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Is Multiple Inheritance the Ultimate Principle in Reusability?

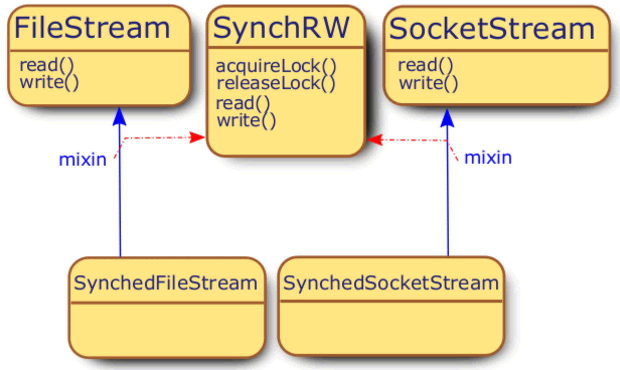
Learning outcomes

1. Identify problems of composition and decomposition
2. Understand semantics of traits
3. Separate function provision, object generation and class relations
4. Traits and existing program languages

Reusability ≡ Inheritance?

- Codesharing in Object Oriented Systems is mostly inheritance-centric.
- Inheritance itself comes in different flavours:
  - single inheritance
  - multiple inheritance
  - mixin inheritance
- All flavours of inheritance tackle problems of *decomposition* and *composition*

Duplication



⚠ Duplication

- Convenient implementation needs *second order types*, only available with ⇝ Mixins or ⇝ Templates

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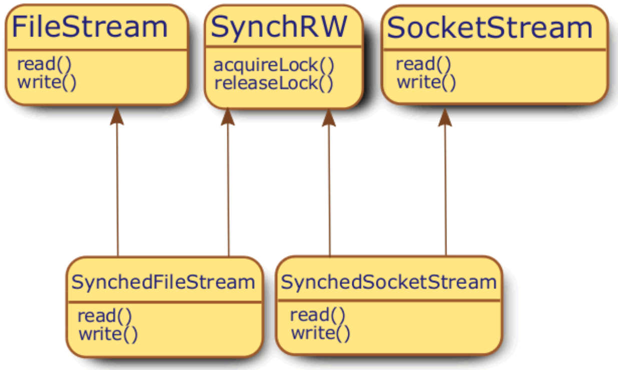
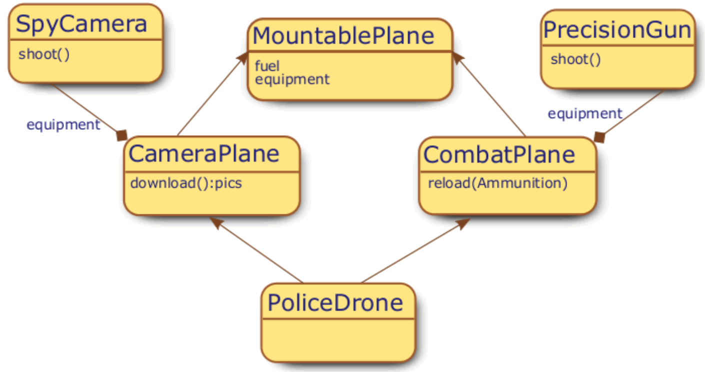


⚠ Duplication

- Convenient implementation needs *second order types*, only available with ⇝ Mixins or ⇝ Templates
- With multiple inheritance, `read`/`write` Code is essentially *identical but duplicated*

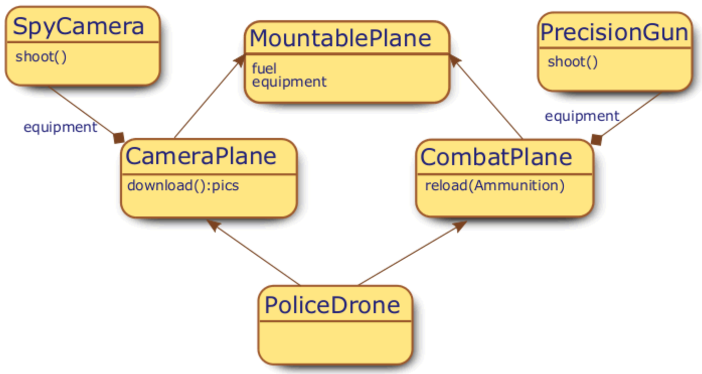
Lack of Control



⚠ Control

- Common base classes are shared or duplicated at class level

Lack of Control



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- Linearization overrides all identically named ancestor methods in parallel

