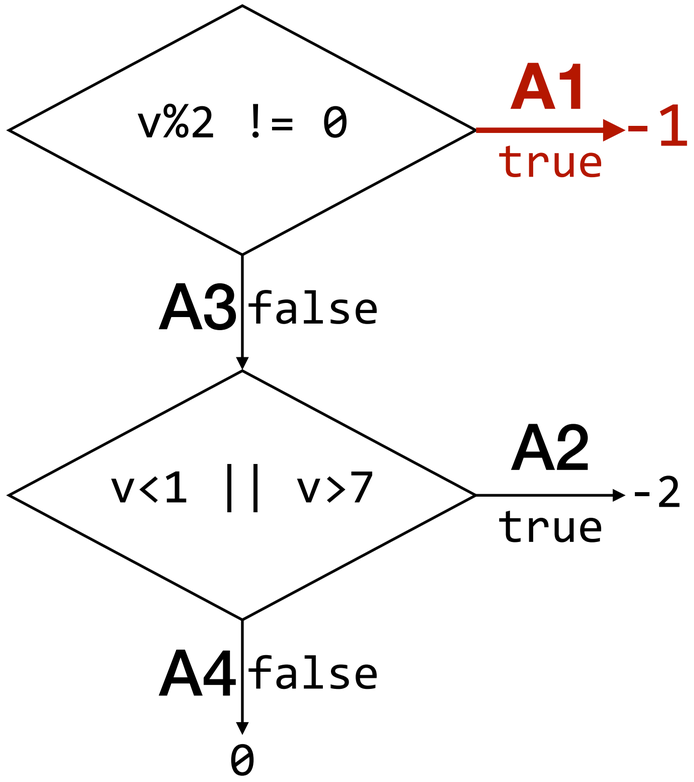


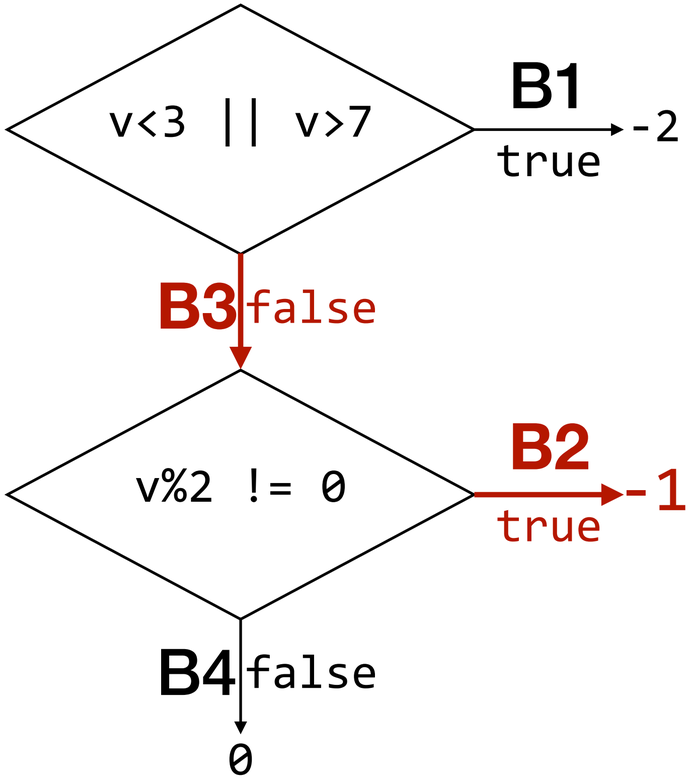


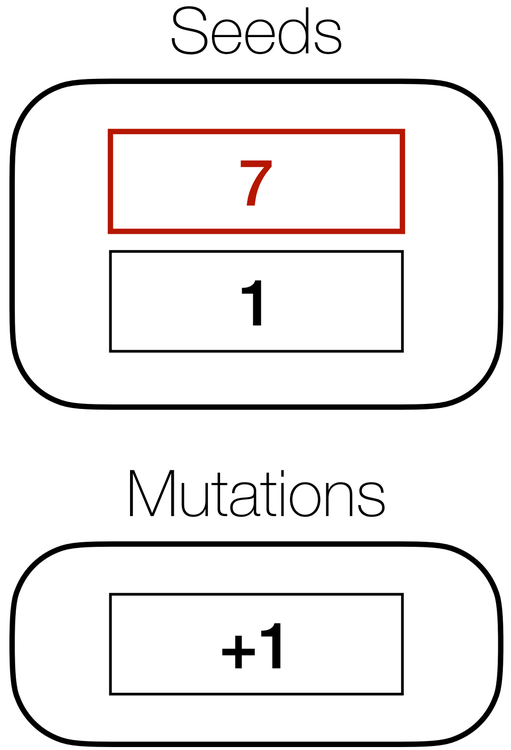


tuple = ({A1}, {B1})

Coarse path δ-diversity considers tuples of the number of covered edges.

