



Chapter 3

Variability Patterns for Object Creation

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Prof. Dr. U. Aßmann

Chair for Software
Engineering

Faculty of Informatics

Dresden University of
Technology

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1) FactoryMethod

2) AbstractFactory

3) Builder





3.1 Factory Method (Polymorphic Constructor)

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A Restriction of Polymorphism

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- ▶ Some polymorphic languages (such as Java) do not allow for exchange of the constructor
- ▶ Problem: constructors are *concrete*, cannot be varied polymorphically

```
// Creator class abstract
public abstract class Creator {
    public void collect() {
        Set mySet = new Set(10);
        // which set should be allocated?
    }
}

// Creator class concrete
public class CreatorB extends Creator {
    public void collect() {
        mySet = new ListBasedSet(10);
    }
}
```

```
// Product class
public class Set extends Collection {
    public Set(int initialLength) {
        ....
    }
}

public class ListBasedSet extends Set {
    public ListBasedSet(int initialLength) {
        ....
    }
}
```

So, creator methods, which employ constructors, must be overridden carefully by hand

Factory Method (Polymorphic Constructor)

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- ▶ Abstract creator classes offer abstract constructors (polymorphic constructors)
 - Concrete subclasses can specialize the constructor
 - Constructor implementation is changed with allocation of concrete Creator

```
// Abstract creator class
public abstract class Creator {
    // factory method
    public abstract Set createSet(int n);
}
```

```
public class Client {
    ... Creator cr = [... subclass]...
    public void collect() {
        Set mySet = cr.createSet(10);
        ....
    }
}
```

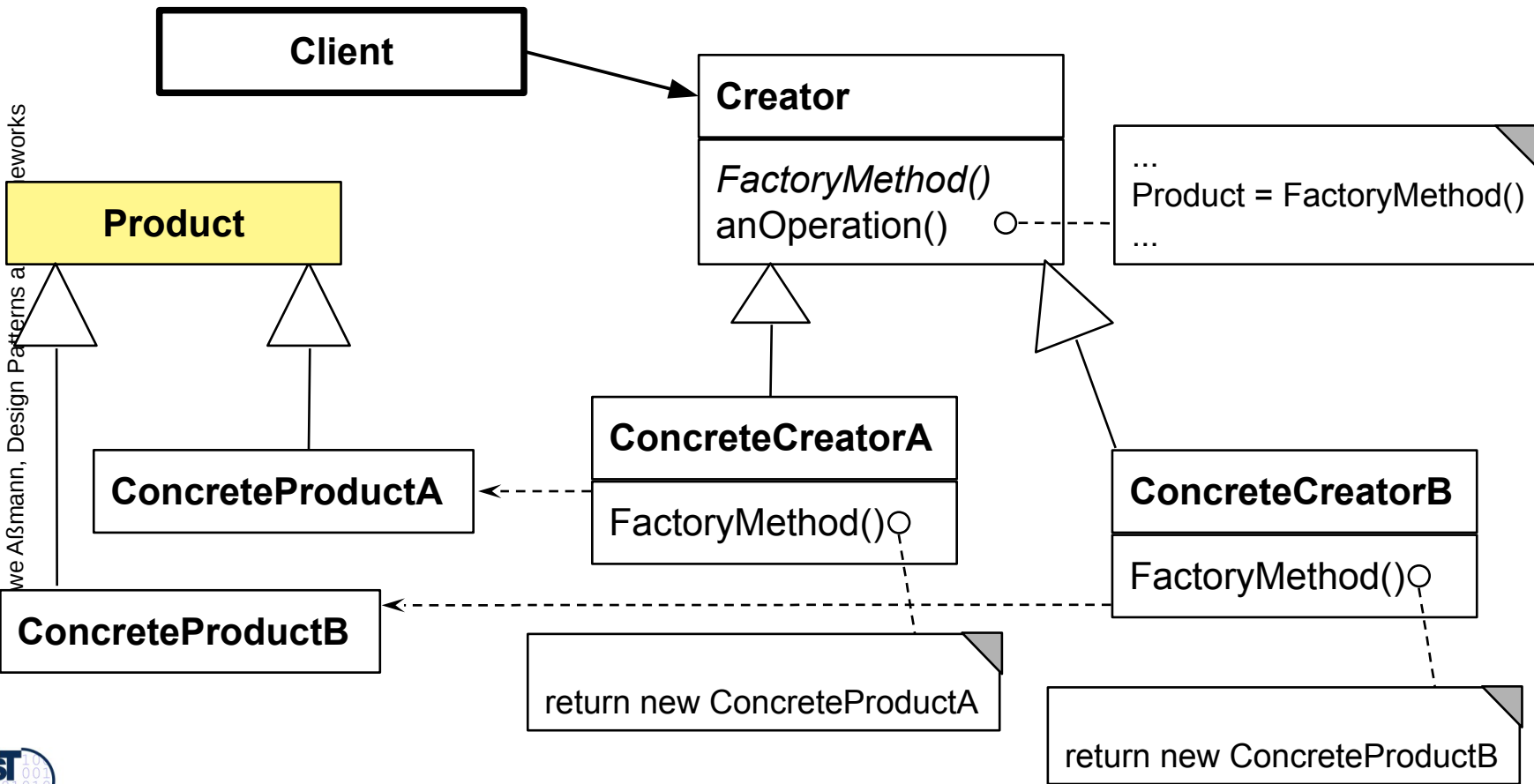


```
// Concrete creator class
public class ConcreteCreator extends Creator {
    public Set createSet(int n) {
        return new ListBasedSet(n);
    }
    ...
}
```

Structure for FactoryMethod

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- ▶ FactoryMethod is a variant of TemplateMethod
- ▶ It hides the allocation of a product



