From the Gaudi User Guide, [3]

A priori, we see no reason why moving to a language which supports the idea of objects, such as C++, should change the way we think of doing physics analysis.

Class Design Principles in Object-Oriented Programming

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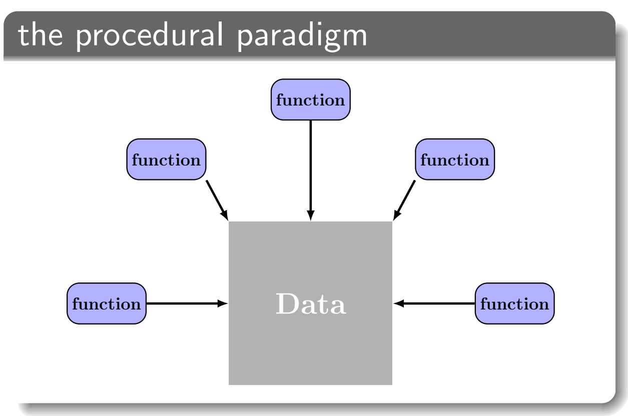
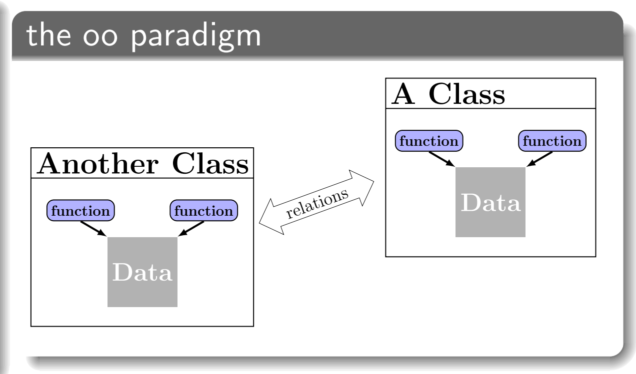
Outline

Procedural vs. OO Programming, from [?]





Top-Down

Bottom-Up

Hep Software Sizes

A History of Code

	lines of code / $1\,\mathrm{loc}$
JADE	$o(10-100)k$
OPAL	$o(100)k$
ATLAS	$o(1)M$

- experiments size and complexity increases
- experiments analysis software size and complexity increases
- We need tools that deal with this complexity!

Programming Paradigms in HEP

physics is about ...

- modelling nature
- objects interact according to laws of nature
  - fields, particles, atoms, molecules, solid states, liquids

object-oriented programming is about ...

- objects and interactions
  - a way of thinking about software well adapted to physics

object-oriented analysis and design ...

- is a software engineering practice
- manages large projects professionally

Orthogonality

Definition

A **Responsibility** of a class is defined as *a reason for the class to change*.

Exercise 1

How many responsibilities do classes a) and b) have?

Definition

Orthogonality([2]) of a system of classes can be defined as the degree of how many classes have independent or non-overlapping *responsibilities*.

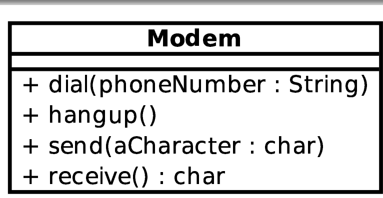
Single-Responsibility Principle

Theorem (from [5])

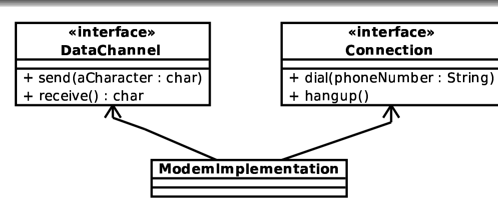
A class should only have **one** *reason to change, i.e. try to create systems with high orthogonality.*

Looking back at Exercise 1 a)

before



after



The Open-Closed Principle

Theorem (from [5])

Software Entities (classes, modules, functions, etc) should be open for extenstion, but closed for modification.

Open

- the **behavior** of an entity can be extended
- as requirements of a system change (that's a fact!), the entities behavior can be **extended or modified** to satisfy these changes

Closed

- extension of behavior does **NOT** result in changing the source code
- the binary executable version of a given entity remains **untouched**

Exercise 2

The above is way too complicated for one slide! Let's have a look at **Exercise 2**!

Reviewed: Open-Closed Principle

The Square/Circle Problem

- *rigid*: adding triangle requires `Shape`, `Square`, `Circle`, `DrawAllShapes` to be recompiled and redeployed
- *fragile*: `switch/case` will be required by all client classes that use Shapes
- *immobile*: reusing `DrawAllShapes` is impossible without including `Shape`, `Square`, `Circle` as well

Solution: Using Abstraction

```
struct Shape {
  virtual void Draw() const = 0;
}

struct Square {
  virtual void Draw() const;
}
```

```
void DrawAllShapes(
  const std::vector<Shape*>& list) {

  std::vector<Shape*>::const_iterator itr;

  for(itr=list.begin();itr!=list.end(); ++itr)
  {
    itr->Draw();
  }

}
```

Summary: The Open-Closed Principle

But hold on ...

