

Chapter 3

Variability Patterns for Object Creation

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- 1) FactoryMethod
- 2) AbstractFactory
- 3) Builder



3.1 Factory Method (Polymorphic Constructor)



A Restriction of Polymorphism

- ▶ Often, polymorphic language 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)

- ▶ 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);
}
```

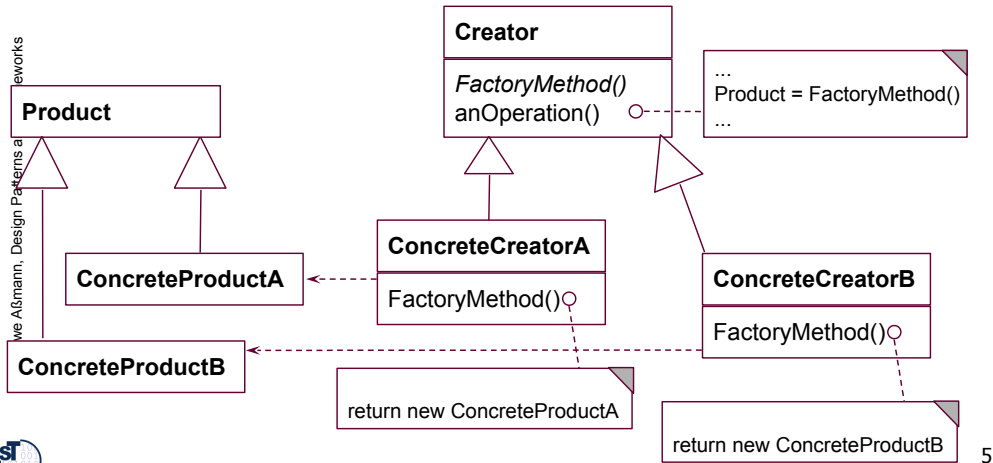
```
public class Client {
    ... Creator cr = [... subclass]..
    public void collect() {
        Set mySet = Creator.createSet(10);
        ....
    }
}
```

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



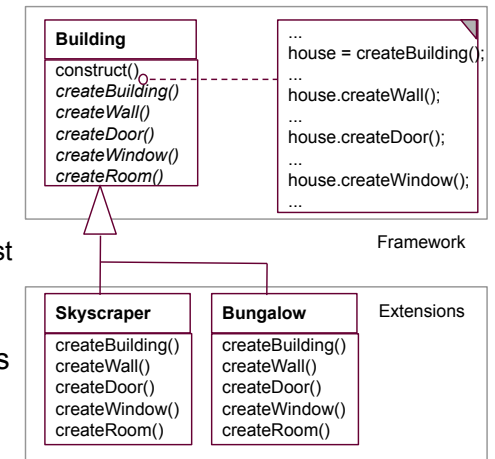
Structure for FactoryMethod

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



Example FactoryMethod for Buildings

- ▶ 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 subclasses of Buildings? (unforeseen extension)



Solution with FactoryMethod

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

```

// 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();
    }
    ...
}
    
```

Flexible Construction with 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();
    ...
}
    
```

Combination of Factory Method and Default Implementation

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

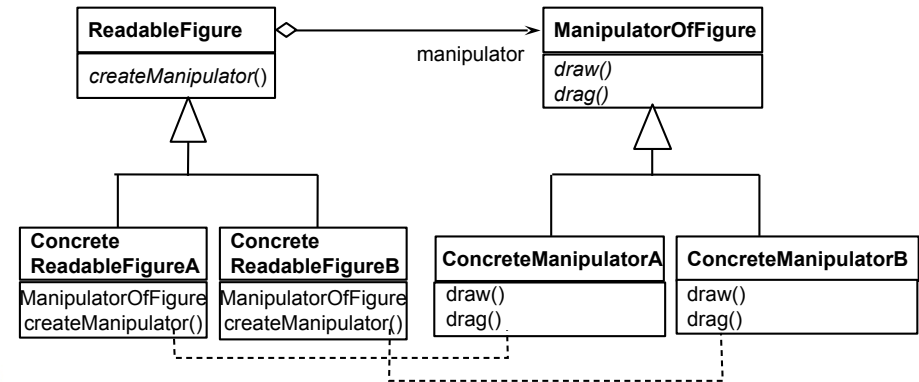
```
// abstract class with default
// behavior
public abstract class Building {
    public abstract
    Building createBuildingInner();
    public
    Building createBuilding() {
        Building b = createBuildingInner();
        Door d = new Door();
        b.setDoor(d);
        return b;
    }
}

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



Factory Methods in Parallel Class Hierarchies

- ▶ 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



Creation of Product Subclasses with Generics

