Incremental Bidirectional Typing via Order Maintenance

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Goal: Live programming

“Programming with continuous editor services”

Goal: Live programming

"Programming with continuous **editor services**"

```
List.map(~f=
 ((key: list(p(ZipperBase.t)),
   persistent_state: persistent_state)) => {
  switch (find_id_opt(specs, key)) {
  | Some((_n, spec)) =>
```

Goal: Live programming

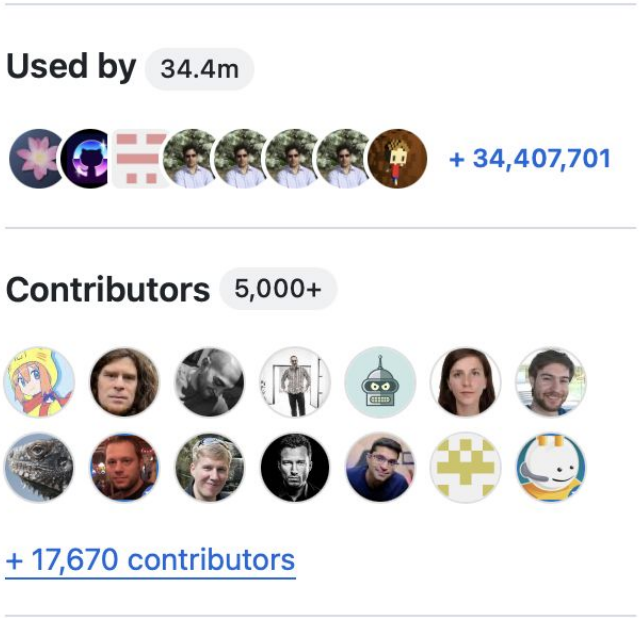
"Programming with **continuous** editor services"

1. Unfailingly (in all editor states)
2. Quickly

Goal: Live programming

"Programming with continuous editor services

... at scale"



Goal: Live programming

"Programming with continuous editor services

... **at scale**"

Computational commons:

Wikipedia-sized collaborative program

Problem

Live programming ⇒ fast services

At scale ⇒ large programs

Type checking is Ω(program size)

???

Solution

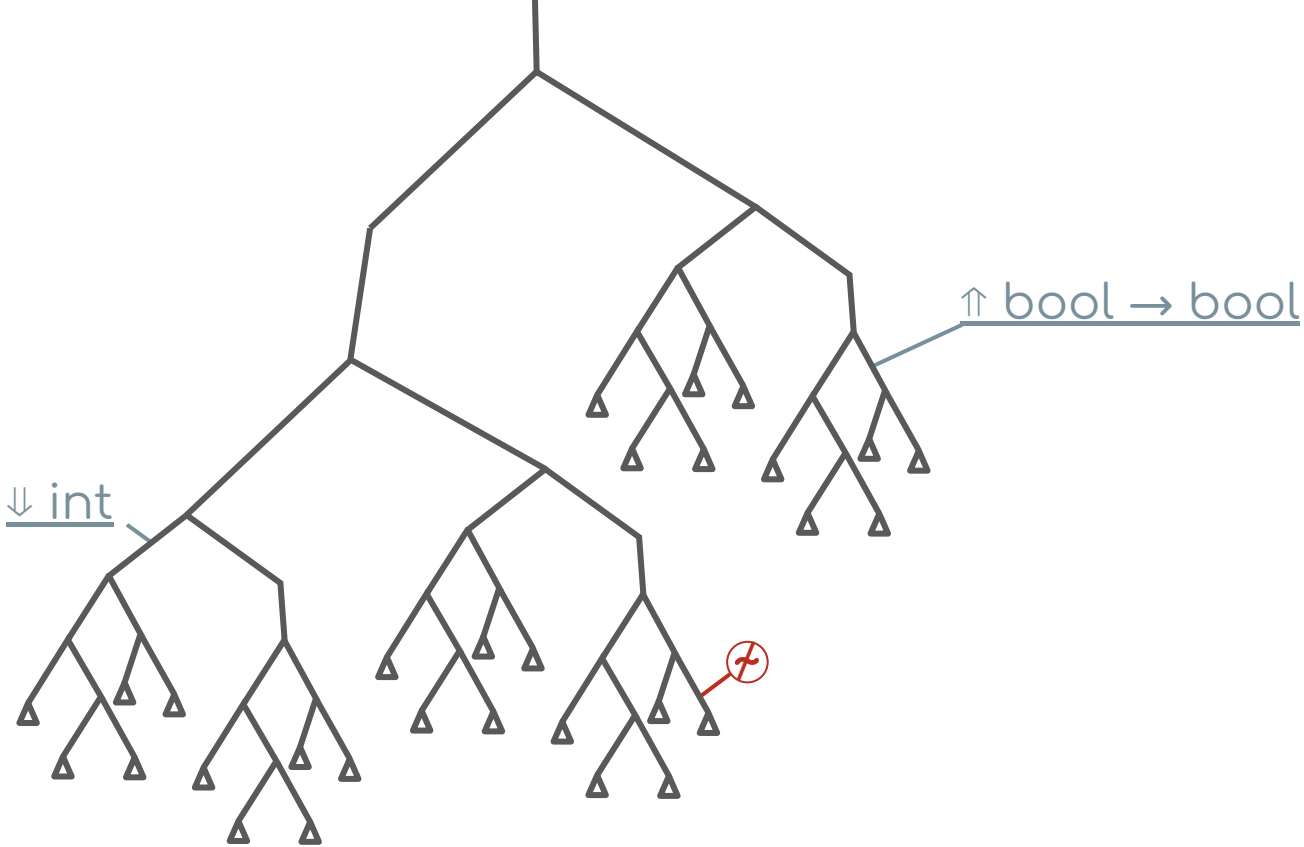
~~Type check each program~~

Key insight:

Most changes are small...

