Forgetful Memoization in Ocaml

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LABORATOIRE DE RECHERCHE EN INFORMATIQUE

UNIVERSITÉ PARIS-SUD 11

Memoization

Computing a function with a cache

```
let memo_f =
  let cache = H.create () in
  fun k →
    try H.find cache k
    with Not_found →
      let v = f k in
      H.add cache k v;
      v

let v1 = memo_f k1 in
...
let v2 = memo_f k2 in (* k2=k1 => O(1) *)
```

Avoid Memory Leaks

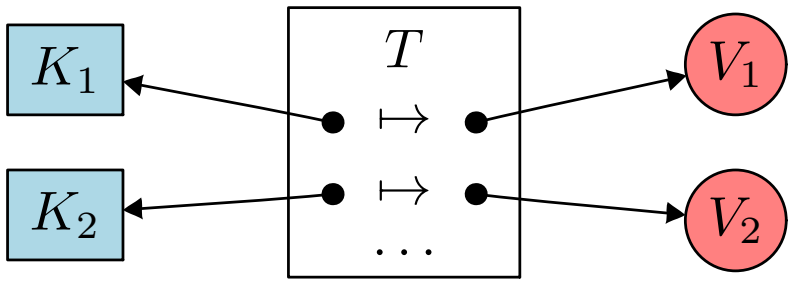
If a key is not needed anymore,
we want to remove the entry from the cache

Particular case: heap-allocated keys
not needed anymore means not reachable (apart from the cache)

Some (Partial) Solutions

Naive Solution

T is a traditional dictionary data structure
(hash table, balanced tree, etc.)



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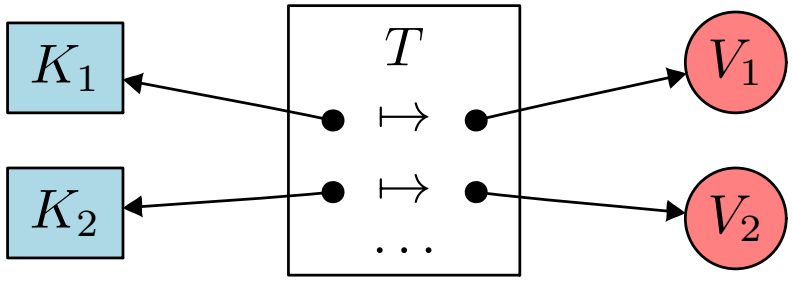


major drawback

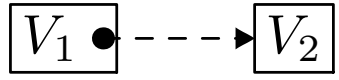
T reachable $\Rightarrow$ all keys and values bound in T are also reachable

conclusion

T should not hold pointers to keys

Weak Pointers

a value can weakly point to another value, depicted

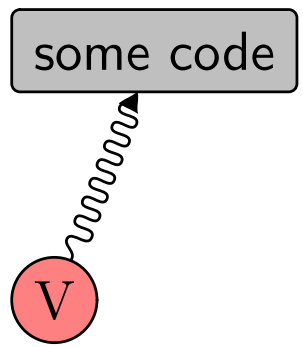


a value not yet reclaimed can be accessed via a weak pointer

```
val get : α Weak.t → int → α option
```

Finalizers

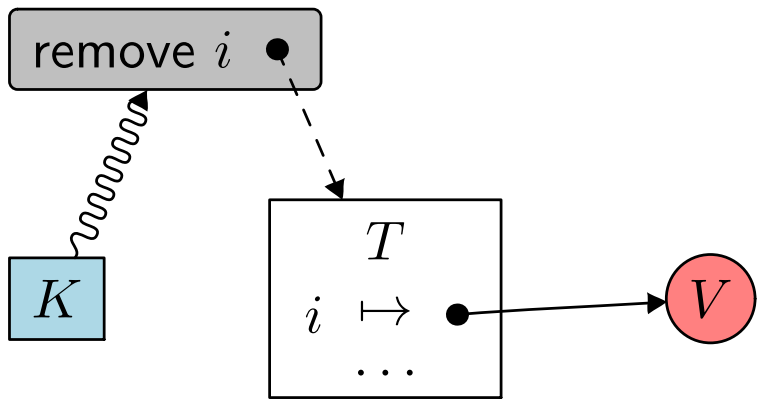
one or several finalizers can be attached to a value



a finalizer is a closure which is executed whenever the corresponding value is going to be reclaimed

A Better Solution?

K is not used directly as index in T



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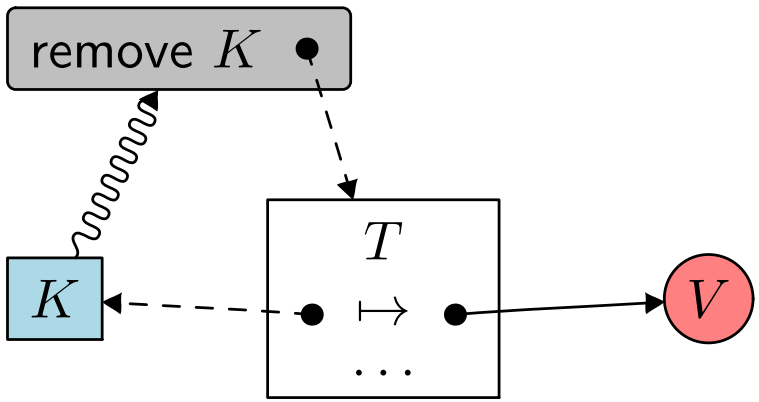
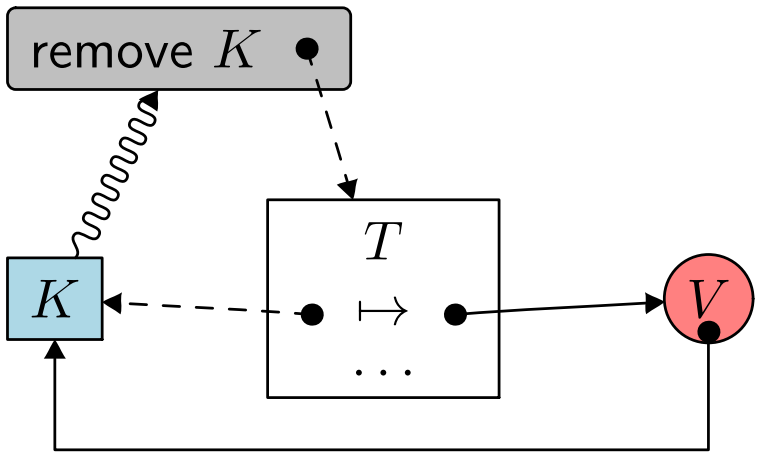


A Better Solution?

