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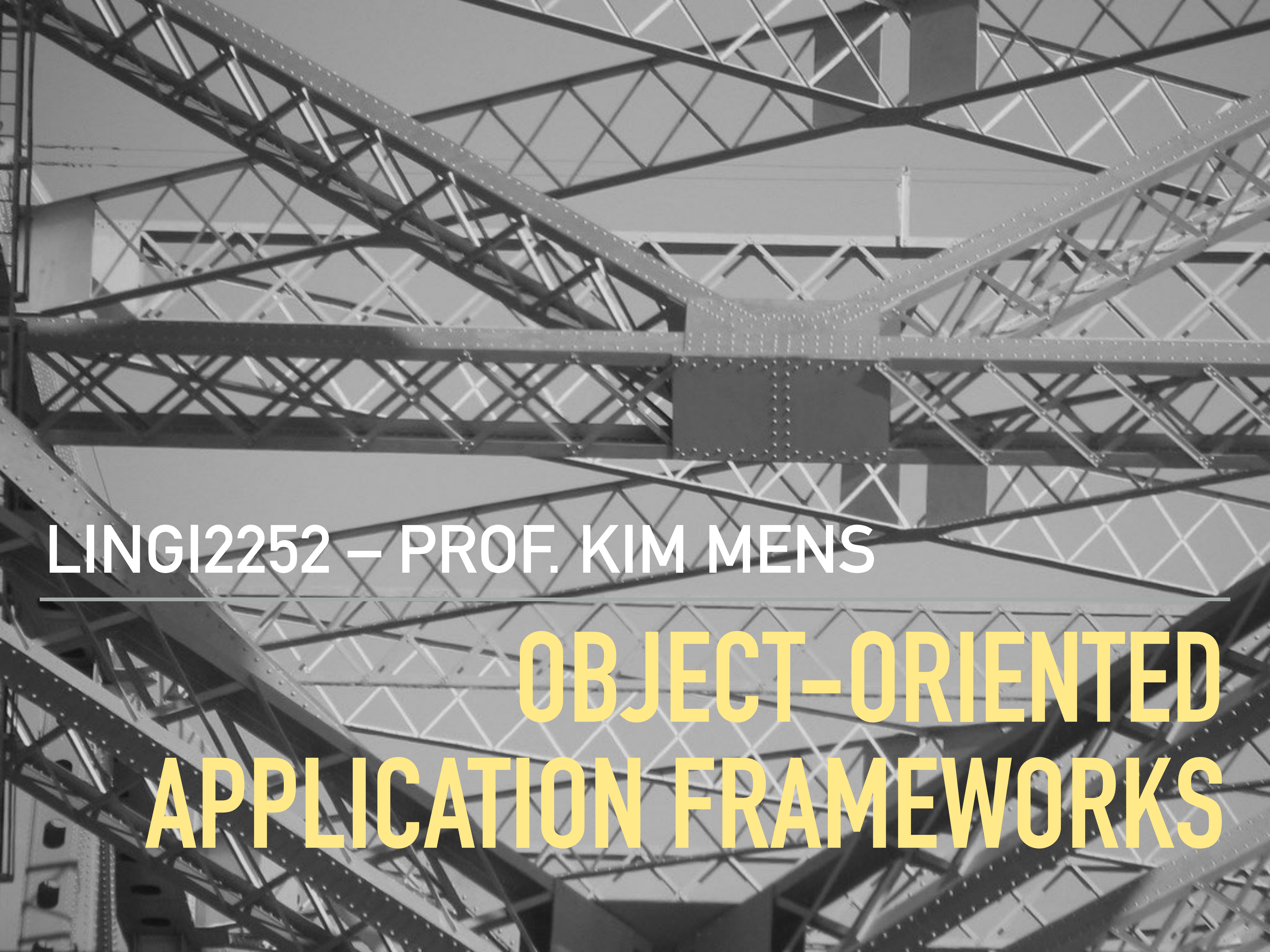
SOFTWARE MAINTENANCE & EVOLUTION



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OBJECT-ORIENTED APPLICATION FRAMEWORKS

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A. WHAT'S A FRAMEWORK?

A SOFTWARE FRAMEWORK

A particular implementation technique for building families of software applications.

A framework represents a common design and partial implementation for the family:

- A *generic solution* for a set of similar problems.
- *Incomplete by nature* : application-specific functionality to be filled in by the *framework customiser*, i.e. the developer of a concrete application.
- Variations are specified by means of so-called *hot spots*.

FRAMEWORKS ARE ABOUT SOFTWARE REUSE

Frameworks are meant to be reused.

Designing a framework is *not easy*:

- A good framework should be *easy to use* and be *flexibly adapted* to a wide range of requirements.
- Identifying the right combination of hot spots is difficult.
- Best achieved via an iterative development process.
- Need at least 3 applications before turning it into a framework

OBJECT-ORIENTED APPLICATION FRAMEWORKS

An object-oriented (application) framework* is

an object-oriented class hierarchy

plus a built-in model of interaction

which defines how objects derived from the class hierarchy *interact* with one another.

Deriving a custom application from a framework is typically done through *class specialisation*.

* [Lewis&al1995, p.vii] Ted Lewis et al. Object Oriented Application Frameworks, Manning Publications, 1995

OBJECT-ORIENTED APPLICATION FRAMEWORKS

Support reuse beyond the class level.

Core functionality implemented as set of abstract classes that cooperate in a well-defined manner.

When deriving a concrete application :

- these abstract classes are specialised by concrete subclasses;
- other concrete classes are chosen from a library of standard components provided by the framework developer.

Customisation is completed by adding new application-specific classes.

EXAMPLES OF FRAMEWORKS

GUI frameworks (e.g., JHotDraw)

Unit testing frameworks (e.g., JUnit)

Collection hierarchy (e.g., Smalltalk or Java)

A particular MVC implementation

Web application frameworks

WHATS'On, an application framework for television broadcast management

YESPLAN, an application framework for event planning

SOME DEFINITIONS OF FRAMEWORKS

[Ralph Johnson, OOPSLA 97] : "A **reusable design** of an application or subsystem, represented by a set of **abstract classes** and the way objects in these classes **collaborate**."

[GoF p. 26] : "A set of **co-operating** classes that make up a **reusable design** for a specific **class of software**."

[Fayad et al. §1] : "The **skeleton** of an application that can be **customised** by an application developer."

[Fayad et al. §16] : "Defines a **high-level language** with which applications within a **domain** are created through **specialisation**."

[Van Gurp & Bosch] : "A **partial design** and **implementation** for an application in a given **domain**."

CENTRAL ASPECTS IN THESE DEFINITIONS

Domain / class of software : has a well defined domain where it provides behaviour

Skeleton / design / high-level language : a common design shared by all customisations

Collaborate / co-operating : a description of the behaviour at a high level of abstraction, defining how classes participating in the framework interact

Reusable / abstract classes / customised / specialisation : can be tailored to a concrete context.

Classes / partial implementation: reuse of code as well as reuse of design

FRAMEWORK TYPES : APPLICABILITY

Domain frameworks capture expertise useful for one particular *problem domain* :

- financial engineering
- television broadcast management
- event planning

Application frameworks capture expertise common to a wide variety of problems :

- graphical user interface frameworks
- collection classes
- web application frameworks

WHY FRAMEWORKS?

Frameworks are one of the best bets on

Software Reuse

High-level design is the main intellectual content of software, and frameworks are a way to reuse it…

Frameworks allow you to reuse both *design and implementation*

> *"Interface design and functional factoring constitutes the key intellectual content of software and are far more difficult to create or re-create than code."*

[Peter Deutsch]

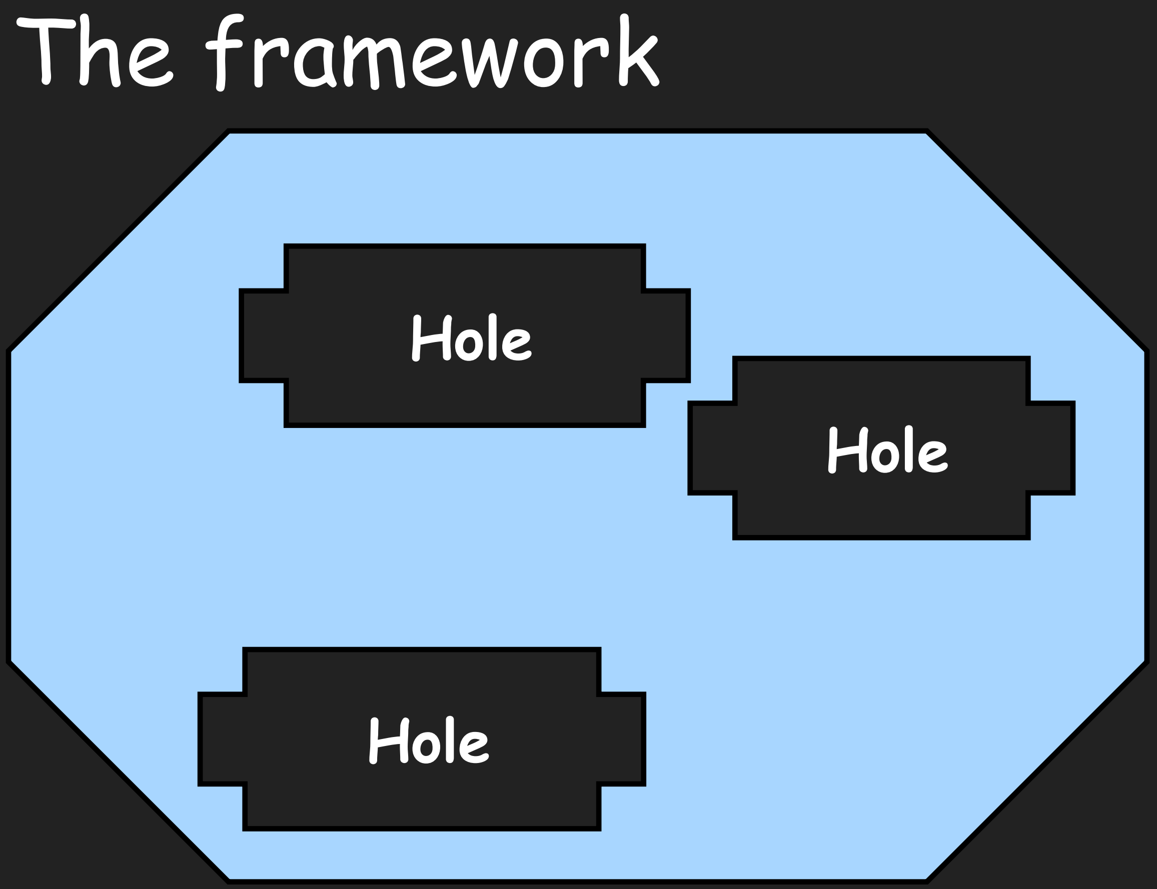
THE DIFFERENT PARTS OF A FRAMEWORK-BASED APPLICATION

An application consists of

- The framework code itself ← provided
  - e.g. JHotDraw
- The framework specialisation code ← your job!
  - e.g. JHotDraw specialisation to handle musical notation
- … and the rest ← your job!
  - drivers, utilities, application parts not handled by the framework….
  - e.g. code to handle musical semantics, playback, etc.

