Environmental Acquisition Revisited

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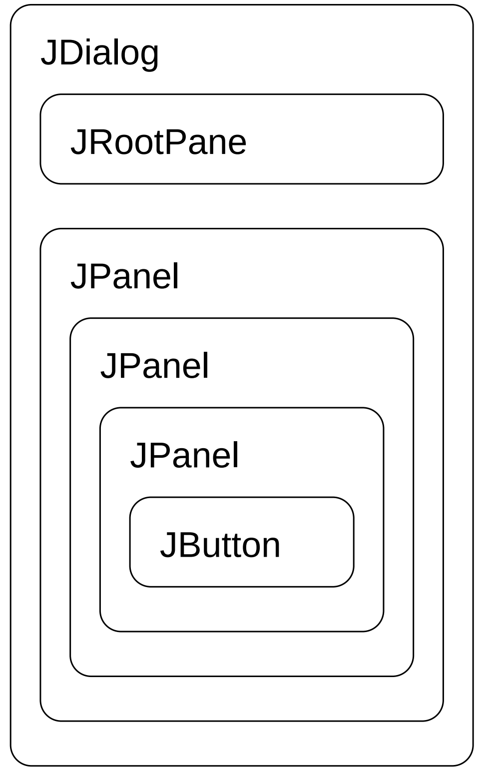
What is Acquisition?