it seems to be a good solution...
but a key can be reachable from a value



preventing K to be reclaimed

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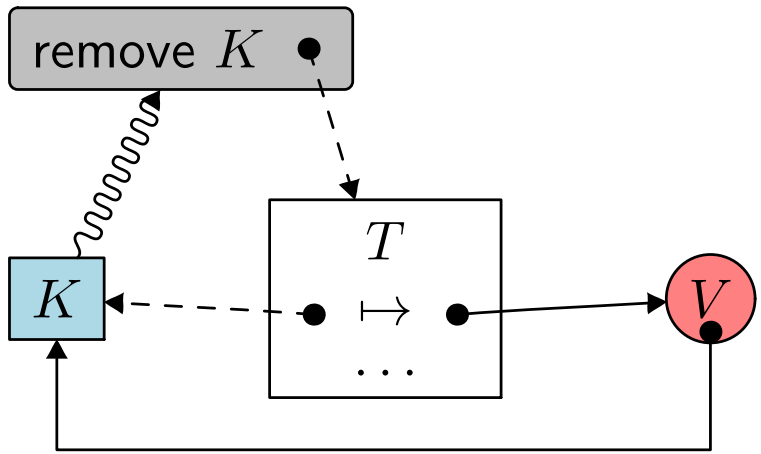


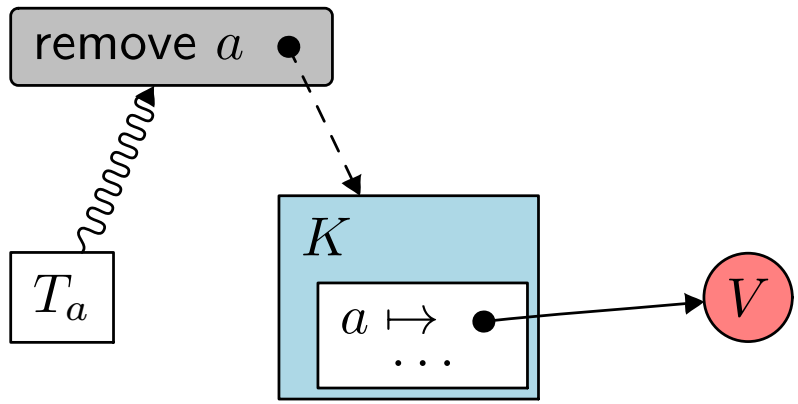
preventing K to be reclaimed

conclusion T should not hold pointers to values either

A Better Solution!

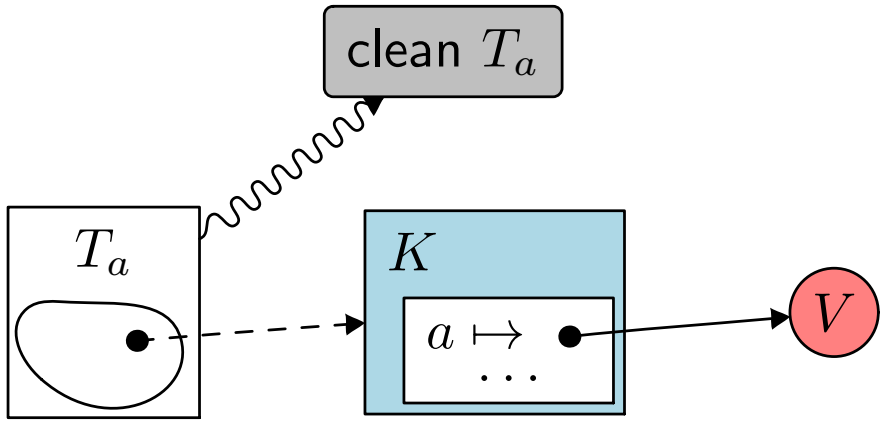
we cannot store bindings inside tables

$\Rightarrow$ let us keep them in keys instead



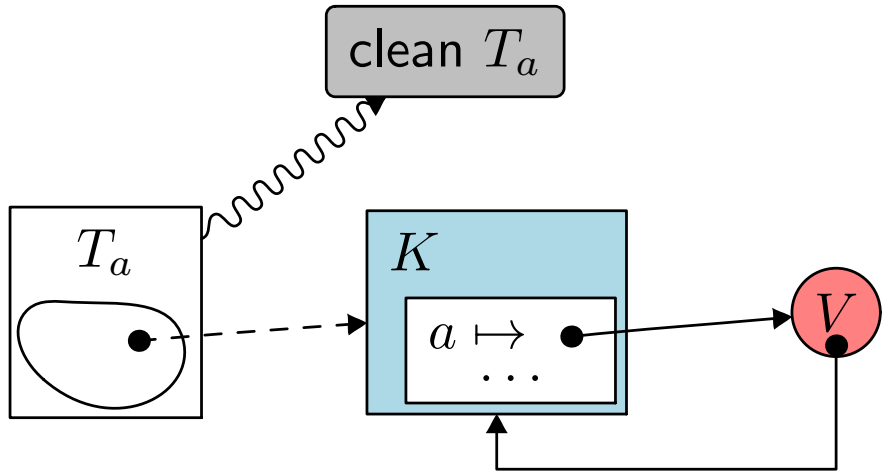
A Better Solution!

improvement: only one finalizer instead of one per key



A Better Solution!

K reachable from V is not a problem anymore



(note: you can implement a similar solution in Haskell using `System.Mem.Weak`)