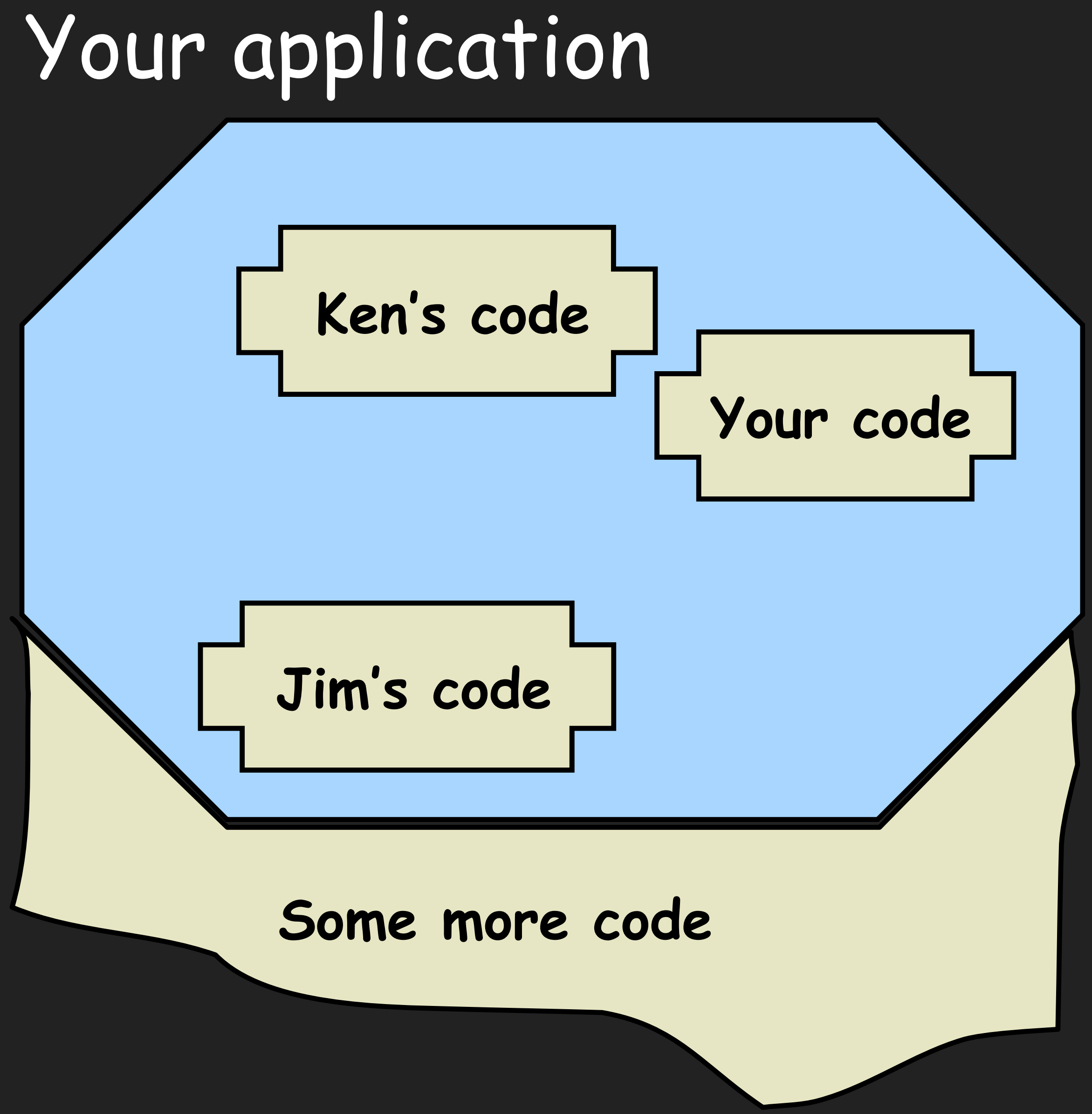
FRAMEWORK DEVELOPMENT = "PROGRAMMING WITH HOLES"

A framework is a partial application



FRAMEWORK DEVELOPMENT = "PROGRAMMING WITH HOLES"

A framework is a partial application



PRINCIPLE OF INVERSION OF CONTROL

a.k.a. the Hollywood principle:

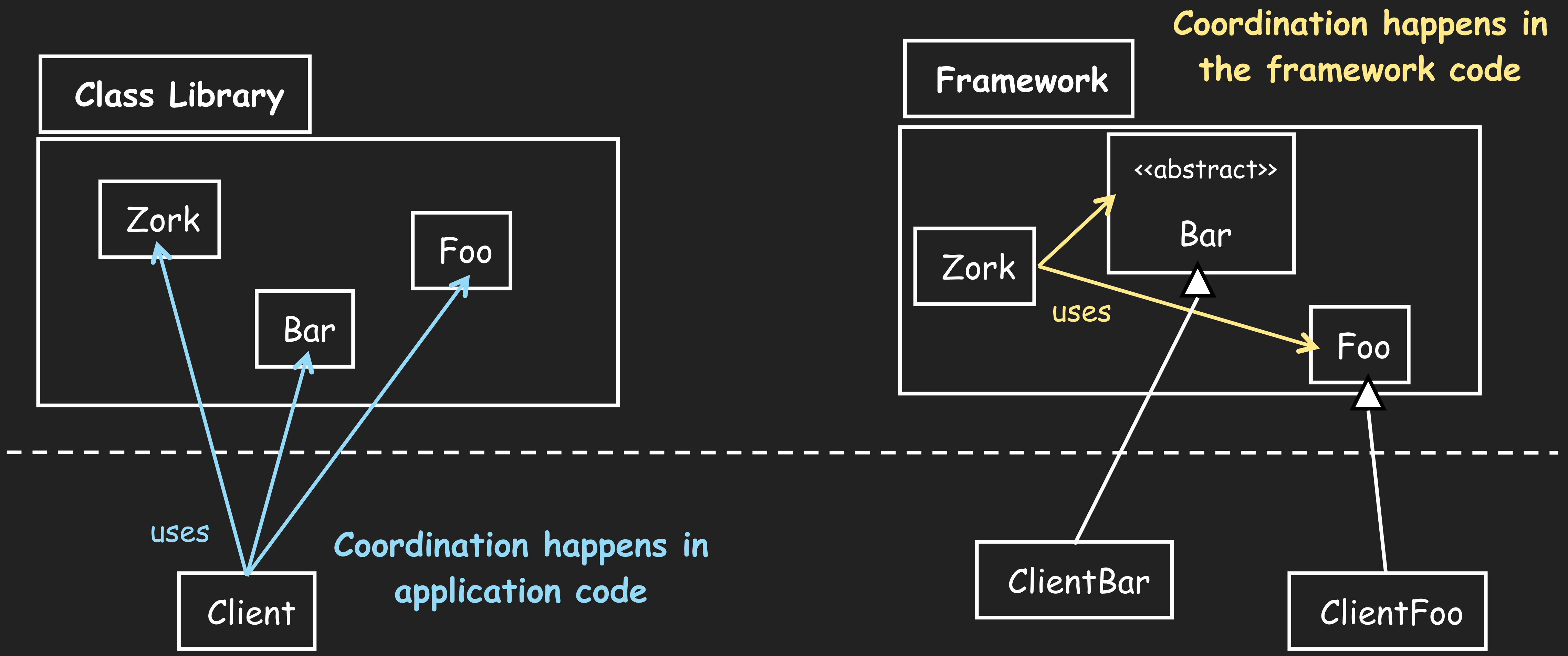
- "Don't call us, we'll call you"

This is what distinguishes a framework from a library

- When using a library, the application calls the library, but the library is not aware of the application.
- When using a framework, the application-specific code written by the programmer gets called by the framework.

PRINCIPLE OF INVERSION OF CONTROL

Frameworks are partial applications and thus (usually) define interaction patterns. Thus they insist on defining the flow of control :



HOTSPOTS

”Separate code that changes from the code that doesn’t”

Hotspots are the ”holes” of a framework

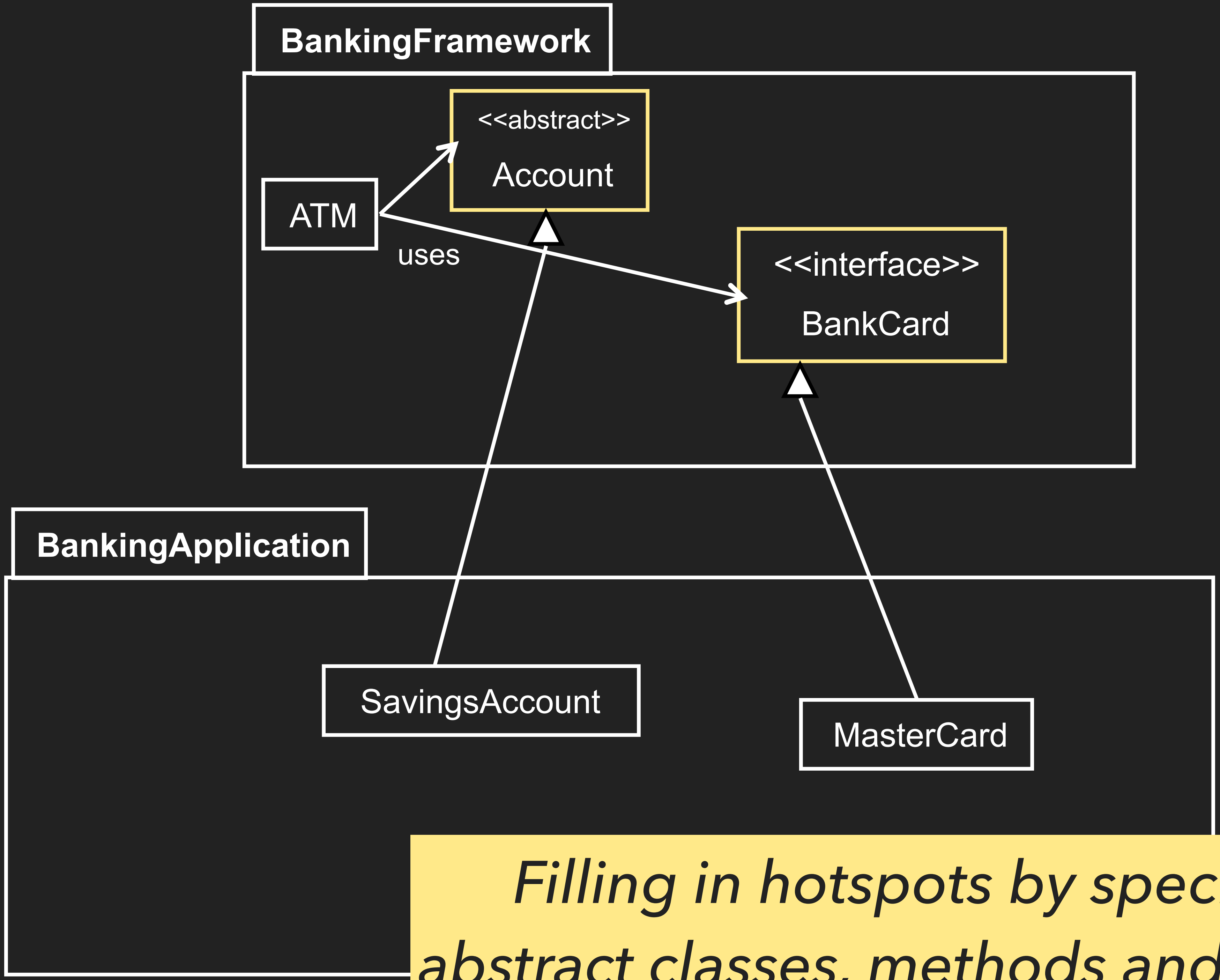
- Code points where specialisation code can alter behaviour or add behaviour to the framework

