Abstractions from Tests

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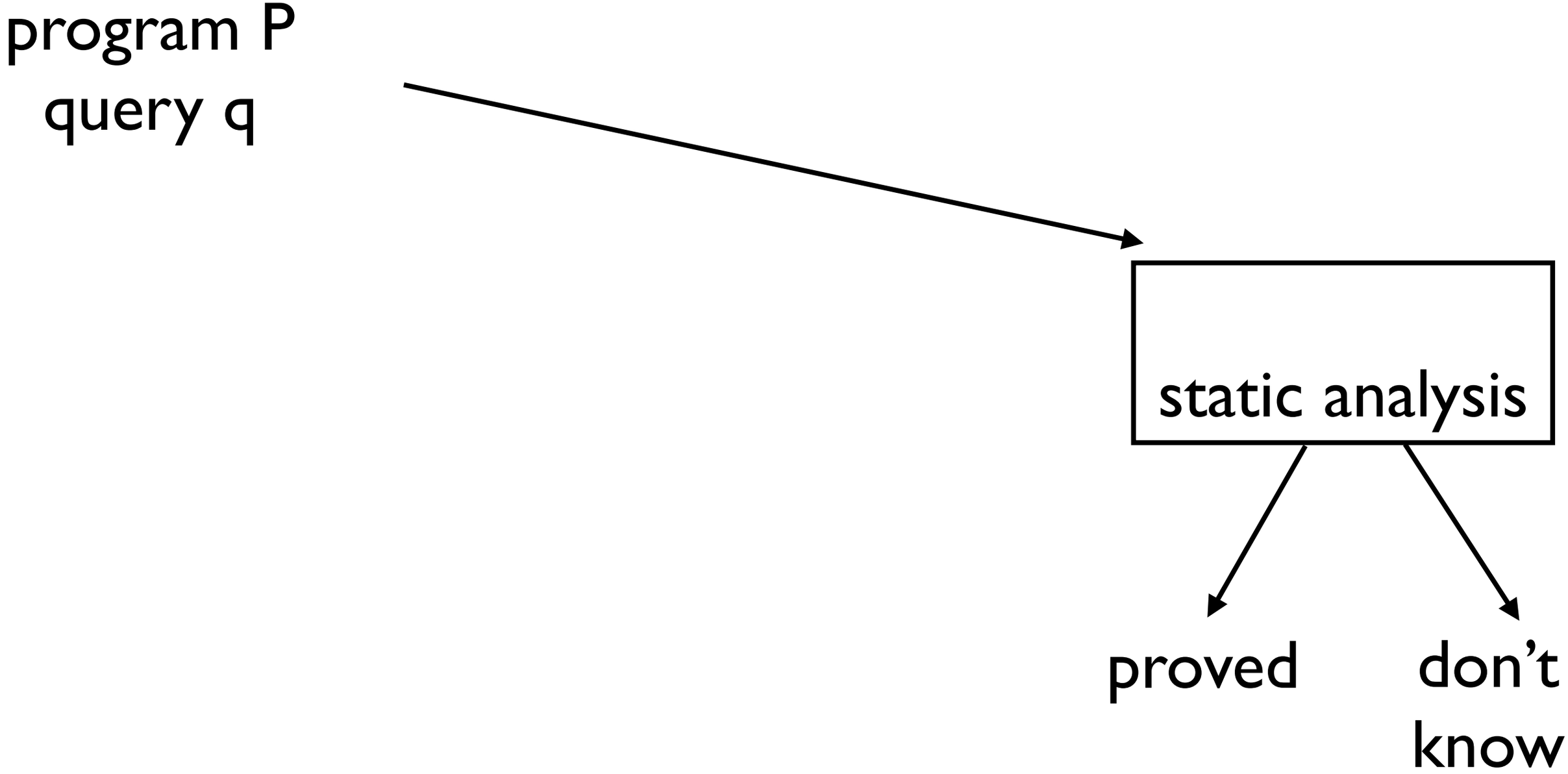
Motivation

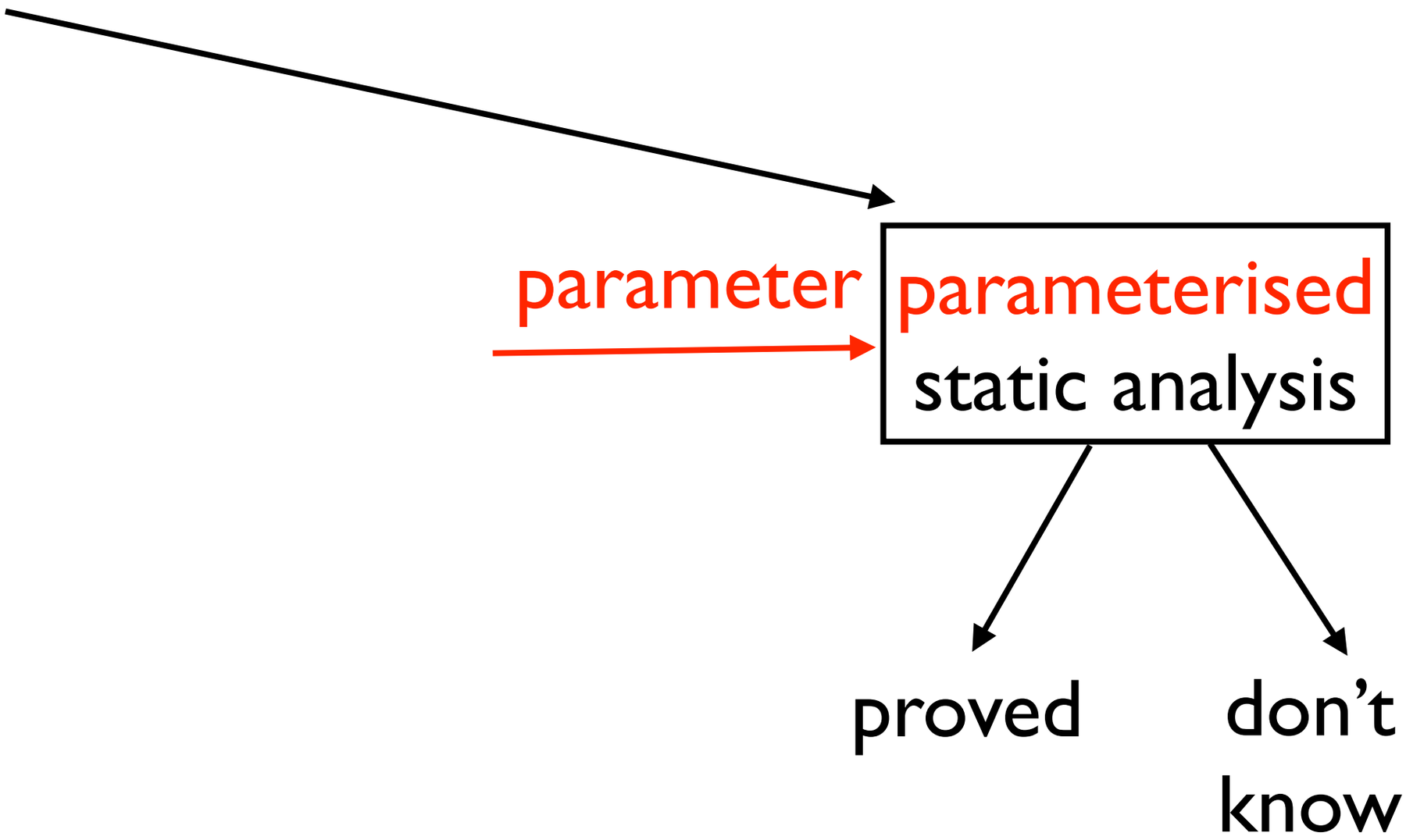
- Great success stories in automatic program verification based on static analysis techniques (SDV, Astree, etc).
- Yet balancing precision and performance of a static analysis is still an art.
- We want to do this balancing automatically.

Typical static analysis



Our approach

program P
query q



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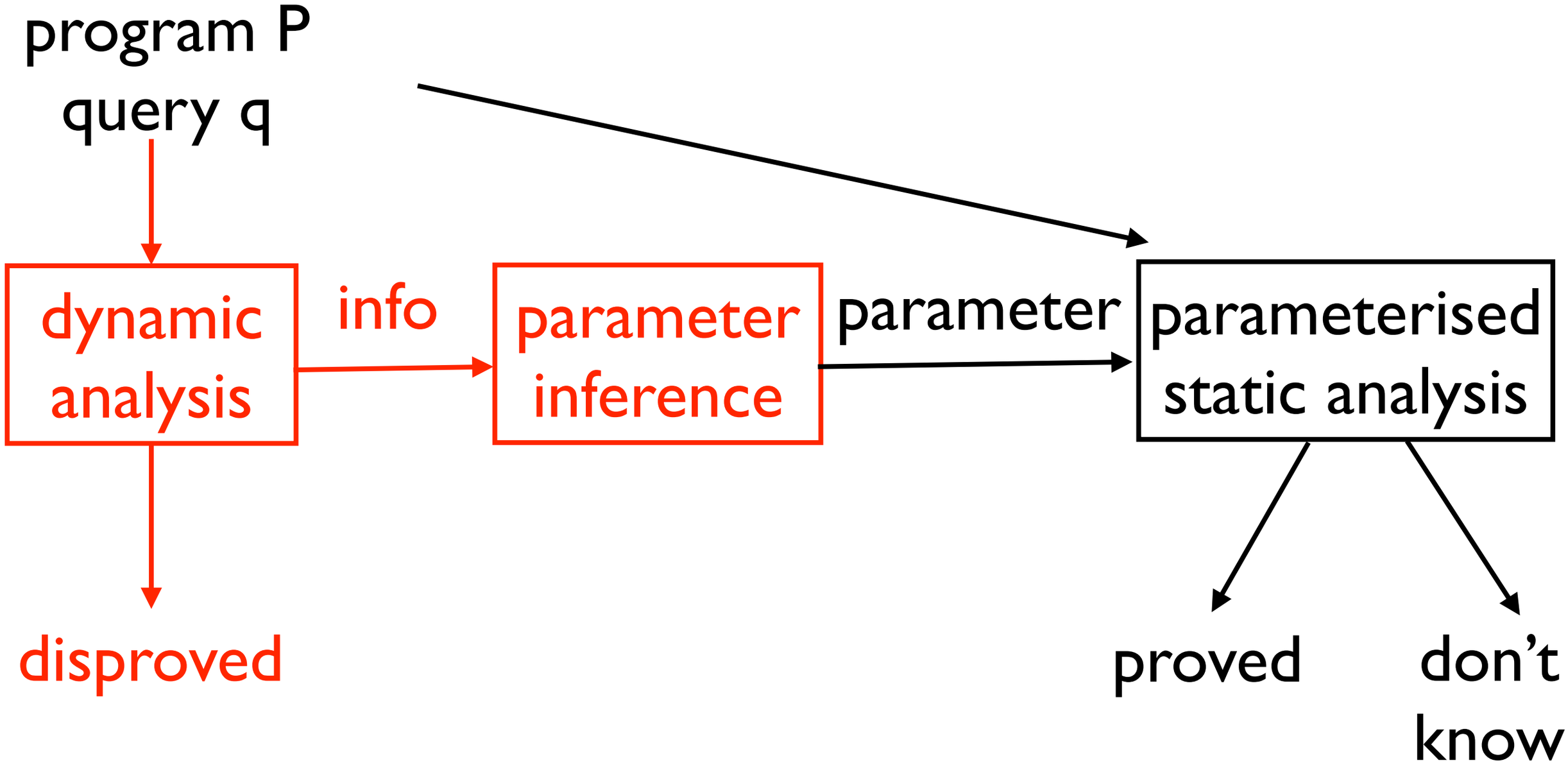
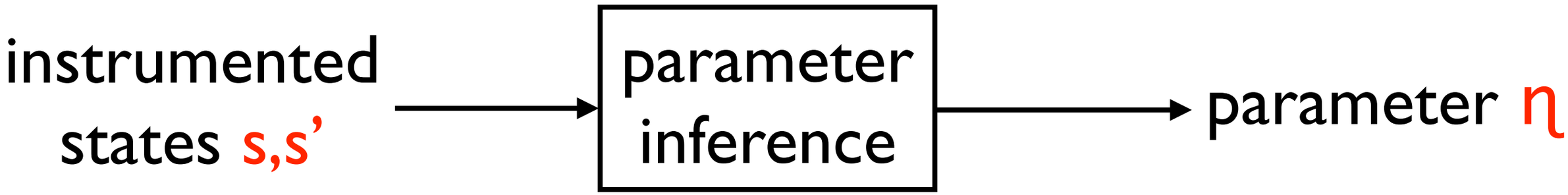
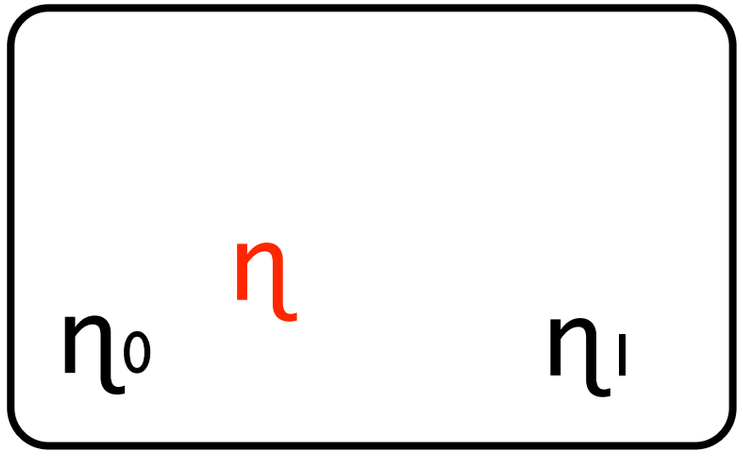


Hypothesis

- If a query is simple, we can find why the query holds simply by looking at a few execution traces.