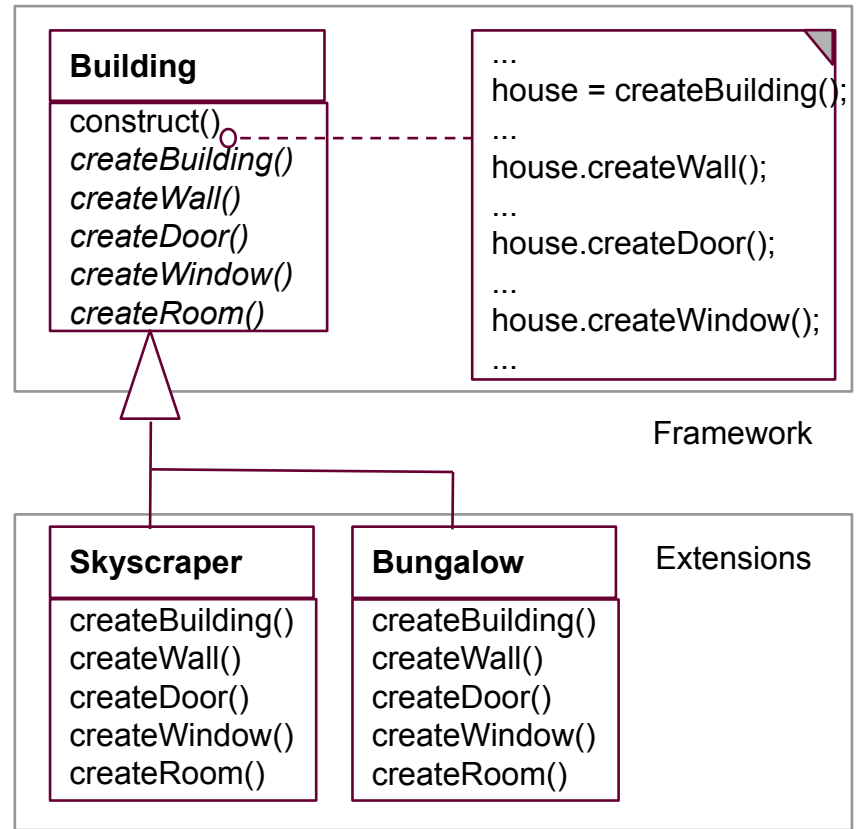
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Example FactoryMethod for Buildings

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- ▶ Consider a framework for planning of buildings
 - Class **Building** with template method **construct** to plan a building interactively
- ▶ Users can create new subclasses of buildings
 - All abstract methods `createWall`, `createRoom`, `createDoor`, `createWindow` must be implemented
- ▶ Problem: How can the framework treat new



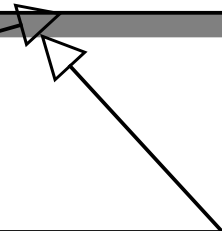
Solution with FactoryMethod

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- ▶ Solution: a FactoryMethod
 - ▶ Subclasses can specialize the constructor and enrich with more behavior, e.g.,

```
// abstract creator class
public abstract class Building {
    public abstract
        Building createBuilding();
    ...
}
```

```
// concrete creator class
public class Skyscraper extends Building {
    Skyscraper() {
        ...
    }
    public Building createBuilding() {
        ... fill in more info ...
        return new Skyscraper();
    }
    ...
}
```

```
// concrete creator class
public class Bungalow extends Building {
    Bungalow() {
        ...
    }
    public Building createBuilding() {
        ... fill in more info ...
        return new Bungalow();
    }
    ...
}
```



Flexible Construction with Reflection

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- ▶ Constructor can allocate objects of statically unknown classes
- ▶ Reflection:
 - Find the class's name and get the class object
 - Then clone the class object

in Java: **Class.forName** (String name)

- ▶ Attention: reflection is usually slow. It has to lookup

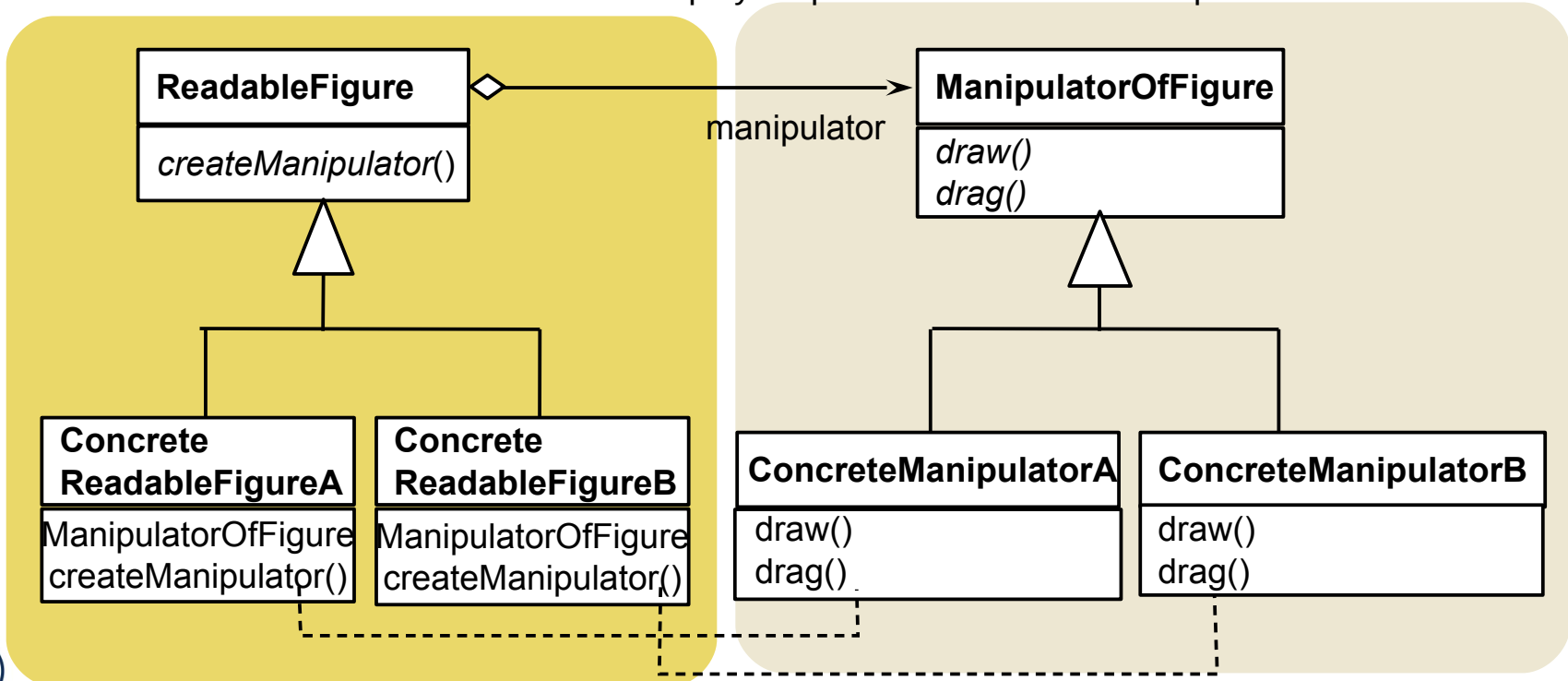
```
bytecode information and must load class code on-the-fly
```

```
createProduct() {  
    // reflective function for class name, called in subclass  
    String className = getClassFromSomeWhere();  
    // get the class object and allocate from there  
    house = (Building) Class.forName(className).newInstance();  
    ...  
}
```