Also known as: hooks / hook methods / variation points

Commonality / variability

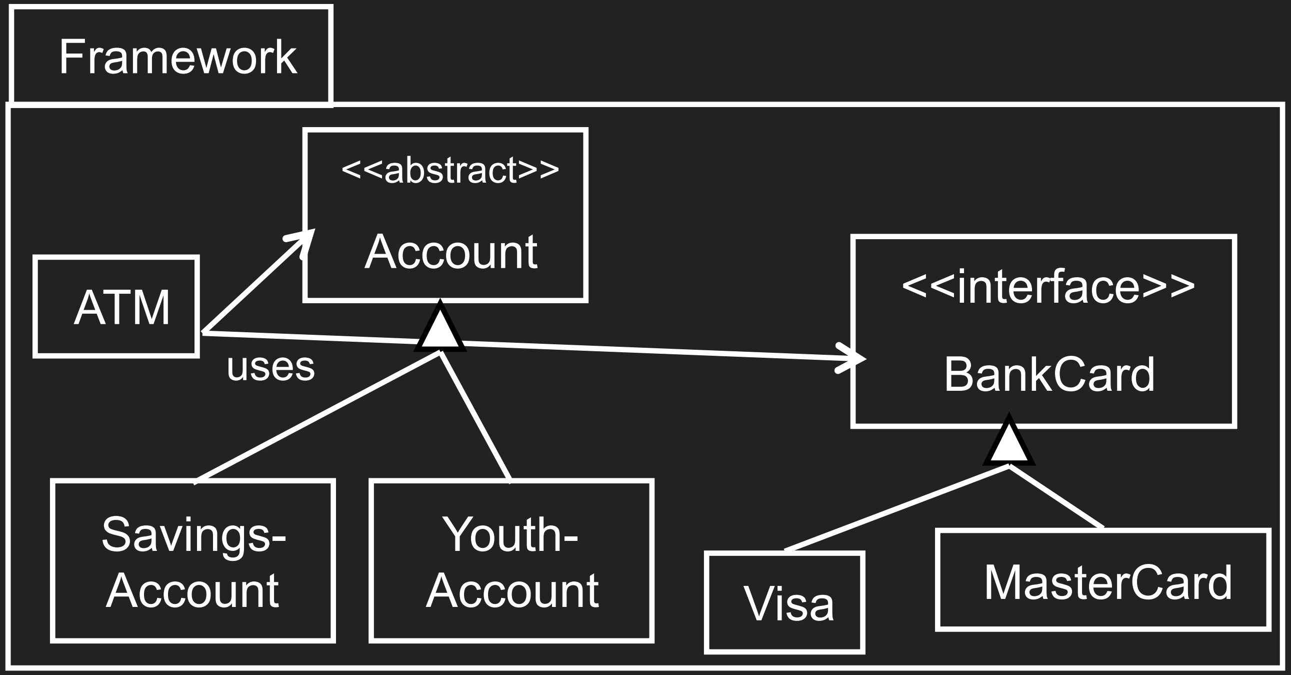
- The framework code defines the commonality
- The hotspots allow for variability

HOTSPOTS BASED UPON INHERITANCE



Filling in hotspots by specialising abstract classes, methods and interfaces

HOTSPOTS BASED UPON COMPOSITION



MyAppl

```
a := SavingsAccount new.
a associate: MasterCard new.
a associate: VISA new.
...
```

Filling in parameters or objects by prefabricated components

FRAMEWORK TYPES : CUSTOMISATION

White box

White-box frameworks

- Customisation through inheritance
- Require insight in (and access to) implementation
- "Easier" to design
- More difficult to learn
- More programming required for application development
- More flexibility

FRAMEWORK TYPES : CUSTOMISATION

Black box

Black-box frameworks

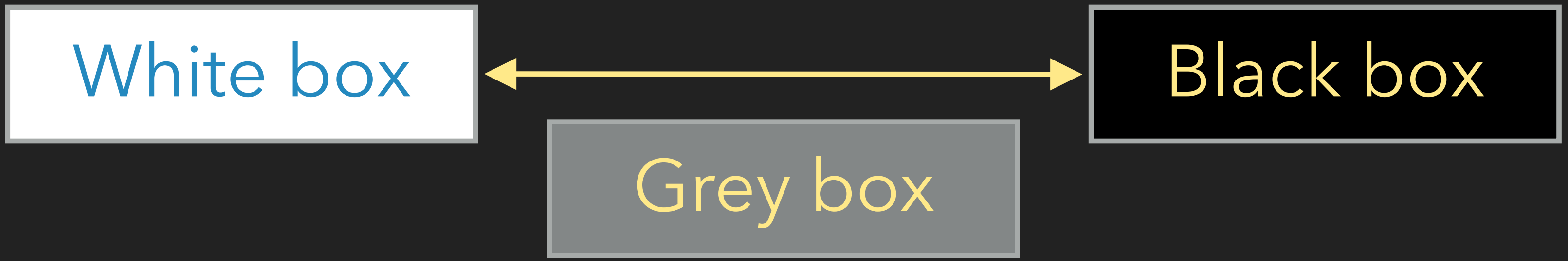
- Customisation through composition
- Require insight in provided components
- ”Harder” to design
- ”Easier” to learn
- Less programming required for application development
- Limited flexibility (no unanticipated variations)

FRAMEWORK TYPES : CUSTOMISATION

Grey box

Grey box frameworks

- White and black box form the extreme boundaries of framework design and usage principles
- Most frameworks live somewhere in between these two extremes



- Grey box frameworks attempt to realise the benefits of both white and black box designs, while trying to avoid the perceived limitations of both
- A successful framework may start its life as white box, maturing towards grey or even black in a number of revisions

CONCRETE EXAMPLE … OF A FRAMEWORK

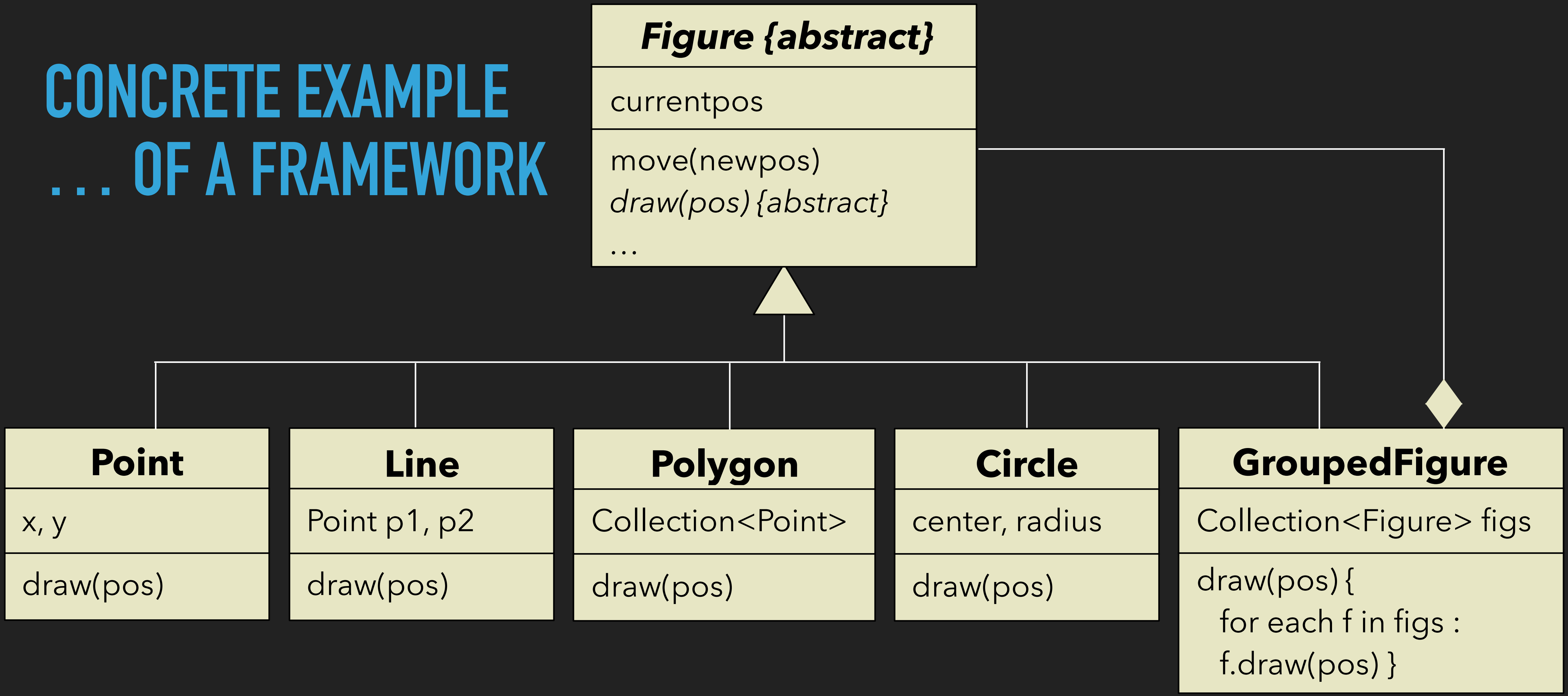


Figure {abstract}

currentpos

move(newpos)
draw(pos) {abstract}
…

Point

x, y

draw(pos)

Line

Point p1, p2

draw(pos)

Polygon

Collection<Point>

draw(pos)

Circle

center, radius

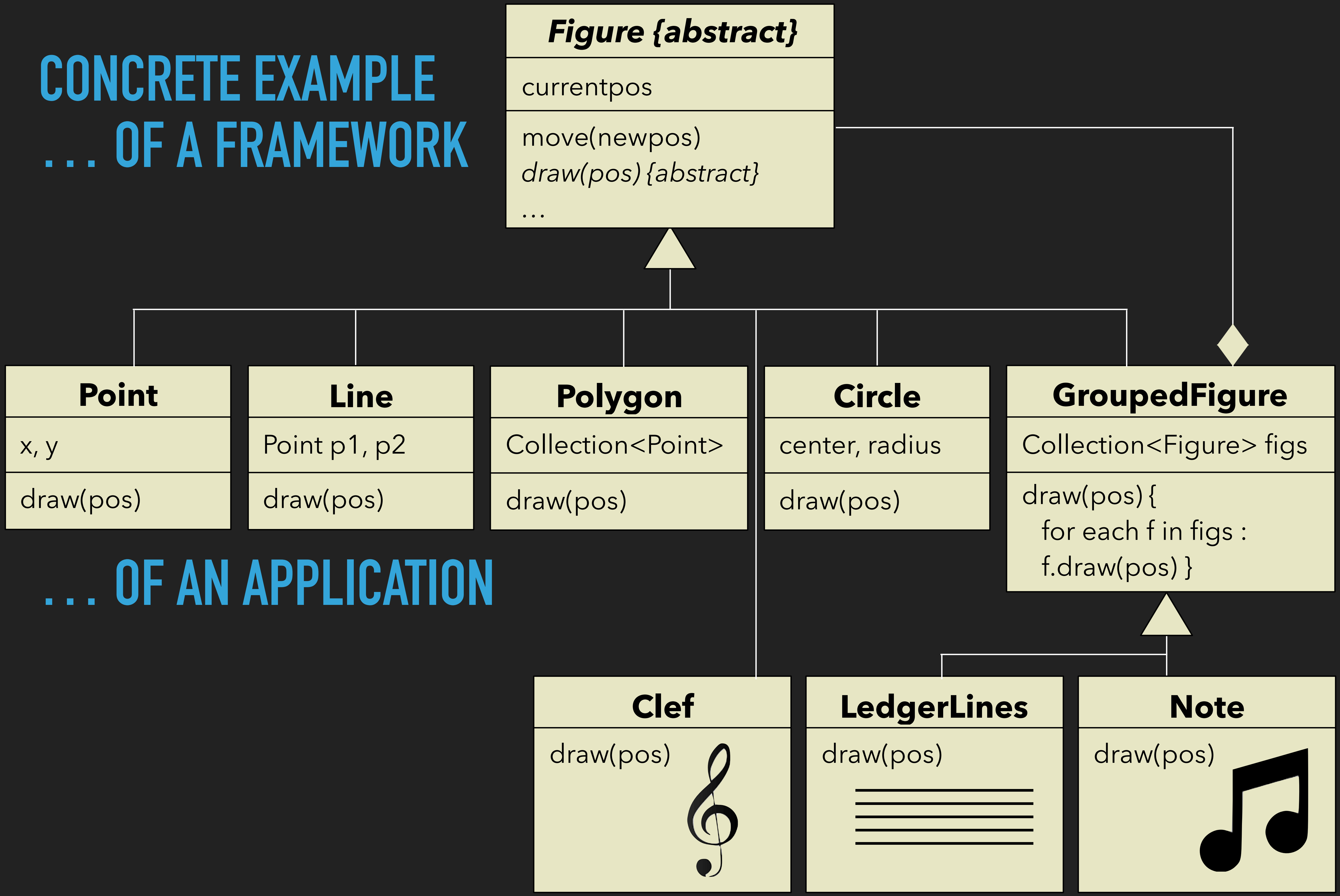
draw(pos)

GroupedFigure

Collection<Figure> figs

```
draw(pos) {
  for each f in figs :
  f.draw(pos) }
```

CONCRETE EXAMPLE
… OF A FRAMEWORK



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```

Clef

draw(pos)

LedgerLines

draw(pos)

Note

draw(pos)