Parameter inference based on separability and minimality





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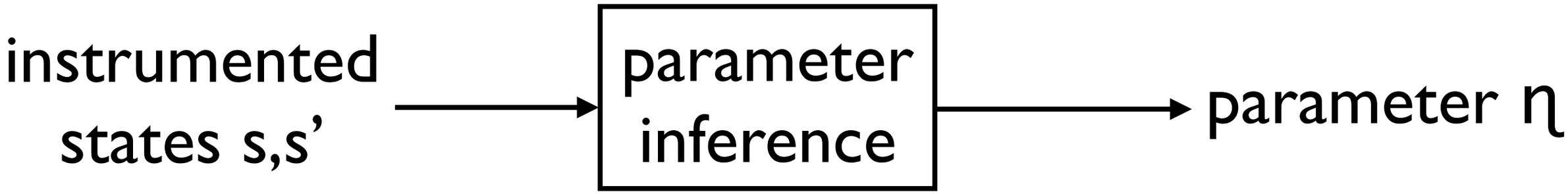
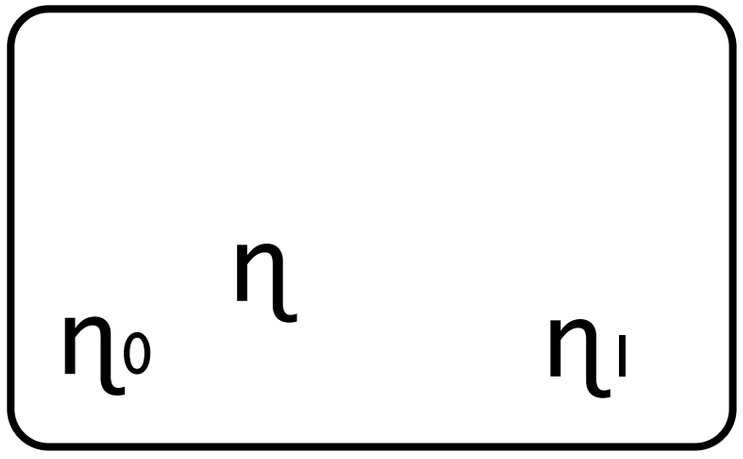


GOOD	BAD
s,s'	

Can separate?



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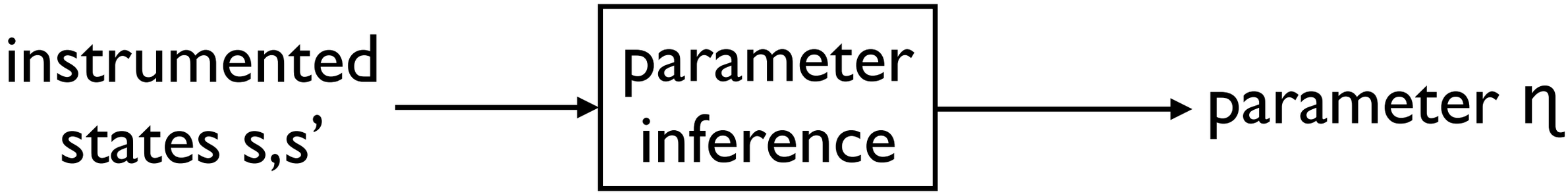

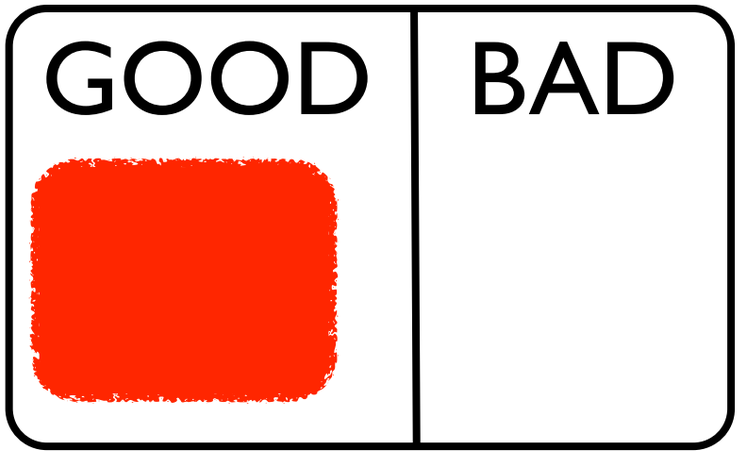

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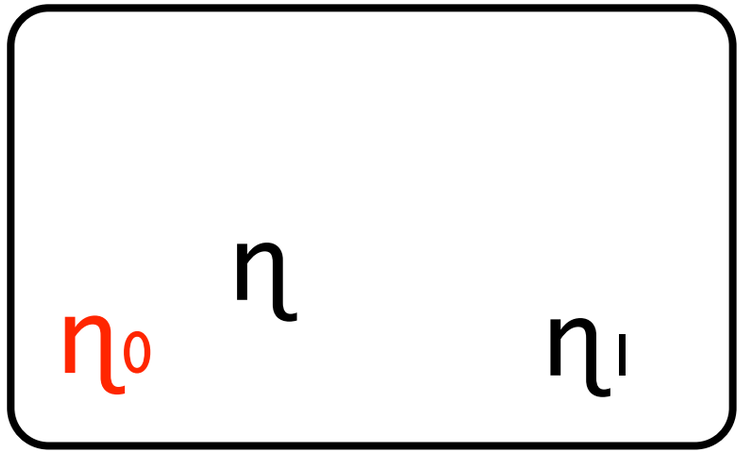

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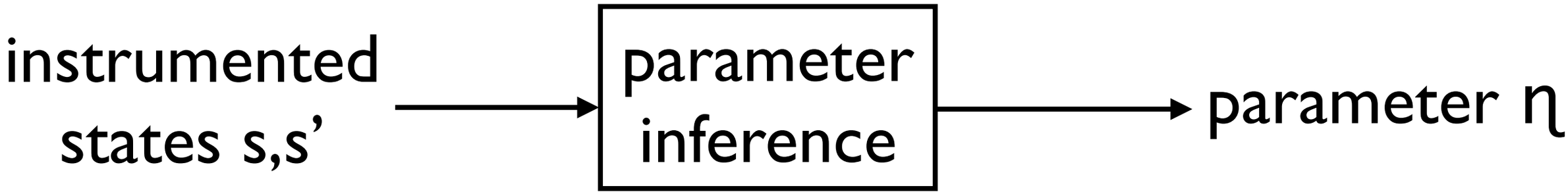

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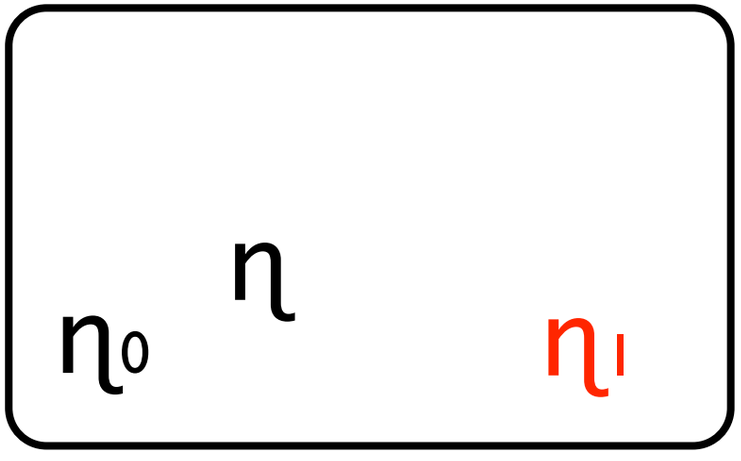

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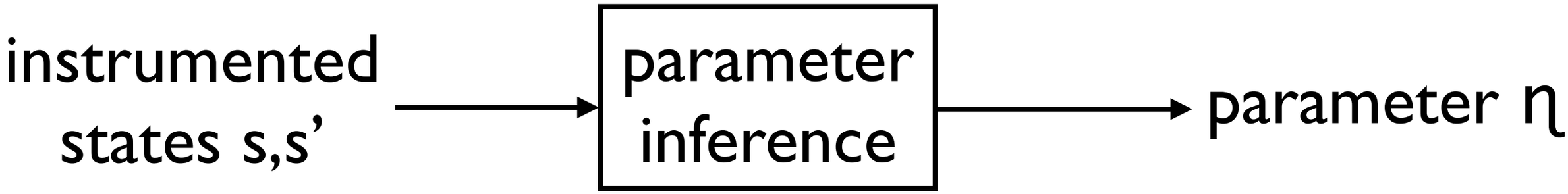
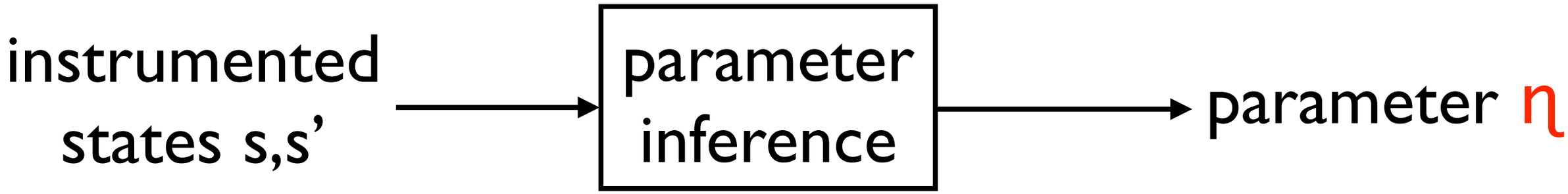


- Computes a separability condition.

Parameter inference based on separability and minimality



- Computes a separability condition.
- Among separable η_i's, choose a minimal η according to an order (which approximately reflects precision).

Thread-escape query

- Does a local variable point to an object that cannot be reached from other threads?