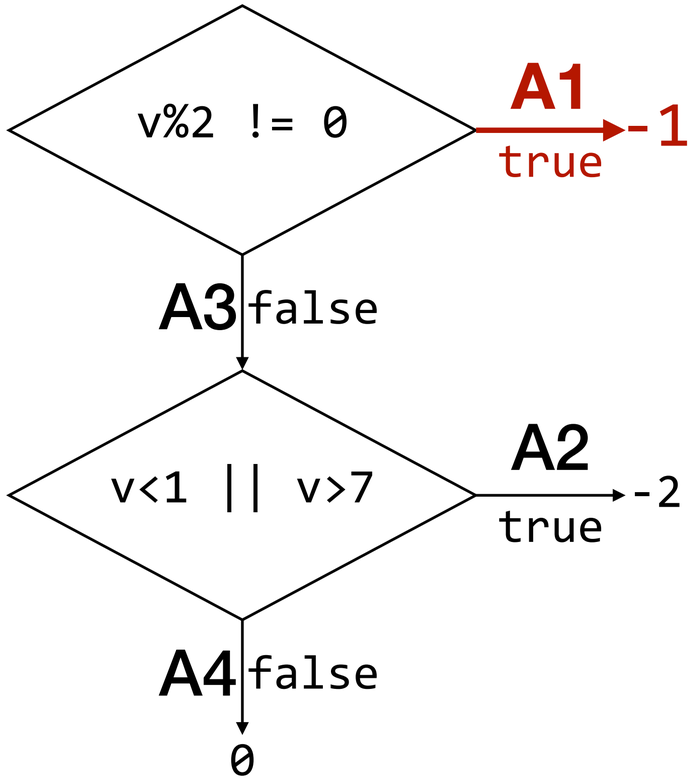


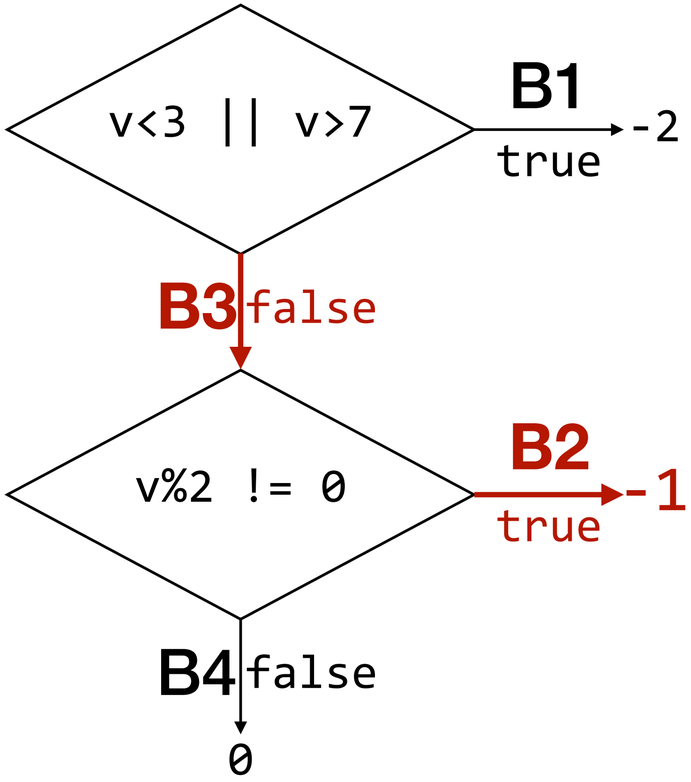


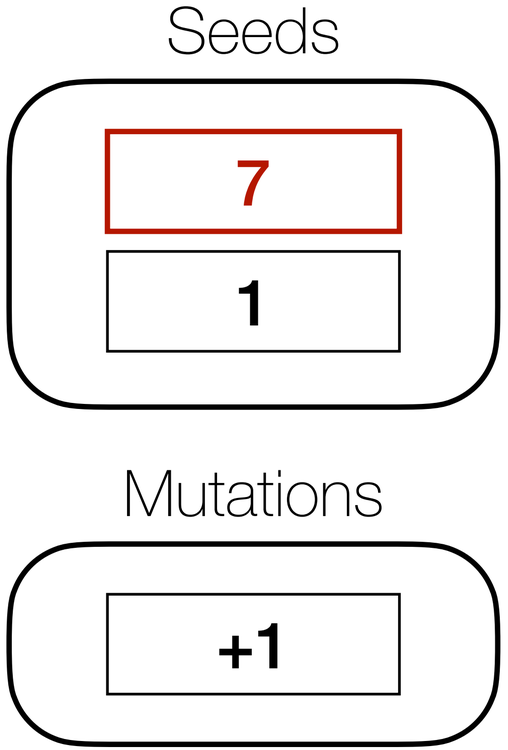


tuple = (|{A1}|, |{B2, B3}|)

Coarse path δ-diversity considers tuples of the number of covered edges.

