Supporting Separation of Concerns Throughout the Lifecycle with Theme/UML

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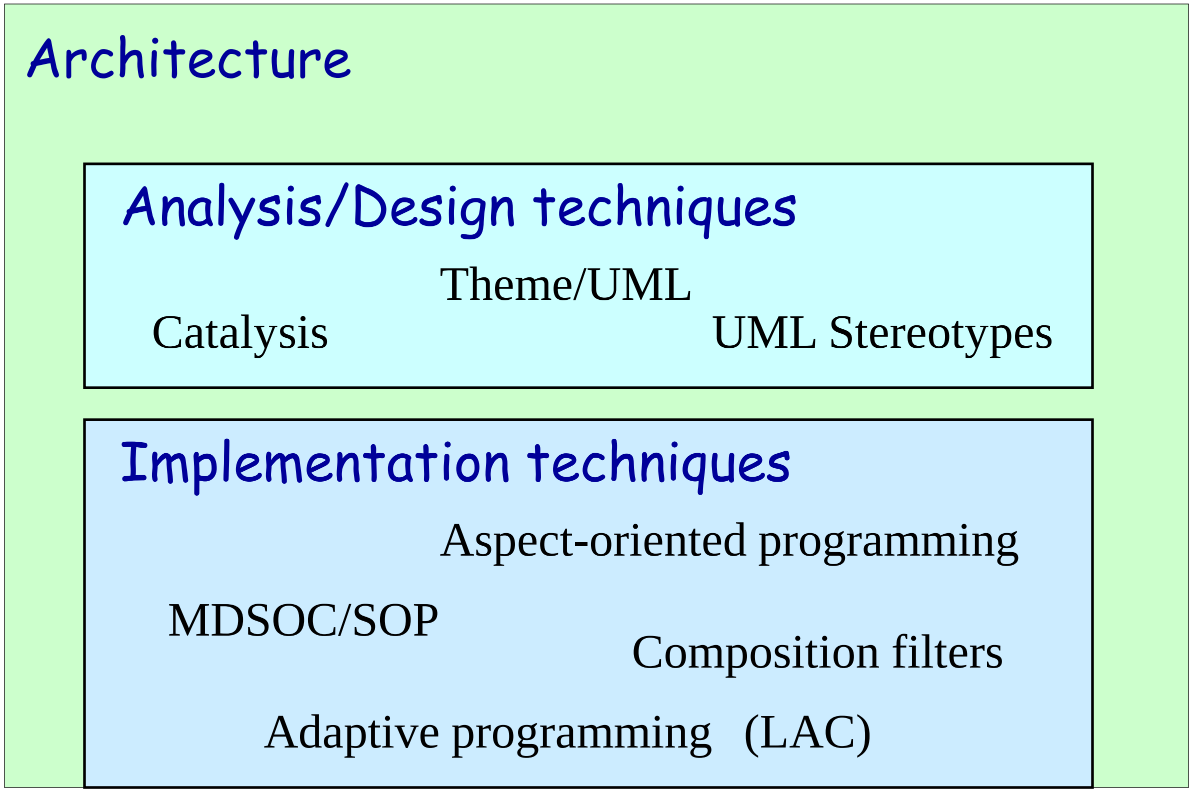
Agenda

- The Aspect-Oriented Software Development (AOSD) field
- The problem addressed with Theme/UML
- Decomposing/composing object-oriented designs
- Composition patterns

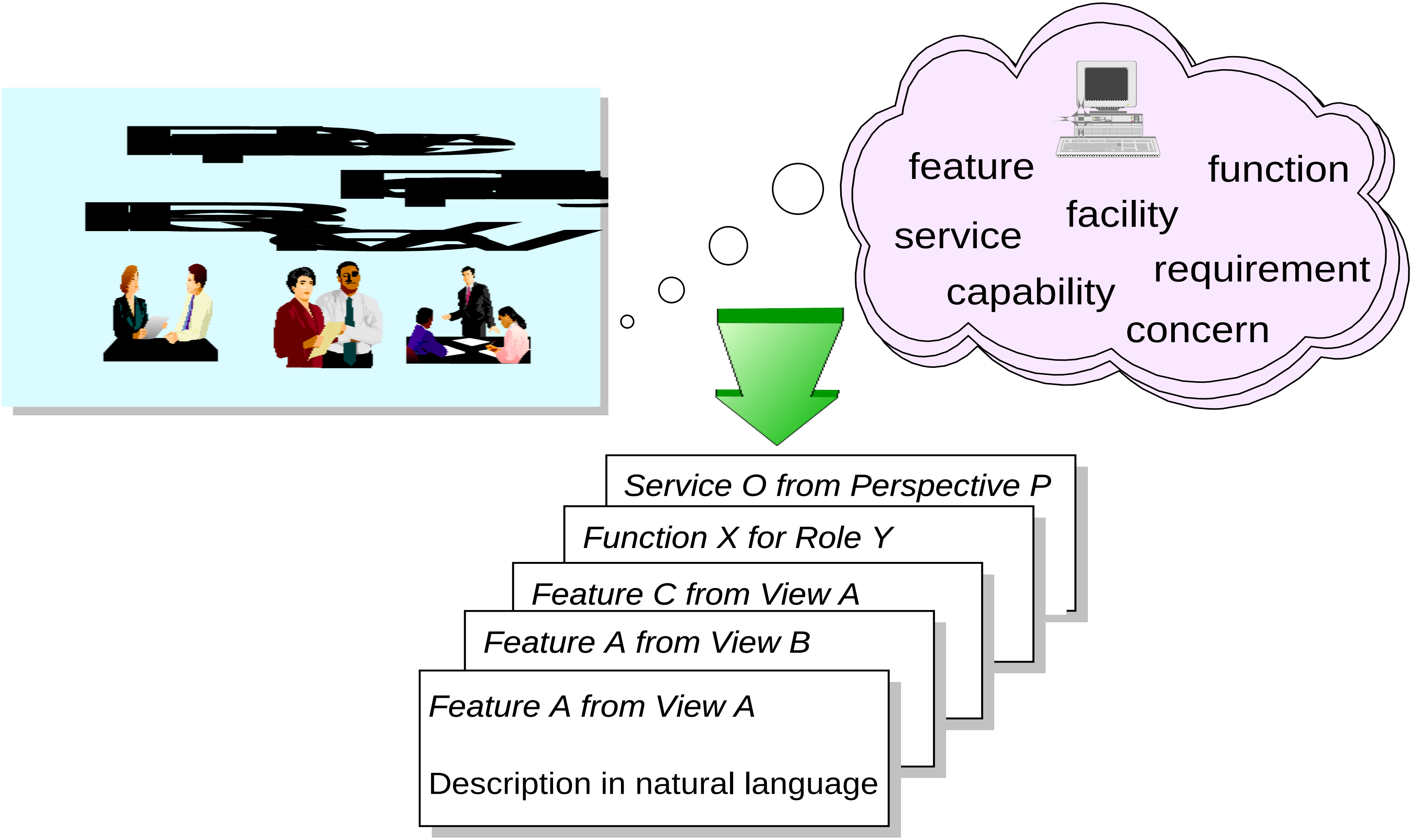
Aspect-Oriented Software Development



(See www.aosd.net for a more complete set of references to the field)

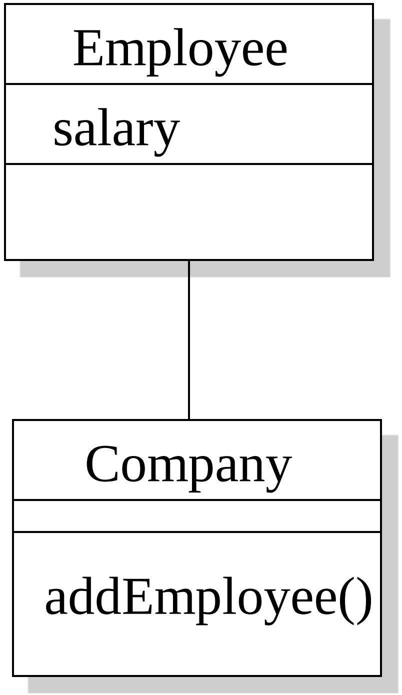
Other approaches to "improving" OO include domain-specific languages, generative programming, generic programming, constraint languages, reflection and metaprogramming, feature-oriented development, views/viewpoints, …