… OF AN APPLICATION

CONCRETE EXAMPLE … OF A FRAMEWORK

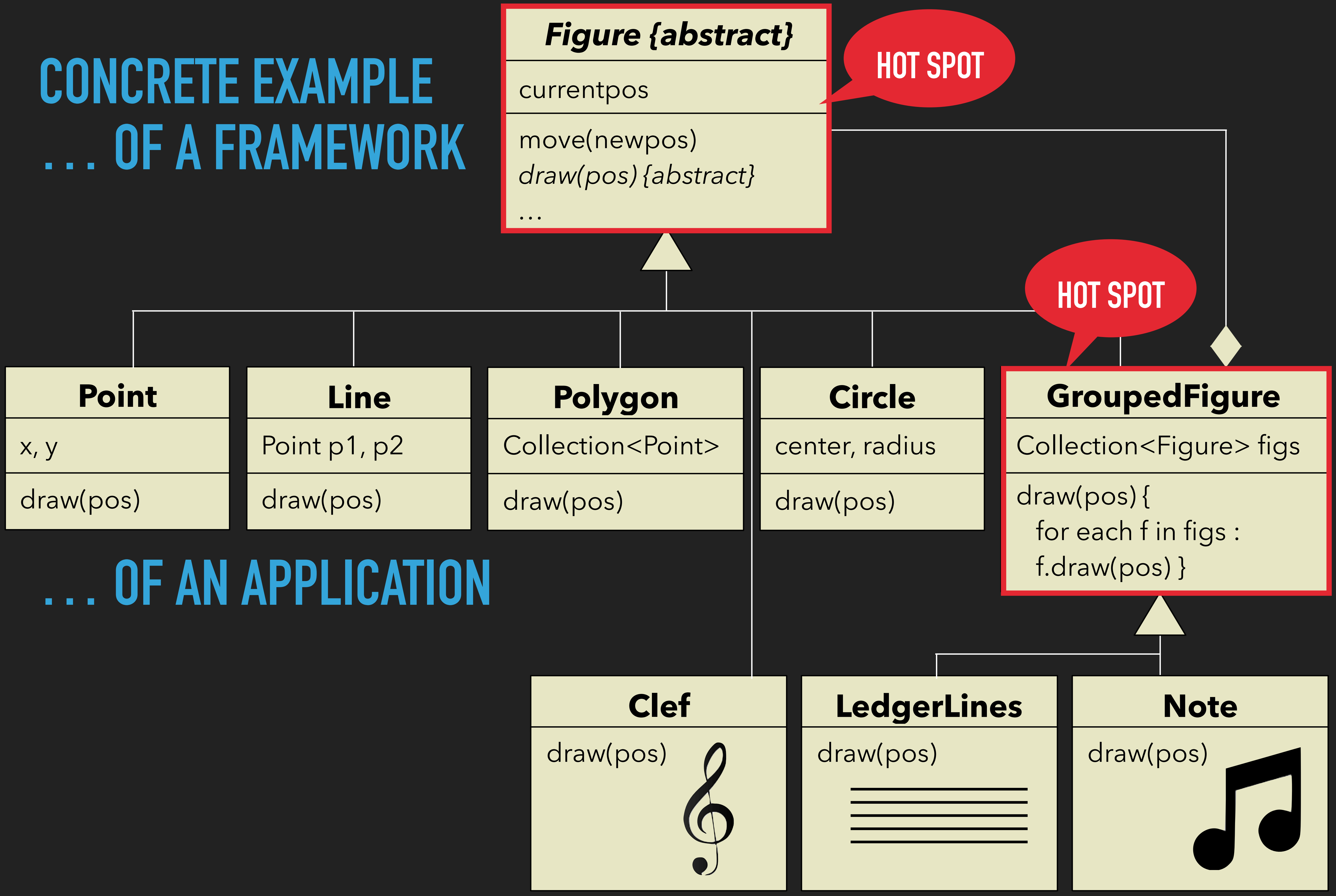

Figure {abstract}

currentpos

move(newpos)
draw(pos) {abstract}
…

HOT SPOT

Point

x, y

draw(pos)

Line

Point p1, p2

draw(pos)

Polygon

Collection<Point>

draw(pos)

Circle

center, radius

draw(pos)

HOT SPOT

GroupedFigure

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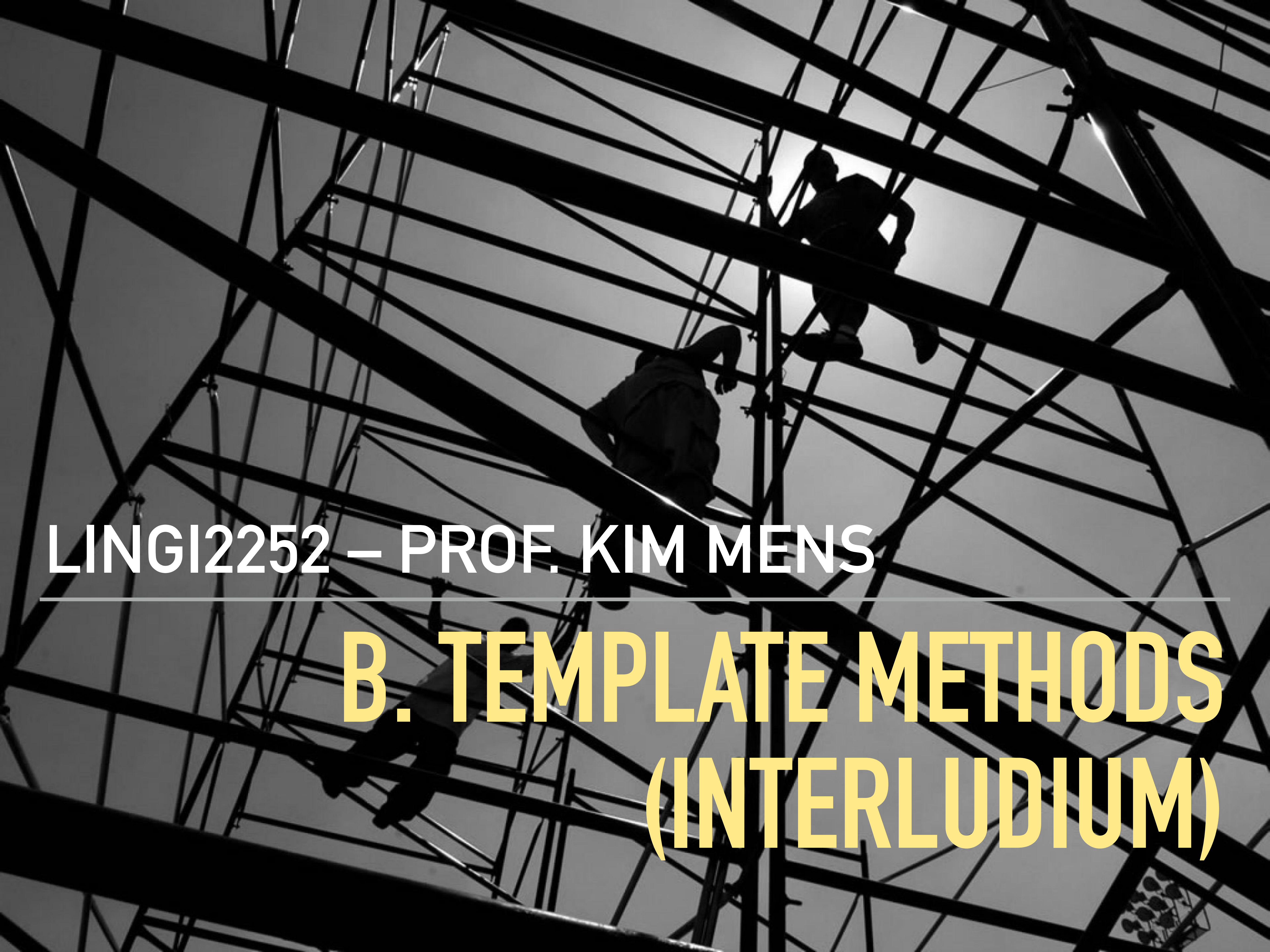

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B. TEMPLATE METHODS (INTERLUDIUM)

TEMPLATE METHOD DESIGN PATTERN

Intent

Defines the skeleton of an algorithm in an operation, deferring some steps to subclasses. Template Method lets subclasses redefine certain steps of the algorithm without changing the algorithm's structure.

Solution

Break out primitive steps into separate methods in ancestor class.

Construct method for basic algorithm in ancestor that calls the primitive methods.

Override the primitive methods in descendant classes to implement specific tasks.

TEMPLATE METHOD DESIGN PATTERN

Consequences

A fundamental technique for code reuse – particularly important in *class libraries and frameworks* to factor out *common behaviour*.

Leads to inverted control structure called “Hollywood Principle”.

A primitive method in the ancestor may provide a default behaviour that descendants may optionally override (called hook methods).

Related Patterns

Factory Method is a form of Template Method used to create families of related objects.

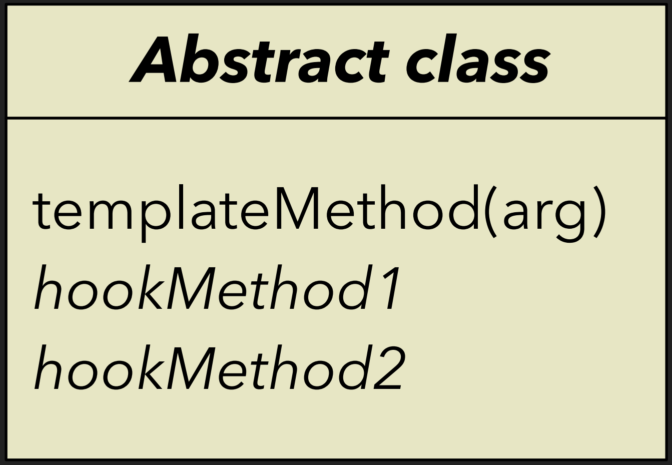
Strategy is an alternate choice when the behaviour needs to be specified or may vary at run-time.

TEMPLATE METHOD IN FRAMEWORKS

A **hotspot** in an object-oriented framework is often implemented via a Template Method.

- The **template method** defines the skeleton of the hot spot
- The variable parts are deferred to the so-called **hook methods**
- The template method is defined on a template class which is part of the framework
- The hook methods are defined on **hook classes**
  - concrete subclasses of the template class that are provided by framework users to customise the framework

TEMPLATE METHOD IN FRAMEWORKS



Abstract class

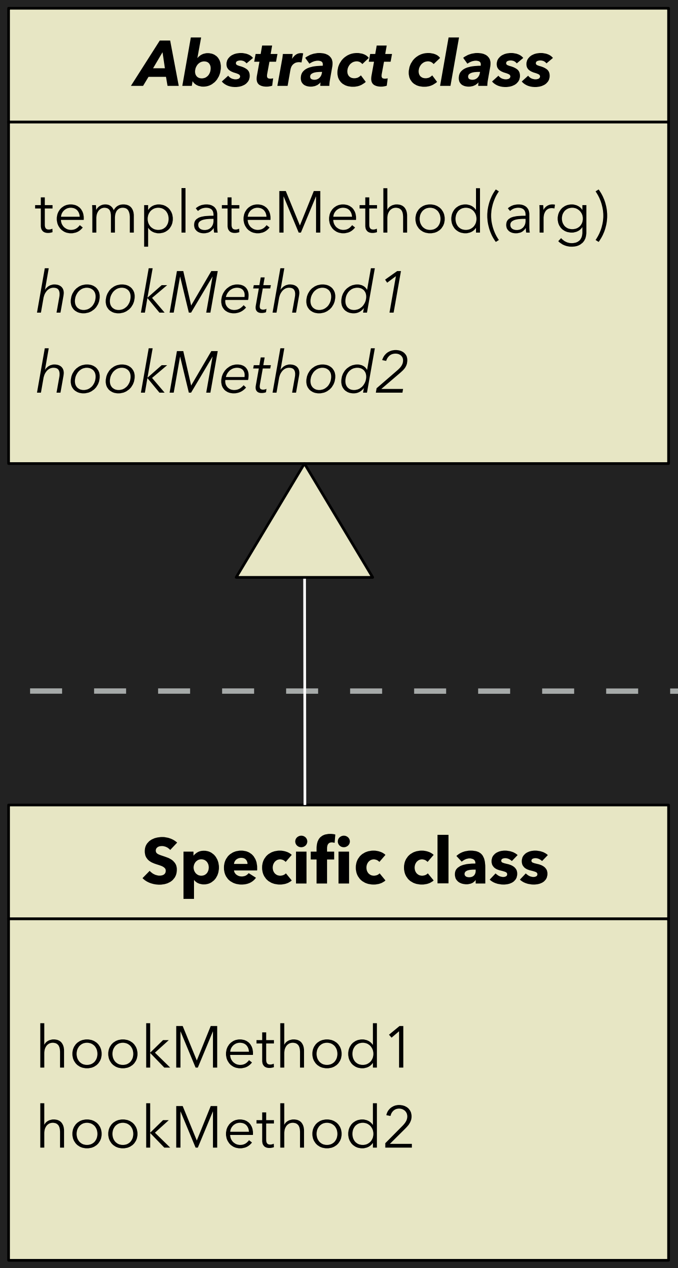
templateMethod(arg)
hookMethod1
hookMethod2

