

C++ Training

3. Design Pattern Cheat Sheet

Klaus Iglberger
July, 29th-30th, 2024

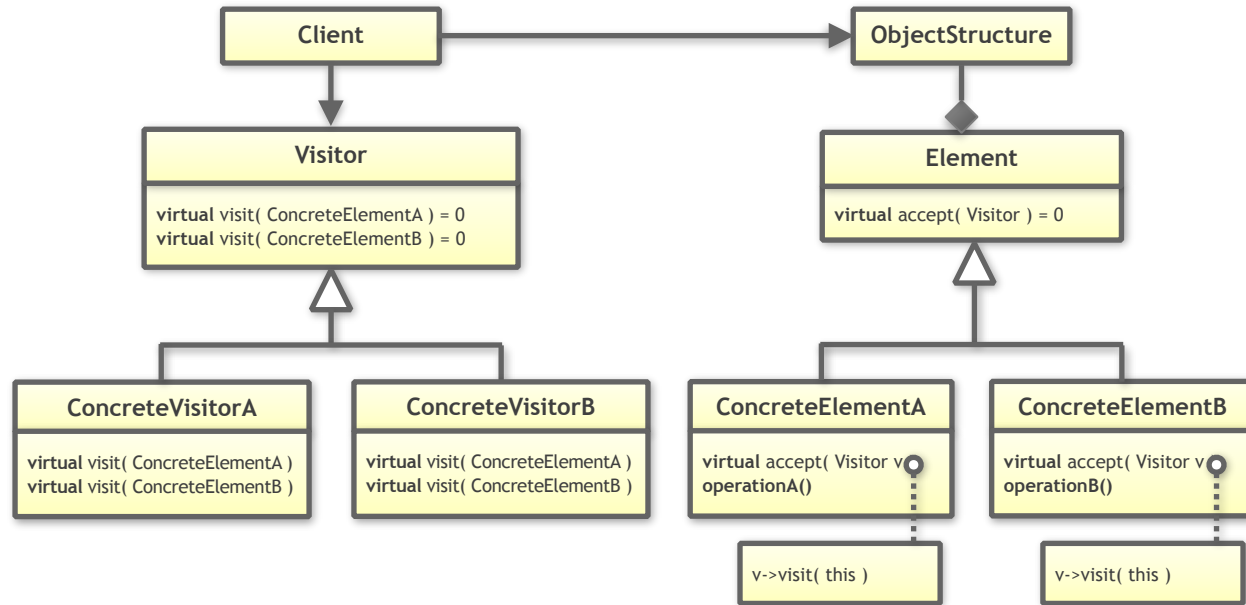
3. Design Pattern Cheat Sheet

Name: **Visitor**

Origin: GoF
Year: 1994

Intent: Represent an operation to be performed of the elements of an object structure. Visitor lets you define a new operation without changing the classes of the elements on which it operates.

Structure:



Advantages/Strengths:

- Easy addition of new operations
- Modern form (std::variant) is non-intrusive

Disadvantages/Weaknesses:

- Difficult addition of new types
- Classic form is intrusive (due to the `accept()` function)

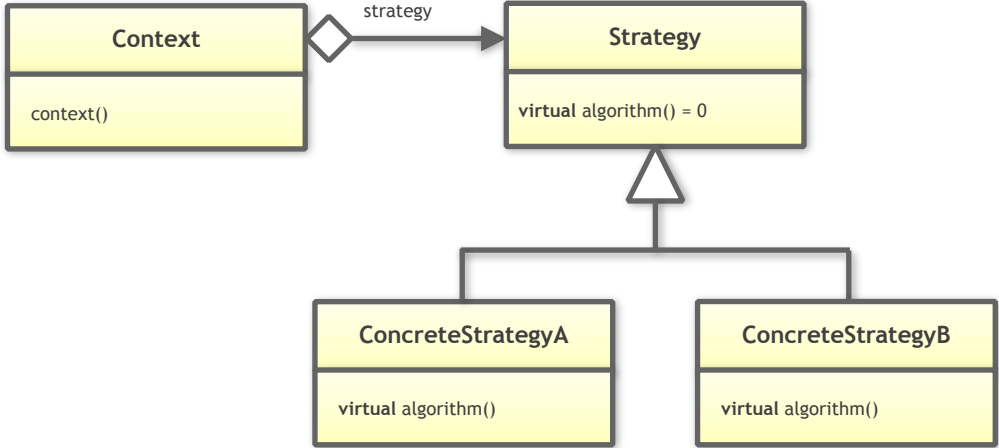
Relation to other design patterns:

- External Polymorphism:** Both separate operations from types, but Visitor enables the addition of operations.

Implementation notes:

- Often implemented by means of `std::variant` (C++17).