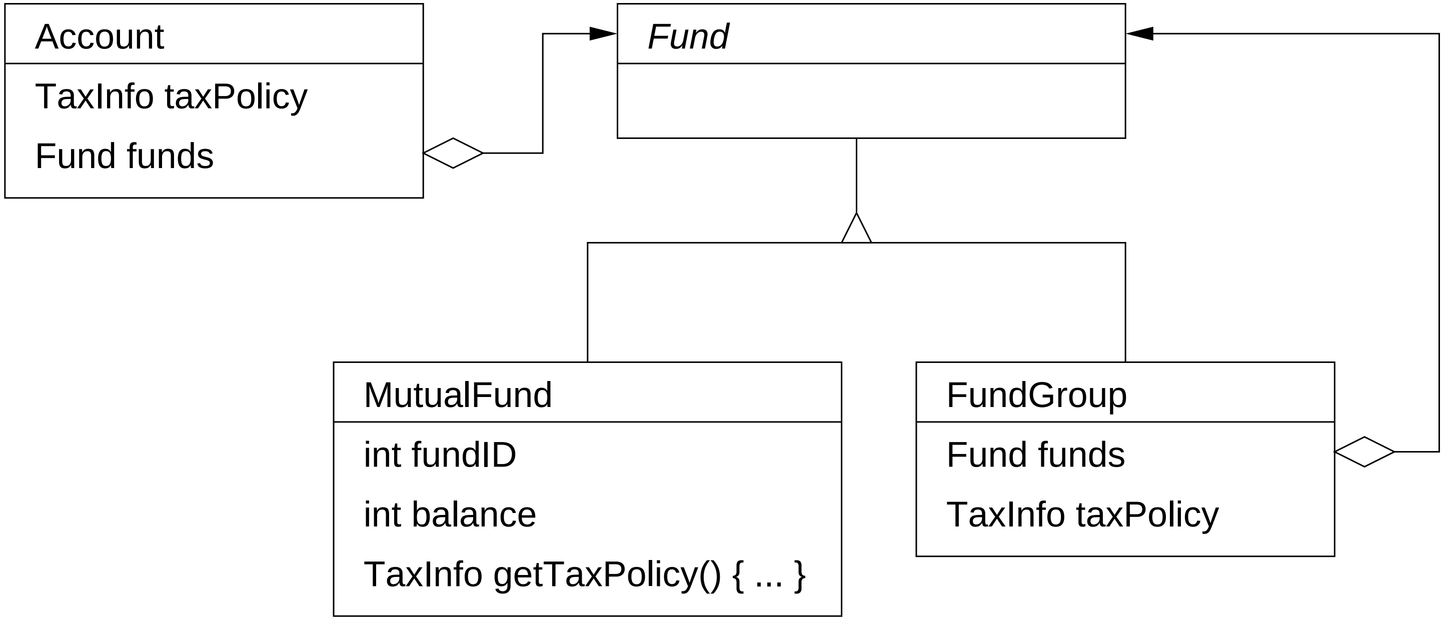
Example: Swing Containers



`JRootPane` located only at top level

`JButton` must chase pointers to access root pane

Example: Financial Application



Operations on *Fund*s must know tax policy

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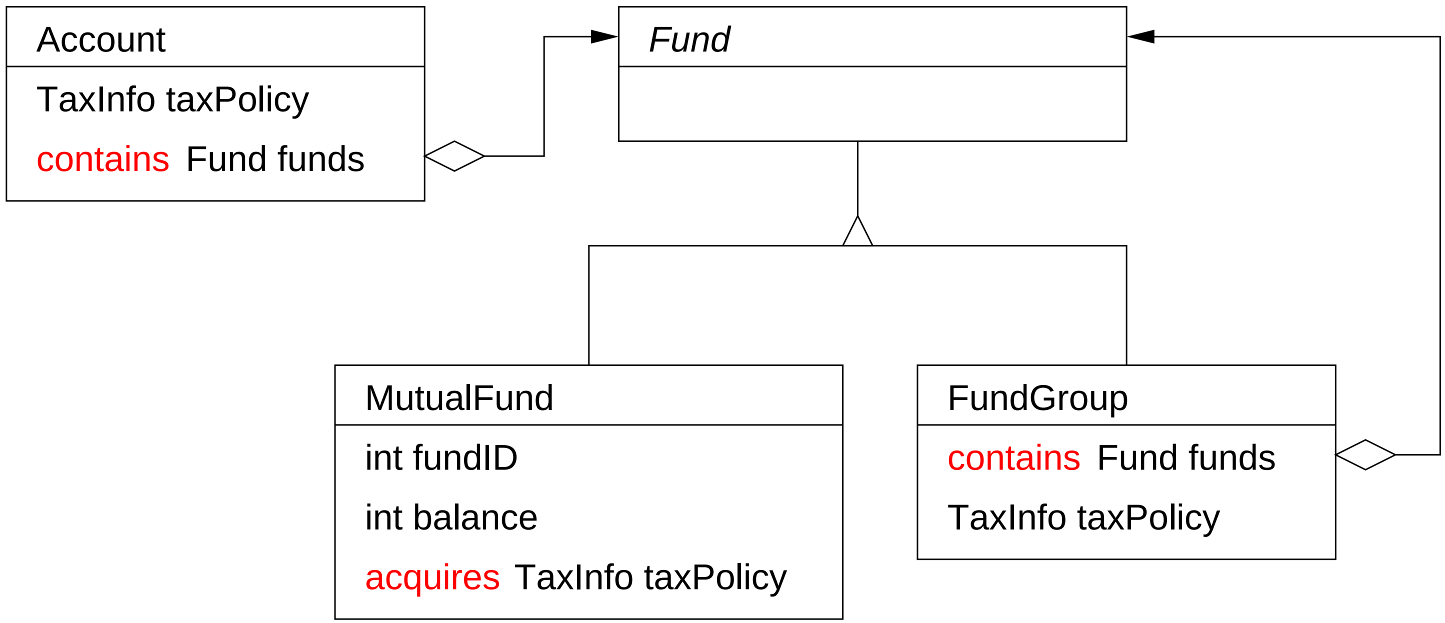
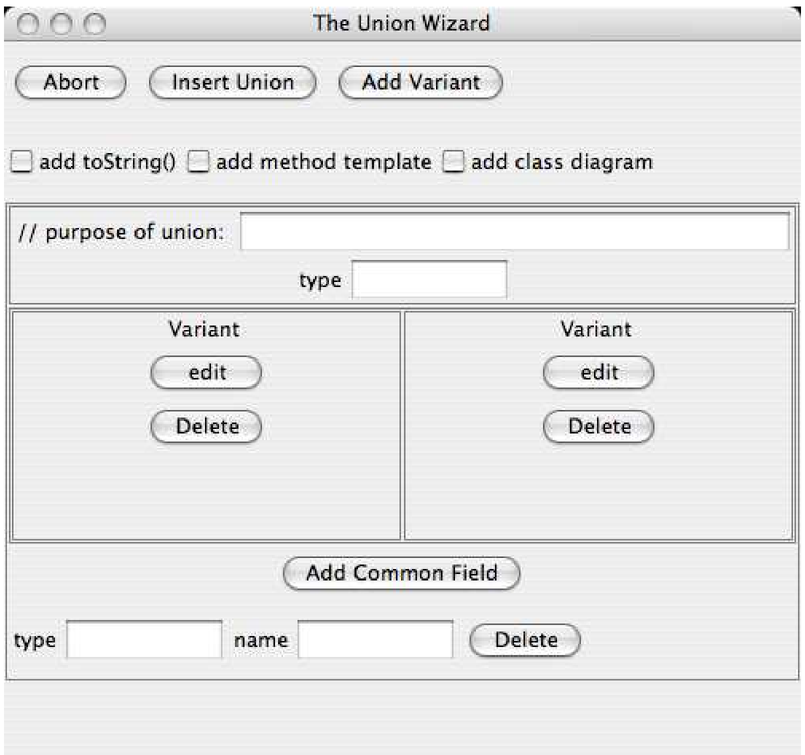
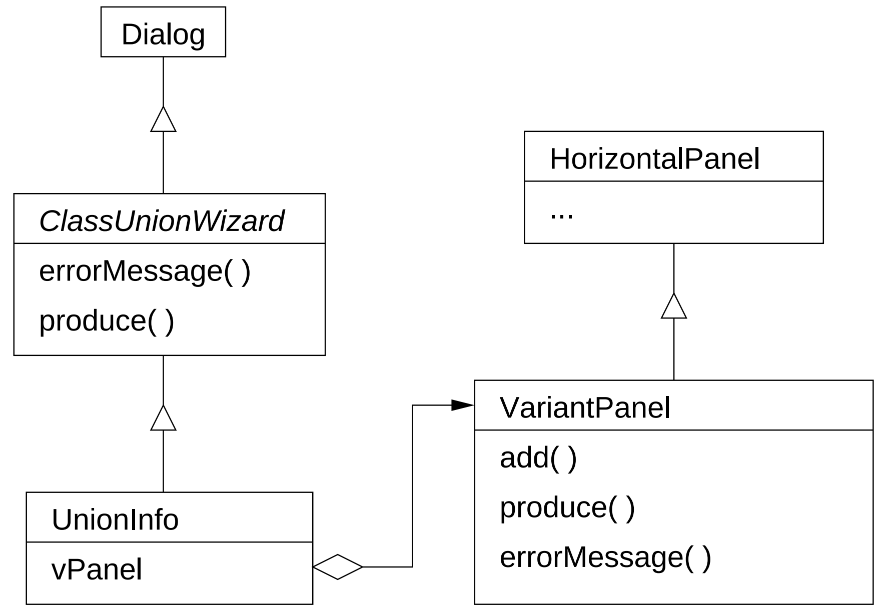


Operations on Funds must know tax policy

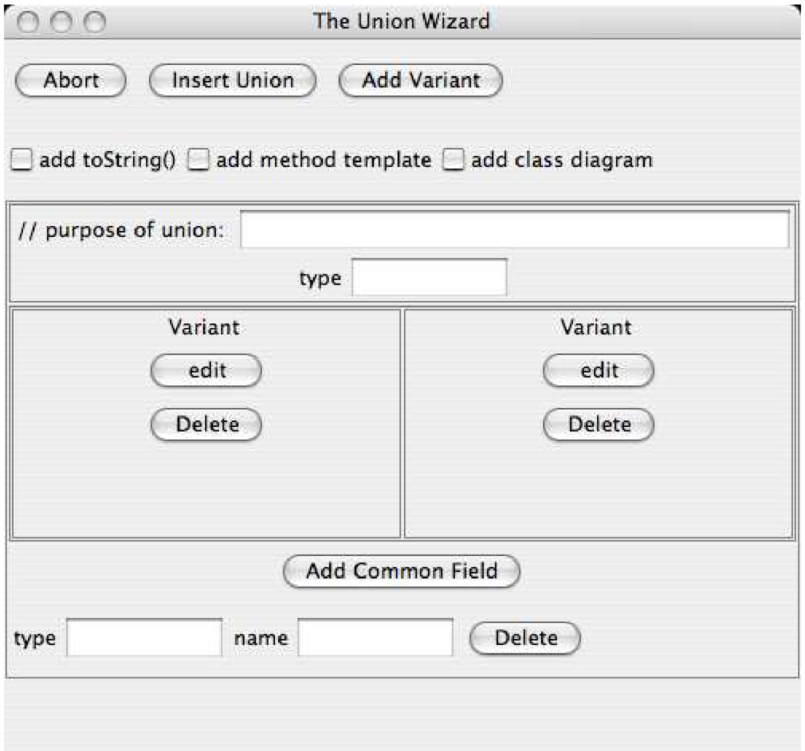
With acquisition, no longer need to maintain and chase parent refs

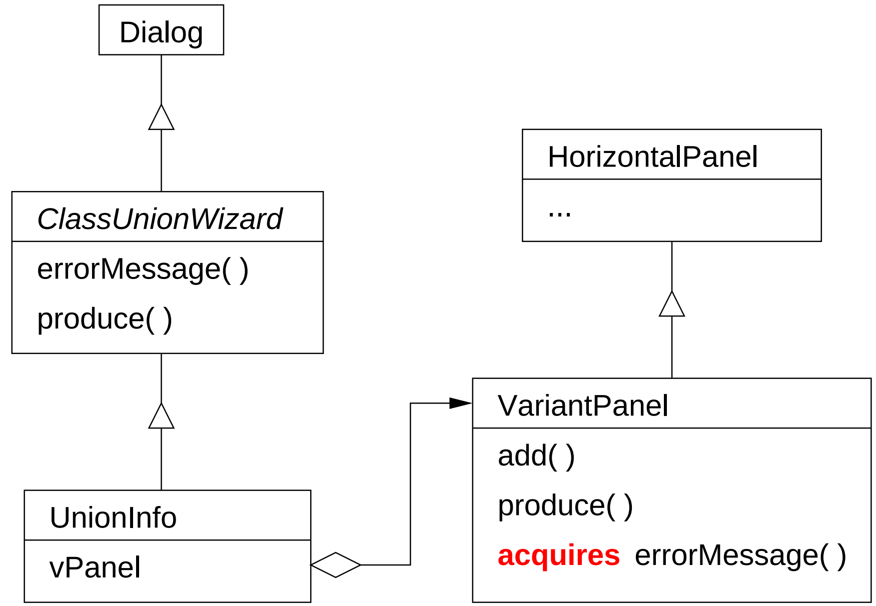
Example: IDE Wizard





Example: Wizard with Acquisition





Containment Invariants

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Containment Invariants

Invariants ensured by language support for acquisition:

- Objects allow access to their containers
- Two-way links (or their analog) are consistent

Restrictions on Acquisition

- Limit object’s “environment” to its containers
- Only specifically marked fields establish containment relationship
- An object may have at most one container
- Object containment cycles forbidden

Jacques: the Formal Model

Jacques

Based on *ClassicJava*, formal model of Java by Flatt, Krishnamurthi, and Felleisen (1998).