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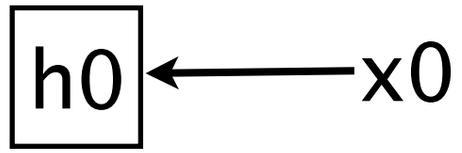

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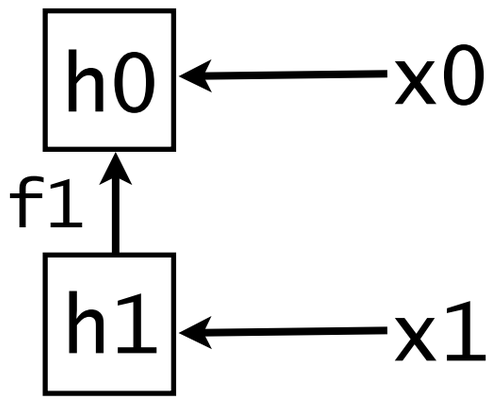

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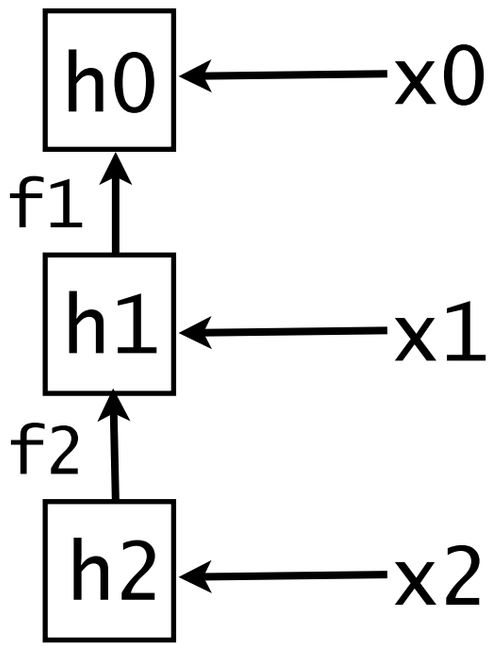

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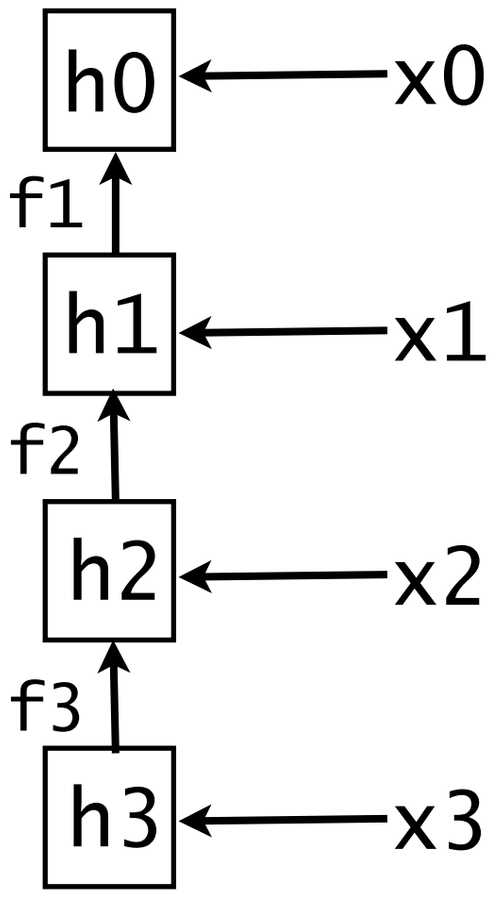

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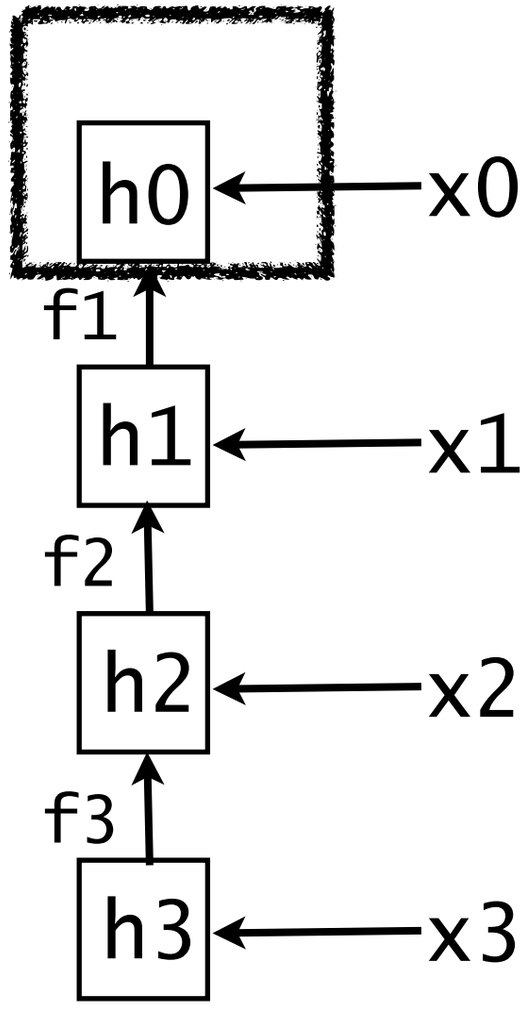

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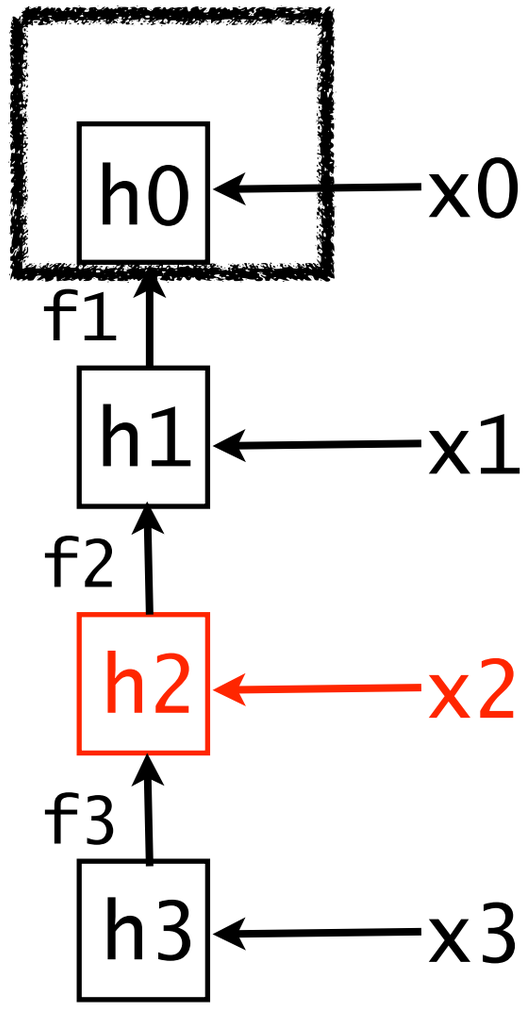

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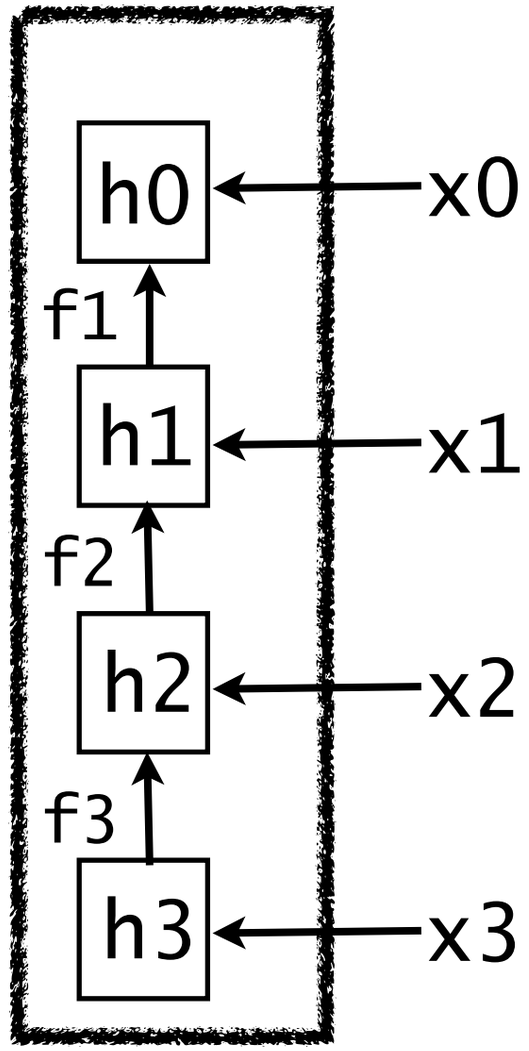

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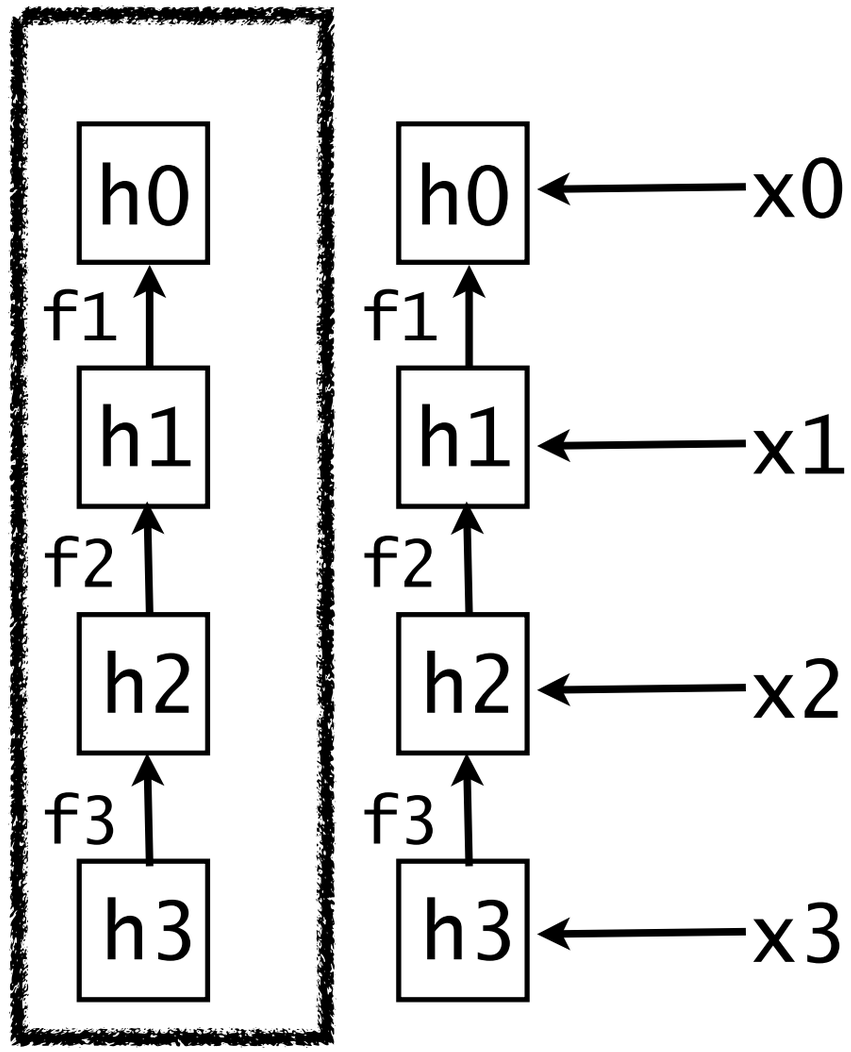

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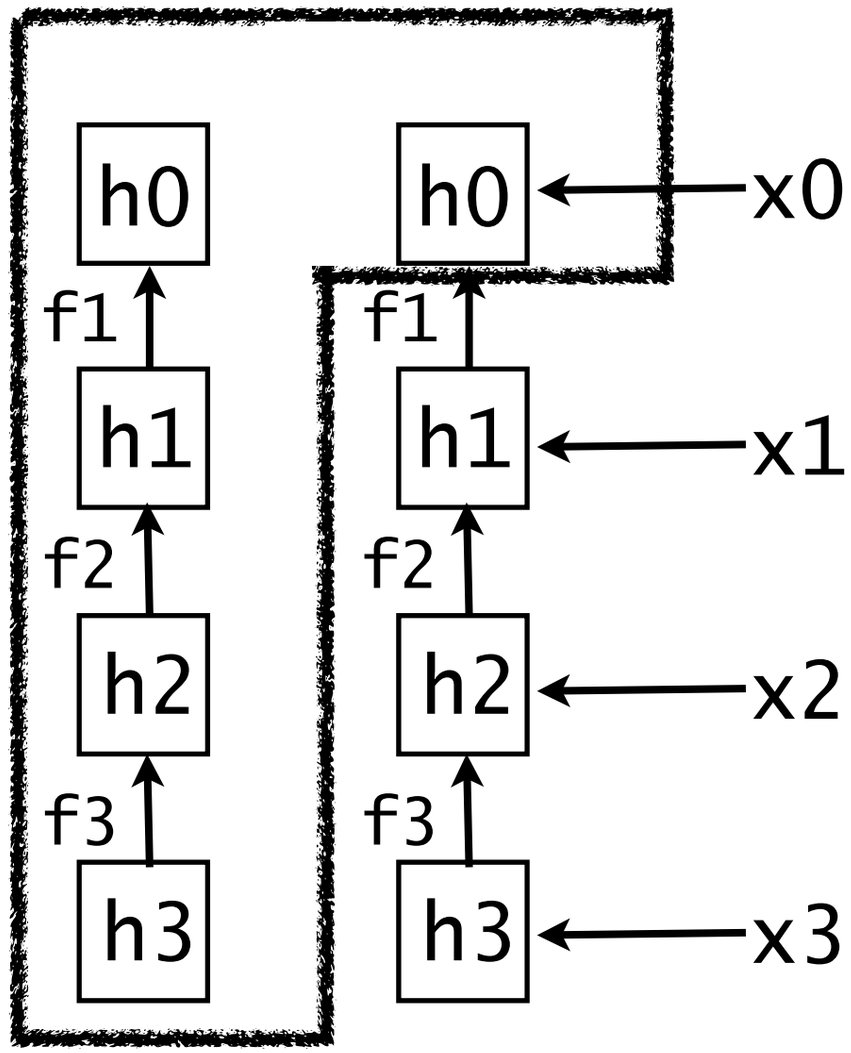