Requirements Specification Paradigm



Object-Oriented Specification Paradigm

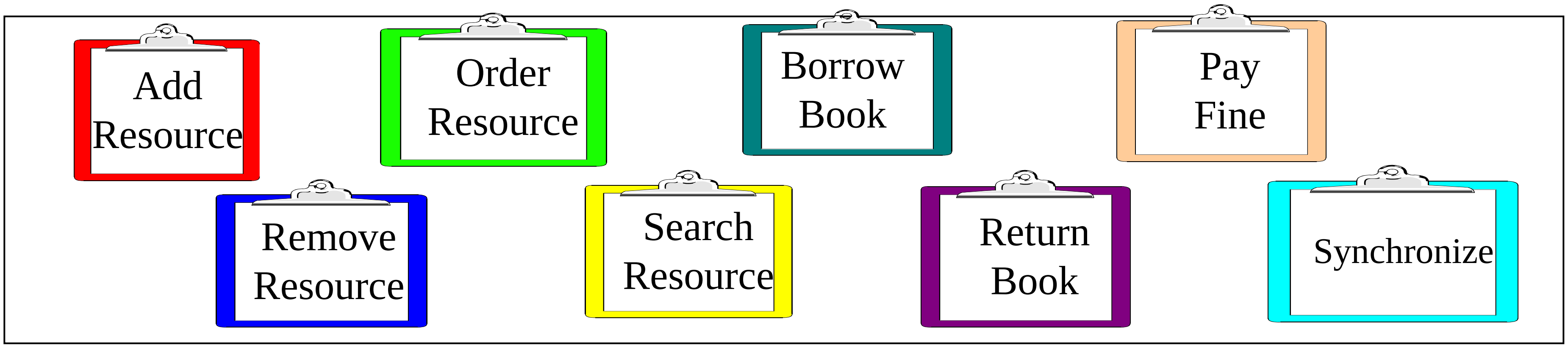
Most basic units of decomposition: *object*, and *class*

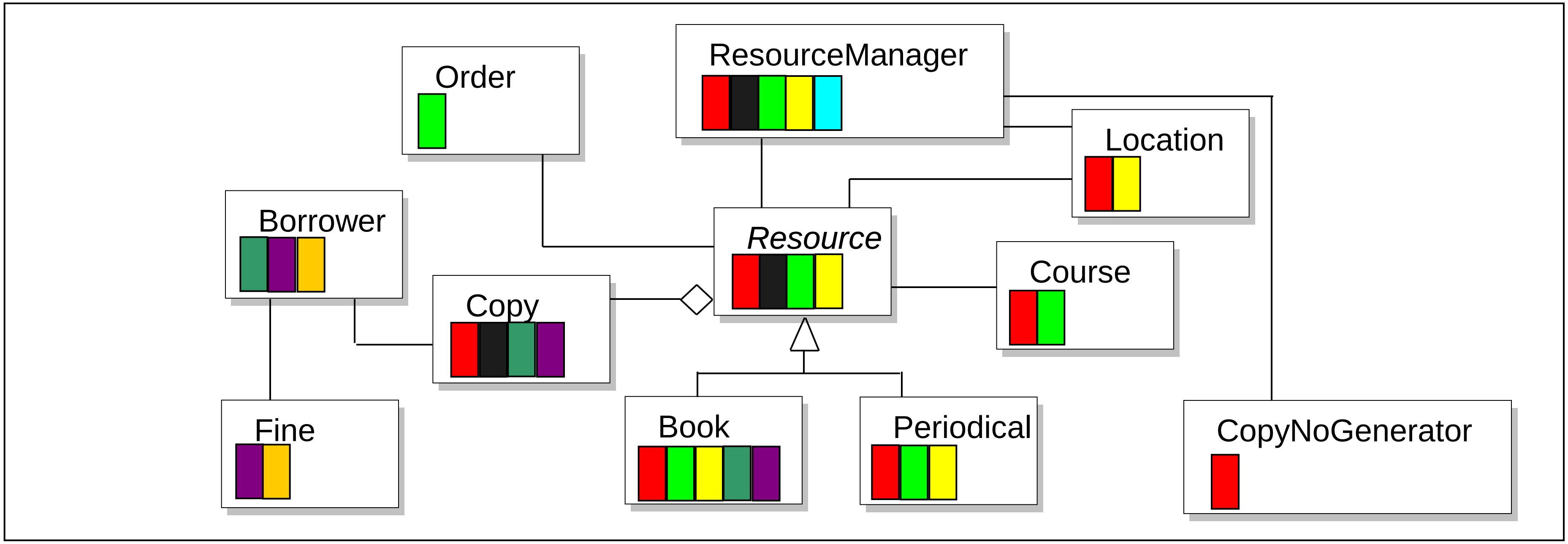


Object encapsulates additional units

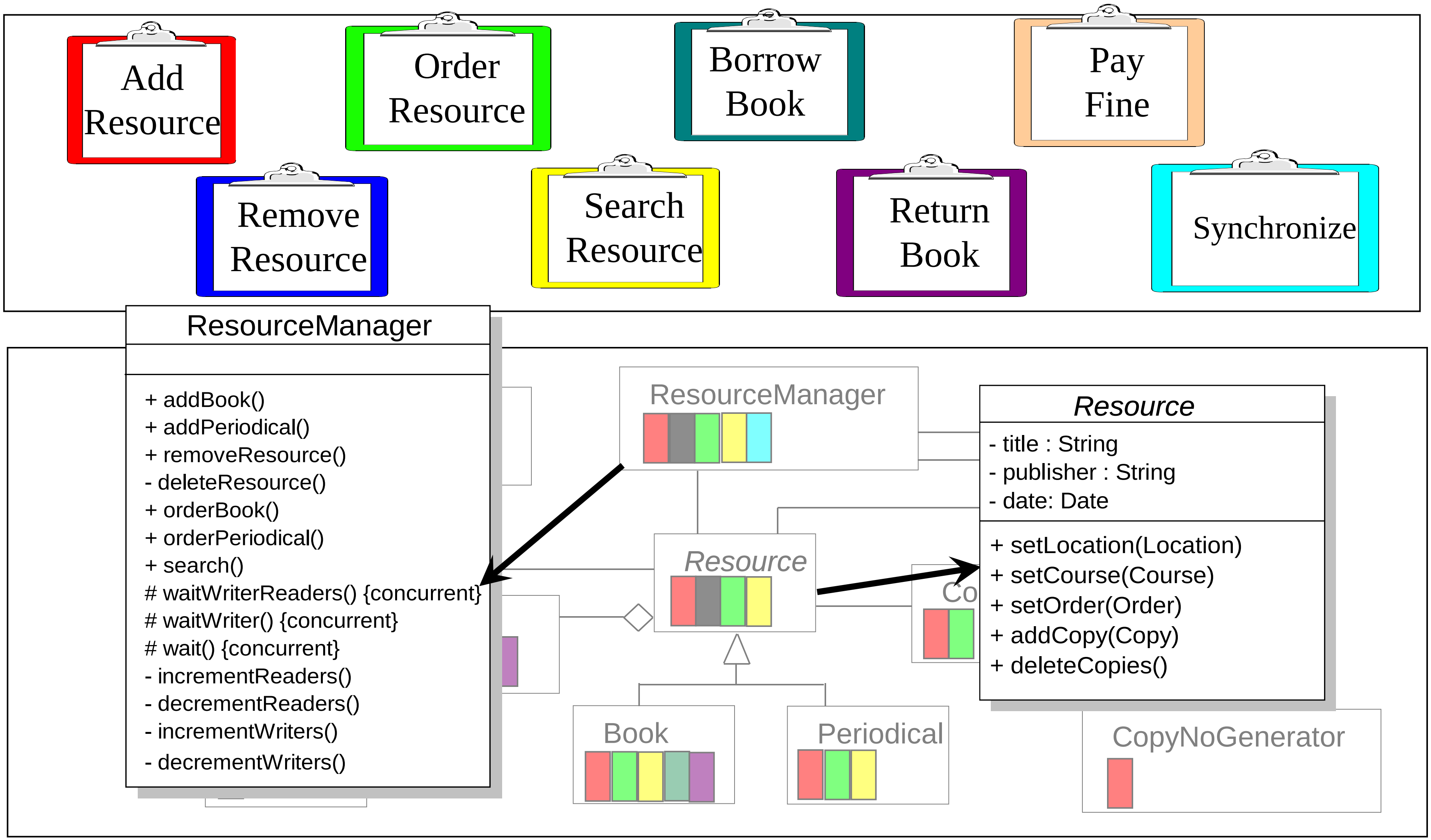
- Structural: attributes and relationships
- Behavioural: operations, interfaces, methods