Factory Methods in Parallel Class Hierarchies

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- ▶ One class hierarchy offers uses a factory method to create objects of a second hierarchy
- ▶ On every level, the factory method is implemented in a parallel class on exactly the same level and abstraction level
 - E.g, ReadableObject and WritableObject in ReadableFigures and FigureManipulators
- ▶ Here, the parallelism constraint is that every readable object must allocate a parallel manipulator.
 - This is a constraint on the polymorphic allocator of the manipulators



Analysis of FactoryMethod – Information Hiding of Abstract Classes

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- ▶ Abstract classes know *when* an object should be allocated, but do not know which of the subclasses will be filled in at runtime
 - The knowledge which subclass should be used is encapsulated into the client subclasses
- ▶ For frameworks this means:
 - The abstract classes of the framework do not know which application class they will work on, but they know when to create an application object
 - The knowledge which application class should be used is encapsulated into the application
- ▶ Relatives of FactoryMethod
 - A FactoryMethod is a HookMethod, used by a TemplateMethod, which returns a product, i.e., FactoryMethods are called in TemplateMethods



3.2 Factory Class (Abstract Factory)

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Forces of the Factory Class Pattern

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- ▶ Given a package with a family of classes (a *product family*). Examples
 - Widgets in a window system
 - Stones in a Tetris game
 - Products of a company
- ▶ How can the product family be switched in one go to a variant?
 - Swing widgets to Windows widgets?
 - 2D-stones to 3D-stones in the Tetris game?
 - Cheap variants of the products of the company to expensive variants?

Factory Class Pattern

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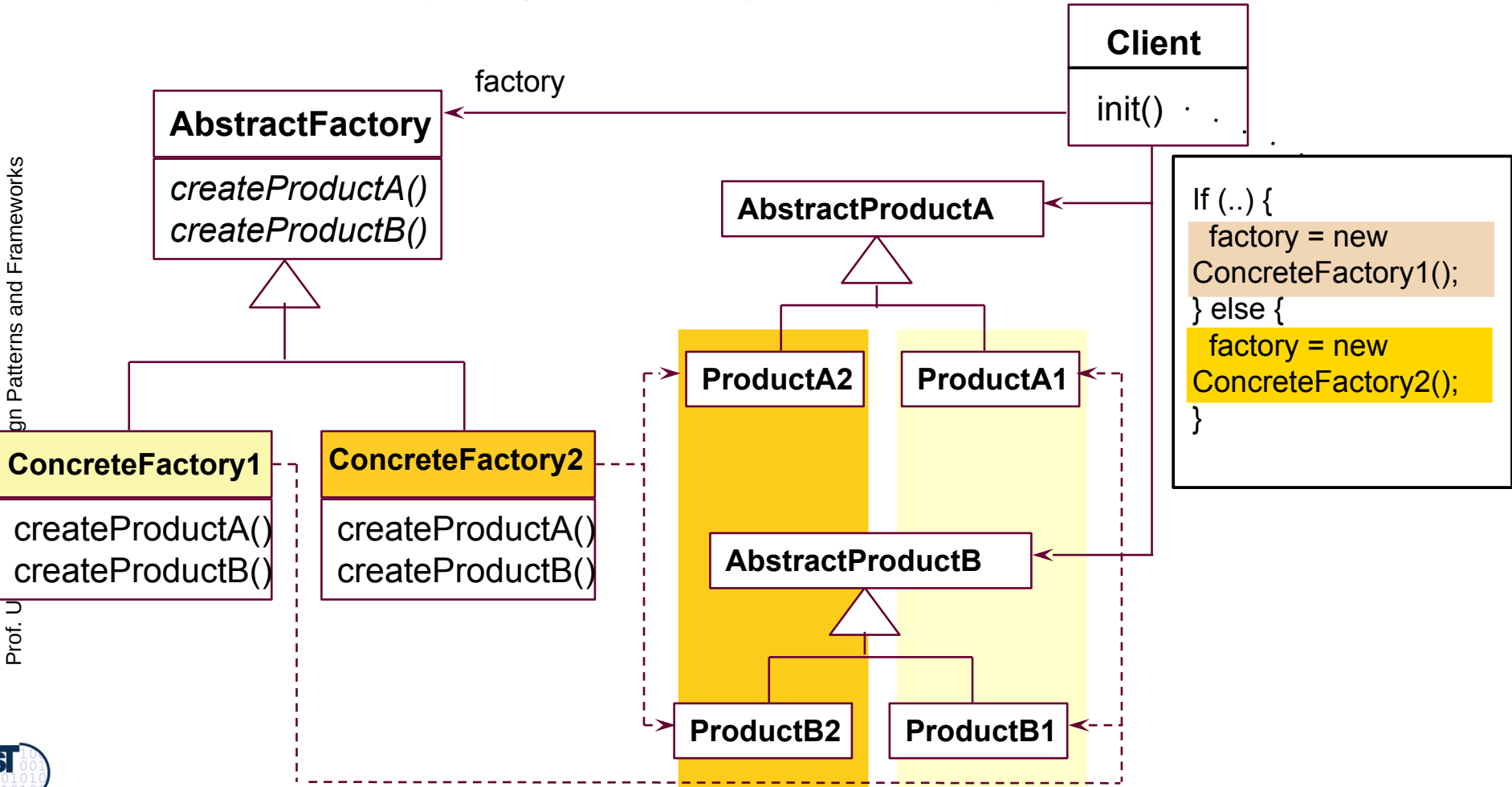
- ▶ A **Factory (FactoryClass)** groups factory methods to a class
 - A Factory is a class that groups a *family of polymorphic constructors* of a family of classes (products)
 - The products can be classes of a layer or a package
 - The products have a strong parallelism constraint (isomorphic hierarchies)
- ▶ An **AbstractFactory** contains the interfaces of the constructors
- ▶ A **ConcreteFactory** contains the implementation of the constructors
 - The Concrete Factories can be exchanged
 - A Concrete Factory represents one concrete family of objects