3. Design Pattern Cheat Sheet

Name: Strategy		Origin: GoF Year: 1994
Intent: Define a family of algorithms, encapsulate each one, and make them interchangeable. Strategy lets the algorithm vary independently from clients that use it.		
Structure:  <pre>classDiagram class Context { context() } class Strategy { <<abstract>> virtual algorithm() = 0 } class ConcreteStrategyA { virtual algorithm() } class ConcreteStrategyB { virtual algorithm() } Context "1" *-- ">" Strategy : strategy Strategy < -- ConcreteStrategyA Strategy < -- ConcreteStrategyB</pre>		
Advantages/Strengths: <ul style="list-style-type: none">Logical decoupling of interface and implementation details		Disadvantages/Weaknesses: <ul style="list-style-type: none">Intrusive (because of dependency injection)Proliferation of different abstractions for different strategies
Relation to other design patterns: <ul style="list-style-type: none">Command: Structurally identical to Strategy, but specifies WHAT should be done, instead of HOW.Bridge: Structurally identical to Strategy, but used only inside a class to switch between possible implementations.State: Structurally identical to Strategy, but used only internally to switch behavior based on some input.		
Implementation notes: <ul style="list-style-type: none">Can be implemented by means of <code>std::function</code> (C++11), which enables value semantics.		

3. Design Pattern Cheat Sheet

Name: Command		Origin: GoF Year: 1994
Intent: Encapsulate a request as an object, thereby letting you parameterise clients with different requests, queue or log requests, and support undoable operations.		
Structure: 		
Advantages/Strengths: <ul style="list-style-type: none">💡 Logical decoupling of interface and implementation details💡 Non-intrusive design pattern		Disadvantages/Weaknesses: <ul style="list-style-type: none">💡 —
Relation to other design patterns: <ul style="list-style-type: none">💡 Strategy: Structurally identical to Command, but specifies HOW should be done, instead of WHAT.💡 Bridge: Structurally identical to Command, but used only inside a class to switch between possible implementations.💡 State: Structurally identical to Command, but used only internally to switch behavior based on some input.		
Implementation notes: <ul style="list-style-type: none">💡 Can be implemented by means of std::function (C++11), which enables value semantics.		

3. Design Pattern Cheat Sheet

Name: State		Origin: GoF Year: 1994
Intent: Allow an object to alter its behavior when its internal state changes. The object will appear to change its class.		
Structure: <pre>classDiagram class Context { request() } class State { <<abstract>> virtual handle() = 0 } class ConcreteStateA { virtual handle() } class ConcreteStateB { virtual handle() } Context o--> State : state State < -- ConcreteStateA State < -- ConcreteStateB</pre>		
Advantages/Strengths: <ul style="list-style-type: none">Structured representation of state machines		Disadvantages/Weaknesses: <ul style="list-style-type: none">Strong coupling between states and transitionsIntrusive design pattern (i.e. usually requires changes when new states/transitions are introduced).
Relation to other design patterns: <ul style="list-style-type: none">Strategy: Structurally identical to State, but exposed to clients (dependency injection).Command: Structurally identical to State, but used externally to encapsulate operations.Bridge: Structurally identical to State, but used only inside a class to switch between possible implementations.		
Implementation notes: <ul style="list-style-type: none">Can be implemented by means of <code>std::variant</code> (C++17), which enables a similar separation of concerns and value semantics.		

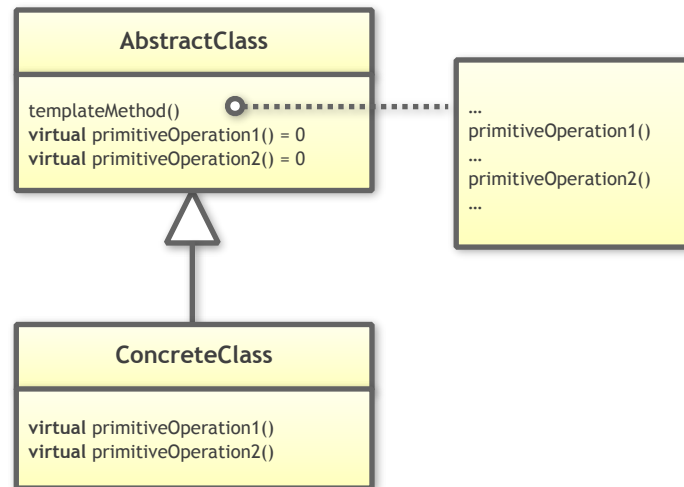
3. Design Pattern Cheat Sheet

Name: Template Method

Origin: GoF
Year: 1994

Intent: Define the skeleton of an algorithm in an operation, deferring some steps to subclasses. Template Method lets subclasses redefine certain steps of an algorithm, without changing the algorithms structure.

Structure:



Advantages/Strengths:

- Separation of interface and implementation details

Disadvantages/Weaknesses:

- —

Relation to other design patterns:

- —

Implementation notes:

- Template Method is the basis for the Non-Virtual Interface Idiom (NVI).

