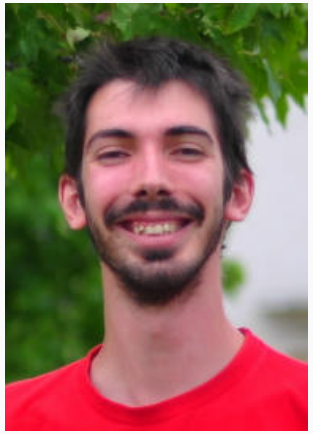
Storable types: free, absorbing, custom

Basile Clément



Gabriel Scherer

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Union-find without Store:

```ocaml
type 'a node = 'a data ref
type 'a data =
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| Root of { rank: int; v: 'a }

val make : 'a -> 'a node
val union :
    ('a -> 'a -> 'a) ->
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Our use-cases: (1) union-find for GADT equations. (2) Alt-Ergo ?

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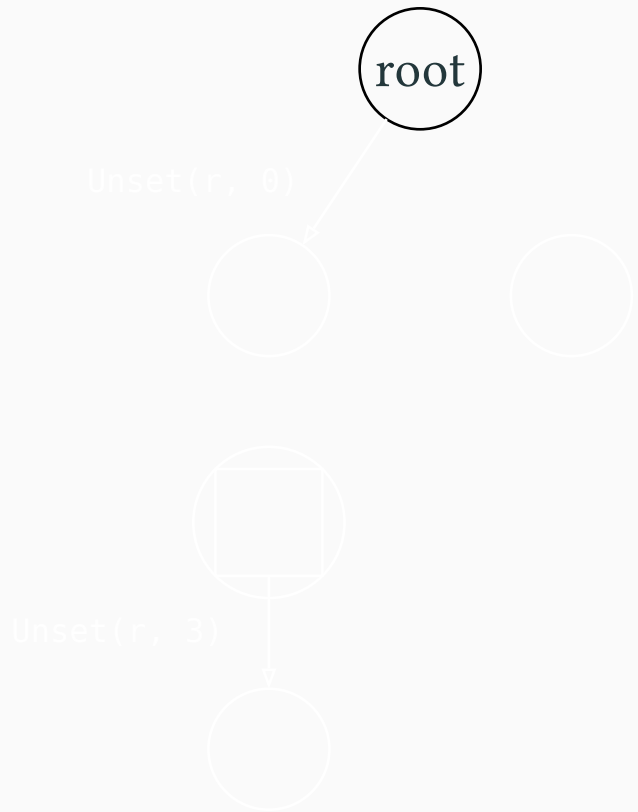

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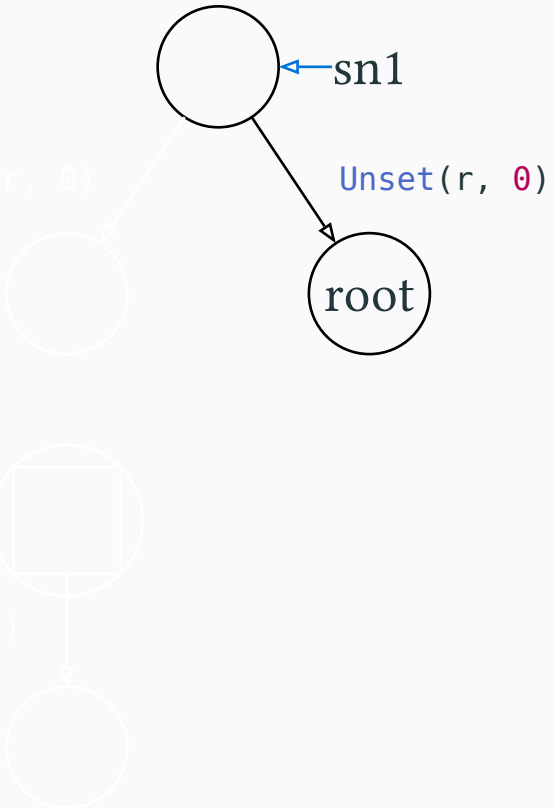

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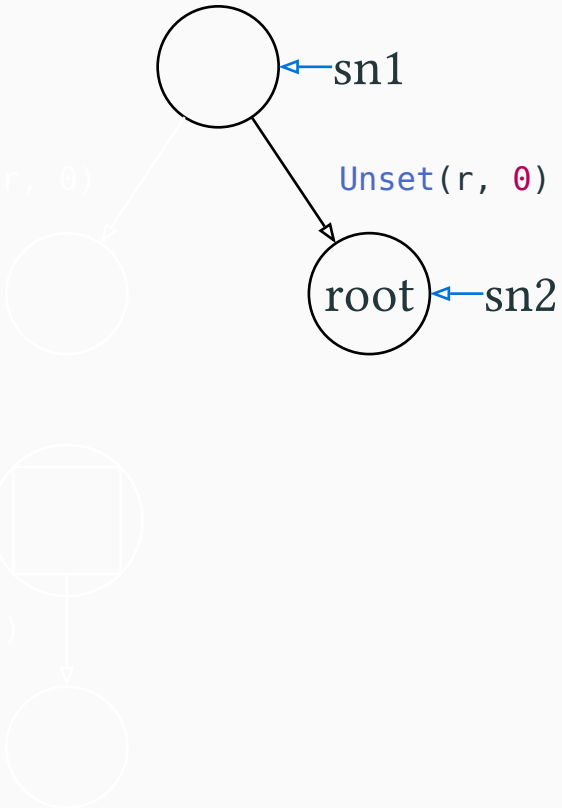

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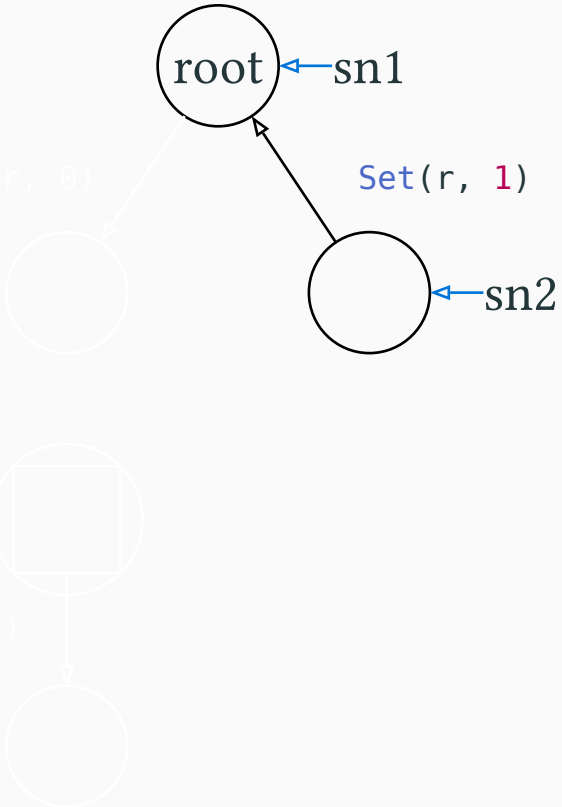

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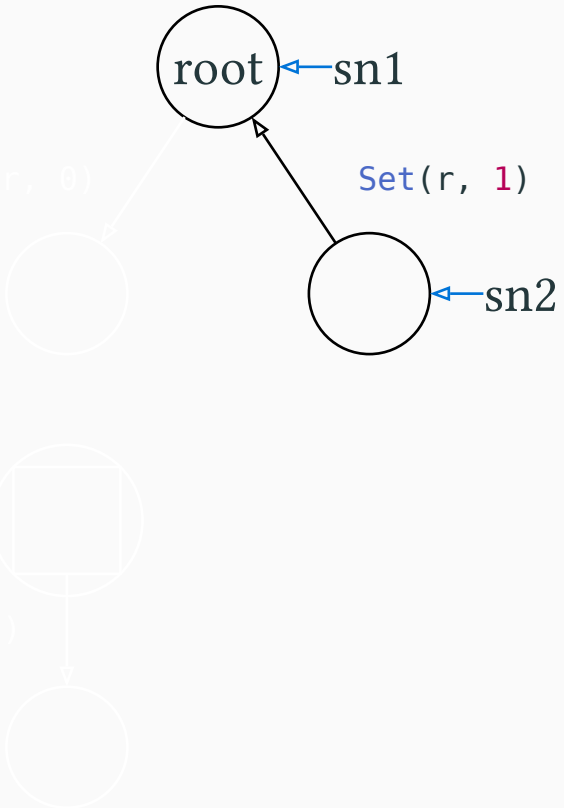