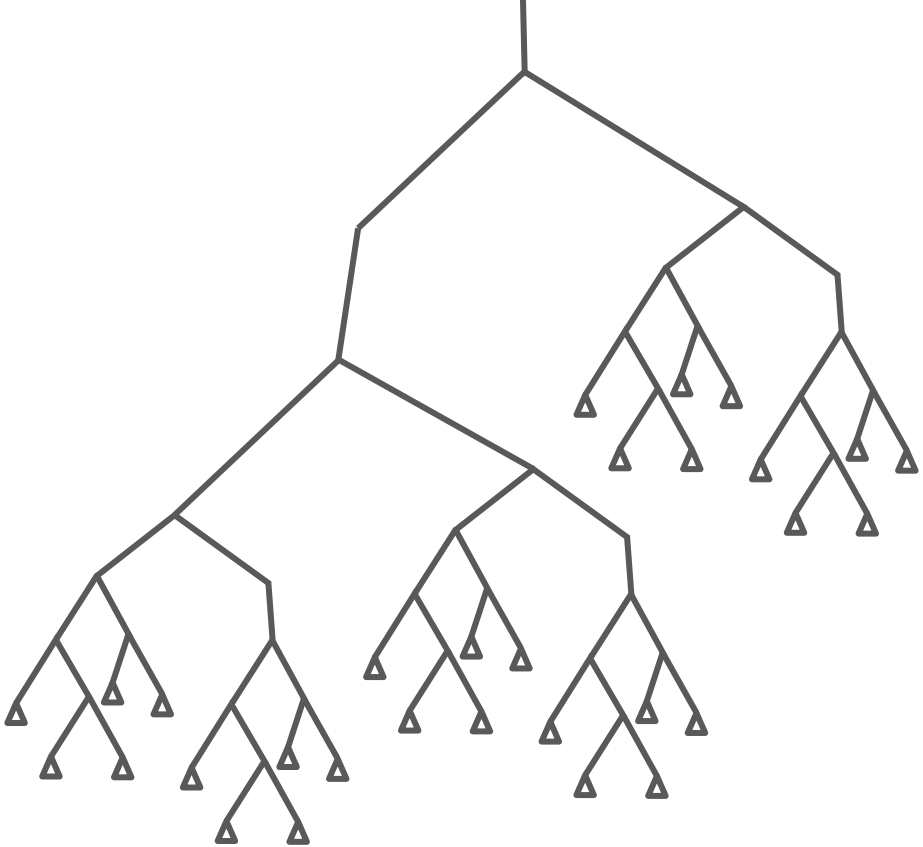
⇒ Reuse typing information!

(Incrementalization)

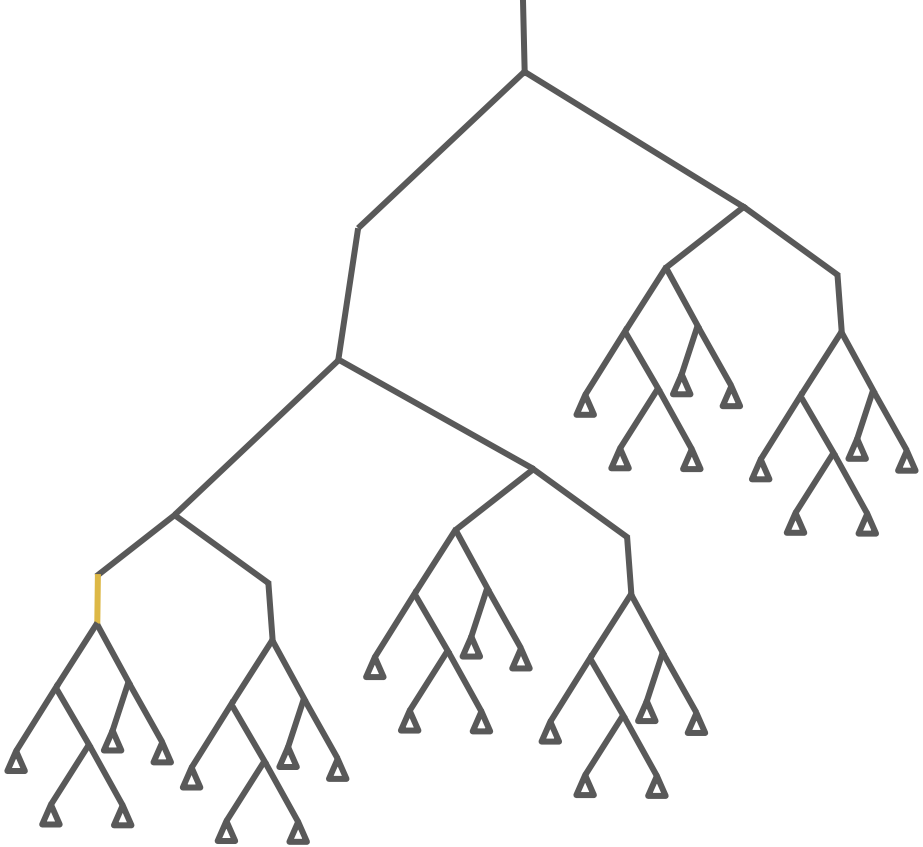


Marked and annotated tree

(marked lambda calculus, Zhao et al. POPL 2024)

