Creational Design Patterns

Part 2

Creational Design Patterns

- Singleton
- Factory Method
- Abstract Factory
- Builder
- Prototype

Creational Patterns: Factory Method

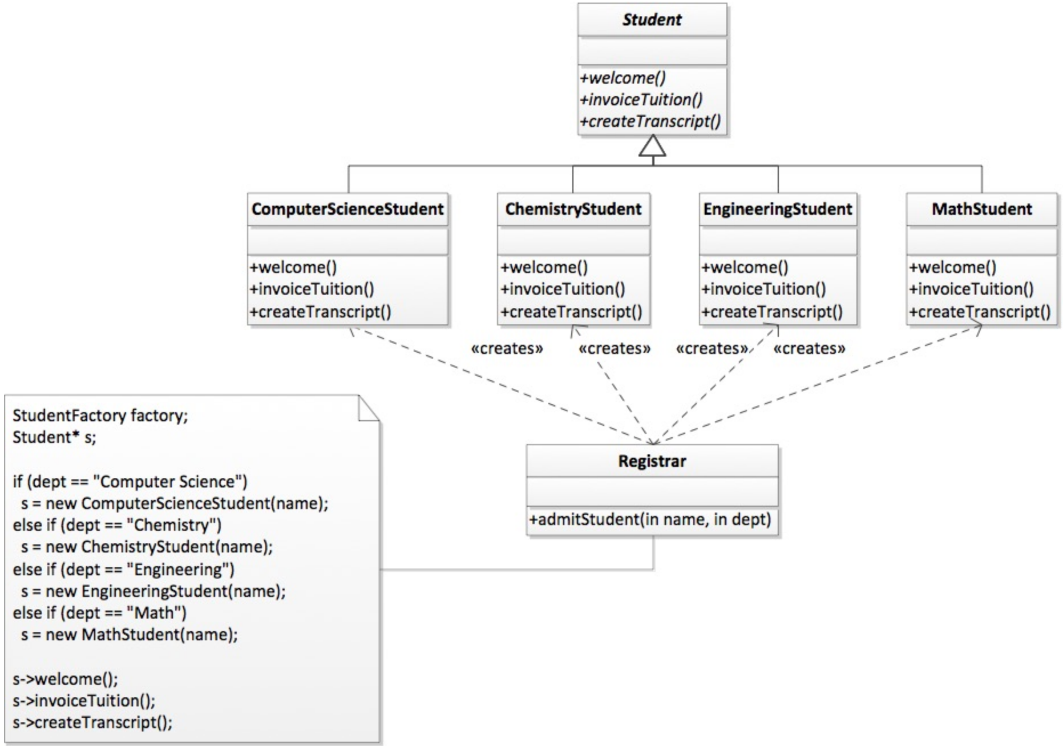
- Suppose we are building a registrar system for Western...
  - Example from Joanne Atlee, University of Waterloo

Creational Patterns: Factory Method

Registrar.cpp

```
void Registrar::admitStudent(const string& name, const string& dept)
{
   Student *s;

   // Instantiate a concrete object -- violate 'program to an
   // interface, not an implementation'
   if (dept == "Computer Science")
      s = new ComputerScienceStudent(name);
   else if (dept == "Chemistry")
      s = new ChemistryStudent(name);
   else if (dept == "Engineering")
      s = new EngineeringStudent(name);
   else if (dept == "Math")
      s = new MathStudent(name);

   // ...
   cout << "Admitting student " << s->name() << endl;
   // Each student type has its own admission operations

   s->welcome();
   s->invoiceTuition();
   s->createTranscript();

   cout << endl;
}
```

Creational Patterns: Factory Method



Creational Patterns: Factory Method

- Problems:
  - Each time we use `new`, we violate the “Program to an interface, not an implementation” design principle
    - Tying code to a concrete implementation in this fashion makes it fragile and less flexible; harder to reuse
    - By coding to an interface instead, our code would work with new classes implementing that interface
  - Furthermore, we have to violate the Open-Closed Principle each time we add a new department

