

Lecture 02

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Arthur Molnar

Creational Patterns

Intro & Example
Abstract Factory
Factory Method
Builder
Prototype
Singleton
Pattern

Creational Patterns

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 - Factory Method
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Creational Patterns

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- Creational patterns abstract the instantiation process
- They hide the the object creation process (remember, "*new is glue*")
- Emphasis placed on fundamental behaviours that can be combined into complex ones
- *What* is created can be decided at compile, or at run time

A-Mazeing

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- We use the common example of building a maze to study these patterns
- A maze is a set of connected *rooms*; each room knows its direct neighbours - another **room**, a **wall** or a **door** leading to another room
- Keeping it simple - directions are north, south, east, west
- Keeping it even simpler - ignore everything else (no multiplayer or pew pew 😊)

A-Mazing

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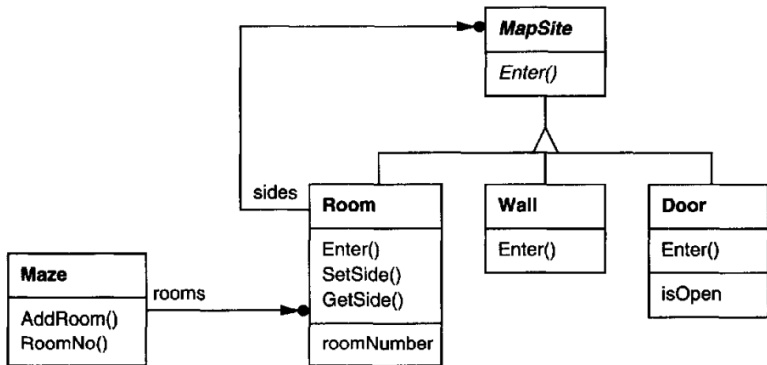


Figure: From [1]

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- *MapSite* is abstract
- The rest are concrete, but can be *subclassed*
- Behaviour of *Enter()* depends on trying a door or another room

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Maze source code

git: /ubb/dp/creational/maze

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What does the source code look like?

- It's incomplete - obviously
- *MazeGame* looks more complicated than it should be
- Could move wall creation code to *Room* constructor...
- Big problem: **inflexible**
- We can't change maze layout, or the type of its elements (e.g. *PewPewRoom*) without changing the code
- Overriding it = new implementation, twice the work
- Changing in place = we might need this version too, kind of error-prone

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Where creational patterns come in:

- Make the design more flexible (not *necessarily* smaller)
- Changing the maze type, or its elements should be easier (some doors need a key or spell, rooms might have a ticking bomb...)
- This can be achieved when we no longer hard-code the creation of the maze's elements
- *New is glue*, remember?

Where creational patterns come in

- **Abstract Factory:** pass *CreateMaze* a parameter that can be used to create maze elements; you can change maze element types by providing a different parameter
- **Factory Method:** instead of using constructor calls, call some virtual functions, which can be replaced by subclassing

Where creational patterns come in

- **Builder:** pass *CreateMaze* an object that can build an entire maze by creating rooms, walls and door sequentially, and then varying this using inheritance.
- **Prototype:** parameterize *CreateMaze* using prototypes for maze elements, which you clone, configure and add to the maze.
- **Singleton:** use it to ensure the maze program uses a single maze, to which all components have access.

Abstract Factory

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Intent

Provide an interface to create a family of related or dependent objects, without specifying concrete classes

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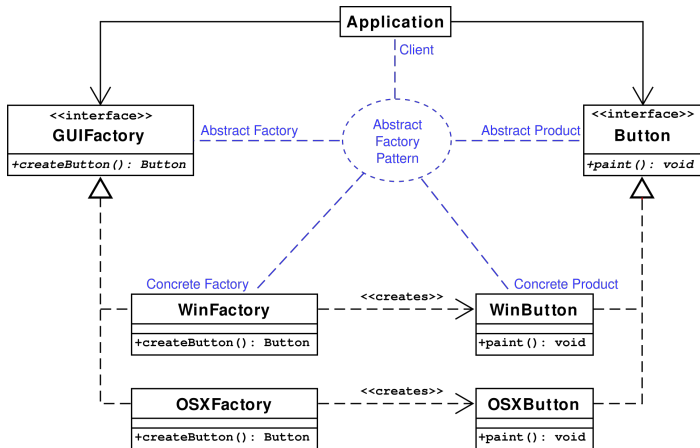