```
// 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>()
}
```



Analysis of FactoryMethod – Information Hiding of Abstract Classes

- ▶ 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)

Forces of the Factory Class Pattern

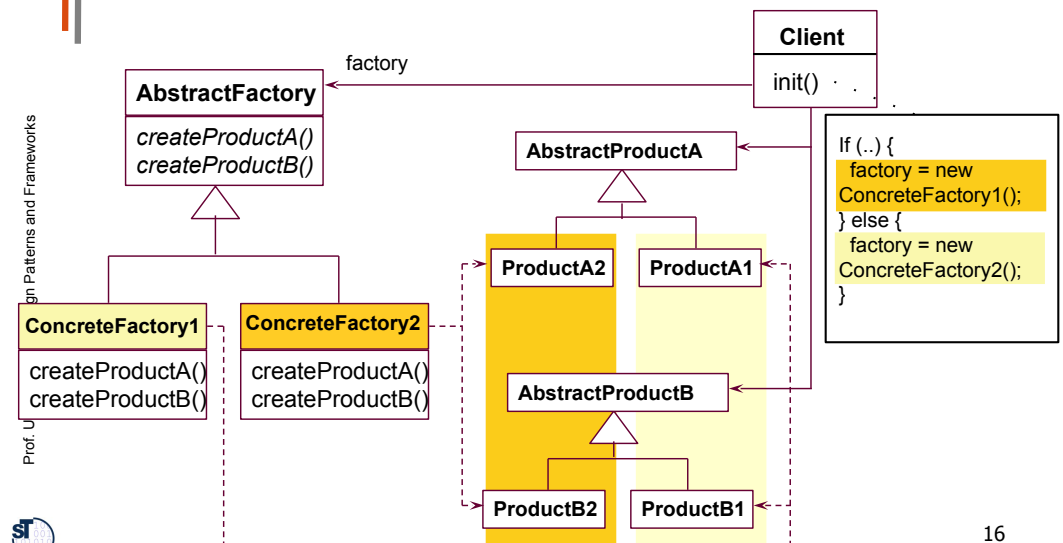
- ▶ Given a package with a family of classes (*a product family*).
Examples
 - Widgets in a window system
 - Stones in a Tetris game
 - Products of a company
- ▶ How can the product family be switched in one go to a variant?
 - Swing widgets to Windows widgets?
 - 2D-stones to 3D-stones in the Tetris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

Factory Class Pattern

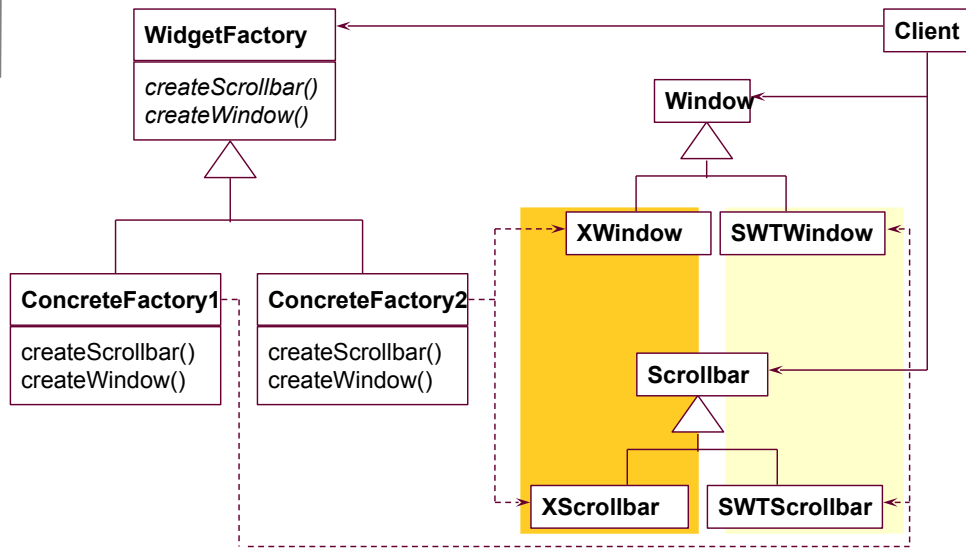
- ▶ A **Factory (FactoryClass)** groups factory methods to a class
 - A Factory is a class that groups a *family of polymorphic constructors* of a family of classes (products)
 - The products can be classes of a layer or a package
 - The products have a strong parallelism constraint (isomorphic hierarchies)