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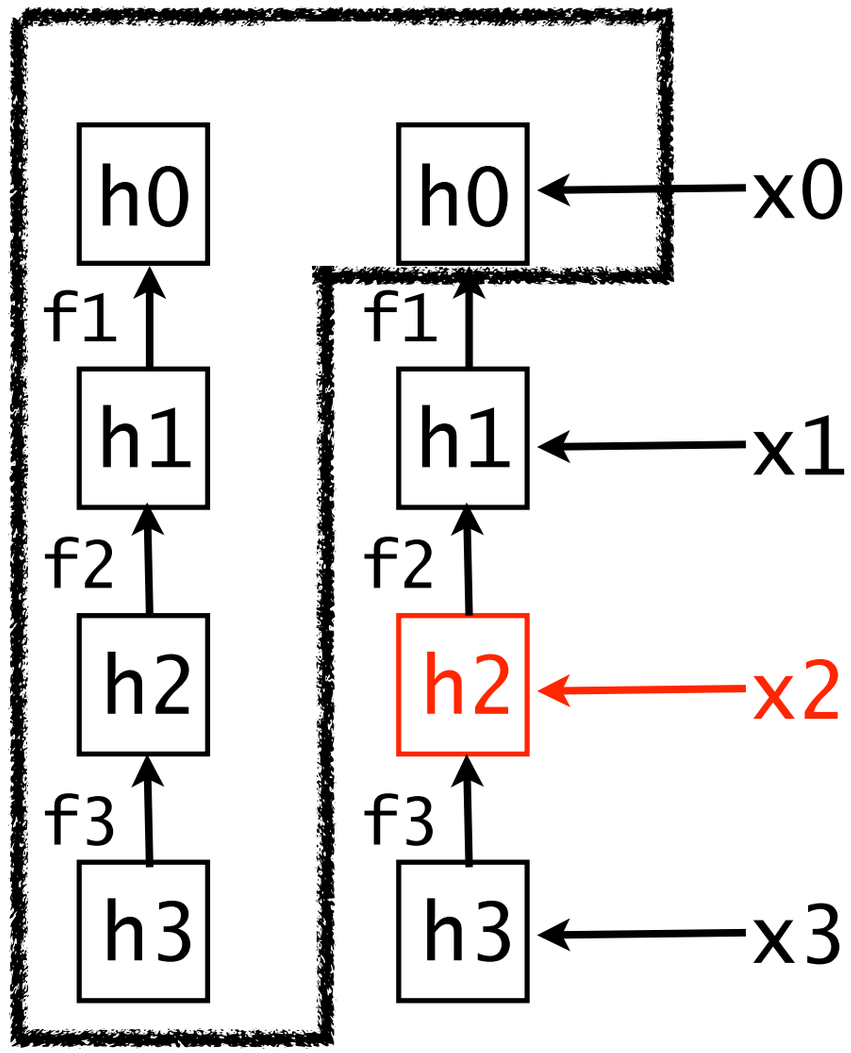

Thread-escape analysis

- Summarise all heap objects with only two abstract nodes E and L.
- $\gamma(E)$ consists of all the thread-escaping objects and possibly more.
- $\gamma(L)$ contains only thread-local objects.

Parameterisation

$$\text{Param} = \text{AllocSite} \to \{\mathrm{L}, \mathrm{E}\}$$

- For each allocation site, it decides whether L or E is used to summarise allocated objects.
- Changes the transfer function of "x=new h_i".
- Objects summarised by L can move to E, but not vice versa.

Thread-escape analysis

- Parameter η = [{h0,h1}↦E, {h2,h3}↦L]

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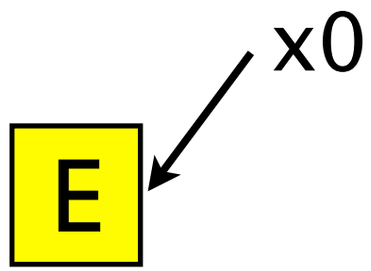

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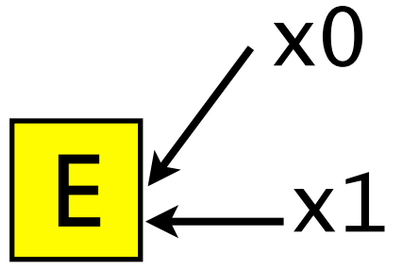

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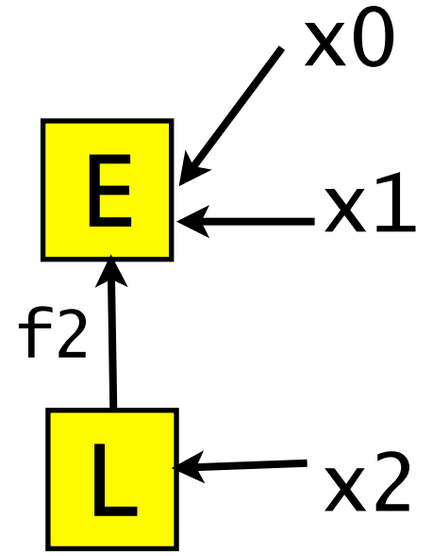

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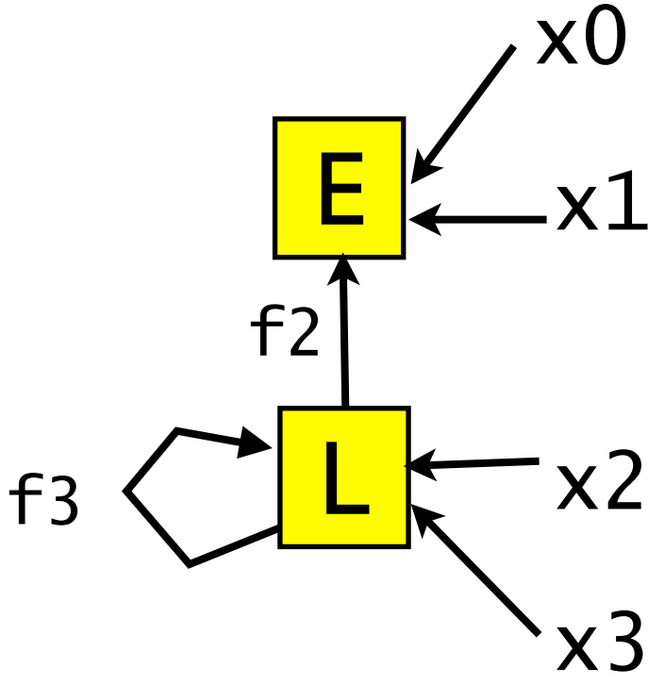

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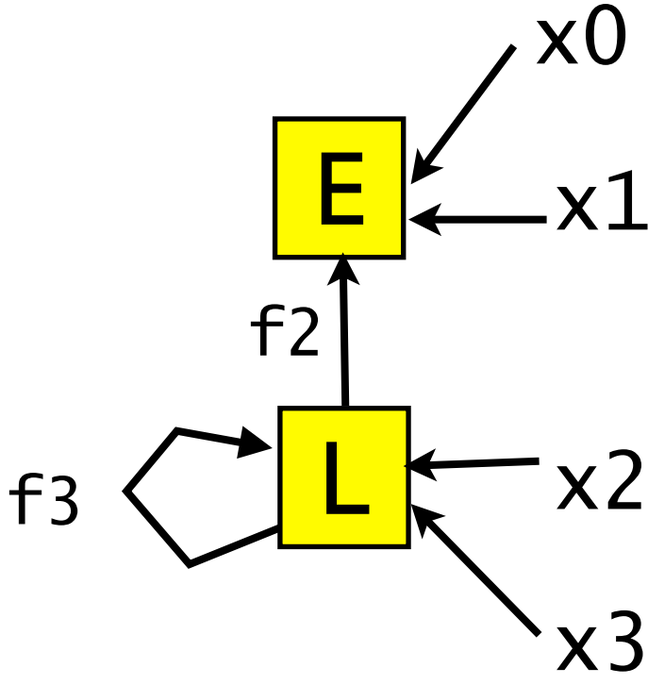

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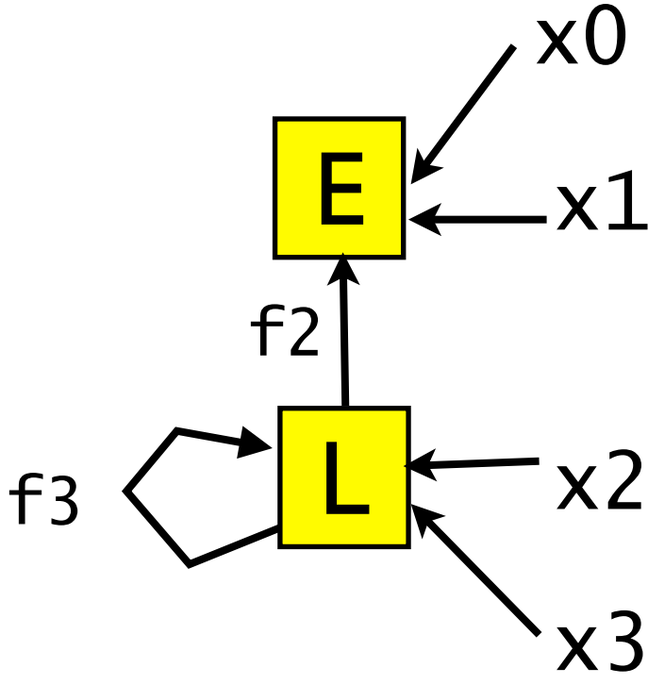

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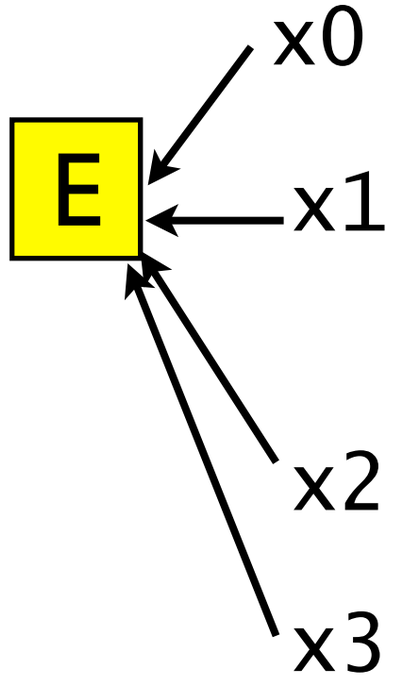

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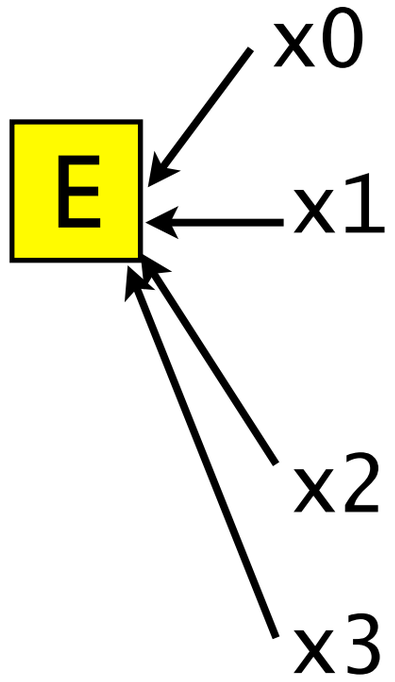