Structural Mismatch
Requirements - OO Designs : Scattering





Structural Mismatch
Requirements - OO Designs : Tangling



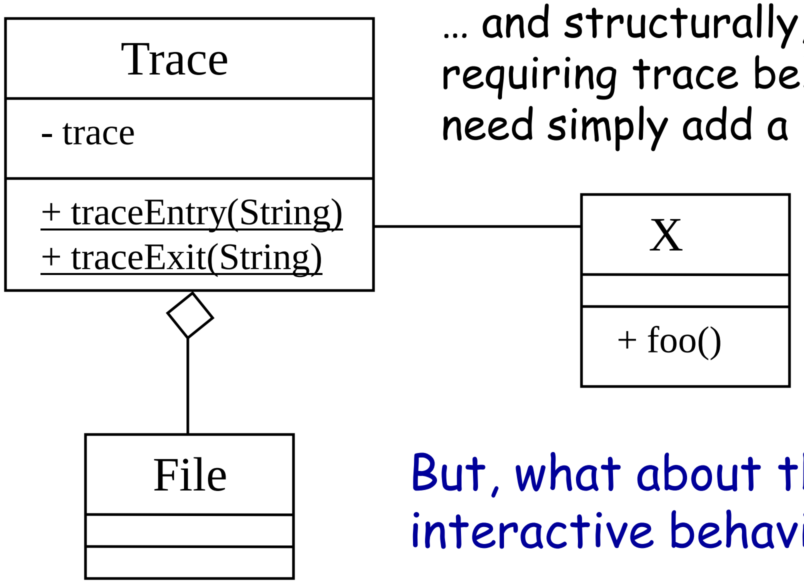
What about crosscutting concerns?

Crosscutting concerns are not well encapsulated by OO languages

- The object-oriented paradigm modularises based on class/object, interfaces and methods
- Where behaviour impacts multiple different classes and methods, (and therefore is *crosscutting*) it is not possible to encapsulate that behaviour using standard OO languages

Simple tracing example: the entry to and exit from each operation called is traced:

Structurally, design elements handling tracing can be separated…

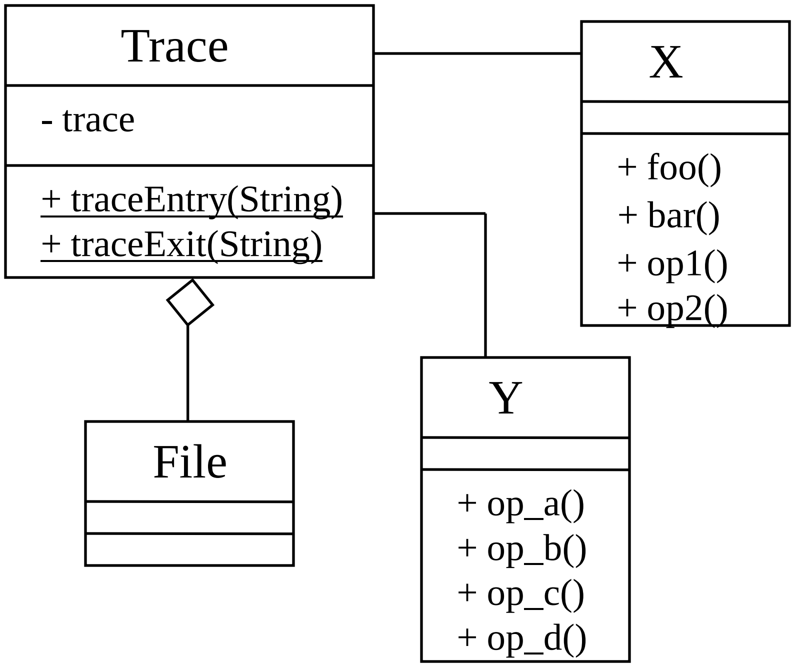


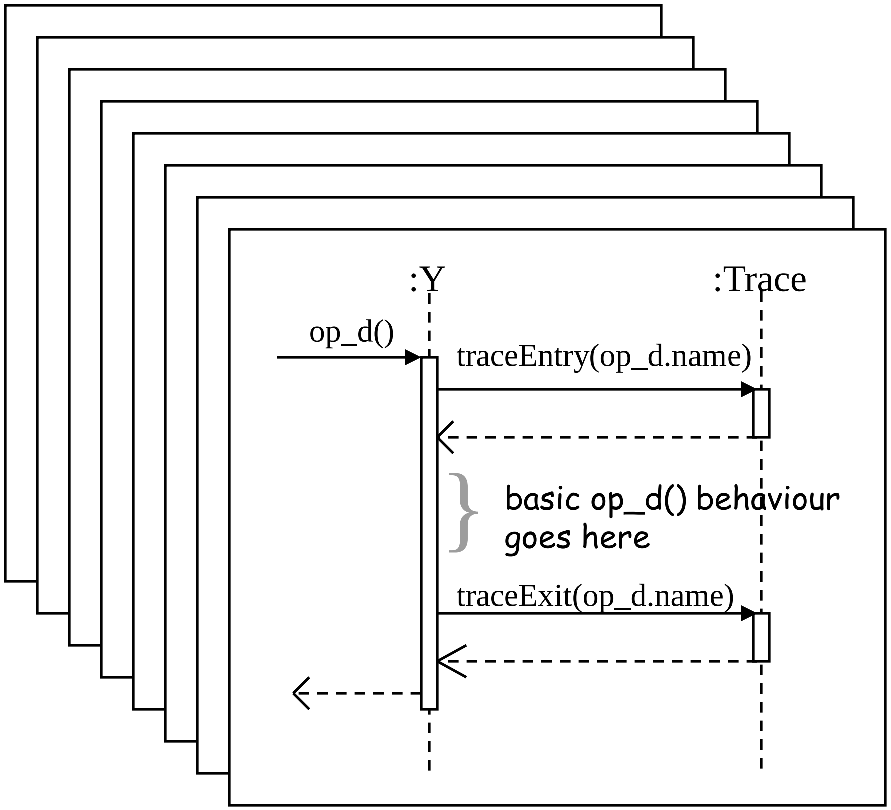
… and structurally, classes requiring trace behaviour need simply add a relationship

But, what about the interactive behaviour?

What about crosscutting concerns?

Crosscutting behaviour must be specified wherever required





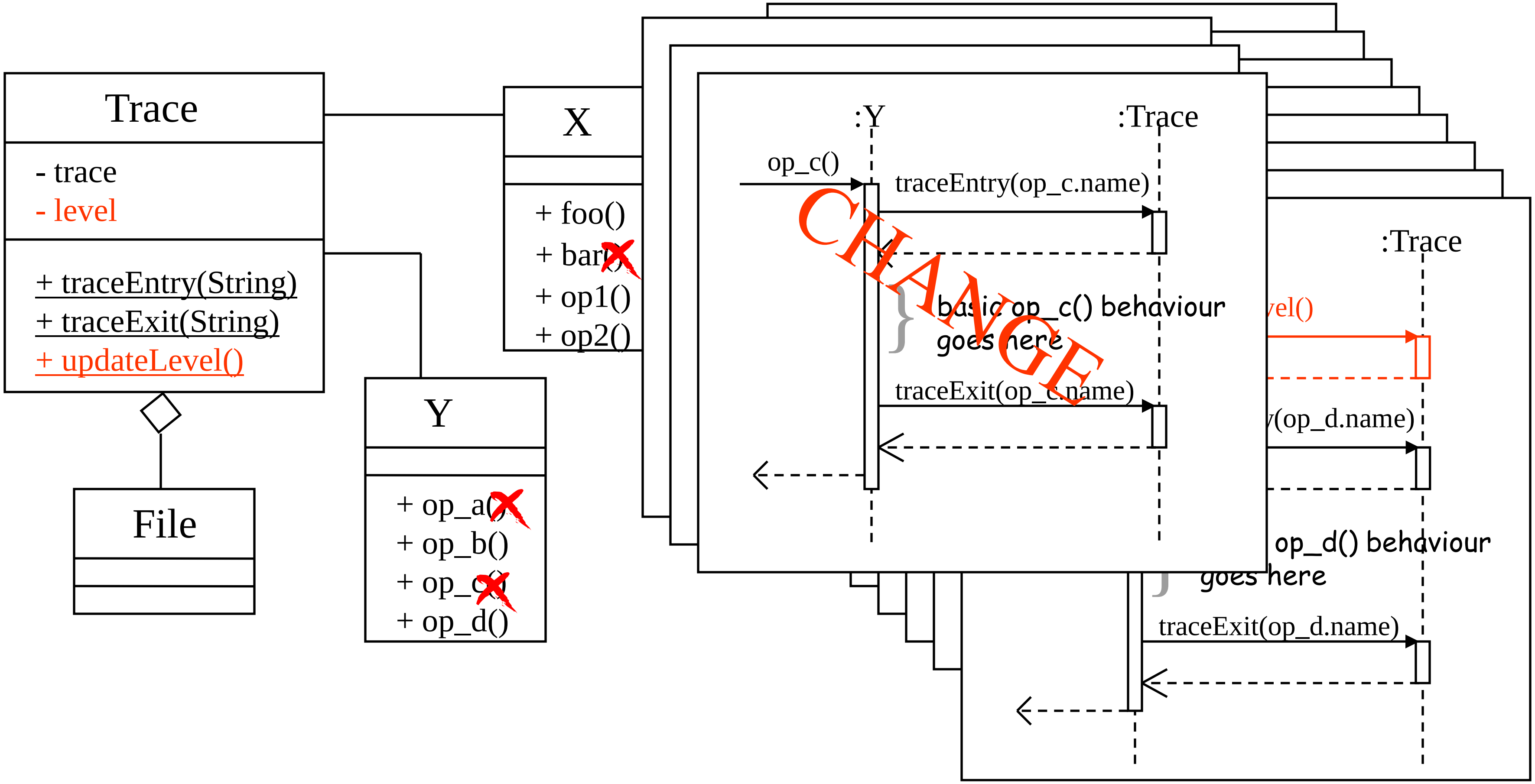
Of course, we could say:

"This isn't code, so a designer would never bother repeating all these interactions"

But other approaches are ad-hoc and undependable

What about crosscutting concerns?

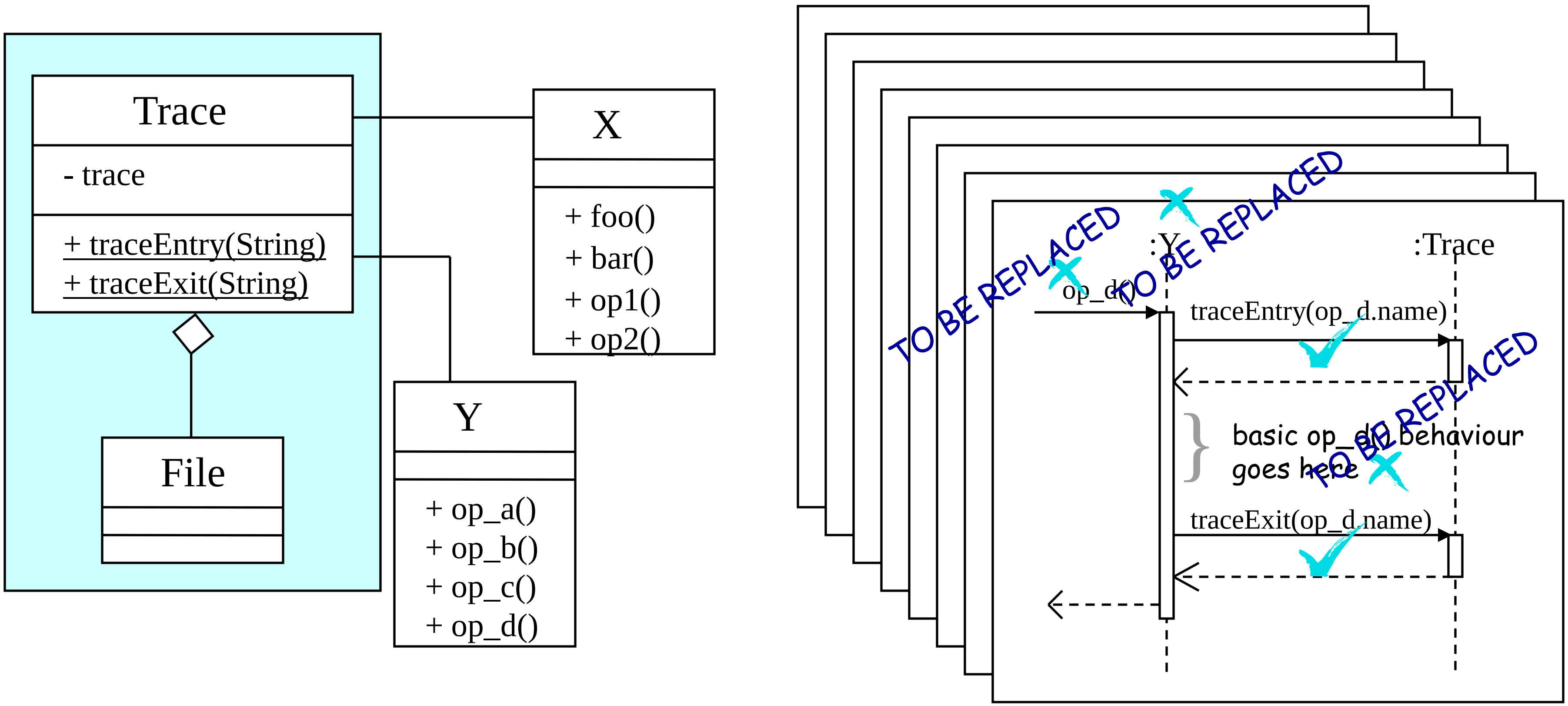
Change to crosscutting behaviour has significant impact across design



- If trace behaviour changes, all interactions have to change.
- If we want to remove trace behaviour from any particular operations, we have to change their interactions.

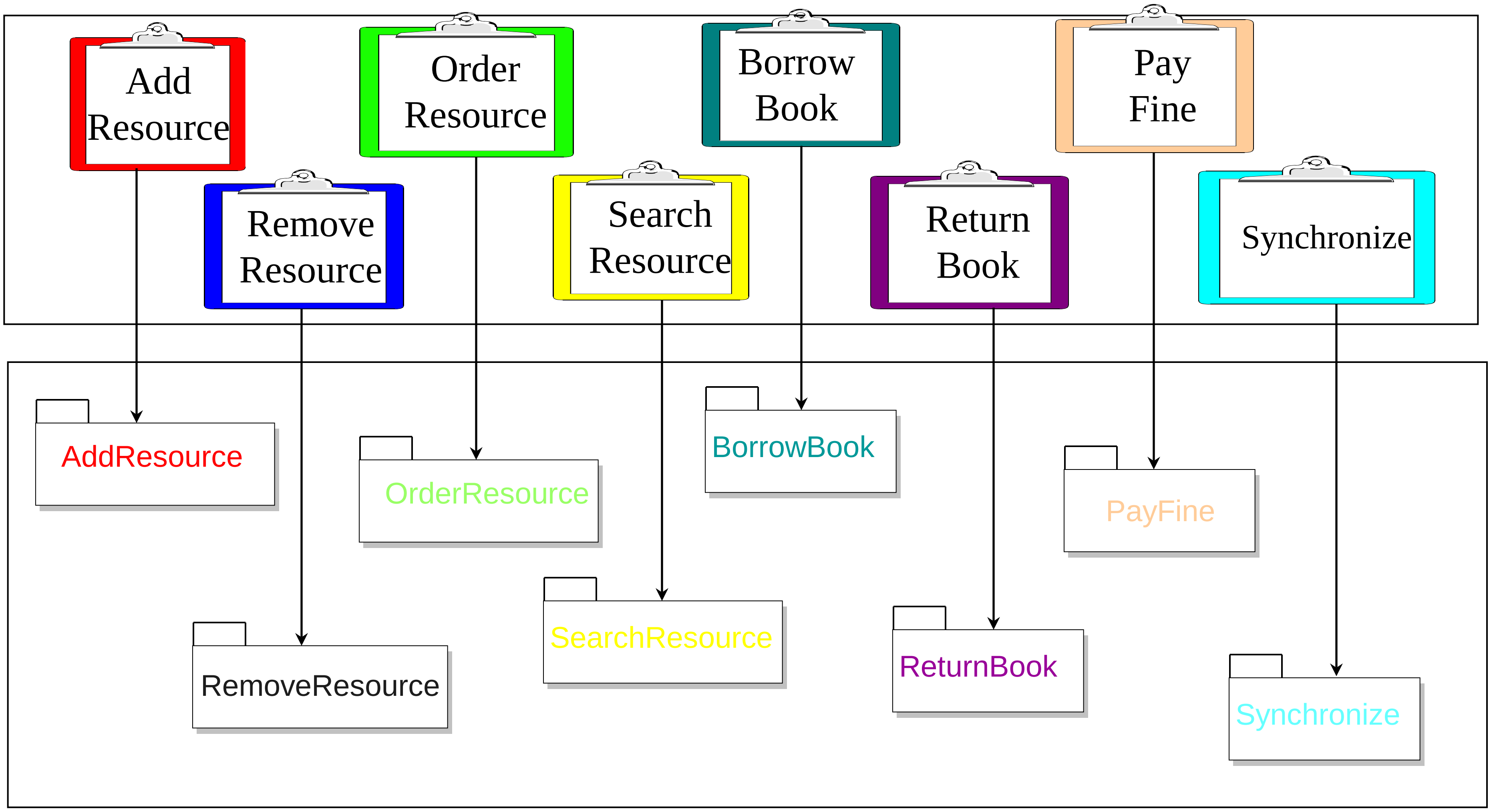
What about crosscutting concerns?

