

C++ Programming: Code patterns design

Programming Patterns

Software design patterns are abstractions that help structure system designs. While not new, since the concept was already described by [Christopher Alexander](#) in its architectural theories, it only gathered some traction in programming due to the publication of [Design Patterns: Elements of Reusable Object-Oriented Software](#) book in October 1994 by [Erich Gamma](#), [Richard Helm](#), [Ralph Johnson](#) and [John Vlissides](#), known as the **Gang of Four (GoF)**, that identifies and describes 23 classic software design patterns.

A design pattern is neither a static solution, nor is it an algorithm. A **pattern** is a way to describe and address by name a repeatable solution or approach to a common design problem, that is, a common way to solve a generic problem (how generic or specific the pattern is depends on how restricted the target goal is). Patterns can emerge on their own or by design. This is why design patterns are useful as an abstraction over the implementation and a help at design stage. With this concept, an easier way to facilitate communication over a design choice as normalization technique is given so that every person can share the design concept.

Depending on the design problem they address, design patterns can be classified in different categories, of which the main categories are:

- [Creational Patterns](#)
- [Structural Patterns](#)
- [Behavioral Patterns](#).

Patterns are commonly found in object-oriented programming languages like C++ or Java. They can be seen as a template for how to solve a problem that occurs in many different situations or applications. It is not code reuse, as it usually does not specify code, but code can be easily created from a design pattern. Object-oriented design patterns typically show relationships and interactions between classes or objects without specifying the final application classes or objects that are involved.

Each design pattern consists of the following parts:

Problem/requirement

To use a design pattern, we need to go through a mini analysis design that may be coded to test out the solution. This section states the requirements of the problem we want to solve. This is usually a common problem that will occur in more than one application.

Forces

This section states the technological boundaries, that helps and guides the creation of the solution.

Solution

This section describes how to write the code to solve the above problem. This is the design part of the design pattern. It may contain class diagrams, sequence diagrams, and or whatever is needed to describe how to code the solution.

Design patterns can be considered as a standardization of commonly agreed best practices to solve specific design problems. One should understand them as a way to implement good design patterns within applications. Doing so will reduce the use of inefficient and obscure solutions. Using design patterns speeds up your design and helps to communicate it to other programmers.

Creational Patterns

In software engineering, **creational design patterns** are design patterns that deal with object creation mechanisms, trying to create objects in a manner suitable to the situation. The basic form of object creation could result in design problems or added complexity to the design. Creational design patterns solve this problem by somehow controlling this object creation.

In this section of the book we assume that the reader has enough familiarity with functions, global variables, stack vs. heap, classes, pointers, and static member functions as introduced before.

As we will see there are several creational design patterns, and all will deal with a specific implementation task, that will create a higher level of abstraction to the code base, we will now cover each one.

Builder

The Builder Creational Pattern is used to separate the construction of a complex object from its representation so that the same construction process can create different objects representations.

Problem

We want to construct a complex object, however we do not want to have a complex constructor member or one that would need many arguments.

Solution

Define an intermediate object whose member functions define the desired object part by part before the object is available to the client. Builder Pattern lets us defer the construction of the object until all the options for creation have been specified.

```
#include <string>
#include <iostream>
#include <memory>
using namespace std;

// "Product"
class Pizza
{
public:
    void setDough(const string& dough)
    {
        m_dough = dough;
    }
    void setSauce(const string& sauce)
    {
        m_sauce = sauce;
    }
    void setTopping(const string& topping)
    {
        m_topping = topping;
    }
    void open() const
    {
        cout << "Pizza with " << m_dough << " dough, " << m_sauce << " sauce and "
              << m_topping << " topping. Mmm." << endl;
    }
private:
    string m_dough;
    string m_sauce;
    string m_topping;
};

// "Abstract Builder"
class PizzaBuilder
{
public:
    virtual ~PizzaBuilder() {};

    Pizza* getPizza()
```

```

    {
        return m_pizza.release();
    }
    void createNewPizzaProduct()
    {
        m_pizza = make_unique<Pizza>();
    }
    virtual void buildDough() = 0;
    virtual void buildSauce() = 0;
    virtual void buildTopping() = 0;
protected:
    unique_ptr<Pizza> m_pizza;
};

//-----

class HawaiianPizzaBuilder : public PizzaBuilder
{
public:
    virtual ~HawaiianPizzaBuilder() {};

    virtual void buildDough()
    {
        m_pizza->setDough("cross");
    }
    virtual void buildSauce()
    {
        m_pizza->setSauce("mild");
    }
    virtual void buildTopping()
    {
        m_pizza->setTopping("ham+pineapple");
    }
};

class SpicyPizzaBuilder : public PizzaBuilder
{
public:
    virtual ~SpicyPizzaBuilder() {};

    virtual void buildDough()
    {
        m_pizza->setDough("pan baked");
    }
    virtual void buildSauce()
    {
        m_pizza->setSauce("hot");
    }
    virtual void buildTopping()
    {
        m_pizza->setTopping("pepperoni+salami");
    }
};

//-----

class Cook
{
public:
    void openPizza()
    {
        m_pizzaBuilder->getPizza()->open();
    }
    void makePizza(PizzaBuilder* pb)
    {
        m_pizzaBuilder = pb;
        m_pizzaBuilder->createNewPizzaProduct();
        m_pizzaBuilder->buildDough();
        m_pizzaBuilder->buildSauce();
        m_pizzaBuilder->buildTopping();
    }
private:
    PizzaBuilder* m_pizzaBuilder;
};

```

```
int main()
{
    Cook cook;
    HawaiianPizzaBuilder hawaiianPizzaBuilder;
    SpicyPizzaBuilder    spicyPizzaBuilder;

    cook.makePizza(&hawaiianPizzaBuilder);
    cook.openPizza();

    cook.makePizza(&spicyPizzaBuilder);
    cook.openPizza();
}
```

You can also use the latest version c++17 standard

```
#include <iostream>
#include <memory>
class Pizza{
public:
    void setDough(const std::string& dough){
        m_dough = dough;
    }
    void setSauce(const std::string& sauce){
        m_sauce = sauce;
    }
    void setTopping(const std::string& topping){
        m_topping = topping;
    }
    void open() const {
        std::cout<<"The Pizza have "<<
            m_dough<<" dough, "<<
            m_sauce<<" sauce, "<<
            m_topping<<" topping."<<
            std::endl;
    }
private:
    std::string m_dough;
    std::string m_sauce;
    std::string m_topping;
};

class PizzaBuilder{
public:
    virtual ~PizzaBuilder() = default;
    void createNewPizza(){
        m_pizza = std::make_unique<Pizza>();
    }
    Pizza* getPizza() {
        return m_pizza.release();
    }
    virtual void buildDough() = 0;
    virtual void buildSauce() = 0;
    virtual void buildTopping() = 0;
protected:
    std::unique_ptr<Pizza> m_pizza;
};

class HawaiianPizzaBuilder:public PizzaBuilder{
public:
    ~HawaiianPizzaBuilder() override = default;
    void buildDough() override {
        m_pizza->setDough("Hawaiian dough");
    }
    void buildSauce() override {
        m_pizza->setSauce("Hawaiian sauce");
    }
    void buildTopping() override {
        m_pizza->setTopping("Hawaiian topping");
    }
};

class SpicyPizzaBuilder:public PizzaBuilder{
public:
```

```

~SpicyPizzaBuilder() override = default;
void buildDough() override {
    m_pizza->setDough("Spicy dough");
}
void buildSauce() override {
    m_pizza->setSauce("Spicy sauce");
}
void buildTopping() override {
    m_pizza->setTopping("Spicy topping");
}
};

class Cook{
public:
    void openPizza() const {
        m_pizzaBuilder->getPizza()->open();
    }
    void createPizza(PizzaBuilder* pizzaBuilder){
        m_pizzaBuilder = pizzaBuilder;
        m_pizzaBuilder->createNewPizza();
        m_pizzaBuilder->buildDough();
        m_pizzaBuilder->buildSauce();
        m_pizzaBuilder->buildTopping();
    }
private:
    PizzaBuilder* m_pizzaBuilder;
};

int main(){
    Cook cook{};
    HawaiianPizzaBuilder hawaiianPizzaBuilder;
    cook.createPizza(&hawaiianPizzaBuilder);
    cook.openPizza();

    SpicyPizzaBuilder spicyPizzaBuilder;
    cook.createPizza(&spicyPizzaBuilder);
    cook.openPizza();
}
//console output
//The Pizza have Hawaiian dough dough, Hawaiian sauce sauce, Hawaiian topping topping.
//The Pizza have Spicy dough dough, Spicy sauce sauce, Spicy topping topping.

```

Factory

Definition: A utility class that creates an instance of a class from a family of derived classes

Abstract Factory

Definition: A utility class that creates an instance of several families of classes. It can also return a factory for a certain group.

The Factory Design Pattern is useful in a situation that requires the creation of many different types of objects, all derived from a common base type. The Factory Method defines a method for creating the objects, which subclasses can then override to specify the derived type that will be created. Thus, at run time, the Factory Method can be passed a description of a desired object (e.g., a string read from user input) and return a base class pointer to a new instance of that object. The pattern works best when a well-designed interface is used for the base class, so there is no need to cast the returned object.

Problem

We want to decide at run time what object is to be created based on some configuration or application parameter. When we write the code, we do not know what class should be instantiated.

Solution

Define an interface for creating an object, but let subclasses decide which class to instantiate. Factory Method lets a class defer instantiation to subclasses.

In the following example, a factory method is used to create laptop or desktop computer objects at run time.

Let's start by defining `Computer`, which is an abstract base class (interface) and its derived classes: `Laptop` and `Desktop`.

```
class Computer
{
public:
    virtual void Run() = 0;
    virtual void Stop() = 0;

    virtual ~Computer() {}; /* without this, you do not call Laptop or Desktop destructor in this example! */
};

class Laptop: public Computer
{
public:
    void Run() override {mHibernating = false;};
    void Stop() override {mHibernating = true;};
    virtual ~Laptop() {}; /* because we have virtual functions, we need virtual destructor */
private:
    bool mHibernating; // Whether or not the machine is hibernating
};

class Desktop: public Computer
{
public:
    void Run() override {mOn = true;};
    void Stop() override {mOn = false;};
    virtual ~Desktop() {};
private:
    bool mOn; // Whether or not the machine has been turned on
};
```

The actual `ComputerFactory` class returns a `Computer`, given a real world description of the object.

```
class ComputerFactory
{
public:
    static Computer *NewComputer(const std::string &description)
    {
        if(description == "laptop")
            return new Laptop;
        if(description == "desktop")
            return new Desktop;
        return nullptr;
    }
};
```

Let's analyze the benefits of this design. First, there is a compilation benefit. If we move the interface `Computer` into a separate header file with the factory, we can then move the implementation of the `NewComputer()` function into a separate implementation file. Now the implementation file for `NewComputer()` is the only one that requires knowledge of the derived classes. Thus, if a change is made to any derived class of `Computer`, or a new `Computer` subtype is added, the implementation file for `NewComputer()` is the only file that needs to be recompiled. Everyone who uses the factory will only care about the interface, which should remain consistent throughout the life of the application.

Also, if there is a need to add a class, and the user is requesting objects through a user interface, no code calling the factory may be required to change to support the additional computer type. The code using the factory would simply pass on the new string to the factory, and allow the factory to handle the new types entirely.