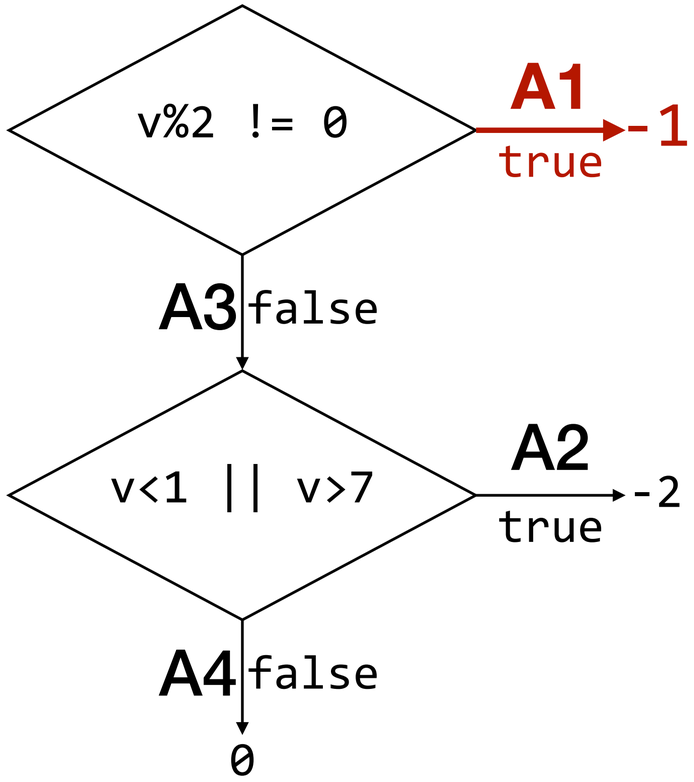


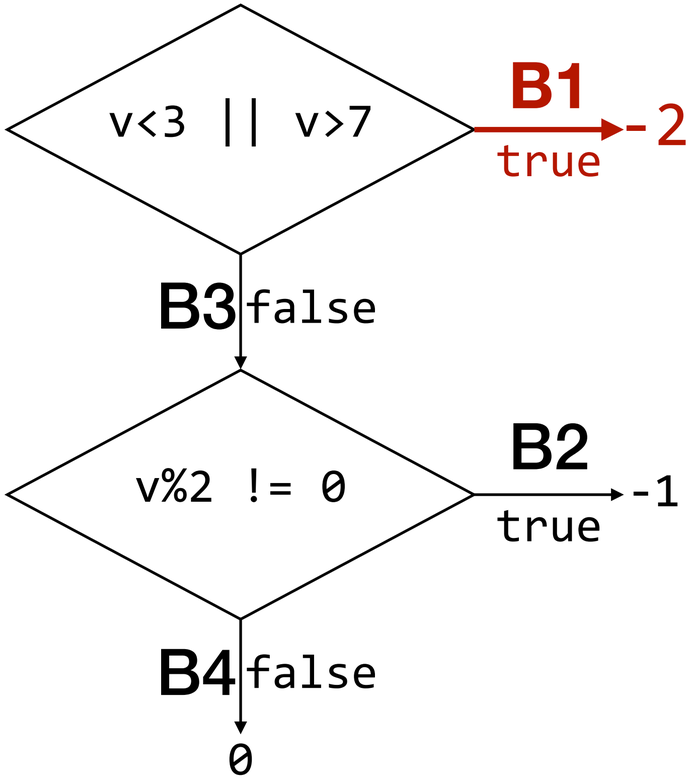


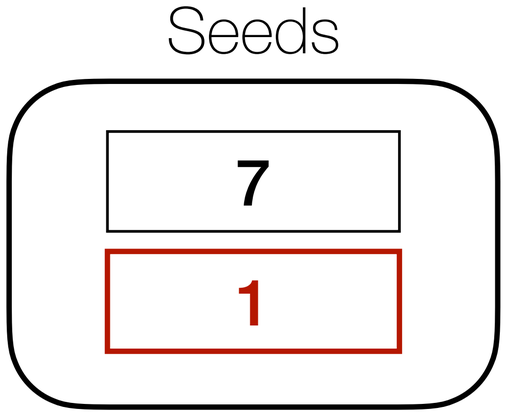


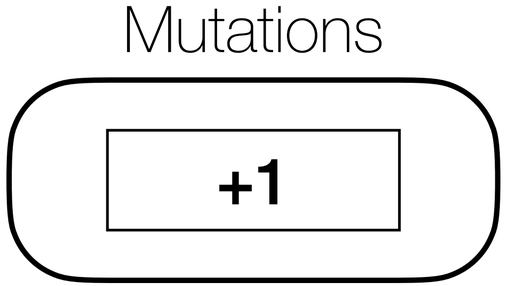
tuple = (1, 2)

Coarse path δ-diversity considers tuples of the number of covered edges.



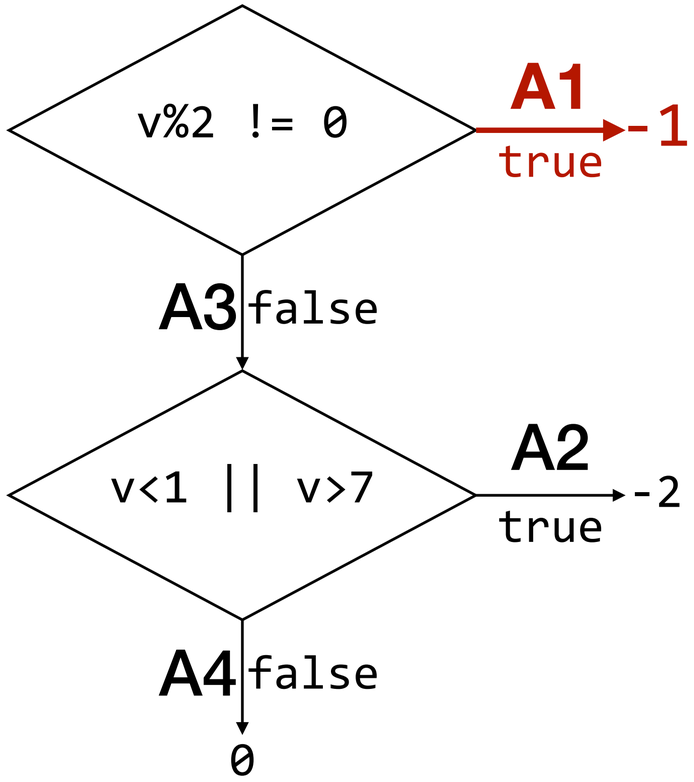


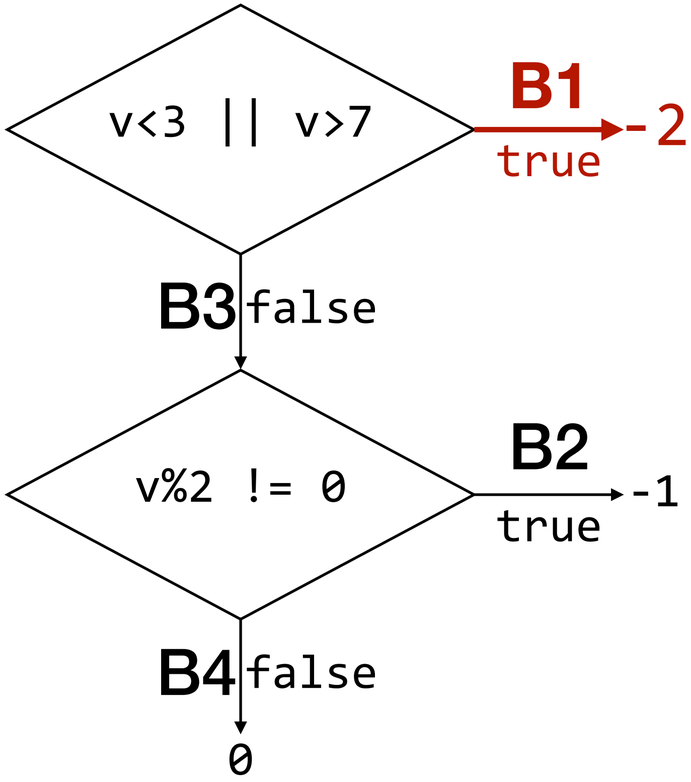


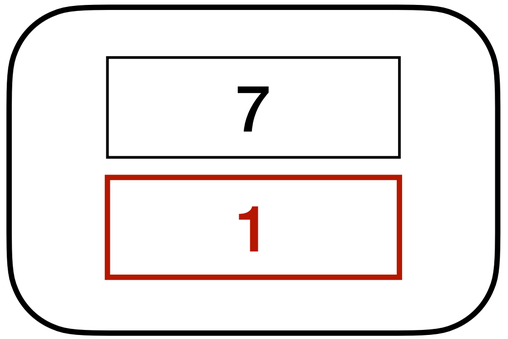


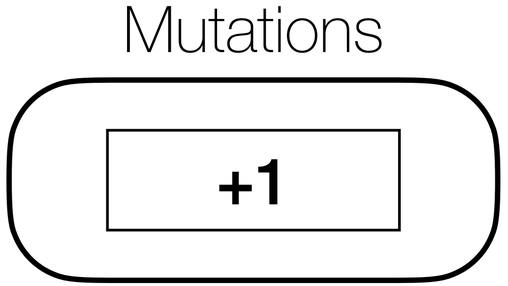
tuple = (|{A1}|, |{B1}|)

Coarse path δ-diversity considers tuples of the number of covered edges.