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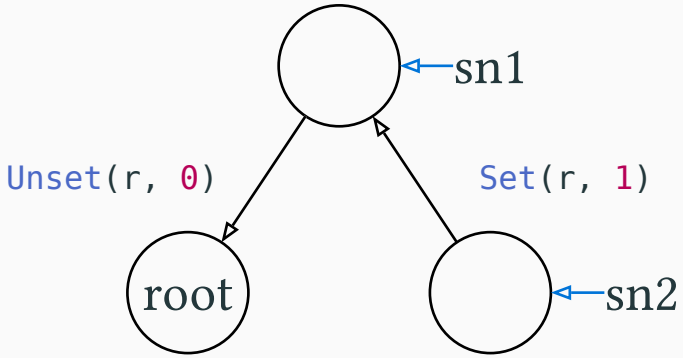

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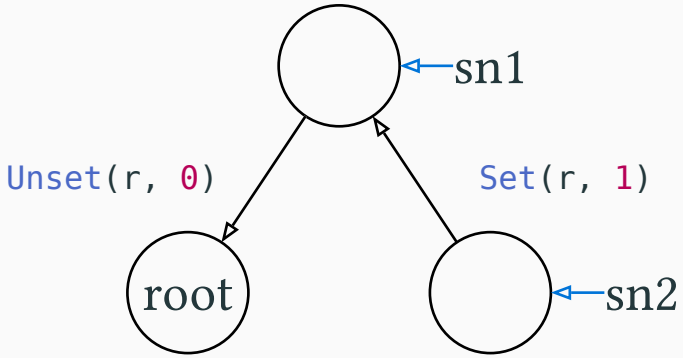

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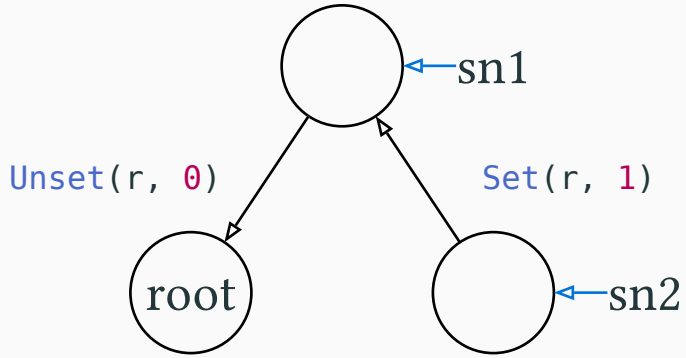

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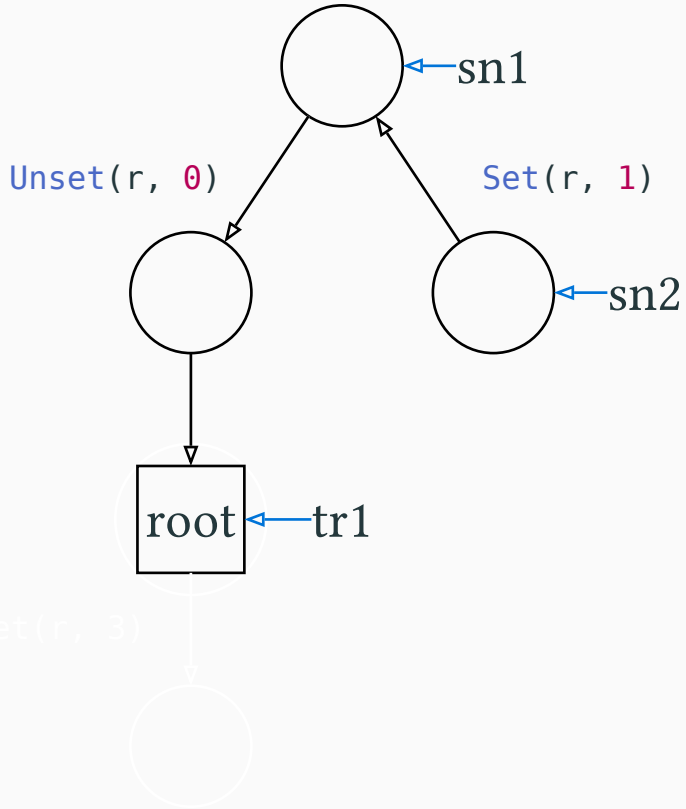

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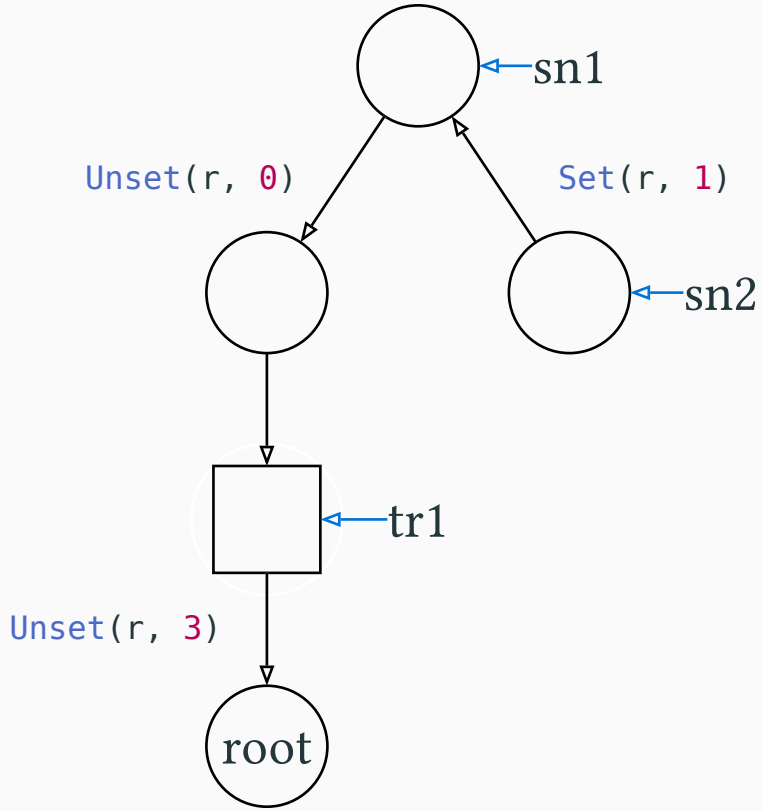