Imagine programming a video game, where you would like to add new types of enemies in the future, each of which has different AI functions and can update differently. By using a factory method, the controller of the program can call to the factory to create the enemies, without any dependency or knowledge of the actual types of enemies. Now, future developers can create new enemies, with new AI controls and new drawing member functions, add it to the factory, and create a level which calls the factory, asking for the enemies by name. Combine this method with an XML description of levels, and developers could create new levels without having to recompile their program. All this, thanks to the separation of creation of objects from the usage of objects.

Another example:

```
#include <stdexcept>
#include <iostream>
#include <memory>
using namespace std;

class Pizza {
public:
    virtual int getPrice() const = 0;
    virtual ~Pizza() {}; /* without this, no destructor for derived Pizza's will be called. */
};

class HamAndMushroomPizza : public Pizza {
public:
    virtual int getPrice() const { return 850; };
    virtual ~HamAndMushroomPizza() {};
};

class DeluxePizza : public Pizza {
public:
    virtual int getPrice() const { return 1050; };
    virtual ~DeluxePizza() {};
};

class HawaiianPizza : public Pizza {
public:
    virtual int getPrice() const { return 1150; };
    virtual ~HawaiianPizza() {};
};

class PizzaFactory {
public:
    enum PizzaType {
        HamMushroom,
        Deluxe,
        Hawaiian
    };

    static unique_ptr<Pizza> createPizza(PizzaType pizzaType) {
        switch (pizzaType) {
            case HamMushroom: return make_unique<HamAndMushroomPizza>();
            case Deluxe:      return make_unique<DeluxePizza>();
            case Hawaiian:    return make_unique<HawaiianPizza>();
        }
        throw "invalid pizza type.";
    }
};

/*
 * Create all available pizzas and print their prices
 */
void pizza_information(PizzaFactory::PizzaType pizzatype)
{
    unique_ptr<Pizza> pizza = PizzaFactory::createPizza(pizzatype);
    cout << "Price of " << pizzatype << " is " << pizza->getPrice() << std::endl;
}

int main()
{
    pizza_information(PizzaFactory::HamMushroom);
    pizza_information(PizzaFactory::Deluxe);
}
```

```

    pizza_information(PizzaFactory::Hawaiian);
}

```

Prototype

A prototype pattern is used in software development when the type of objects to create is determined by a prototypical instance, which is cloned to produce new objects. This pattern is used, for example, when the inherent cost of creating a new object in the standard way (e.g., using the `new` keyword) is prohibitively expensive for a given application.

Implementation: Declare an abstract base class that specifies a pure virtual `clone()` method. Any class that needs a "polymorphic constructor" capability derives itself from the abstract base class, and implements the `clone()` operation.

Here the client code first invokes the factory method. This factory method, depending on the parameter, finds out the concrete class. On this concrete class, the `clone()` method is called and the object is returned by the factory method.

- This is a sample implementation of Prototype method. We have the detailed description of all the components here.
 - Record class, which is a pure virtual class that has a pure virtual method `clone()`.
 - CarRecord, BikeRecord and PersonRecord as concrete implementation of a Record class.
 - An [enum](#) RecordType as one to one mapping of each concrete implementation of Record class.
 - RecordFactory class that has a Factory method `CreateRecord(...)`. This method requires an [enum](#) RecordType as parameter and depending on this parameter it returns the concrete implementation of Record class.

```

/** Implementation of Prototype Method */
#include <iostream>
#include <unordered_map>
#include <string>
#include <memory>
using namespace std;

/** Record is the base Prototype */
class Record
{
public:
    virtual ~Record() {}
    virtual void print() = 0;
    virtual unique_ptr<Record> clone() = 0;
};

/** CarRecord is a Concrete Prototype */
class CarRecord : public Record
{
private:
    string m_carName;
    int m_ID;

public:
    CarRecord(string carName, int ID) : m_carName(carName), m_ID(ID)
    {
    }

    void print() override
    {
        cout << "Car Record" << endl
              << "Name : " << m_carName << endl
              << "Number: " << m_ID << endl << endl;
    }

    unique_ptr<Record> clone() override
    {
        return make_unique<CarRecord>(*this);
    }
};

```



```

/** BikeRecord is the Concrete Prototype */
class BikeRecord : public Record
{
private:
    string m_bikeName;
    int m_ID;

public:
    BikeRecord(string bikeName, int ID) : m_bikeName(bikeName), m_ID(ID)
    {
    }

    void print() override
    {
        cout << "Bike Record" << endl
              << "Name  : " << m_bikeName << endl
              << "Number: " << m_ID << endl << endl;
    }

    unique_ptr<Record> clone() override
    {
        return make_unique<BikeRecord>(*this);
    }
};

/** PersonRecord is the Concrete Prototype */
class PersonRecord : public Record
{
private:
    string m_personName;
    int m_age;

public:
    PersonRecord(string personName, int age) : m_personName(personName), m_age(age)
    {
    }

    void print() override
    {
        cout << "Person Record" << endl
              << "Name  : " << m_personName << endl
              << "Age   : " << m_age << endl << endl;
    }

    unique_ptr<Record> clone() override
    {
        return make_unique<PersonRecord>(*this);
    }
};

/** Opaque record type, avoids exposing concrete implementations */
enum RecordType
{
    CAR,
    BIKE,
    PERSON
};

/** RecordFactory is the client */
class RecordFactory
{
private:
    unordered_map<RecordType, unique_ptr<Record>, hash<int>> m_records;

public:
    RecordFactory()
    {
        m_records[CAR]      = make_unique<CarRecord>("Ferrari", 5050);
        m_records[BIKE]     = make_unique<BikeRecord>("Yamaha", 2525);
        m_records[PERSON]   = make_unique<PersonRecord>("Tom", 25);
    }

    unique_ptr<Record> createRecord(RecordType recordType)
    {

```

```

        return m_records[recordType]->clone();
    }
};

int main()
{
    RecordFactory recordFactory;

    auto record = recordFactory.createRecord(CAR);
    record->print();

    record = recordFactory.createRecord(BIKE);
    record->print();

    record = recordFactory.createRecord(PERSON);
    record->print();
}

```

Another example:

To implement the pattern, declare an abstract base class that specifies a pure virtual `clone()` member function. Any class that needs a "polymorphic constructor" capability derives itself from the abstract base class, and implements the `clone()` operation.

The client, instead of writing code that invokes the `new` operator on a hard-wired class name, calls the `clone()` member function on the prototype, calls a factory member function with a parameter designating the particular concrete derived class desired, or invokes the `clone()` member function through some mechanism provided by another design pattern.

```

class CPrototypeMonster
{
protected:
    CString      _name;
public:
    CPrototypeMonster();
    CPrototypeMonster( const CPrototypeMonster& copy );
    virtual ~CPrototypeMonster();

    virtual CPrototypeMonster*   Clone() const=0; // This forces every derived class to provide an
override for this function.
    void      Name( CString name );
    CString   Name() const;
};

class CGreenMonster : public CPrototypeMonster
{
protected:
    int      _numberOfArms;
    double   _slimeAvailable;
public:
    CGreenMonster();
    CGreenMonster( const CGreenMonster& copy );
    ~CGreenMonster();

    virtual CPrototypeMonster*   Clone() const;
    void      NumberOfArms( int numberOfArms );
    void      SlimeAvailable( double slimeAvailable );

    int      NumberOfArms() const;
    double   SlimeAvailable() const;
};

class CPurpleMonster : public CPrototypeMonster
{
protected:
    int      _intensityOfBadBreath;
    double   _lengthOfWhiplikeAntenna;
public:
    CPurpleMonster();
    CPurpleMonster( const CPurpleMonster& copy );
    ~CPurpleMonster();
}

```

```

    virtual CPrototypeMonster*    Clone() const;

    void    IntensityOfBadBreath( int intensityOfBadBreath );
    void    LengthOfWhiplikeAntenna( double lengthOfWhiplikeAntenna );

    int      IntensityOfBadBreath() const;
    double   LengthOfWhiplikeAntenna() const;
};

class CBellyMonster : public CPrototypeMonster
{
protected:
    double    _roomAvailableInBelly;
public:
    CBellyMonster();
    CBellyMonster( const CBellyMonster& copy );
    ~CBellyMonster();

    virtual CPrototypeMonster*    Clone() const;

    void    RoomAvailableInBelly( double roomAvailableInBelly );
    double   RoomAvailableInBelly() const;
};

CPrototypeMonster* CGreenMonster::Clone() const
{
    return new CGreenMonster(*this);
}

CPrototypeMonster* CPurpleMonster::Clone() const
{
    return new CPurpleMonster(*this);
}

CPrototypeMonster* CBellyMonster::Clone() const
{
    return new CBellyMonster(*this);
}

```

A client of one of the concrete monster classes only needs a reference (pointer) to a CPrototypeMonster class object to be able to call the 'Clone' function and create copies of that object. The function below demonstrates this concept:

```

void DoSomeStuffWithAMonster( const CPrototypeMonster* originalMonster )
{
    CPrototypeMonster* newMonster = originalMonster->Clone();
    ASSERT( newMonster );

    newMonster->Name( "MyOwnMonster" );
    // Add code doing all sorts of cool stuff with the monster.
    delete newMonster;
}

```

Now originalMonster can be passed as a pointer to CGreenMonster, CPurpleMonster or CBellyMonster.

Singleton

The **Singleton pattern** ensures that a class has only one instance and provides a global point of access to that instance. It is named after the singleton set, which is defined to be a set containing one element. This is useful when exactly one object is needed to coordinate actions across the system.

Check list

- Define a private static attribute in the "single instance" class.
- Define a public static accessor function in the class.

- Do "lazy initialization" (creation on first use) in the accessor function.
- Define all constructors to be protected or private.
- Clients may only use the accessor function to manipulate the Singleton.

Let's take a look at how a Singleton differs from other variable types.

Like a global variable, the Singleton exists outside of the scope of any functions. Traditional implementation uses a static member function of the Singleton class, which will create a single instance of the Singleton class on the first call, and forever return that instance. The following code example illustrates the elements of a C++ singleton class, that simply stores a single string.

```
class StringSingleton
{
public:
    // Some accessor functions for the class, itself
    std::string GetString() const
    {return mString;}
    void SetString(const std::string &newStr)
    {mString = newStr;}

    // The magic function, which allows access to the class from anywhere
    // To get the value of the instance of the class, call:
    //     StringSingleton::Instance().GetString();
    static StringSingleton &Instance()
    {
        // This line only runs once, thus creating the only instance in existence
        static std::auto_ptr<StringSingleton> instance( new StringSingleton );
        // dereferencing the variable here, saves the caller from having to use
        // the arrow operator, and removes temptation to try and delete the
        // returned instance.
        return *instance; // always returns the same instance
    }

private:
    // We need to make some given functions private to finish the definition of the singleton
    StringSingleton(){} // default constructor available only to members or friends of this class

    // Note that the next two functions are not given bodies, thus any attempt
    // to call them implicitly will return as compiler errors. This prevents
    // accidental copying of the only instance of the class.
    StringSingleton(const StringSingleton &old); // disallow copy constructor
    const StringSingleton &operator=(const StringSingleton &old); //disallow assignment operator

    // Note that although this should be allowed,
    // some compilers may not implement private destructors
    // This prevents others from deleting our one single instance, which was otherwise created on the heap
    ~StringSingleton(){}
private: // private data for an instance of this class
    std::string mString;
};
```

Variations of Singletons:

Applications of Singleton Class:

One common use of the singleton design pattern is for application configurations. Configurations may need to be accessible globally, and future expansions to the application configurations may be needed. The subset C's closest alternative would be to create a single global *struct*. This had the lack of clarity as to where this object was instantiated, as well as not guaranteeing the existence of the object.