The framework

Framework user = a customiser

(a developer of a concrete application)

TEMPLATE METHOD IN FRAMEWORKS



Abstract class

templateMethod(arg)
hookMethod1
hookMethod2

Specific class

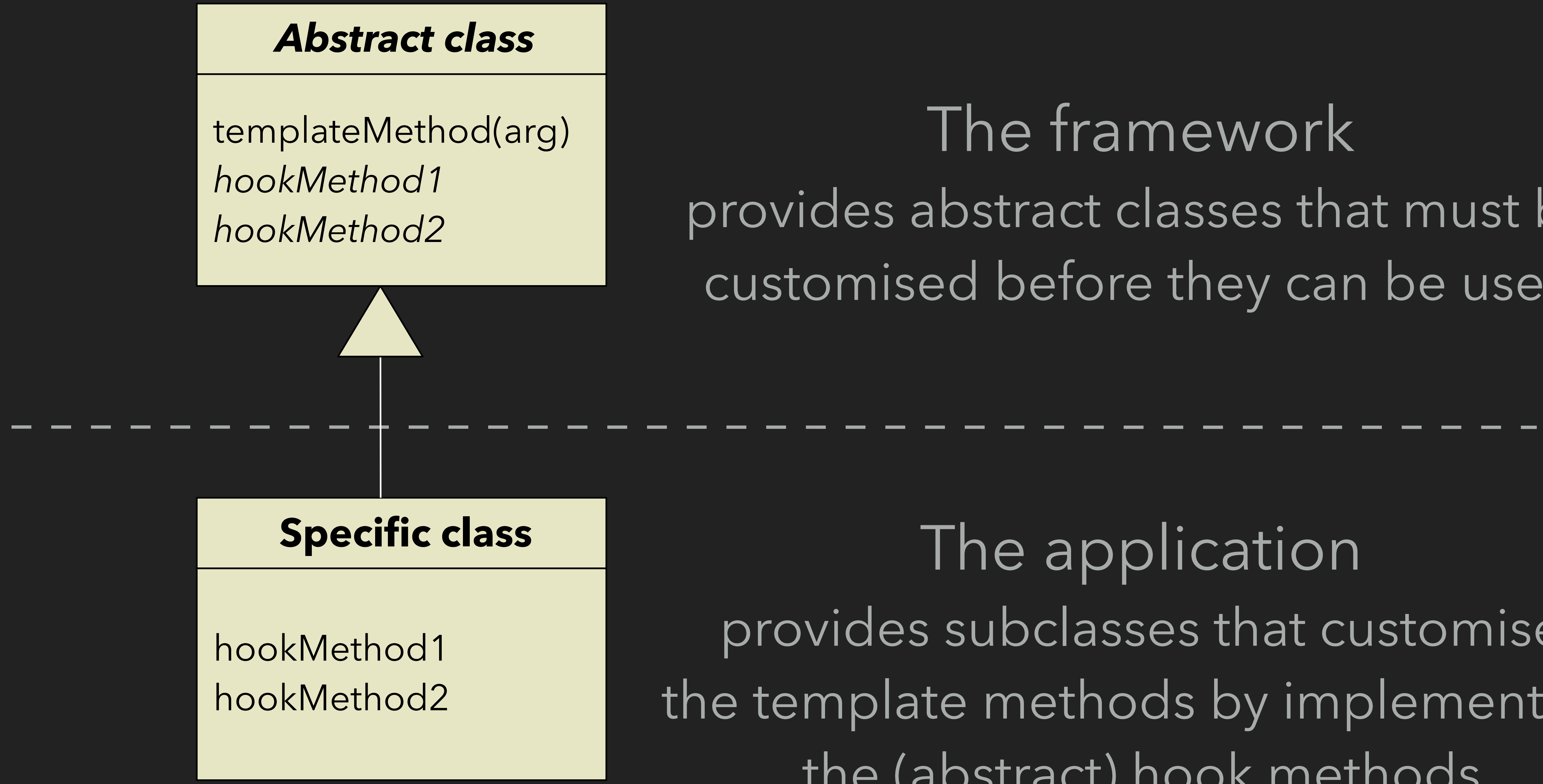
hookMethod1
hookMethod2

The framework

The application

customises a framework’s hot spots

TEMPLATE METHOD IN FRAMEWORKS



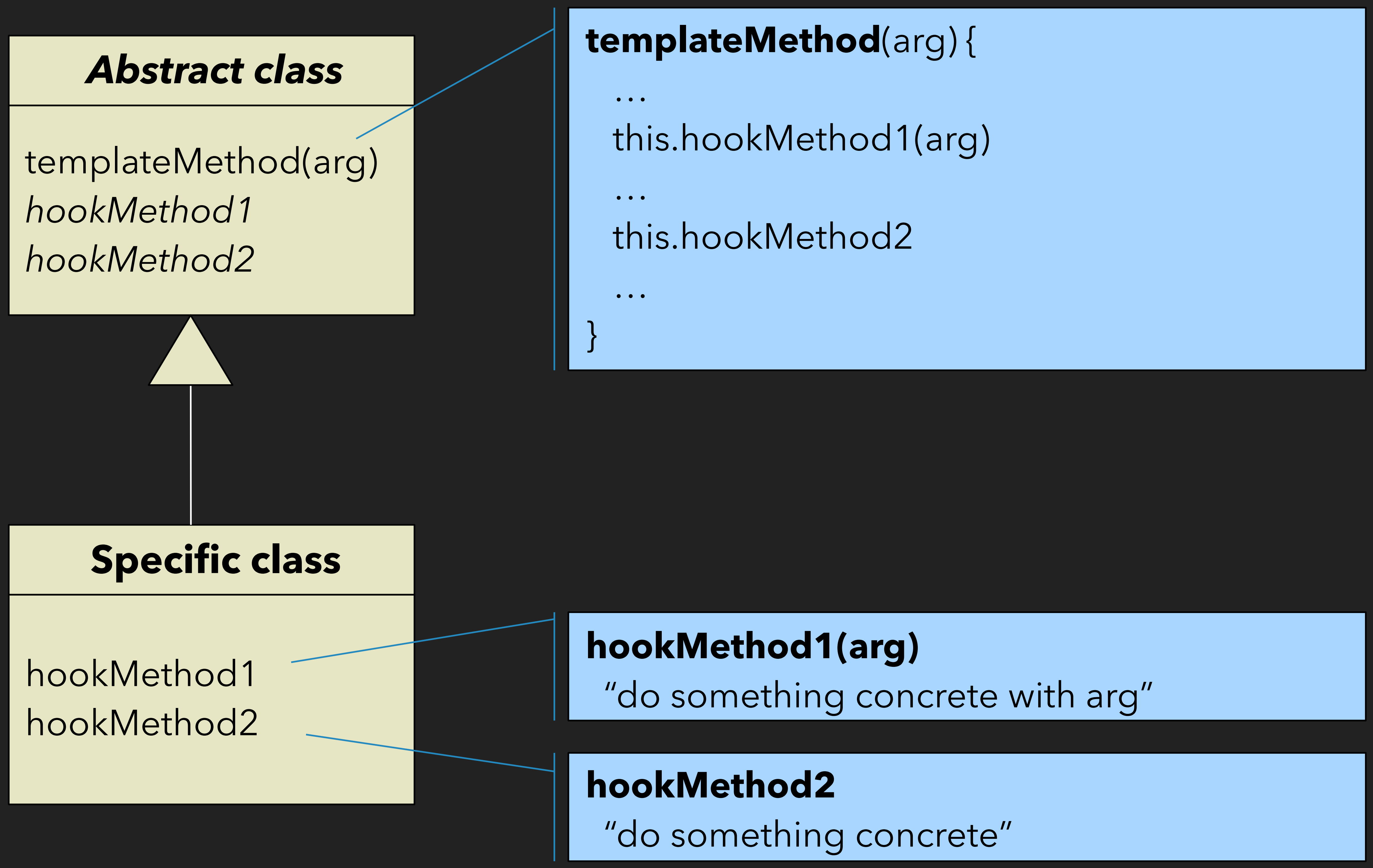
The framework

provides abstract classes that must be customised before they can be used

The application

provides subclasses that customise the template methods by implementing the (abstract) hook methods

TEMPLATE METHOD DESIGN PATTERN



```
templateMethod(arg) {
  …
  this.hookMethod1(arg)
  …
  this.hookMethod2
  …
}
```

```
hookMethod1(arg)
 "do something concrete with arg"
```

```
hookMethod2
 "do something concrete"
```