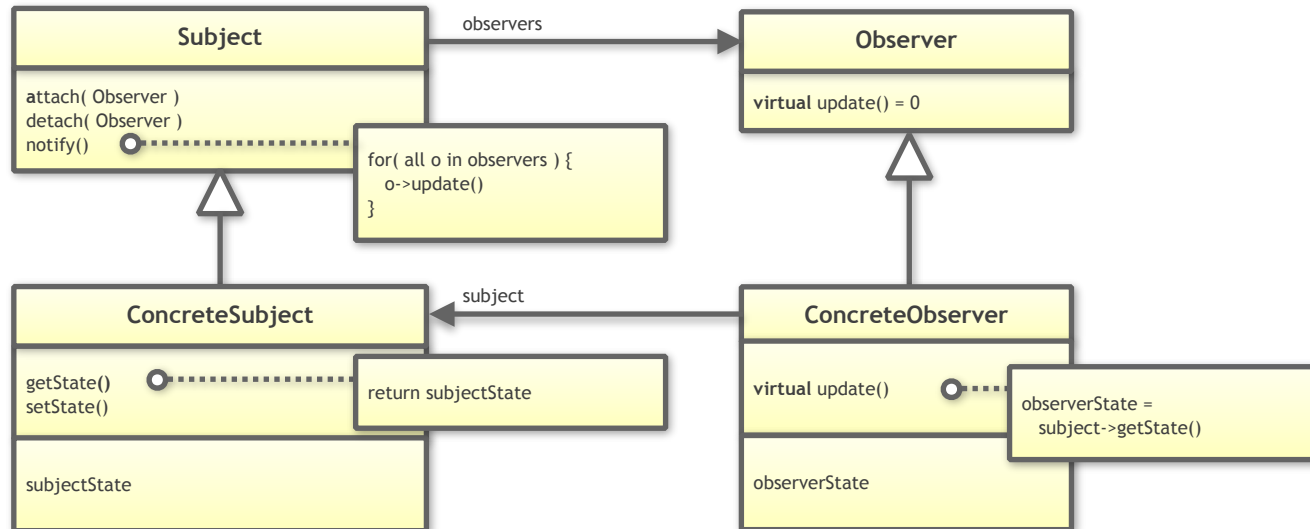
3. Design Pattern Cheat Sheet

Name: Observer

Origin: GoF
Year: 1994

Intent: Define a one-to-many dependency between objects so that when one object changes state, all its dependents are notified and updated automatically.

Structure:



Advantages/Strengths:

- 💡 Separation of interface and implementation details

Disadvantages/Weaknesses:

- 💡 Intrusive design pattern

Relation to other design patterns:

💡 —

Implementation notes:

- 💡 Can be implemented by means of `std::function` (C++11), which enables value semantics.
- 💡 Can be implemented as push or pull observer

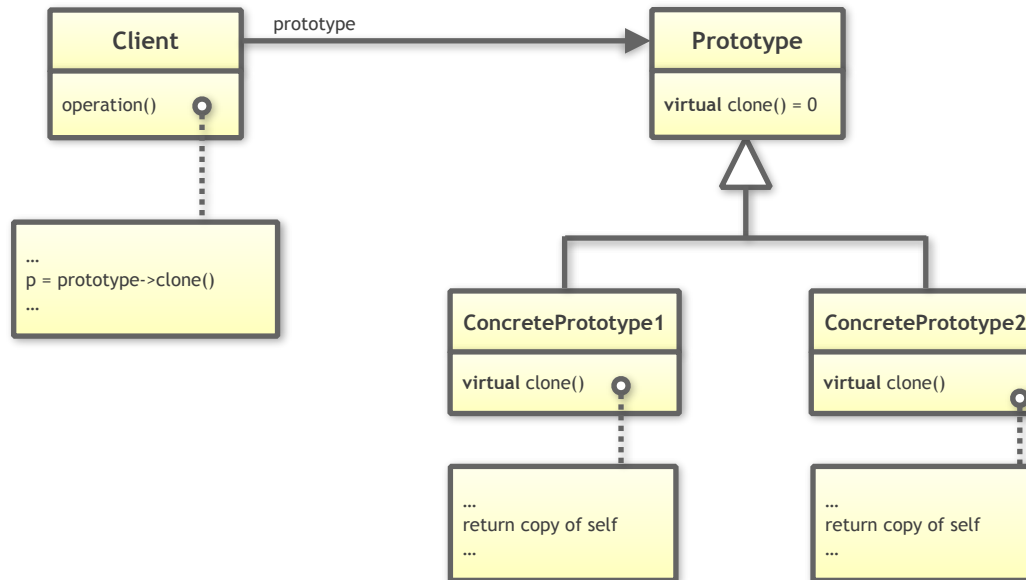
3. Design Pattern Cheat Sheet

Name: Prototype

Origin: GoF
Year: 1994

Intent: Specify the kind of objects to create using a prototypical instance, and create new objects by copying this prototype.