Reuse of crosscutting behaviour is not straightforward



- From a structural perspective, reuse may be reasonably straightforward – in this case, the classes and methods relating to trace have been separated.
- However, reuse of the behavioural specification is less easy. We have to examine the interactions, and extract the relevant pieces.

Theme/UML: Decomposition based on Requirements Specification



Implications of Decomposition based on Requirements

- Support for *overlapping* specifications

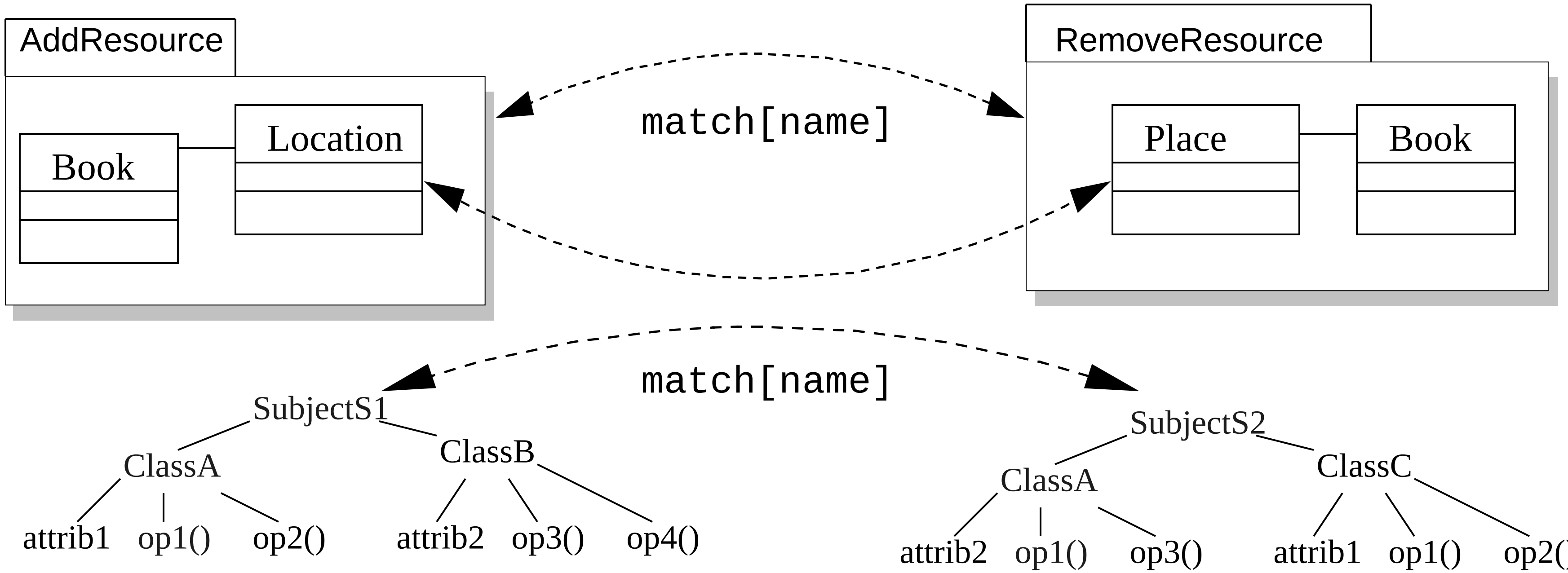
  Same core concepts appear in different subjects with possibly different specifications

- "*Crosscutting*" specifications supported

  Behaviour affecting multiple classes may be separated using composition patterns

Composing Design Models:
Composition Relationship

- A new kind of design relationship
- Defined between design elements indicating:
    - ✓ the elements that correspond (implicit, explicit)



Composing Design Models:
Composition Relationship

- A new kind of design relationship
- Defined between design elements indicating:
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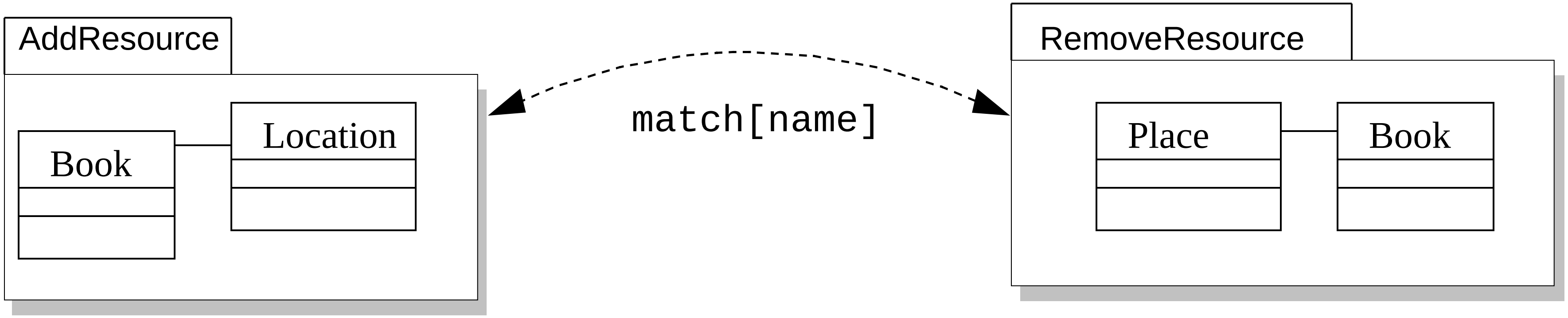
  - ✓ how corresponding elements are to be integrated – that is, understood as an integrated whole….



MERGE Integration: All design elements relevant for composed design

Composing Design Models:
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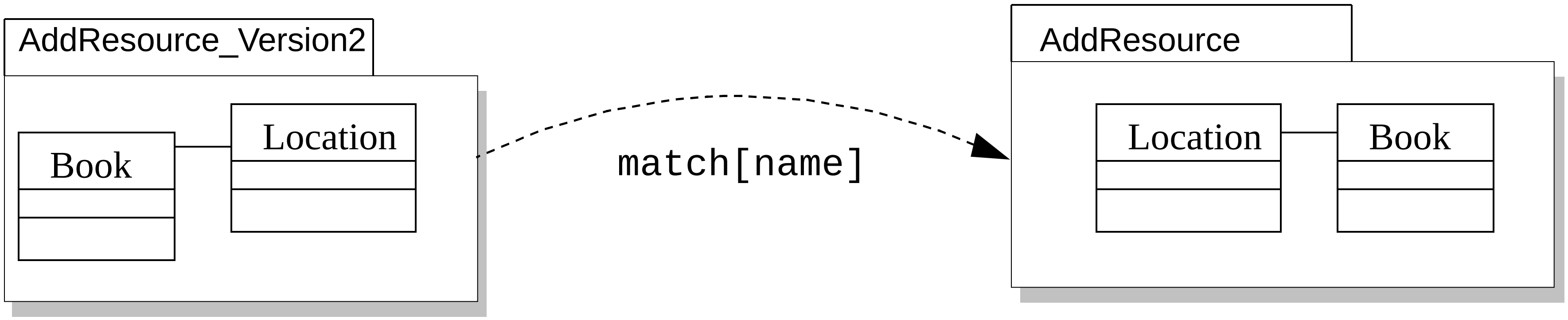