Supported features:

- core OO: classes, inheritance, method dispatch
- field assignment

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Supported features:

- core OO: classes, inheritance, method dispatch
- field assignment
- field and method acquisition
- explicit marks for “containment” fields
- list of possible containers in class definitions

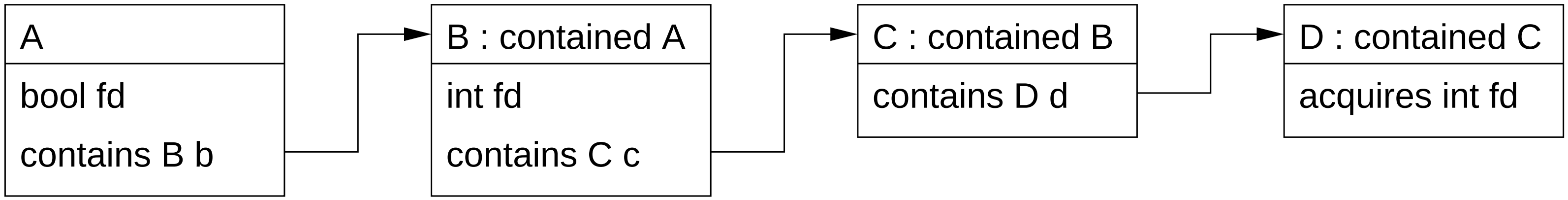
Wizard Example

```
class UnionInfo extends ClassUnionWizard {
    VariantPanel vPanel;
    ...
}

class VariantPanel extends HorizontalPanel {

    Button editButton;
    void add(...) { ... }
    void produce(...) { ... }
    void errorMessage(String msg) { ... }
}
```

Jacques: Wizard Example

```
class UnionInfo extends ClassUnionWizard {
    contains VariantPanel vPanel;
    ...
}

class VariantPanel extends HorizontalPanel
        contained ClassUnionWizard {
    Button editButton;
    void add(...) { ... }
    void produce(...) { ... }
    acquires void errorMessage(String msg);
}
```

Static Check I



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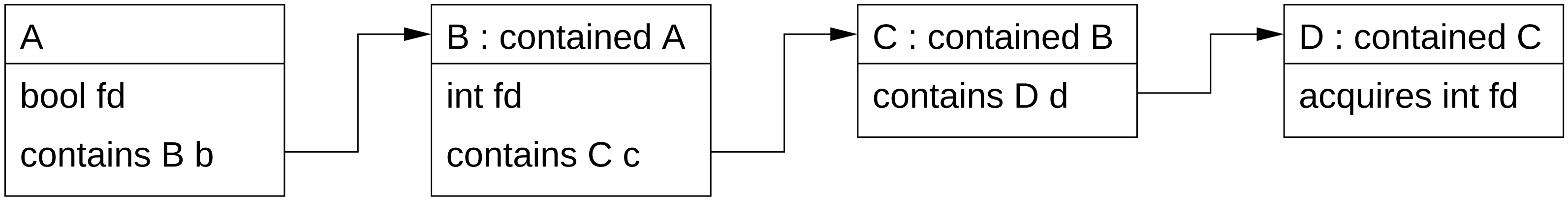
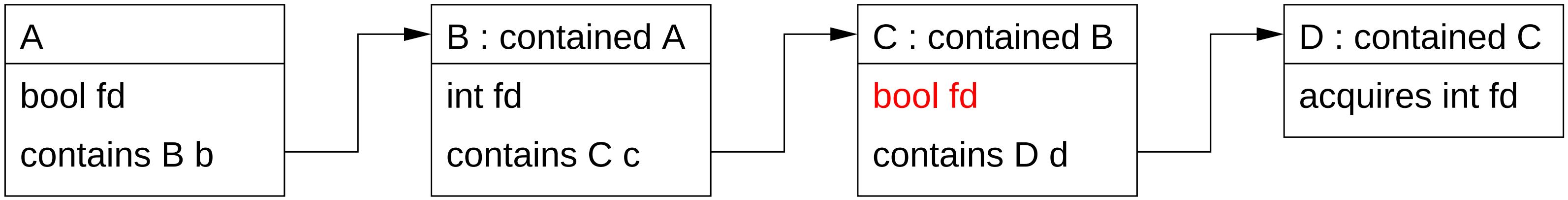


`D` acquires `fd` from `B`, and types match.

Program is well-typed.

Static Check II



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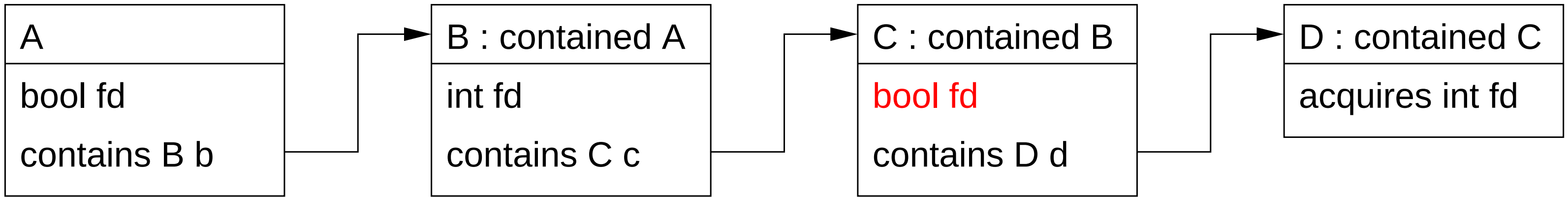
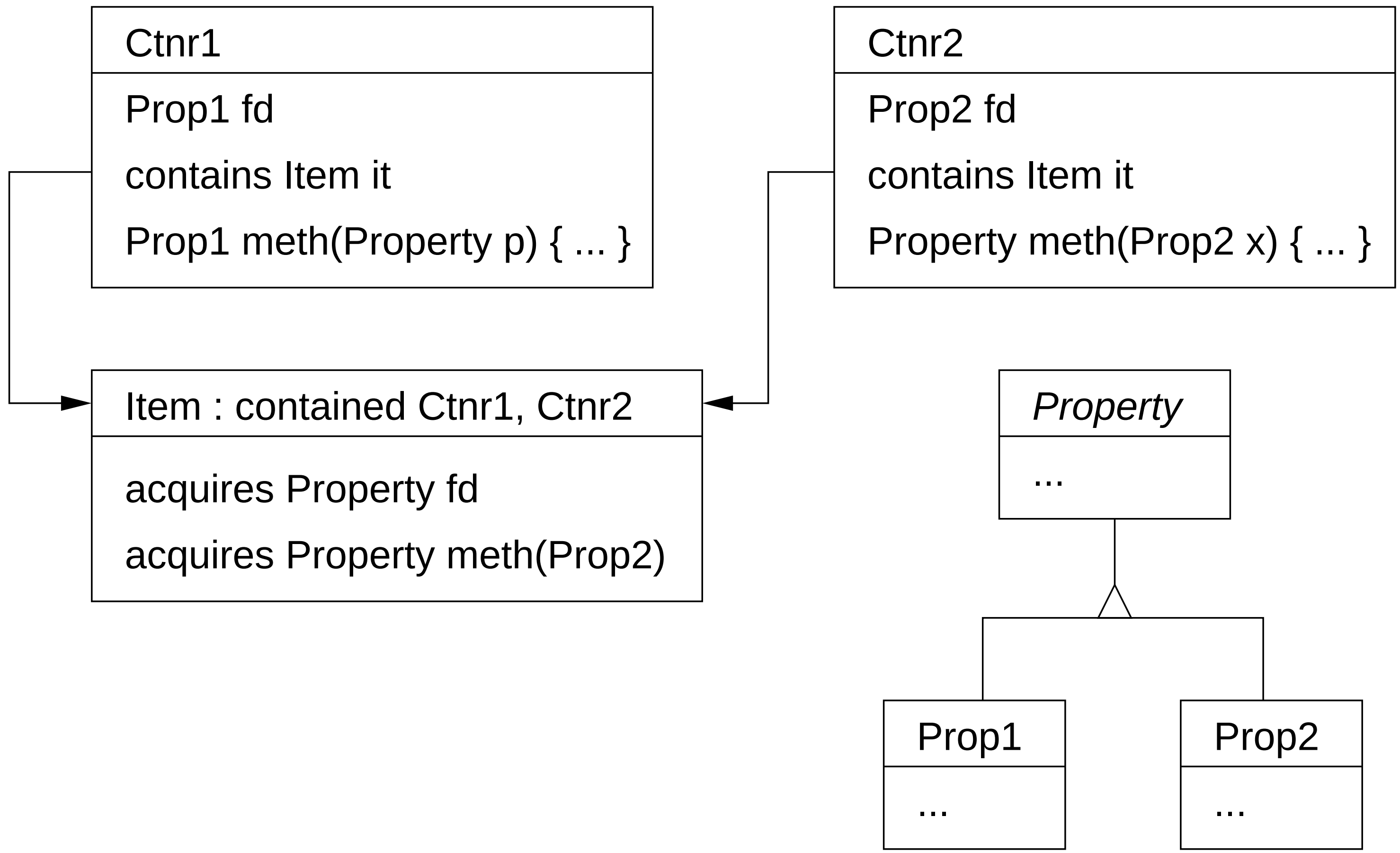