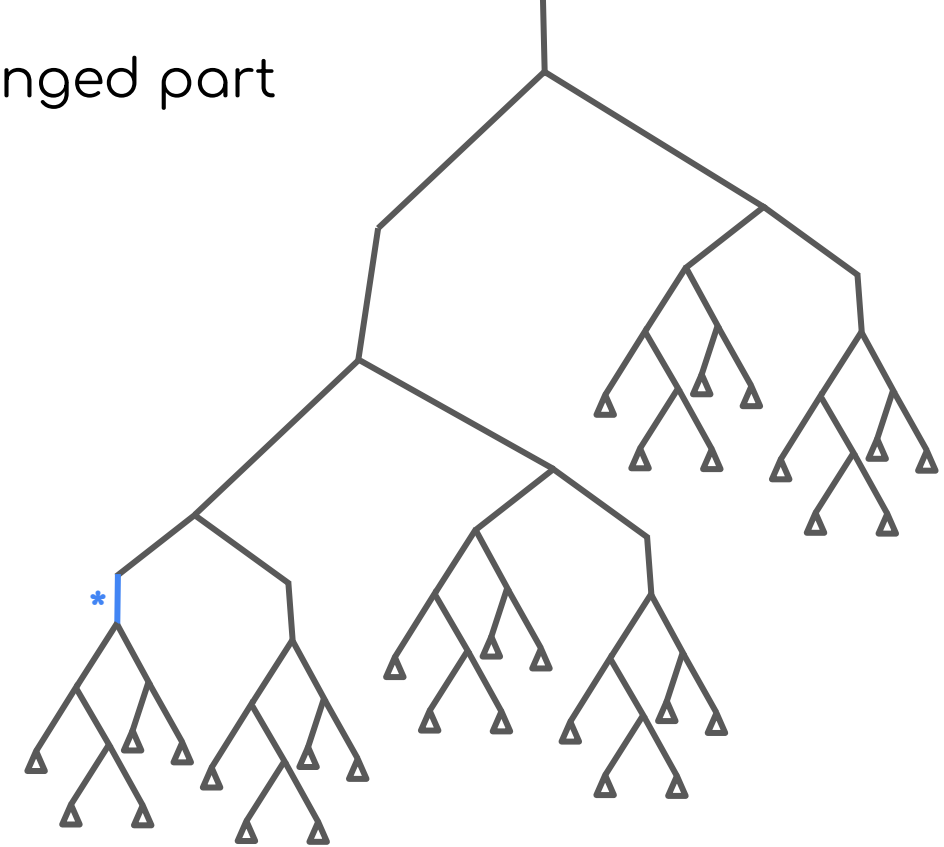


Local propagation



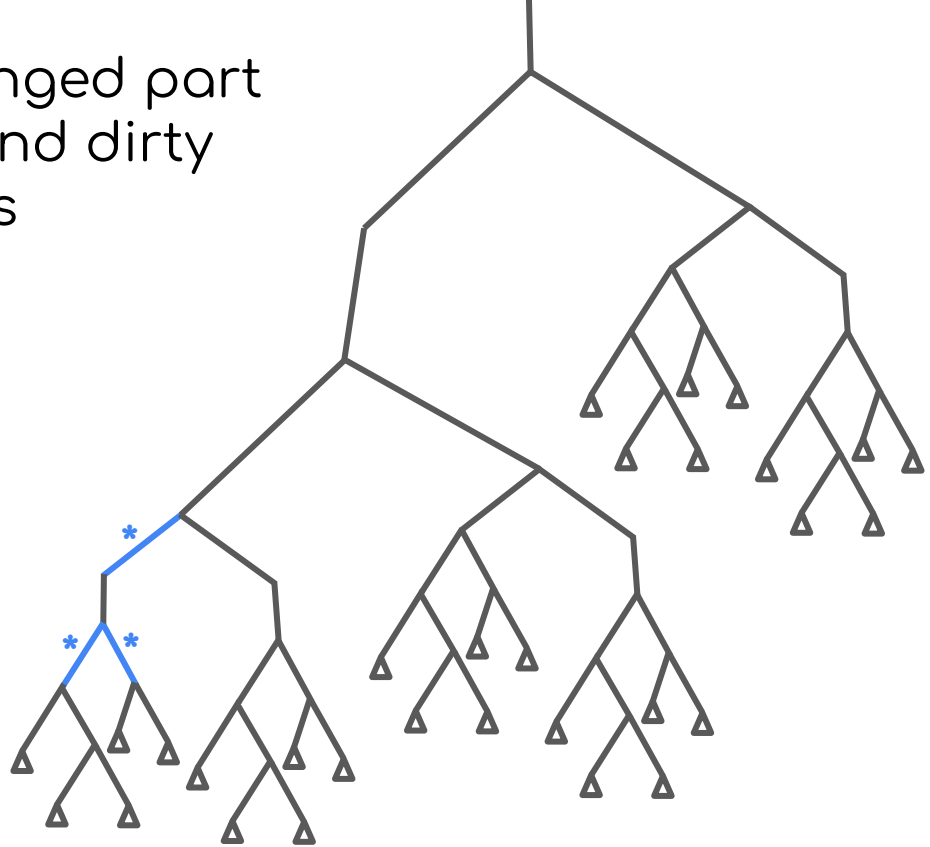
Local propagation

1. Dirty changed part



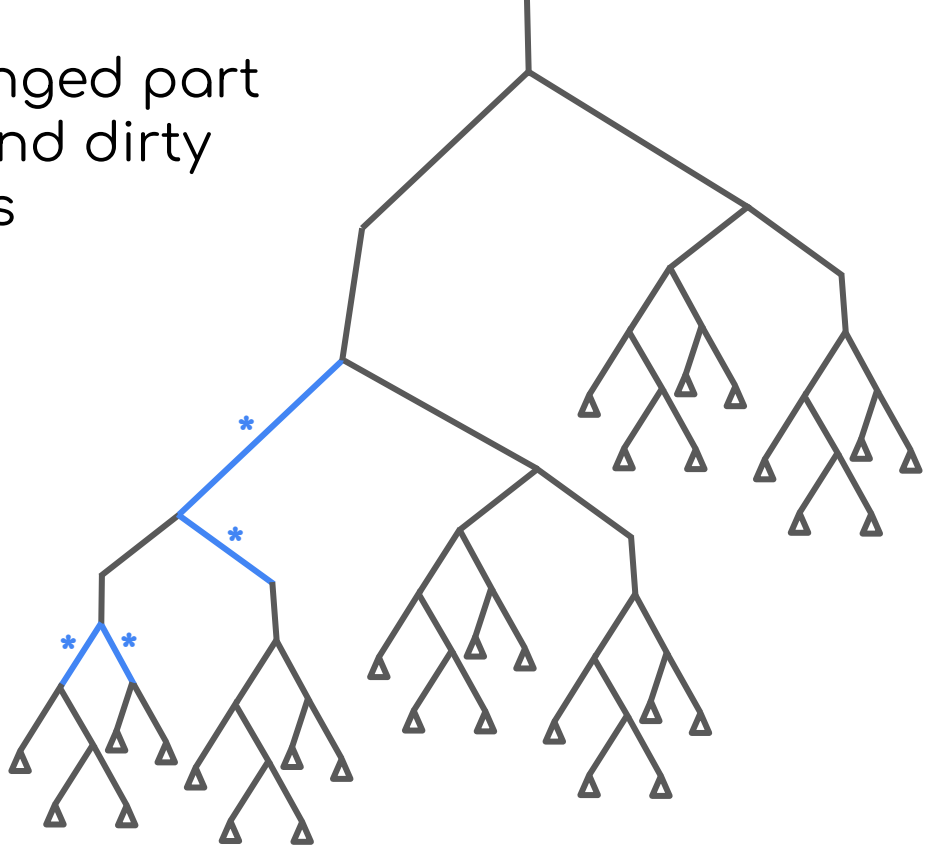
Local propagation

1. Dirty changed part
2. Update and dirty neighbors



Local propagation

1. Dirty changed part
2. Update and dirty neighbors