Take, for example, the situation of another developer using your singleton inside the constructor of their object. Then, yet another developer decides to create an instance of the second class in the global scope. If you had simply used a global variable, the order of linking would then matter. Since your global will be accessed, possibly before main begins executing, there is no definition as to whether the global is initialized, or the constructor of the second class is called first. This behavior can then change with slight

modifications to other areas of code, which would change order of global code execution. Such an error can be very hard to debug. But, with use of the singleton, the first time the object is accessed, the object will also be created. You now have an object which will always exist, in relation to being used, and will never exist if never used.

A second common use of this class is in updating old code to work in a new architecture. Since developers may have used globals liberally, moving them into a single class and making it a singleton, can be an intermediary step to bring the program inline to stronger object oriented structure.

Another example:

```
#include <iostream>
using namespace std;

/* Place holder for thread synchronization mutex */
class Mutex
{ /* placeholder for code to create, use, and free a mutex */
};

/* Place holder for thread synchronization lock */
class Lock
{ public:
    Lock(Mutex& m) : mutex(m) { /* placeholder code to acquire the mutex */ }
    ~Lock() { /* placeholder code to release the mutex */ }
private:
    Mutex & mutex;
};

class Singleton
{ public:
    static Singleton* GetInstance();
    int a;
    ~Singleton() { cout << "In Destructor" << endl; }

private:
    Singleton(int _a) : a(_a) { cout << "In Constructor" << endl; }

    static Mutex mutex;

    // Not defined, to prevent copying
    Singleton(const Singleton& );
    Singleton& operator =(const Singleton& other);
};

Mutex Singleton::mutex;

Singleton* Singleton::GetInstance()
{
    Lock lock(mutex);

    cout << "Get Instance" << endl;

    // Initialized during first access
    static Singleton inst(1);

    return &inst;
}

int main()
{
    Singleton* singleton = Singleton::GetInstance();
    cout << "The value of the singleton: " << singleton->a << endl;
    return 0;
}
```

Structural Patterns

Adapter

Convert the interface of a class into another interface that clients expect. **Adapter** lets classes work together that couldn't otherwise because of incompatible interfaces.

```
#include <iostream>

class Hindu { // Abstract Target
public:
    virtual ~Hindu() = default;
    virtual void performsHinduRitual() const = 0;
};

class HinduFemale : public Hindu { // Concrete Target
public:
    virtual void performsHinduRitual() const override {std::cout << "Hindu girl performs Hindu
ritual." << std::endl;}
};

class Muslim { // Abstract Adaptee
public:
    virtual ~Muslim() = default;
    virtual void performsMuslimRitual() const = 0;
};

class MuslimFemale : public Muslim { // Concrete Adaptee
public:
    virtual void performsMuslimRitual() const override {std::cout << "Muslim girl performs Muslim
ritual." << std::endl;}
};

class HinduRitual {
public:
    void carryOutRitual (Hindu* hindu) {
        std::cout << "On with the Hindu rituals!" << std::endl;
        hindu->performsHinduRitual();
    }
};

class HinduAdapter : public Hindu { // Adapter
private:
    Muslim* muslim;
public:
    HinduAdapter (Muslim* m) : muslim(m) {}
    virtual void performsHinduRitual() const override {muslim->performsMuslimRitual();}
};

int main() { // Client code
    HinduFemale* hinduGirl = new HinduFemale;
    MuslimFemale* muslimGirl = new MuslimFemale;
    HinduRitual hinduRitual;
    // hinduRitual.carryOutRitual (muslimGirl); // Will not compile of course since the parameter must be of
    // type Hindu*.
    HinduAdapter* adaptedMuslim = new HinduAdapter (muslimGirl); // muslimGirl has adapted to become a
    Hindu!

    hinduRitual.carryOutRitual (hinduGirl);
    hinduRitual.carryOutRitual (adaptedMuslim); // So now muslimGirl, in the form of adaptedMuslim,
    participates in the hinduRitual!
    // Note that muslimGirl is carrying out her own type of ritual in hinduRitual though.

    delete adaptedMuslim; // adaptedMuslim is not needed anymore
    delete muslimGirl; // muslimGirl is not needed anymore
    delete hinduGirl; // hinduGirl is not needed anymore, too
    return 0;
}
```

Bridge

The Bridge Pattern is used to separate out the interface from its implementation. Doing this gives the flexibility so that both can vary independently.

The following example will output:

```
API1.circle at 1:2 7.5
API2.circle at 5:7 27.5
```

```
#include <iostream>

using namespace std;

/* Implementor*/
class DrawingAPI {
public:
    virtual void drawCircle(double x, double y, double radius) = 0;
    virtual ~DrawingAPI() {}
};

/* Concrete ImplementorA*/
class DrawingAPI1 : public DrawingAPI {
public:
    void drawCircle(double x, double y, double radius) {
        cout << "API1.circle at " << x << ':' << y << ' ' << radius << endl;
    }
};

/* Concrete ImplementorB*/
class DrawingAPI2 : public DrawingAPI {
public:
    void drawCircle(double x, double y, double radius) {
        cout << "API2.circle at " << x << ':' << y << ' ' << radius << endl;
    }
};

/* Abstraction*/
class Shape {
public:
    virtual ~Shape() {}
    virtual void draw() = 0;
    virtual void resizeByPercentage(double pct) = 0;
};

/* Refined Abstraction*/
class CircleShape : public Shape {
public:
    CircleShape(double x, double y, double radius, DrawingAPI *drawingAPI) :
        m_x(x), m_y(y), m_radius(radius), m_drawingAPI(drawingAPI)
    {}
    void draw() {
        m_drawingAPI->drawCircle(m_x, m_y, m_radius);
    }
    void resizeByPercentage(double pct) {
        m_radius *= pct;
    }
private:
    double m_x, m_y, m_radius;
    DrawingAPI *m_drawingAPI;
};

int main(void) {
    CircleShape circle1(1,2,3,new DrawingAPI1());
    CircleShape circle2(5,7,11,new DrawingAPI2());
    circle1.resizeByPercentage(2.5);
    circle2.resizeByPercentage(2.5);
    circle1.draw();
    circle2.draw();
    return 0;
}
```

Composite

Composite lets clients treat individual objects and compositions of objects uniformly. The Composite pattern can represent both the conditions. In this pattern, one can develop tree structures for representing part-whole hierarchies.

```
#include <vector>
#include <iostream> // std::cout
#include <memory> // std::auto_ptr
#include <algorithm> // std::for_each
using namespace std;

class Graphic
{
public:
    virtual void print() const = 0;
    virtual ~Graphic() {}
};

class Ellipse : public Graphic
{
public:
    void print() const {
        cout << "Ellipse \n";
    }
};

class CompositeGraphic : public Graphic
{
public:
    void print() const {
        for(Graphic * a: graphicList_) {
            a->print();
        }
    }

    void add(Graphic *aGraphic) {
        graphicList_.push_back(aGraphic);
    }

private:
    vector<Graphic*> graphicList_;
};

int main()
{
    // Initialize four ellipses
    const auto_ptr<Ellipse> ellipse1(new Ellipse());
    const auto_ptr<Ellipse> ellipse2(new Ellipse());
    const auto_ptr<Ellipse> ellipse3(new Ellipse());
    const auto_ptr<Ellipse> ellipse4(new Ellipse());

    // Initialize three composite graphics
    const auto_ptr<CompositeGraphic> graphic(new CompositeGraphic());
    const auto_ptr<CompositeGraphic> graphic1(new CompositeGraphic());
    const auto_ptr<CompositeGraphic> graphic2(new CompositeGraphic());

    // Composes the graphics
    graphic1->add(ellipse1.get());
    graphic1->add(ellipse2.get());
    graphic1->add(ellipse3.get());

    graphic2->add(ellipse4.get());

    graphic->add(graphic1.get());
    graphic->add(graphic2.get());

    // Prints the complete graphic (four times the string "Ellipse")
    graphic->print();
    return 0;
}
```


Decorator

The decorator pattern helps to attach additional behavior or responsibilities to an object dynamically. Decorators provide a flexible alternative to subclassing for extending functionality. This is also called “Wrapper”. If your application does some kind of filtering, then Decorator might be good pattern to consider for the job.

```
#include <string>
#include <iostream>
using namespace std;

class Car //Our Abstract base class
{
    protected:
        string _str;
    public:
        Car()
        {
            _str = "Unknown Car";
        }

        virtual string getDescription()
        {
            return _str;
        }

        virtual double getCost() = 0;

        virtual ~Car()
        {
            cout << "~Car()\n";
        }
};

class OptionsDecorator : public Car //Decorator Base class
{
    public:
        virtual string getDescription() = 0;

        virtual ~OptionsDecorator()
        {
            cout<<"~OptionsDecorator()\n";
        }
};

class CarModell : public Car
{
    public:
        CarModell()
        {
            _str = "CarModell";
        }

        virtual double getCost()
        {
            return 31000.23;
        }

        ~CarModell()
        {
            cout<<"~CarModell()\n";
        }
};

class Navigation: public OptionsDecorator
{
    Car *_b;
    public:
        Navigation(Car *b)
        {
            _b = b;
        }
};
```

```

    string getDescription()
    {
        return _b->getDescription() + ", Navigation";
    }

    double getCost()
    {
        return 300.56 + _b->getCost();
    }
    ~Navigation()
    {
        cout << "~Navigation()\n";
        delete _b;
    }
};

class PremiumSoundSystem: public OptionsDecorator
{
    Car *_b;

public:
    PremiumSoundSystem(Car *b)
    {
        _b = b;
    }
    string getDescription()
    {
        return _b->getDescription() + ", PremiumSoundSystem";
    }

    double getCost()
    {
        return 0.30 + _b->getCost();
    }
    ~PremiumSoundSystem()
    {
        cout << "~PremiumSoundSystem()\n";
        delete _b;
    }
};

class ManualTransmission: public OptionsDecorator
{
    Car *_b;

public:
    ManualTransmission(Car *b)
    {
        _b = b;
    }
    string getDescription()
    {
        return _b->getDescription()+ ", ManualTransmission";
    }

    double getCost()
    {
        return 0.30 + _b->getCost();
    }
    ~ManualTransmission()
    {
        cout << "~ManualTransmission()\n";
        delete _b;
    }
};

int main()
{
    //Create our Car that we want to buy
    Car *b = new CarModell();

    cout << "Base model of " << b->getDescription() << " costs $" << b->getCost() << "\n";

    //Who wants base model let's add some more features

    b = new Navigation(b);
    cout << b->getDescription() << " will cost you $" << b->getCost() << "\n";
}

```

```

    b = new PremiumSoundSystem(b);
    b = new ManualTransmission(b);
    cout << b->getDescription() << " will cost you $" << b->getCost() << "\n";

    // WARNING! Here we leak the CarModell, Navigation and PremiumSoundSystem objects!
    // Either we delete them explicitly or rewrite the Decorators to take
    // ownership and delete their Cars when destroyed.
    delete b;

    return 0;
}

```

The output of the program above is:

```

Base model of CarModell costs $31000.2
CarModell, Navigation will cost you $31300.8
CarModell, Navigation, PremiumSoundSystem, ManualTransmission will cost you $31301.4
~ManualTransmission
~PremiumSoundSystem()
~Navigation()
~CarModell
~Car()
~OptionsDecorator()
~Car()
~OptionsDecorator()
~Car()
~OptionsDecorator()
~Car()