Figure: From
https://en.wikipedia.org/wiki/Abstract_factory_pattern

Abstract Factory

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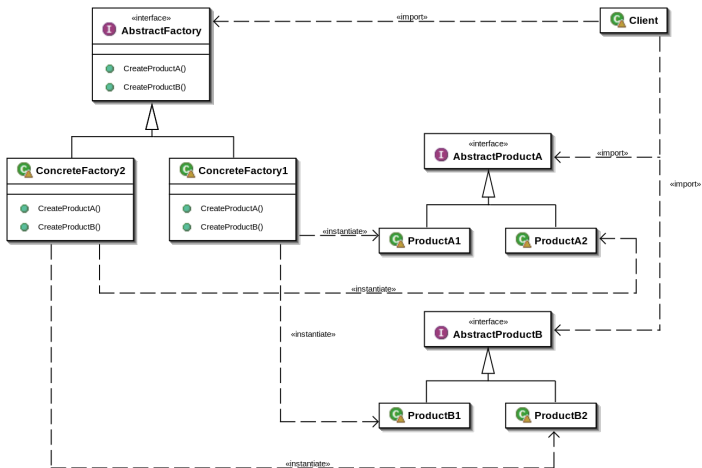


Figure: From

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Abstract Factory

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- The base class is abstract, and several concrete factories implement it
- The *Client* only refers the *AbstractFactory* and abstract products, in order to remove dependency to actual implementations
- *Client* only commits to the interface, not the implementation => Open/Closed principle using polymorphism
- The *Factory* enforces dependency between classes (e.g. don't try to use a *macOS* button in a Windows context)

Abstract Factory

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When to use, tips & tricks

- System independent from how products are created and composed
- System can be configured with several product families (hint: check out *Factory* if it's not a product family)
- Products should be used together
- Supporting new products is difficult, due to extensively specified interfaces
- Implementations are usually based on the *Factory Method*, and since there is usually a single concrete factory, it can be implemented as a *Singleton*

Abstract Factory

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Source code

git: `/src/ubb/dp/creational/AbstractFactoryExample`

Factory Method

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Gang of Four

"Define an interface for creating an object, but let subclasses decide which class to instantiate. The Factory method lets a class defer instantiation it uses to subclasses."

- Define an interface for object instantiation, but let subclasses decide the type that is created
- The *abstract factory* is one of this pattern's users

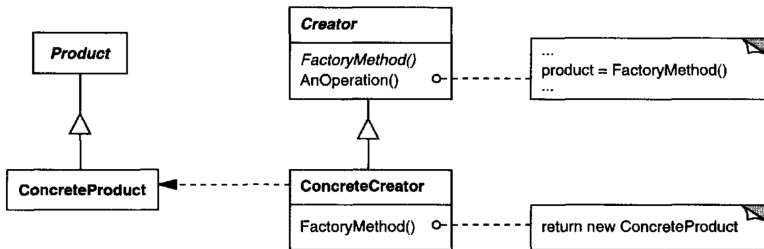
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Factory Method

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Varieties

- Creator can be concrete and create a default object, which subclasses can override (provides a hook)
- Creator can be parameterized, with the created type depending on the provided parameter (**e.g.** `Logger.getLogger(String name)` (concrete factory))
- Concrete creators can also be templated, according to the *Product* they should create

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Source code

git: `/src/ubb/dp/creational/FactoryExample`

Builder

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- Separate the construction of a complex object from its representation
- The same construction process can result in different representations
- Construction is made step by step

Example: Rich Text Format (RTF) conversion

- "Understanding" the file format, **and** converting it to another one (e.g. ASCII, TeX, PDF representation) are different things
- The first part is common, the second one isn't
- A good solution will not duplicate code, and will be *open for extension* - additional converters can be added later on

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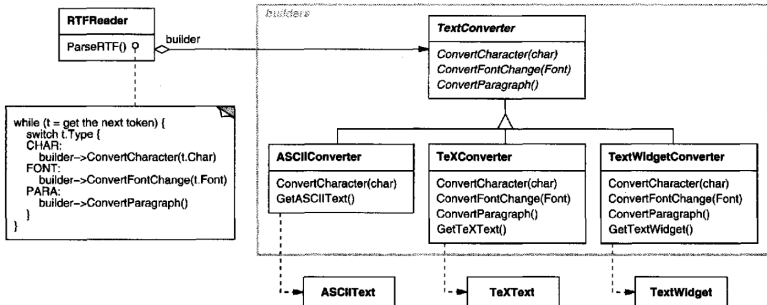


Figure: From [1]

Builder

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- ASCII converter only cares about the text elements
- TeX converts all RTF elements to TeX
- The *TextWidget* converter produces a GUI element

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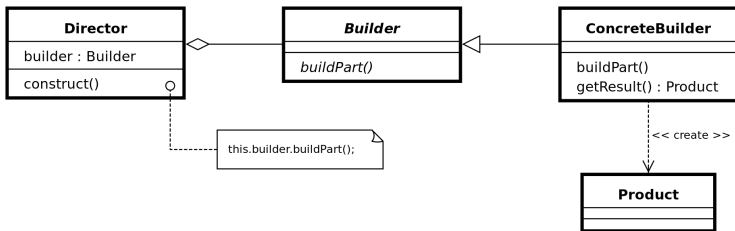


Figure: From
https://en.wikipedia.org/wiki/Builder_pattern

Roles in the *Builder* pattern

- **Director:** constructs the object using the *Builder* interface (e.g. the RTF reader in our example)
- **Builder:** specifies the interface for creating the parts of the product (e.g. the *TextConverter*)
- **Concrete builder:** constructs & assembles the product, keeps track of the representation, provides an interface to retrieve it (e.g. the *TeXConverter* from our example)
- **Product:** the complex object being constructed (e.g. *ASCIIText*, *TextWidget*)