Creational Patterns: Factory Method

- Toward a solution: encapsulate what varies

StudentFactory.cpp

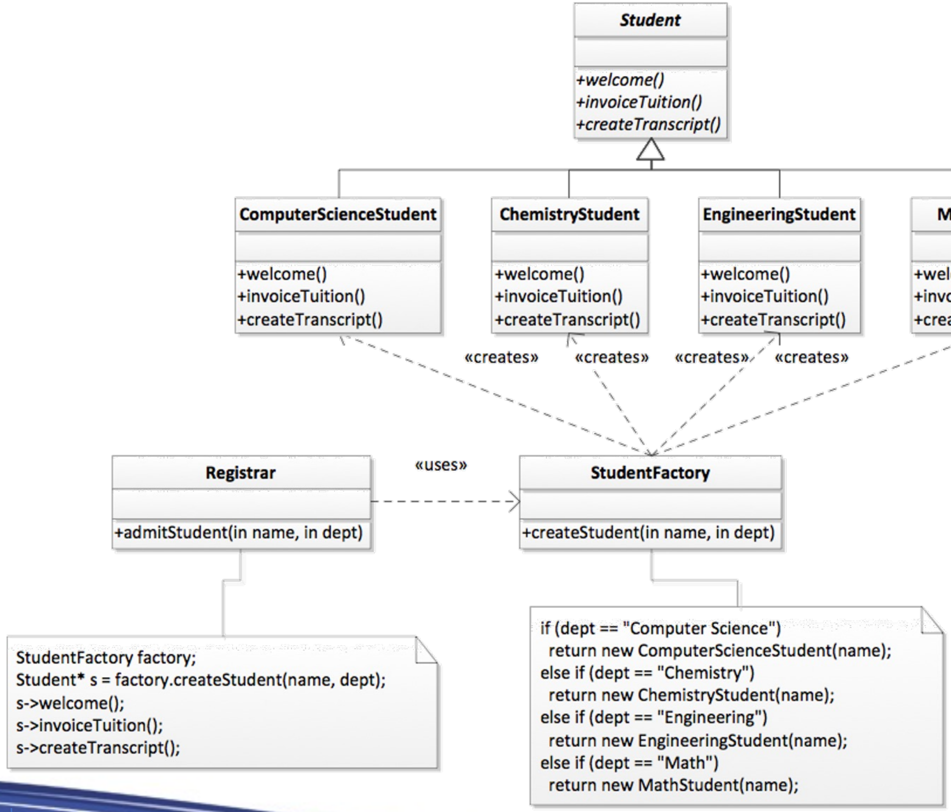
```
Student* StudentFactory::createStudent(const string& name, const string& dept)
{
   Student *s;

   // Instantiate a concrete object -- violate 'program to an
   // interface, not an implementation'
   if (dept == "Computer Science")
      s = new ComputerScienceStudent(name);
   else if (dept == "Chemistry")
      s = new ChemistryStudent(name);
   else if (dept == "Engineering")
      s = new EngineeringStudent(name);
   else if (dept == "Math")
      s = new MathStudent(name);

   // ...

   return s;
}
```

Creational Patterns: Factory Method

Registrar.cpp

```
void Registrar::admitStudent(const string& name, const string& dept)
{
   Student *s;
   StudentFactory factory;

   s = factory.createStudent(name, dept);

   cout << "Admitting student " << s->name() << endl;

   // Each student type has its own admission operations

   s->welcome();
   s->invoiceTuition();
   s->createTranscript();

   cout << endl;
}
```

Creational Patterns: Factory Method



Creational Patterns: Factory Method

- This is called a *Simple Factory* – not a design pattern
  - Keep in mind that `StudentFactory` may have many clients
  - We might also have other classes that need to create students
  - This encapsulates `Student` creation in one class so we only have to make changes in one place when new `Student` types added
  - This also decouples `Registrar` from concrete implementations, making it much more reusable