```

Another example(C++14):

```

#include <iostream>
#include <string>
#include <memory>

class Interface {
public:
    virtual ~Interface() { }
    virtual void write (std::string&) = 0;
};

class Core : public Interface {
public:
    ~Core() {std::cout << "Core destructor called.\n";}
    virtual void write (std::string& text) override {}; // Do nothing.
};

class Decorator : public Interface {
private:
    std::unique_ptr<Interface> interface;
public:
    Decorator (std::unique_ptr<Interface> c) {interface = std::move(c);}
    virtual void write (std::string& text) override {interface->write(text);}
};

class MessengerWithSalutation : public Decorator {
private:
    std::string salutation;
public:
    MessengerWithSalutation (std::unique_ptr<Interface> c, const std::string& str) :
Decorator(std::move(c)), salutation(str) {}
    ~MessengerWithSalutation() {std::cout << "Messenger destructor called.\n";}
    virtual void write (std::string& text) override {
        text = salutation + "\n\n" + text;
        Decorator::write(text);
    }
};

class MessengerWithValediction : public Decorator {
private:

```

```

        std::string valediction;
    public:
        MessengerWithValediction (std::unique_ptr<Interface> c, const std::string& str) :
Decorator(std::move(c)), valediction(str) {}
        ~MessengerWithValediction() {std::cout << "MessengerWithValediction destructor called.\n";}
        virtual void write (std::string& text) override {
            Decorator::write(text);
            text += "\n\n" + valediction;
        }
};

int main() {
    const std::string salutation = "Greetings,";
    const std::string valediction = "Sincerly, Andy";
    std::string message1 = "This message is not decorated.";
    std::string message2 = "This message is decorated with a salutation.";
    std::string message3 = "This message is decorated with a valediction.";
    std::string message4 = "This message is decorated with a salutation and a valediction.";

    std::unique_ptr<Interface> messenger1 = std::make_unique<Core>();
    std::unique_ptr<Interface> messenger2 = std::make_unique<MessengerWithSalutation>
(std::make_unique<Core>(), salutation);
    std::unique_ptr<Interface> messenger3 = std::make_unique<MessengerWithValediction>
(std::make_unique<Core>(), valediction);
    std::unique_ptr<Interface> messenger4 = std::make_unique<MessengerWithValediction>
(std::make_unique<MessengerWithSalutation>
        (std::make_unique<Core>(), salutation), valediction);

    messenger1->write(message1);
    std::cout << message1 << '\n';
    std::cout << "\n-----\n\n";

    messenger2->write(message2);
    std::cout << message2 << '\n';
    std::cout << "\n-----\n\n";

    messenger3->write(message3);
    std::cout << message3 << '\n';
    std::cout << "\n-----\n\n";

    messenger4->write(message4);
    std::cout << message4 << '\n';
    std::cout << "\n-----\n\n";
}

```

The output of the program above is:

```

This message is not decorated.
-----

Greetings,
This message is decorated with a salutation.
-----

This message is decorated with a valediction.
Sincerly, Andy
-----

Greetings,
This message is decorated with a salutation and a valediction.
Sincerly, Andy
-----

MessengerWithValediction destructor called.
Messenger destructor called.

```

```
Core destructor called.
MessengerWithValediction destructor called.
Core destructor called.
Messenger destructor called.
Core destructor called.
Core destructor called.
```

Facade

The Facade Pattern hides the complexities of the system by providing an interface to the client from where the client can access the system on a unified interface. Facade defines a higher-level interface that makes the subsystem easier to use. For instance making one class method perform a complex process by calling several other classes.

```
/*Facade is one of the easiest patterns I think... And this is very simple example.
Imagine you set up a smart house where everything is on remote. So to turn the lights on you push lights on
button - And same for TV,
AC, Alarm, Music, etc...

When you leave a house you would need to push a 100 buttons to make sure everything is off and are good to
go which could be little
annoying if you are lazy like me
so I defined a Facade for leaving and coming back. (Facade functions represent buttons...) So when I come
and leave I just make one
call and it takes care of everything...
*/
```

```
#include <string>
#include <iostream>

using namespace std;

class Alarm
{
public:
    void alarmOn()
    {
        cout << "Alarm is on and house is secured"<<endl;
    }

    void alarmOff()
    {
        cout << "Alarm is off and you can go into the house"<<endl;
    }
};

class Ac
{
public:
    void acOn()
    {
        cout << "Ac is on"<<endl;
    }

    void acOff()
    {
        cout << "AC is off"<<endl;
    }
};

class Tv
{
public:
    void tvOn()
    {
        cout << "Tv is on"<<endl;
    }

    void tvOff()
```

```

    {
        cout << "TV is off"<<endl;
    }
};

class HouseFacade
{
    Alarm alarm;
    Ac ac;
    Tv tv;

public:
    HouseFacade(){}

    void goToWork()
    {
        ac.acOff();
        tv.tvOff();
        alarm.alarmOn();
    }

    void comeHome()
    {
        alarm.alarmOff();
        ac.acOn();
        tv.tvOn();
    }
};

int main()
{
    HouseFacade hf;

    //Rather than calling 100 different on and off functions thanks to facade I only have 2 functions...
    hf.goToWork();
    hf.comeHome();
}

```

The output of the program above is:

```

AC is off
TV is off
Alarm is on and house is secured
Alarm is off and you can go into the house
Ac is on
Tv is on

```

Flyweight

The pattern for saving memory (basically) by sharing properties of objects. Imagine a huge number of similar objects which all have most of their properties the same. It is natural to move these properties out of these objects to some external data structure and provide each object with the link to that data structure.

```

#include <iostream>
#include <string>
#include <vector>

#define NUMBER_OF_SAME_TYPE_CHARS 3;

/* Actual flyweight objects class (declaration) */
class FlyweightCharacter;

/*
    FlyweightCharacterAbstractBuilder is a class holding the properties which are shared by
    many objects. So instead of keeping these properties in those objects we keep them externally, making
    objects flyweight. See more details in the comments of main function.
*/

```

```

class FlyweightCharacterAbstractBuilder {
    FlyweightCharacterAbstractBuilder() {}
    ~FlyweightCharacterAbstractBuilder() {}
public:
    static std::vector<float> fontSizes; // lets imagine that sizes may be of floating point type
    static std::vector<std::string> fontNames; // font name may be of variable length (lets take 6 bytes is
average)

    static void setFontsAndNames();
    static FlyweightCharacter createFlyweightCharacter(unsigned short fontSizeIndex,
        unsigned short fontNameIndex,
        unsigned short positionInStream);
};

std::vector<float> FlyweightCharacterAbstractBuilder::fontSizes(3);
std::vector<std::string> FlyweightCharacterAbstractBuilder::fontNames(3);
void FlyweightCharacterAbstractBuilder::setFontAndNames() {
    fontSizes[0] = 1.0;
    fontSizes[1] = 1.5;
    fontSizes[2] = 2.0;

    fontNames[0] = "first_font";
    fontNames[1] = "second_font";
    fontNames[2] = "third_font";
}

class FlyweightCharacter {
    unsigned short fontSizeIndex; // index instead of actual font size
    unsigned short fontNameIndex; // index instead of font name

    unsigned positionInStream;
public:
    FlyweightCharacter(unsigned short fontSizeIndex, unsigned short fontNameIndex, unsigned short
positionInStream):
        fontSizeIndex(fontSizeIndex), fontNameIndex(fontNameIndex), positionInStream(positionInStream) {}
    void print() {
        std::cout << "Font Size: " << FlyweightCharacterAbstractBuilder::fontSizes[fontSizeIndex]
            << ", font Name: " << FlyweightCharacterAbstractBuilder::fontNames[fontNameIndex]
            << ", character stream position: " << positionInStream << std::endl;
    }
    ~FlyweightCharacter() {}
};

FlyweightCharacter FlyweightCharacterAbstractBuilder::createFlyweightCharacter(unsigned short fontSizeIndex,
unsigned short fontNameIndex, unsigned short positionInStream) {
    FlyweightCharacter fc(fontSizeIndex, fontNameIndex, positionInStream);

    return fc;
}

int main(int argc, char** argv) {
    std::vector<FlyweightCharacter> chars;

    FlyweightCharacterAbstractBuilder::setFontAndNames();
    unsigned short limit = NUMBER_OF_SAME_TYPE_CHARS;

    for (unsigned short i = 0; i < limit; i++) {
        chars.push_back(FlyweightCharacterAbstractBuilder::createFlyweightCharacter(0, 0, i));
        chars.push_back(FlyweightCharacterAbstractBuilder::createFlyweightCharacter(1, 1, i + 1 * limit));
        chars.push_back(FlyweightCharacterAbstractBuilder::createFlyweightCharacter(2, 2, i + 2 * limit));
    }
    /*
    Each char stores links to its fontName and fontSize so what we get is:

    each object instead of allocating 6 bytes (convention above) for string
    and 4 bytes for float allocates 2 bytes for fontNameIndex and fontSizeIndex.

    That means for each char we save 6 + 4 - 2 - 2 = 6 bytes.
    Now imagine we have NUMBER_OF_SAME_TYPE_CHARS = 1000 i.e. with our code
    we will have 3 groups of chars with 1000 chars in each group which will save
    3 * 1000 * 6 - (3 * 6 + 3 * 4) = 17970 saved bytes.

    3 * 6 + 3 * 4 is a number of bytes allocated by FlyweightCharacterAbstractBuilder.

```

So the idea of the pattern is to move properties shared by many objects to some external container. The objects in that case don't store the data themselves they store only links to the data which saves memory and make the objects lighter. The data size of properties stored externally may be significant which will save REALLY huge amount of memory and will make each object super light in comparison to its counterpart. That's where the name of the pattern comes from: flyweight (i.e. very light).

```
*/
for (unsigned short i = 0; i < chars.size(); i++) {
    chars[i].print();
}

std::cin.get(); return 0;
}
```

Proxy

The Proxy Pattern will provide an object a surrogate or placeholder for another object to control access to it. It is used when you need to represent a complex object with a simpler one. If creation of an object is expensive, it can be postponed until the very need arises and meanwhile a simpler object can serve as a placeholder. This placeholder object is called the “Proxy” for the complex object.

```
#include <iostream>
#include <memory>

class ICar {
public:
    virtual ~ICar() { std::cout << "ICar destructor!" << std::endl; }

    virtual void DriveCar() = 0;
};

class Car : public ICar {
public:
    void DriveCar() override { std::cout << "Car has been driven!" << std::endl; }
};

class ProxyCar : public ICar {
public:
    ProxyCar(int driver_age) : driver_age_(driver_age) {}

    void DriveCar() override {
        if (driver_age_ > 16) {
            real_car_>DriveCar();
        } else {
            std::cout << "Sorry, the driver is too young to drive." << std::endl;
        }
    }

private:
    std::unique_ptr<ICar> real_car_ = std::make_unique<Car>();
    int driver_age_;
};

int main() {
    std::unique_ptr<ICar> car = std::make_unique<ProxyCar>(16);
    car->DriveCar();

    car = std::make_unique<ProxyCar>(25);
    car->DriveCar();
    return 0;
}
```

Curiously Recurring Template

This technique is known more widely as a Mixin. Mixins are described in the literature to be a powerful tool for expressing abstractions^[*citation needed*].

Interface-based Programming (IBP)

Interface-based programming is closely related with Modular Programming and Object-Oriented Programming, it defines the application as a collection of inter-coupled modules (interconnected and which plug into each other via interface). Modules can be unplugged, replaced, or upgraded, without the need of compromising the contents of other modules.

The total system complexity is greatly reduced. Interface Based Programming adds more to modular Programming in that it insists that Interfaces are to be added to these modules. The entire system is thus viewed as Components and the interfaces that helps them to co-act.