- ▶ 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
- ▶ Hence, an AbstractFactory offers an interface to create families of related objects
 - That depend on each other
 - Without naming their constructors explicitly

Structure for Factory Class

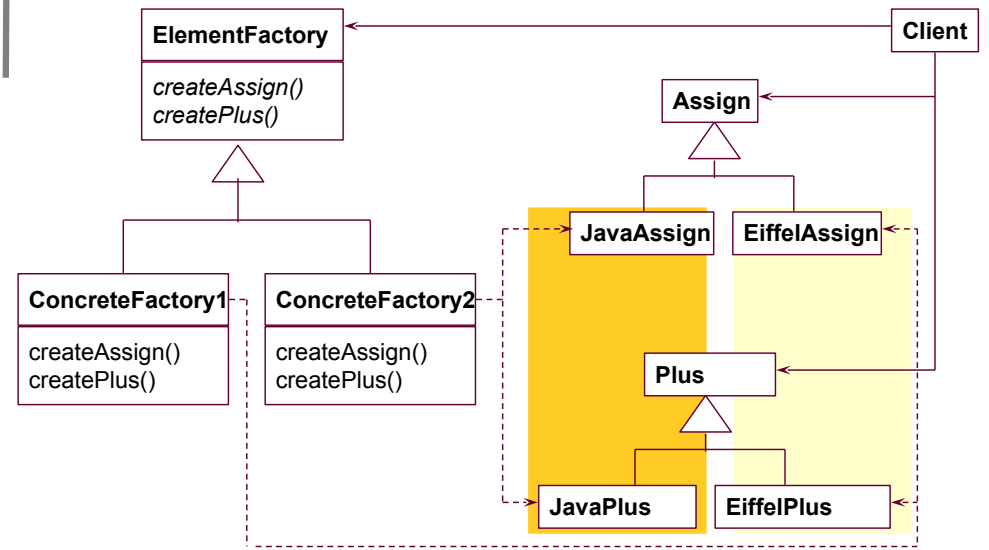
- ▶ By creating the concrete factory, the client determines the entire family of products (here: family 1 or 2)



Example for Factory Class



Example for Factory Class in Compilers

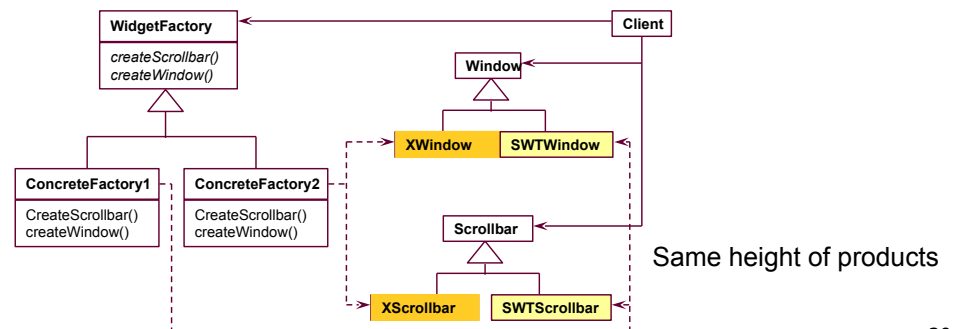


Employment of Factory Class

- ▶ 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

- ▶ 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



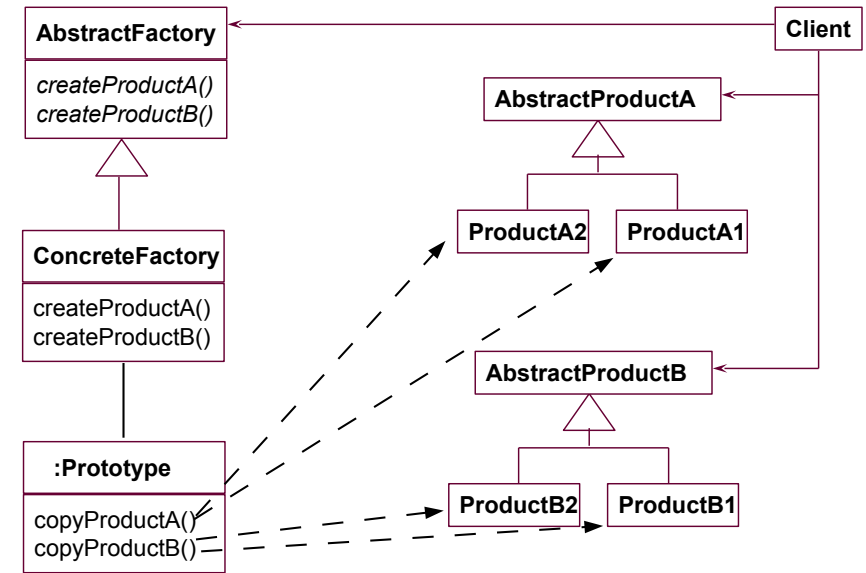
Same height of products

Variant: The Prototyping Factory

- ▶ 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



Variant: Factory with Interpretive FactoryMethod

- ▶ 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