`D` acquires `fd` from `C`, and types are not compatible.

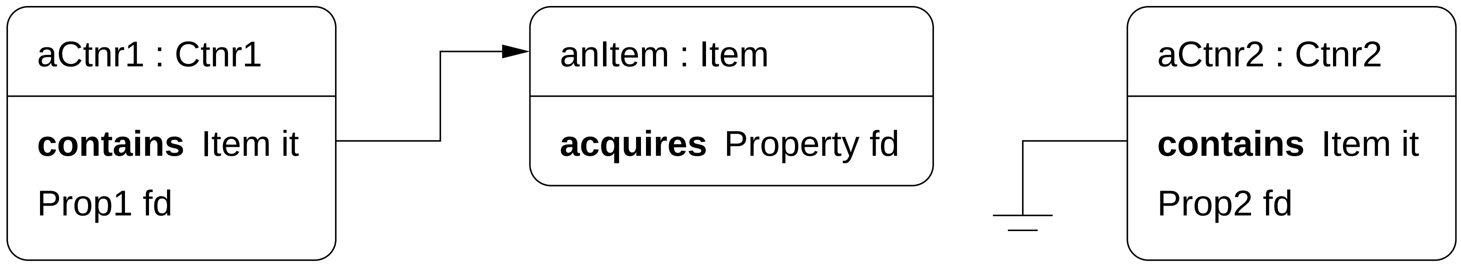
Program is not well-typed.

Design Decisions

Running Example



Acquisition by Value and by Name



When does `anItem` acquire `fd`'s value?

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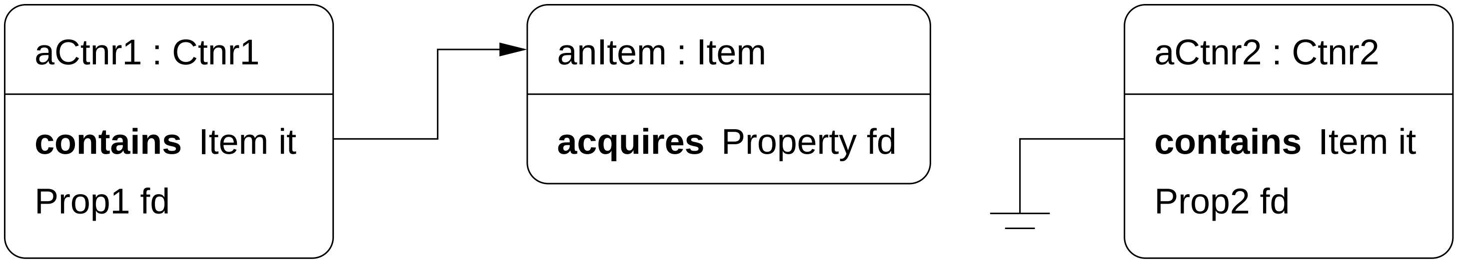

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- By value: when `anItem` is placed into `aCtnr1`.

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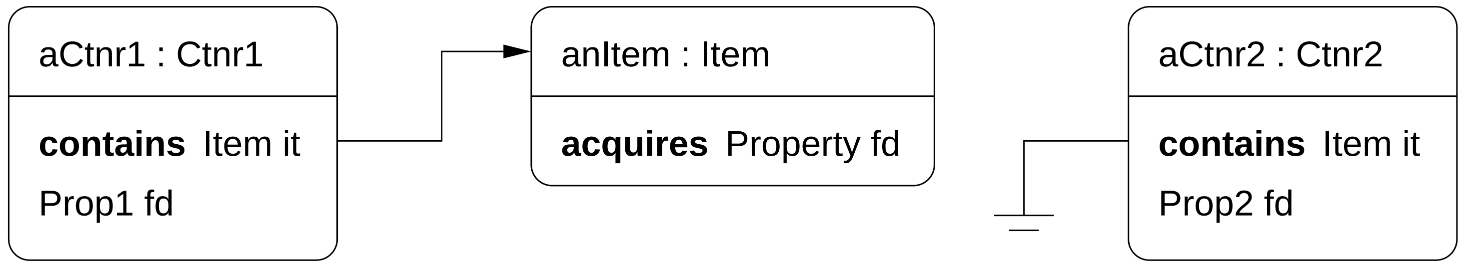

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- By name: when `anItem.fd` is referenced.

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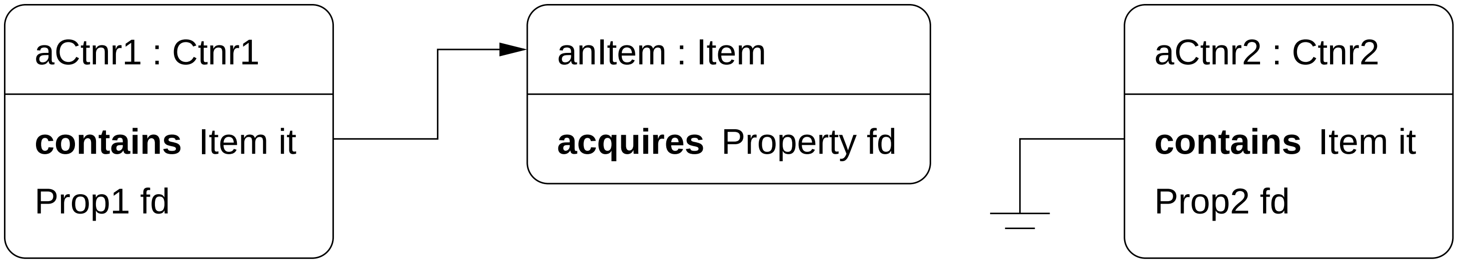

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- By value: when `anItem` is placed into `aCtnr1`.
- By name: when `anItem.fd` is referenced.

Both are sound; primarily affects visibility of assignments.