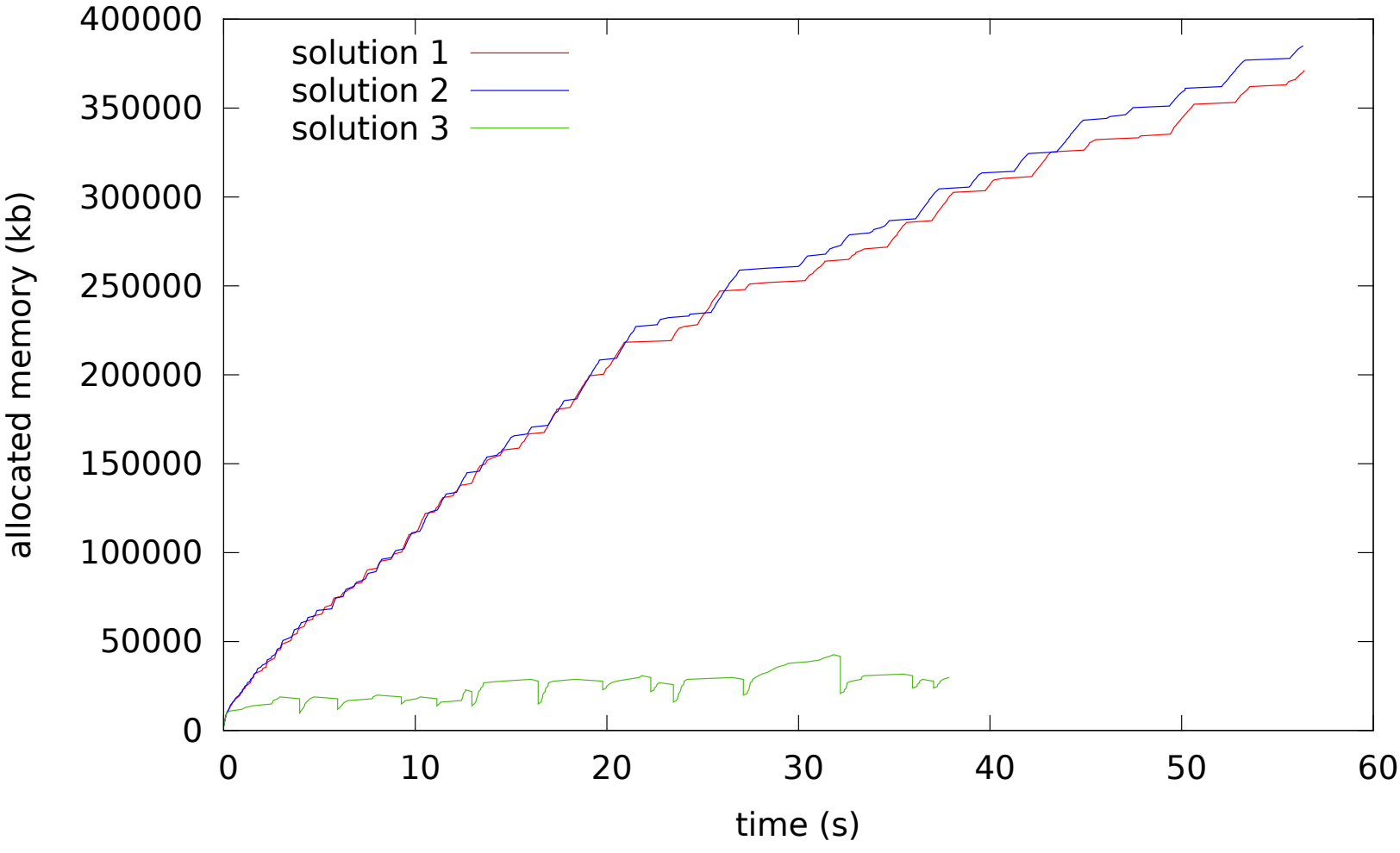
Implementation

implemented as an Ocaml library

```
type cache (* = (int, Obj.t) Hashtbl.t *)

type α key = private {
  node  : α;
  cache : cache;
}

val create : α → α key

val memoize : (α key → β) → (α key → β)
```

Benchmarks

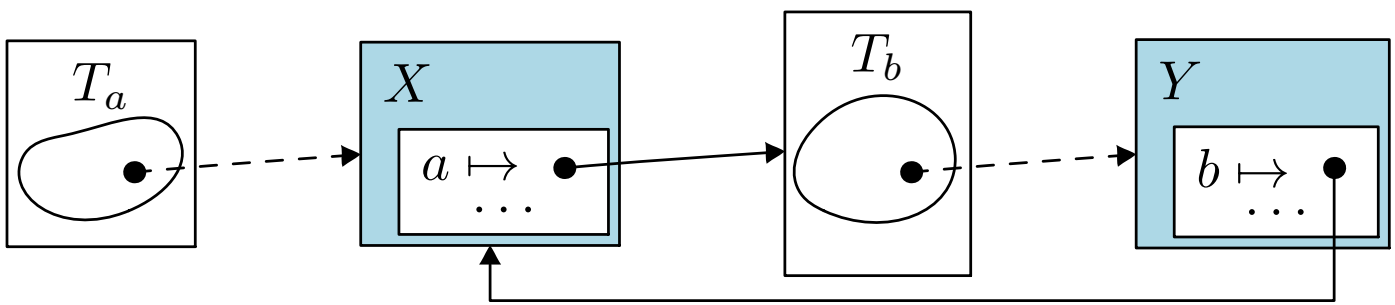
transformation of 1,448 proof tasks sharing subterms



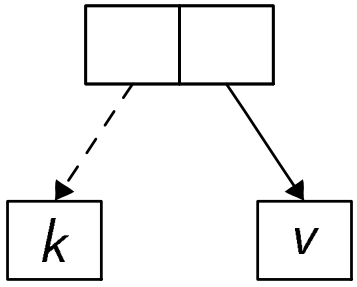
Still not Perfect

of course, the roles of K and T being symmetric,
if T is reachable from V the "cycle issue" is still there

example: we want to memoize the **K** combinator $\mathbf{K}(X, Y) = X$
we first memoize the partial application to X, the result being another memoization table



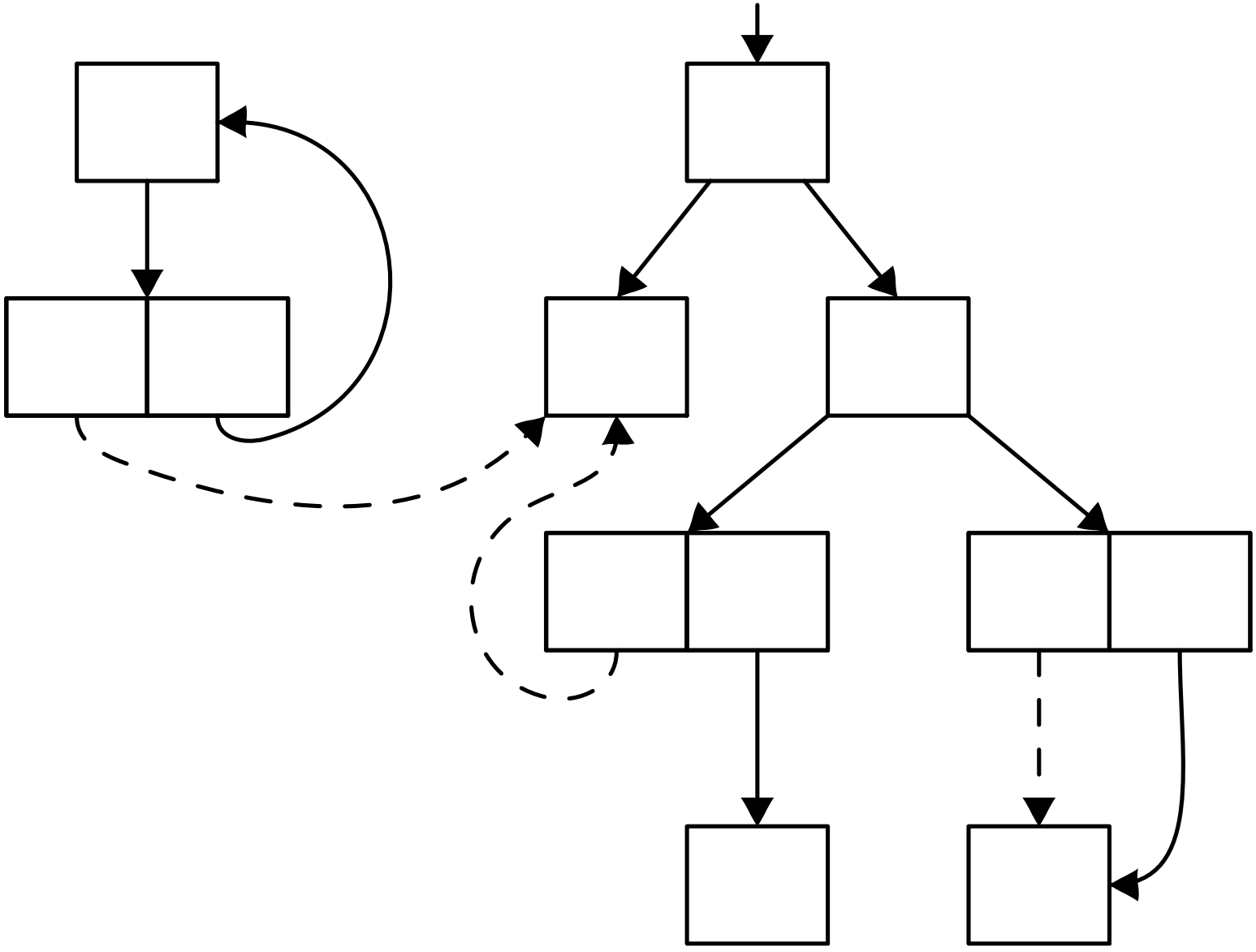
Ephemerons [Hayes 1997]



v can be reclaimed
if *k* or the ephemeron can be reclaimed

```
module Ephemeron : sig

    type (α,β) t

    val create : α → β → (α,β) t

    val check : (α,β) t → bool
    val get : (α,β) t → β option
    val get_key : (α,β) t → α option

end
```