Interface-based Programming increases the *modularity* of the application and hence its maintainability at a later development cycles, especially when each module must be developed by different teams. It is a well-known methodology that has been around for a long time and it is a core technology behind frameworks such as CORBA.

This is particularly convenient when third parties develop additional components for the established system. They just have to develop components that satisfy the interface specified by the parent application vendor.

Thus the publisher of the interfaces assures that he will not change the interface and the subscriber agrees to implement the interface as whole without any deviation. An interface is therefore said to be a *Contractual agreement* and the programming paradigm based on this is termed as "interface based programming".

Behavioral Patterns

Chain of Responsibility

Chain of Responsibility pattern has the intent to avoid coupling the sender of a request to its receiver by giving more than one object a chance to handle the request. Chains the receiving objects and passes the requests along the chain until an object handles it.

```
#include <iostream>

using namespace std;

class Handler {
protected:
    Handler *next;

public:
    Handler() {
        next = NULL;
    }

    virtual ~Handler() { }

    virtual void request(int value) = 0;

    void setNextHandler(Handler *nextInLine) {
        next = nextInLine;
    }
};

class SpecialHandler : public Handler {
private:
    int myLimit;
    int myId;

public:
    SpecialHandler(int limit, int id) {
        myLimit = limit;
        myId = id;
    }
};
```

```

    ~SpecialHandler() { }

    void request(int value) {
        if(value < myLimit) {
            cout << "Handler " << myId << " handled the request with a limit of " << myLimit << endl;
        } else if(next != NULL) {
            next->request(value);
        } else {
            cout << "Sorry, I am the last handler (" << myId << ") and I can't handle the request." <<
endl;
        }
    }
};

int main () {
    Handler *h1 = new SpecialHandler(10, 1);
    Handler *h2 = new SpecialHandler(20, 2);
    Handler *h3 = new SpecialHandler(30, 3);

    h1->setNextHandler(h2);
    h2->setNextHandler(h3);

    h1->request(18);

    h1->request(40);

    delete h1;
    delete h2;
    delete h3;

    return 0;
}

```

Command

Command pattern is an Object behavioral pattern that decouples sender and receiver by encapsulating a request as an object, thereby letting you parameterize clients with different requests, queue or log requests, and support undo-able operations. It can also be thought as an object oriented equivalent of call back method.

Call Back: It is a function that is registered to be called at later point of time based on user actions.

```

#include <iostream>

using namespace std;

/*the Command interface*/
class Command
{
public:
    virtual void execute()=0;
};

/*Receiver class*/
class Light {
public:
    Light() { }

    void turnOn()
    {
        cout << "The light is on" << endl;
    }

    void turnOff()
    {
        cout << "The light is off" << endl;
    }
};

```

```

/*the Command for turning on the light*/
class FlipUpCommand: public Command
{
public:

    FlipUpCommand(Light& light):theLight(light)
    {

    }

    virtual void execute()
    {
        theLight.turnOn();
    }

private:
    Light& theLight;
};

/*the Command for turning off the light*/
class FlipDownCommand: public Command
{
public:
    FlipDownCommand(Light& light) :theLight(light)
    {

    }
    virtual void execute()
    {
        theLight.turnOff();
    }
private:
    Light& theLight;
};

class Switch {
public:
    Switch(Command& flipUpCmd, Command& flipDownCmd)
    :flipUpCommand(flipUpCmd),flipDownCommand(flipDownCmd)
    {

    }

    void flipUp()
    {
        flipUpCommand.execute();
    }

    void flipDown()
    {
        flipDownCommand.execute();
    }

private:
    Command& flipUpCommand;
    Command& flipDownCommand;
};

/*The test class or client*/
int main()
{
    Light lamp;
    FlipUpCommand switchUp(lamp);
    FlipDownCommand switchDown(lamp);

    Switch s(switchUp, switchDown);
    s.flipUp();
    s.flipDown();
}

```

Interpreter

Given a language, define a representation for its grammar along with an interpreter that uses the representation to interpret sentences in the language.

```
#include <iostream>
#include <string>
#include <map>
#include <list>

namespace wikibooks_design_patterns
{
    // based on the Java sample around here

    typedef std::string String;
    struct Expression;
    typedef std::map<String, Expression*> Map;
    typedef std::list<Expression*> Stack;

    struct Expression {
        virtual int interpret(Map variables) = 0;
        virtual ~Expression() {}
    };

    class Number : public Expression {
    private:
        int number;
    public:
        Number(int number) { this->number = number; }
        int interpret(Map variables) { return number; }
    };

    class Plus : public Expression {
        Expression* leftOperand;
        Expression* rightOperand;
    public:

        Plus(Expression* left, Expression* right) {
            leftOperand = left;
            rightOperand = right;
        }
        ~Plus(){
            delete leftOperand;
            delete rightOperand;
        }

        int interpret(Map variables) {
            return leftOperand->interpret(variables) + rightOperand->interpret(variables);
        }
    };

    class Minus : public Expression {
        Expression* leftOperand;
        Expression* rightOperand;
    public:
        Minus(Expression* left, Expression* right) {
            leftOperand = left;
            rightOperand = right;
        }
        ~Minus(){
            delete leftOperand;
            delete rightOperand;
        }

        int interpret(Map variables) {
            return leftOperand->interpret(variables) - rightOperand->interpret(variables);
        }
    };
};
```

```

class Variable : public Expression {
    String name;
public:
    Variable(String name) { this->name = name; }
    int interpret(Map variables) {
        if(variables.end() == variables.find(name)) return 0;
        return variables[name]->interpret(variables);
    }
};

// While the interpreter pattern does not address parsing, a parser is provided for completeness.

class Evaluator : public Expression {
    Expression* syntaxTree;
public:
    Evaluator(String expression){
        Stack expressionStack;

        size_t last = 0;
        for (size_t next = 0; String::npos != last; last = (String::npos == next) ? next : (1+next)) {
            next = expression.find(' ', last);
            String token( expression.substr(last, (String::npos == next) ? (expression.length()-last) : (next-
last)));

            if (token == "+") {
                Expression* right = expressionStack.back(); expressionStack.pop_back();
                Expression* left = expressionStack.back(); expressionStack.pop_back();
                Expression* subExpression = new Plus(right, left);
                expressionStack.push_back( subExpression );
            }
            else if (token == "-") {
                // it's necessary remove first the right operand from the stack
                Expression* right = expressionStack.back(); expressionStack.pop_back();
                // ..and after the left one
                Expression* left = expressionStack.back(); expressionStack.pop_back();
                Expression* subExpression = new Minus(left, right);
                expressionStack.push_back( subExpression );
            }
            else
                expressionStack.push_back( new Variable(token) );
        }

        syntaxTree = expressionStack.back(); expressionStack.pop_back();
    }

    ~Evaluator() {
        delete syntaxTree;
    }

    int interpret(Map context) {
        return syntaxTree->interpret(context);
    }
};

void main()
{
    using namespace wikibooks_design_patterns;

    Evaluator sentence("w x z - +");

    static
    const int sequences[][3] = {
        {5, 10, 42}, {1, 3, 2}, {7, 9, -5},
    };
    for (size_t i = 0; sizeof(sequences)/sizeof(sequences[0]) > i; ++i) {
        Map variables;
        variables["w"] = new Number(sequences[i][0]);
        variables["x"] = new Number(sequences[i][1]);
        variables["z"] = new Number(sequences[i][2]);
        int result = sentence.interpret(variables);
        for (Map::iterator it = variables.begin(); variables.end() != it; ++it) delete it->second;
    }
}

```

```

    std::cout<<"Interpreter result: "<<result<<std::endl;
}
}

```

Iterator

The 'iterator' design pattern is used liberally within the STL for traversal of various containers. The full understanding of this will liberate a developer to create highly reusable and easily understandable^[*citation needed*] data containers.

The basic idea of the iterator is that it permits the traversal of a container (like a pointer moving across an array). However, to get to the next element of a container, you need not know anything about how the container is constructed. This is the iterators job. By simply using the member functions provided by the iterator, you can move, in the intended order of the container, from the first element to the last element.

Let us start by considering a traditional single dimensional array with a pointer moving from the start to the end. This example assumes knowledge of pointer arithmetic. Note that the use of "it" or "itr," henceforth, is a short version of "iterator."

```

const int ARRAY_LEN = 42;
int *myArray = new int[ARRAY_LEN];
// Set the iterator to point to the first memory location of the array
int *arrayItr = myArray;
// Move through each element of the array, setting it equal to its position in the array
for(int i = 0; i < ARRAY_LEN; ++i)
{
    // set the value of the current location in the array
    *arrayItr = i;
    // by incrementing the pointer, we move it to the next position in the array.
    // This is easy for a contiguous memory container, since pointer arithmetic
    // handles the traversal.
    ++arrayItr;
}
// Do not be messy, clean up after yourself
delete[] myArray;

```

This code works very quickly for arrays, but how would we traverse a linked list, when the memory is not contiguous? Consider the implementation of a rudimentary linked list as follows:

```

class IteratorCannotMoveToNext{}; // Error class
class MyIntLList
{
public:
    // The Node class represents a single element in the linked list.
    // The node has a next node and a previous node, so that the user
    // may move from one position to the next, or step back a single
    // position. Notice that the traversal of a linked list is O(N),
    // as is searching, since the list is not ordered.
    class Node
    {
    public:
        Node():mNextNode(0),mPrevNode(0),mValue(0){}
        Node *mNextNode;
        Node *mPrevNode;
        int mValue;
    };
    MyIntLList():mSize(0)
    {}
    ~MyIntLList()
    {
        while(!Empty())
            pop_front();
    } // See expansion for further implementation;
    int Size() const {return mSize;}
    // Add this value to the end of the list

```

```

void push_back(int value)
{
    Node *newNode = new Node;
    newNode->mValue = value;
    newNode->mPrevNode = mTail;
    mTail->mNextNode = newNode;
    mTail = newNode;
    ++mSize;
}
// Remove the value from the beginning of the list
void pop_front()
{
    if(Empty())
        return;
    Node *tmpnode = mHead;
    mHead = mHead->mNextNode;
    delete tmpnode;
    --mSize;
}
bool Empty()
{return mSize == 0;}

// This is where the iterator definition will go,
// but lets finish the definition of the list, first

private:
    Node *mHead;
    Node *mTail;
    int mSize;
};

```

This linked list has non-contiguous memory, and is therefore not a candidate for pointer arithmetic. And we do not want to expose the internals of the list to other developers, forcing them to learn them, and keeping us from changing it.

This is where the iterator comes in. The common interface makes learning the usage of the container easier, and hides the traversal logic from other developers.