OVERRIDE Integration: Design elements replace previous specifications

Composing Design Models:
Composition Relationship

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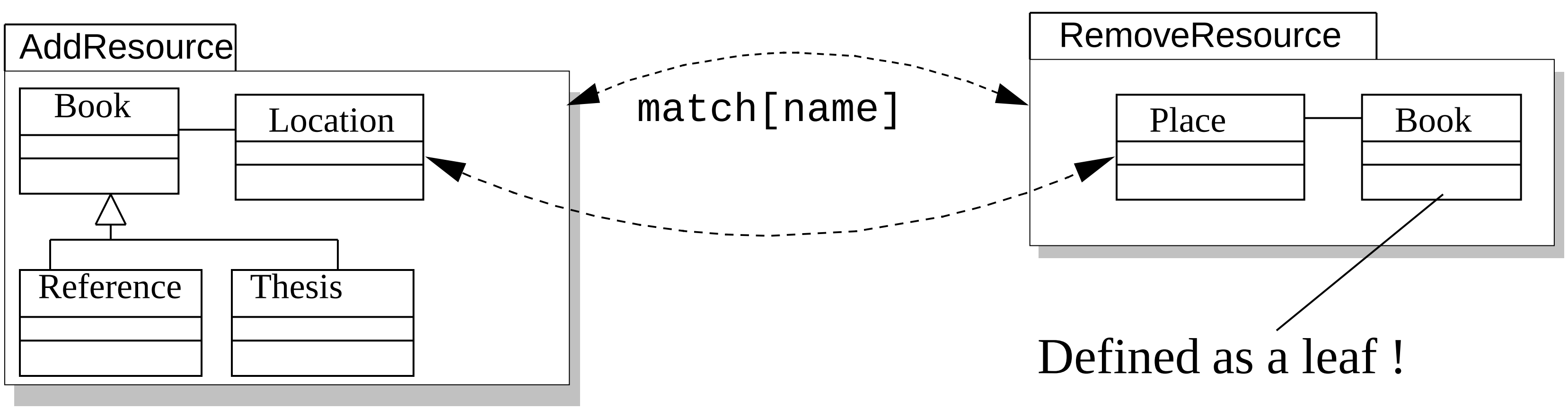
  - ✓ how corresponding elements are to be integrated
  - ✓ how to reconcile conflicts



Composing Design Models:
Composition Relationship

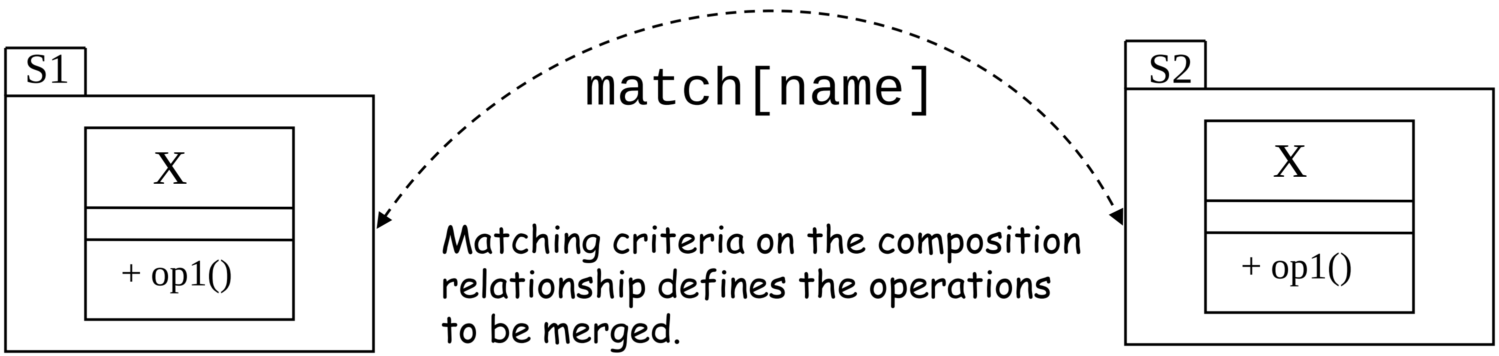
- A new kind of design relationship
- Defined between design elements indicating:
  - ✓ the elements that correspond (implicit, explicit)
  - ✓ how corresponding elements are to be integrated
  - ✓ how to reconcile conflicts
    - ❖ potential for conflict with any UML construct's properties
    - ❖ composition model supports reconciliation attachments to CR:
      - precedence
      - default values
      - explicit values
      - transform functions

Composing Design Models:
Composition Relationship

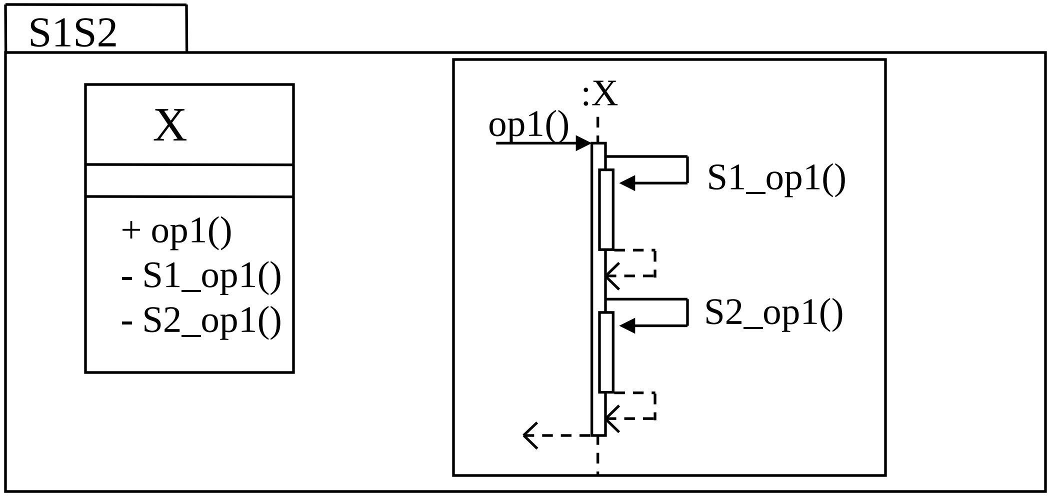
- A new kind of design relationship
- Defined between design elements indicating:
  - ✓ the elements that correspond (implicit, explicit)
  - ✓ how corresponding elements are to be integrated
  - ✓ how to reconcile conflicts
  - ✓ the “real” elements to replace placeholders in patterns
    - Particularly useful for composing “cross-cutting” behaviour patterns
    - Combination of composition semantics and UML templates

Merging behaviours from different models

- This is specified with a *composition relationship* which details the elements to be merged.



- Composition semantics uses *delegation* to merge corresponding operations from different models



Capturing crosscutting behaviour in a composition pattern

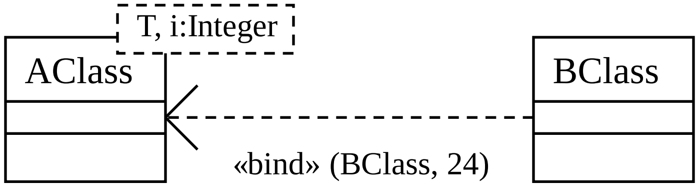
- A "Composition Pattern" (CP) is a package that contains the design models required to specify crosscutting behaviour
- A CP may be composed with other design models, merging those design models with the crosscutting behaviour.
- A CP does not contain a reference to any particular design element its aspect may crosscut.