Structure:



Advantages/Strengths:

💡 THE solution for virtual copying (`clone()`) acts like a keyword

Disadvantages/Weaknesses:

💡 Only applicable in an **OOP setting** with inheritance hierarchies
💡 **Intrusive** design pattern

Relation to other design patterns:

💡 —

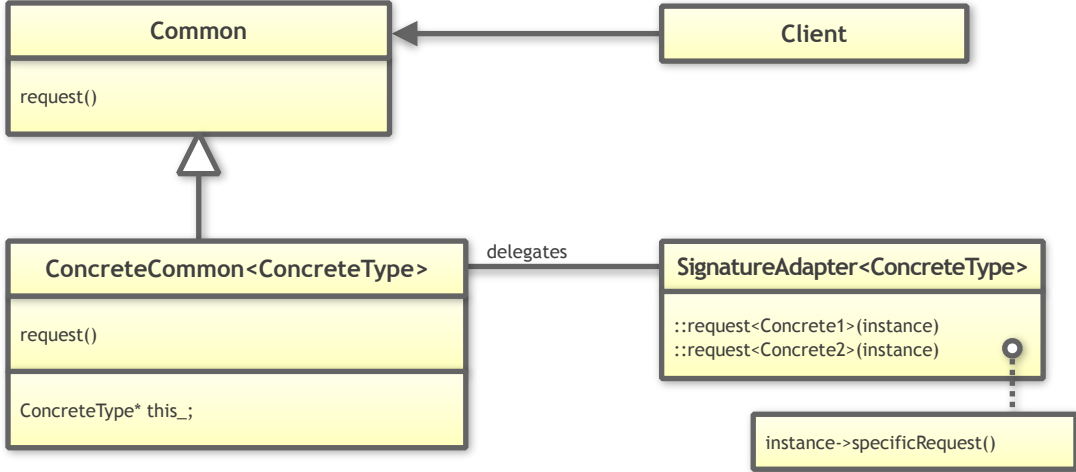
Implementation notes:

💡 There is no new (modern) implementation. Therefore the function name `clone()` is very strongly attached to this design pattern.

3. Design Pattern Cheat Sheet

Name: <i>Bridge</i>		Origin: GoF Year: 1994
Intent: Decouple an abstraction from its implementation so that the two can vary independently.		
Structure: <pre>classDiagram class Abstraction { operation() } class Implementor { virtual operation() = 0 } class ConcreteImplA { virtual operation() } class ConcreteImplB { virtual operation() } Abstraction o--> Implementor : impl Implementor < -- ConcreteImplA Implementor < -- ConcreteImplB</pre>		
Advantages/Strengths: <ul style="list-style-type: none">💡 Strong decoupling of physical dependencies		Disadvantages/Weaknesses: <ul style="list-style-type: none">💡 Introduces a performance penalty
Relation to other design patterns: <ul style="list-style-type: none">💡 Strategy: Structurally identical to Bridge, but exposed to clients (dependency injection).💡 Command: Structurally identical to Bridge, but used externally to encapsulate operations.💡 State: Structurally identical to Bridge, but used only internally to switch behavior based on some input.		
Implementation notes: <ul style="list-style-type: none">💡 As an alternative to the dynamic memory, it is possible to implement a Bridge by means of Small-Buffer-Optimization (see Fast Pimpl).💡 In case a <code>std::unique_ptr</code> is used, the destructor of the <code>Implementor</code> class still needs to be defined in the source file.		

3. Design Pattern Cheat Sheet

Name: External Polymorphism	Origin: “External Polymorphism” by Cleeland, Schmidt and Harrison Year: 1996
Intent: Convert the interface of a class into another interface clients expect. Adapter lets classes work together that couldn't otherwise because of incompatible interfaces.	
Structure:  <pre>graph TD Client --> Common class Common { request() } class ConcreteCommon["ConcreteCommon<ConcreteType>"] { request() ConcreteType* this_ } class SignatureAdapter["SignatureAdapter<ConcreteType>"] { requestConcrete1(instance) requestConcrete2(instance) } class ConcreteTypeInstance["instance->specificRequest()"] ConcreteCommon -- > Common ConcreteCommon -- delegates --> SignatureAdapter SignatureAdapter -.-> ConcreteTypeInstance</pre> <p>The diagram illustrates the structure of External Polymorphism. It features a Common interface with a <code>request()</code> method. A Client depends on the Common interface. ConcreteCommon<ConcreteType> is a concrete implementation that inherits from Common and implements the <code>request()</code> method. It holds a reference to a ConcreteType object (<code>ConcreteType* this_;</code>). SignatureAdapter<ConcreteType> is an adapter class that implements the <code>request()</code> method by delegating the call to <code>instance->specificRequest()</code>. The adapter class has two methods: <code>::request<Concrete1>(instance)</code> and <code>::request<Concrete2>(instance)</code>. A dashed line indicates the delegation from the adapter to the <code>instance->specificRequest()</code> method.</p>	
Advantages/Strengths: <ul style="list-style-type: none">Very strong decoupling of types and operationsEasy to add new typesNon-intrusive design pattern	Disadvantages/Weaknesses: <ul style="list-style-type: none">Difficult to introduce new operations
Relation to other design patterns: <ul style="list-style-type: none">Adapter: Adapter is based on an existing inheritance hierarchy, while External Polymorphism introduces a new hierarchy.	
Implementation notes: <ul style="list-style-type: none">Possible optimizations: Small Buffer Optimization (SBO), manual virtual function tables,	