3. Repeat



Local propagation

1. Dirty changed part
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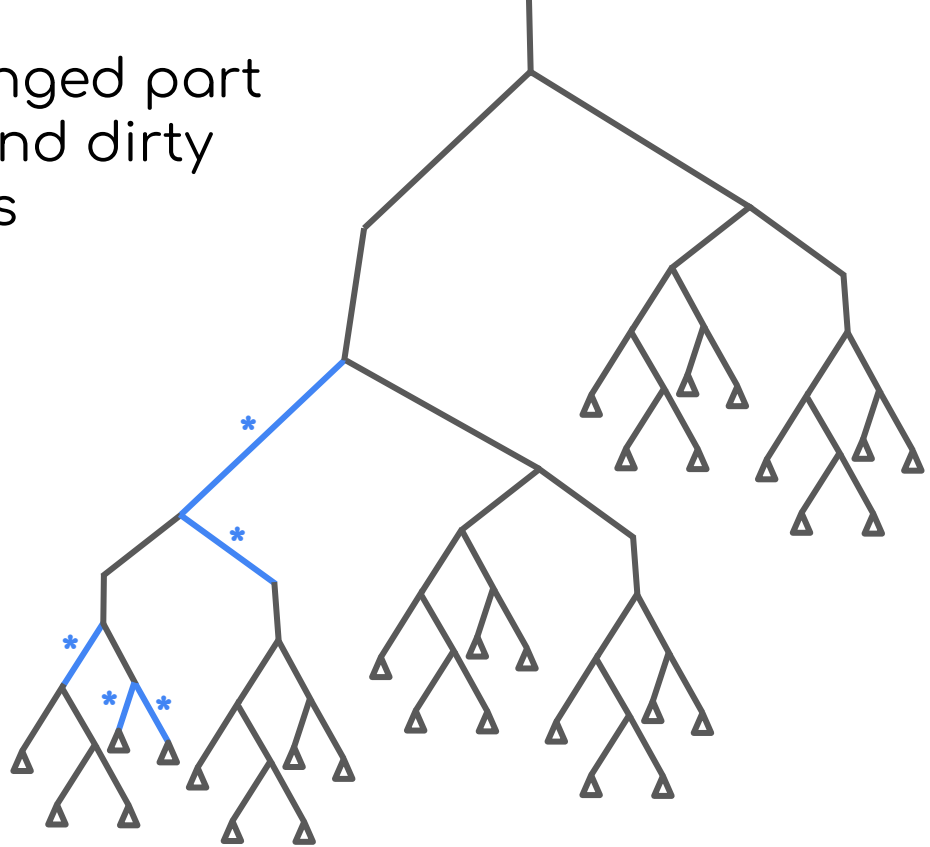
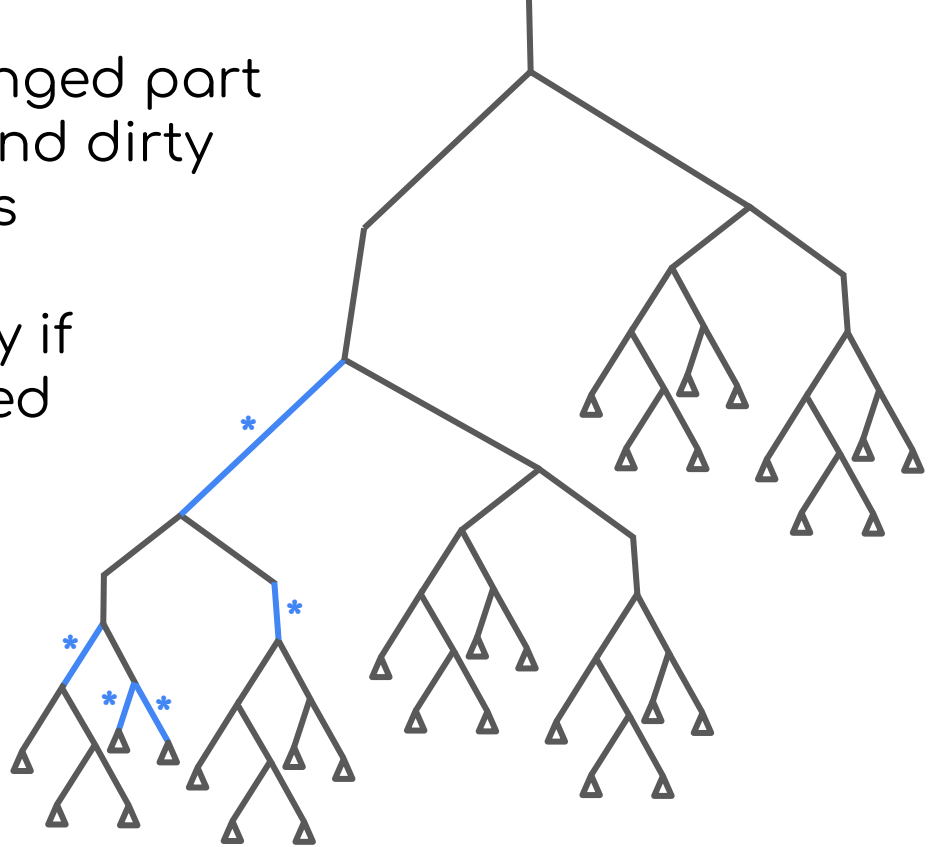


Local propagation

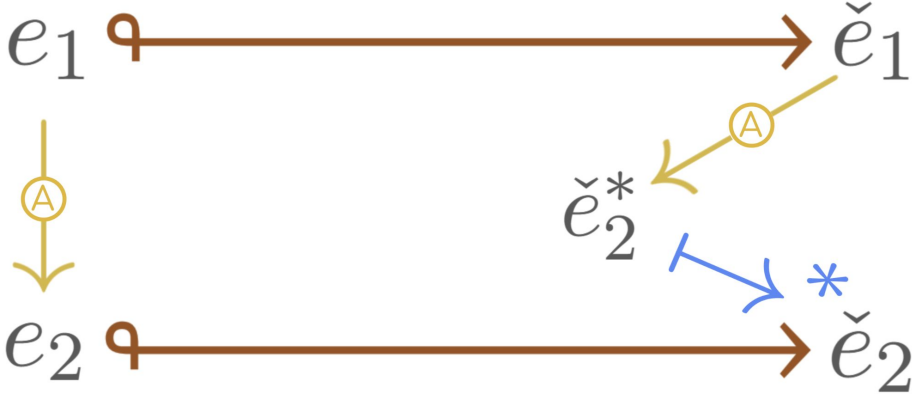
1. Dirty changed part
2. Update and dirty neighbors
3. Repeat
4. Don't dirty if unchanged