- These properties of CPs present two important requirements for a design language:

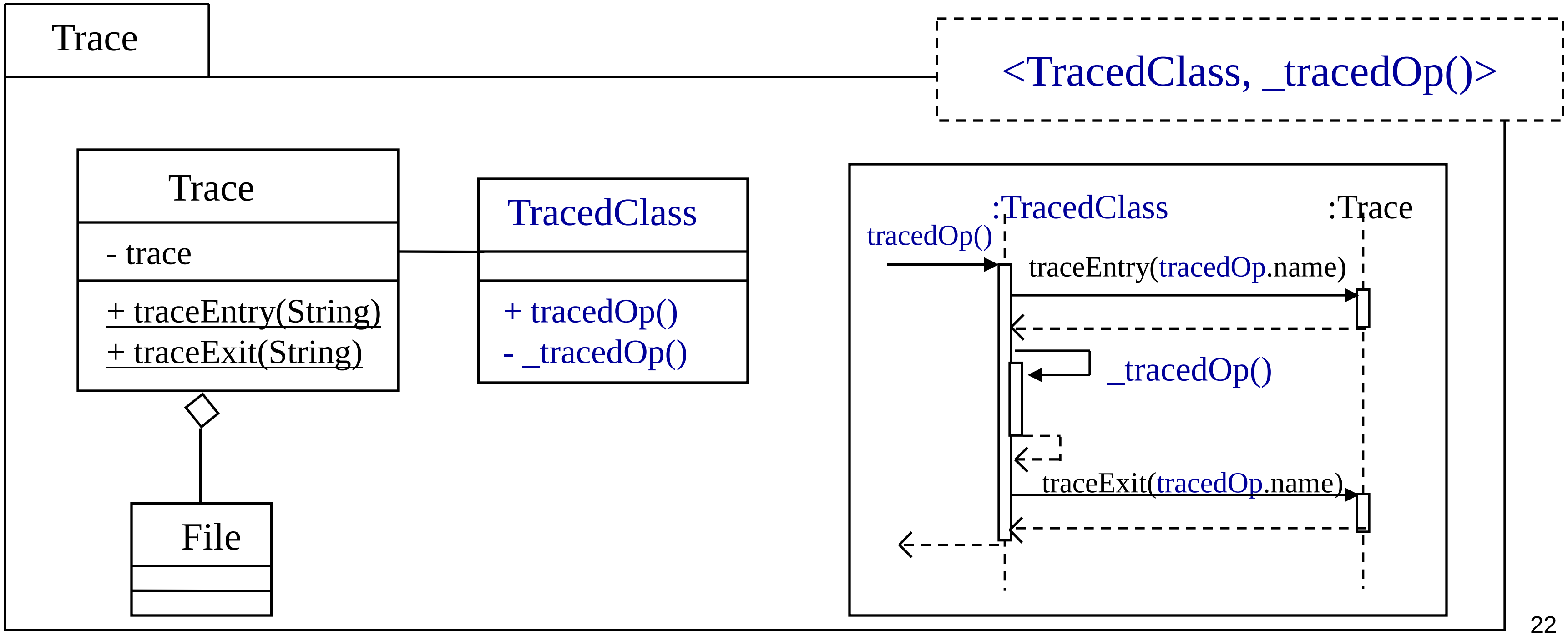
  1. Merge semantics for crosscutting behaviours
  2. The ability to reason about elements it may crosscut without explicit reference

Reasoning about elements to be crosscut

- The UML has a notion of *templates* which are described as "parameterised model elements", with formal parameters which may be "bound" by actual model elements.

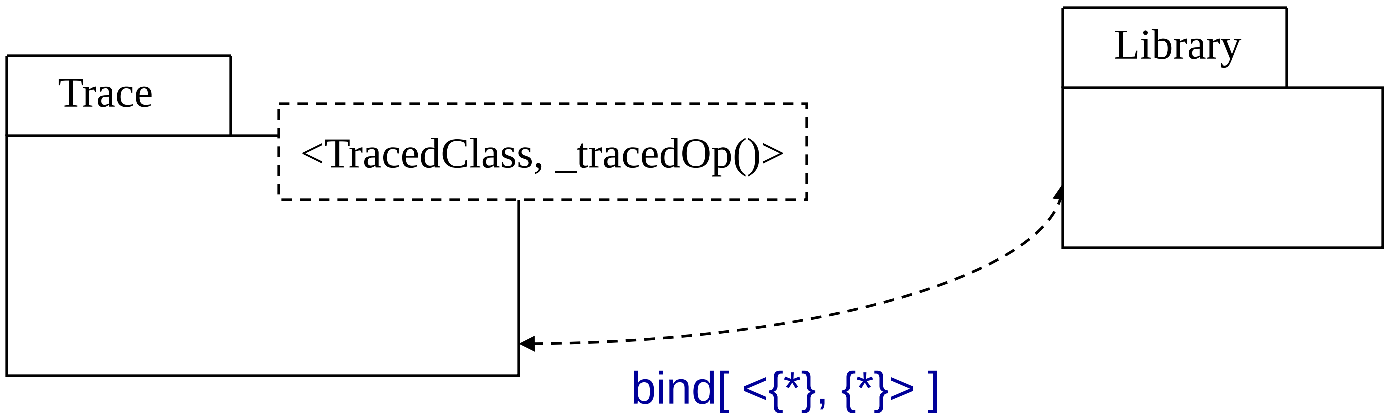


- CPs extend the UML notion of templates, allowing a package to have multiple *pattern classes* with *template parameters* within those pattern classes



Binding composition pattern to a base design

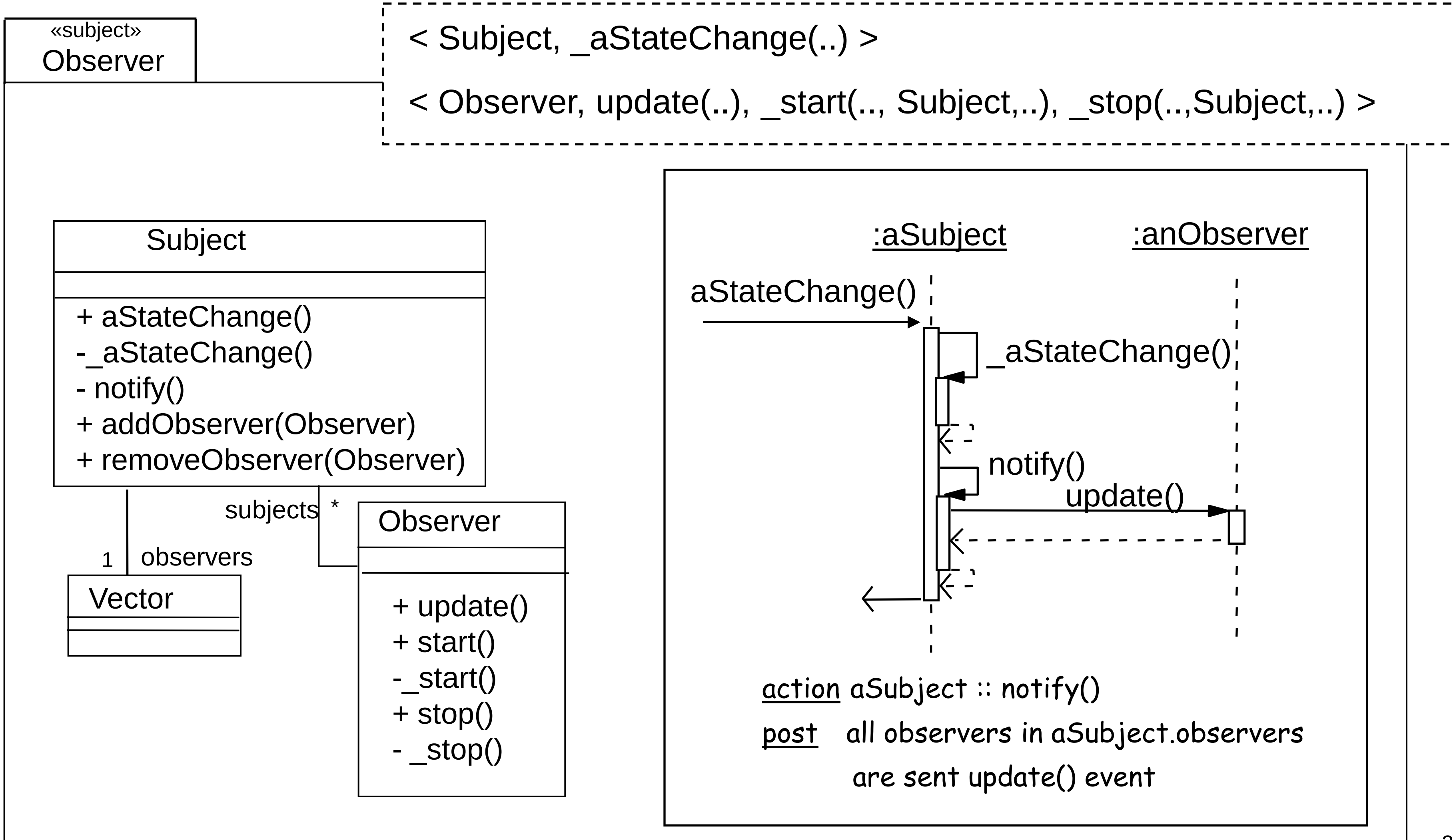
- CPs also build on the UML notion of a template binding relationship by extending composition relationships to include the ability to *bind* multiple real elements to the parameters