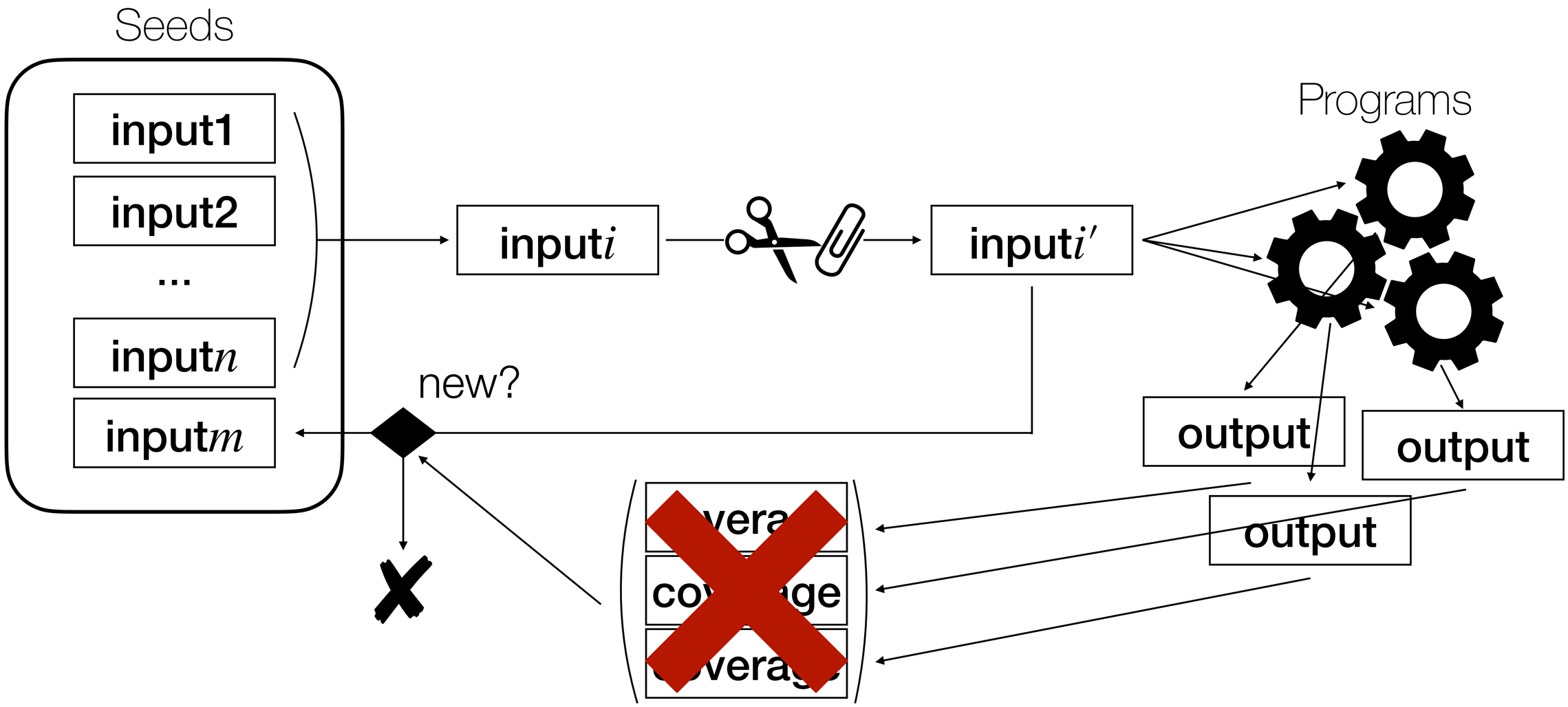




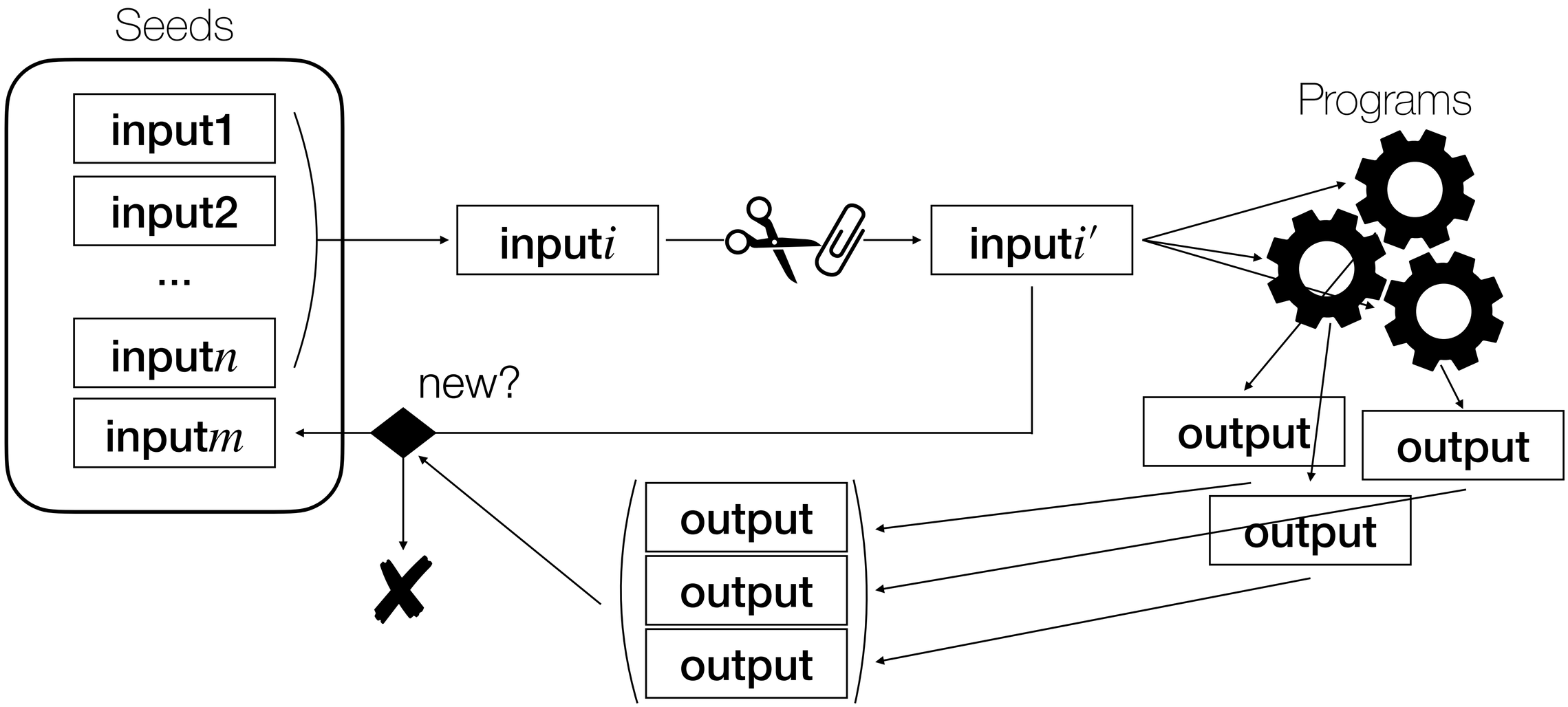


tuple = (1, 1)