Local propagation

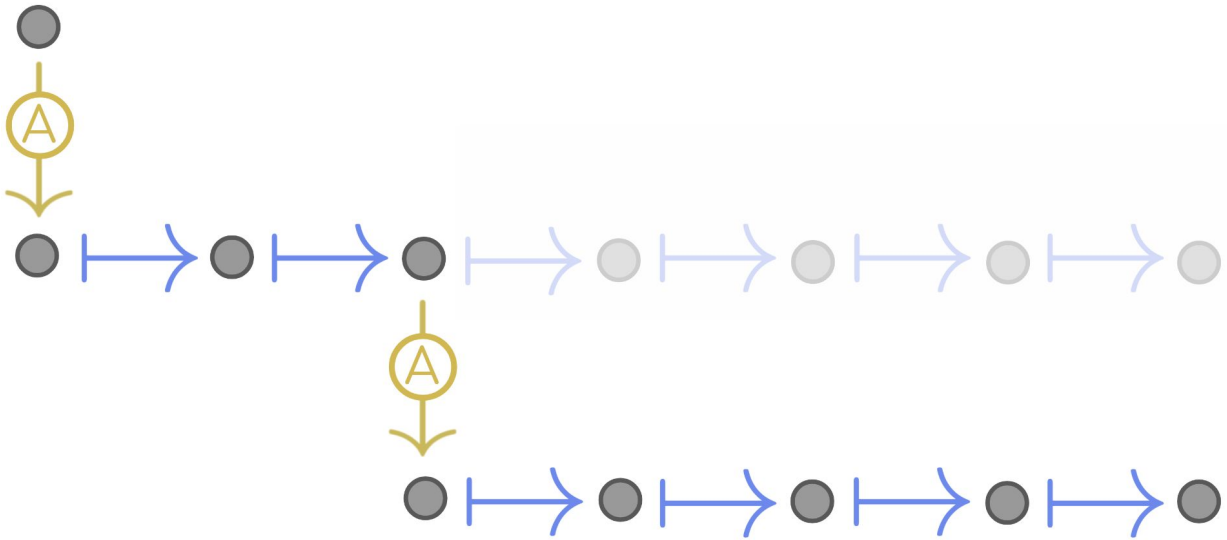
Properties

THEOREM 5.1 (VALIDITY). *If program p is well-formed and $p \xmapsto{\overline{A}} p'$, then p' is well-marked.*



Properties

THEOREM 5.2 (CONVERGENCE). *If program p is well-formed, $p \xmapsto{\overline{A}} p_1$, and $p \xmapsto{\overline{A}} p_2$, then $p_1 = p_2$.*



Properties

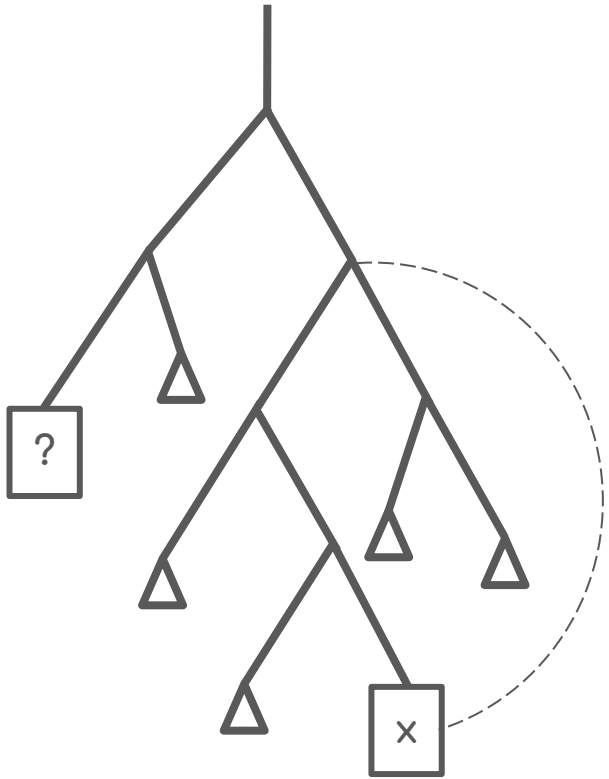
THEOREM 5.3 (TERMINATION). *There is no infinite sequence* $\{p_n\}_{n=0}^{\infty}$ *such that* $\forall n.\ p_n \longmapsto p_{n+1}$.

Update propagation terminates.