CONCRETE EXAMPLE

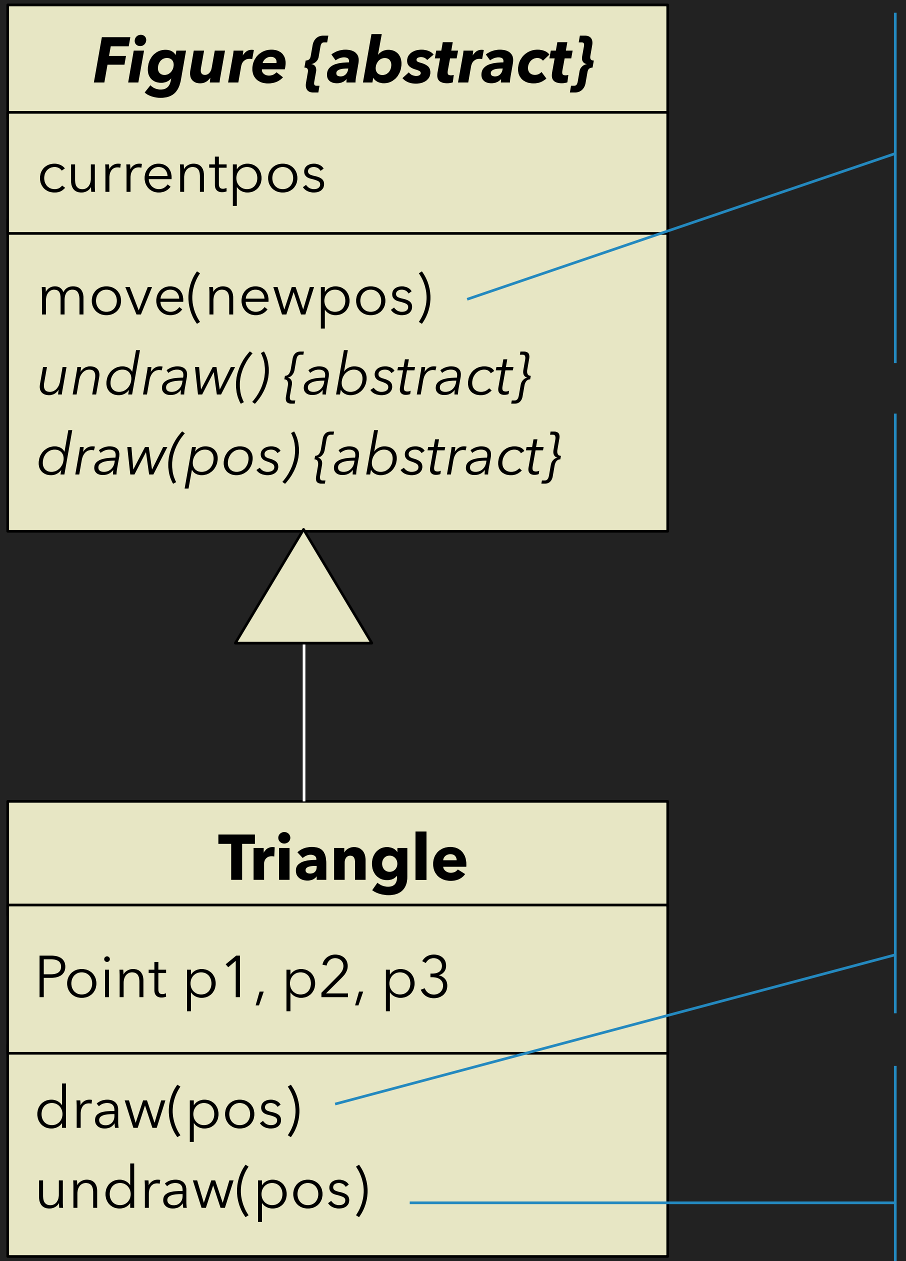


Figure {abstract}

currentpos

move(newpos)
undraw() {abstract}
draw(pos) {abstract}

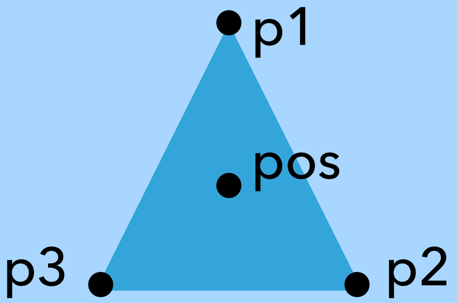
Triangle

Point p1, p2, p3

draw(pos)
undraw(pos)

```
move(newpos) {
  this.undraw();
  this.draw(newpos);
}
```

```
draw(pos) {
  "draw this Triangle at position pos"
```



```
}
```

```
undraw(pos) {
  "remove this figure at its position currentpos"
  ...
}
```

SUMMARY

Template methods

are a key technique for building OO application frameworks

Methods

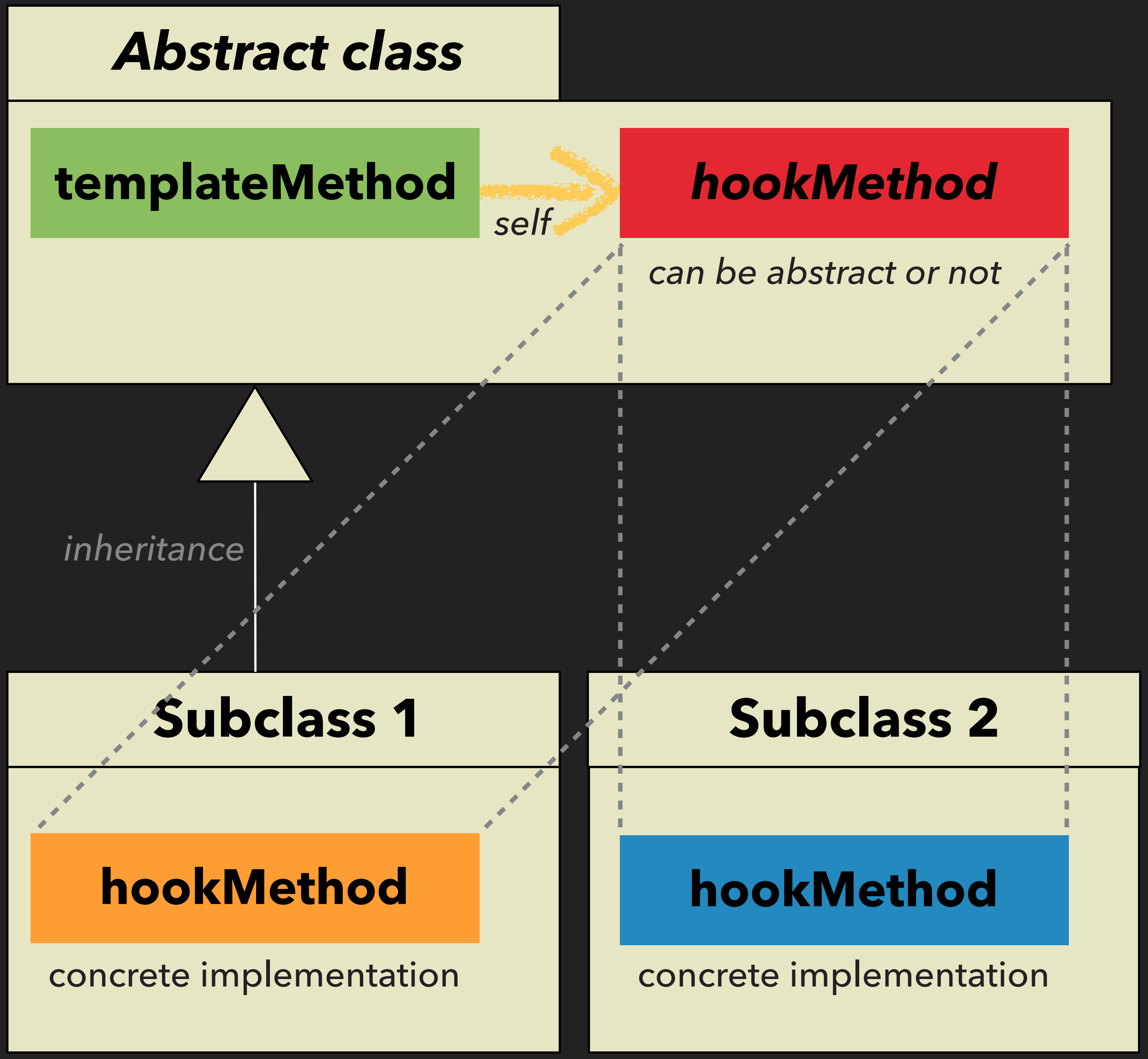
as units of reuse

Inheritance

as parametrisation mechanism

Late binding of self

self is dynamic; acts as a hook



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C. FRAMEWORKS (CONTINUED)

CONTRACT BETWEEN FRAMEWORK AND APPLICATION DEVELOPER

Framework (developer) must :

- Provide expensive domain knowledge and design
- Provide concrete, reliable, executable software
- Be sufficiently flexibility to specialise for required context.
- Be usable and "easy" to learn (this is a non-trivial requirement)

Application (developer) must :

- keep the contracts of hotspots
- understand and follow the interaction rules

LEARNING FRAMEWORKS

Understanding a framework is vital for success

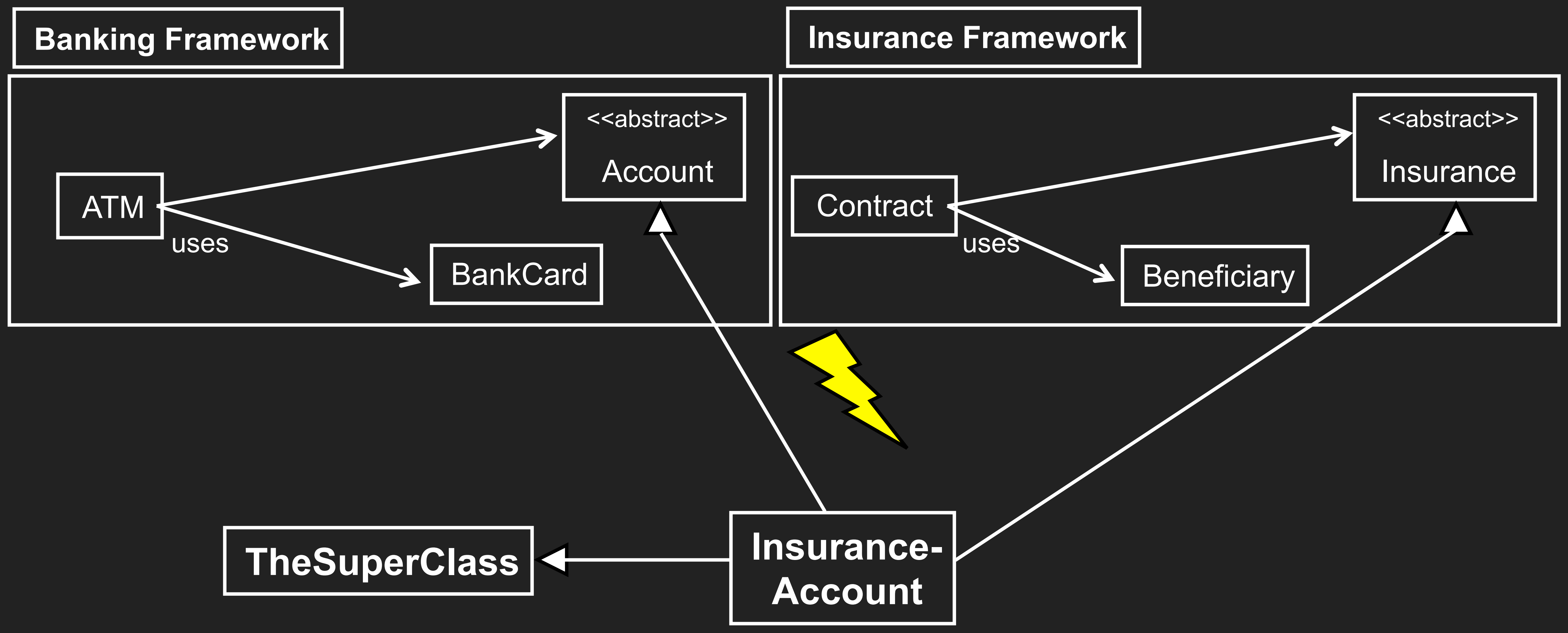
- more difficult to understand abstract entities than concrete classes
- interaction patterns are 'hidden' but vital in order to use a framework correctly

Learning a framework is not easy

- Steep learning curve
- Black box frameworks easier to learn than white box

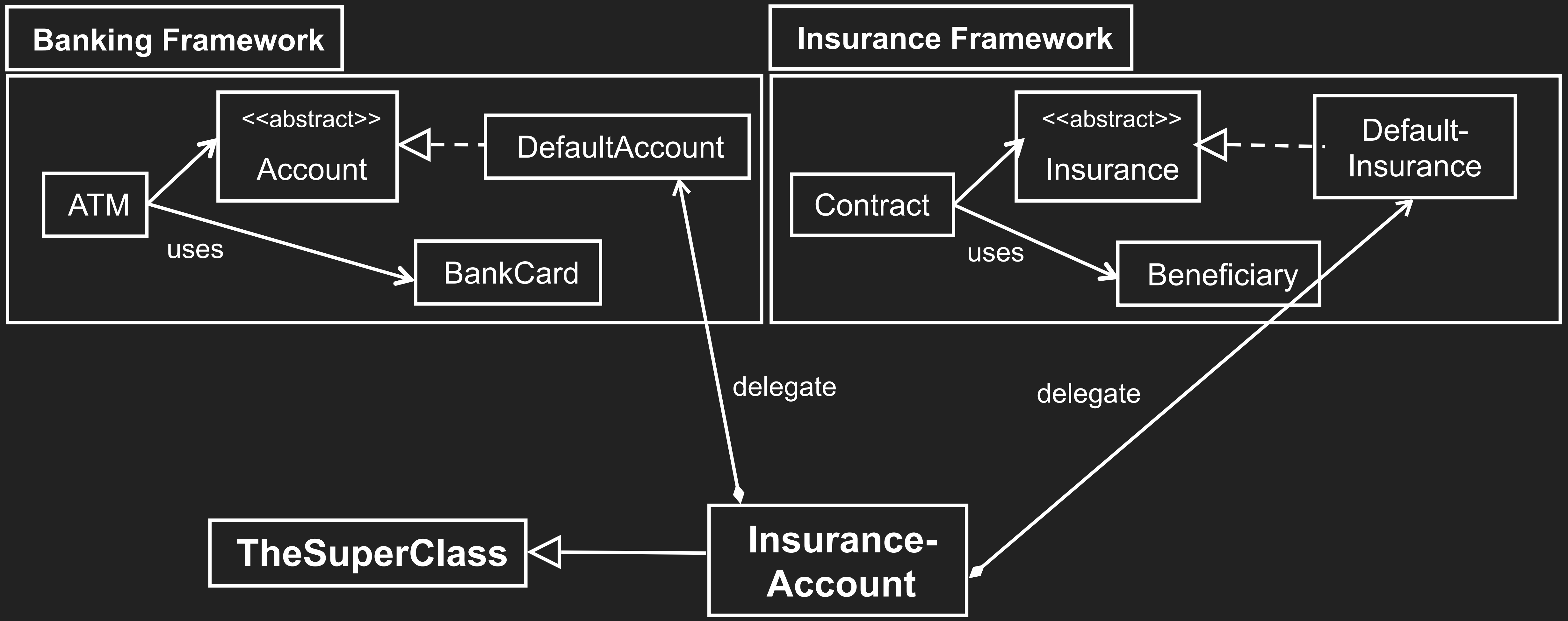
FRAMEWORK COMPOSITION…

How to use more than one framework in a single application ?