Garbage Collection with Ephemerons



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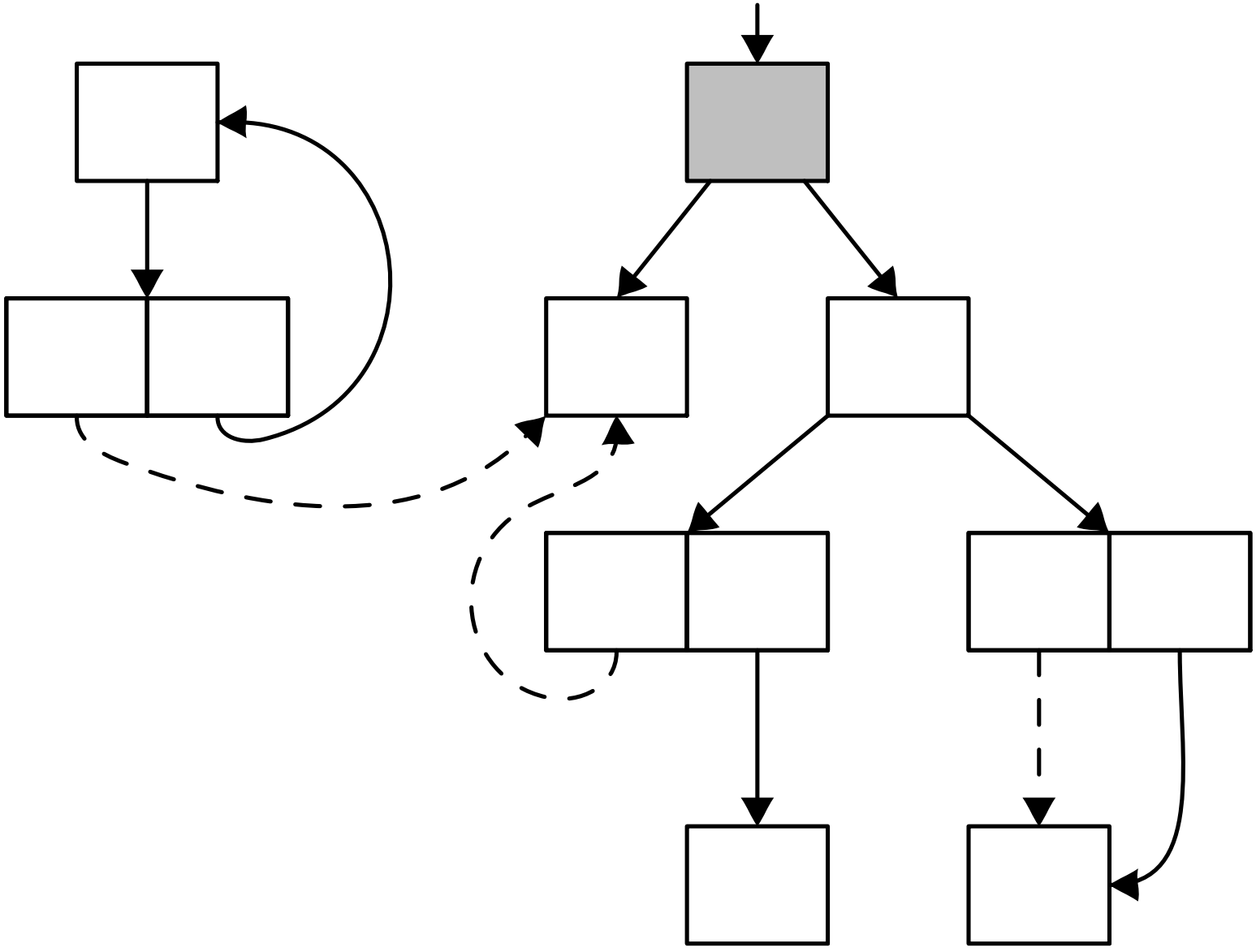

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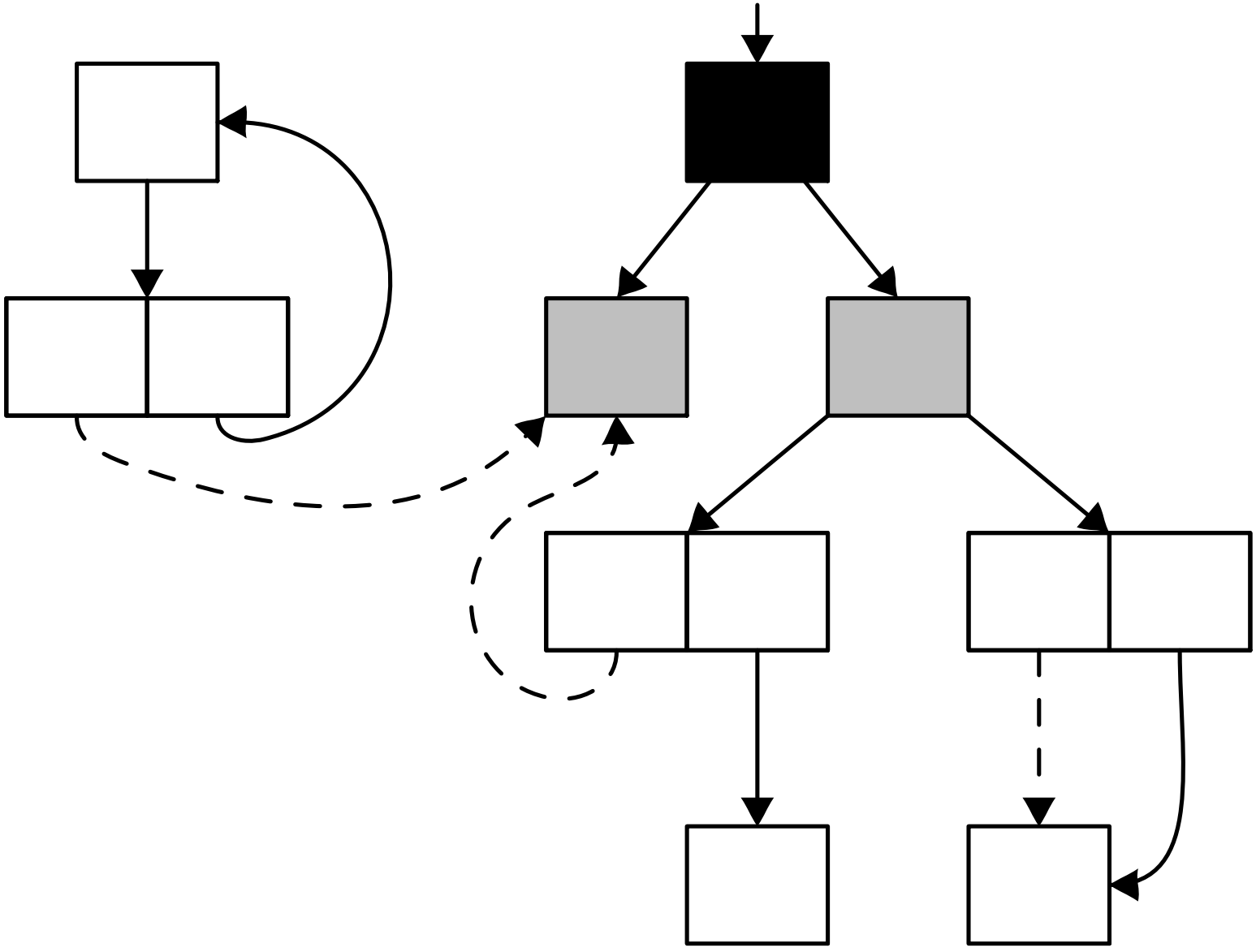

