Object Oriented Software Design II

Real Application Design

Christian Nastasi
http://retis.sssup.it/~lipari
http://retis.sssup.it/~chris/cpp

Scuola Superiore Sant'Anna – Pisa

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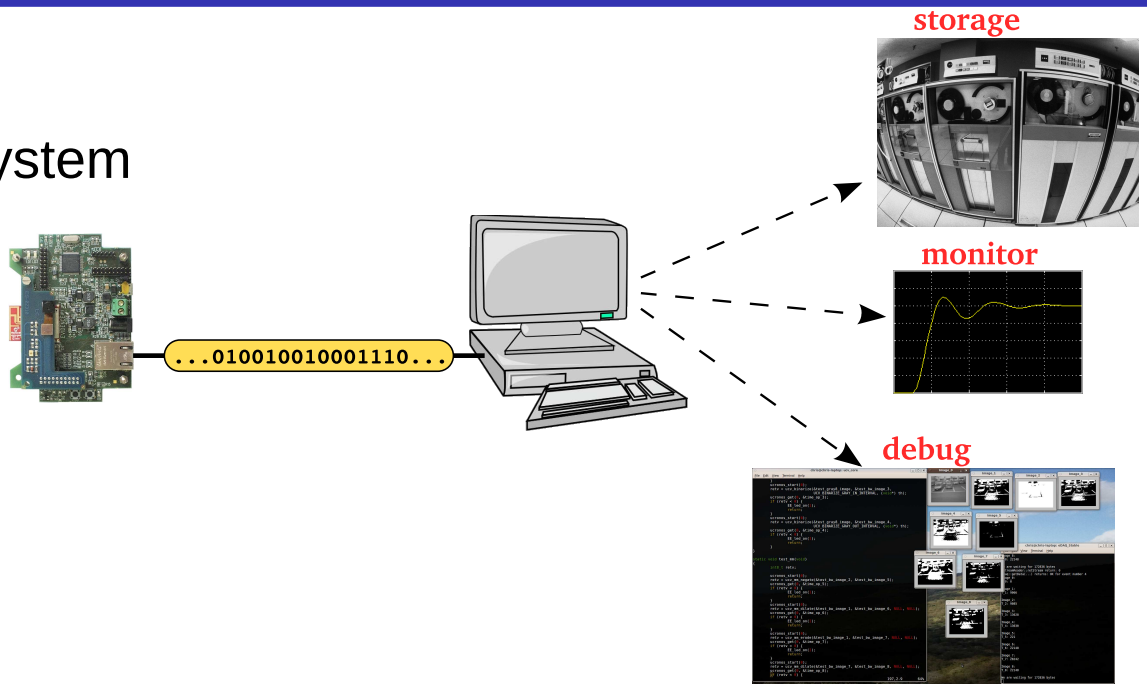
Outline

Outline

Data AcQuisition System

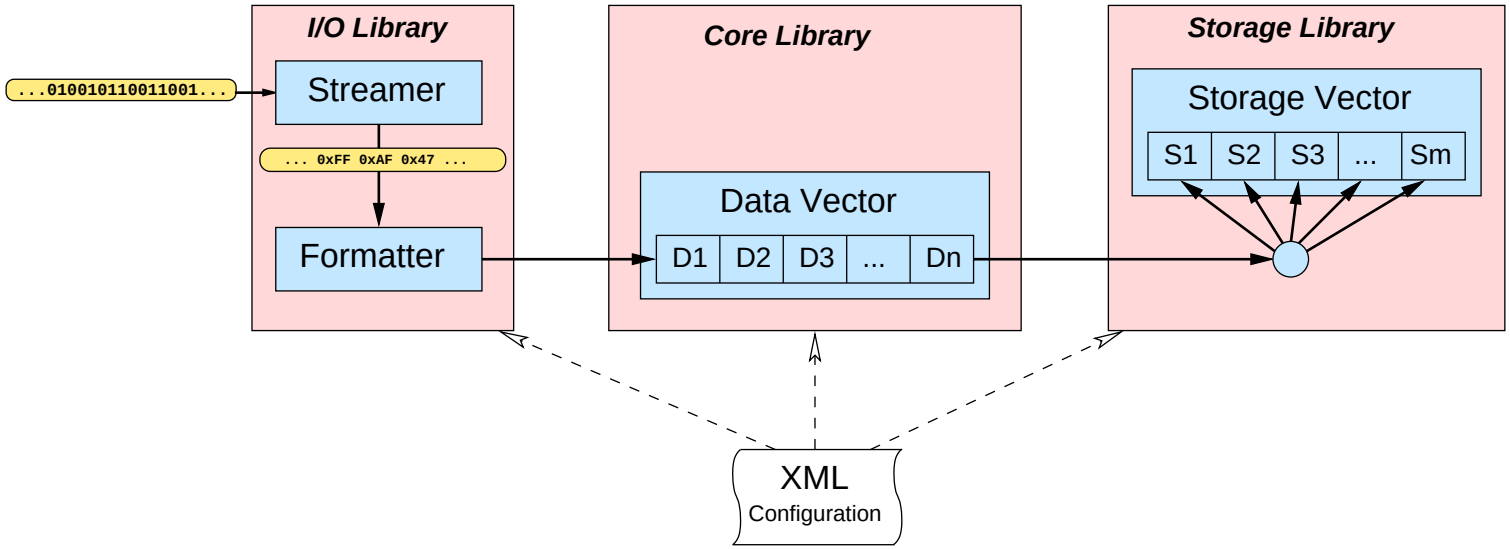
A basic DAQ system



duck-lab: an open-source DAQ framework

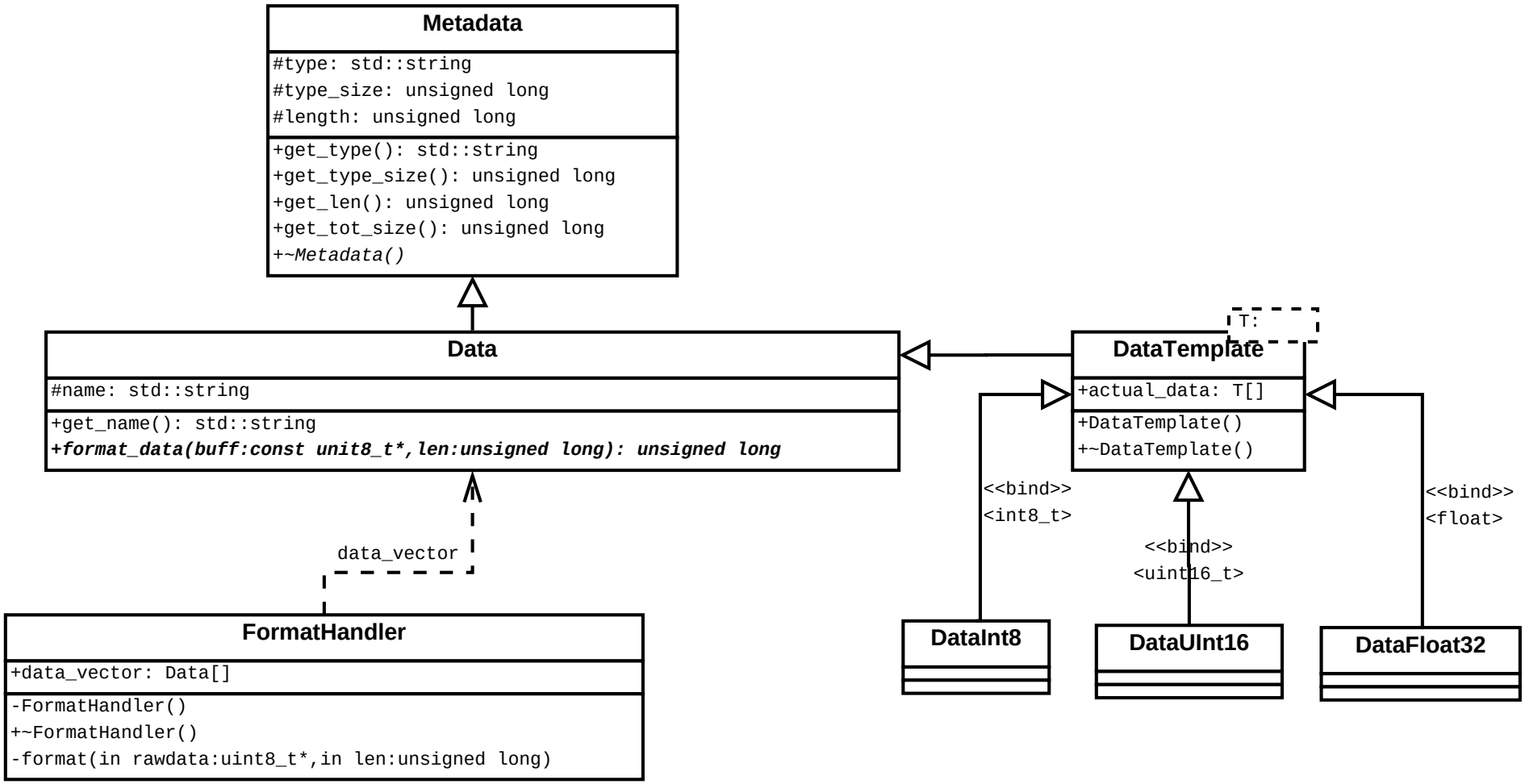
- Project (temporary) home page:
  `http://retis.sssup.it/~chris/duck-lab`
- Mercurial revision control: `https://rtn.sssup.it/hg/duck-lab`
  `(hg clone https://rtn.sssup.it/hg/duck-lab)`