- did the abstraction from above close `DrawAllShapes` against all changes?
  - **No**, there is no model of abstraction that is natural to all contexts!
  - closure can never be complete, only strategic
- how to deal with possible changes?
  1. derive possible changes from software requirements
  2. implement necessary abstractions
  3. wait!

To Summarize

- conforming to the open-closed principle yields greatest benefits of OOP (flexibility, reusability, maintainability)
- apply abstraction to parts of software that exhibit frequent change
- Resisting premature abstraction is as important as abstraction itself.

The Liskov Substitution Principle

Theorem (paraphrased from [4])

Subtypes must be substitutable for their base types.

Exercise 3

Try to answer question 3 a) and b) !

Review & Summary: The Liskov Substitution Principle

Observations from Exercise 3

- Violations of Liskov Substitution Principle result in Run-Time Type Information to be used
  - violates the Open-Closed Principle
- an (inheritance) model can never be validated in isolation
  - but rather with its use (users) in mind
  - `Is-A` relationship within inheritance refers to **behavior** that can be **assumed** or that **clients depend upon**.
- how to ensure/enforce Liskov Substitution Principle?
  - Design-by-Contract
  - in C++: only by assertions or Unit Tests

Summary

- this principle ensures: maintainability, reusability, robustness
- Liskov Substitution Principle enables the Open-Closed Principle
- the contract of a base type has to be well understood, if not even enforced by the code

The Dependency-Inversion Principle

Theorem (from [5])

1. *High level modules* **should not depend** *upon low level modules. Both should depend upon abstractions.*
2. *Abstractions* **should not depend** *upon details. details should depend upon abstractions.*

Exercise 4

Please complete 4 a)!

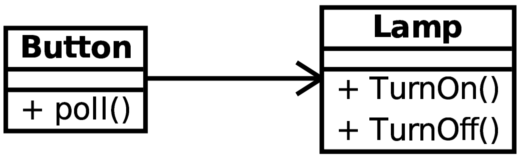
Observations: The Dependency-Inversion Principle

Exercise 4 continued

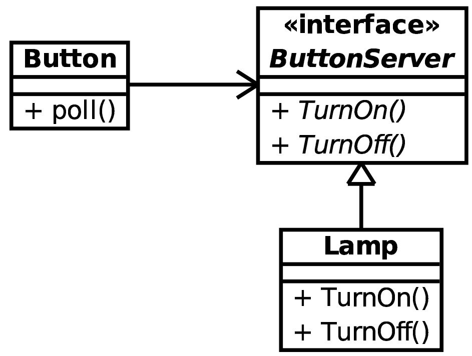
1. The vendor of `Lamp` changes it's definition. All methods containing `Turn` are renamed to `Ramp`! Face your design with that!
2. Look at `Button`: Can it be reused for classes of type `Signal`?

Exercise 4: A Solution

Naive Ansatz



Inverted Dependency

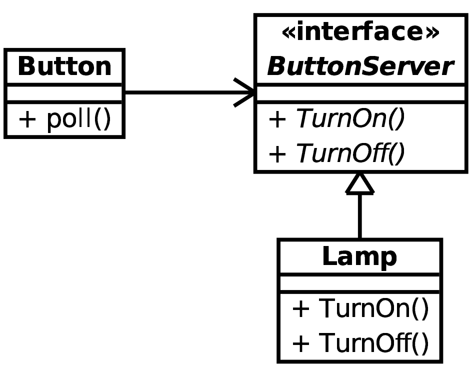


Review: The Dependency-Inversion Principle

Dynamic and Static Polymorphism

in C++, both can help to invert dependencies

Dynamic Polymorphism through Abstract Interfaces



Static Polymorphism through template classes

```
template <class TurnableObject>
class Button {

TurnableObject* itsTurnable;

public:
  Button(TurnableObject* _object = 0 ):
    itsTurnable(_object)
    {};

  void poll() {
    if(/*some condition*/)
      itsTurnable.TurnOn();
    }
};
```

- compile-time polymorphism
- design-by-policy, see [1]

Summary: The Dependency-Inversion Principle

Summary

- dependency of policies on details is natural to procedural design
- inversion of dependencies is hallmark of (good) object-oriented design
- Dependency-Inversion Principle is at the heart of reusable frameworks (no matter what size)
- enables the Open-Closed Principle

Summary

What is left to say ...

did not cover:

- module design principles
- clean code principles
- useful coding conventions

What I tried to say ...

- although having a slow learning curve, OOP can help do highly-sophisticated physics analysis
- learning OO Class Design prevents sleepless nights of debugging or copy-and-past'ing
- Coding may not be our profession, but we do it everyday anyhow, so we better know our craft!

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