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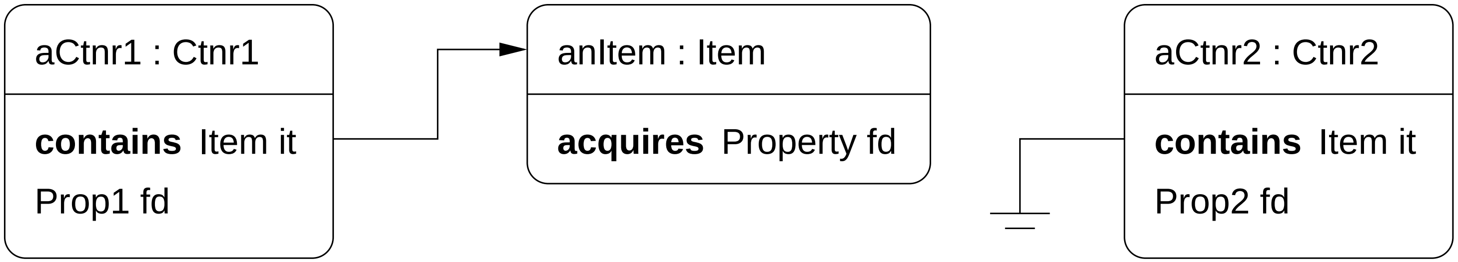

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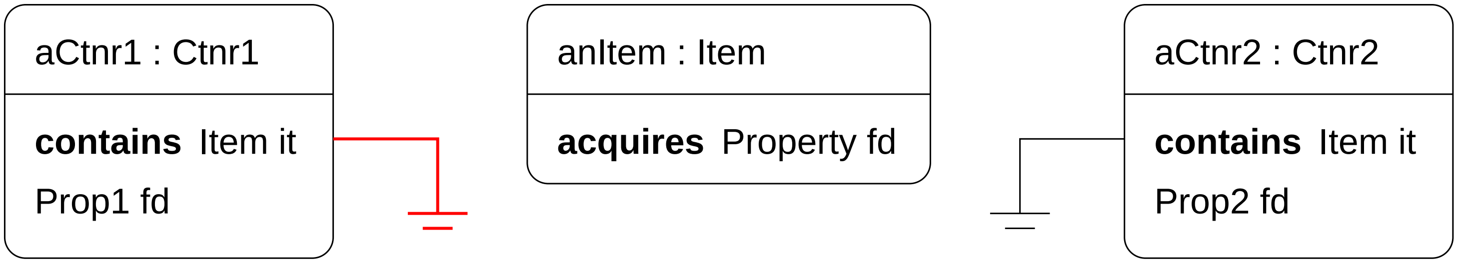

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1. `aCtnr1.it` := **null**;
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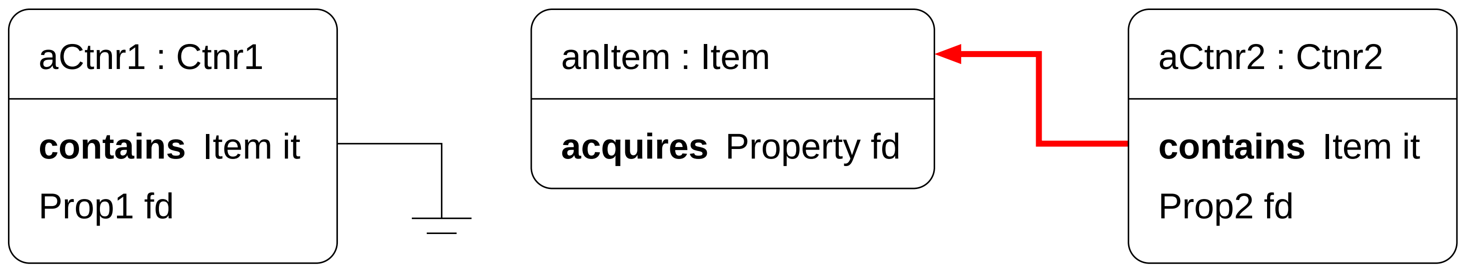

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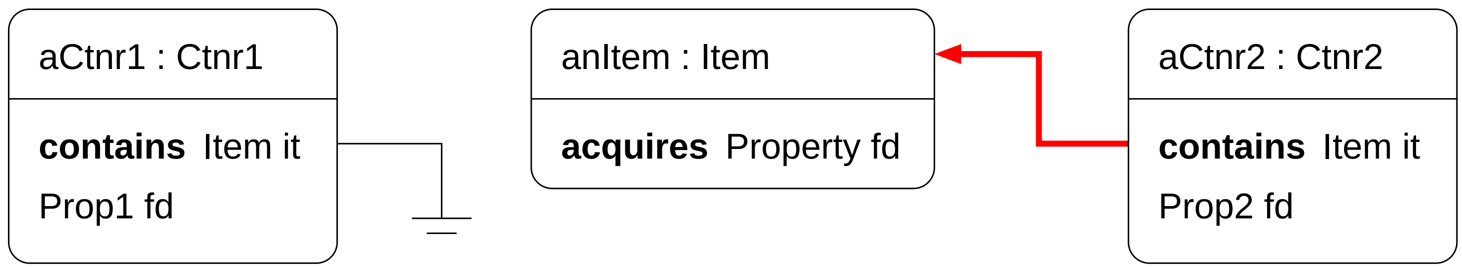

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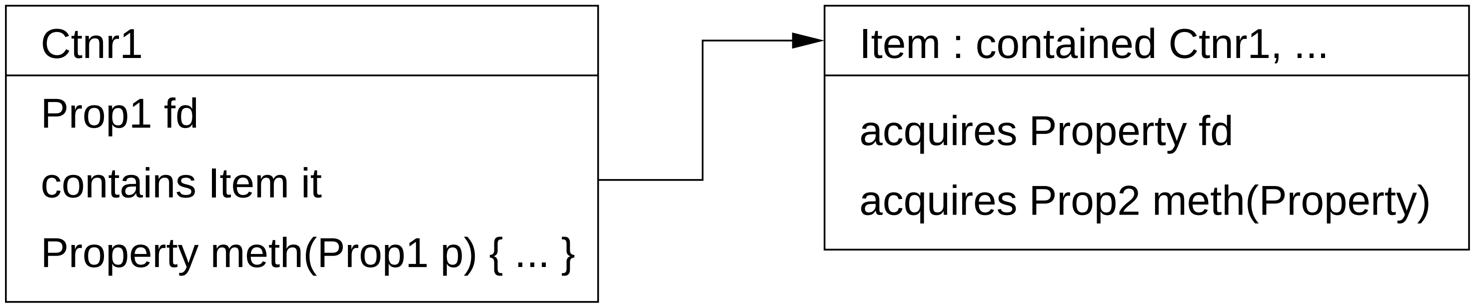
We implement acquisition-by-name; it avoids both issues.