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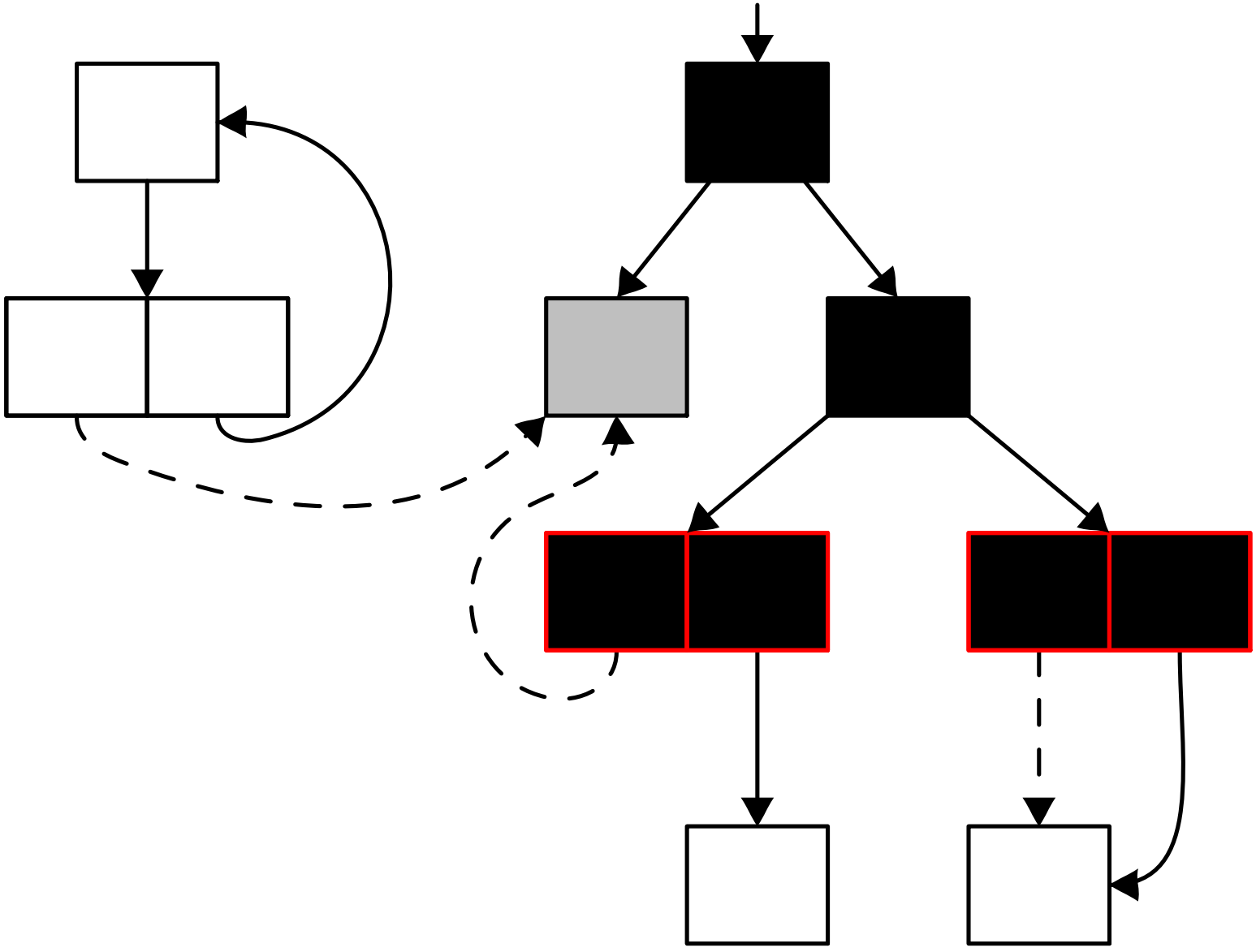

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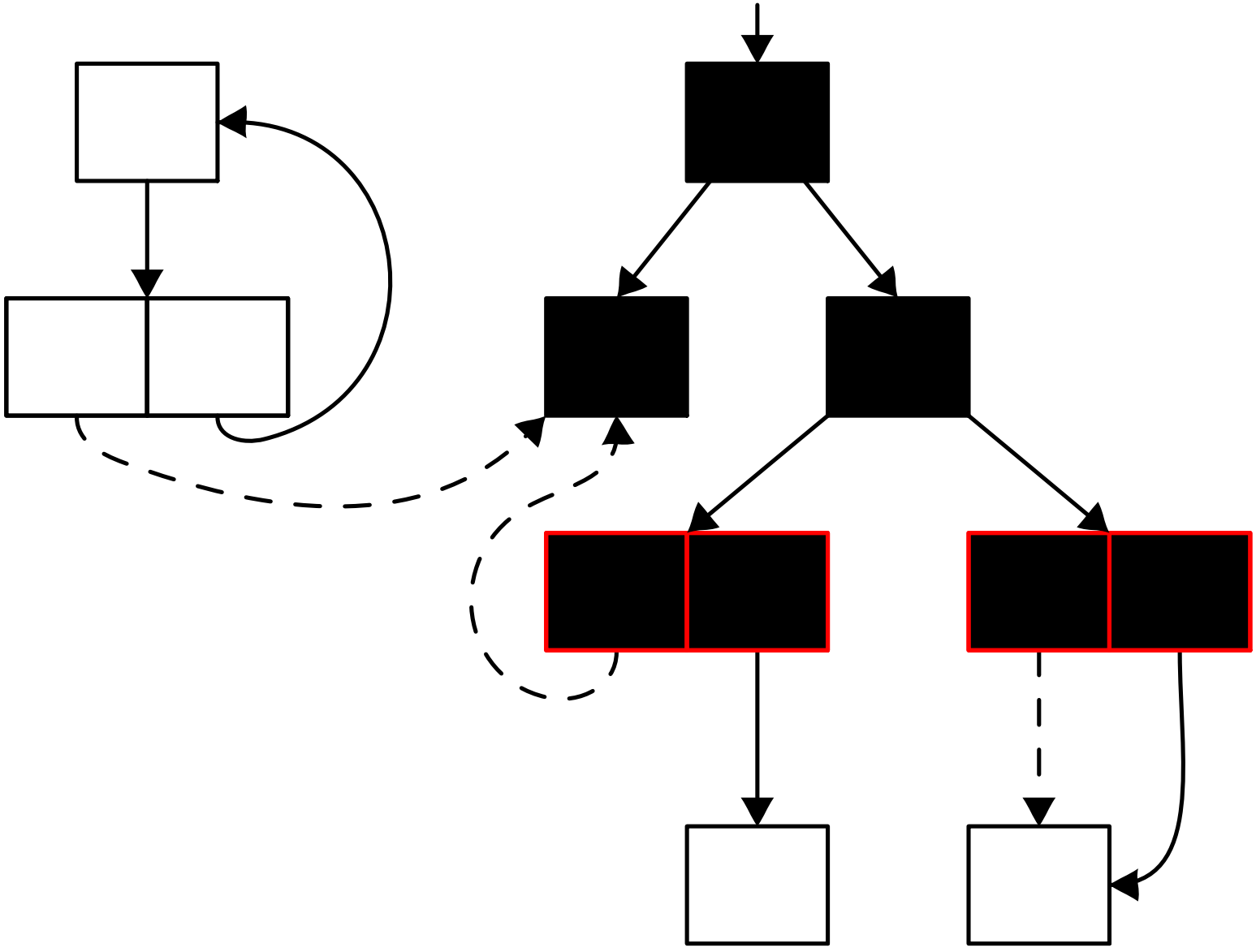