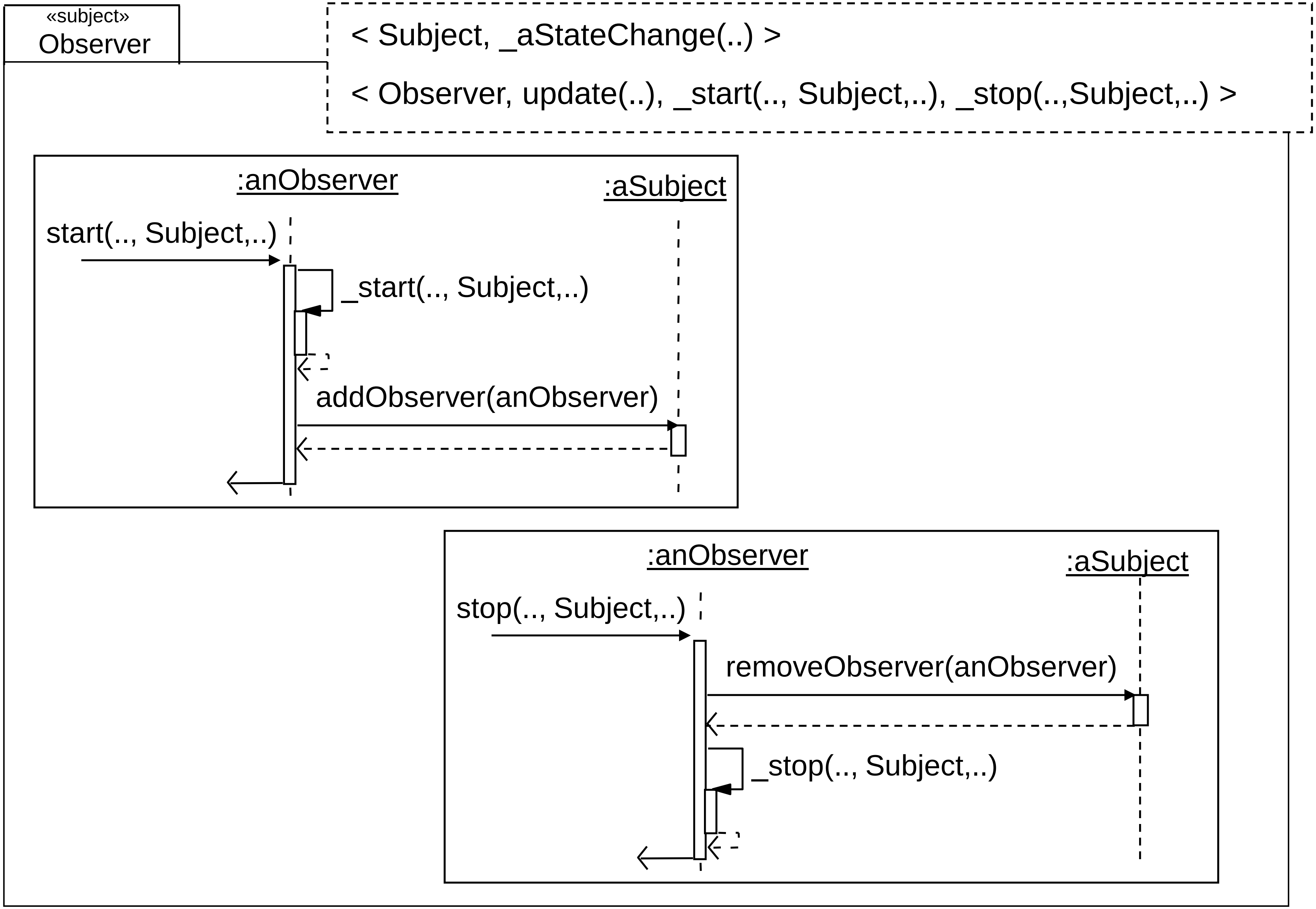
- Any class from the base design that replaces a pattern class has the specification of the pattern class merged with it.
- Crosscutting behaviours are merged as defined by the interactions – one is generated for each of the operations that replace the template

Observer aspect example (1 of 2)

- The observer pattern defines interactions between multiple pattern classes - *subjects* whose changes in state are of interest to *observers*

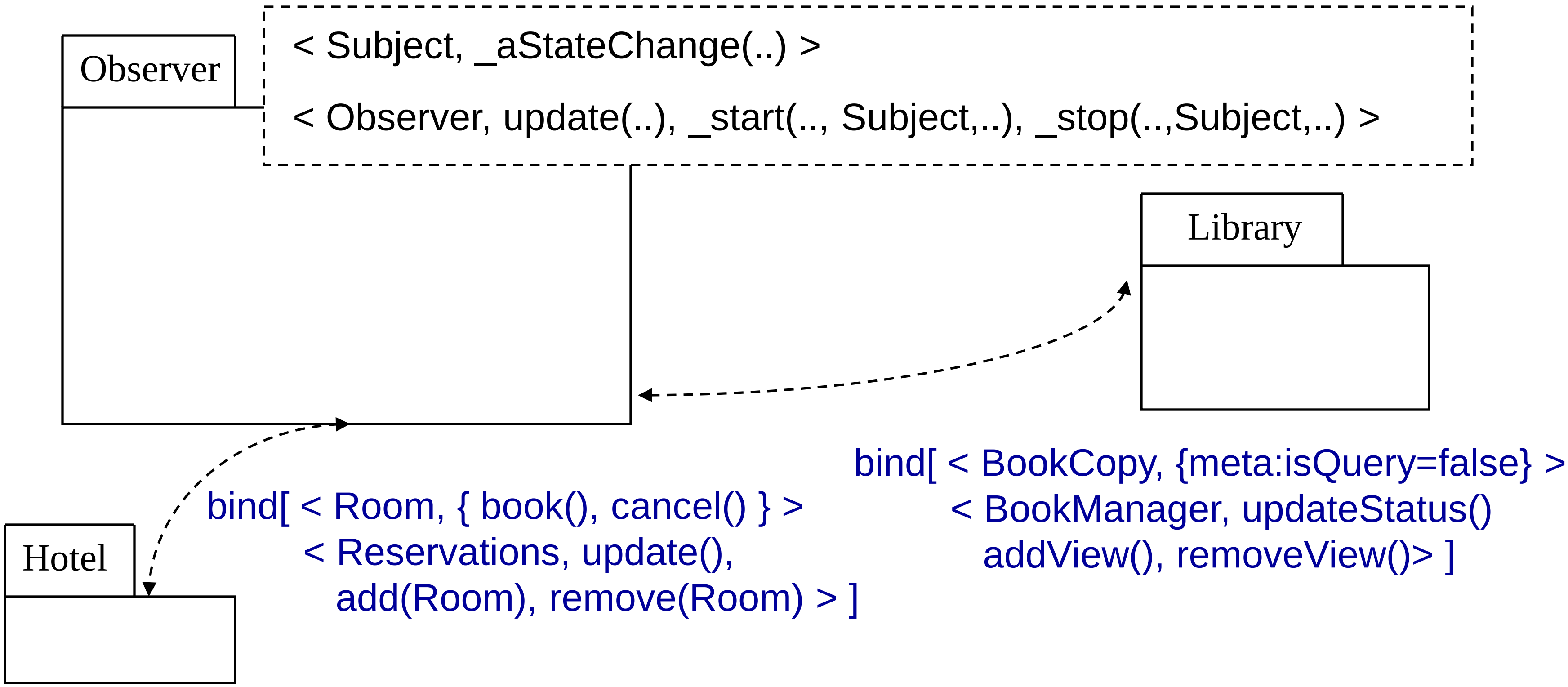


Observer aspect example (2 of 2)



CPs as reusable aspect designs

- CPs do not explicitly refer to any actual design elements they work with. As such, they may be composed with any design model.



Theme/UML within the software lifecycle

Compose the designs vs. map to an implementation language

- Specification of composition at design stage
- Two options for composition:
  - Implement individual designs – then compose
    - ✓ Traceability, with extensibility benefits
    - ✓ Reusable implementations
    - ✗ Need similar compositional language (e.g. AspectJ, Hyper/J)
  - Compose designs, and then implement
    - ✗ Lose traceability with code – inherent extensibility difficulties
    - ✗ Code is not reusable
    - ✓ Can write code using favourite OO language

Summary

- Current design approaches lead to design models that are difficult to extend, change and reuse.
- Theme/UML supports independent, reusable designs, including designs of crosscutting behaviour with composition patterns.
- CPs may be composed with non-pattern designs, and multiple designs may be composed together.
- Mapping Theme/UML decomposed models to compositional implementation languages supports:
  - traceability of the designs to code
  - ease of initial implementation and evolution of crosscutting and base code.