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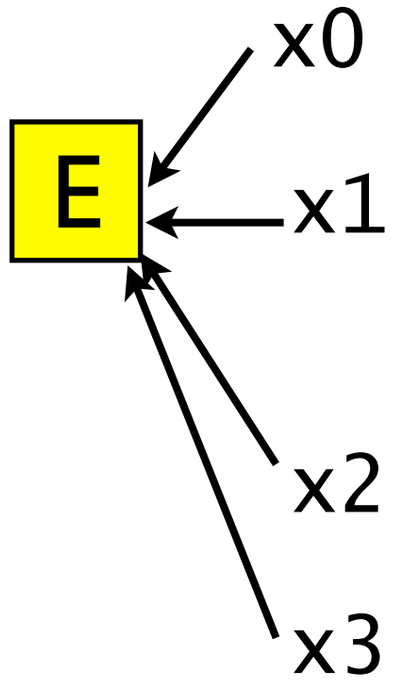

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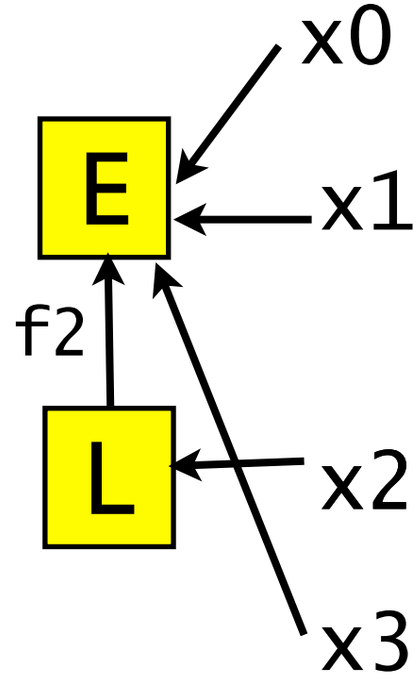

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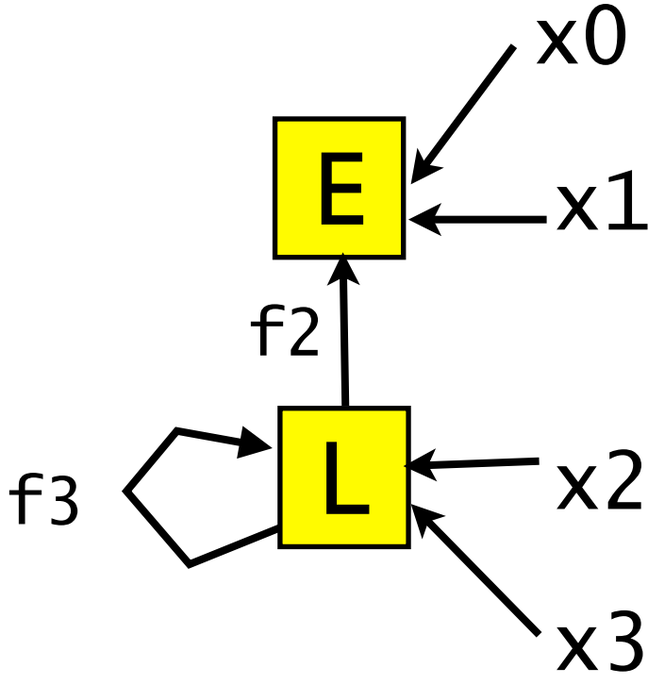

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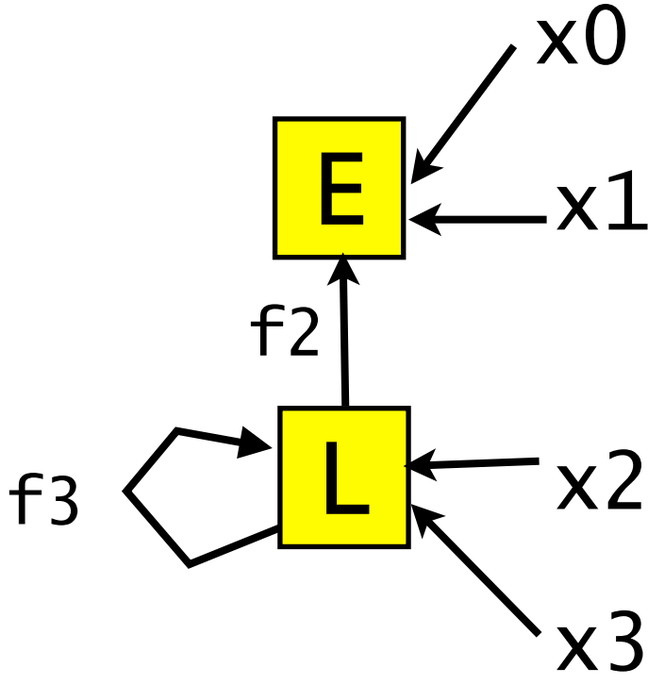

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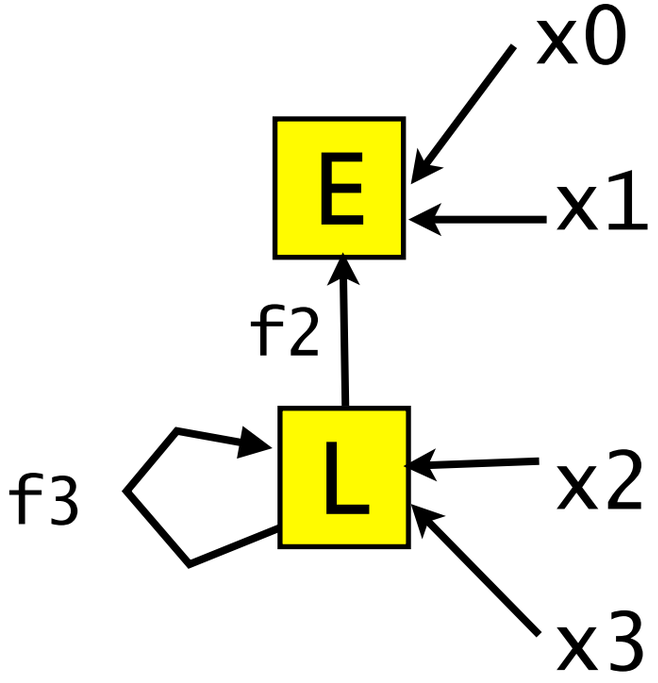

Difficulties in choosing a good parameter

- Using more L makes the analysis more expensive.

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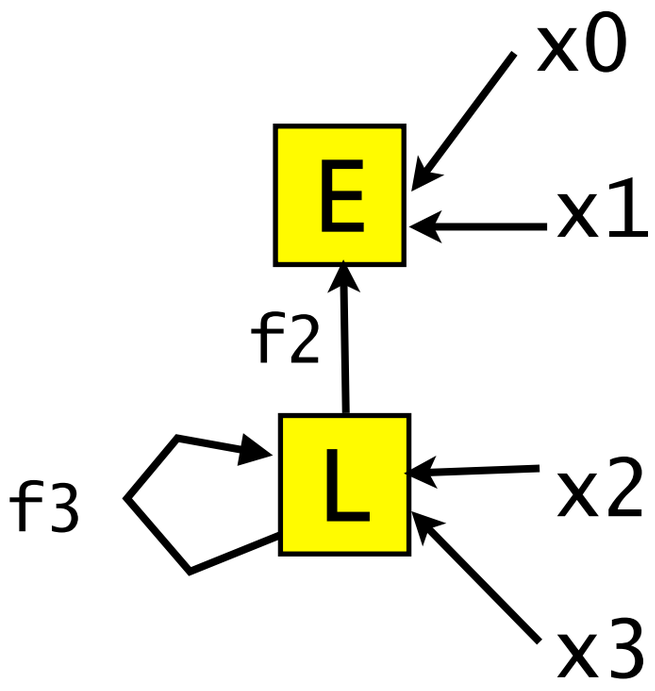
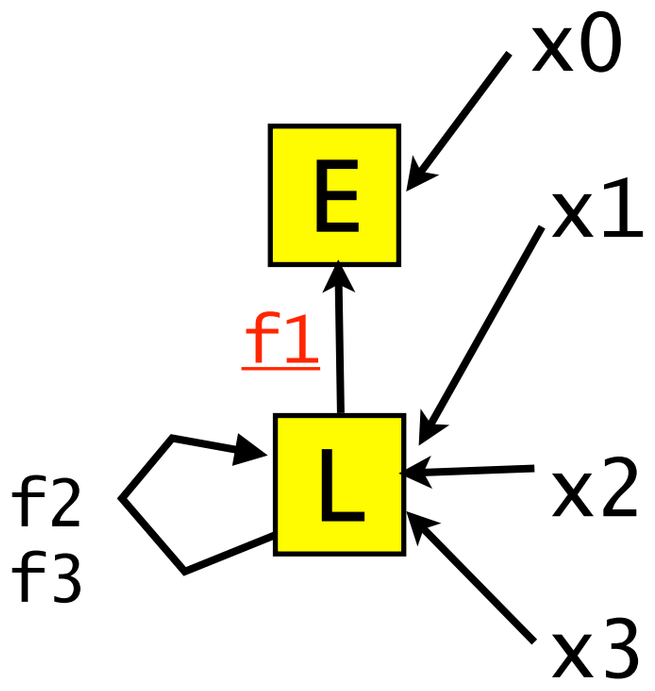


[{h0}↦E, {h1,h2,h3}↦L]



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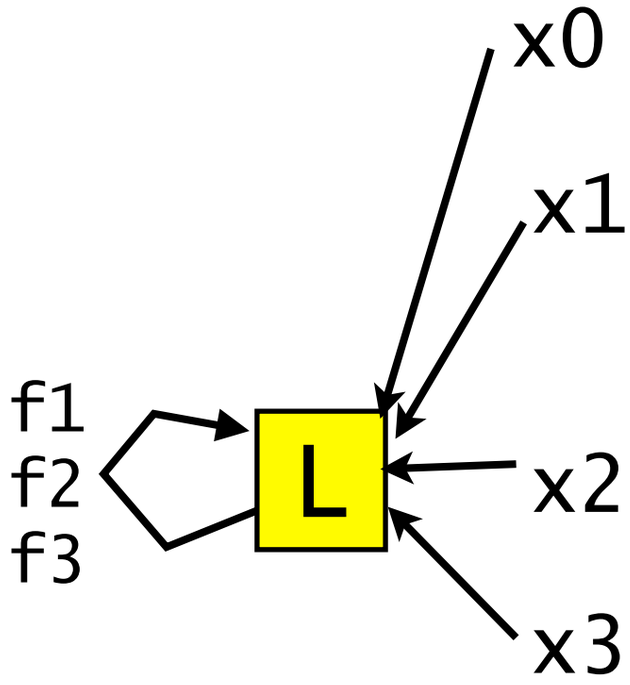

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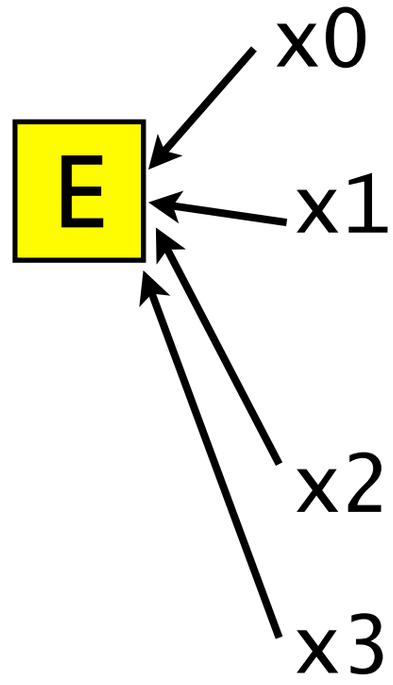