Structure for Factory Class

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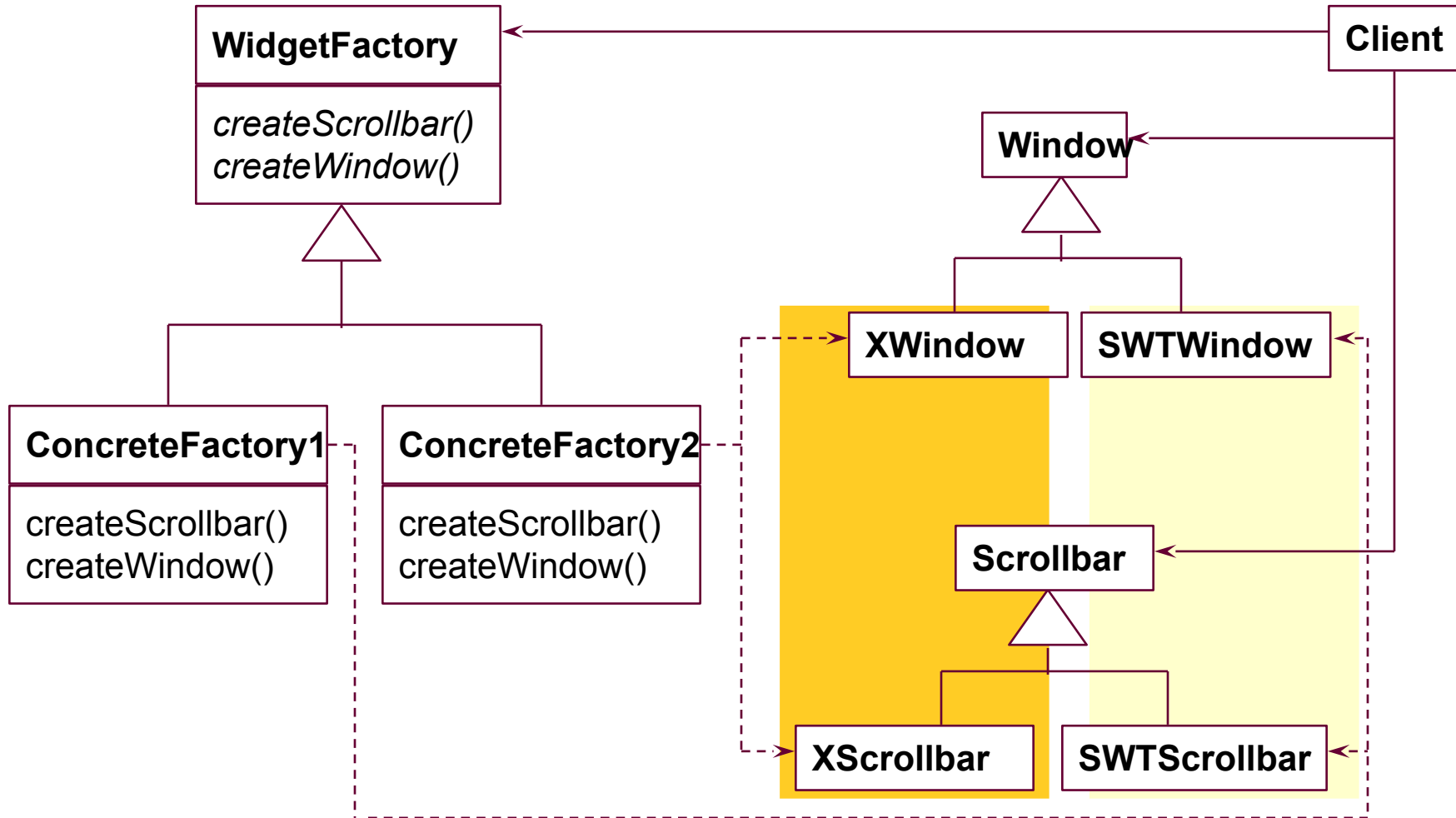
- ▶ By creating the concrete factory, the client determines the entire family of products (here: family 1 or 2)

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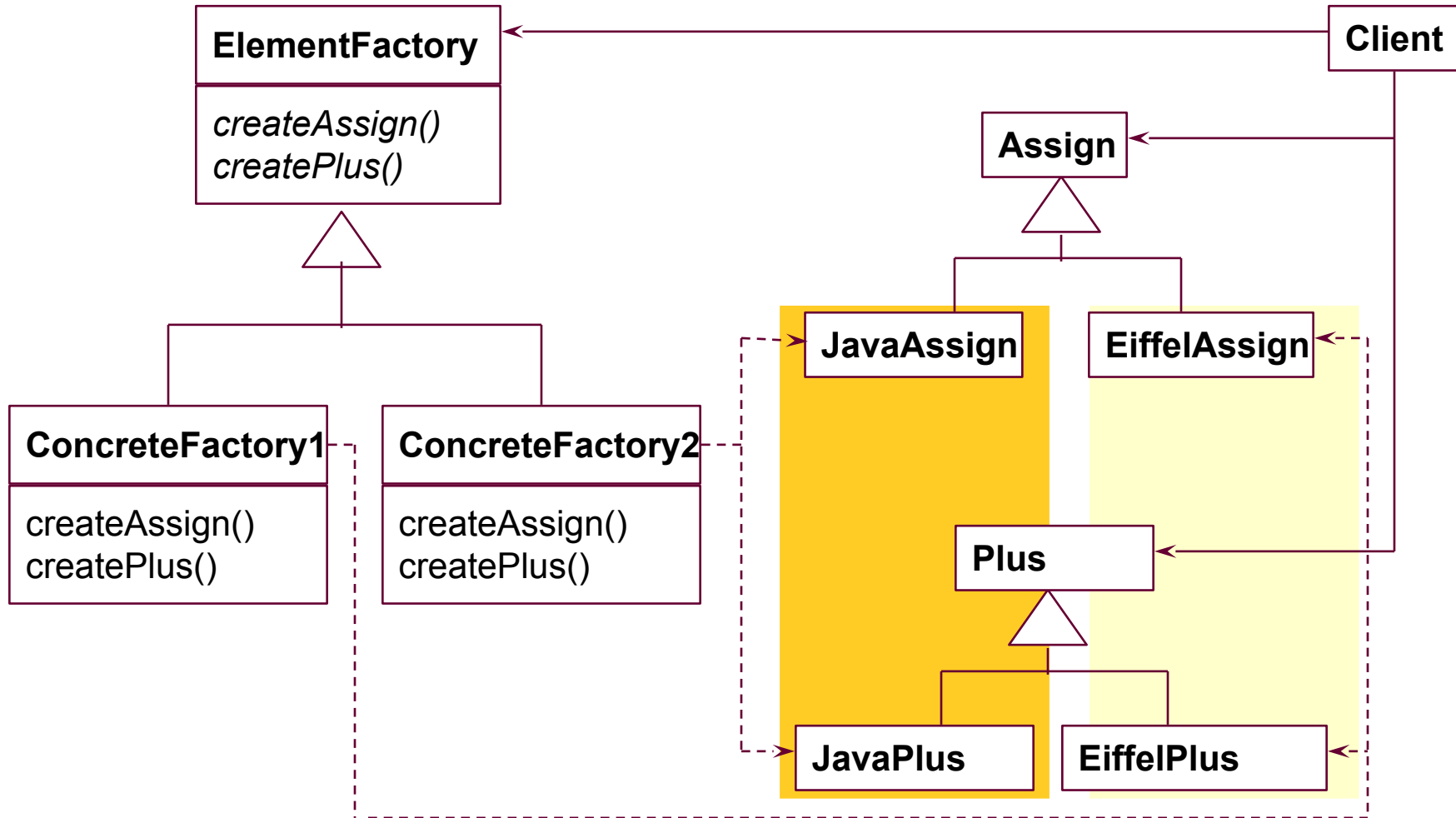
Example for Factory Class