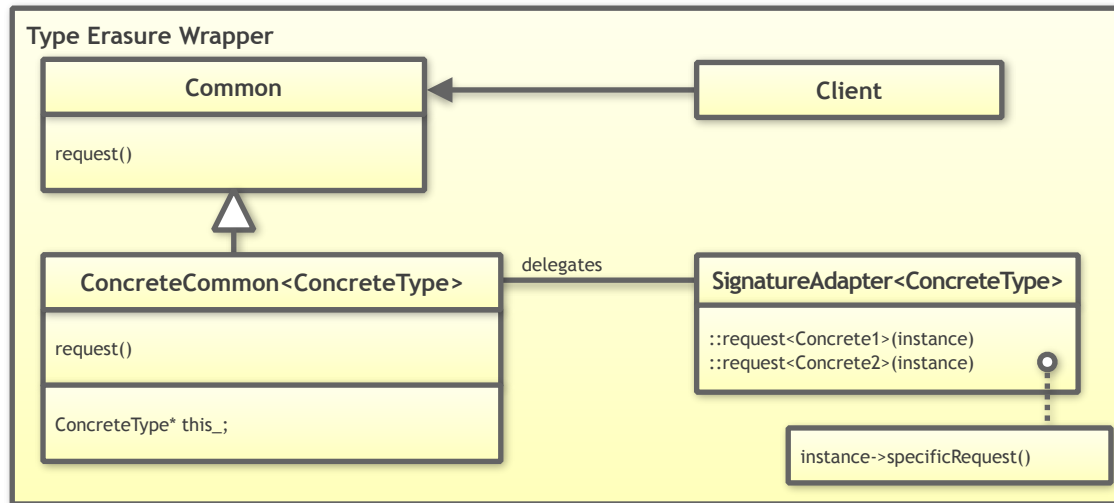
3. Design Pattern Cheat Sheet

Name: Type Erasure

Origin: “Valued Conversions” by Kevin Henney
Year: 2000

Intent: Provide a value-based, non-intrusive abstraction for an extendable set of unrelated, potentially non-polymorphic types with the same semantic behavior.

Structure:



Advantages/Strengths:

- Very strong decoupling of types and operations
- Easy to add new types
- Non-intrusive** design pattern
- Value Semantics**

Disadvantages/Weaknesses:

- Difficult to introduce new operations
- Somewhat tricky implementation details

Relation to other design patterns:

- External Polymorphism:** Type Erasure is the value semantics based solution of External Polymorphism.
- Bridge:** Type Erasure implements a bridge to the private implementation details

Implementation notes:

- Possible optimizations: Small Buffer Optimization (SBO), manual virtual function tables,
- Type Erasure is a **non-intrusive** design pattern.