Let us examine the code for the iterator, itself.

```

/*
 * The iterator class knows the internals of the linked list, so that it
 * may move from one element to the next. In this implementation, I have
 * chosen the classic traversal method of overloading the increment
 * operators. More thorough implementations of a bi-directional linked
 * list would include decrement operators so that the iterator may move
 * in the opposite direction.
 */
class Iterator
{
public:
    Iterator(Node *position):mCurrNode(position){}
    // Prefix increment
    const Iterator &operator++()
    {
        if(mCurrNode == 0 || mCurrNode->mNextNode == 0)
            throw IteratorCannotMoveToNext();
        mCurrNode = mCurrNode->mNextNode;
        return *this;
    }
    // Postfix increment
    Iterator operator++(int)
    {
        Iterator tempItr = *this;
        ++(*this);
        return tempItr;
    }
    // Dereferencing operator returns the current node, which should then
    // be dereferenced for the int. TODO: Check syntax for overloading
    // dereferencing operator
    Node * operator*()

```

```

    {return mCurrNode;}
    // TODO: implement arrow operator and clean up example usage following
private:
    Node *mCurrNode;
};
// The following two functions make it possible to create
// iterators for an instance of this class.
// First position for iterators should be the first element in the container.
Iterator Begin(){return Iterator(mHead);}
// Final position for iterators should be one past the last element in the container.
Iterator End(){return Iterator(0);}

```

With this implementation, it is now possible, without knowledge of the size of the container or how its data is organized, to move through each element in order, manipulating or simply accessing the data. This is done through the accessors in the MyIntLList class, Begin() and End().

```

// Create a list
MyIntLList myList;
// Add some items to the list
for(int i = 0; i < 10; ++i)
    myList.push_back(i);
// Move through the list, adding 42 to each item.
for(MyIntLList::Iterator it = myList.Begin(); it != myList.End(); ++it)
    (*it)->mValue += 42;

```

The following program gives the implementation of an iterator design pattern with a generic template:

```

/*****
/* Iterator.h
/*****
#ifndef MY_ITERATOR_HEADER
#define MY_ITERATOR_HEADER

#include <iterator>
#include <vector>
#include <set>

////////////////////////////////////
template<class T, class U>
class Iterator
{
public:
    typedef typename std::vector<T>::iterator iter_type;
    Iterator(U *pData):m_pData(pData){
        m_it = m_pData->m_data.begin();
    }

    void first()
    {
        m_it = m_pData->m_data.begin();
    }

    void next()
    {
        m_it++;
    }

    bool isDone()
    {
        return (m_it == m_pData->m_data.end());
    }

    iter_type current()
    {
        return m_it;
    }
private:
    U *m_pData;
    iter_type m_it;

```



```

};

template<class T, class U, class A>
class setIterator
{
public:
    typedef typename std::set<T,U>::iterator iter_type;

    setIterator(A *pData):m_pData(pData)
    {
        m_it = m_pData->m_data.begin();
    }

    void first()
    {
        m_it = m_pData->m_data.begin();
    }

    void next()
    {
        m_it++;
    }

    bool isDone()
    {
        return (m_it == m_pData->m_data.end());
    }

    iter_type current()
    {
        return m_it;
    }

private:
    A          *m_pData;
    iter_type  m_it;
};
#endif

```

```

/*****
/* Aggregate.h */
/*****
#ifndef MY_DATACOLLECTION_HEADER
#define MY_DATACOLLECTION_HEADER
#include "Iterator.h"

template <class T>
class aggregate
{
    friend class Iterator<T, aggregate>;
public:
    void add(T a)
    {
        m_data.push_back(a);
    }

    Iterator<T, aggregate> *create_iterator()
    {
        return new Iterator<T, aggregate>(this);
    }

private:
    std::vector<T> m_data;
};

template <class T, class U>
class aggregateSet
{
    friend class setIterator<T, U, aggregateSet>;
public:
    void add(T a)
    {
        m_data.insert(a);
    }

```

```

    }

    setIterator<T, U, aggregateSet> *create_iterator()
    {
        return new setIterator<T,U,aggregateSet>(this);
    }

    void Print()
    {
        copy(m_data.begin(), m_data.end(), std::ostream_iterator<T>(std::cout, "\n"));
    }

private:
    std::set<T,U> m_data;
};

#endif

```

```

/*****
/* Iterator Test.cpp
/*****
#include <iostream>
#include <string>
#include "Aggregate.h"
using namespace std;

class Money
{
public:
    Money(int a = 0): m_data(a) {}

    void SetMoney(int a)
    {
        m_data = a;
    }

    int GetMoney()
    {
        return m_data;
    }

private:
    int m_data;
};

class Name
{
public:
    Name(string name): m_name(name) {}

    const string &GetName() const
    {
        return m_name;
    }

    friend ostream &operator<<(ostream& out, Name name)
    {
        out << name.GetName();
        return out;
    }

private:
    string m_name;
};

struct NameLess
{
    bool operator()(const Name &lhs, const Name &rhs) const
    {
        return (lhs.GetName() < rhs.GetName());
    }
};

```

```

int main()
{
    //sample 1
    cout << "_____Iterator with int_____" << endl;
    aggregate<int> agg;

    for (int i = 0; i < 10; i++)
        agg.add(i);

    Iterator< int, aggregate<int> > *it = agg.create_iterator();
    for(it->first(); !it->isDone(); it->next())
        cout << *it->current() << endl;

    //sample 2
    aggregate<Money> agg2;
    Money a(100), b(1000), c(10000);
    agg2.add(a);
    agg2.add(b);
    agg2.add(c);

    cout << "_____Iterator with Class Money_____" << endl;
    Iterator<Money, aggregate<Money> > *it2 = agg2.create_iterator();
    for (it2->first(); !it2->isDone(); it2->next())
        cout << it2->current()->GetMoney() << endl;

    //sample 3
    cout << "_____Set Iterator with Class Name_____" << endl;

    aggregateSet<Name, NameLess> aset;
    aset.add(Name("Qmt"));
    aset.add(Name("Bmt"));
    aset.add(Name("Cmt"));
    aset.add(Name("Amt"));

    setIterator<Name, NameLess, aggregateSet<Name, NameLess> > *it3 = aset.create_iterator();
    for (it3->first(); !it3->isDone(); it3->next())
        cout << (*it3->current()) << endl;
}

```

Console output:

```

_____Iterator with int_____
0
1
2
3
4
5
6
7
8
9
_____Iterator with Class Money_____
100
1000
10000
_____Set Iterator with Class Name_____
Amt
Bmt
Cmt
Qmt

```

Mediator

Define an object that encapsulates how a set of objects interact. Mediator promotes loose coupling by keeping objects from referring to each other explicitly, and it lets you vary their interaction independently.

```

#include <iostream>
#include <string>
#include <list>

class MediatorInterface;

class ColleagueInterface {
    std::string name;
public:
    ColleagueInterface (const std::string& newName) : name (newName) {}
    std::string getName() const {return name;}
    virtual void sendMessage (const MediatorInterface&, const std::string&) const = 0;
    virtual void receiveMessage (const ColleagueInterface*, const std::string&) const = 0;
};

class Colleague : public ColleagueInterface {
public:
    using ColleagueInterface::ColleagueInterface;
    virtual void sendMessage (const MediatorInterface&, const std::string&) const override;
private:
    virtual void receiveMessage (const ColleagueInterface*, const std::string&) const override;
};

class MediatorInterface {
private:
    std::list<ColleagueInterface*> colleagueList;
public:
    const std::list<ColleagueInterface*> getColleagueList() const {return colleagueList;}
    virtual void distributeMessage (const ColleagueInterface*, const std::string&) const = 0;
    virtual void registerColleague (ColleagueInterface* colleague) {colleagueList.emplace_back
(colleague);}
};

class Mediator : public MediatorInterface {
    virtual void distributeMessage (const ColleagueInterface*, const std::string&) const override;
};

void Colleague::sendMessage (const MediatorInterface& mediator, const std::string& message) const {
    mediator.distributeMessage (this, message);
}

void Colleague::receiveMessage (const ColleagueInterface* sender, const std::string& message) const {
    std::cout << getName() << " received the message from " << sender->getName() << ": " << message <<
std::endl;
}

void Mediator::distributeMessage (const ColleagueInterface* sender, const std::string& message) const {
    for (const ColleagueInterface* x : getColleagueList())
        if (x != sender) // Do not send the message back to the sender
            x->receiveMessage (sender, message);
}

int main() {
    Colleague *bob = new Colleague ("Bob"), *sam = new Colleague ("Sam"), *frank = new Colleague
("Frank"), *tom = new Colleague ("Tom");
    Colleague* staff[] = {bob, sam, frank, tom};
    Mediator mediatorStaff, mediatorSamsBuddies;
    for (Colleague* x : staff)
        mediatorStaff.registerColleague(x);
    bob->sendMessage (mediatorStaff, "I'm quitting this job!");
    mediatorSamsBuddies.registerColleague (frank); mediatorSamsBuddies.registerColleague (tom); // Sam's
buddies only
    sam->sendMessage (mediatorSamsBuddies, "Hooray! He's gone! Let's go for a drink, guys!");
    return 0;
}

```

Memento

Without violating encapsulation the Memento Pattern will capture and externalize an object's internal state so that the object can be restored to this state later. Though the Gang of Four uses friend as a way to implement this pattern it is not the best design^[*citation needed*]. It can also be implemented using PIMPL (pointer to implementation or opaque pointer). Best Use case is 'Undo-Redo' in an editor.

The Originator (the object to be saved) creates a snap-shot of itself as a Memento object, and passes that reference to the Caretaker object. The Caretaker object keeps the Memento until such a time as the Originator may want to revert to a previous state as recorded in the Memento object.

See memoize (<http://perldoc.perl.org/Memoize.html>) for an *old-school* example of this pattern.

```
#include <iostream>
#include <string>
#include <sstream>
#include <vector>

const std::string NAME = "Object";

template <typename T>
std::string toString (const T& t) {
    std::stringstream ss;
    ss << t;
    return ss.str();
}

class Memento;

class Object {
private:
    int value;
    std::string name;
    double decimal; // and suppose there are loads of other data members
public:
    Object (int newValue): value (newValue), name (NAME + toString (value)), decimal ((float)value /
100) {}
    void doubleValue() {value = 2 * value; name = NAME + toString (value); decimal = (float)value /
100;}
    void increaseByOne() {value++; name = NAME + toString (value); decimal = (float)value / 100;}
    int getValue() const {return value;}
    std::string getName() const {return name;}
    double getDecimal() const {return decimal;}
    Memento* createMemento() const;
    void reinstateMemento (Memento* mem);
};

class Memento {
private:
    Object object;
public:
    Memento (const Object& obj): object (obj) {}
    Object snapshot() const {return object;} // want a snapshot of Object itself because of its
many data members
};

Memento* Object::createMemento() const {
    return new Memento (*this);
}

void Object::reinstateMemento (Memento* mem) {
    *this = mem->snapshot();
}

class Command {
private:
    typedef void (Object::*Action)();
    Object* receiver;
    Action action;
    static std::vector<Command*> commandList;
    static std::vector<Memento*> mementoList;
```

```

    static int numCommands;
    static int maxCommands;
public:
    Command (Object *newReceiver, Action newAction): receiver (newReceiver), action (newAction) {}
    virtual void execute() {
        if (mementoList.size() < numCommands + 1)
            mementoList.resize (numCommands + 1);
        mementoList[numCommands] = receiver->createMemento(); // saves the last value
        if (commandList.size() < numCommands + 1)
            commandList.resize (numCommands + 1);
        commandList[numCommands] = this; // saves the last command
        if (numCommands > maxCommands)
            maxCommands = numCommands;
        numCommands++;
        (receiver->*action)();
    }
    static void undo() {
        if (numCommands == 0)
        {
            std::cout << "There is nothing to undo at this point." << std::endl;
            return;
        }
        commandList[numCommands - 1]->receiver->reinstateMemento (mementoList[numCommands - 1]);
        numCommands--;
    }
    void static redo() {
        if (numCommands > maxCommands)
        {
            std::cout << "There is nothing to redo at this point." << std::endl;
            return ;
        }
        Command* commandRedo = commandList[numCommands];
        (commandRedo->receiver->*(commandRedo->action))();
        numCommands++;
    }
};

std::vector<Command*> Command::commandList;
std::vector<Memento*> Command::mementoList;
int Command::numCommands = 0;
int Command::maxCommands = 0;

int main()
{
    int i;
    std::cout << "Please enter an integer: ";
    std::cin >> i;
    Object *object = new Object(i);

    Command *commands[3];
    commands[1] = new Command(object, &Object::doubleValue);
    commands[2] = new Command(object, &Object::increaseByOne);

    std::cout << "0.Exit, 1.Double, 2.Increase by one, 3.Undo, 4.Redo: ";
    std::cin >> i;

    while (i != 0)
    {
        if (i == 3)
            Command::undo();
        else if (i == 4)
            Command::redo();
        else if (i > 0 && i <= 2)
            commands[i]->execute();
        else
        {
            std::cout << "Enter a proper choice: ";
            std::cin >> i;
            continue;
        }
        std::cout << "    " << object->getValue() << "    " << object->getName() << "    " << object->getDecimal() << std::endl;
        std::cout << "0.Exit, 1.Double, 2.Increase by one, 3.Undo, 4.Redo: ";
        std::cin >> i;
    }
}

```

```

    }
}

```

Observer

The Observer Pattern defines a one-to-many dependency between objects so that when one object changes state, all its dependents are notified and updated automatically.