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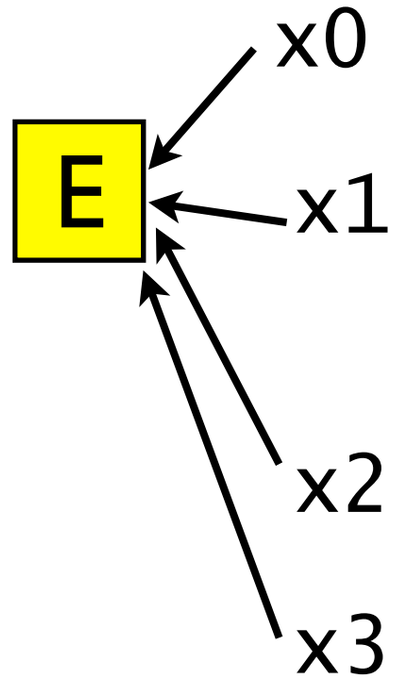
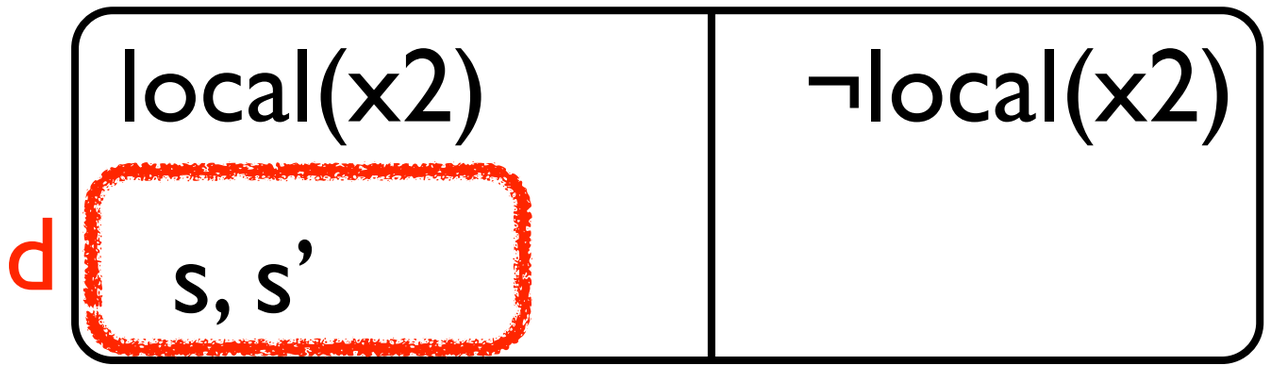
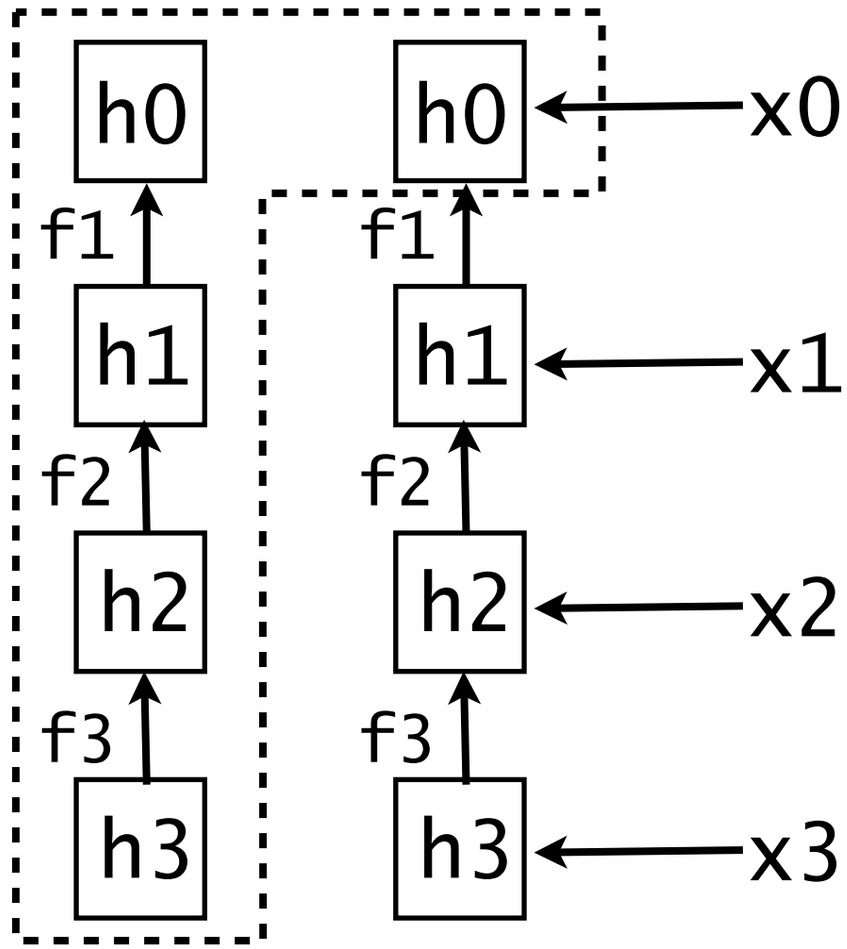


Separability question



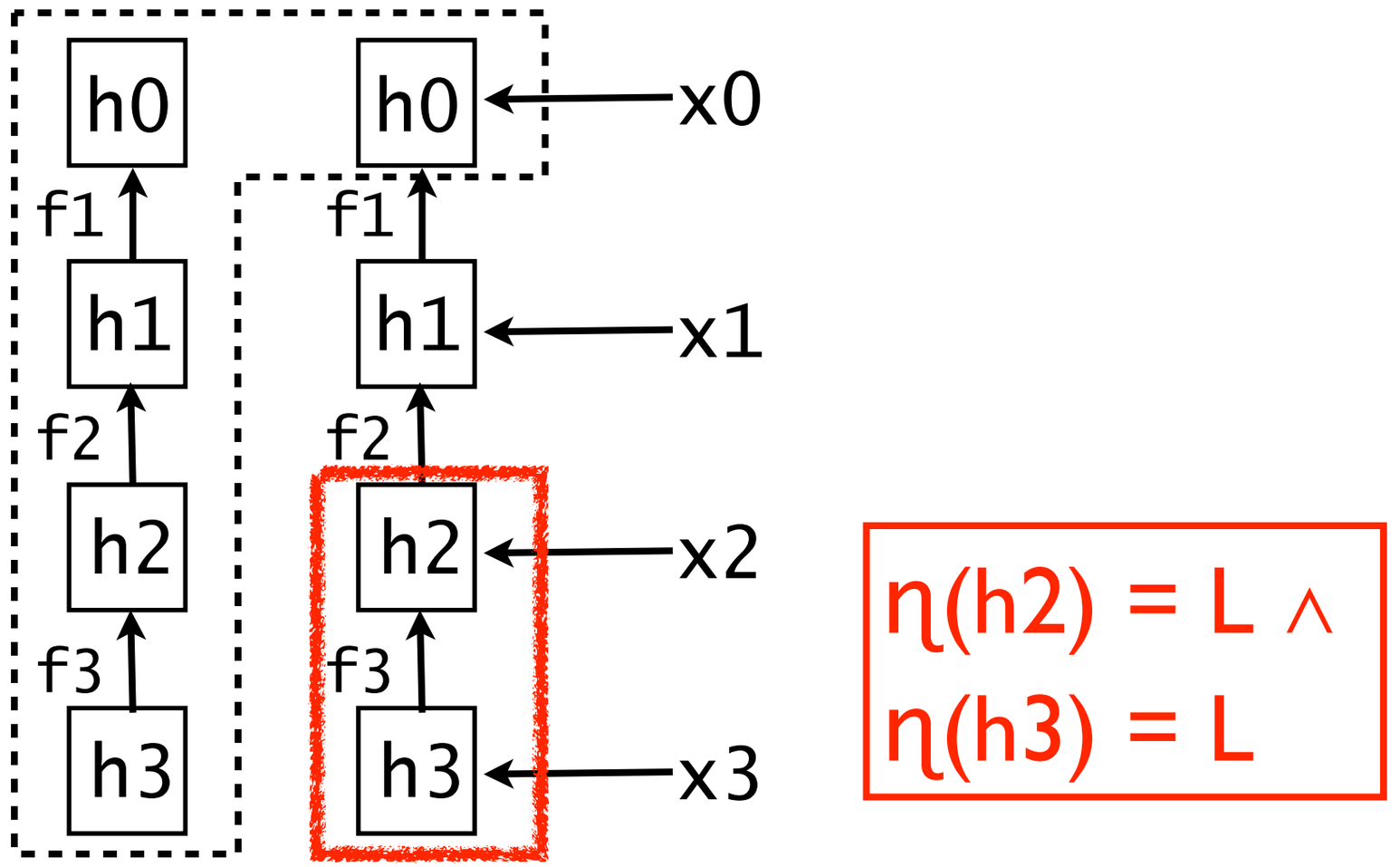
- Does analysis(η) have an abstract element d separating {s, s’} from ¬local(x2)?
- We use a generic answer to this question during our parameter inference.

Separability from ¬local(x2)



- This state satisfies local(x2).

Separability from ¬local(x2)

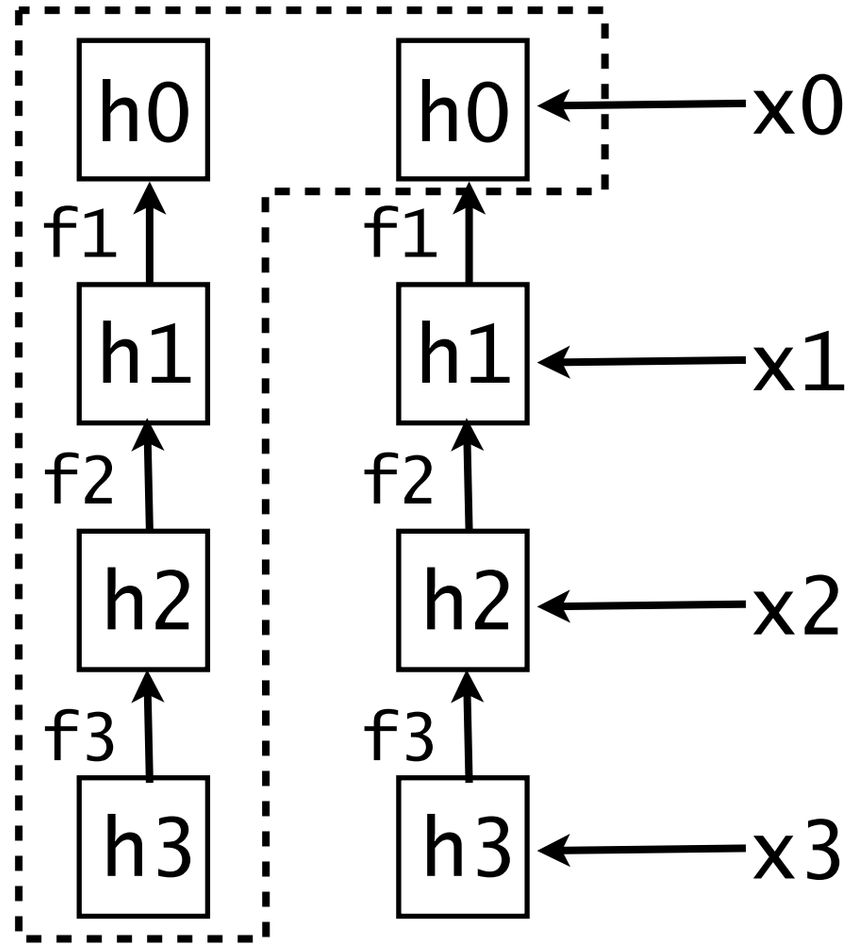


η(h2) = L ∧
η(h3) = L

- This state satisfies local(x2).
- Separated from ¬local(x2) by analysis(η) iff (η ∘ allocSite ∘ backReach)(x2) = {L}.