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Example for Factory Class in Compilers

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Employment of Factory Class

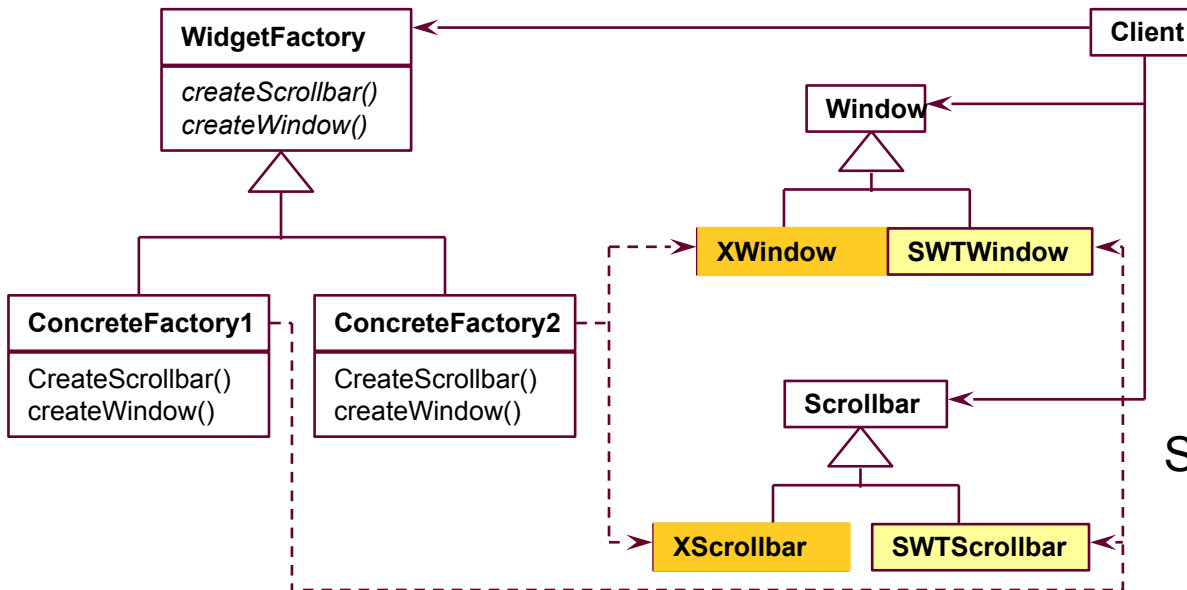
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- ▶ For window styles
 - All widgets are used by the framework abstractly
 - The concrete style is determined by a concrete factory class
 - Swing, AWT, ...
- ▶ In office systems
 - For families of similar documents
- ▶ In business systems
 - For families of similar products
- ▶ For tools on several languages
- ▶ Factory Class is related to Tools-and-Materials (TAM), because products are materials (see later)

Pragmatics of Factory Class

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- ▶ A factory deals with 3+x inheritance hierarchies (factory, product 1, ..., product n)
- ▶ The n product hierarchies must be maintained *in parallel*, i.e., they form ParallelHierarchies
- ▶ The factory pattern ensures that all objects are created with the parallelism constraint



Same height of products

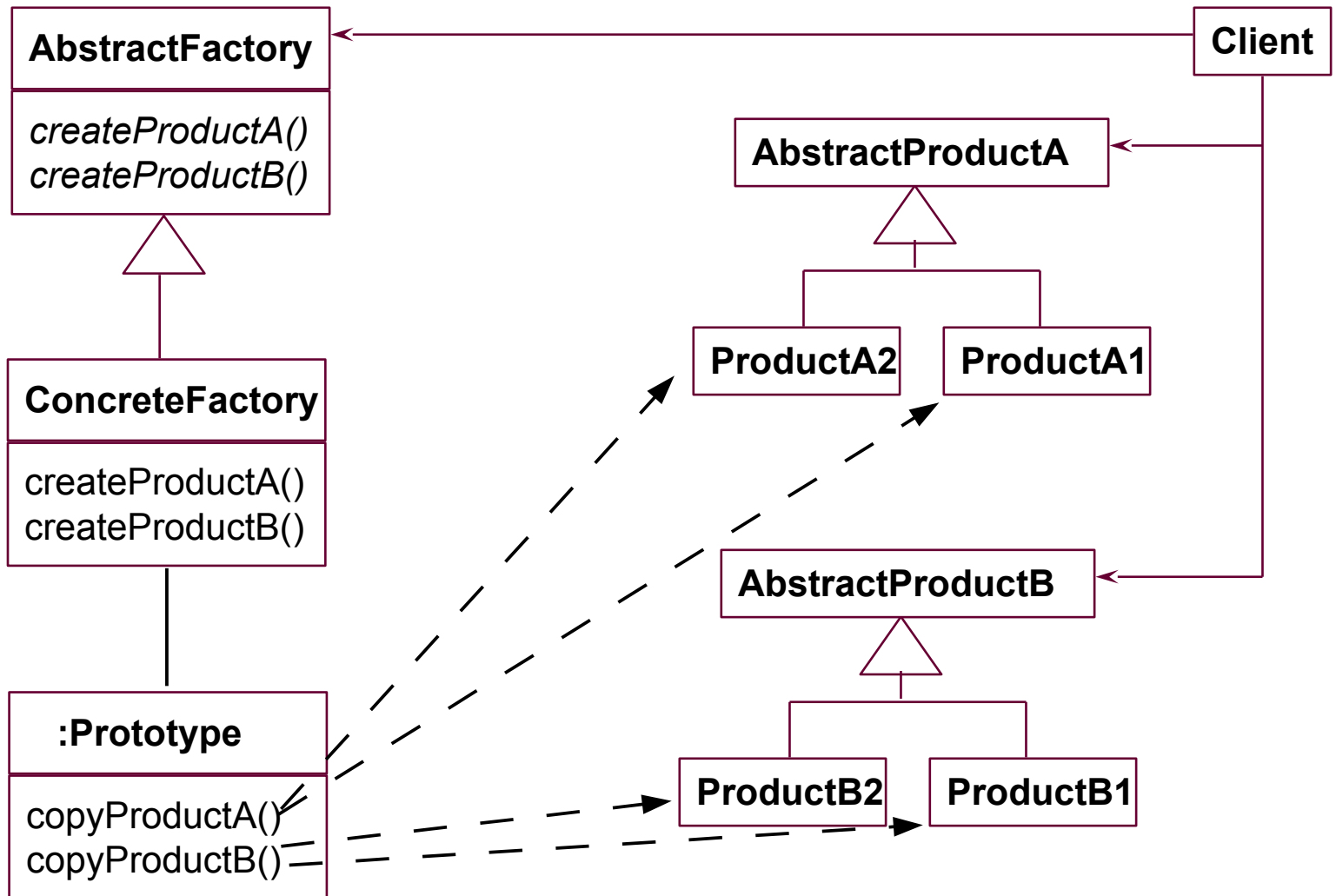
Variant: The Prototyping Factory

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- ▶ Concrete factories need not be created; one instance is enough, if prototypes of the products exist
- ▶ To produce new products, the ConcreteFactory clones the set of available products
- ▶ The variability of products is handled by the cloning of the prototypes