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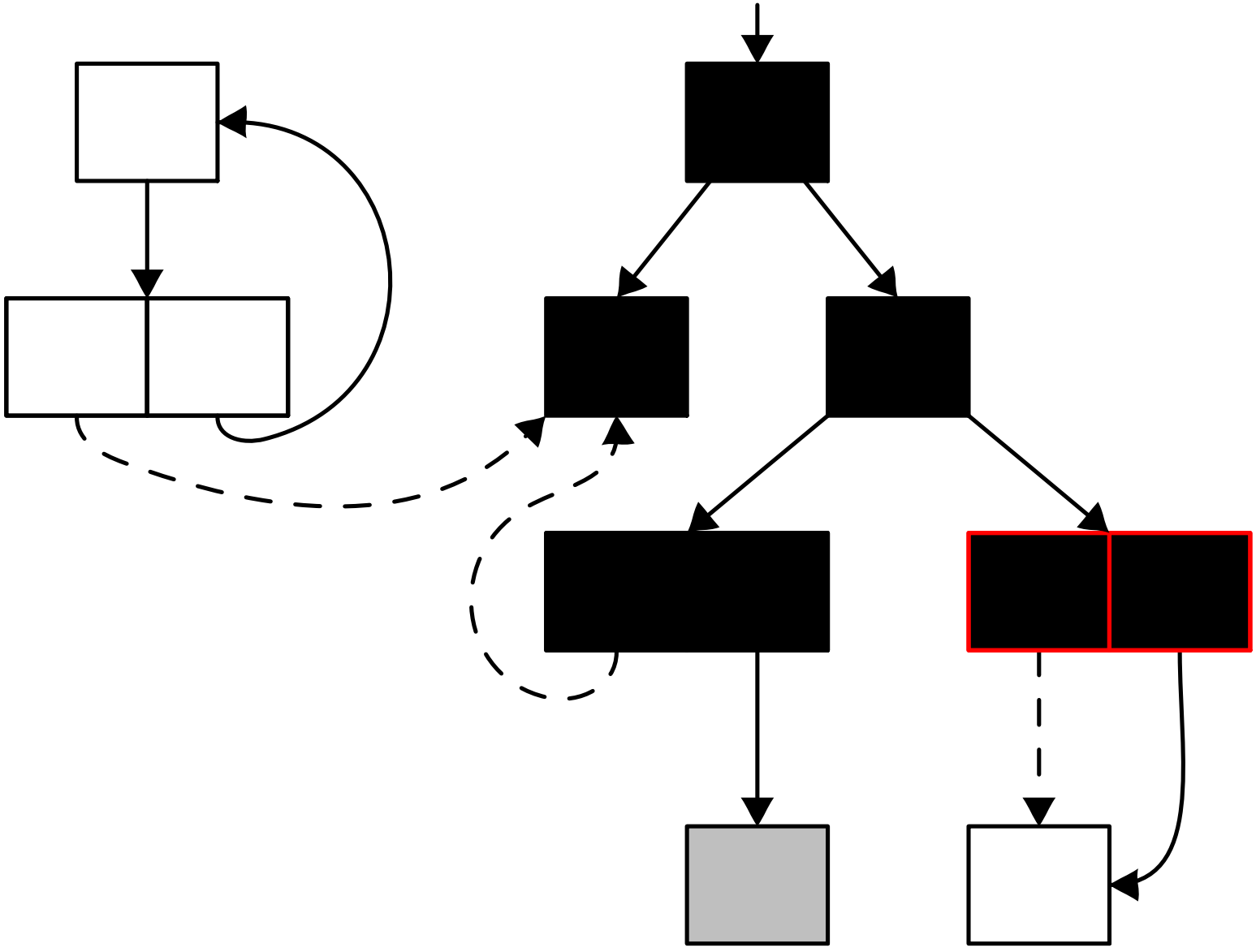