duck-lab architecture



- We have defined a hierarchy for `Data`
- We have defined the interaction with the Formatter, implemented by the `FormatHandler` class

duck-lab architecture



The `FormatHandler` class

- We have done `Data` creation/destruction
- We have done `Data` formatting

```
class FormatHandler {
public:
    FormatHandler();
    ~FormatHandler();
    void format(const uint8_t* rawdata,
                unsigned long len);
private:
    std::vector<Data*> data_vector;
};
```

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Switch-based concrete object allocation (bad)

Polymorphic destruction (good!)

Polymorphic formatting with delegation to the `Data` classes (good!)

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Switch-based concrete object allocation (bad)

Polymorphic destruction (good!)

Polymorphic formatting with delegation to the `Data` classes (good!)

- So, given the following configuration (XML)

```
<message_description>
   <data data_type="uint16"  data_name="data_name_1" data_len="2"/>
   <data data_type="float32" data_name="data_name_2" data_len="1"/>
   <data data_type="int8"    data_name="data_name_3" data_len="4"/>
</message_description>
```

FormatHandler::FormatHandler()

DataExample3.cc

```
FormatHandler::FormatHandler()
{
        // We create the data vector according to XML config
        vector<XmlDataElement> config = parse_xml_data();

        vector<XmlDataElement>::const_iterator it;
        for (it = config.begin(); it != config.end(); ++it) {
                Data *d;
                if (it->type == "int8")
                        d = new DataInt8(it->name, it->len);
                else if (it->type == "uint16")
                        d = new DataUInt16(it->name, it->len);
                else if (it->type == "float32")
                        d = new DataFloat32(it->name, it->len);
                else {
                        cout << "Unknown data type = '" << it->type <<
                                "' ! Skipping" << endl;
                        continue;
                }
                data_vector.push_back(d);
        }
}
```

- **Unmanageable**: adding new new data requires adding `else if`.

FormatHandler::~FormatHandler()

DataExample3.cc

```
FormatHandler::~FormatHandler()
{
        // We have to destroy the data vector properly
        vector<Data*>::iterator it;
        for (it = data_vector.begin(); it != data_vector.end(); ++it)
                delete *it;
}
```

FormatHandler::format()

DataExample3.cc

```
void FormatHandler::format(uint8_t* rawdata, unsigned long len)
{
        vector<Data*>::iterator it;
        for (it = data_vector.begin(); it != data_vector.end(); ++it) {
                unsigned long required_len = (*it)->get_tot_size();
                if (required_len > len) {
                        cout << "Not enough bytes to read Data. Returning" <<
                                endl;
                        return;
                }
                if ((*it)->get_type() == "int8") {
                        DataInt8 *d = static_cast<DataInt8*>(*it);
                        // memcpy if fine with int8
                        memcpy(d->actual_data, rawdata, required_len);
                } else if ((*it)->get_type() == "uint16") {
                        DataUInt16 *d = static_cast<DataUInt16*>(*it);
                        // Fix endianess before memcpy!
                        memcpy(d->actual_data, rawdata, required_len);
                } else if ((*it)->get_type() == "float32") {
                        DataFloat32 *d = static_cast<DataFloat32*>(*it);
                        // Fix endianess before memcpy!
                        memcpy(d->actual_data, rawdata, required_len);
                } else {
                        cout << "Unknown data type = '" << (*it)->get_type() <<
                                "' ! Skipping" << endl;
                        continue;
                }
                len -= required_len;
                rawdata += required_len;
        }
}
```

FormatHandler::format()

```
class Data : public Metadata {
//...
public:
    virtual unsigned long format_data(const uint8_t* buff, unsigned long len) = 0;
//...
};
```

DataExample4.cc

```
void FormatHandler::format(uint8_t* rawdata, unsigned long len)
{
        vector<Data*>::iterator it;
        for (it = data_vector.begin(); it != data_vector.end(); ++it) {
                unsigned long used_bytes = (*it)->format_data(rawdata, len);
                len -= used_bytes;
                rawdata += used_bytes;
        }
}
```

```
template<class T>
class DataTemplate : public Data {
//...
public:
    unsigned long format_data(const uint8_t* buff, unsigned long len)
    {
        unsigned long required_len = get_tot_size();
        if (required_len > len) {
            std::cout << "Not enough bytes to read Data." << std::endl;
            return 0;
        }
        memcpy(actual_data, buff, required_len);
        return required_len;
    };
//...
};
```

What’s next

- We’ll see how to solve the Data Vector creation problem

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- We'll see how to solve the Data Vector creation problem
- Using delegation in `FormatHandler::FormatHandler()`
- Using a design pattern: *Factory Method*