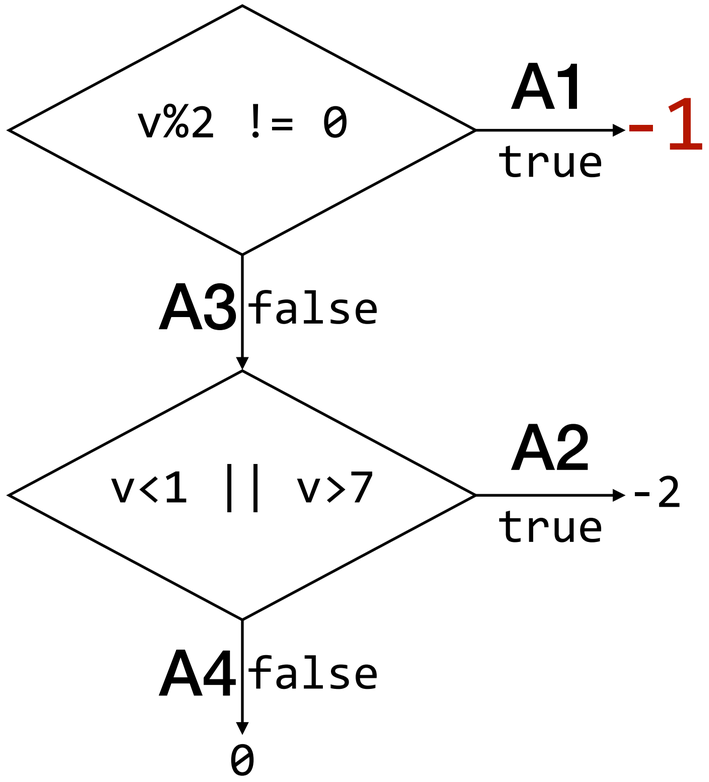
NEZHA works even in a black-box setting.

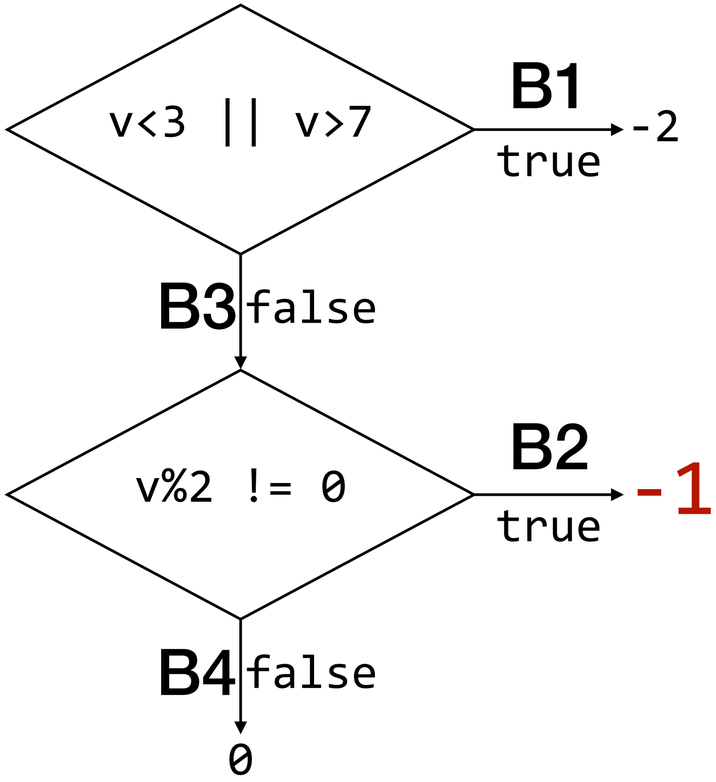


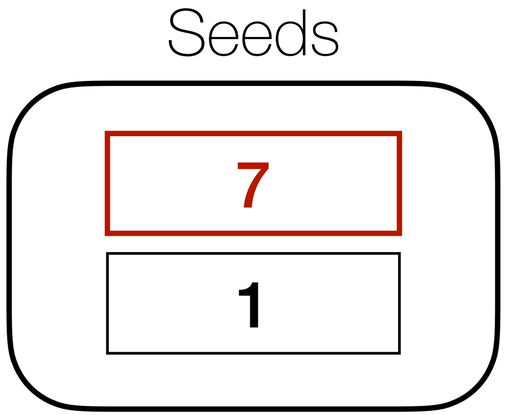
NEZHA works even in a black-box setting.

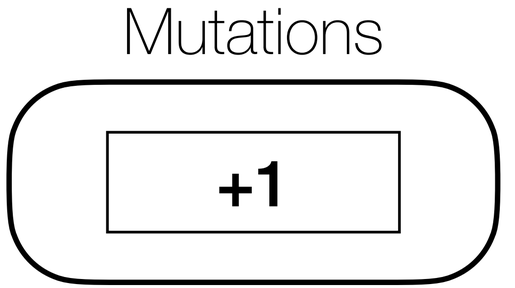


Output δ-diversity considers tuples of outputs.