Creational Patterns: Factory Method

- Problems with this Simple Factory:
  - We’ve just offloaded the problem to a new class; instead of high coupling between `Registrar` and the various classes, we now have high coupling between `StudentFactory` and the `Student` classes
  - Still have to violate the Open-Closed Principle when we want to add new `Student` types to `StudentFactory`
  - The `if-else` block is unwieldy
  - Using `strings` as parameters is error-prone

Creational Patterns: Factory Method

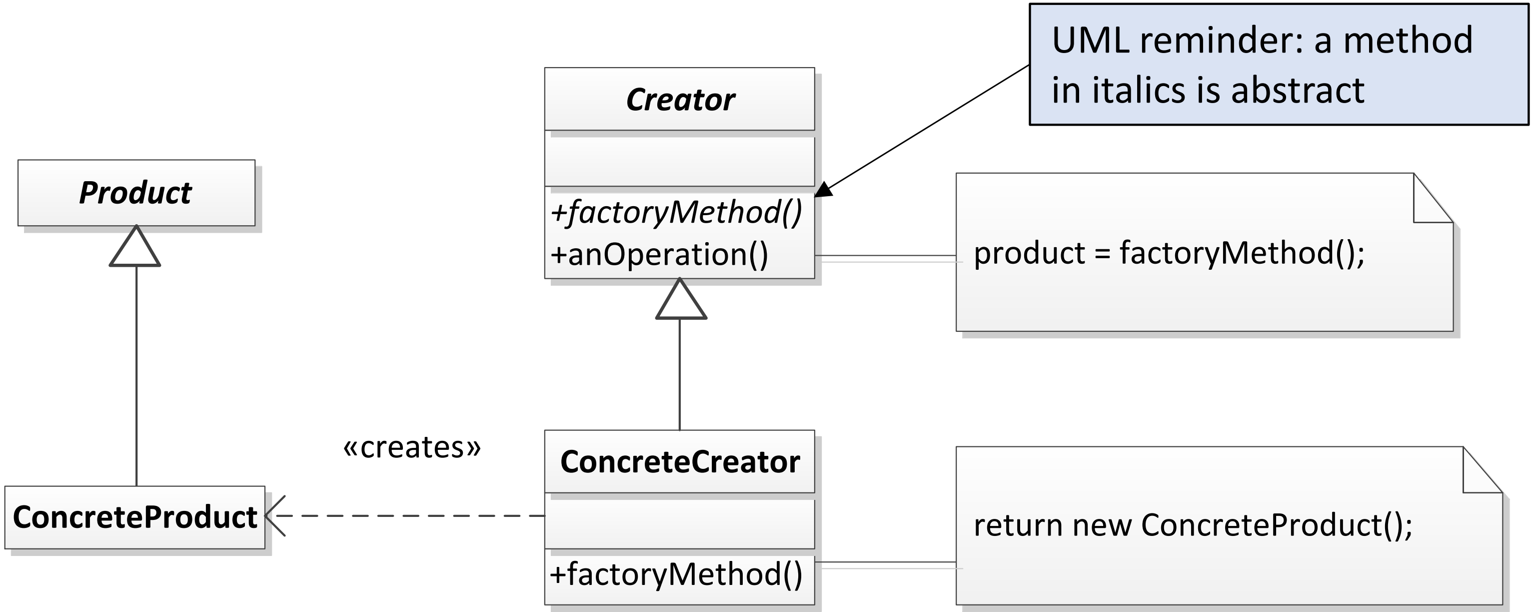
Design Pattern:
Factory Method

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

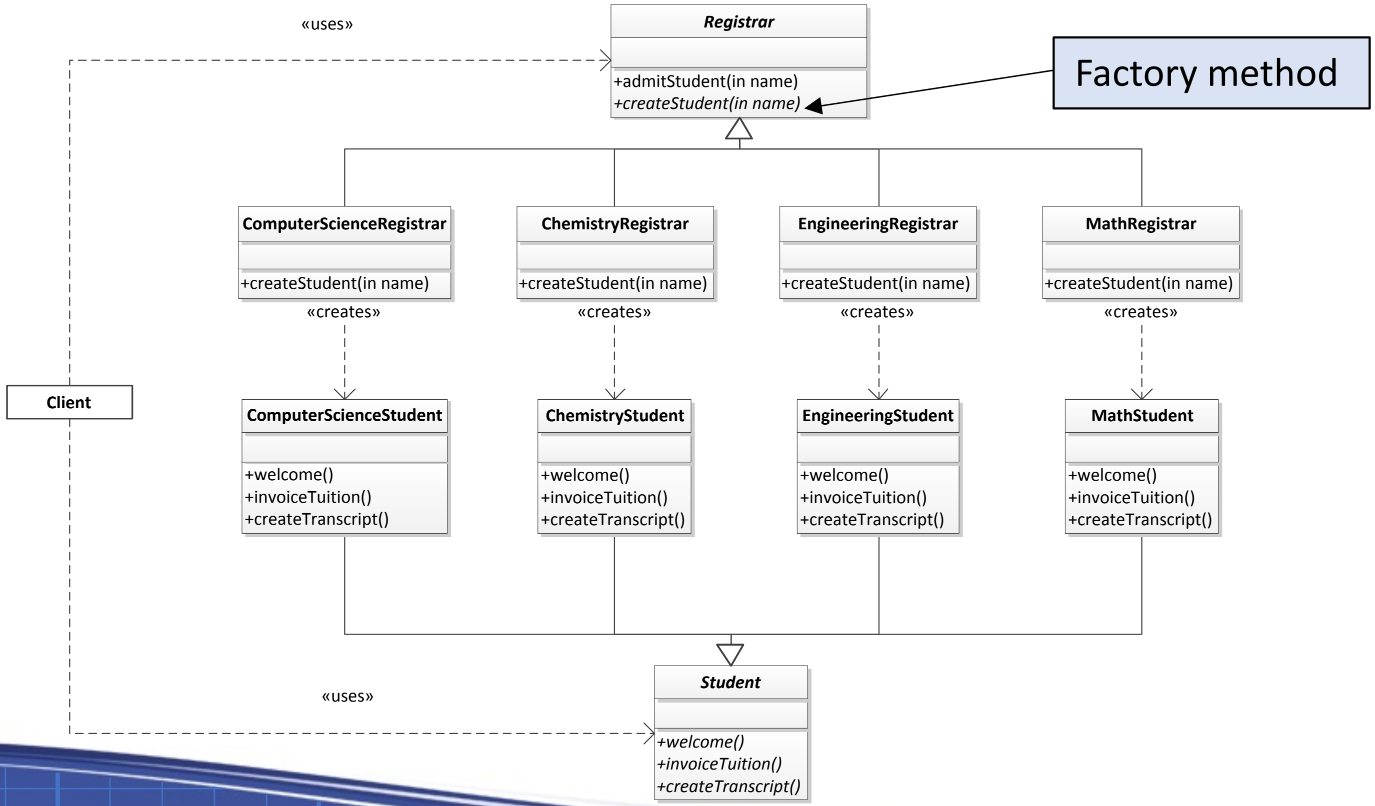
Creational Patterns: Factory Method

- Applicability:
  - A class can’t anticipate the class of objects it must create
  - A class wants its subclasses to specify the objects it creates

Creational Patterns: Factory Method



Creational Patterns: Factory Method



Creational Patterns: Factory Method

Registrar.h

```
class Registrar
{
   public:
      void admitStudent(const std::string& name);

   protected:
      virtual Student* createStudent(const std::string& name) = 0;
};
```

Creational Patterns: Factory Method

Registrar.cpp

```
void Registrar::admitStudent(const string& name)
{
   Student *s = this->createStudent(name);

   cout << "Admitting student " << s->name() << endl;

   // Each student type has its own admission operations
   s->welcome();
   s->invoiceTuition();
   s->createTranscript();

   cout << endl;
}
```