Outline

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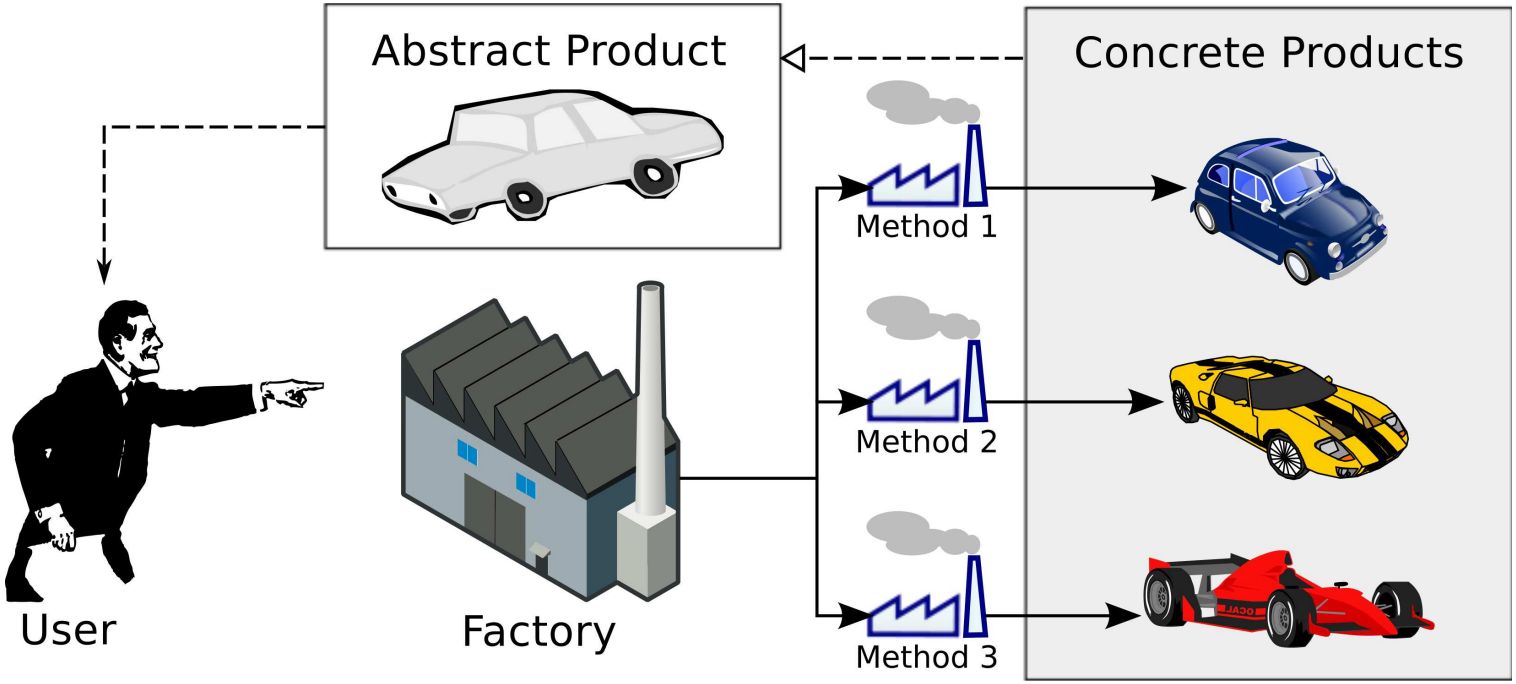
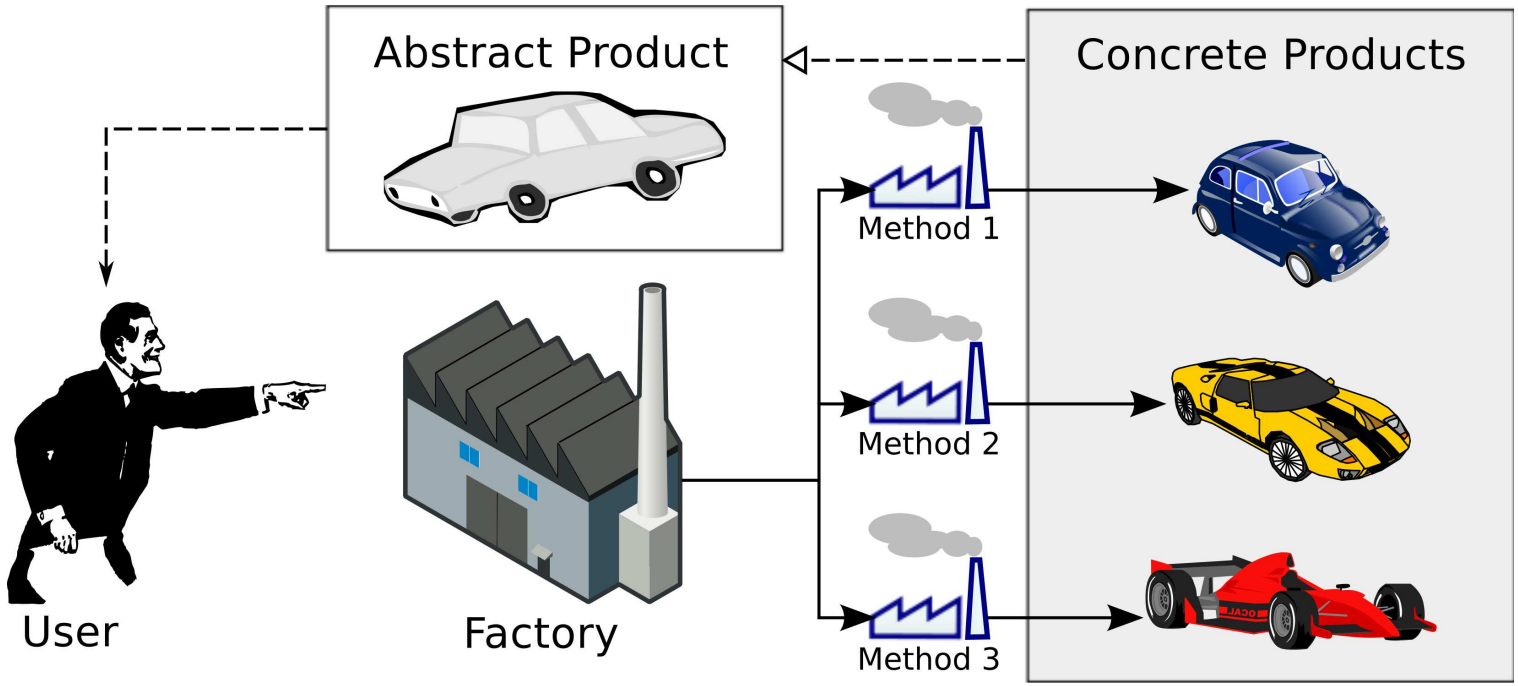
Class Factory

Creational design pattern known as *Factory Method Pattern*



Class Factory

Creational design pattern known as *Factory Method Pattern*

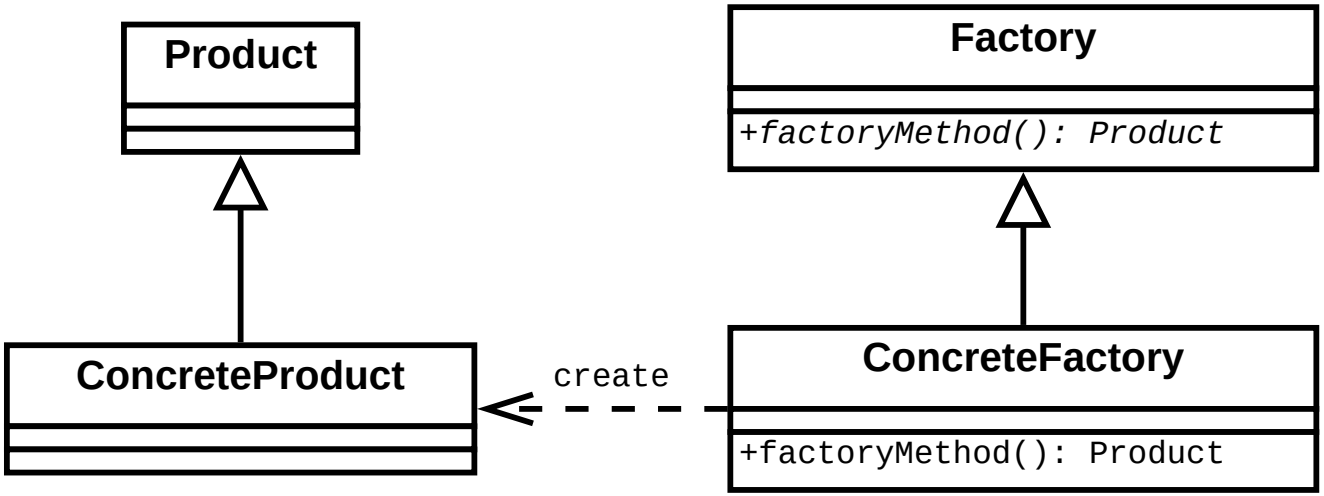


- A *factory* is the location or a concrete class in the code at which objects are constructed.
- The intent in employing the pattern is to insulate the creation of objects from their usage.
- New derived types can be introduced with no change to the code that uses the base class.

[wikipedia]

UML class diagram

The Factory Method in UML



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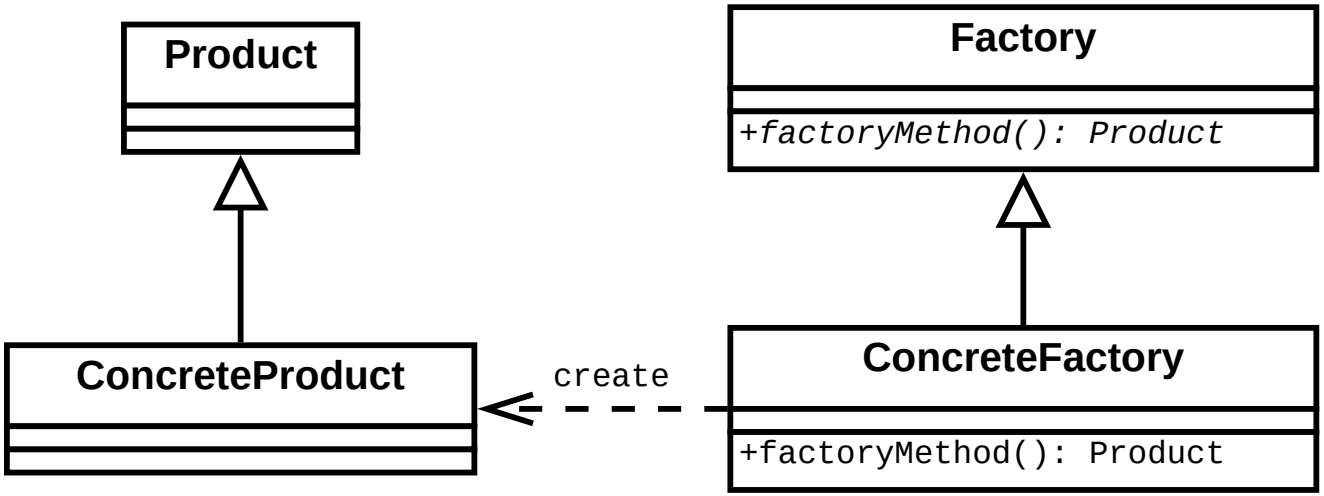