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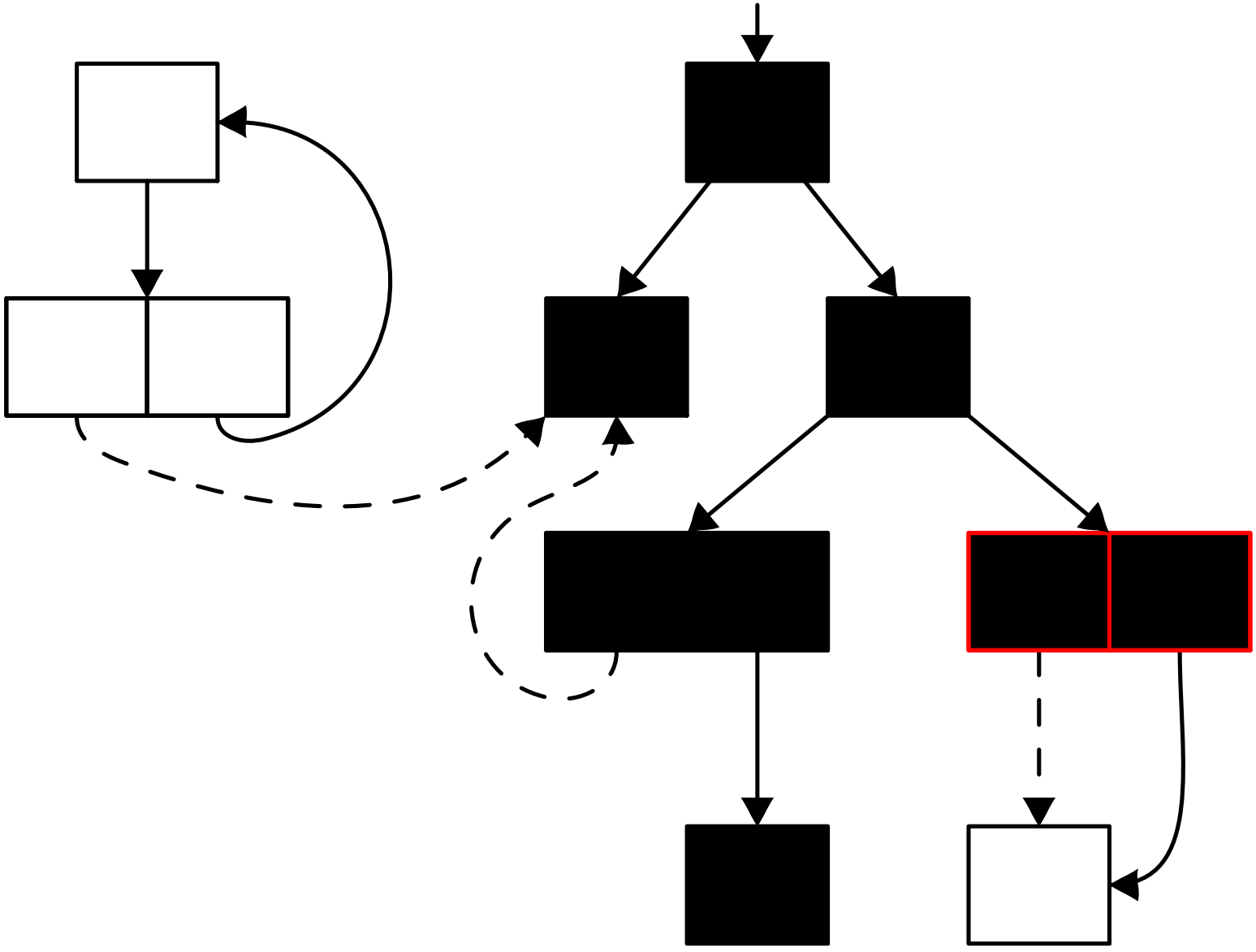

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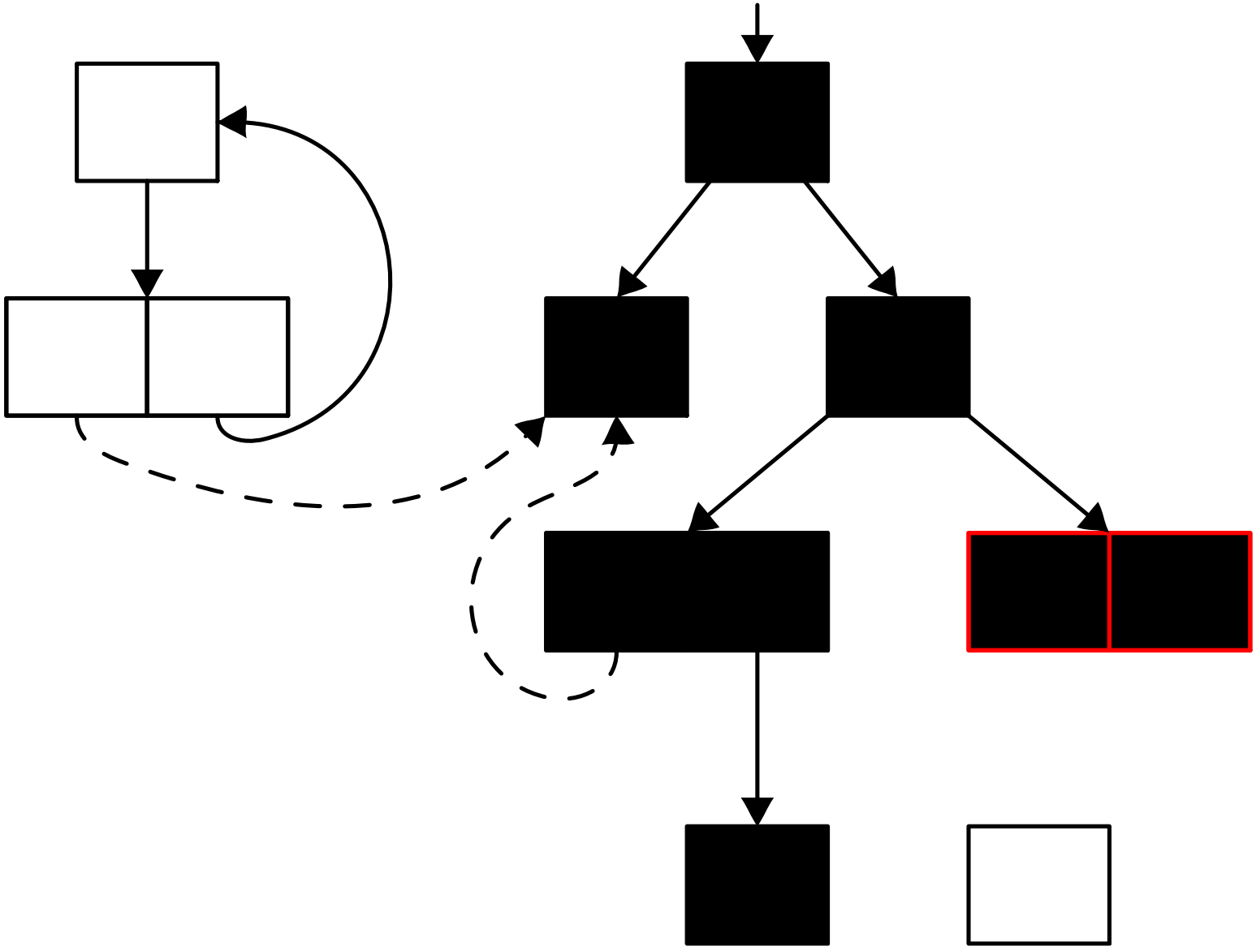