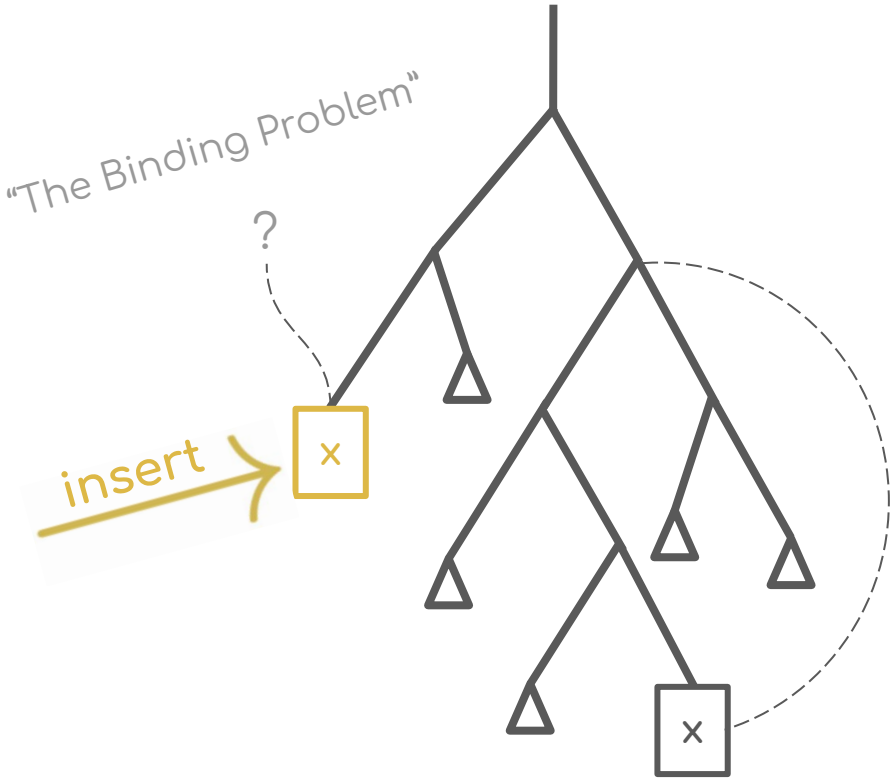
Problems

1. Order of updates?
2. Type checking isn't local
   ⇒ Maintain bindings

Binding Pointers

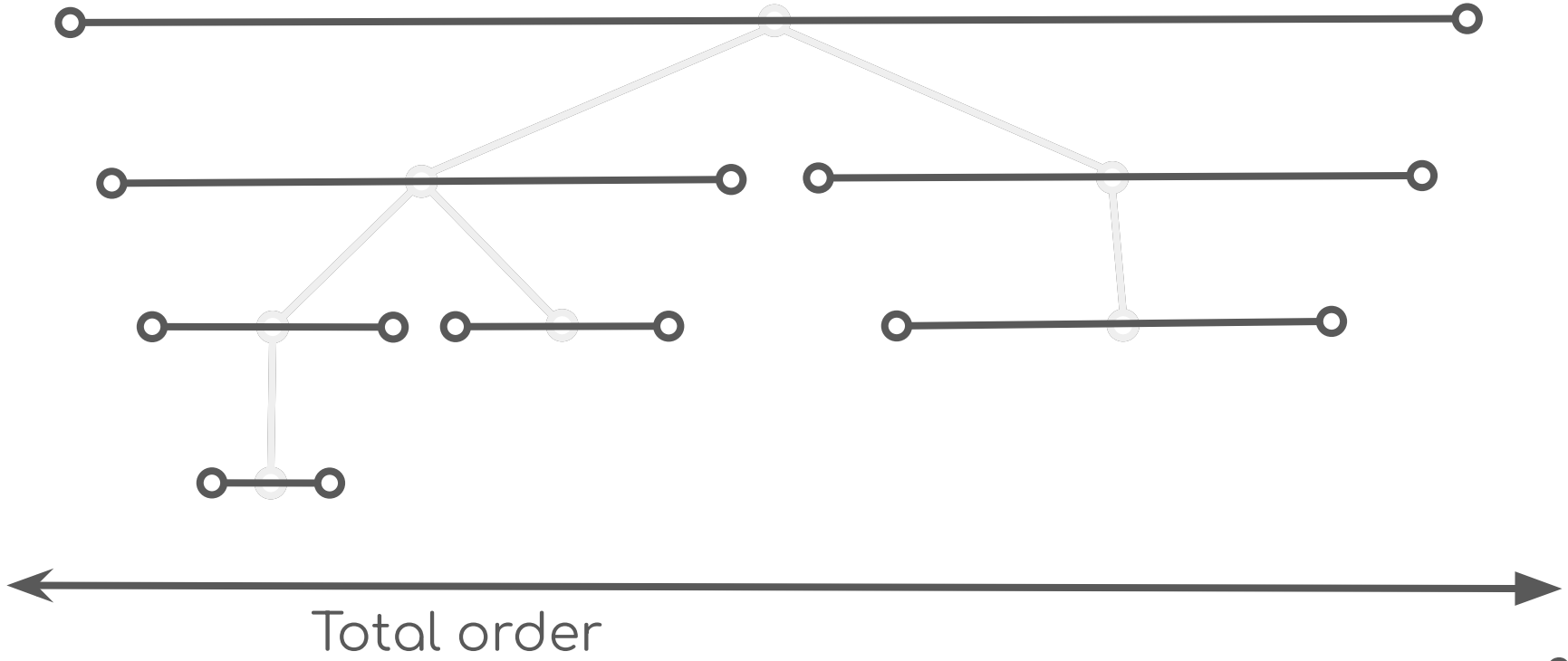


Binding Pointers

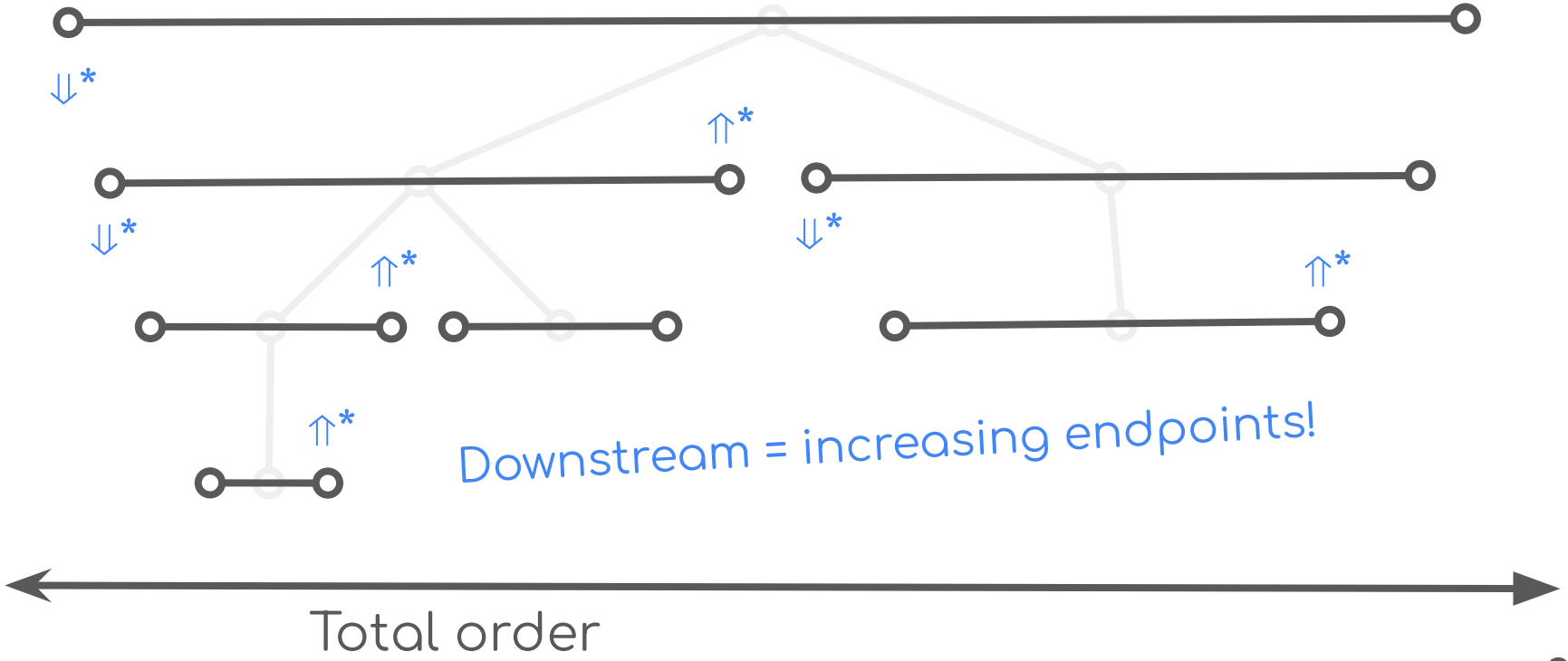


Order Maintenance

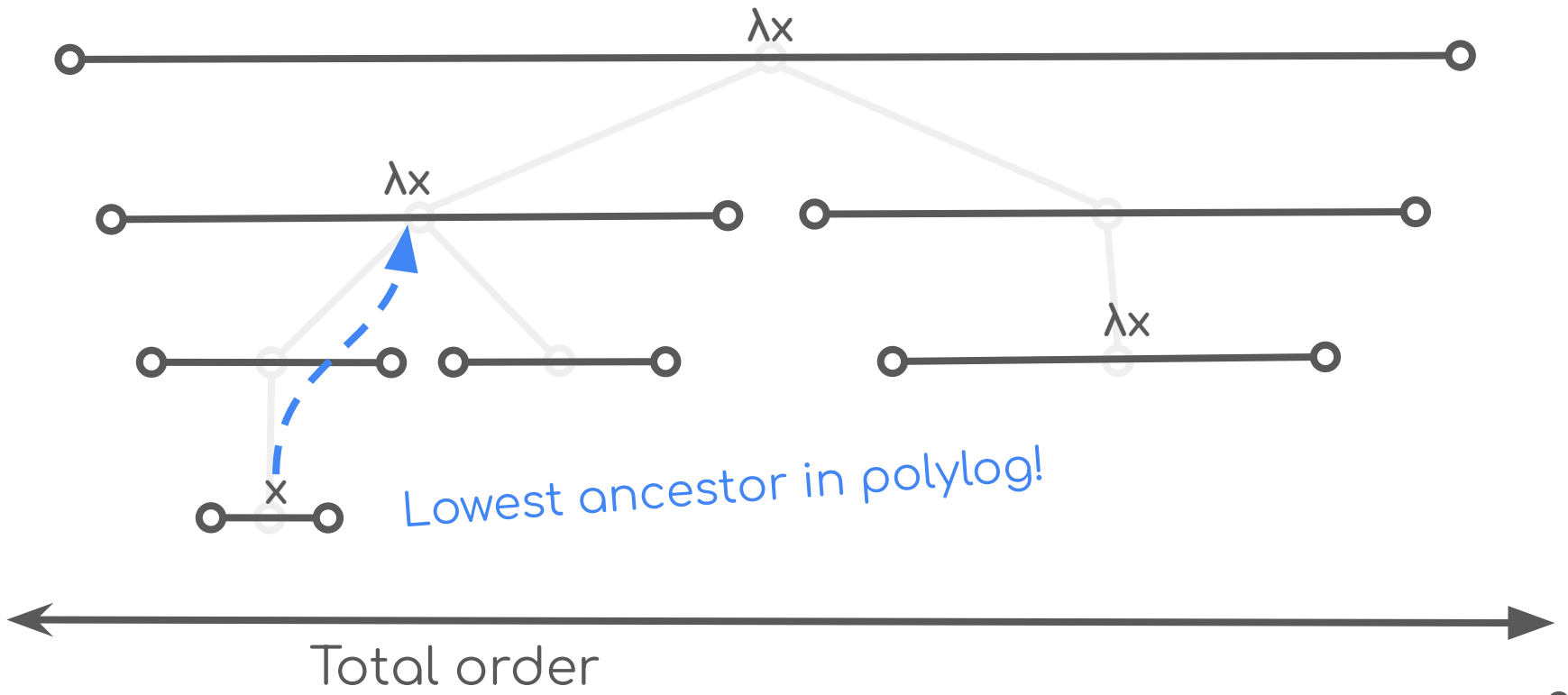