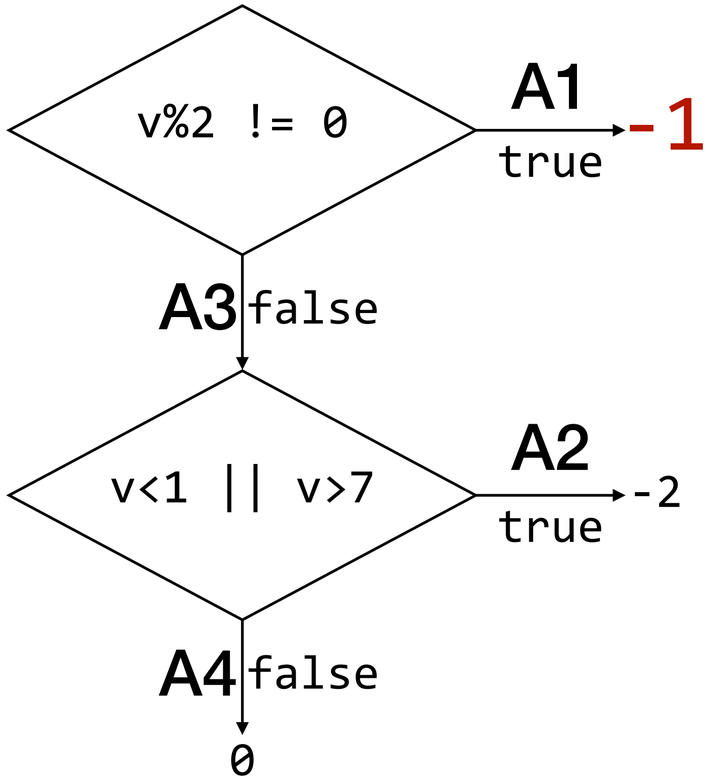


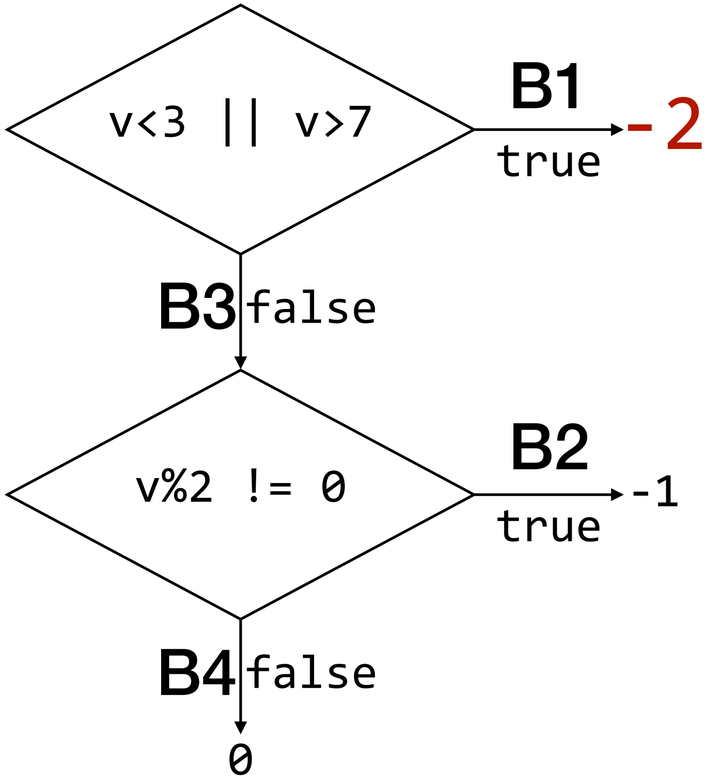


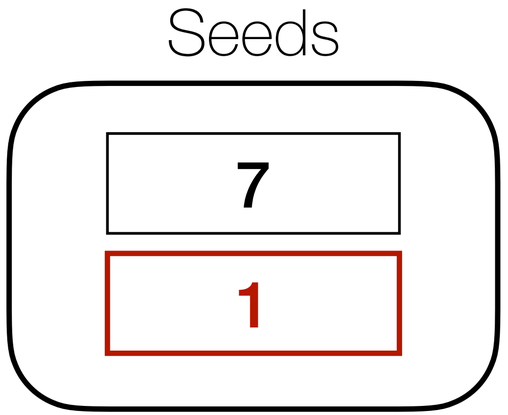


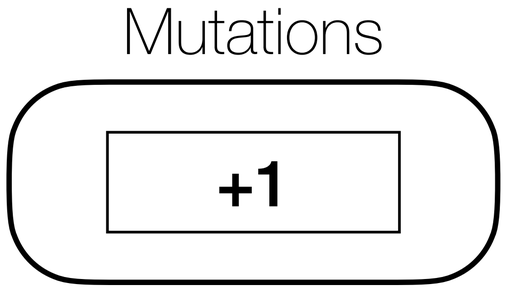
tuple = (-1, -1)

Output δ-diversity considers tuples of outputs.









tuple = (-1, -2)

Evaluation

1. Effectiveness
2. NEZHA vs Domain-specific differential testing
3. NEZHA vs Domain-independent fuzzers
4. Path δ-diversity vs Output δ-diversity

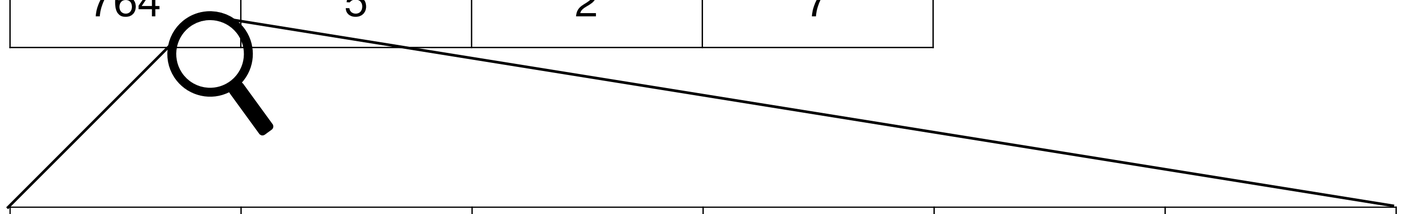
NEZHA **effectively discovers discrepancies.**

SSL/TLS	XZ	ELF	PDF
764	5	2	7

# of discrepancies

NEZHA effectively discovers discrepancies.

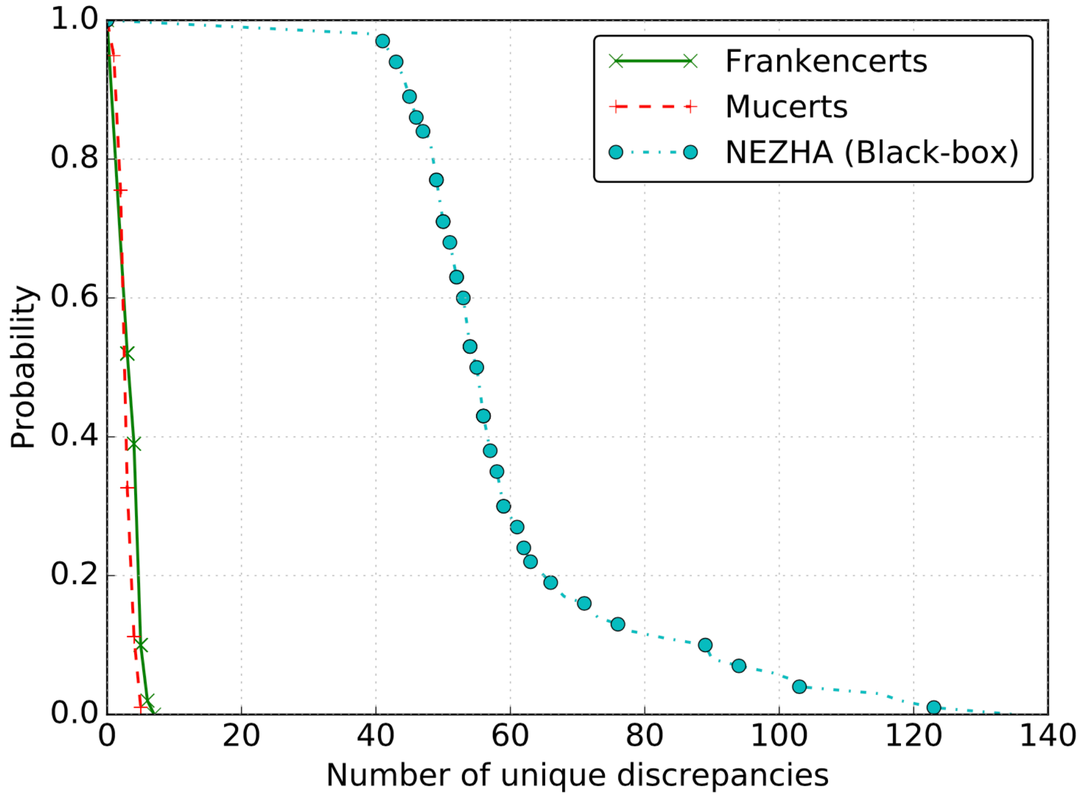
SSL/TLS	XZ	ELF	PDF
764	5	2	7



	LibreSSL	BoringSSL	wolfSSL	mbedTLS	GnuTLS
OpenSSL	10	1	8	33	25
LibreSSL		11	8	19	19
BoringSSL			8	33	25
wolfSSL				6	8
mbedTLS					31

# of discrepancies

NEZHA outperforms existing domain-specific differential testing frameworks.