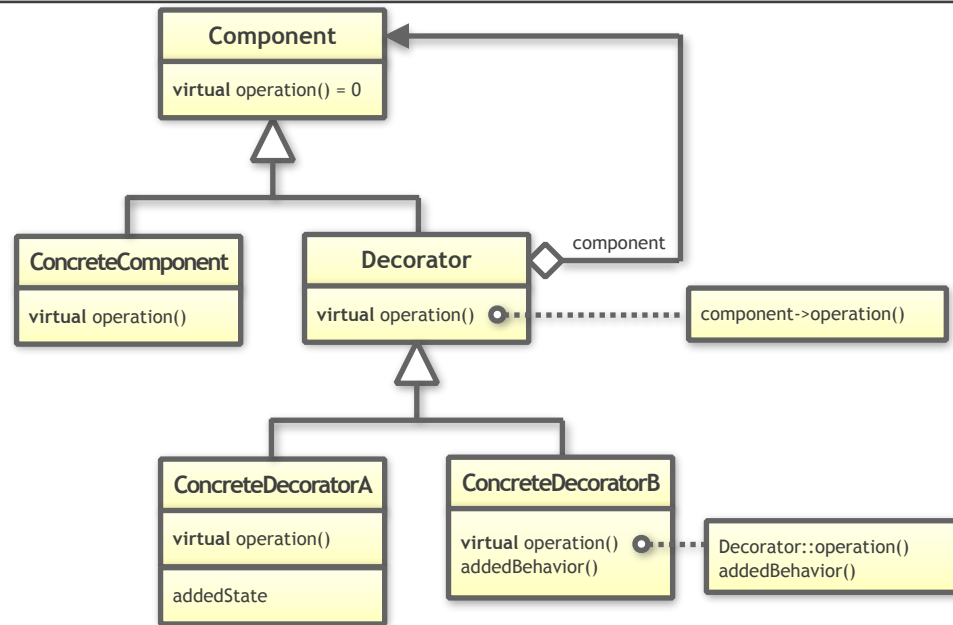
3. Design Pattern Cheat Sheet

Name: Decorator

Origin: GoF
Year: 1994

Intent: Attach additional responsibilities to an object dynamically. Decorators provide a flexible alternative to subclassing for extending functionality.

Structure:



Advantages/Strengths:

- Non-intrusive addition of behavior for existing types

Disadvantages/Weaknesses:

- Difficult to introduce new functions

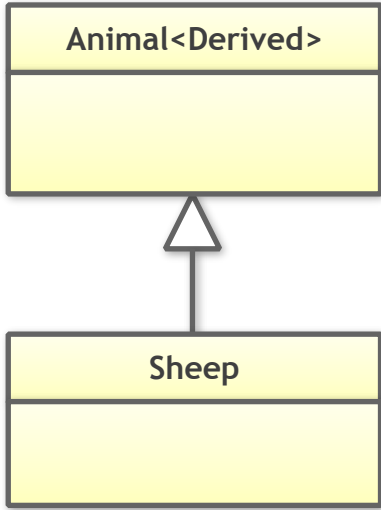
Relation to other design patterns:

- Strategy:** Strategy is focused on extracting some implementation detail, Decorator is extending the functionality.
- Adapter:** Adapter changes an interface, Decorator preserves it.

Implementation notes:

- Can be implemented by means of an inheritance hierarchy, with Type Erasure, or as template.

3. Design Pattern Cheat Sheet

Name: C RTP		Origin: “Curiously Recurring Template Patterns”, James Copley Year: 1995
Intent: Define a compile-time abstraction for a family of related types.		
Structure:  <pre>classDiagram class AnimalDerived["Animal<Derived>"] class Sheep Sheep -- > AnimalDerived</pre>		
Advantages/Strengths: <ul style="list-style-type: none">💡 Suited for maximum performance, no runtime overhead		Disadvantages/Weaknesses: <ul style="list-style-type: none">💡 Loss of a common base class💡 Template-heavy
Relation to other design patterns: <ul style="list-style-type: none">💡 Expression Templates: Combines very well with the intention of Expression Templates.		
Implementation notes: <ul style="list-style-type: none">💡 Can be implemented by means of an inheritance hierarchy, with Type Erasure, or as template.💡 CRTP is an intrusive design pattern.		

3. Design Pattern Cheat Sheet

Name: Expression Templates	Origin: “Expression Templates”, Todd Veldhuizen Year: 1995
Intent: Introduce lazy evaluation for expressions.	
Structure: <pre>classDiagram class Expression["Expression<Operand1, Operand2>"] { commonInterface1() commonInterface2() } class Operand1 { commonInterface1() commonInterface2() } class Operand2 { commonInterface1() commonInterface2() } Expression --> Operand1 : delegates Expression --> Operand2 : delegates</pre>	
Advantages/Strengths: <ul style="list-style-type: none">💡 Suited for maximum performance, no runtime overhead	Disadvantages/Weaknesses: <ul style="list-style-type: none">💡 Template-heavy
Relation to other design patterns: <ul style="list-style-type: none">💡 Decorator: Expressions templates are based on the Decorator design pattern.	
Implementation notes: <ul style="list-style-type: none">💡 Expression Templates is a non-intrusive design pattern.	

3. Design Pattern Cheat Sheet

Name: Adapter	Origin: GoF Year: 1994
Intent: Convert the interface of a class into another interface clients expect. Adapter lets classes work together that couldn't otherwise because of incompatible interfaces.	
Structure: <pre>classDiagram class DrawingEditor class Shape { virtual BondingBox() virtual CreateManipulator() } class Line { virtual BondingBox() virtual CreateManipulator() } class TextShape { virtual BondingBox() virtual CreateManipulator() } class TextView { GetExtent() } DrawingEditor --> Shape Shape < -- Line Shape < -- TextShape TextShape --> TextView TextShape ..> TextView : return text->getExtent() TextShape ..> TextManipulator : return new TextManipulator</pre>	
Advantages/Strengths: <ul style="list-style-type: none">💡 Non-intrusive design pattern💡 Applicable for both classes and functions	Disadvantages/Weaknesses: <ul style="list-style-type: none">💡 —
Relation to other design patterns: <ul style="list-style-type: none">💡 External Polymorphism: EP creates a new inheritance hierarchy, while Adapter is based on an existing hierarchy.💡 Decorator: Decorator preserves an interface and adds behavior, while Adapter changes an interface and does not add behavior	
Implementation notes: <ul style="list-style-type: none">💡 Next to the classical inheritance-based implementation, adapters can be templates (e.g. <code>std::stack</code> and <code>std::queue</code>) and simple functions (shims; e.g. <code>std::begin()</code>).	