“Circumfix” Order Intervals



“Circumfix” Order Intervals



“Circumfix” Order Intervals



Two Algorithms for Maintaining Order in a List

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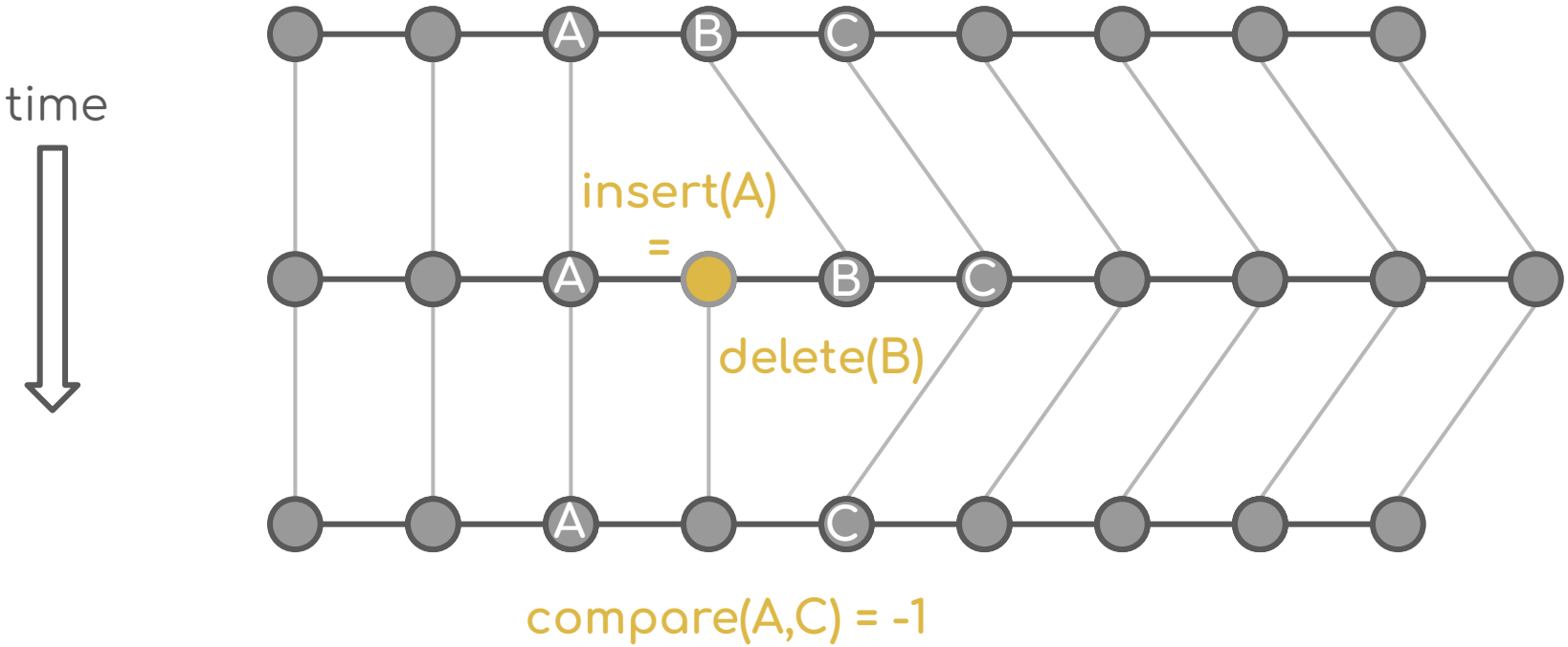
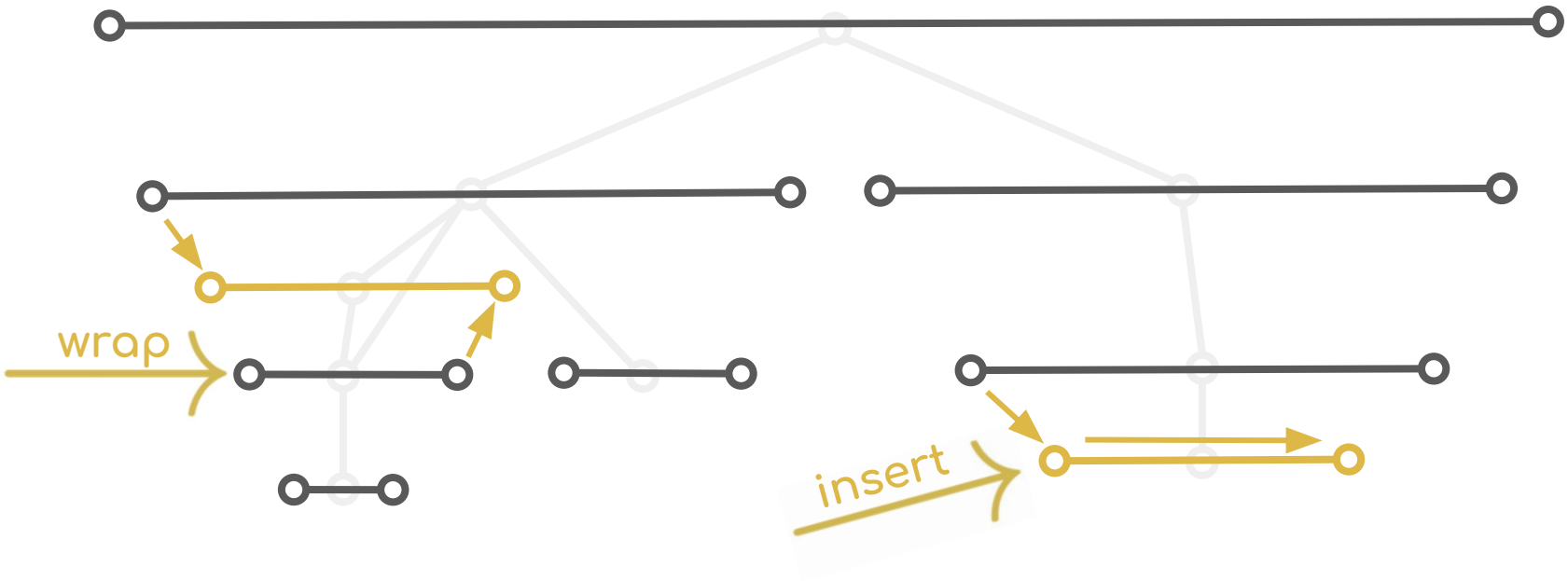