```

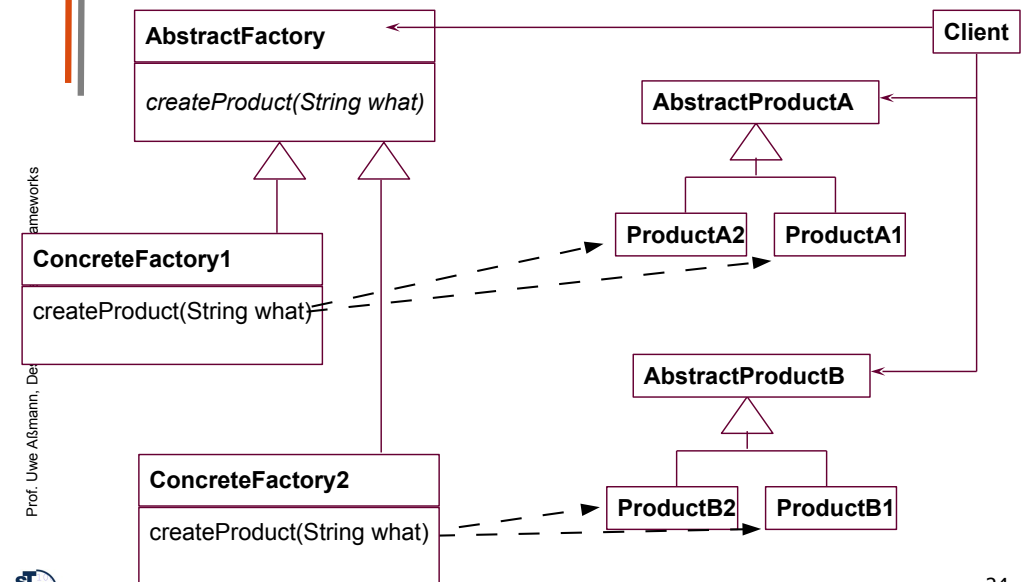
public class abstractFactory {
    abstract Product createProduct(String what);
}
    