Structure for Prototyping Factory

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Variant: Factory with Interpretive FactoryMethod

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- ▶ If more factory methods should be added, this becomes tedious, since the AbstractFactory and all concrete factories must be edited
- ▶ Instead: one factory method with parameter string

```
public class abstractFactory {  
    abstract Product createProduct(String what);  
}
```

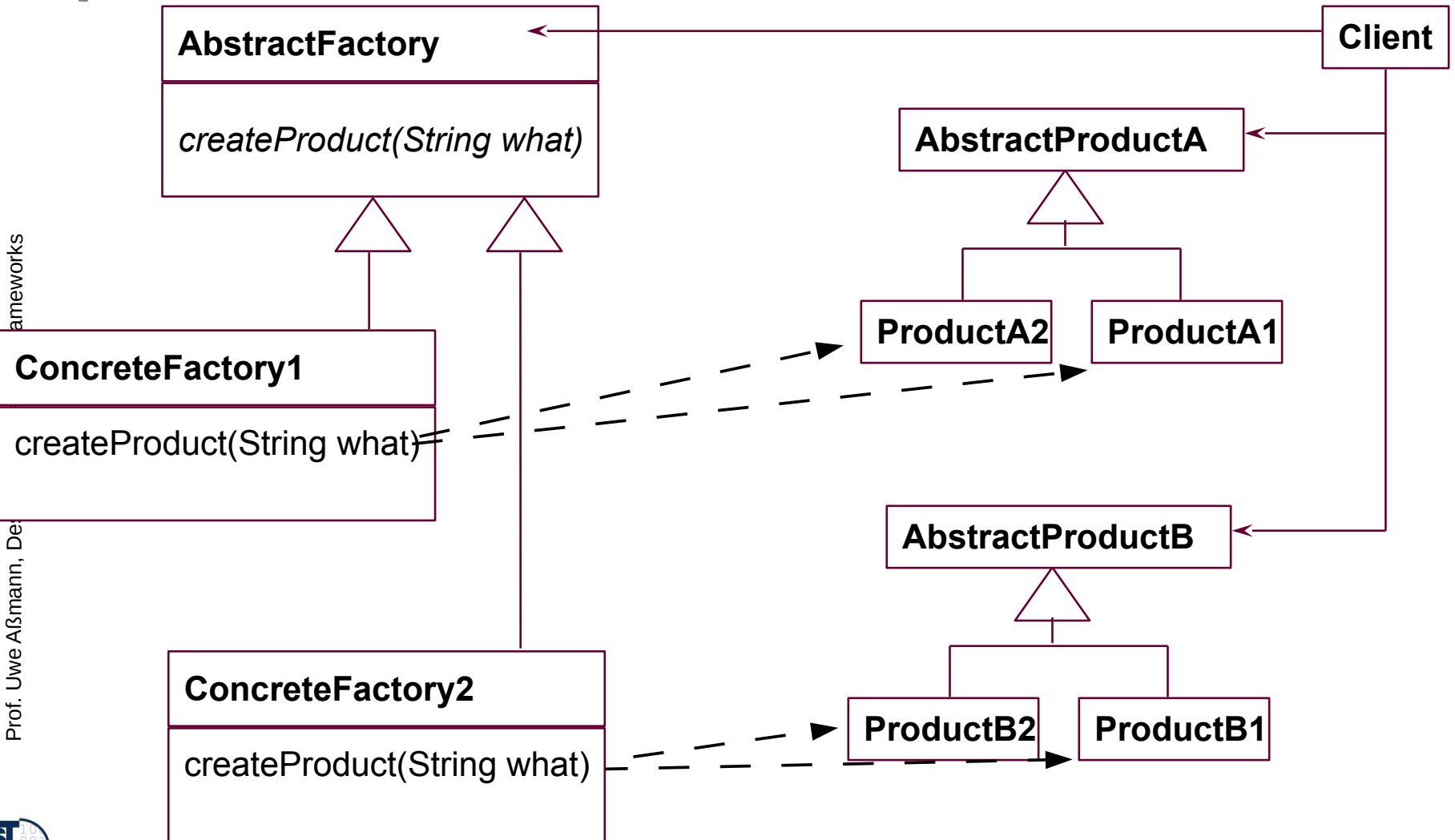
```
public class concreteFactory extends abstractFactory {  
    Product createProduct(String what) {  
        if (what.eq("p1")) {  
            return new P1();  
        }  
        else .....  
    }  
}
```

Structure for Interpretive Factory

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frameworks

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Factory Class - Employment

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- ▶ Make a system independent of the way how its objects are created
- ▶ Hide constructors to make the way of creation exchangeable with types
- ▶ For product families
 - In which families of objects need to be created together; but the way how is varied
- ▶ Related Patterns
 - An abstract factory is a special form of hook class, to be called by some template classes.
 - Often, a factory is a Singleton (a Singleton is a class with only one instance)
 - Concrete factories can be created by parameterizing the factory with Prototype objects