3. Design Pattern Cheat Sheet

Name: Proxy		Origin: GoF Year: 1994
Intent: Provide a surrogate or placeholder for another object to control access to it.		
Structure: <pre>classDiagram class Graphic { <<abstract>> virtual Draw() virtual GetExtent() virtual Store() virtual Load() } class Image { virtual Draw() virtual GetExtent() virtual Store() virtual Load() imageImp extent } class ImageProxy { virtual Draw() virtual GetExtent() virtual Store() virtual Load() fileName extent } Graphic < -- Image Graphic < -- ImageProxy ImageProxy ..> Image : if(image == 0) ImageProxy ..> Image : image = LoadImage(fileName); ImageProxy ..> Image : image->Draw(); ImageProxy ..> Image : if(image == 0) ImageProxy ..> Image : return extent; ImageProxy ..> Image : else ImageProxy ..> Image : return image->GetExtent();</pre>		
Advantages/Strengths: <ul style="list-style-type: none">Non-intrusive design patternUsually invisible to the caller.		Disadvantages/Weaknesses: <ul style="list-style-type: none">—
Relation to other design patterns: <ul style="list-style-type: none">Adapter: Proxy is focused on managing access, while Adapter is focused on changing an interfaceDecorator: Decorators can be combined hierarchically, Proxies cannot		
Implementation notes: <ul style="list-style-type: none">Can appear in a class hierarchy, but also in the context of templates (e.g. <code>std::vector<bool></code> or <code>std::bitset<N>::operator[]</code>)		

3. Design Pattern Cheat Sheet

Name: Factory Method		Origin: GoF Year: 1994
Intent: Define an interface for creating an object, but let subclasses decide which class to instantiate. Factory Method lets a class defer instantiation to subclasses.		
Structure: <pre>classDiagram class Product { <<abstract>> virtual factoryMethod() = 0 } class ConcreteProduct class Creator { <<abstract>> virtual factoryMethod() } class ConcreteCreator { virtual factoryMethod() } Product < -- ConcreteProduct Creator < -- ConcreteCreator ConcreteCreator ..> ConcreteProduct</pre>		
Advantages/Strengths: 💡 Logical decoupling of interface and implementation details		Disadvantages/Weaknesses: 💡 Intrusive (because of dependency injection)
Relation to other design patterns: 💡 Strategy: Factory Method is very similar to Strategy, but focused on creating something (possibly introducing a second abstraction)		
Implementation notes: 💡 New products should not be returned by raw pointer, but by <code>std::unique_ptr</code> , Type Erasure, or <code>std::variant</code> . 💡 A simple function creating something is often called a “factory function”, which has nothing to do with this design pattern.		

3. Design Pattern Cheat Sheet

Name: Builder		Origin: GoF Year: 1994
Intent: Separate the construction of a complex object from its representation so that the same construction process can create different representations.		
Structure: <pre>classDiagram class Director { +construct() } class Builder { +virtual buildPart() = 0 } class ConcreteBuilder { +virtual buildPart() getResult() } Director o-- Builder : impl Builder < -- ConcreteBuilder Director ..> : for all objects in structure { builder->buildPart() }</pre>		
Advantages/Strengths: <ul style="list-style-type: none">Logical separation of the steps of a build process		Disadvantages/Weaknesses: <ul style="list-style-type: none">Usually intrusive (because of dependency injection)
Relation to other design patterns: <ul style="list-style-type: none">Factory Method: Builder is usually composed of several Factory Methods		
Implementation notes: <ul style="list-style-type: none">New products should not be returned by raw pointer, but by <code>std::unique_ptr</code>, Type Erasure, or <code>std::variant</code>.		