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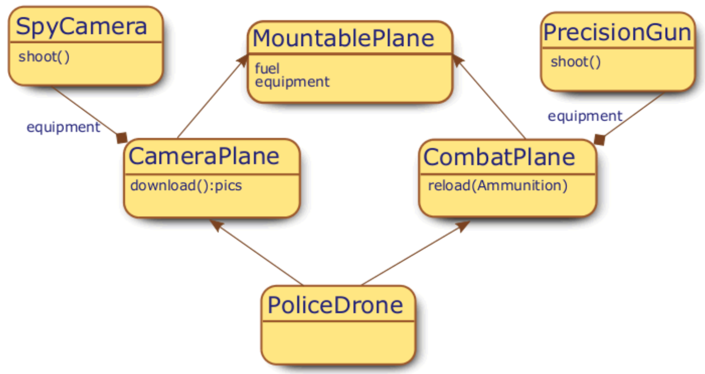
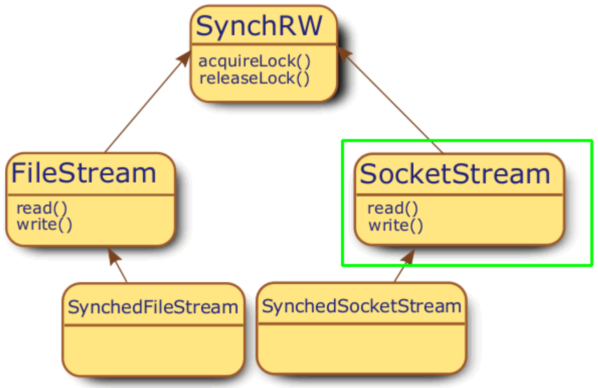


⚠ Control

- Common base classes are shared or duplicated at class level
- Linearization overrides all identically named ancestor methods in parallel
- `super` as ancestor reference vs. qualified specification

⇝ No *fine-grained specification* of duplication or sharing

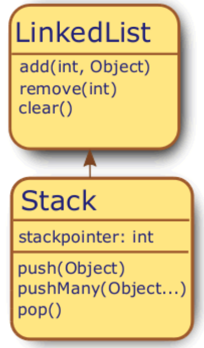
Fragility



Inappropriate Hierarchies

- Implemented methods (`acquireLock/releaseLock`) *to high*

Fragility



Inappropriate Hierarchies

- Implemented methods (`acquireLock/releaseLock`) *to high*
- High up specified methods *turn obsolete*, but there is no statically safe way to remove them

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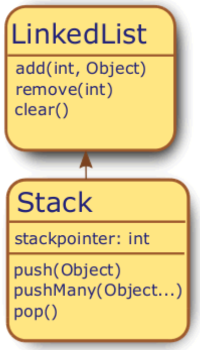

Inappropriate Hierarchies

- Implemented methods (`acquireLock/releaseLock`) *to high*
- High up specified methods *turn obsolete*, but there is no statically safe way to remove them ⚠ Liskov Substitution Principle!

Is Implementation Inheritance even an *Anti-Pattern*?

Excerpt from the Java 8 API documentation for class `Properties`:

> *"Because `Properties` inherits from `Hashtable`, the `put` and `putAll` methods can be applied to a `Properties` object. Their use is strongly discouraged as they allow the caller to insert entries whose keys or values are not `Strings`. The `setProperty` method should be used instead. If the `store` or `save` method is called on a "compromised" `Properties` object that contains a non-`String` key or value, the call will fail…"*

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⚠ Misuse of inheritance

Implementation Inheritance itself as a pattern for code reusage is often misused!
⇝ All that is possible will once be done!

(De-)Composition problems

All the problems of

- Duplication
- Fragility
- Lack of fine-grained control

are centered around the question

"How do I distribute functionality over a hierarchy"

⇝ *functional (de-)composition*

The idea behind Traits

- A lot of the problems originate from the coupling of implementation and modelling
- Interfaces seem to be hierarchical
- Functionality seems to be modular

⚠ Central idea

Separate Object creation from modelling hierarchies and assembling functionality.