3.3 Builder (Factory with Protocol, Structured Factory)

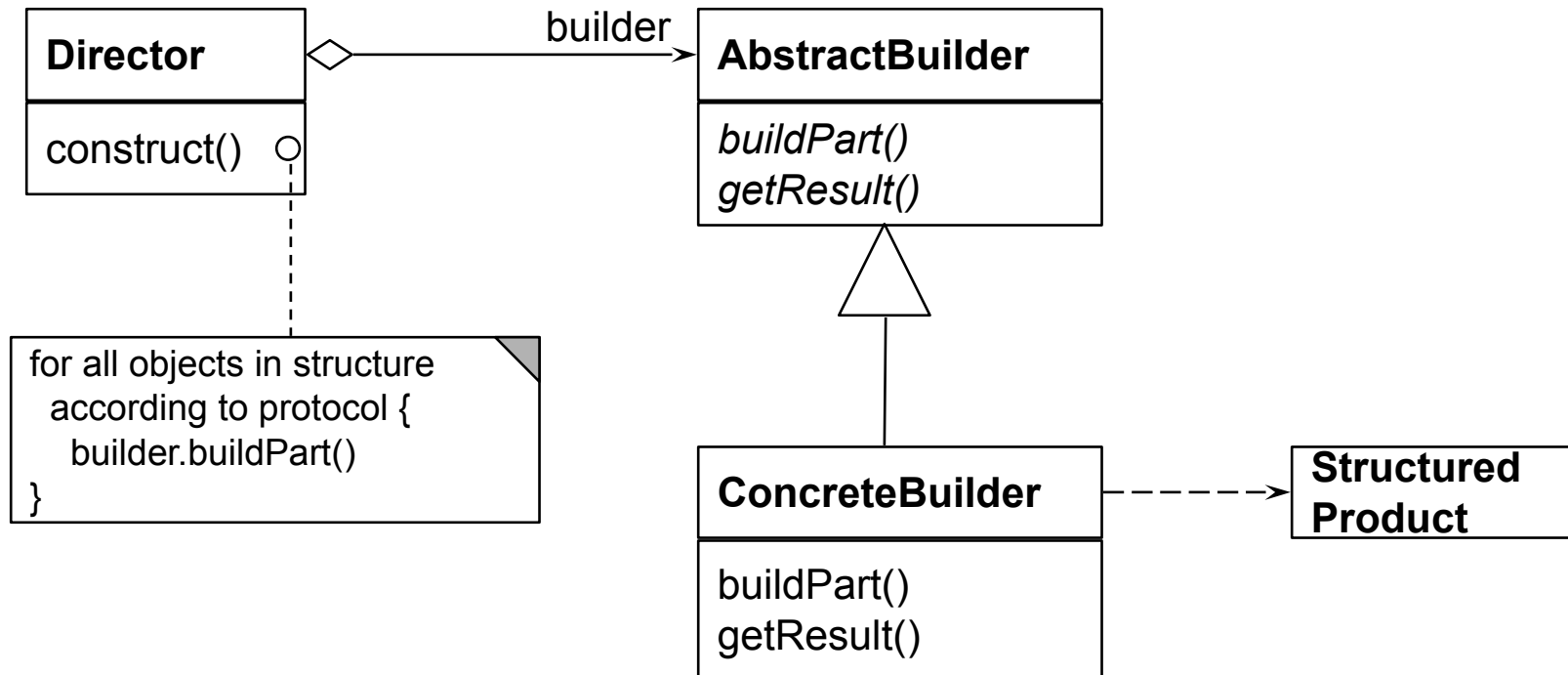
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Structure for Builder

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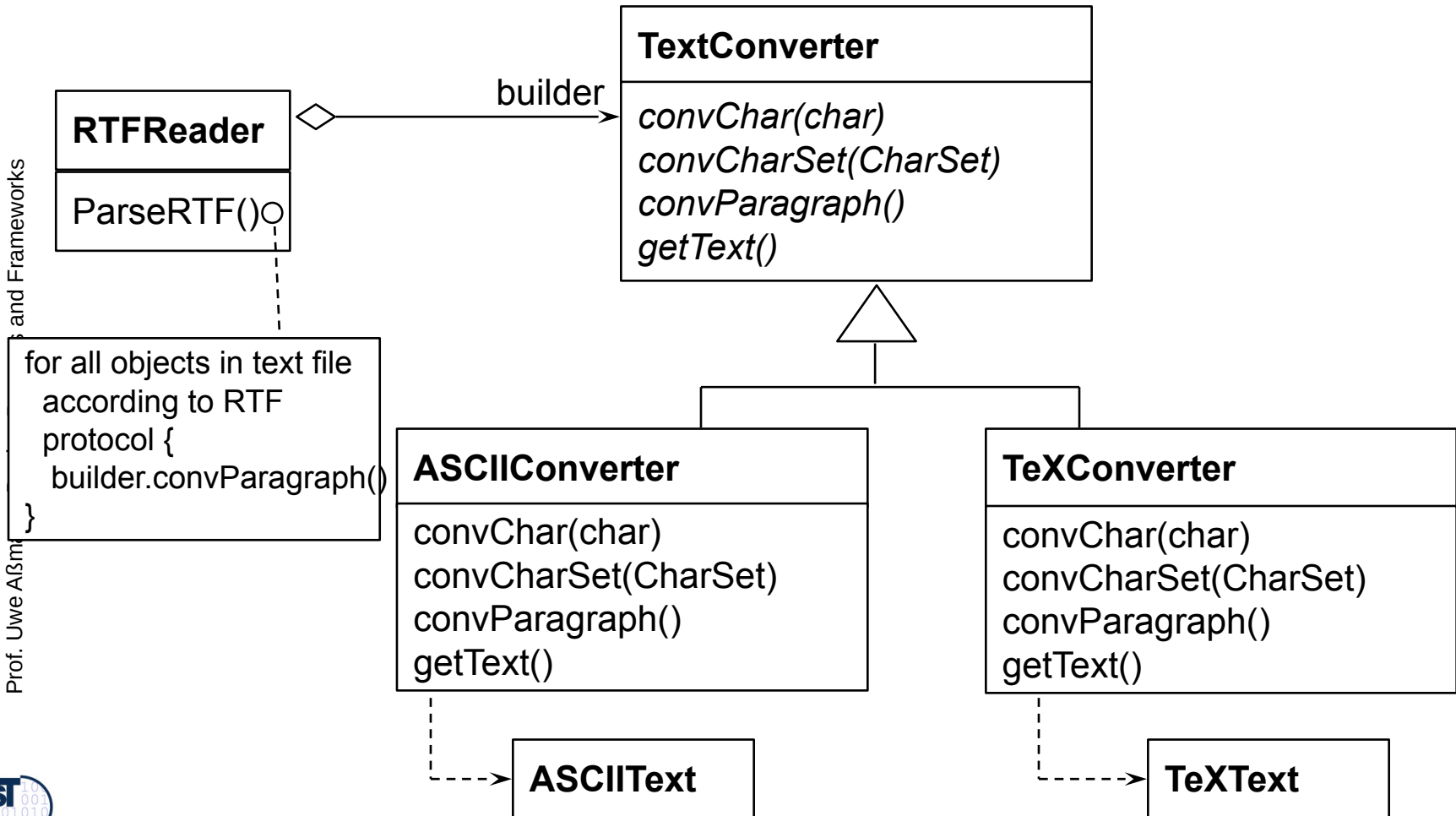
- ▶ The Builder is a Factory that produces a *structured* product (a whole with parts)
 - e.g., a business object or product data of a PDM