Problem

In one place or many places in the application we need to be aware about a system event or an application state change. We'd like to have a standard way of subscribing to listening for system events and a standard way of notifying the interested parties. The notification should be automated after an interested party subscribed to the system event or application state change. There also should be a way to unsubscribe.

Forces

Observers and observables probably should be represented by objects. The observer objects will be notified by the observable objects.

Solution

After subscribing the listening objects will be notified by a way of method call.

```

#include <list>
#include <algorithm>
#include <iostream>
using namespace std;

// The Abstract Observer
class ObserverBoardInterface
{
public:
    virtual void update(float a, float b, float c) = 0;
};

// Abstract Interface for Displays
class DisplayBoardInterface
{
public:
    virtual void show() = 0;
};

// The Abstract Subject
class WeatherDataInterface
{
public:
    virtual void registerOb(ObserverBoardInterface* ob) = 0;
    virtual void removeOb(ObserverBoardInterface* ob) = 0;
    virtual void notifyOb() = 0;
};

// The Concrete Subject
class ParaWeatherData: public WeatherDataInterface
{
public:
    void SensorDataChange(float a, float b, float c)
    {
        m_humidity = a;
        m_temperature = b;
        m_pressure = c;
        notifyOb();
    }

    void registerOb(ObserverBoardInterface* ob)
    {
        m_obs.push_back(ob);
    }
}

```

```

    }

    void removeOb(ObserverBoardInterface* ob)
    {
        m_obs.remove(ob);
    }
protected:
    void notifyOb()
    {
        list<ObserverBoardInterface*>::iterator pos = m_obs.begin();
        while (pos != m_obs.end())
        {
            ((ObserverBoardInterface* )(*pos))->update(m_humidity,m_temperature,m_pressure);
            (dynamic_cast<DisplayBoardInterface*>(*pos))->show();
            ++pos;
        }
    }

private:
    float      m_humidity;
    float      m_temperature;
    float      m_pressure;
    list<ObserverBoardInterface* > m_obs;
};

// A Concrete Observer
class CurrentConditionBoard : public ObserverBoardInterface, public DisplayBoardInterface
{
public:
    CurrentConditionBoard(ParaWeatherData& a):m_data(a)
    {
        m_data.registerOb(this);
    }
    void show()
    {
        cout<<"____CurrentConditionBoard____"<<endl;
        cout<<"humidity: "<<m_h<<endl;
        cout<<"temperature: "<<m_t<<endl;
        cout<<"pressure: "<<m_p<<endl;
        cout<<"_____"<<endl;
    }

    void update(float h, float t, float p)
    {
        m_h = h;
        m_t = t;
        m_p = p;
    }

private:
    float m_h;
    float m_t;
    float m_p;
    ParaWeatherData& m_data;
};

// A Concrete Observer
class StatisticBoard : public ObserverBoardInterface, public DisplayBoardInterface
{
public:
    StatisticBoard(ParaWeatherData& a):m_maxt(-1000),m_mint(1000),m_avet(0),m_count(0),m_data(a)
    {
        m_data.registerOb(this);
    }

    void show()
    {
        cout<<"____StatisticBoard____"<<endl;
        cout<<"lowest temperature: "<<m_mint<<endl;
        cout<<"highest temperature: "<<m_maxt<<endl;
        cout<<"average temperature: "<<m_avet<<endl;
        cout<<"_____"<<endl;
    }

    void update(float h, float t, float p)

```



```

    {
        ++m_count;
        if (t>m_maxt)
        {
            m_maxt = t;
        }
        if (t<m_mint)
        {
            m_mint = t;
        }
        m_ave = (m_ave * (m_count-1) + t)/m_count;
    }

private:
    float m_maxt;
    float m_mint;
    float m_ave;
    int m_count;
    ParaWeatherData& m_data;
};

int main(int argc, char *argv[])
{
    ParaWeatherData * wdata = new ParaWeatherData;
    CurrentConditionBoard* currentB = new CurrentConditionBoard(*wdata);
    StatisticBoard* statisticB = new StatisticBoard(*wdata);

    wdata->SensorDataChange(10.2, 28.2, 1001);
    wdata->SensorDataChange(12, 30.12, 1003);
    wdata->SensorDataChange(10.2, 26, 806);
    wdata->SensorDataChange(10.3, 35.9, 900);

    wdata->removeOb(currentB);

    wdata->SensorDataChange(100, 40, 1900);

    delete statisticB;
    delete currentB;
    delete wdata;

    return 0;
}

```

State

The State Pattern allows an object to alter its behavior when its internal state changes. The object will appear as having changed its class.

```

#include <iostream>
#include <string>
#include <cstdlib>
#include <ctime>
#include <memory>

enum Input {DUCK_DOWN, STAND_UP, JUMP, DIVE};

class Fighter;
class StandingState; class JumpingState; class DivingState;

class FighterState {
public:
    static std::shared_ptr<StandingState> standing;
    static std::shared_ptr<DivingState> diving;
    virtual ~FighterState() = default;
    virtual void handleInput (Fighter&, Input) = 0;
    virtual void update (Fighter&) = 0;
};

```

```

class DuckingState : public FighterState {
private:
    int chargingTime;
    static const int FullRestTime = 5;
public:
    DuckingState() : chargingTime(0) {}
    virtual void handleInput (Fighter&, Input) override;
    virtual void update (Fighter&) override;
};

class StandingState : public FighterState {
public:
    virtual void handleInput (Fighter&, Input) override;
    virtual void update (Fighter&) override;
};

class JumpingState : public FighterState {
private:
    int jumpingHeight;
public:
    JumpingState() {jumpingHeight = std::rand() % 5 + 1;}
    virtual void handleInput (Fighter&, Input) override;
    virtual void update (Fighter&) override;
};

class DivingState : public FighterState {
public:
    virtual void handleInput (Fighter&, Input) override;
    virtual void update (Fighter&) override;
};

std::shared_ptr<StandingState> FighterState::standing (new StandingState);
std::shared_ptr<DivingState> FighterState::diving (new DivingState);

class Fighter {
private:
    std::string name;
    std::shared_ptr<FighterState> state;
    int fatigueLevel = std::rand() % 10;
public:
    Fighter (const std::string& newName) : name (newName), state (FighterState::standing) {}
    std::string getName() const {return name;}
    int getFatigueLevel() const {return fatigueLevel;}
    virtual void handleInput (Input input) {state->handleInput (*this, input);} // delegate input
    handling to 'state'.
    void changeState (std::shared_ptr<FighterState> newState) {state = newState; updateWithNewState();}
    void standsUp() {std::cout << getName() << " stands up." << std::endl;}
    void ducksDown() {std::cout << getName() << " ducks down." << std::endl;}
    void jumps() {std::cout << getName() << " jumps into the air." << std::endl;}
    void dives() {std::cout << getName() << " makes a dive attack in the middle of the jump!" <<
std::endl;}
    void feelsStrong() {std::cout << getName() << " feels strong!" << std::endl;}
    void changeFatigueLevelBy (int change) {fatigueLevel += change; std::cout << "fatigueLevel = " <<
fatigueLevel << std::endl;}
private:
    virtual void updateWithNewState() {state->update(*this);} // delegate updating to 'state'
};

void StandingState::handleInput (Fighter& fighter, Input input) {
    switch (input) {
        case STAND_UP: std::cout << fighter.getName() << " remains standing." << std::endl; return;
        case DUCK_DOWN: fighter.changeState (std::shared_ptr<DuckingState> (new DuckingState)); return;
        case JUMP: fighter.jumps(); return fighter.changeState (std::shared_ptr<JumpingState> (new
JumpingState));
        default: std::cout << "One cannot do that while standing. " << fighter.getName() << " remains
standing by default." << std::endl;
    }
}

void StandingState::update (Fighter& fighter) {
    if (fighter.getFatigueLevel() > 0)
        fighter.changeFatigueLevelBy(-1);
}

```

```

void DuckingState::handleInput (Fighter& fighter, Input input) {
    switch (input) {
        case STAND_UP: fighter.changeState (FighterState::standing); return fighter.standsUp();
        case DUCK_DOWN:
            std::cout << fighter.getName() << " remains in ducking position, ";
            if (chargingTime < FullRestTime) std::cout << "recovering in the meantime." << std::endl;
            else std::cout << "fully recovered." << std::endl;
            return update (fighter);
        default:
            std::cout << "One cannot do that while ducking. " << fighter.getName() << " remains in ducking
position by default." << std::endl;
            update (fighter);
    }
}

void DuckingState::update (Fighter& fighter) {
    chargingTime++;
    std::cout << "Charging time = " << chargingTime << "." << std::endl;
    if (fighter.getFatigueLevel() > 0)
        fighter.changeFatigueLevelBy(-1);
    if (chargingTime >= FullRestTime && fighter.getFatigueLevel() <= 3)
        fighter.feelsStrong();
}

void JumpingState::handleInput (Fighter& fighter, Input input) {
    switch (input) {
        case DIVE: fighter.changeState (FighterState::diving); return fighter.dives();
        default:
            std::cout << "One cannot do that in the middle of a jump. " << fighter.getName() << " lands
from his jump and is now standing again." << std::endl;
            fighter.changeState (FighterState::standing);
    }
}

void JumpingState::update (Fighter& fighter) {
    std::cout << fighter.getName() << " has jumped " << jumpingHeight << " feet into the air." << std::endl;
    if (jumpingHeight >= 3)
        fighter.changeFatigueLevelBy(1);
}

void DivingState::handleInput (Fighter& fighter, Input) {
    std::cout << "Regardless of what the user input is, " << fighter.getName() << " lands from his dive and
is now standing again." << std::endl;
    fighter.changeState (FighterState::standing);
}

void DivingState::update (Fighter& fighter) {
    fighter.changeFatigueLevelBy(2);
}

int main() {
    std::srand(std::time(nullptr));
    Fighter rex ("Rex the Fighter"), borg ("Borg the Fighter");
    std::cout << rex.getName() << " and " << borg.getName() << " are currently standing." << std::endl;
    int choice;
    auto chooseAction = [&choice](Fighter& fighter) {
+ 1      std::cout << std::endl << DUCK_DOWN + 1 << ") Duck down " << STAND_UP + 1 << ") Stand up " << JUMP
        << ") Jump " << DIVE + 1 << ") Dive in the middle of a jump" << std::endl;
        std::cout << "Choice for " << fighter.getName() << "? ";
        std::cin >> choice;
        const Input input1 = static_cast<Input>(choice - 1);
        fighter.handleInput (input1);
    };
    while (true) {
        chooseAction (rex);
        chooseAction (borg);
    }
}