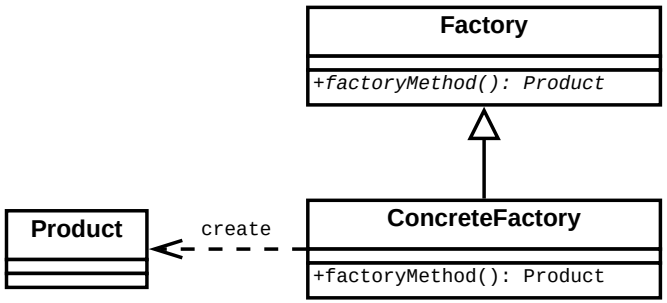

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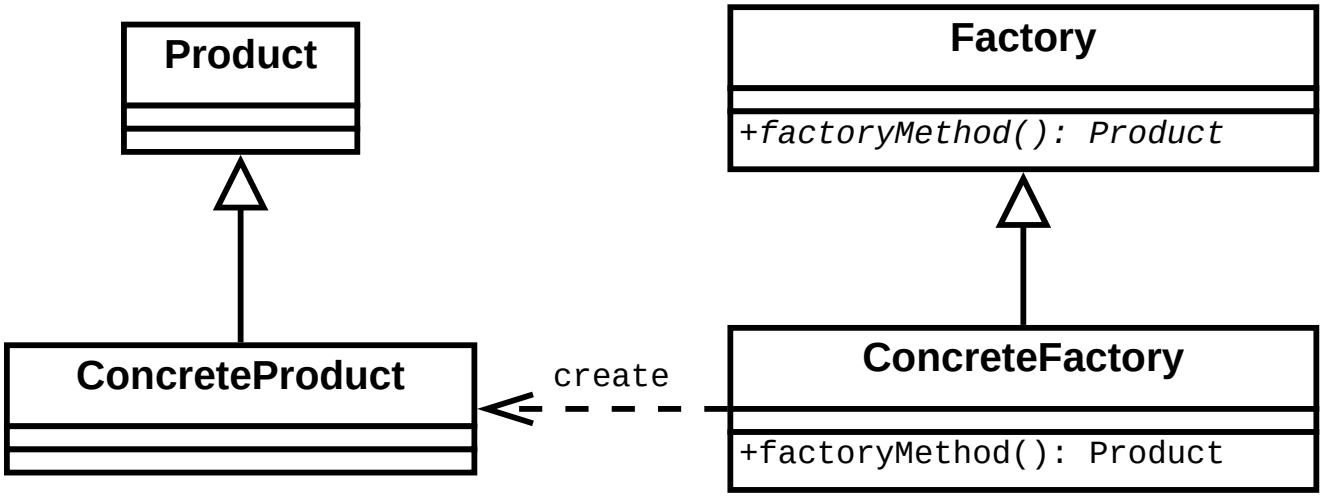

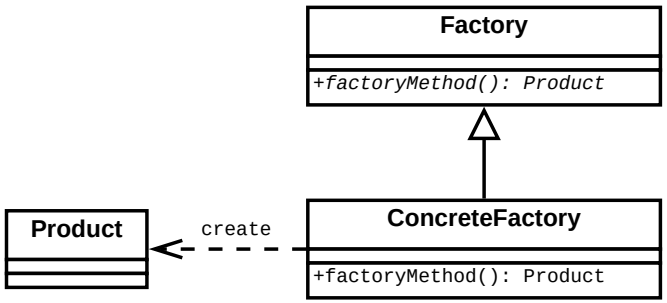

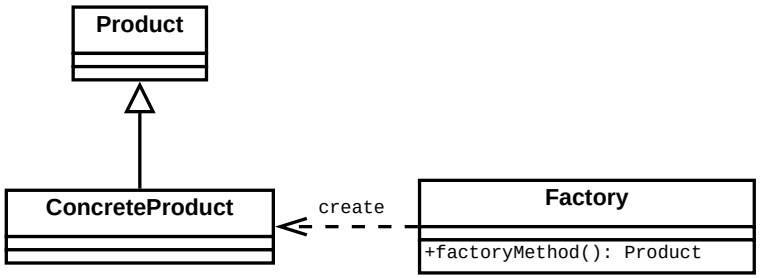

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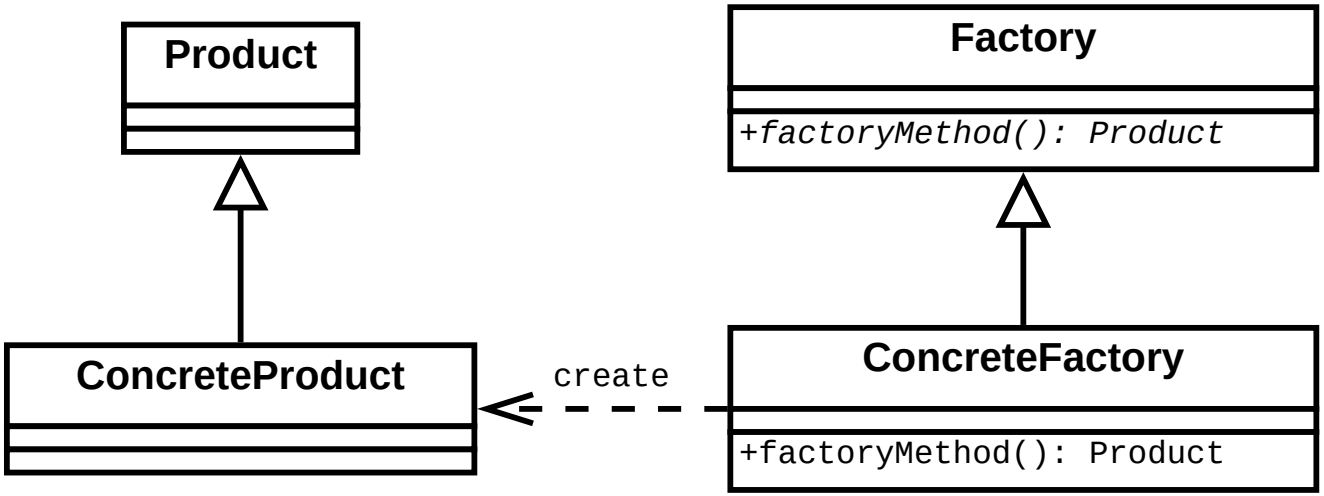
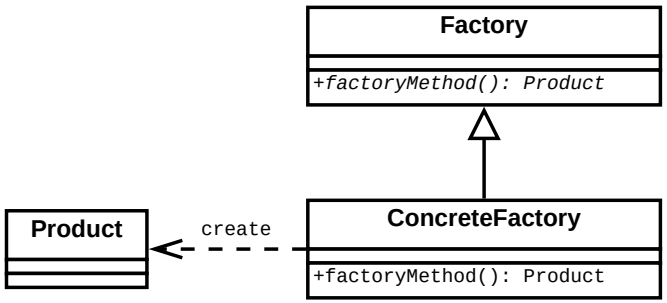
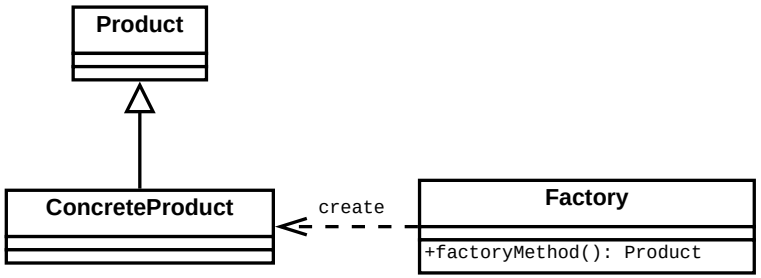
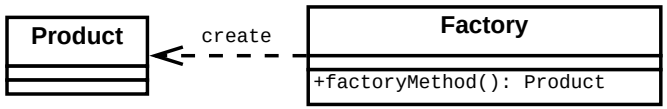




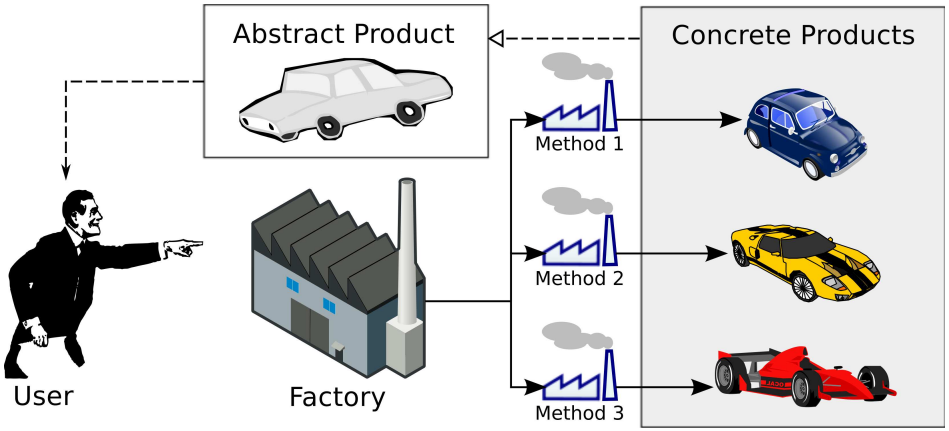




Factory Method Pattern

“Define an interface for creating an object, but let the classes which implement the interface decide which class to instantiate. The Factory method lets a class defer instantiation to subclasses.”