FRAMEWORK COMPOSITION…

A possible solution : using delegation.



SUMMARY

- Frameworks
  - partial / skeleton application within a well-defined domain
  - can be tailored / customised for a specific application
  - reuse of implementation and design
- Inversion of Control ("Hollywood" principle)
  - framework defines flow and interaction patterns
- Hotspots = 'hooks' into framework where tailoring is made
  - inheritance based : white box approach
  - composition based : black box approach
- Commonality and variability
- Use of template methods as implementation technique

FURTHER READING

Object-Oriented Application Frameworks
Ted Lewis and friends
Manning Publications, 1995

Building Application Frameworks: Object-Oriented Foundations of Framework Design
Mohamed E. Fayad, Douglas C. Schmidt, Ralph E. Johnson
John Wiley & Sons, 1999

Java Application Frameworks
Darren Govoni, John Wiley & Sons, 1999

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D. DESIGN PATTERNS VS. FRAMEWORKS

DESIGN PATTERNS VS FRAMEWORKS

Both frameworks and design patterns are ways of describing and documenting solutions to common problems

But design patterns are not frameworks

Patterns are more abstract

And many patterns may be involved in the solution of one problem

DESIGN PATTERNS VS FRAMEWORKS

Frameworks

- codify designs for solving a family of problems within a *specific domain*
- are instantiated by *inheritance and composition* of classes
- can contain several *instances* of multiple design patterns
- are more “shrink-wrapped”, ready for immediate use

DESIGN PATTERNS VS FRAMEWORKS

Design patterns are

more abstract

smaller architectural elements

less specialised

than *frameworks*

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E. REFACTORING TO A FRAMEWORK

THREE CATEGORIES OF REFACTORINGS RELATED TO FRAMEWORK DEVELOPMENT

Three categories of refactorings

> that correspond to generic design evolutions occurring frequently in object-oriented software systems. [Demeyer&al 2000]

1. Create template methods
2. Optimise class hierarchies
3. Incorporate composition relationships

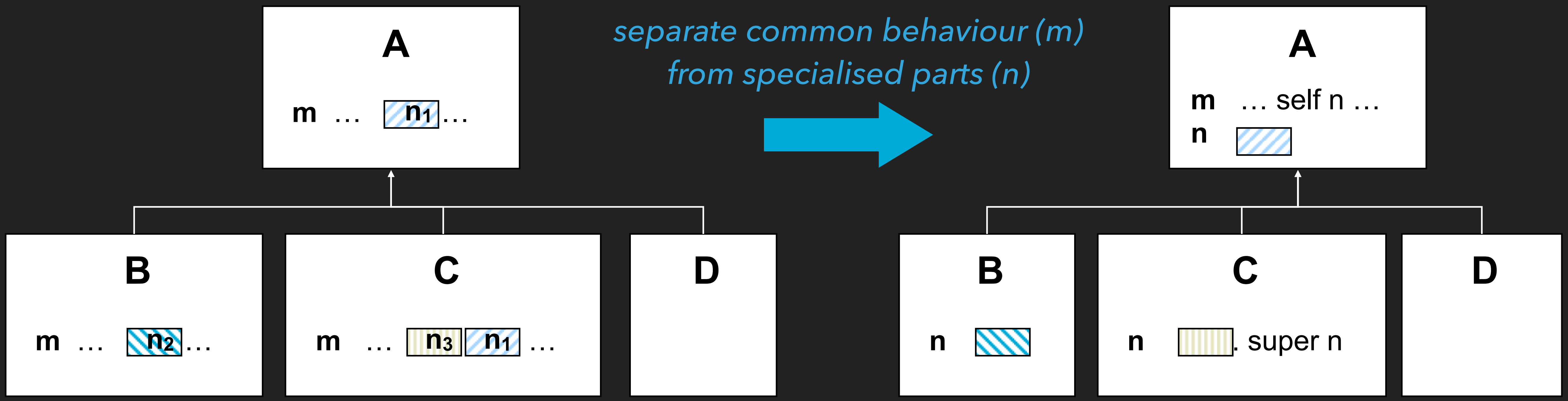
[Demeyer&al2000] Serge Demeyer, Stéphane Ducasse, Oscar Nierstrasz. Finding Refactorings via Change Metrics. ACM SIGPLAN Notices, 2000

THREE CATEGORIES OF REFACTORINGS RELATED TO FRAMEWORK DEVELOPMENT

1. Create template methods

Split methods into smaller chunks to separate common behaviour from specialised parts so that subclasses can override.

Used to improve reusability, remove duplicated functionality.



separate common behaviour (m) from specialised parts (n)

THREE CATEGORIES OF REFACTORINGS RELATED TO FRAMEWORK DEVELOPMENT

2. Optimise class hierarchies

   Insert or remove classes within a class hierarchy and redistribute the functionality accordingly.

   Used to increase cohesion, simplify interfaces, remove duplicated functionality.

   Two subcategories :

   A. *refactor to specialise*

   B. *refactor to generalise*

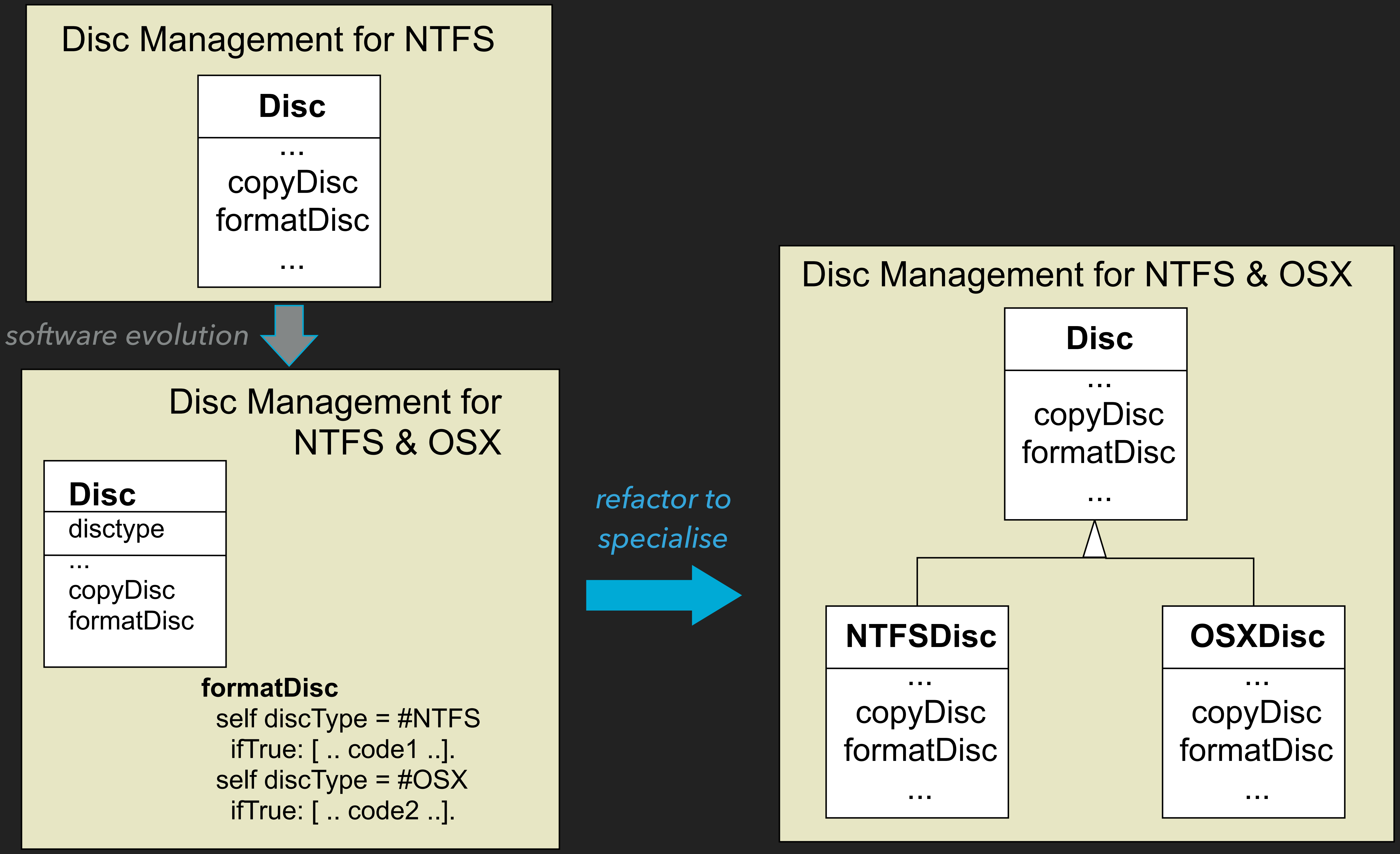
2. OPTIMISING CLASS HIERARCHIES

A. Refactor to specialise ↓

Improve framework design by decomposing a large, complex class into several smaller classes.

The complex class usually embodies both a general abstraction and several different concrete cases that are candidates for specialisation.

2A. REFACTOR TO SPECIALISE : EXAMPLE



Disc Management for NTFS

Disc
...
copyDisc
formatDisc
...

software evolution

Disc Management for NTFS & OSX

Disc
disctype
...
copyDisc
formatDisc

```
formatDisc
  self discType = #NTFS
    ifTrue: [ .. code1 ..].
  self discType = #OSX
    ifTrue: [ .. code2 ..].
```

refactor to specialise

Disc Management for NTFS & OSX

Disc
...
copyDisc
formatDisc
...

NTFSDisc
...
copyDisc
formatDisc
...

OSXDisc
...
copyDisc
formatDisc
...

2A. REFACTOR TO SPECIALISE

Specialise a class by adding subclasses corresponding to the conditions in a conditional expression:

Choose a conditional whose conditions suggest subclasses (this depends on the desired abstraction).

For each condition, create a subclass with a class invariant that matches the condition.

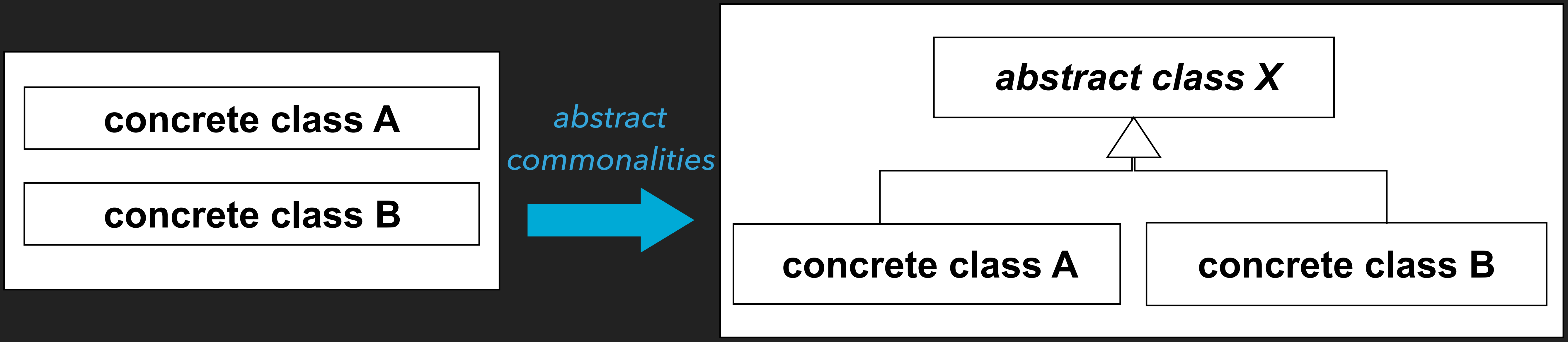
Copy the body of the condition to each subclass, and in each class simplify the conditional based on the invariant that is true for the subclass.