Creational Patterns: Factory Method

ComputerScienceRegistrar.cpp

```
class ComputerScienceRegistrar : public Registrar
{
   public:
      virtual Student* createStudent(const std::string& name)
      {
         return new ComputerScienceStudent(name);
      }
};
```

Creational Patterns: Factory Method

main.cpp

```
void enrollStudents(map<string, Registrar*>& registrars, map<string, string> studentsToEnroll)
{
   for (map<string, string>::iterator it = studentsToEnroll.begin(); it != studentsToEnroll.end(); ++it)
   {
      Registrar* registrar = registrars[it->second];
      registrar->admitStudent(it->first);
   }
}

int main()
{
   // Still have to hard-code concrete classes somewhere
   // But, we'll use Registrar and Student throughout our
   // code as much as possible -- see enrollStudents()
   map<string, Registrar*> registrars;
   registrars["cs"] = new ComputerScienceRegistrar();
   registrars["eng"] = new EngineeringRegistrar();
   registrars["math"] = new MathRegistrar();

   map<string, string> studentsToEnroll;
   studentsToEnroll["Jeff"] = "cs";
   studentsToEnroll["Bob"] = "eng";
   studentsToEnroll["Jane"] = "math";

   enrollStudents(registrars, studentsToEnroll);
}
```

Creational Patterns: Factory Method

Another example:

- Suppose we are creating a game with various levels
- We have a `GameLevel` class and a `Monster` class
- Each level will have specific monsters
  - Fire monsters on fire levels, ice monsters on ice levels, electric monsters on electric levels, etc.
- `GameLevel` is a client, and it uses `Monster` products

Creational Patterns: Factory Method

```
class GameLevel
{
   public:
   GameLevel()
   {
      // Create the level
      ...
      // Create monsters for the level
      ...
      // Add the monsters to the level
      ...
   }
};
```

Creational Patterns: Factory Method

- Solution 1: Use `if-else` everywhere we need to create a `Monster`

```
Monster* m;

if (isFireLevel)
{
   m = new FireMonster();
}
else if (isIceLevel)
{
   m = new IceMonster();
}
else
{
   m = new RegularMonster();
}
```

Creational Patterns: Factory Method

- Solution 2: Move `if-else` inside a special method

```
Monster* createMonster()
{
   if (isFireLevel)
   {
      return new FireMonster();
   }
   else if (isIceLevel)
   {
      return new IceMonster();
   }
   else
   {
      return new RegularMonster();
   }
}
```

Creational Patterns: Factory Method

- The factory method is solution 2, with a twist
  - `createMonster` function is protected
  - `FireGameLevel` and `IceGameLevel` will overload it
    - Will change the monsters used in the `GameLevel`

Creational Patterns: Factory Method

```
class GameLevel
{
   public:
      GameLevel()
      {
         // Create the level
         ...
         // Create monsters for the level
         Monster* m1 = createMonster();
         Monster* m2 = createMonster();
         // Add the monsters to the level
         ...
      }
      ...
   protected:
      // Can provide a default implementation
      virtual Monster* createMonster()
      {
        return new RegularMonster();
      }
};
```

Creational Patterns: Factory Method

```
class FireGameLevel : public GameLevel
{
   public:
      // inherits the constructor
   protected:
      virtual Monster* createMonster()
      {
         return new FireMonster();
      }
};
```

Creational Patterns: Factory Method

```
class IceGameLevel : public GameLevel
{
   public:
      // inherits the constructor
   protected:
      virtual Monster* createMonster()
      {
         return new IceMonster();
      }
};
```

Creational Patterns: Factory Method

- Consequences:
  - Factory methods eliminate the need to bind application-specific classes into our code
    - The code only deals with the Product interface, so it can work with any user-defined ConcreteProduct classes
    - Our `Registrar` only deals with the `Student` interface, so it can work with any user-defined concrete student classes
  - Clients have to subclass the Creator class just to create a particular ConcreteProduct object