```

```

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



Structure for Interpretive Factory



Factory Class - Employment

- ▶ 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

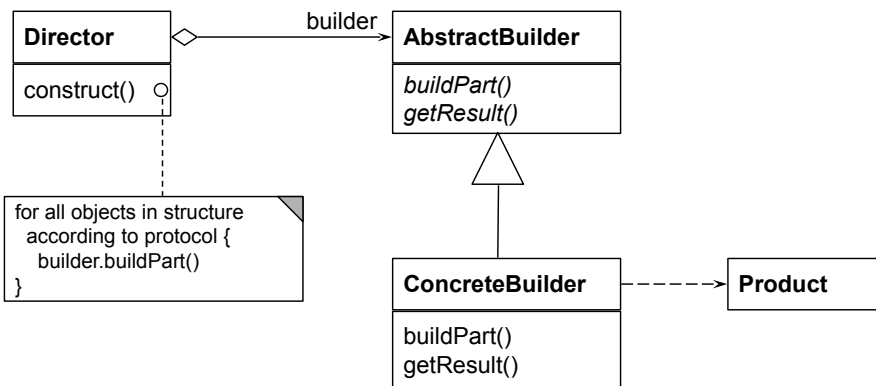


3.3 Builder (Factory with Protocol, Structured Factory)



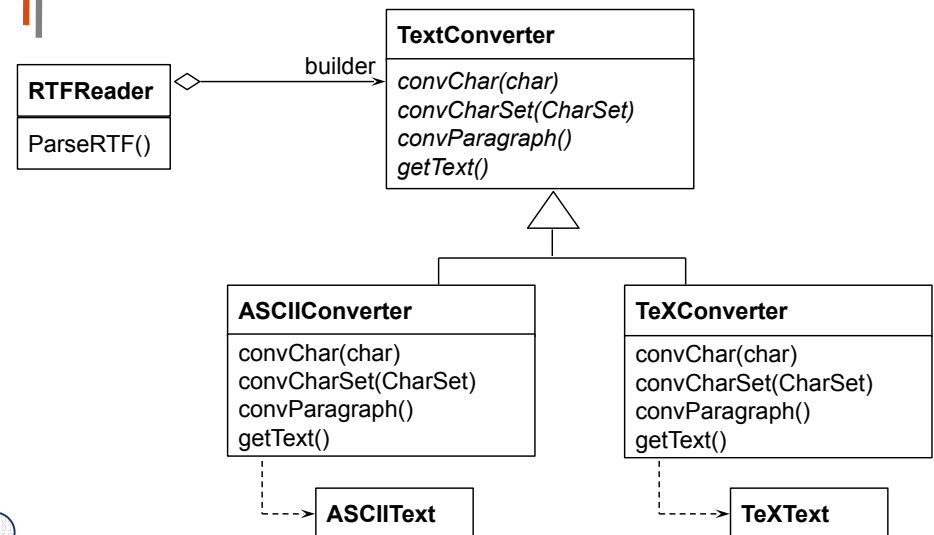
Structure for Builder

- ▶ 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

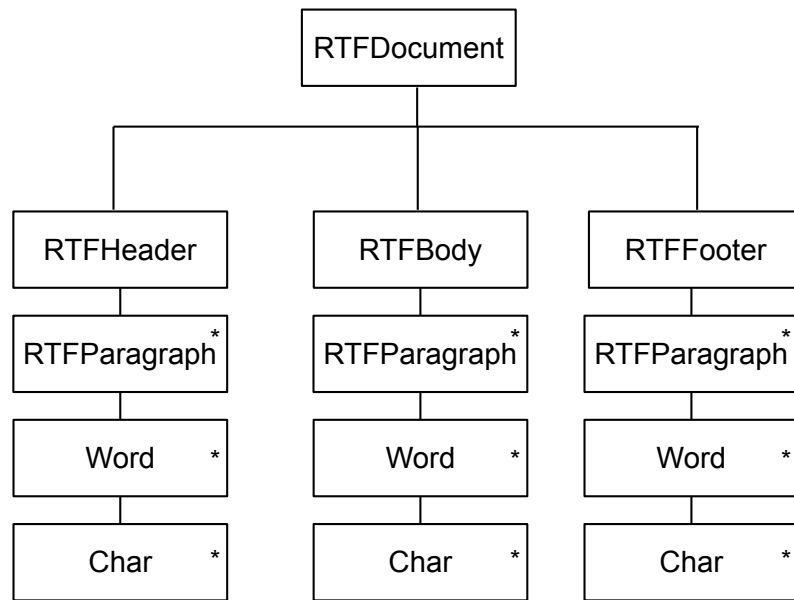


Example Builder

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



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



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The Builder

- ▶ 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

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Builder: Information Hiding

- ▶ 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

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Known Uses

- ▶ 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

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The End