Type Variance in Acquisition



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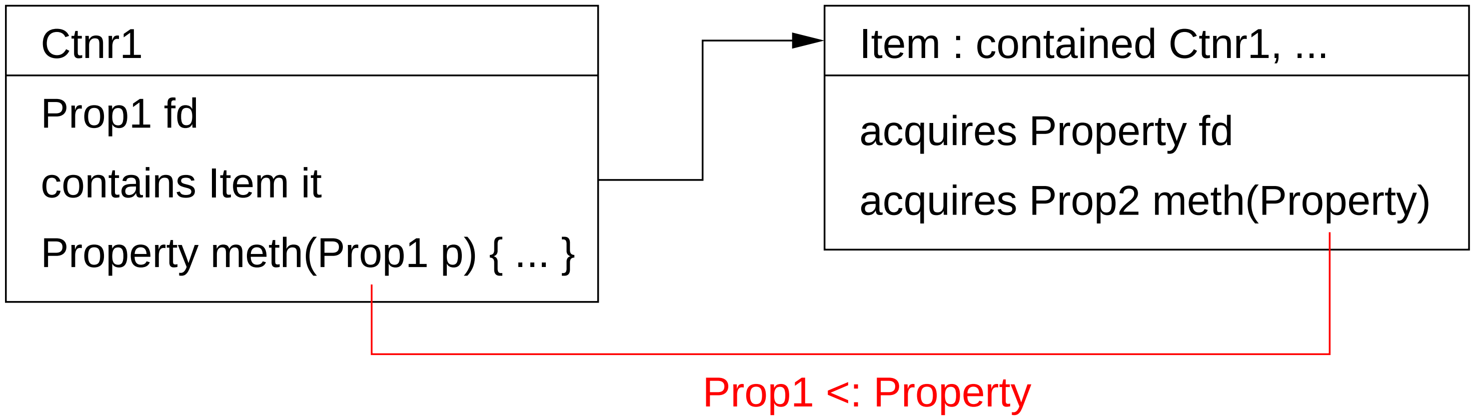

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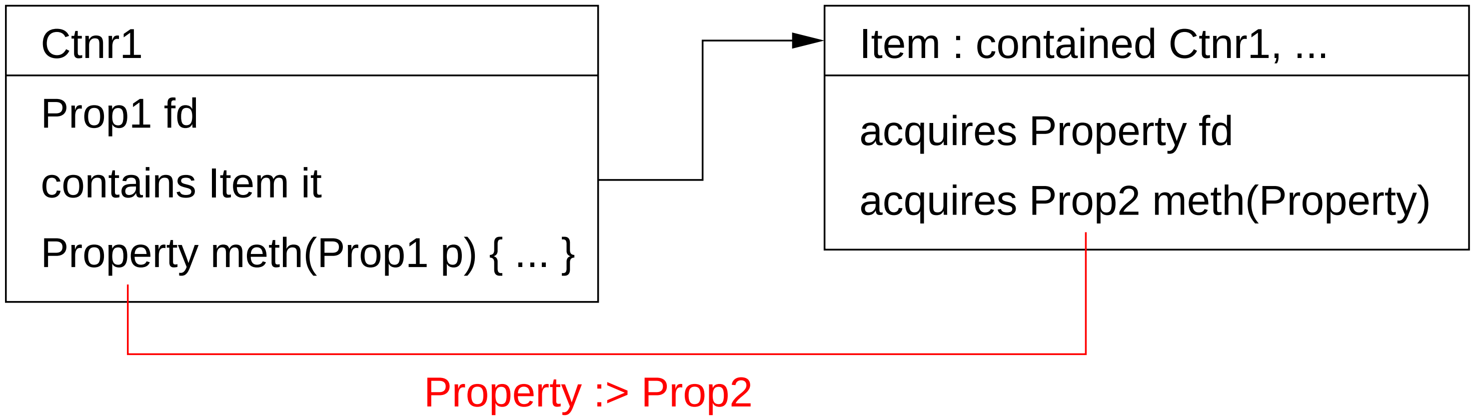

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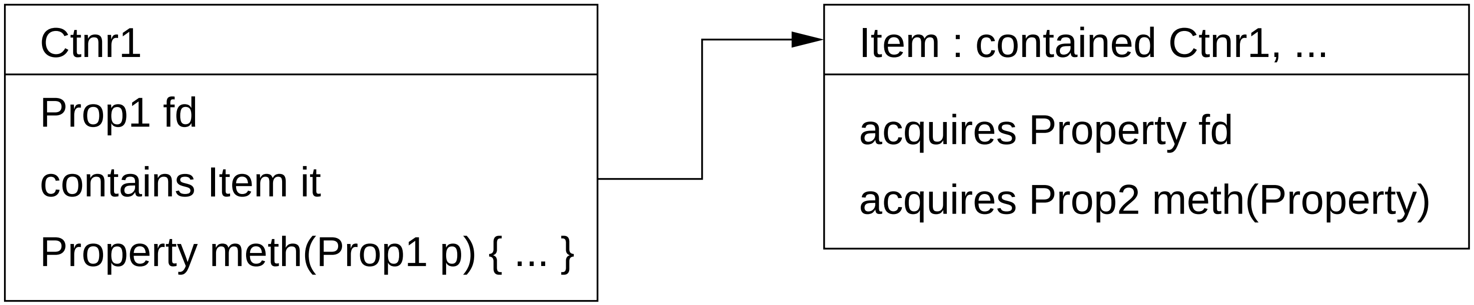

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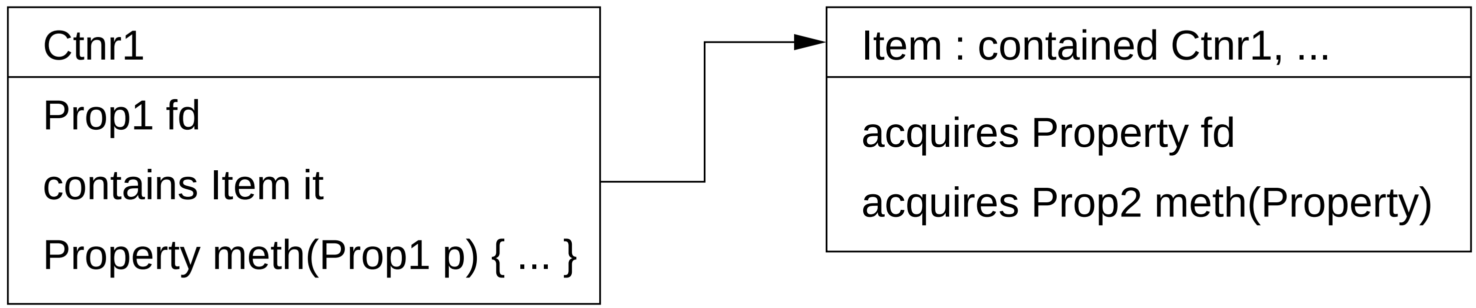

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Co/contravariance don't apply.

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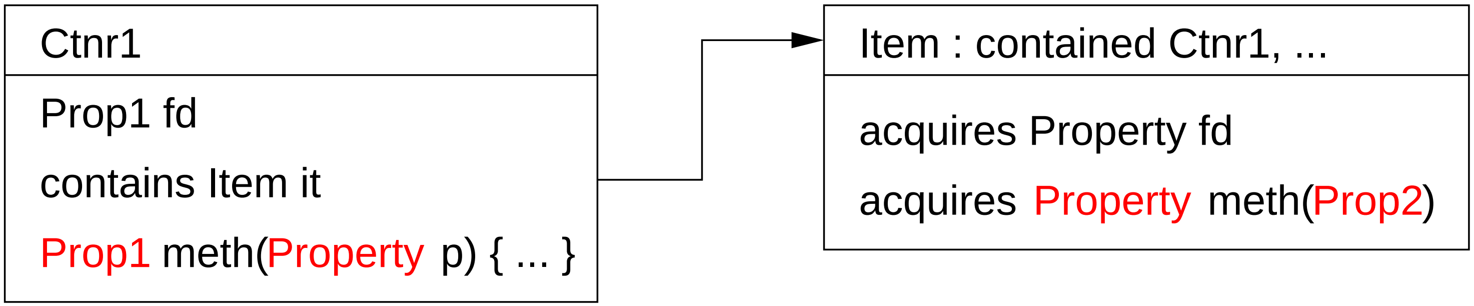
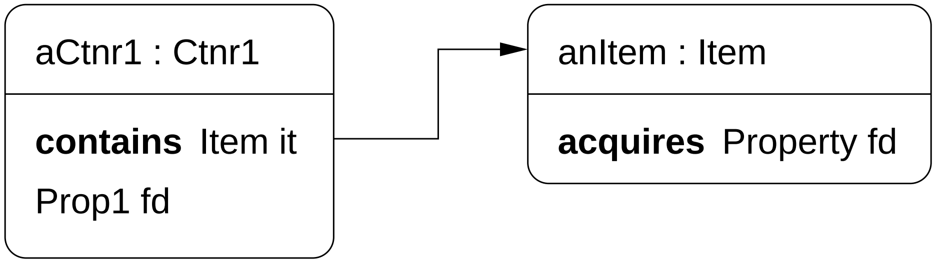


Variance is still possible.