Parameter inference

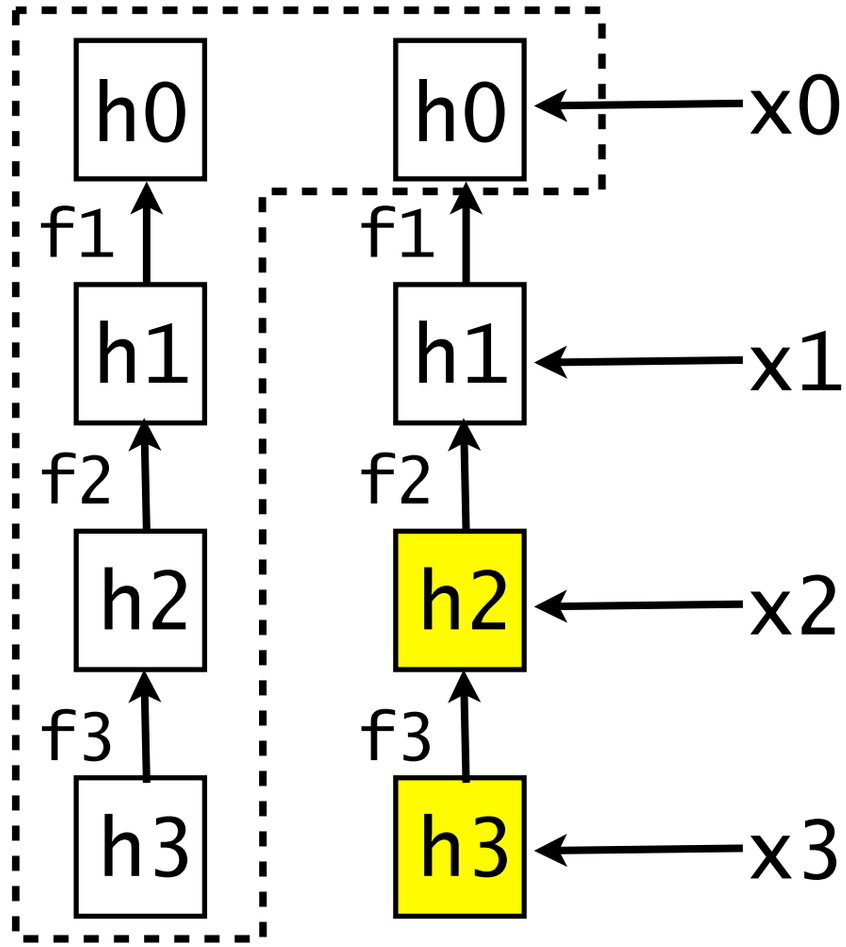
1. Testing gives states where local(x2) holds.



Parameter inference

1. Testing gives states where local(x2) holds.

2. Compute the alloc. sites H of objects that can reach x2.



H = {h2, h3}

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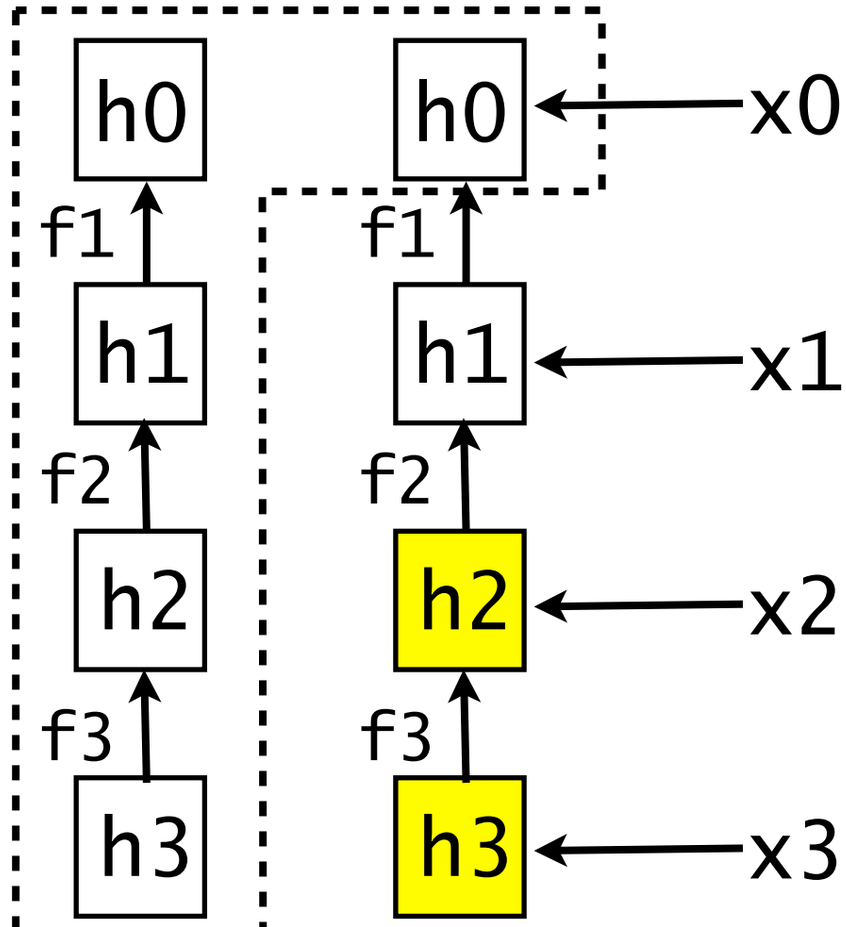

$H = \{h2, h3\}$

$\eta = [\{h0,h1\} \mapsto E, \{h2,h3\} \mapsto L]$

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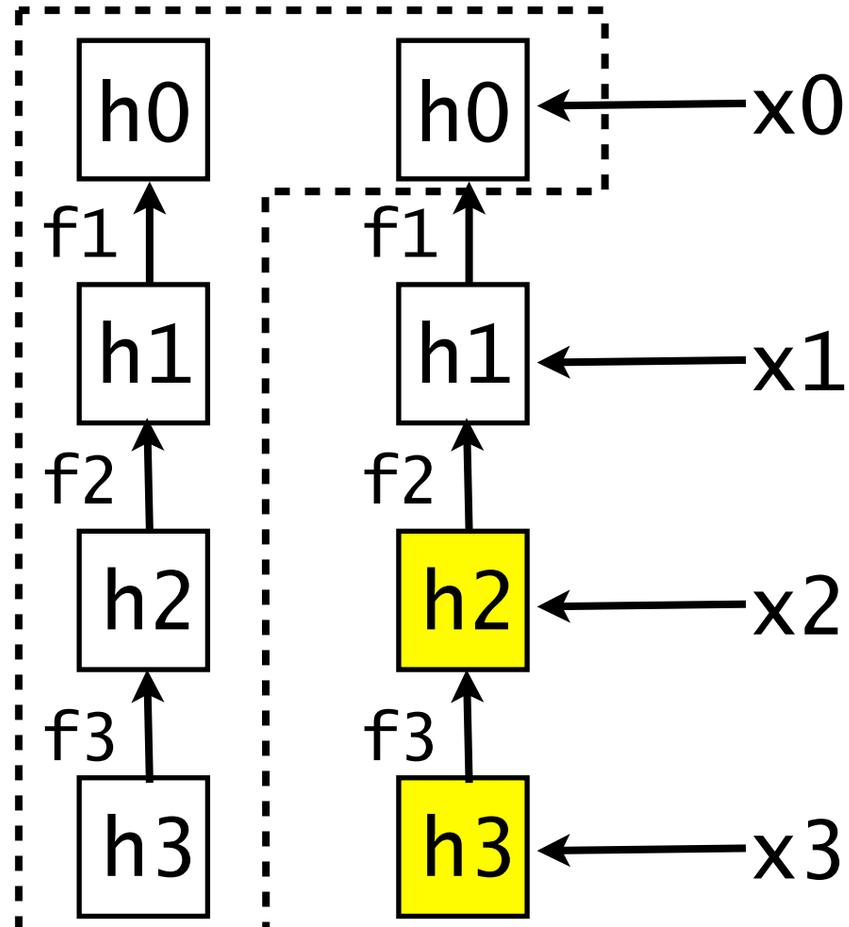

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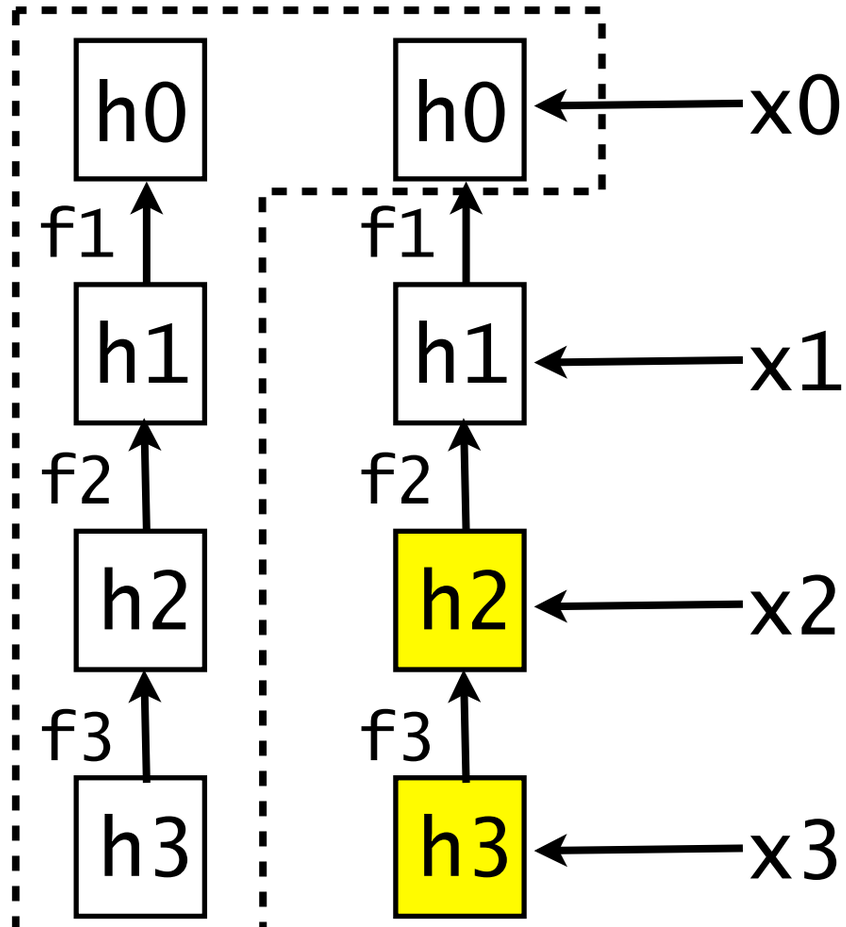
separability

minimality



H = {h2, h3}

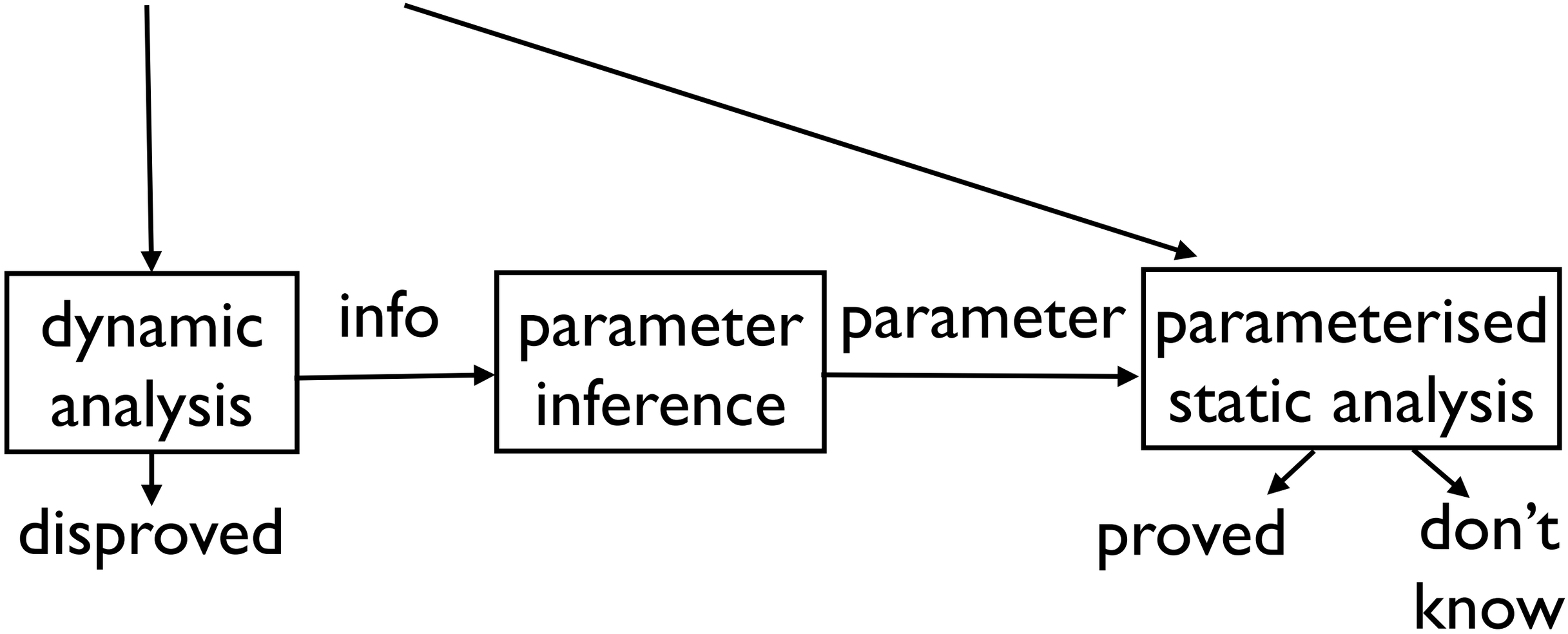
η = [{h0,h1}↦E, {h2,h3}↦L]

Does it work?