[Design Patterns: Elements of Reusable Object-Oriented Software]



Main benefit?

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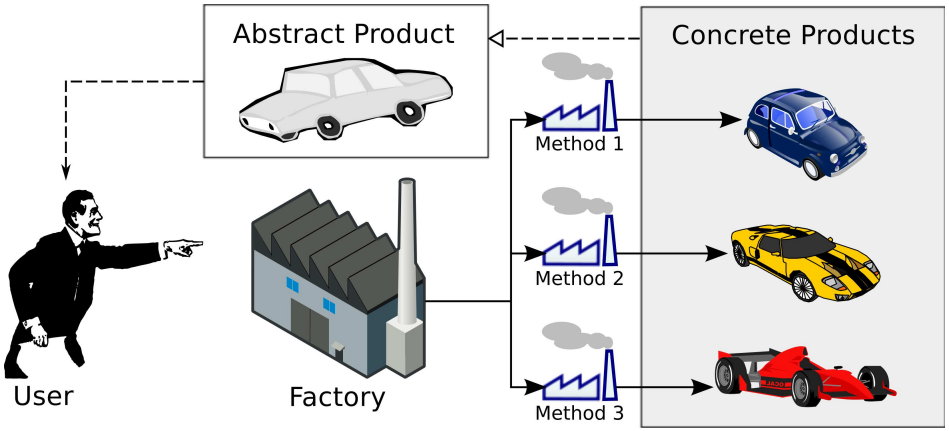

Main benefit?

- **Delegation**: the *user* does not have access to creation information.

Other benefits

Other benefits

- Named constructor idiom: factory methods rather than constructors

```
class Complex {
     Complex(double a, double b) { /*...*/ };
public:
     static Complex* fromCartesian(double r, double i) { return new Complex(r, i); }

     static Complex* fromPolar(double m, double a)
                                        {return new Complex(m * cos(a), m * sin(a)); }
}
Complex* c1 = Complex.fromPolar(1, 3.14);     // creates z = -1
Complex* c2 = Complex.fromCartesian(1, 3.14); // creates z = 1 + j3.14
```

Other benefits

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```

- Encapsulating creation: factory hides creation logic

```
class ClassFactory {
public:
    static Product* create(const std::string& file_name)
    {
        std::string type = get_type_from_file(file_name);
        if (type == "type_1") {
            new ConcreteProduct1(/*might take params*/);
        } else if (type == "type_2") {
            new ConcreteProduct2(/*might take other params*/);
        } // etc...
    }
}
Product* p = ClassFactory.create("config.xml");
```

Outline

Family of factories

- Sometimes factories might belong to the same family
- Example: the family of *vehicles*
  - *Cars*
  - *Motorcycles*
  - ...

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The abstraction of set of factories belonging to the same family is called *Abstract Factory*.

- It's a creational design pattern
- "Provide an interface for creating families of related or dependent objects without specifying their concrete classes"

[Design Patterns: Elements of Reusable Object-Oriented Software]

The Abstract Factory Pattern

Given a set of related factories...

The Abstract Factory Pattern

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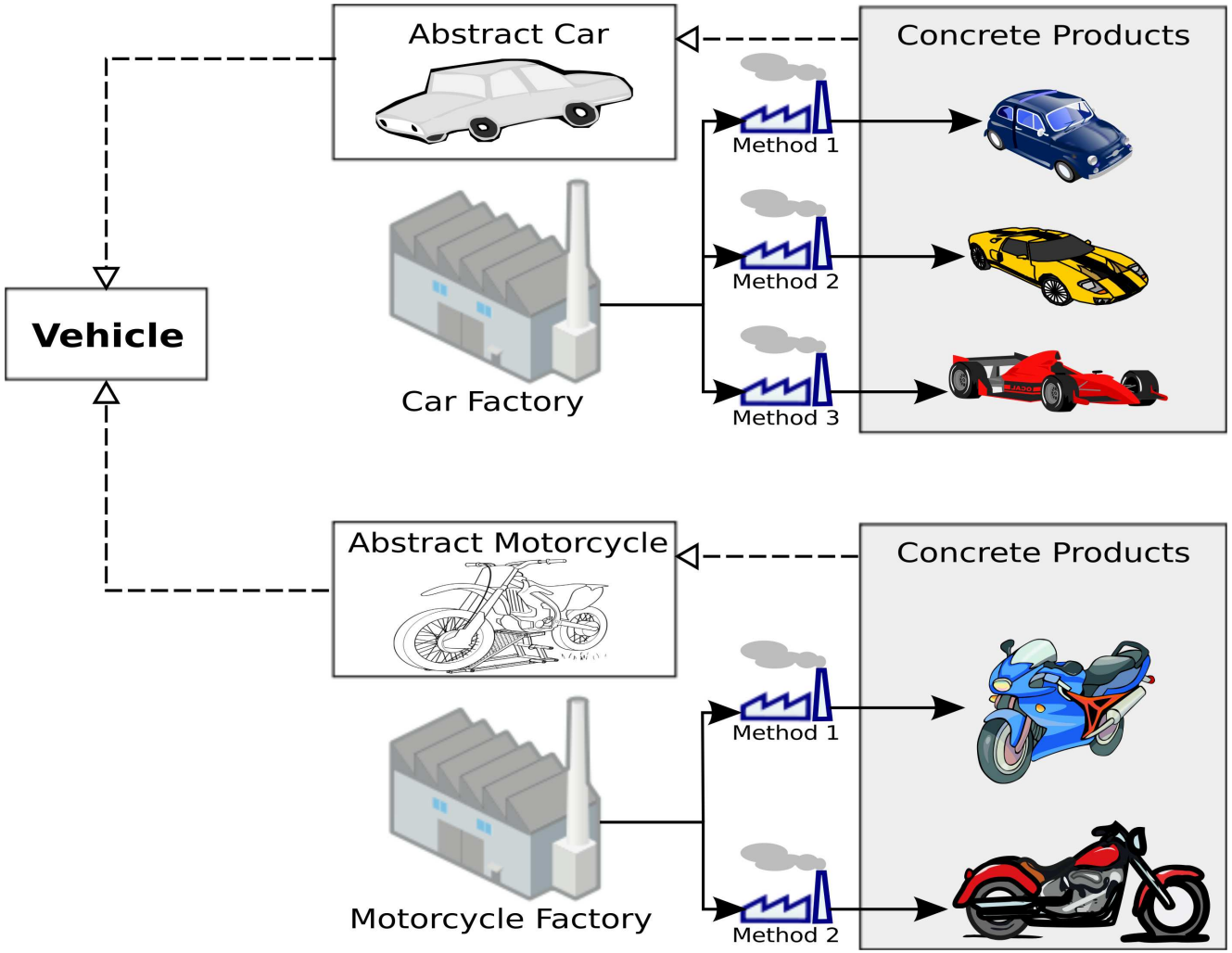