Acquiring class may expect more *general* type.

Assignment to Acquired Fields



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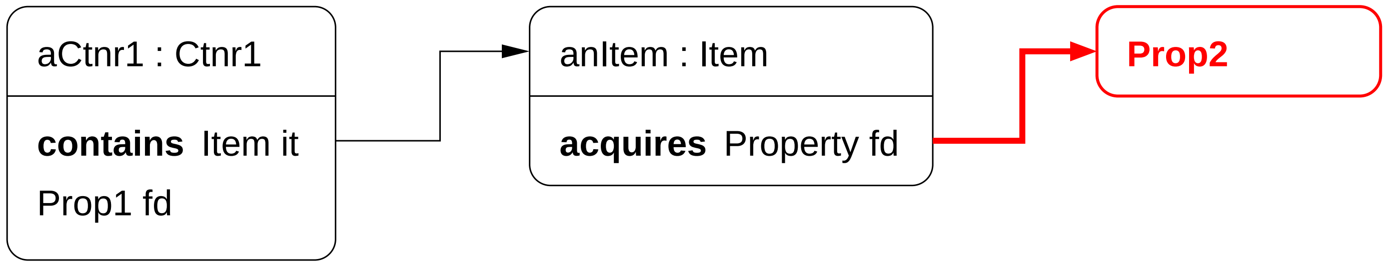

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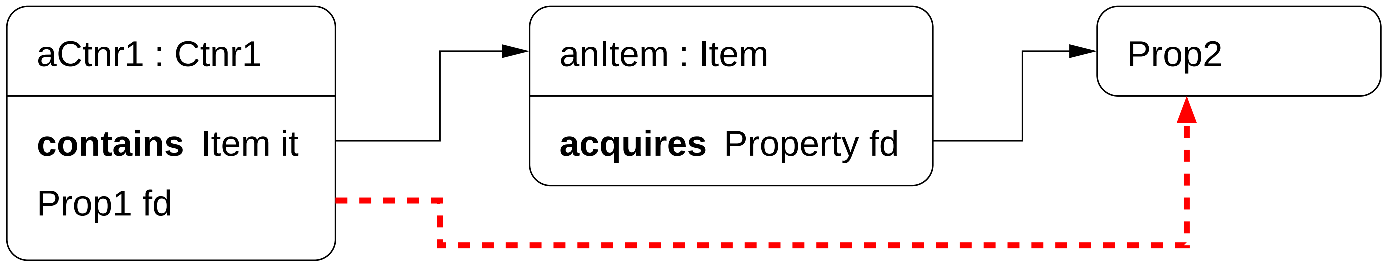

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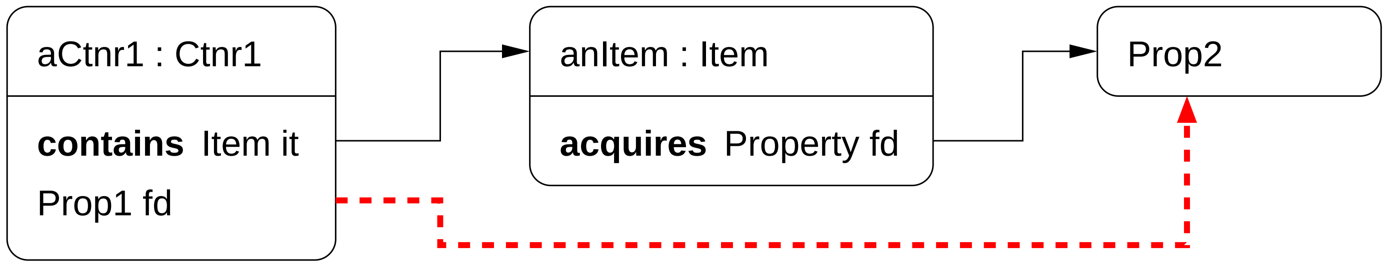

In a naïve system, `anItem.fd` := `new Prop2()` type-checks.

But `anItem.fd` is an alias to `aCtnr1.fd`.

Unsafe: `aCtnr1.fd` is no longer a `Prop1`.

Assignment to Acquired Fields

Three possible solutions:

1. Forbid subsumption on the right-hand side of assignments to acquired fields.

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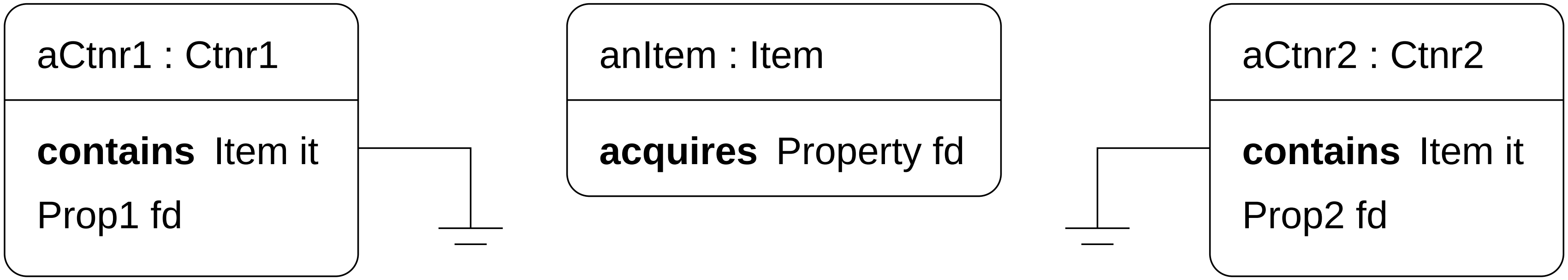
Jacques implements option 3: right balance between flexibility and safety.

Changing Containers



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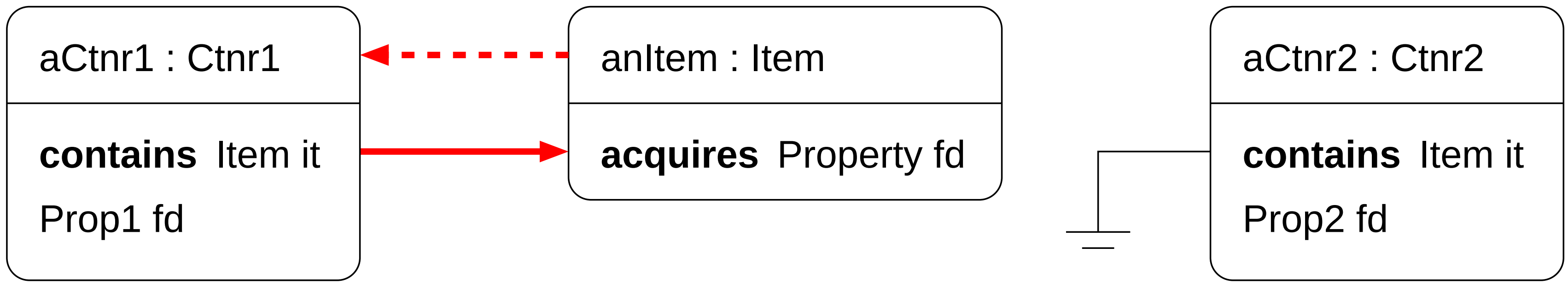