Maintaining Order



Maintaining Intervals



Prior Work

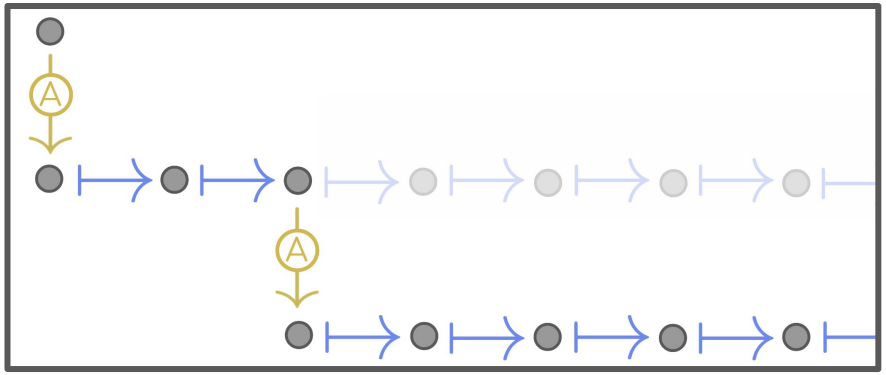
Language implementations

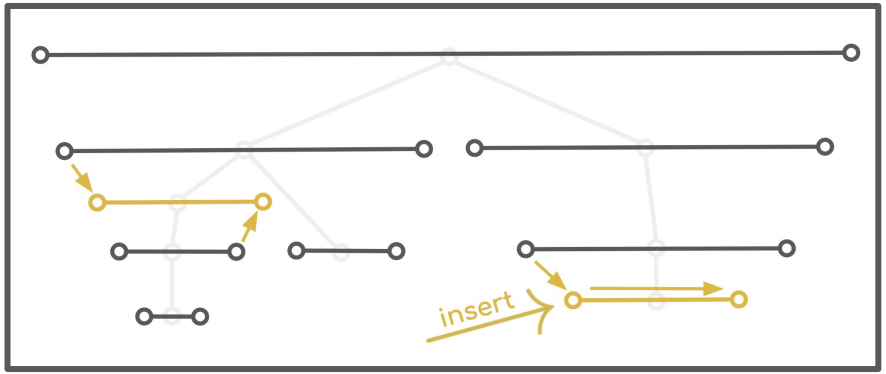
Adaptive FP: Acar et al, ‘02

Datalog: Pacak et al, ‘20 & Szabó et al, ‘16

Browser layout: Kirisame et al, ‘25

Thank you!




insert