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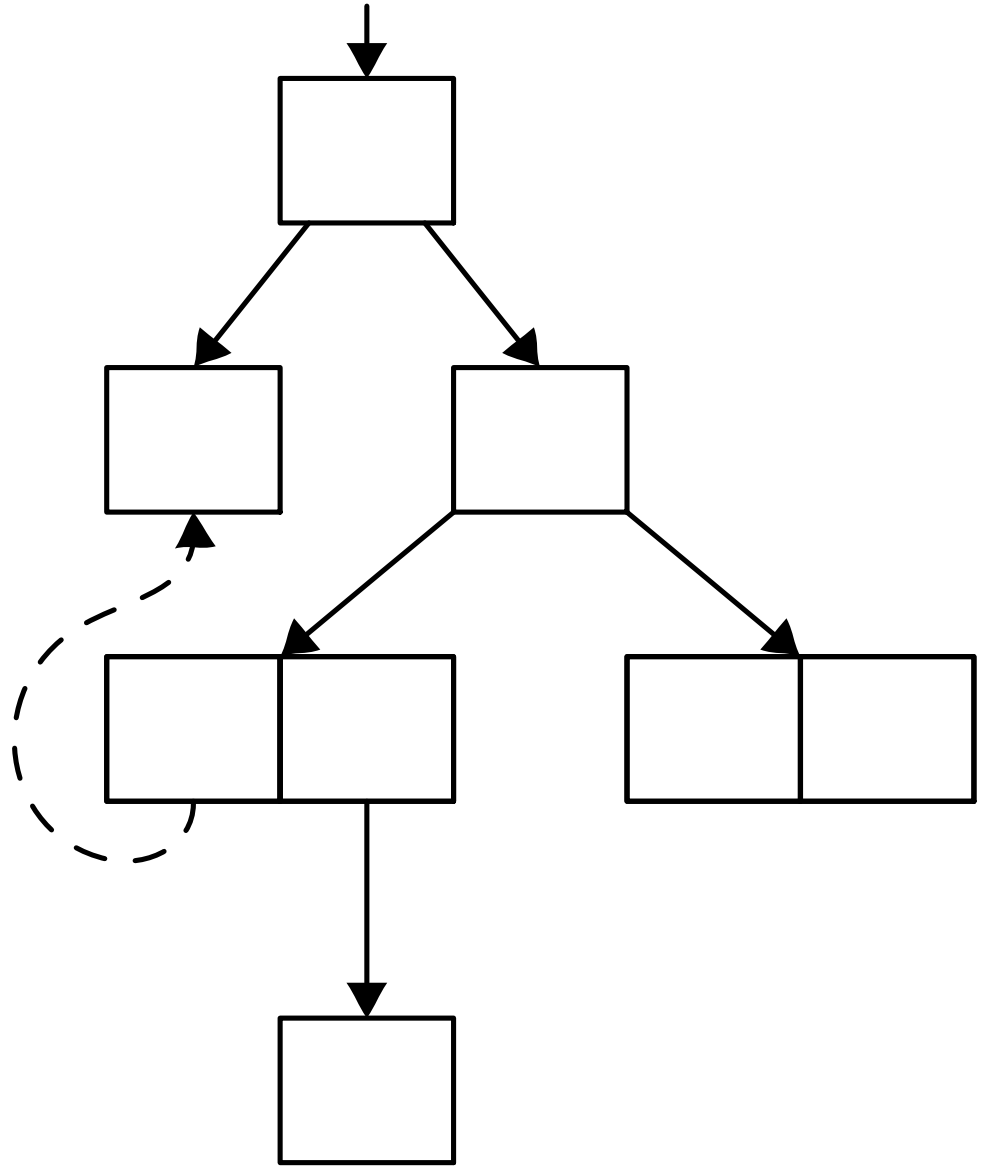

Patched Ocaml Runtime

- use a new tag to represent ephemeron values
- use 4 words

- add $O(n \cdot c)$ operations to mark phase. n number of ephemerons, c the longest chain of ephemerons.
- +84 lines in `major_gc.c` in `mark_slice`
- +70 lines in `weak.c`

Weak Hash Tables with Ephemerons

```
type (α,β) bucketlist =
| Empty
| Cons of (α,β) Ephemeron.t × (α,β) bucketlist
```

Benchmarks

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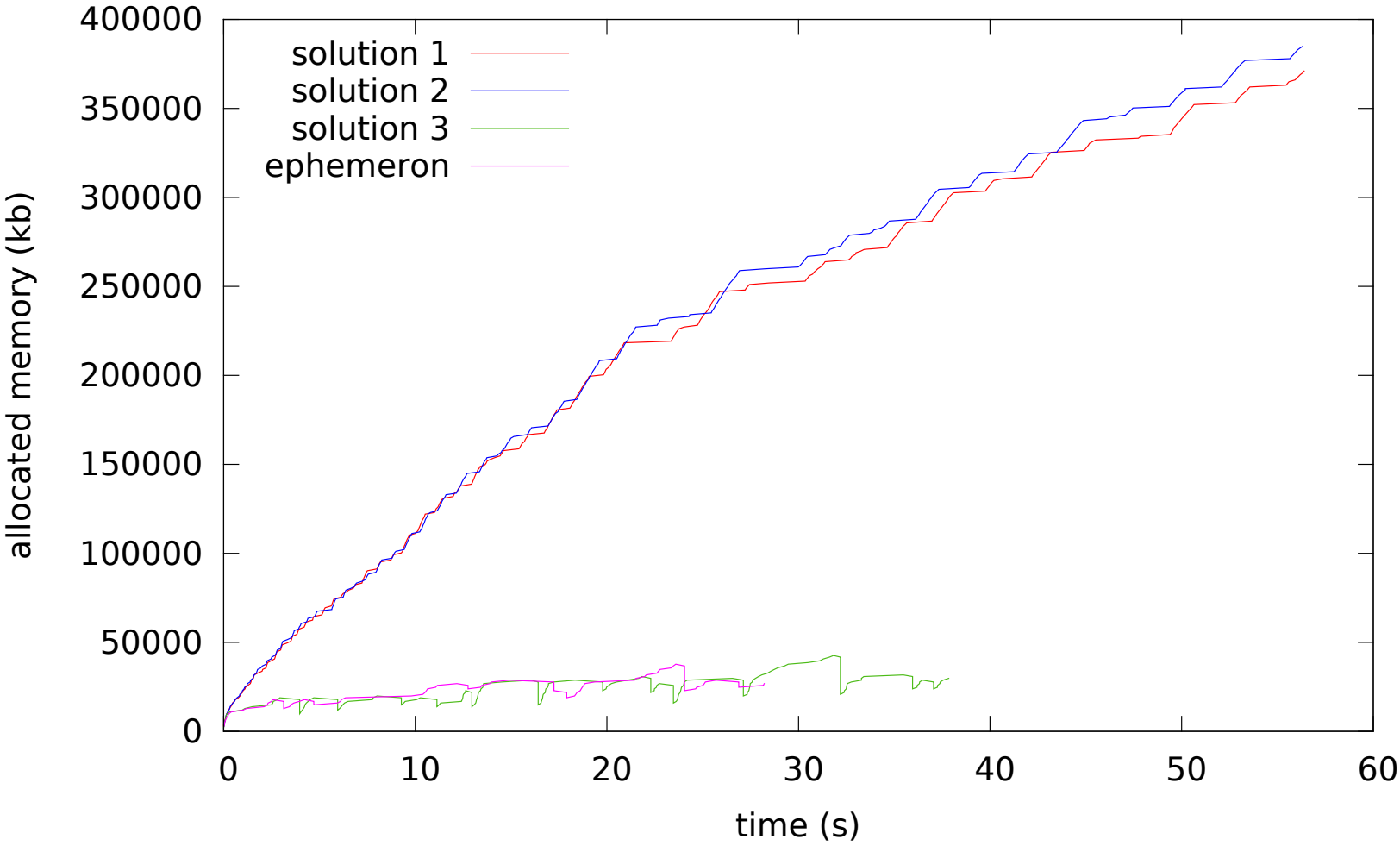

References

- B. Hayes, Ephemerons: a New Finalization Mechanism, OOPSLA'97
- Remi Vanicat 2002, Hweak: the key and the value are weak, so not fit for memoization
- Zheng Li 2007, Weaktbl: doesn't release a key when there is a cycle from value to key