Specialise some (or all) expressions that create instances of the superclass.

2. OPTIMISING CLASS HIERARCHIES

B. Refactor to generalise

Identify proper abstractions (e.g. abstract classes) by examining concrete examples and generalising their commonalities.



2B. REFACTOR TO GENERALISE

Abstract classes and frameworks are generalisations

People think concretely, not abstractly

Abstractions are found bottom up, by examining concrete examples first

Generalisation proceeds by:

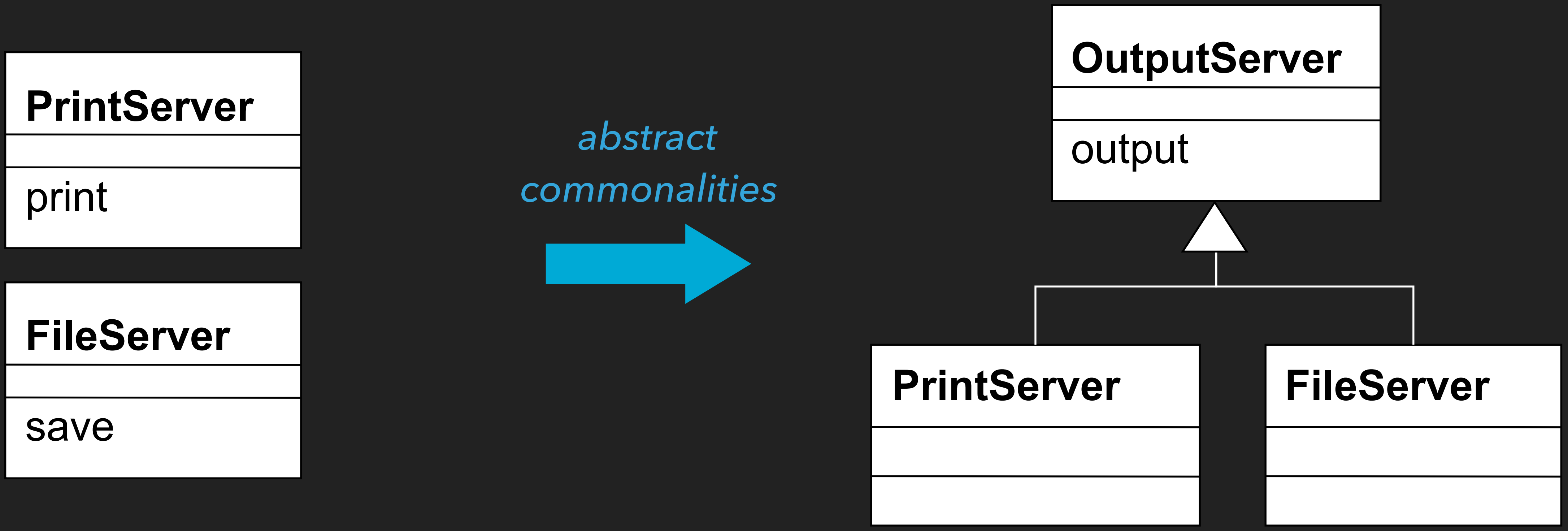
- finding things that are given different names but are really the same (and thus renaming them)
- parameterisation to eliminate differences
- breaking large things into small things so that similar components can be found

2B. REFACTOR TO GENERALISE

Steps to create an abstract superclass :

- Create a common superclass
- Make method signatures compatible
- Add method signatures to the superclass
- Make method bodies compatible
- Make instance variables compatible
- Move instance variables to the superclass
- Move common code to the abstract superclass

2B. REFACTOR TO GENERALISE : EXAMPLE



THREE CATEGORIES OF REFACTORINGS RELATED TO FRAMEWORK DEVELOPMENT

3. Incorporate composition relationships

    Move functionality to (newly created) sibling classes.

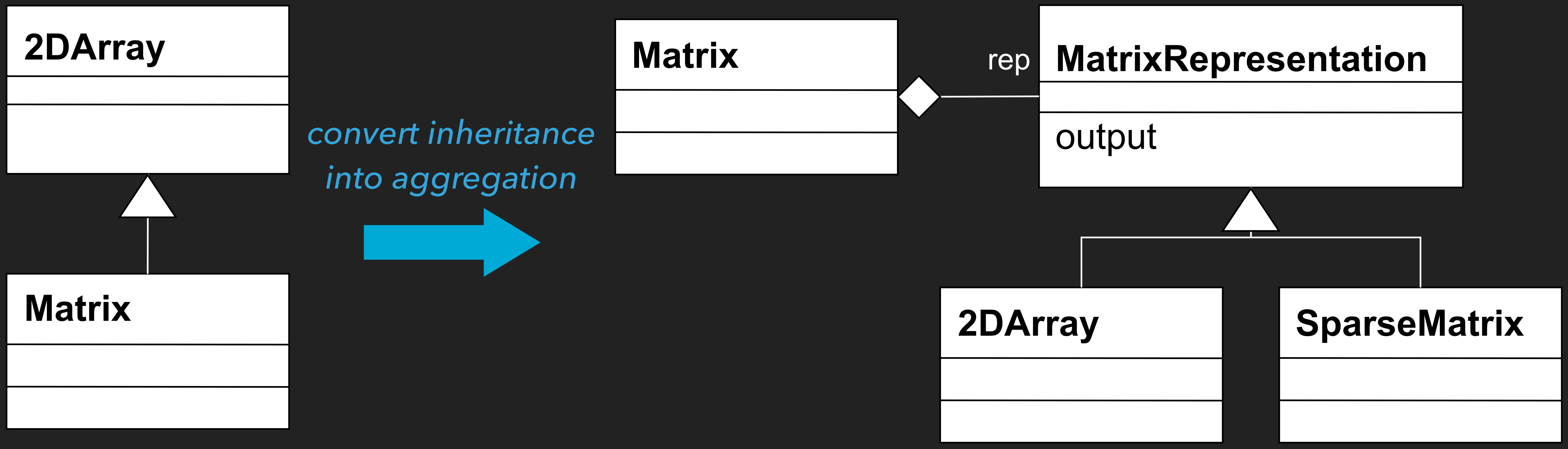
    Used to reduce coupling, migrate towards black-box frameworks.

Motivation :

Inheritance is sometimes overused and incorrectly used in modelling the relationships among classes.

Aggregations are an alternative way to model these relationships.

3. INCORPORATING COMPOSITION RELATIONSHIPS : EXAMPLE



3. INCORPORATING COMPOSITION RELATIONSHIPS

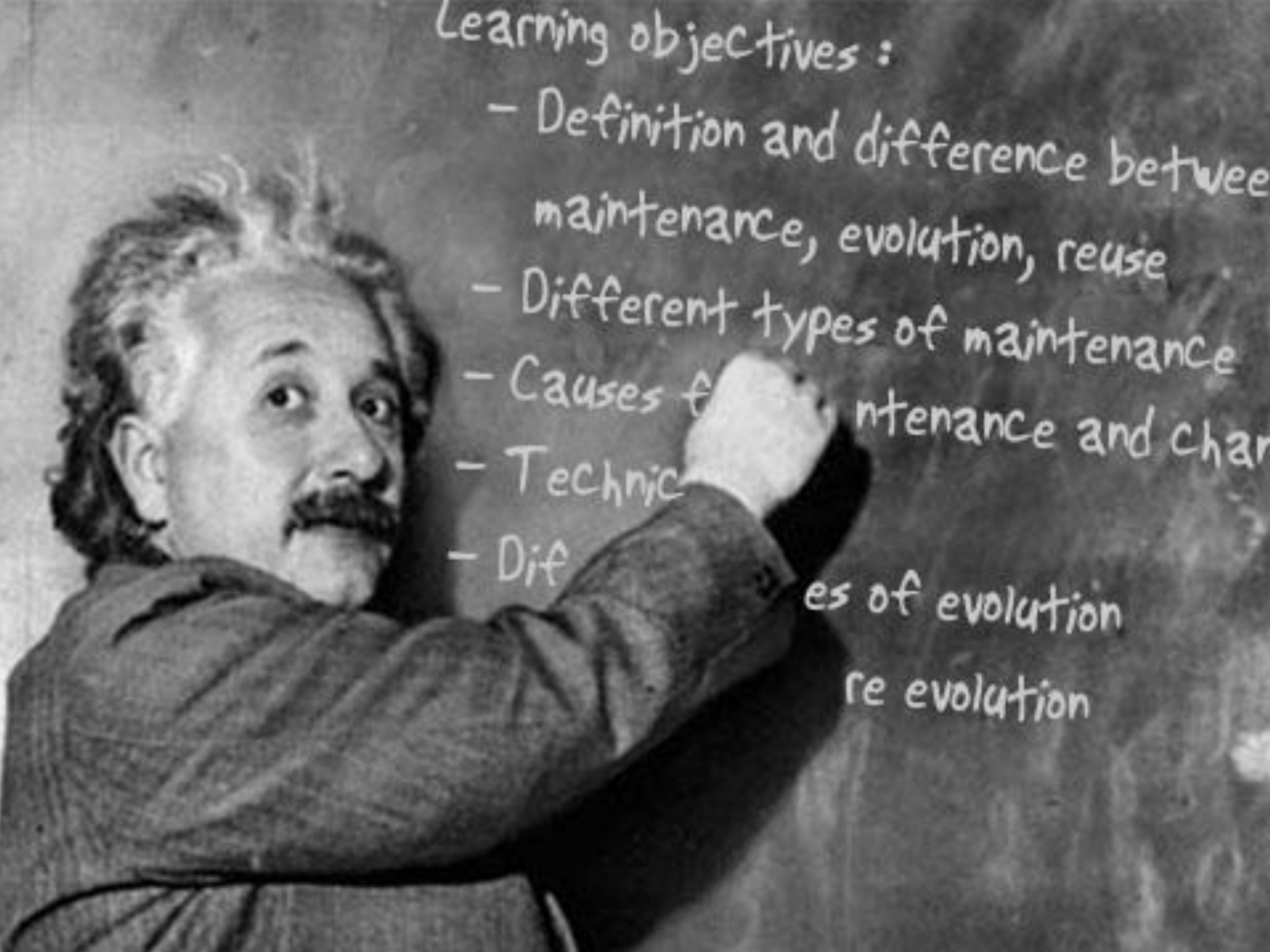
Refactorings regarding aggregations :

Move instance variables/methods from an aggregate class to the class of one of its components.

Move instance variables/methods from a component class to the aggregate classes that contain components which are instances of the component class.

Convert a relationship, modelled using inheritance, into an aggregation and vice versa. [Johnson&Opdyke1993]

[Johnson&Opdyke1993] Ralph E. Johnson, William F. Opdyke. Refactoring and Aggregation. International Symposium on Object Technologies for Advanced Software. Springer Berlin Heidelberg, 1993.



Learning objectives :

- Definition and difference betwee
  maintenance, evolution, reuse
- Different types of maintenance
- Causes f ntenance and char
- Technic
- Dif
  es of evolution
  re evolution

POSSIBLE QUESTIONS

- Define and explain, in your own words, what an object-oriented application framework is and illustrate it with a concrete example of a framework you know.
- Discuss why/how object-oriented application frameworks can achieve software reuse.
- Explain, and illustrate with a concrete example, the principle of inversion of control (a.k.a. the Hollywood principle) when building object-oriented application frameworks.
- What distinguishes an object-oriented application framework from a library?
- What is a hotspot in a framework? Explain and illustrate schematically.
- What types of frameworks can be distinguished and what are the main differences between each of these types?
  - (white box / black box / grey box)
- Explain and illustrate the Template Method design pattern and discuss its key importance to implement object-oriented application frameworks.

CLASS… IS… DISMISSED.