Example RTF-Document Builder

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- ▶ RTF grammar defines a protocol for the sequence of text converter functions



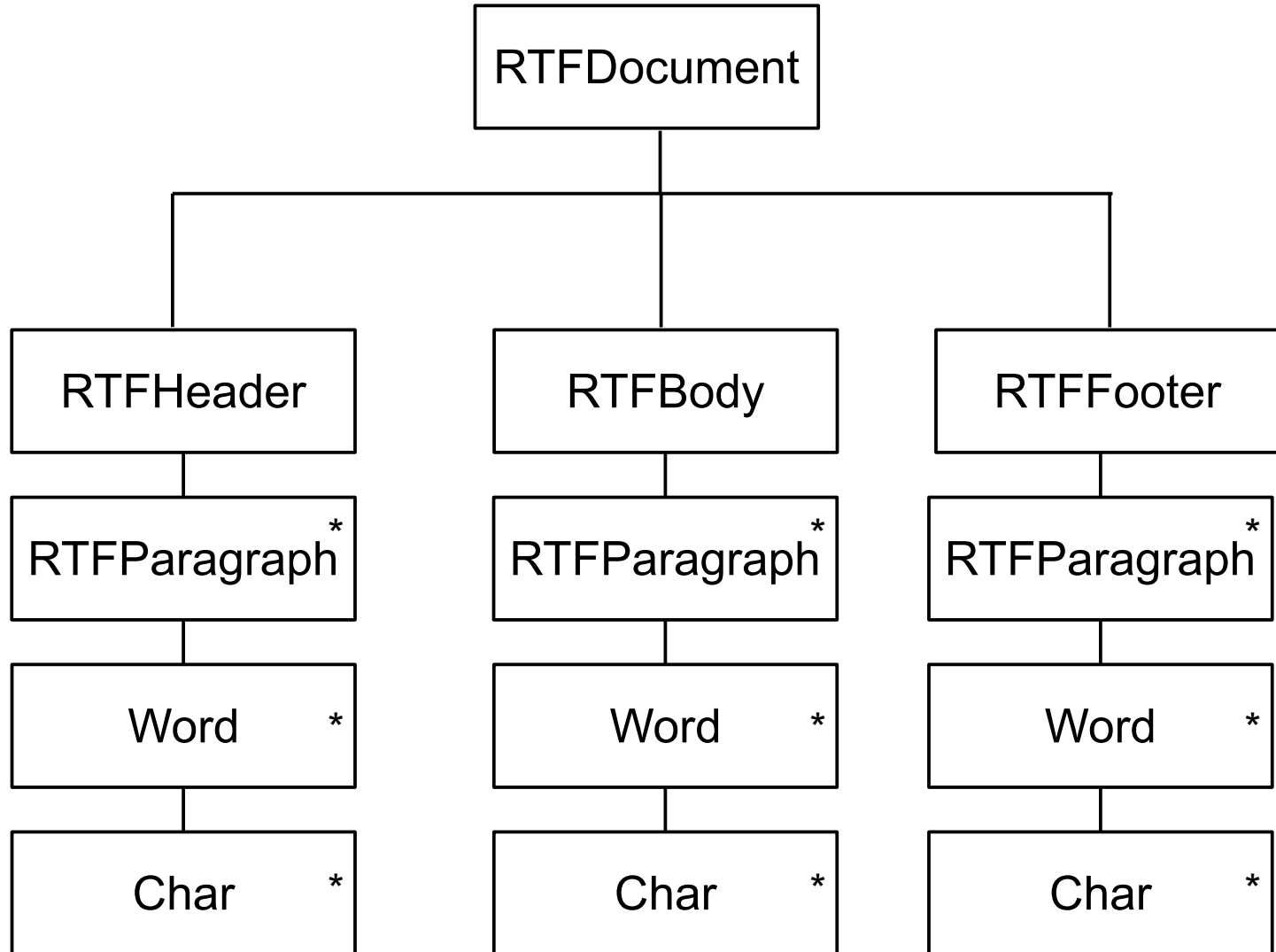
Builder Protocol (E.g., Specified by EBNF)

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```
-- Grammar in EBNF
RTFDocument ::= RTFHeader RTFBody RTFFooter .
RTFHeader ::= RTFParagraph* .
RTFParagraph ::= Word* .
Word ::= Char* .
RTFBody ::= RTFParagraph* .
RTFFooter ::= RTFParagraph* .
```

RTF Builder Protocol (E.g., Specified by JSP)

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The Builder

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- ▶ Maintains an internal state that memorizes the point of time in construction of the complex data structure
- ▶ Data structure defines a protocol for calls to the elementary functions
- ▶ Data structure must be defined by a
 - Grammar
 - JSP, regular expression
 - Protocol machine (statechart acceptor)
 - Other mechanisms, such as Petri nets
- ▶ The other way round: as soon as we have a data structure
 - Defined by a grammar, regular expressions, or JSP
 - We can build a constructor with the Builder pattern

Builder: Information Hiding

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- ▶ The builder hides
 - The protocol (the structure of the data)
 - The current status
 - The implementation of the data structure
- ▶ Similar to an Iterator, the structure is hidden

Known Uses

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- ▶ Parsers in compilers are builders that contain the grammar of the concrete syntax of the programming language
- ▶ Builders for intermediate representations of all kinds of languages
 - Programming languages
 - Specification languages
 - Graphic languages such as UML
- ▶ Builders for all complex data structures
 - Databases with integrity constraints

Appendix

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Combination of Factory Method and Default Implementation

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- ▶ FactoryMethods can contain default implementations to share behavior
- ▶ Subclass has to call super()

```
// abstract class with default
// behavior
public abstract class Building {
    public abstract
        Building createBuildingInner();
    public
        Building createBuilding() {
            Building b = createBuildingInner();
            Door d = new Door();
            b.setDoor(d);
            return b;
        }
    ...
}
```

```
// concrete class with additional
// behavior
public class Skyscraper extends Building {
    // concretization of hook
    public Building createBuildingInner() {
        return new Skyscraper();
    }
    ...
}
```

Creation of Product Subclasses with Generics

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```
// Generic factory class
template<class TheProduct>
class StandardProducer<TheProduct> : public Producer {
    Product* StandardProducer<TheProduct>{ } {
        return new <TheProduct>();
    }
    ...
}
```

```
// Application of generic factory class creates concrete
// FactoryMethod automatically
Public abstract class Building {
    StandardProducer<MyProduct> myProducer;
    myProducer = new myProducer.StandardProducer<MyProduct>()
}
```