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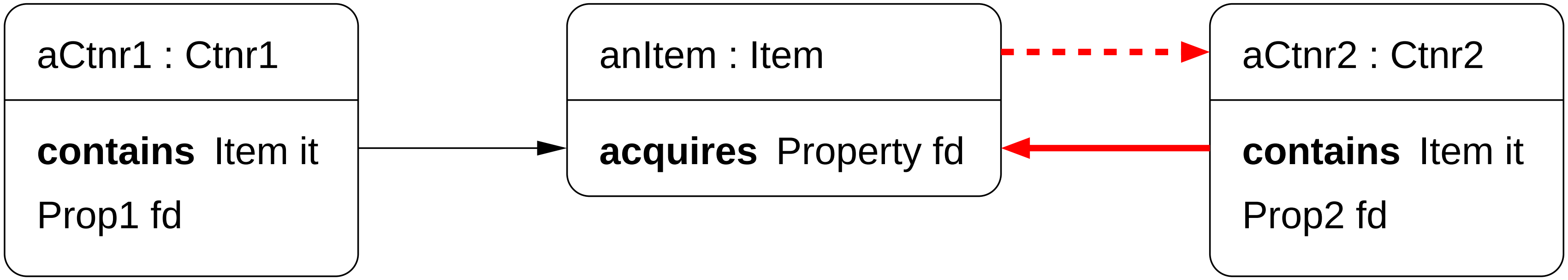

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Violates two-way reference invariant.

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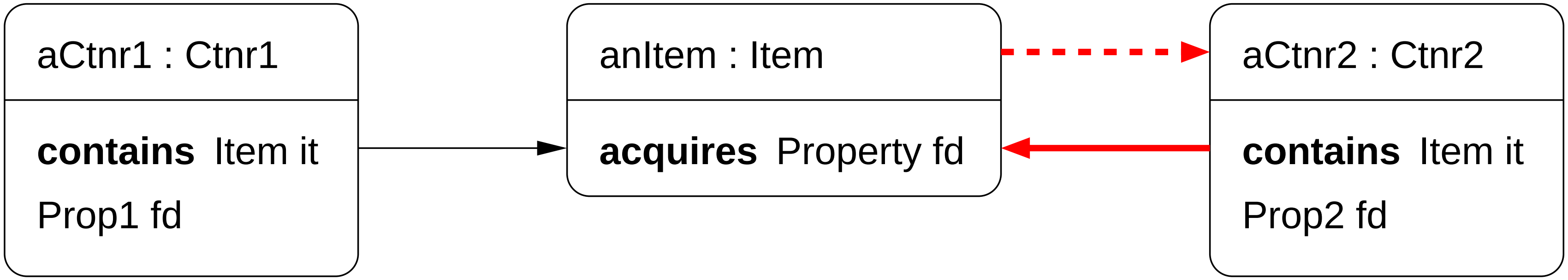


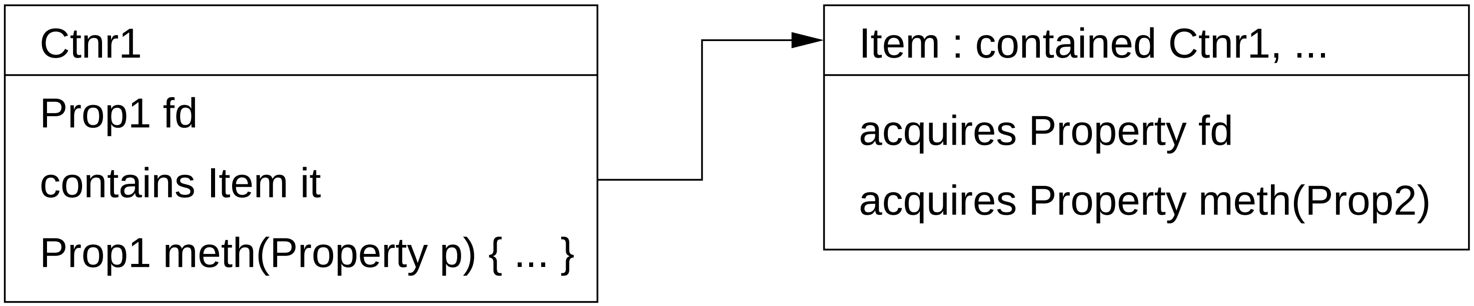
Assignment `aCtnr1.it := anItem` automatically updates hidden parent ref.

Can change existing containment tree: `aCtnr2.it := anItem`.

Violates two-way reference invariant.

So we forbid this assignment.

Forwarding and Delegation



What is **this** when executing acquired method `anItem.meth(...)`?

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- Forwarding: **this** refers to providing object (`aCtnr1`)

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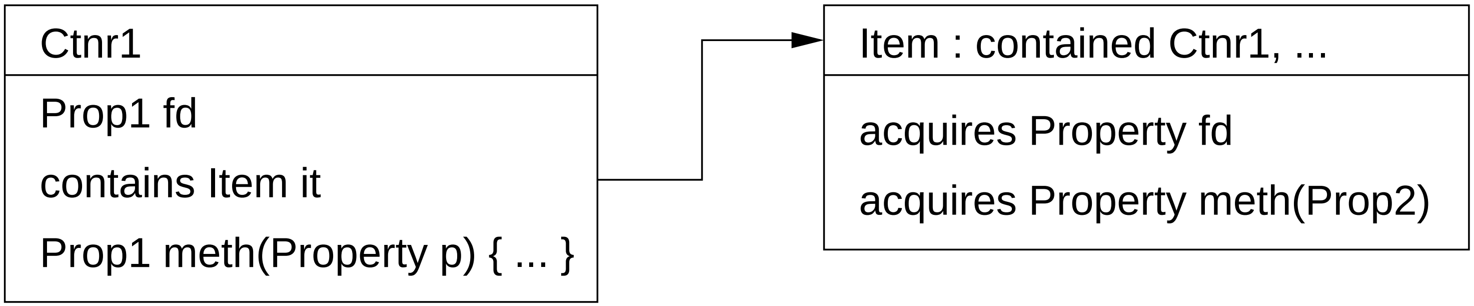

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Delegation unsafe: body of `Ctnr1.meth` type-checked under assumption that **this** : `Ctnr1`.

Type Soundness

Jacques Soundness

If program P has type t, then evaluating P has one of the following results:

- The result is an object reference with the right type, or
- The result is **null**, or
- The program diverges, or
- The program halts with an error:
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- The program halts with an error:
  - dereferenced **null**
  - bad cast
  - incomplete context
  - object already contained
  - container cycle

Conclusions

Contributions

We have placed demonstrated acquisition's technical feasibility and placed it on a firm theoretical foundation.

- We developed a formal model for reasoning about acquisition in the context of a Java-like language.
- We used the formal model to re-examine Gil & Lorenz's conclusions about type safety.
- We explored the interactions between acquisition and assignment.

Future Work

- Wider range of examples of acquisition.
- Practical experience: implement this and use it.
- More advanced type systems:
  - Can we infer list of possible containers for a class?
  - Can a resource-aware type system ensure that the “incomplete context” exception is never generated?

Related Work

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- Also constrain object containment—to limit object aliasing
- Could help us ensure no object has multiple containers
- But resulting constraints on aliasing too restrictive
- Cannot statically prevent "incomplete context" exceptions

Thank you.

cobbe@ccs.neu.edu