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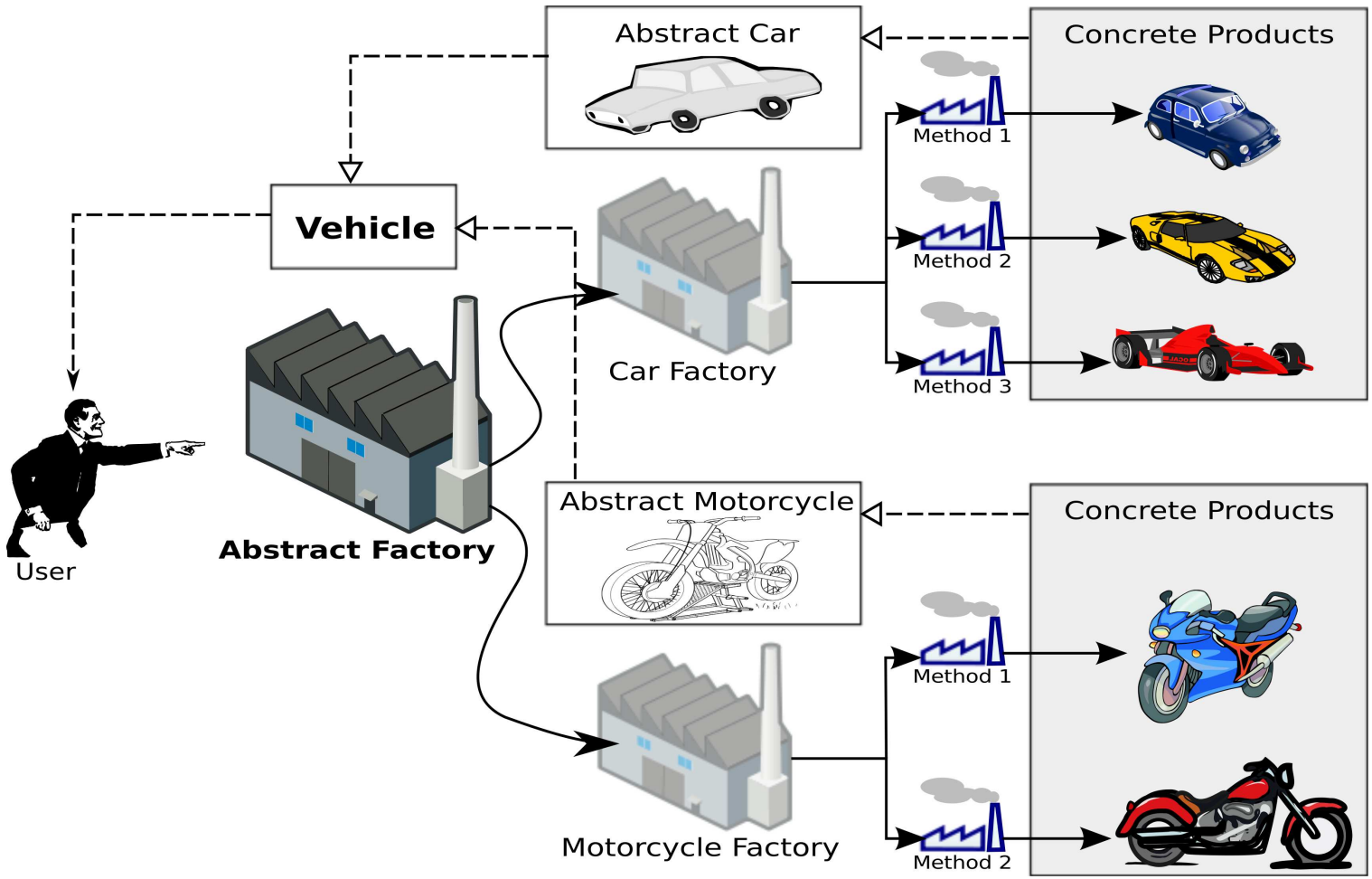
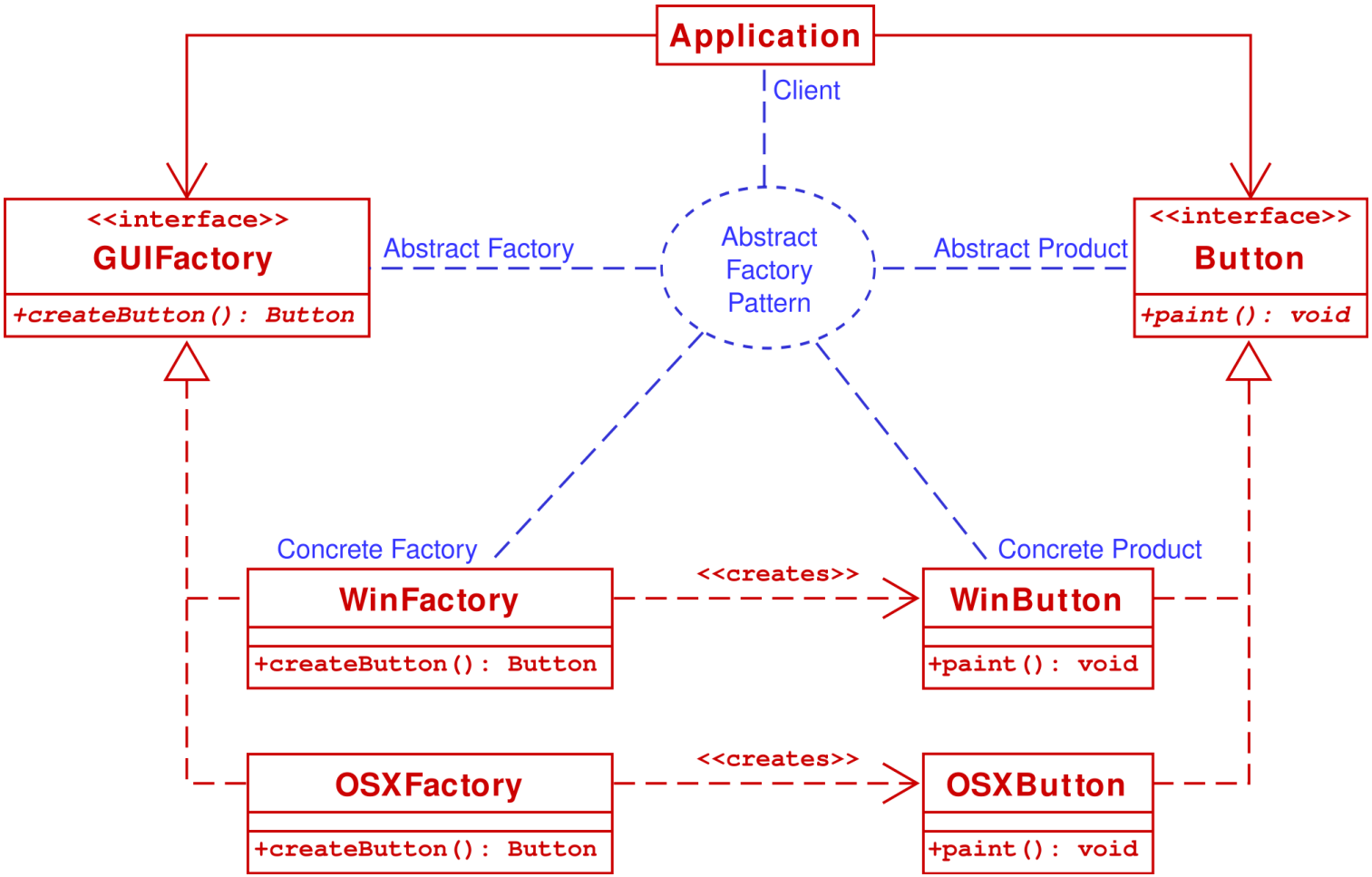


UML class diagram

The Abstract Factory in UML



[wikipedia]

Outline

Example

Let's consider the *Disney's cartoons* problem:

- The *user* wants to animate cartoons
- The *user* does not care about their creation process