Setting of experiments

- 6 concurrent Java programs from Dacapo:
  - 161K - 491K bytecode (including analysed JDK).
    - Up to 5K allocation sites per program.
- 47K queries, but only 17K(37%) reached during testing.
- Considered only these reachable queries.

6 Java prog. (161K-491K) up to 5K sites
17K queries



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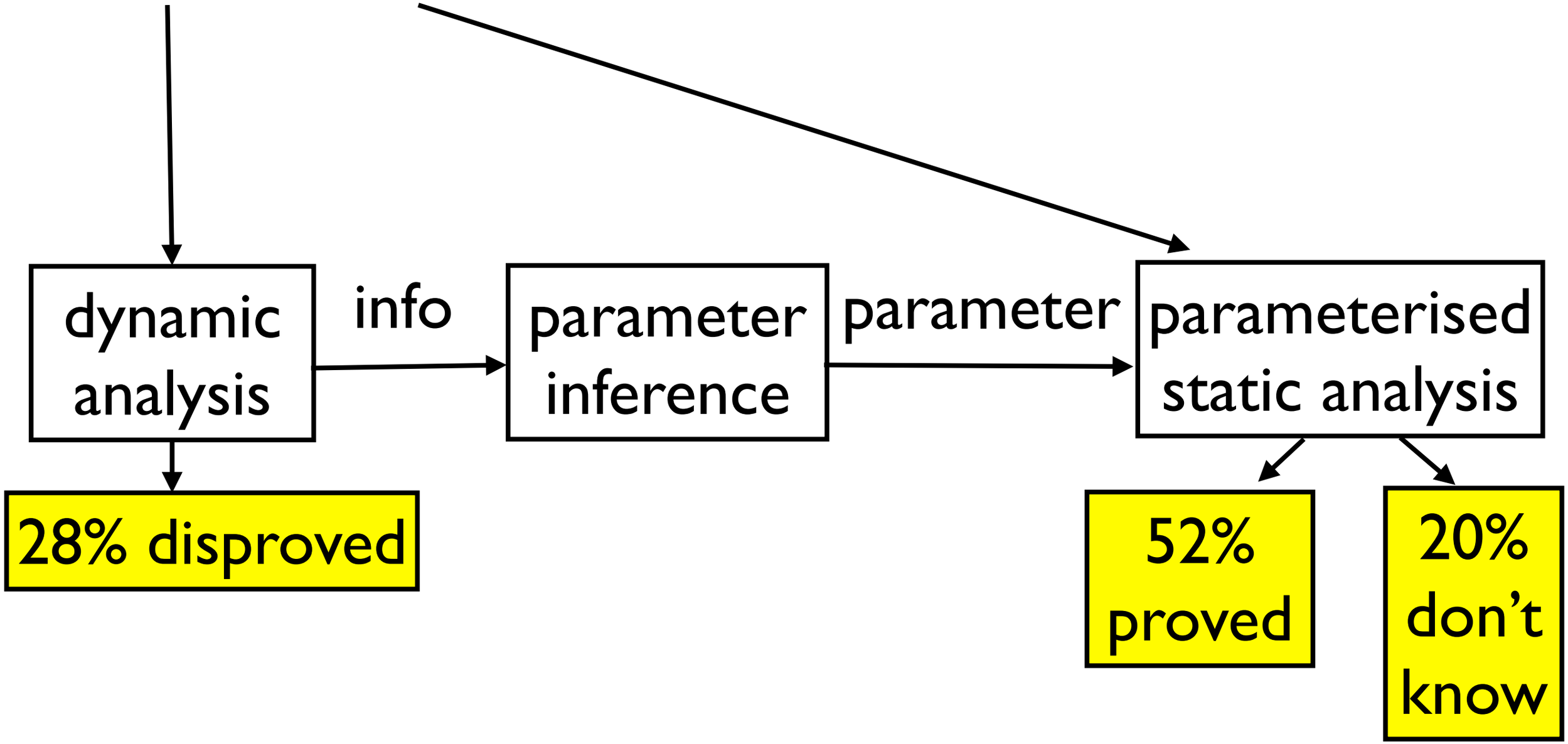

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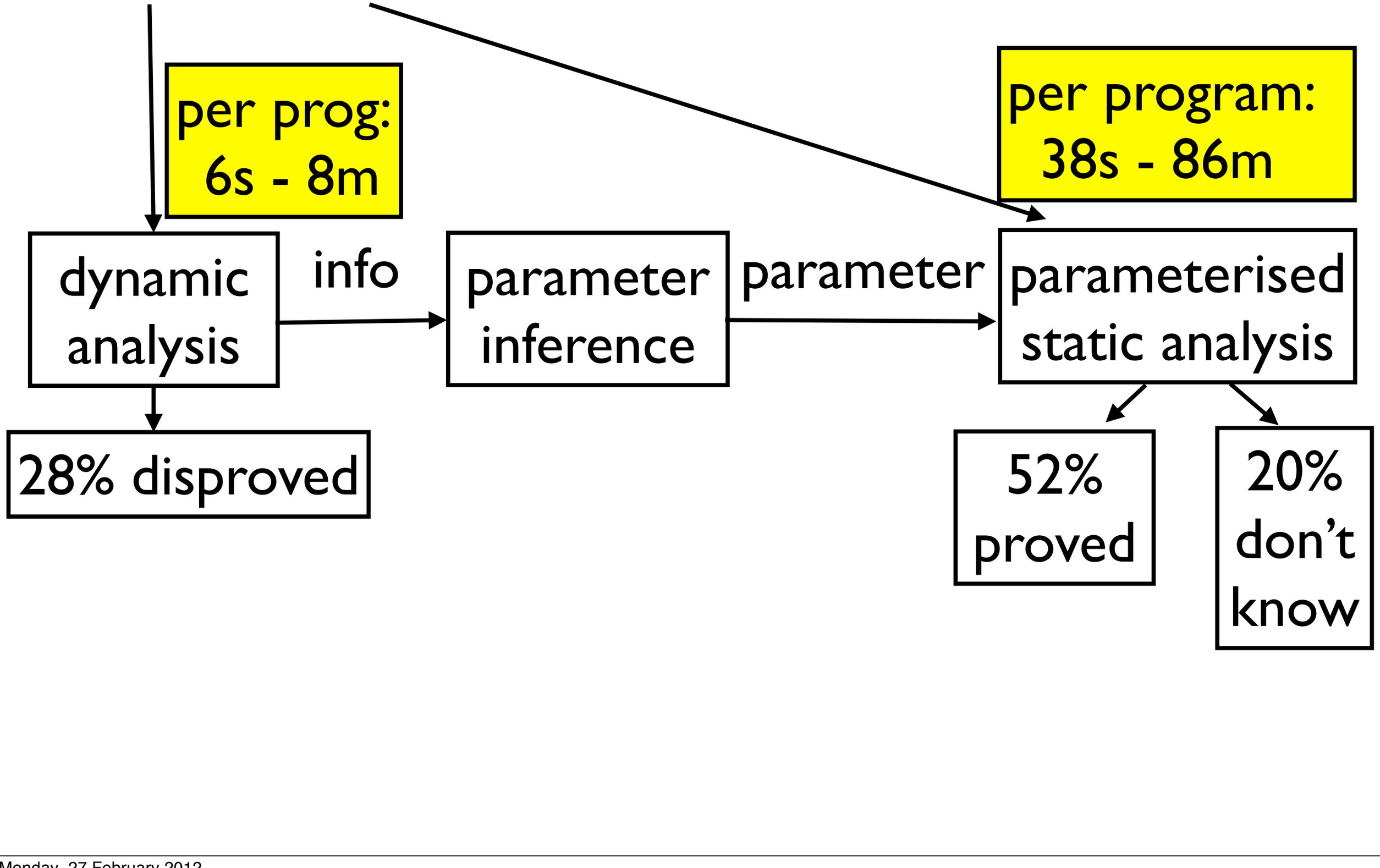

6 Java prog. (161K-491K) up to 5K sites
17K queries

per prog:
6s - 8m

per program:
38s - 86m

dynamic analysis

info

parameter inference

parameter

parameterised static analysis

28% disproved

L-mapped sites:
avg 4.8, max 195

52% proved

20% don't know

6 Java prog. (161K-491K) up to 5K sites
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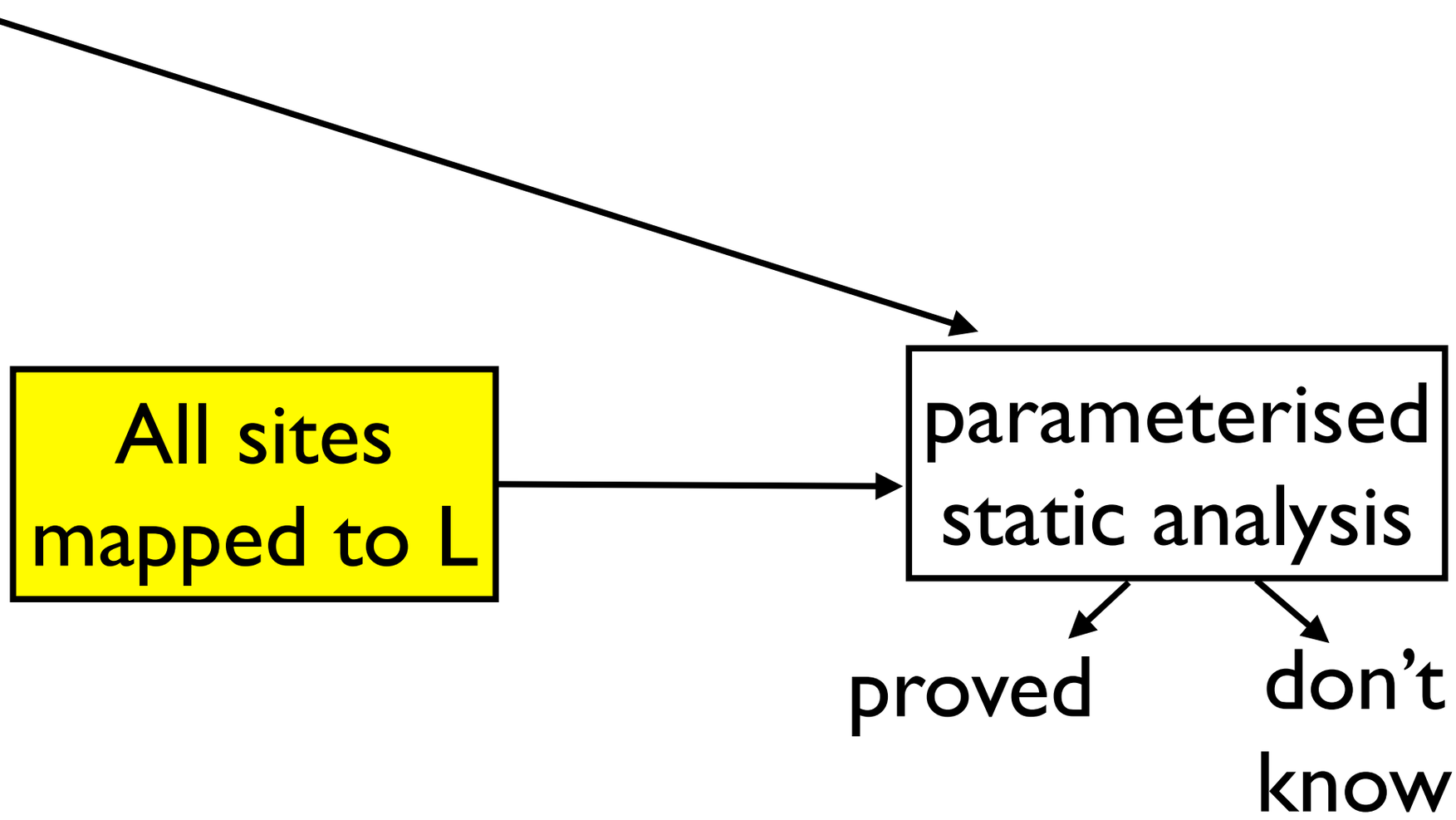

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