```

Strategy

Defines a family of algorithms, encapsulates each one, and make them interchangeable. Strategy lets the algorithm vary independently from clients who use it.

```
#include <iostream>
using namespace std;

class StrategyInterface
{
public:
    virtual void execute() const = 0;
};

class ConcreteStrategyA: public StrategyInterface
{
public:
    void execute() const override
    {
        cout << "Called ConcreteStrategyA execute method" << endl;
    }
};

class ConcreteStrategyB: public StrategyInterface
{
public:
    void execute() const override
    {
        cout << "Called ConcreteStrategyB execute method" << endl;
    }
};

class ConcreteStrategyC: public StrategyInterface
{
public:
    void execute() const override
    {
        cout << "Called ConcreteStrategyC execute method" << endl;
    }
};

class Context
{
private:
    StrategyInterface * strategy_;

public:
    explicit Context(StrategyInterface *strategy):strategy_(strategy)
    {
    }

    void set_strategy(StrategyInterface *strategy)
    {
        strategy_ = strategy;
    }

    void execute() const
    {
        strategy_->execute();
    }
};

int main(int argc, char *argv[])
{
    ConcreteStrategyA concreteStrategyA;
    ConcreteStrategyB concreteStrategyB;
    ConcreteStrategyC concreteStrategyC;

    Context contextA(&concreteStrategyA);
    Context contextB(&concreteStrategyB);
    Context contextC(&concreteStrategyC);

    contextA.execute(); // output: "Called ConcreteStrategyA execute method"
    contextB.execute(); // output: "Called ConcreteStrategyB execute method"
    contextC.execute(); // output: "Called ConcreteStrategyC execute method"
```

```

contextA.set_strategy(&concreteStrategyB);
contextA.execute(); // output: "Called ConcreteStrategyB execute method"
contextA.set_strategy(&concreteStrategyC);
contextA.execute(); // output: "Called ConcreteStrategyC execute method"

return 0;
}

```

Template Method

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

```

#include <ctime>
#include <assert.h>
#include <iostream>

namespace wikibooks_design_patterns
{
    /**
     * An abstract class that is common to several games in
     * which players play against the others, but only one is
     * playing at a given time.
     */

    class Game
    {
    public:
        Game(): playersCount(0), movesCount(0), playerWon(-1)
        {
            srand( (unsigned)time( NULL));
        }

        /* A template method : */
        void playOneGame(const int playersCount = 0)
        {
            if (playersCount)
            {
                this->playersCount = playersCount;

                InitializeGame();
                assert(this->playersCount);

                int j = 0;
                while (!endOfGame())
                {
                    makePlay(j);
                    j = (j + 1) % this->playersCount;
                    if (!j)
                    {
                        ++movesCount;
                    }
                }
                printWinner();
            }

        protected:
            virtual void initializeGame() = 0;
            virtual void makePlay(int player) = 0;
            virtual bool endOfGame() = 0;
            virtual void printWinner() = 0;

        private:
            void InitializeGame()
            {
                movesCount = 0;
                playerWon = -1;
            }
        }
    }

```

```

        initializeGame();
    }

protected:
    int playersCount;
    int movesCount;
    int playerWon;
};

//Now we can extend this class in order
//to implement actual games:

class Monopoly: public Game {

    /* Implementation of necessary concrete methods */
    void initializeGame() {
        // Initialize players
        playersCount = rand() * 7 / RAND_MAX + 2;
        // Initialize money
    }
    void makePlay(int player) {
        // Process one turn of player

        // Decide winner
        if (movesCount < 20)
            return;
        const int chances = (movesCount > 199) ? 199 : movesCount;
        const int random = MOVES_WIN_CORRECTION * rand() * 200 / RAND_MAX;
        if (random < chances)
            playerWon = player;
    }
    bool endOfGame() {
        // Return true if game is over
        // according to Monopoly rules
        return (-1 != playerWon);
    }
    void printWinner() {
        assert(playerWon >= 0);
        assert(playerWon < playersCount);

        // Display who won
        std::cout<<"Monopoly, player "<<playerWon<<" won in "<<movesCount<<" moves."<<std::endl;
    }

private:
    enum
    {
        MOVES_WIN_CORRECTION = 20,
    };
};

class Chess: public Game {

    /* Implementation of necessary concrete methods */
    void initializeGame() {
        // Initialize players
        playersCount = 2;
        // Put the pieces on the board
    }
    void makePlay(int player) {
        assert(player < playersCount);

        // Process a turn for the player

        // decide winner
        if (movesCount < 2)
            return;
        const int chances = (movesCount > 99) ? 99 : movesCount;
        const int random = MOVES_WIN_CORRECTION * rand() * 100 / RAND_MAX;
        //std::cout<<random<<" : "<<chances<<std::endl;
        if (random < chances)
            playerWon = player;
    }
    bool endOfGame() {
        // Return true if in Checkmate or

```

```

        // Stalemate has been reached
    return (-1 != playerWon);
}
void printWinner() {
    assert(playerWon >= 0);
    assert(playerWon < playersCount);

    // Display the winning player
    std::cout<<"Player "<<playerWon<<" won in "<<movesCount<<" moves."<<std::endl;
}

private:
    enum
    {
        MOVES_WIN_CORRECTION = 7,
    };
};

}

int main()
{
    using namespace wikibooks_design_patterns;

    Game* game = NULL;

    Chess chess;
    game = &chess;
    for (unsigned i = 0; i < 100; ++i)
        game->playOneGame();

    Monopoly monopoly;
    game = &monopoly;
    for (unsigned i = 0; i < 100; ++i)
        game->playOneGame();

    return 0;
}

```

Visitor

The Visitor Pattern will represent an operation to be performed on the elements of an object structure by letting you define a new operation without changing the classes of the elements on which it operates.

```

#include <string>
#include <iostream>
#include <vector>

using namespace std;

class Wheel;
class Engine;
class Body;
class Car;

// interface to all car 'parts'
struct CarElementVisitor
{
    virtual void visit(Wheel& wheel) const = 0;
    virtual void visit(Engine& engine) const = 0;
    virtual void visit(Body& body) const = 0;

    virtual void visitCar(Car& car) const = 0;
    virtual ~CarElementVisitor() {};
};

// interface to one part
struct CarElement
{
    virtual void accept(const CarElementVisitor& visitor) = 0;
}

```

```

    virtual ~CarElement() {}
};

// wheel element, there are four wheels with unique names
class Wheel : public CarElement
{
public:
    explicit Wheel(const string& name) :
        name_(name)
    {
    }
    const string& getName() const
    {
        return name_;
    }
    void accept(const CarElementVisitor& visitor)
    {
        visitor.visit(*this);
    }
private:
    string name_;
};

// engine
class Engine : public CarElement
{
public:
    void accept(const CarElementVisitor& visitor)
    {
        visitor.visit(*this);
    }
};

// body
class Body : public CarElement
{
public:
    void accept(const CarElementVisitor& visitor)
    {
        visitor.visit(*this);
    }
};

// car, all car elements(parts) together
class Car
{
public:
    vector<CarElement*>& getElements()
    {
        return elements_;
    }
    Car()
    {
        // assume that neither push_back nor Wheel(const string&) may throw
        elements_.push_back( new Wheel("front left") );
        elements_.push_back( new Wheel("front right") );
        elements_.push_back( new Wheel("back left") );
        elements_.push_back( new Wheel("back right") );
        elements_.push_back( new Body() );
        elements_.push_back( new Engine() );
    }
    ~Car()
    {
        for(vector<CarElement*>::iterator it = elements_.begin();
            it != elements_.end(); ++it)
        {
            delete *it;
        }
    }
private:
    vector<CarElement*> elements_;
};

// PrintVisitor and DoVisitor show by using a different implementation the Car class is unchanged
// even though the algorithm is different in PrintVisitor and DoVisitor.

```



```

class CarElementPrintVisitor : public CarElementVisitor
{
public:
    void visit(Wheel& wheel) const
    {
        cout << "Visiting " << wheel.getName() << " wheel" << endl;
    }
    void visit(Engine& engine) const
    {
        cout << "Visiting engine" << endl;
    }
    void visit(Body& body) const
    {
        cout << "Visiting body" << endl;
    }
    void visitCar(Car& car) const
    {
        cout << endl << "Visiting car" << endl;
        vector<CarElement*>& elems = car.getElements();
        for(vector<CarElement*>::iterator it = elems.begin();
            it != elems.end(); ++it )
        {
            (*it)->accept(*this); // this issues the callback i.e. to this from the element
        }
        cout << "Visited car" << endl;
    }
};

class CarElementDoVisitor : public CarElementVisitor
{
public:
    // these are specific implementations added to the original object without modifying the original struct
    void visit(Wheel& wheel) const
    {
        cout << "Kicking my " << wheel.getName() << " wheel" << endl;
    }
    void visit(Engine& engine) const
    {
        cout << "Starting my engine" << endl;
    }
    void visit(Body& body) const
    {
        cout << "Moving my body" << endl;
    }
    void visitCar(Car& car) const
    {
        cout << endl << "Starting my car" << endl;
        vector<CarElement*>& elems = car.getElements();
        for(vector<CarElement*>::iterator it = elems.begin();
            it != elems.end(); ++it )
        {
            (*it)->accept(*this); // this issues the callback i.e. to this from the element
        }
        cout << "Stopped car" << endl;
    }
};

int main()
{
    Car car;
    CarElementPrintVisitor printVisitor;
    CarElementDoVisitor doVisitor;

    printVisitor.visitCar(car);
    doVisitor.visitCar(car);

    return 0;
}

```

Model-View-Controller (MVC)

A pattern often used by applications that need the ability to maintain multiple views of the same data. The model-view-controller pattern was until recently^[*citation needed*] a very common pattern especially for graphic user interlace programming, it splits the code in 3 pieces. The model, the view, and the controller.

The Model is the actual data representation (for example, Array vs Linked List) or other objects representing a database. The View is an interface to reading the model or a fat client GUI. The Controller provides the interface of changing or modifying the data, and then selecting the "Next Best View" (NBV).

Newcomers will probably see this "MVC" model as wasteful, mainly because you are working with many extra objects at runtime, when it seems like one giant object will do. But the secret to the MVC pattern is not writing the code, but in maintaining it, and allowing people to modify the code without changing much else. Also, keep in mind, that different developers have different strengths and weaknesses, so team building around MVC is easier. Imagine a View Team that is responsible for great views, a Model Team that knows a lot about data, and a Controller Team that see the big picture of application flow, handing requests, working with the model, and selecting the most appropriate next view for that client.

For example: A naive central database can be organized using only a "model", for example, a straight array. However, later on, it may be more applicable to use a linked list. All array accesses will have to be remade into their respective Linked List form (for example, you would change myarray[5] into mylist.at(5) or whatever is equivalent in the language you use).

Well, if we followed the MVC pattern, the central database would be accessed using some sort of a function, for example, myarray.at(5). If we change the model from an array to a linked list, all we have to do is change the view with the model, and the whole program is changed. Keep the interface the same but change the underpinnings of it. This would allow us to make optimizations more freely and quickly than before.

One of the great advantages of the Model-View-Controller Pattern is obviously the ability to reuse the application's logic (which is implemented in the model) when implementing a different view. A good example is found in web development, where a common task is to implement an external API inside of an existing piece of software. If the MVC pattern has cleanly been followed, this only requires modification to the controller, which can have the ability to render different types of views dependent on the content type requested by the user agent.

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