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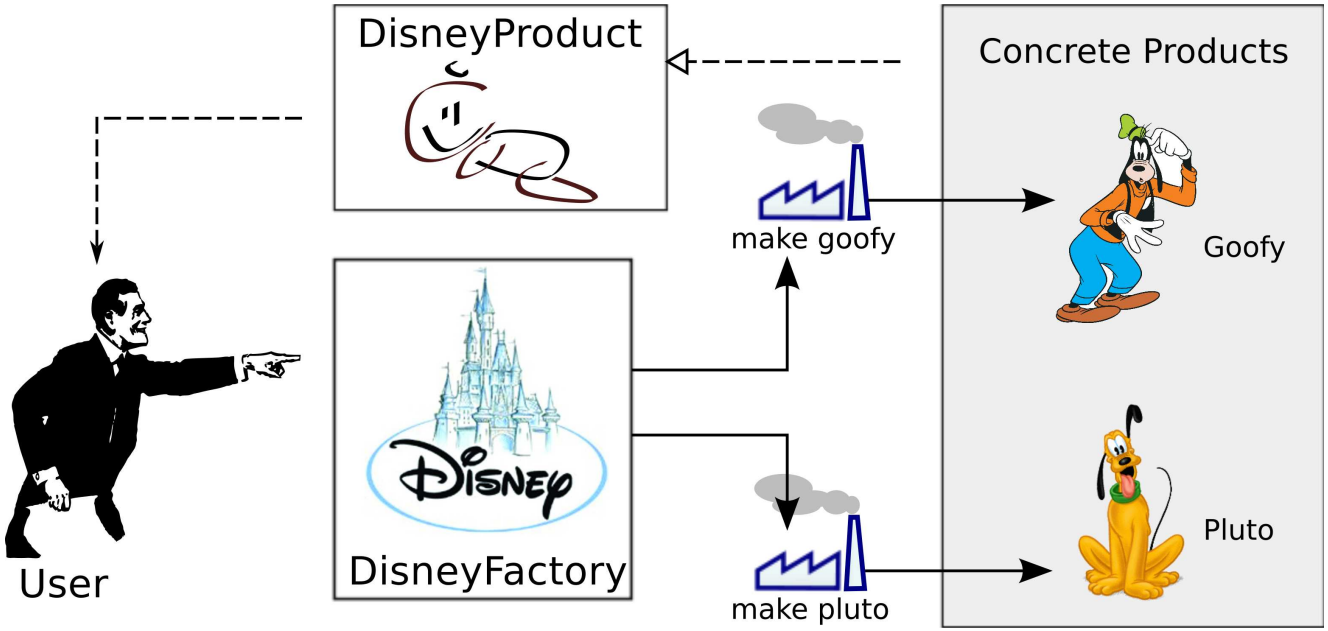
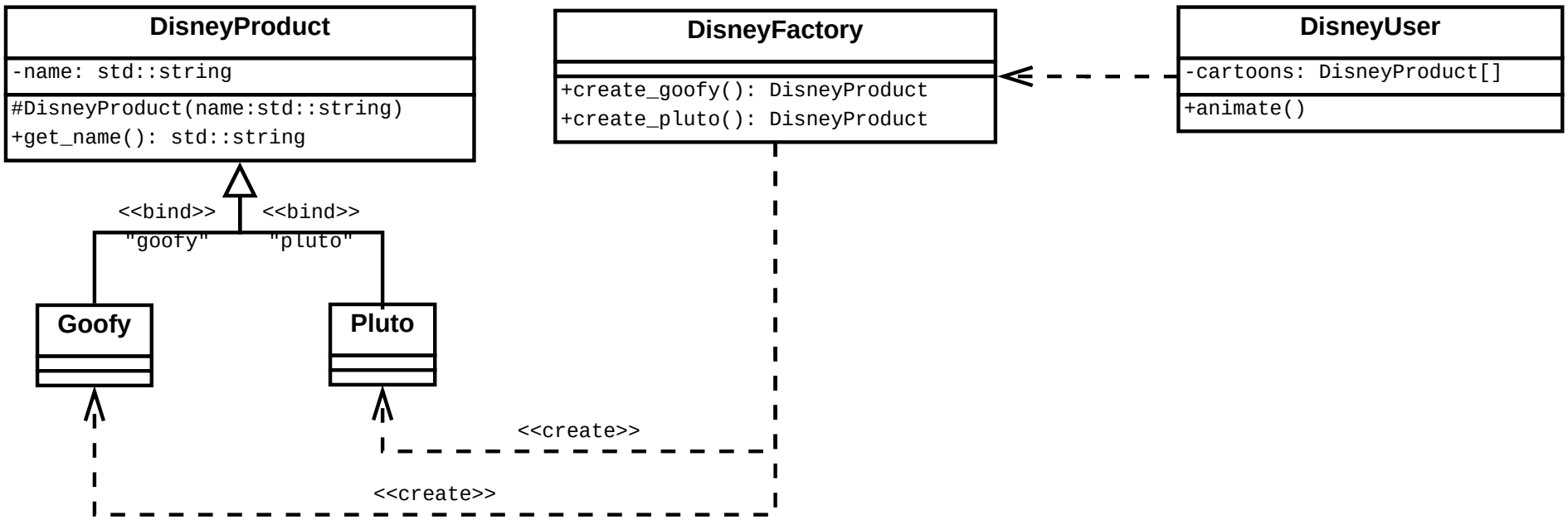


The Disney's cartoons problem

A possible solution (UML class diagram)



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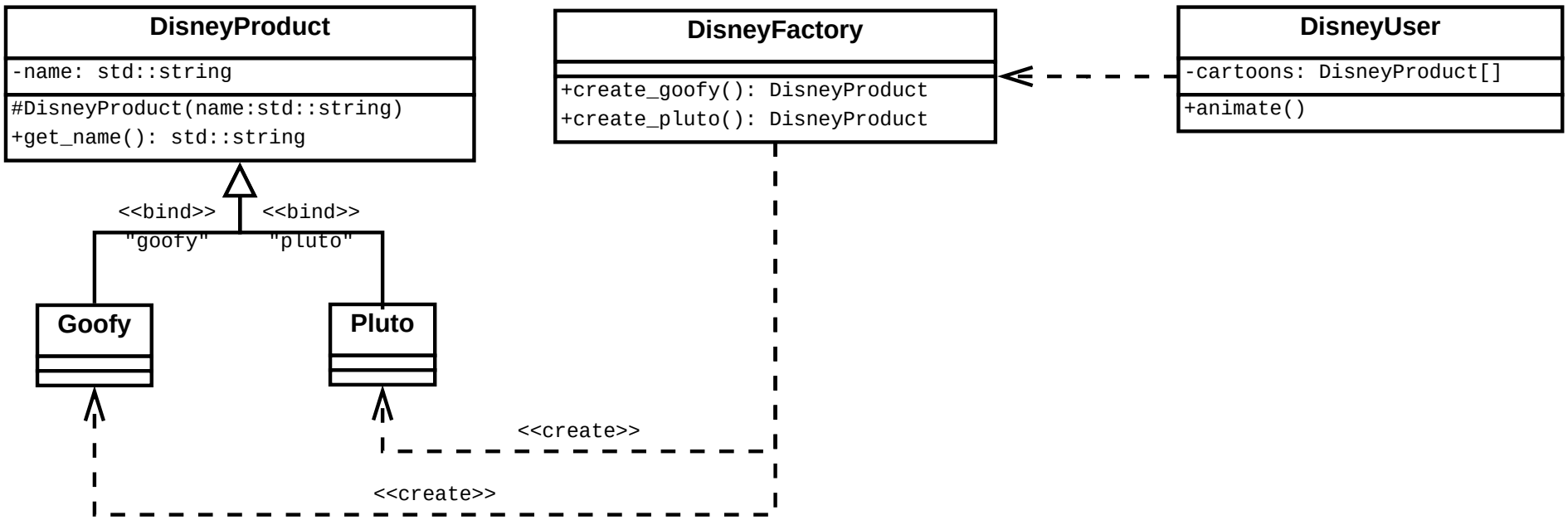

- Let's try to implement in C++
- Some requirements:
  - The creation of object is exclusively managed by the Factory
  - Delegating as much as we can (i.e. hiding to the User)

C++: DisneyProduct

FactoryExample1.h

```
class DisneyProduct {
public:
        virtual ~DisneyProduct() {};
        inline std::string get_name(void) const { return name; };
protected:
        DisneyProduct(const std::string& n) : name(n) {};
private:
        DisneyProduct(const DisneyProduct&);
        DisneyProduct &operator=(const DisneyProduct&);
        std::string name;
};
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- protected constructor: only derived class can call it
- why virtual destructor?

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```

- protected constructor: only derived class can call it
- why virtual destructor?
- why other private members?

C++: Goofy, Pluto and DisneyFactory

```
class Goofy : public DisneyProduct {
    Goofy() : DisneyProduct("goofy") {};
};

class Pluto : public DisneyProduct {
    Pluto() : DisneyProduct("pluto") {};
};
```

```
class DisneyFactory {
public:
    DisneyProduct* create_goofy(void) { return new Goofy(); }
    DisneyProduct* create_pluto(void) { return new Pluto(); }
};
```

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- **Problem**: does not compile, why?
- `Goofy::Goofy()` and `Pluto::Pluto()` are private, hidden to `DisneyFactory`.

C++: Goofy, Pluto and DisneyFactory

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class Goofy : public DisneyProduct {
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    Pluto() : DisneyProduct("pluto") {};
};
```

```
class DisneyFactory {
public:
    DisneyProduct* create_goofy(void) { return new Goofy(); }
    DisneyProduct* create_pluto(void) { return new Pluto(); }
};
```

- **Problem**: does not compile, why?
- `Goofy::Goofy()` and `Pluto::Pluto()` are private, hidden to `DisneyFactory`.
- **Solution**: using *friendship*

C++: friendly Goofy and Pluto

After all, Goofy and Pluto are Disney's friends :)

FactoryExample1.h

```
class Goofy : public DisneyProduct {
private:
        Goofy() : DisneyProduct("goofy") {};
        friend class DisneyFactory;
};

class Pluto : public DisneyProduct {
private:
        Pluto() : DisneyProduct("pluto") {};
        friend class DisneyFactory;
};
```