⇝ Use interfaces to design hierarchical signature propagation
⇝ Use *traits* as modules for assembling functionality
⇝ Use classes as frames for entities, which can create objects

Classes and Methods – again

The building blocks for classes are

- a countable set of method *names* $\mathcal{N}$
- a countable set of method *bodies* $\mathbb{B}$

Classes map names to elements from the *flat lattice* $\mathcal{B}$ (called bindings), consisting of:

- attribute offsets $\in \mathbb{N}^+$
- method bodies $\in \mathbb{B}$ or classes $\in \mathcal{C}$
- $\bot$ (yet) undefined
- $\top$ in conflict

and the partial order $\bot \sqsubseteq m \sqsubseteq \top$ for each $m \in \mathcal{B}$

Definition (Abstract Class $\in \mathcal{C}$)

A partial function $c : \mathcal{N} \mapsto \mathcal{B}$ is called abstract class.

Definition (Interface and Class)

An abstract class c is called (with pre beeing the preimage)

interface iff $\forall_{n \in \text{pre}(c)} \,.\, c(n) = \bot$.

(concrete) class iff $\forall_{n \in \text{pre}(c)} \,.\, \bot \sqsubset c(n) \sqsubset \top$.

Traits – Composition

Definition (Trait $\in \mathcal{T}$)

An abstract class t is called *trait* iff $\forall_{n \in \text{pre}(t)} \,.\, t(n) \notin \mathbb{N}^+$ (i.e. without attributes)

The *trait sum* $+ : \mathcal{T} \times \mathcal{T} \mapsto \mathcal{T}$ is the componentwise least upper bound:

$$(c_1 + c_2)(n) = b_1 \sqcup b_2 = \begin{cases} b_2 & \text{if } b_1 = \bot \vee n \notin \text{pre}(c_1) \\ b_1 & \text{if } b_2 = \bot \vee n \notin \text{pre}(c_2) \\ b_2 & \text{if } b_1 = b_2 \\ \top & \text{otherwise} \end{cases} \quad \text{with } b_i = c_i(n)$$

Trait-Expressions also comprise:

- *exclusion* $- : \mathcal{T} \times \mathcal{N} \mapsto \mathcal{T}$: $\quad (t - a)(n) = \begin{cases} \text{undef} & \text{if } a = n \\ t(n) & \text{otherwise} \end{cases}$
- *aliasing* $[\rightarrow] : \mathcal{T} \times \mathcal{N} \times \mathcal{N} \mapsto \mathcal{T}$: $\quad t[a \rightarrow b](n) = \begin{cases} t(n) & \text{if } n \neq a \\ t(b) & \text{if } n = a \end{cases}$

Traits t can be connected to classes c by the asymmetric join:

$$(c \,\overleftarrow{\sqcup}\, t)(n) = \begin{cases} c(n) & \text{if } n \in \text{pre}(c) \\ t(n) & \text{otherwise} \end{cases}$$

Traits – Concepts

Trait composition principles

Flat ordering All traits have the same precedence under $+$
$\rightsquigarrow$ explicit disambiguation with aliasing and exclusion

Precedence Under asymmetric join $\overleftarrow{\sqcup}$, class methods take precedence over trait methods

Flattening After asymmetric join $\overleftarrow{\sqcup}$: Non-overridden trait methods have the same semantics as class methods

⚠ Conflicts . . .

arise if composed traits map methods with identical names to different bodies

Conflict treatment

- ✓ Methods can be aliased ($\rightarrow$)
- ✓ Methods can be excluded ($-$)
- ✓ Class methods override trait methods and sort out conflicts ($\overleftarrow{\sqcup}$)

Disambiguation

Traits vs. Mixins vs. Class-Inheritance

All different kinds of type expressions:

- Definition of curried *second order type operators* + Linearization

Explicitly: Traits differ from Mixins

- Traits are applied to a class *in parallel*, Mixins *sequentially*
- Trait *composition is unordered*, avoiding linearization effects
- Traits do *not contain attributes*, avoiding state conflicts
- With traits, *glue code* is concentrated in single classes

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- Combination of principles

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Traits in the Context of Modularity Problems

Decomposition Problems

- ✓ *Duplicated Features* ... can easily be factored out into unique traits.
- ✓ *Inappropriate Hierarchies* – Trait composition for reusable code concentrates inheritance on shaping interface relations.

Composition Problems

- ✓ *Conflicting Features* – Traits have no state, other conflicts resolved via exclusion, aliasing or overriding.
- ✓ *Lack of Control* – During trait composition precedence is chosen seperately for each feature.
- ✓ *Dispersal of Glue Code* ... deferred to and concentrated in the final class.
- ✓ *Fragile Hierarchies* – Trait details are hideable due to missing hierarchy.

Can we augment classical languages by traits?