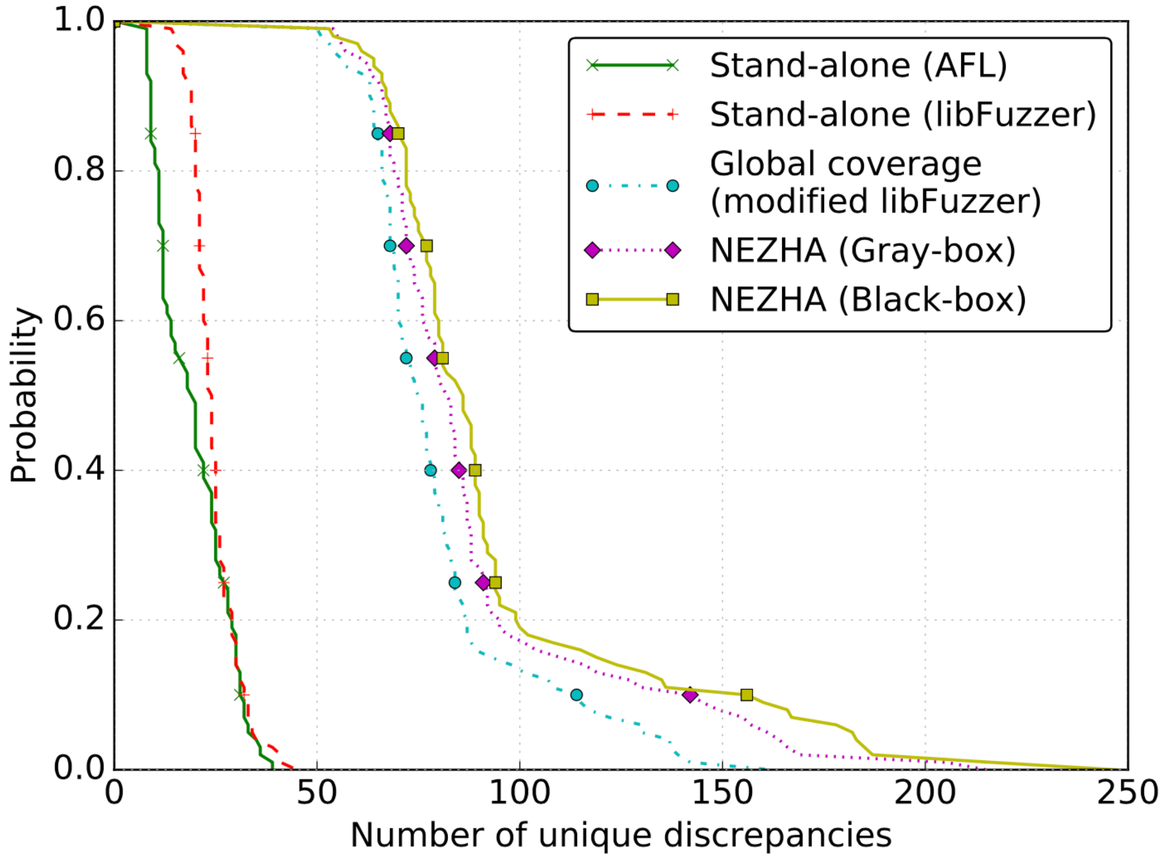


Mucerts
19

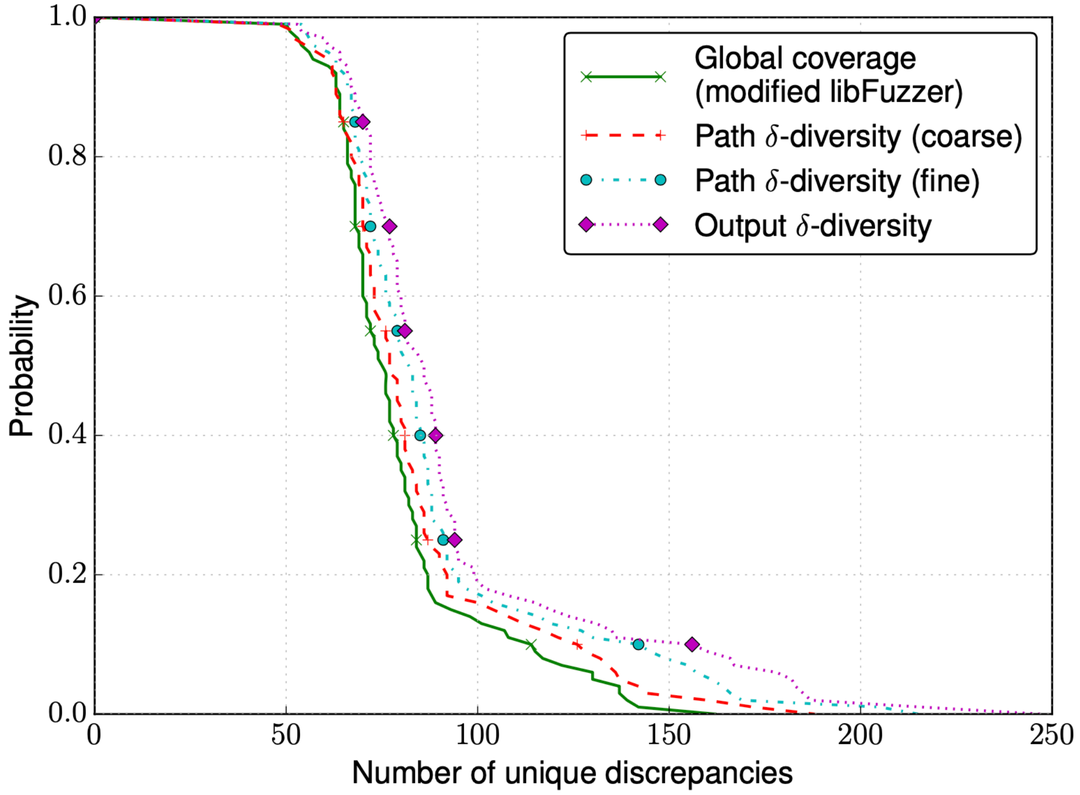
Frankencerts
10

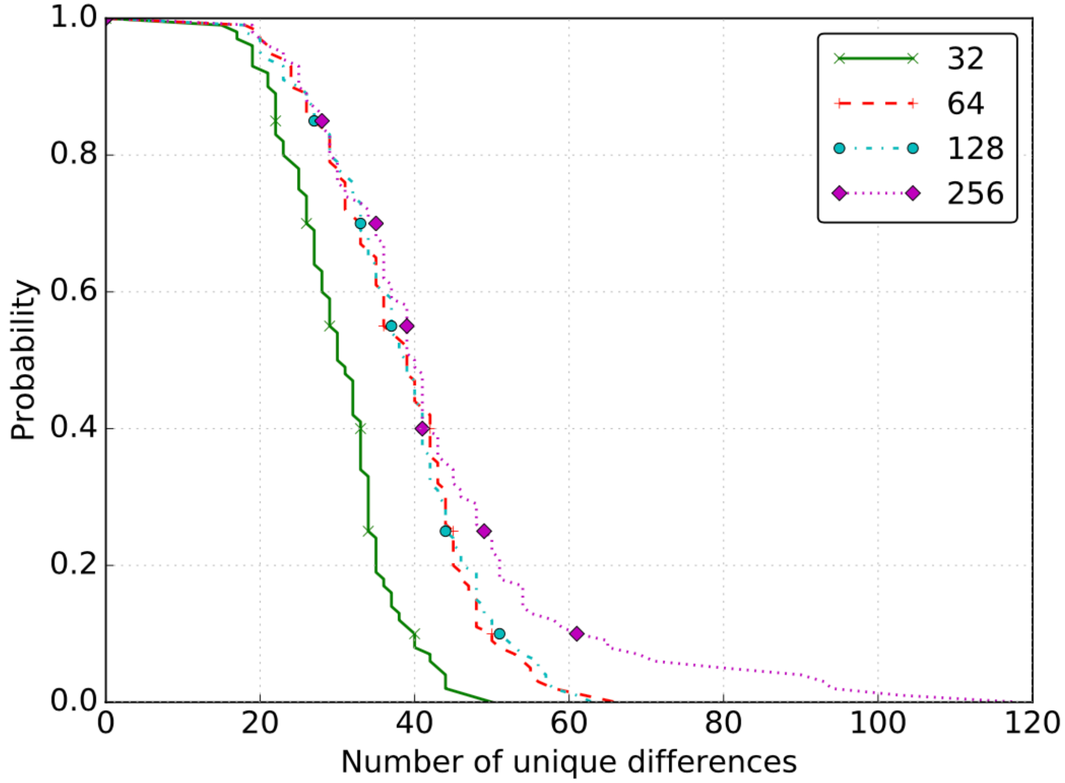
NEZHA
521

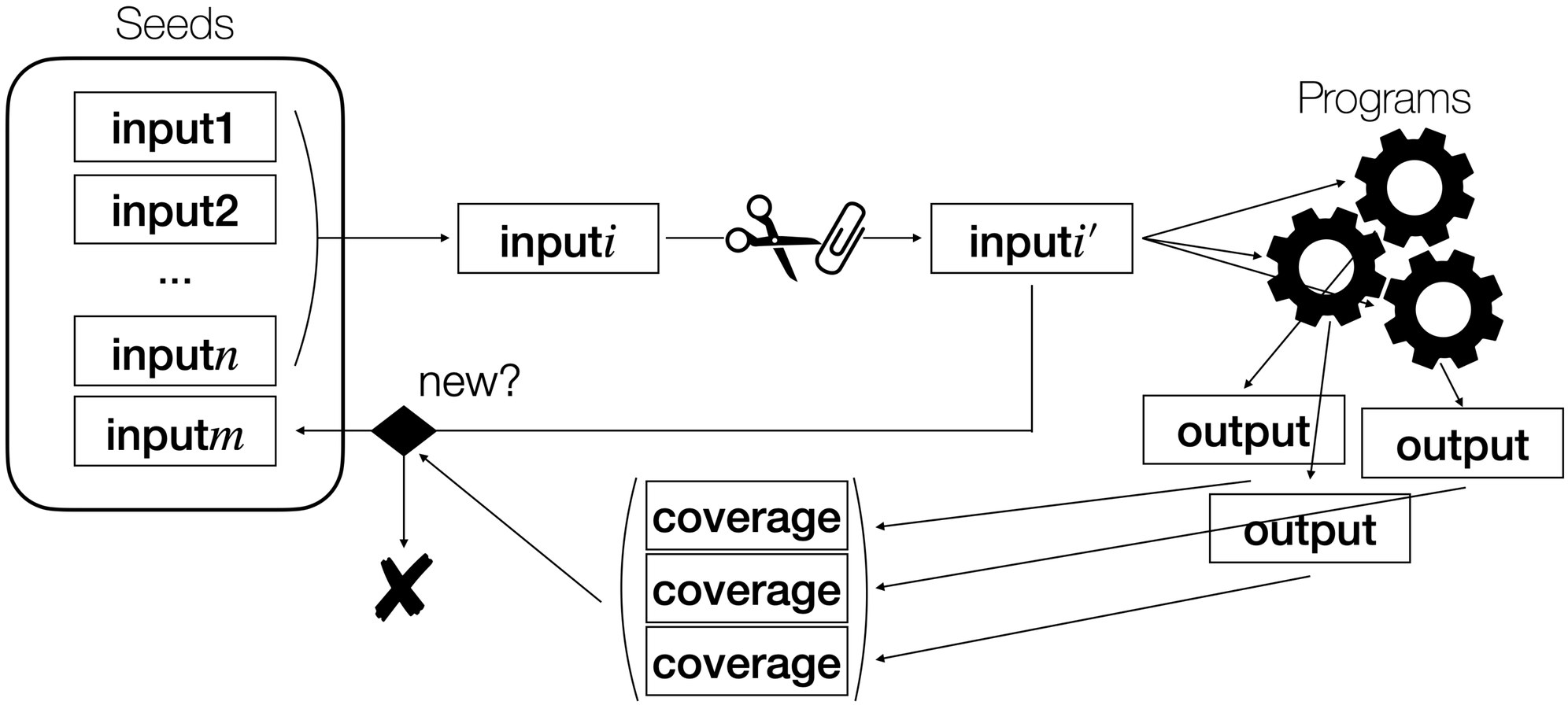
NEZHA outperforms existing domain-independent fuzzers.



Output δ-diversity is as good as path δ-diversity when outputs are fine-grained.







NEZHA

- δ-diversity
  - Fine path δ-diversity
  - Coarse path δ-diversity
  - Output δ-diversity