This is now valid!

```
class DisneyFactory {
public:
    DisneyProduct* create_goofy(void) { return new Goofy(); }
    DisneyProduct* create_pluto(void) { return new Pluto(); }
};
```

C++: the DisneyUser

FactoryExample1.h

```
enum DisneyCharacterID {
        GOOFY_ID = 0,
        PLUTO_ID = 1,
};
```

FactoryExample1.h

```
class DisneyUser {
public:
        DisneyUser();
        ~DisneyUser();
        void animate(void);
private:
        DisneyProduct* create_cartoon(int id);

        DisneyProduct** toons;
        size_t len_toons;
};
```

```
DisneyUser::DisneyUser()
{
    const int config[] = {GOOFY_ID, PLUTO_ID,
                          PLUTO_ID, 1234/*invalid*/};

    len_toons = 4;
    toons = new DisneyProduct*[4];
    for (size_t i = 0; i < 4; i++)
        toons[i] = create_cartoon(config[i]);
}

DisneyUser::~DisneyUser()
{
    for (size_t i = 0; i < len_toons; i++)
        if (toons[i])
            delete toons[i];
    delete[] toons;
}
```

Equivalent to a configuration file

Allocation of the cartoon container: array of `DisneyProduct*`

Delete each cartoon from the container

Delete the container itself

C++: the DisneyUser

FactoryExample1.cc

```
DisneyProduct* DisneyUser::create_cartoon(int id)
{
        DisneyFactory factory;
        switch(id) {
        case GOOFY_ID:
                return factory.create_goofy();
        case PLUTO_ID:
                return factory.create_pluto();
        }
        return NULL;
}

void DisneyUser::animate(void)
{
        for (size_t i = 0; i < len_toons; i++)
                if (toons[i])
                        cout << "Hullo, my name is " <<
                                toons[i]->get_name() << endl;
}
```

The full example is:

`./examples/09.real-application_factories-examples/FactoryExample1.c`

First improvement

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- The `DisneyProduct*` container is so old-fashioned

```
class DisneyUser {
private:
    DisneyProduct** toons;
    size_t len_toons;
//...
};
```

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```
class DisneyUser {
private:
    DisneyProduct** toons;
    size_t len_toons;
//...
};
```

- Part of the creation logic is on the *User* side

```
DisneyProduct* DisneyUser::create_cartoon(int id)
{
    DisneyFactory factory;
    switch(id) {
    case GOOFY_ID:
        return factory.create_goofy();
    case PLUTO_ID:
        return factory.create_pluto();
    }
    return NULL;
}
<<<<<<< HEAD
```

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```
class DisneyUser {
    std::vector<DisneyProduct*> toons;
//...
};
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class DisneyUser {
    std::vector<DisneyProduct*> toons;
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};
```

- Let's encapsulate the `create_cartoon()` in the Factory

FactoryExample2.cc

```
DisneyProduct* DisneyFactory::create(int id)
{
        switch(id) {
        case GOOFY_ID:
                return new Goofy();
        case PLUTO_ID:
                return new Pluto();
        }
        return NULL;
}
```

FactoryExample2.cc

```
DisneyUser::DisneyUser()
{
        const int config[] = {GOOFY_ID, PLUTO_ID,
                              PLUTO_ID, 1234/*invalid*/};

        DisneyFactory factory;

        for (size_t i = 0; i < 4; i++) {
                DisneyProduct *p = factory.create(config[i]);
                if (p)
                        toons.push_back(p);
        }
}
```

The full example is:

`./examples/09.real-application_factories-examples/FactoryExample2.c`

Second improvement

Can we get rid of the `switch`-based implementation?

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- Use a look-up table

ID	Factory
GOOFY_ID	Goofy Creator
PLUTO_ID	Pluto Creator
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- **A**: Creator function

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ID	Factory
GOOFY_ID	Goofy Creator
PLUTO_ID	Pluto Creator
...	...

- **Q**: What shall we put on the right side of the table?
- **A**: Creator function

```
enum DisneyCharacterID {
        GOOFY_ID = 0,
        PLUTO_ID,
        MAX_CHARACTERS
};
//...
typedef DisneyProduct* (*creator_type_t)(void);
//...
creator_type_t lookup_table[MAX_CHARACTERS];
```

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- **Q**: Where shall we put the constructor functions?
- **A**: Either in the Factory or in the Products.

```
class Goofy : public DisneyProduct {
private:
        Goofy() : DisneyProduct("goofy") {};
        DisneyProduct* create(void)
                        { return new Goofy(); };
        friend class DisneyFactory;
};

class Pluto : public DisneyProduct {
private:
        Pluto() : DisneyProduct("pluto") {};
        DisneyProduct* create(void)
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- **Solution**: The creator function must be `static`!

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class Goofy : public DisneyProduct {
private:
        Goofy() : DisneyProduct("goofy") {};
        static DisneyProduct* create(void)
                        { return new Goofy(); };
        friend class DisneyFactory;
};

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        Pluto() : DisneyProduct("pluto") {};
        static DisneyProduct* create(void)
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        Pluto() : DisneyProduct("pluto") {};
        static DisneyProduct* create(void)
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        friend class DisneyFactory;
};
```

There is also another issue:

- how many instances of the Factory can we have?

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        Pluto() : DisneyProduct("pluto") {};
        static DisneyProduct* create(void)
                        { return new Pluto(); };
        friend class DisneyFactory;
};
```

There is also another issue:

- how many instances of the Factory can we have?
- The Factory is meant to be a singleton!

Second improvement

How to do a singleton of the `DisneyFactory` class?

FactoryExample3.h

```
class DisneyFactory {
public:
        typedef DisneyProduct* (*creator_type_t)(void);

        static DisneyProduct* create(int id);
private:
        static creator_type_t lookup_table[MAX_CHARACTERS];
};
```

FactoryExample3.cc

```
DisneyFactory::creator_type_t DisneyFactory::lookup_table[MAX_CHARACTERS] = {
        Goofy::create,  // GOOFY_ID = 0
        Pluto::create,  // PLUTO_ID = 1
};

DisneyProduct* DisneyFactory::create(int id)
{
        if (id >= MAX_CHARACTERS || id < 0)
                return NULL;
        return lookup_table[id]();
}
```

The full example is:
`./examples/09.real-application_factories-examples/FactoryExample3.cc`

Third improvement

The `enumeration`-based object identifiers are not exciting...

The full example is:
`./examples/09.real-application_factories-examples/FactoryEx`

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const int config[] = {GOOFY_ID, PLUTO_ID, PLUTO_ID, 1234/*invalid*/};
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The full example is:
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- We would like to have `string` based IDs
- Example: `"goofy"`, `"pluto"`

```
const char* config[] = {"goofy", "pluto", "pluto", "invalid_id"};
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```
const char* config[] = {"goofy", "pluto", "pluto", "invalid_id"};
```

- **Q**: How do we change the look-up table?

  No silly answers: conversion function from string to enumeration.

```
static creator_type_t lookup_table[MAX_CHARACTERS];
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```
static creator_type_t lookup_table[MAX_CHARACTERS];
```

- **A**: Associative container: `std::map<>` of course!

```
static std::map<std::string, creator_type_t> lookup_table;
```

The full example is:
`./examples/09.real-application_factories-examples/FactoryEx`

Third improvement

FactoryExample4.cc

```
map<std::string, DisneyFactory::creator_type_t> DisneyFactory::lookup_table;

DisneyProduct* DisneyFactory::create(const string& id)
{
        if (lookup_table.empty()) {
                lookup_table["goofy"] = Goofy::create;
                lookup_table["pluto"] = Pluto::create;
        }
        if (lookup_table.find(id) == lookup_table.end())
                return NULL;
        return lookup_table[id]();
}

DisneyUser::DisneyUser()
{
        const char* config[] = {"goofy", "pluto", "pluto", "invalid_id"};

        for (size_t i = 0; i < 4; i++) {
                DisneyProduct *p = DisneyFactory::create(config[i]);
                if (p)
                        toons.push_back(p);
        }
}
```

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  2. adding a new entry in the look-up table...

```
if (lookup_table.empty()) {
    lookup_table["goofy"] = Goofy::create;
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  ... in the `DisneyFactory` class implementation

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```

  ... in the `DisneyFactory` class implementation

- We can avoid step 2!

Exercise

Implement the Factory Method in the duck-lab.

- Start from code in `./example/DataExample5/`
- Use the factory pattern for the `Data` hirarchy

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- Start from code in `./example/DataExample5/`
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- Can we generalize the solution using templates?