Using the builder pattern

- Lets you vary the product internal representation
- Improves encapsulation by hiding product internal representation
- Compared to *factory* patterns, provides more control over the build process

Implementation issues

- Sometimes appending the latest element to the *Product* under construction is enough (e.g. converters example, Java's *StringBuilder*, *Calendar*, *Locale*), but sometimes it isn't (e.g. the Maze game example), and additional data structures are required (e.g. parse trees)
- No abstract product class!?
- Base class with concrete but empty methods. Why? 😊

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Source code

git: /src/ubb/dp/creational/BuilderExample

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What is it?

- Use a prototype instance to decide the types of objects to create
- Clone the prototype to obtain new instances

When to use it?

- System independent of how product are created, composed and represented, **and**
- classes to instantiate are provided at run-time (dynamically loaded)
- want to avoid building a factory hierarchy

Prototype Example

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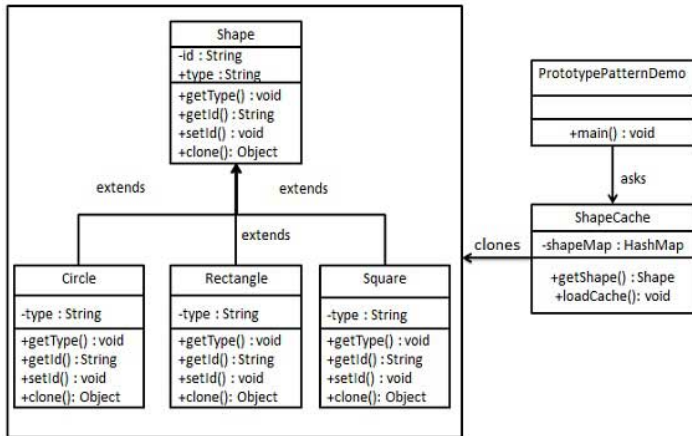


Figure: From https://www.tutorialspoint.com/design_pattern/prototype_pattern.htm

Prototype Example 1

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Source code

git: `/src/ubb/dp/creational/ShapesPrototype`

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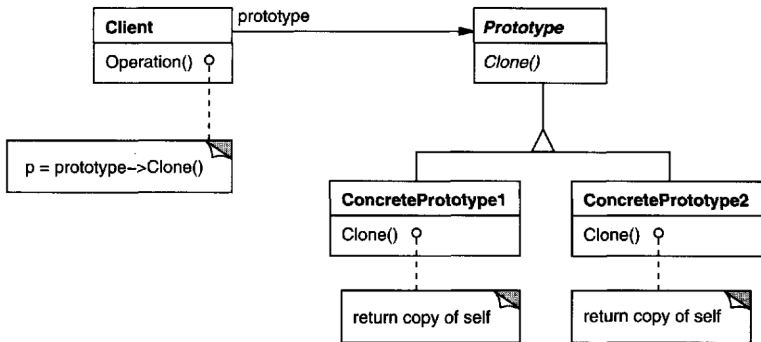


Figure: From [1]

Prototype

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Pattern roles

- **Prototype:** declares the interface for cloning itself (e.g. could be Java's **Cloneable**, but read this first: <https://www.artima.com/intv/bloch13.html>)
- **ConcretePrototype:** implements the actual operation to clone itself
- **Client:** creates new objects using cloning

Prototype Example 2

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Building a maze using the *Prototype* pattern

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git: /src/ubb/dp/creational/PrototypeMaze

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Consequences

- Shares benefits with the *factory* patterns (hides product details from clients)
- Better support using dynamic binding
- Avoid building class hierarchies for purposes of design
- Implement a *PrototypeManager* for handling prototype instances (maybe as *Singleton?*)

Drawbacks

- Implementation issues with shallow vs. deep copy, composition, circular references
- Implementation woes given *Java's Cloneable* interface (does not include the *clone()* method, objects are built using field-copy and not constructors, leading to possible invariant violations)

Singleton Pattern

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- Ensure a class has a single instance
- Provide a global access point to that instance
- **e.g.** graphical user interface, file system, database connection
- Instead of using a global variable, make the class itself responsible of its sole instance
- The *Singleton* class can be inherited from

Singleton Pattern

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- *Singleton* design allows you to control the number of instances
- Allows extension through polymorphism, unlike *C++* static methods
- **e.g.** graphical user interface, file system, database connection
- Instead of using a global variable, make the class itself responsible of its sole instance

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- The *Singleton* class can be inherited from
- Thread safety should be ensured
- *Lazy* versus *eager* instance creation
- Using a *SingletonRegistry* provides a global management point for several singleton classes
- *Multiton* is the singleton pattern allowing several instances

Singletons !?

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Building a correct singleton maze factory in *Java*

Source code

git: `/src/ubb/dp/creational/MazeSingleton`