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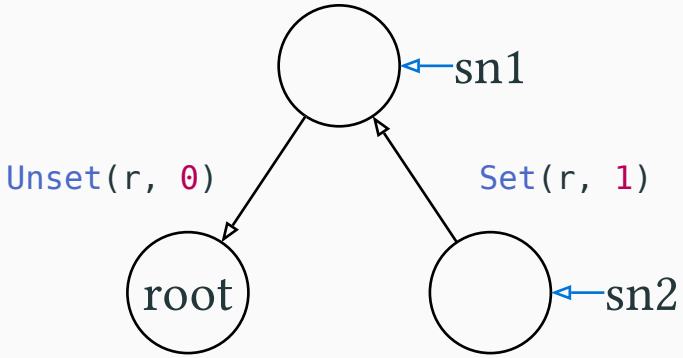

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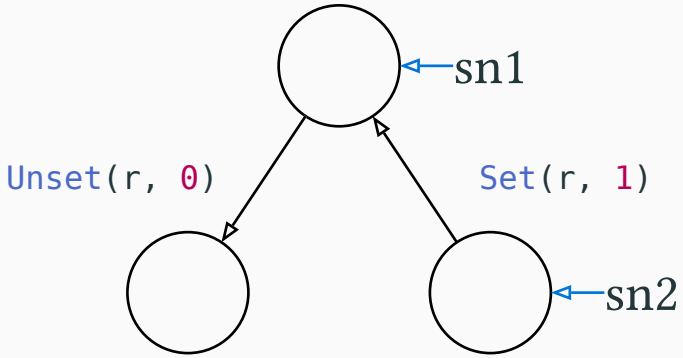

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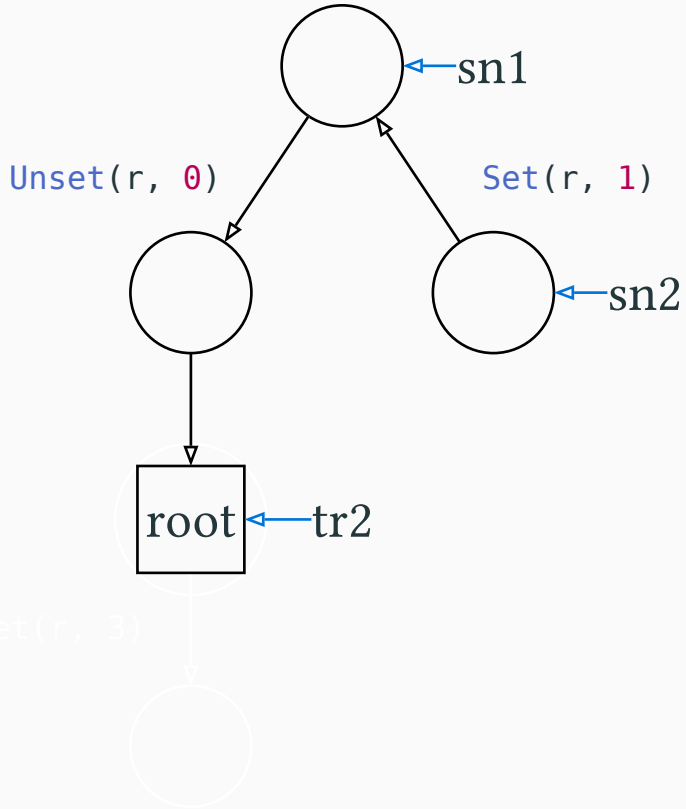

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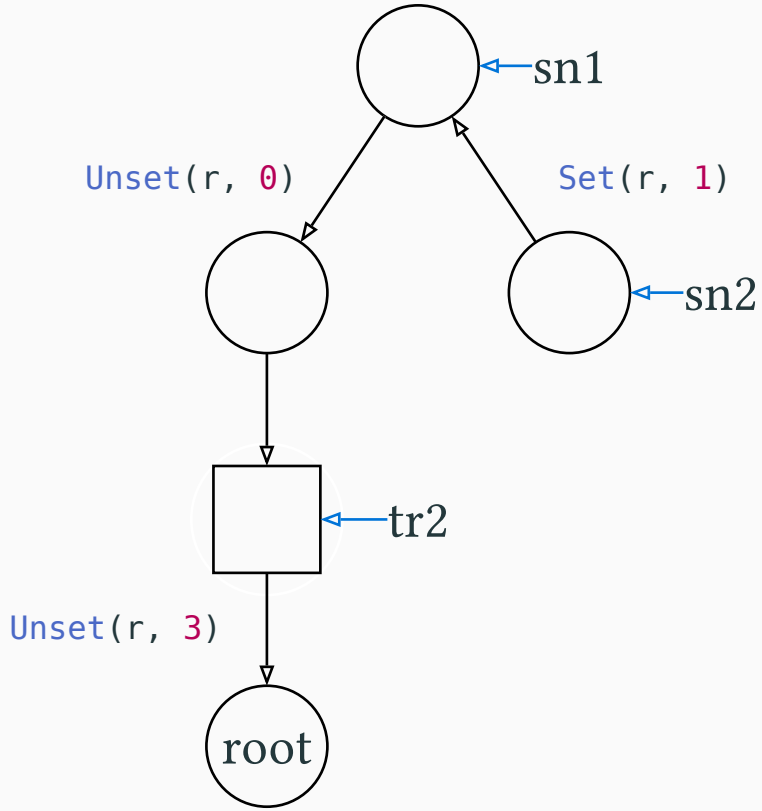

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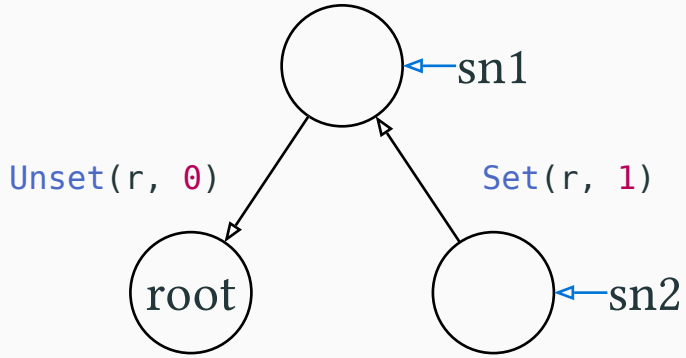

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Fine for simple data structures whose implementation you own.

What if the implementation is very complex or outside your control?

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The present work: *storable types* in Store:

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Bonus question: what about record elision?

Operations, anti-operations

Operations update the state.

Anti-operations revert a state update.

For references:

```
type 'a op = Set of 'a       (* new value *)
type 'a antiop = Unset of 'a (* previous value *)
```

For an append-only stack (first attempt):

```
type 'a op = Push of 'a
type 'a antiop = Pop
```

No record elision: we must store several `Pop` nodes.

Composition of anti-operations (example)

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Composition of anti-operations: `(Pop m) . (Pop n)` is `Pop (m + n)`.
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We can update the last recorded anti-operation by composition.
A different presentation of anti-operations allows record elision:

```
type 'a op = Push of 'a
type 'a antiop = Truncate of {length:int}
```

Composition of anti-operations (general)

Users come with their data-structure and a set of update operations.

We ask them to design a monoid $(A, \cdot)$
of **antioperations** A with a **composition** operation $(\cdot)$.

We identify three important classes of anti-operations:

1. **free**: $(A, \cdot)$ is a free monoid: record individual nodes
2. **absorbing**: $\forall ab,\ \ a.b = a$
   reference-like, benefit from record elision
3. **custom**: neither free nor absorbing

Composition properties $\Longrightarrow$ performance tradeoffs.

We offer three APIs, in increasing order of complexity.

`Free`: API + example

```
module Free : sig
  val modify :
    store -> 'a -> op:('a -> unit) -> anti:('a -> unit) -> unit
end
```

Example:

```
module RareRef = struct
  type 'a t = 'a ref
  [..]
  let set store r v =
    let setter v = fun r -> r := v in
    Free.modify store r (setter v) (setter !r)
end
```

```
module Absorbing : sig
  type ('a, 'op, 'anti) descr = {
    capture : 'a -> 'anti;
    rollback : 'a -> 'anti -> unit;
    undo : 'a -> 'anti -> 'op;
    redo : 'a -> 'op -> 'anti;
  }

  type ('a, 'op, 'anti) t
  val make : ('a, 'op, 'anti) descr -> 'a -> ('a, 'op, 'anti) t
  val get : ('a, 'op, 'anti) t -> 'a
  val modify : store -> 'a t -> unit
end
```

```
(* internally *) type _ t = Absorbing : { value : 'a;
                  mutable generation : Generation.t;
                      descr : ('a, 'op, 'anti) descr; } -> 'a t
```

`Absorbing`: Example

```
1   module PushQueue = struct
2     type 'a t = ('a Dynarray.t, 'a array, int) Absorbing.t
3     let capture = Dynarray.length
4     let rollback = Dynarray.truncate
5     let undo arr n = [..]
6     let redo arr suff = [..]
7     let descr = { capture; rollback; undo; redo; }
8
9     let create _s =
10      Absorbing.make descr (Dynarray.create ())
11    let push s d v =
12      Absorbing.modify s d;
13      Dynarray.add_last (Absorbing.get d) v
14    let length _s d =
15      Dynarray.length (Absorbing.get d)
16  end
```

Custom: API

```
module Custom : sig
  type ('a, 'op, 'trail) descr = {
    record : 'a -> 'trail;
    append : 'trail -> 'trail -> unit;
    rollback : 'a -> 'trail -> unit;
    undo : 'a -> 'trail -> 'op;
    redo : 'a -> 'op -> 'trail -> unit;
  }

  type ('a, 'op, 'trail) t
  val make : ('a, 'op, 'trail) descr -> 'a -> ('a, 'op, 'trail) t
  val get : ('a, 'op, 'trail) t -> 'a
  val modify : store -> ('a, 'op, 'trail) t -> 'trail
end
```

`Custom`: Example

```
1 module Queue = struct
2   type 'a op = { truncate: int; suffix : 'a Dynarray.t }
3   type 'a trail = { mutable truncate: int; mutable suffix : 'a list }
4   type 'a t = ('a, 'a op, 'a trail) Custom.t
5   [..] (* you don't want to see the rest... *)
6 end
```

Conclusion

What's better than a new API? **Three** new APIs for storable types in Store.

Also: a solid basis for us to add built-in data structures to Store: queues, hashtables, etc.

SMT authors want this. (Basile Clément works on Alt-Ergo at OCamlPro)

Take-away: the performance of recording operations depends on
the algebraic structure of anti-operations.

Full code: https://gitlab.com/basile.clement/store/-/tree/jfla2025+existentials

… soon in a new `Store` release.