3. Design Pattern Cheat Sheet

Name: Iterator		Origin: GoF Year: 1994
Intent: Provide a way to access the elements of an aggregate object sequentially without exposing its underlying representation.		
Structure: <pre>classDiagram class Aggregate { +createliterator() } class ConcreteAggregate { +createliterator() } class Iterator { +virtual first() = 0 +virtual next() = 0 +virtual isDone() = 0 +virtual currentItem() = 0 } class ConcreteIterator { } class Client { } Aggregate < -- ConcreteAggregate Iterator < -- ConcreteIterator Client --> Aggregate Client --> Iterator ConcreteAggregate ..> ConcreteIterator</pre>		
Advantages/Strengths: <ul style="list-style-type: none">💡 Very idiomatic in C++ due to the STL		Disadvantages/Weaknesses: <ul style="list-style-type: none">💡 Separation in three steps (increment, compare, access) opens the possibility of access violations
Relation to other design patterns: <ul style="list-style-type: none">💡 —		
Implementation notes: <ul style="list-style-type: none">💡 In C++, it is very unusual to implement this pattern in the form of an inheritance hierarchy.💡 A Type Erasure implementation of Iterator would have to build on the GoF form because of the inequality comparison of iterators.		

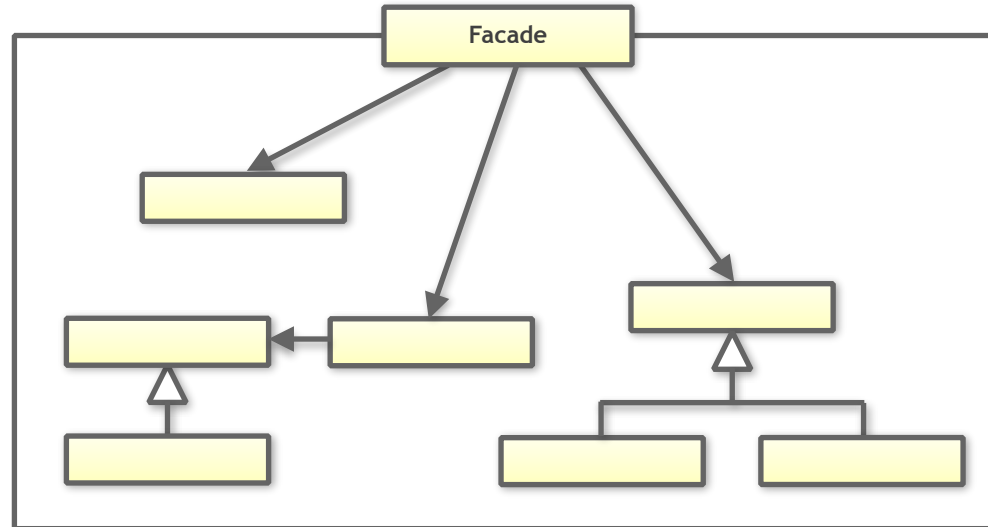
3. Design Pattern Cheat Sheet

Name: Facade

Origin: GoF
Year: 1994

Intent: Provide a unified interface to a set of interfaces in a subsystem. Facade defines a higher-level interface that makes the subsystem easier to use.

Structure:



Advantages/Strengths:

- Great simplification of complexity
- Non-intrusive design pattern

Disadvantages/Weaknesses:

-

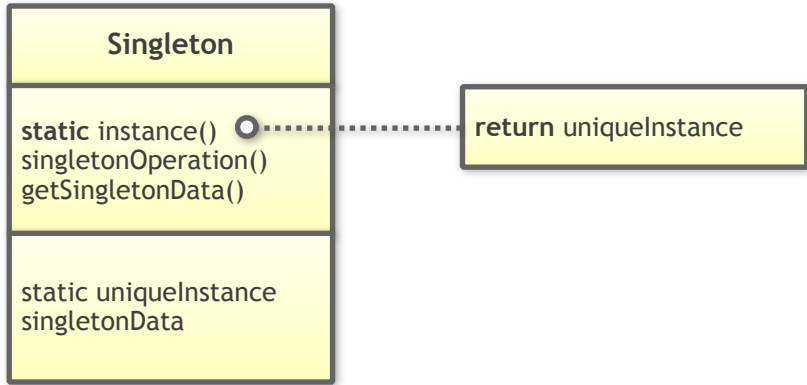
Relation to other design patterns:

-

Implementation notes:

- Can be a class (not necessarily a base class) or function.

3. Design Pattern Cheat Sheet

Name: Singleton		Origin: GoF Year: 1994
Intent: Ensure a class only has one instance, and provide a global point of access to it.		
Structure: 		
Advantages/Strengths: 💡 —		Disadvantages/Weaknesses: 💡 Destroys design/architecture due to lack of dependency management 💡 Provides the characteristics of a global variable/constant
Relation to other design patterns: 💡 —		
Implementation notes: 💡 Singleton is not a design pattern, as it doesn't provide any abstraction or dependency reduction. It is an implementation pattern.		

email: klaus.iglberger@gmx.de

LinkedIn: [linkedin.com/in/klaus-iglberger](https://www.linkedin.com/in/klaus-iglberger)

Xing: [xing.com/profile/Klaus_Iglberger/cv](https://www.xing.com/profile/Klaus_Iglberger/cv)