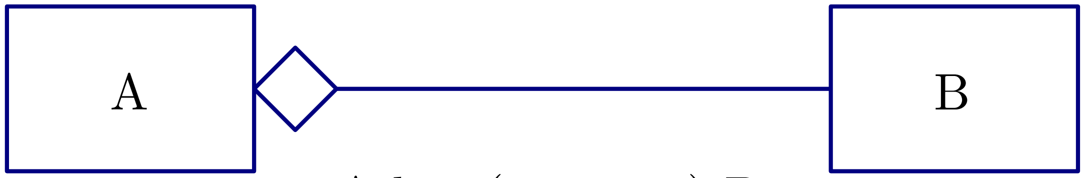
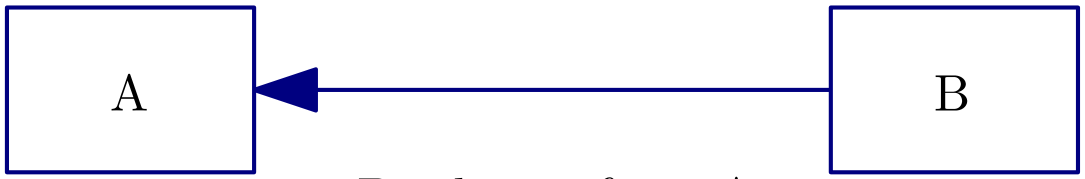
SOLID Principles for Object-Oriented Design

- CSCE 315: Programming Studio
- Instructor: Yoonsuck Choe
- Slides based on Robert Martin's book and web page: `http://butunclebob.com/ArticleS.UncleBob.PrinciplesOfOod`
- See the URL above for diagram notations.
- Topic motivated by Chris Weldon @ Improving.

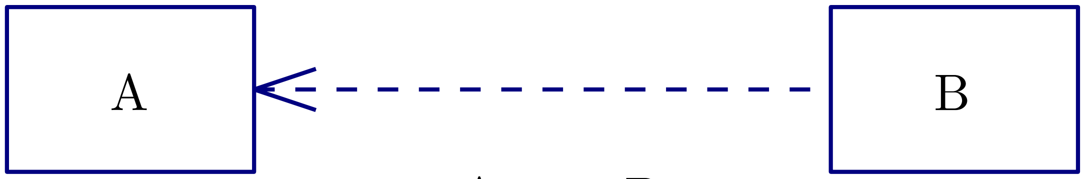
Notations



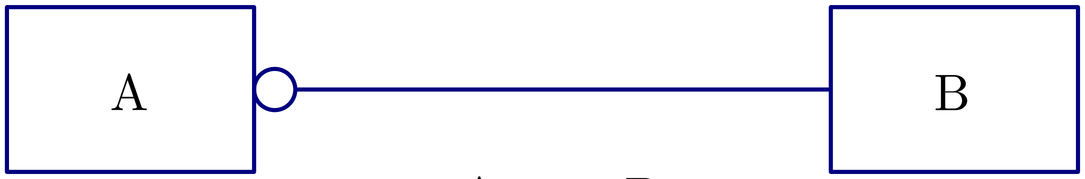
A has (contains) B



B inherits from A



A uses B



A uses B

SOLID Principles

- Acronym of acronyms:
  - **S**RP: Single Responsibility Principle
  - **O**CP: Open-Closed Principle
  - **L**SP: Liskov Substitution Principle
  - **I**SP: Interface Segregation Principle
  - **D**IP: Dependency Inversion Principle
- Basically a set of principles for object-oriented design (with focus on designing the classes).

History of SOLID

Robert C. Martin is the main person behind these ideas (some individual ideas predate him though).

- First appeared as a news group posting in 1995.
- Full treatment given in Martin and Martin, *Agile Principles, Patterns, and Practices in C#*, Prentice Hall, 2006. (The PPP book)
- Lots of online learning material (find on your own).

Benefits of SOLID

- Provides a principled way to manage dependency.
- Serves as a solid foundation for OOD upon which more complicated design patterns can be built upon and incorporated naturally.
- Results in code that are flexible, robust, and reusable.

Detailed Benefits

Write code so that

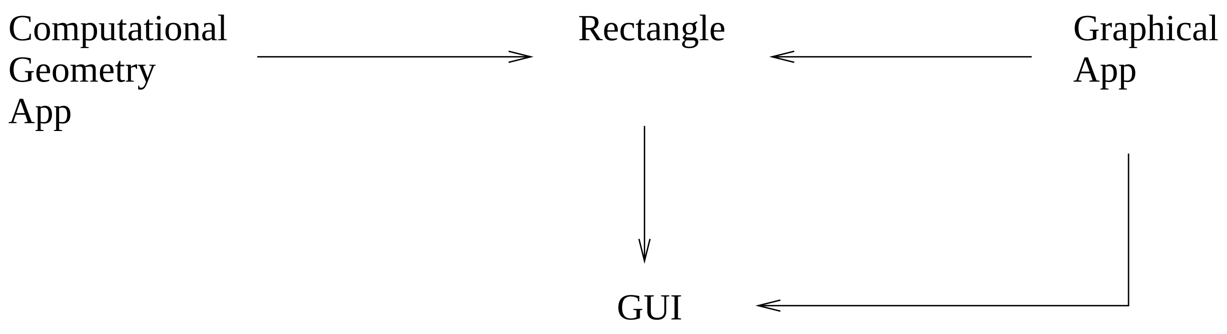
- testable and easily understood
- where things are where they’re expected to be
- where classes narrowly do what they were intended to do
- can be adjusted and extended quickly without producing bugs
- separates the policy (rules) from the details (implementation)
- allows for implementations to be swapped out easily

* https://khalilstemmler.com/articles/solid-principles/solid-typescript/

First Pass at Understanding SOLID

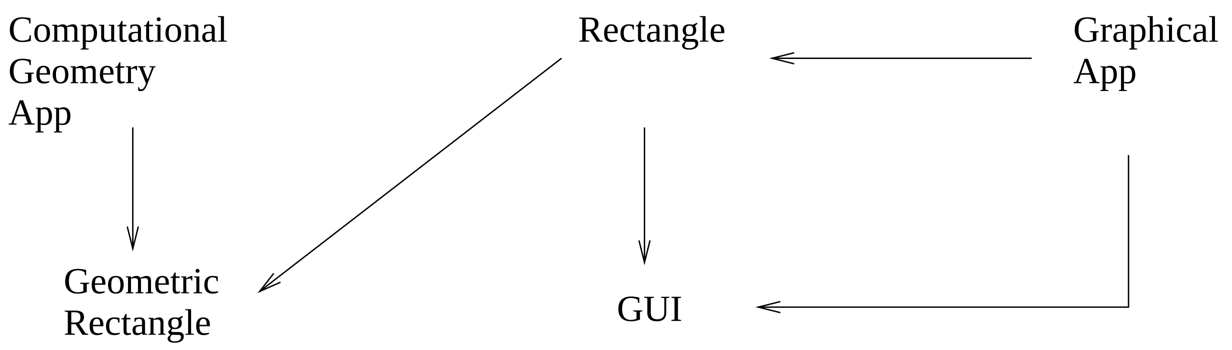
- SRP: “A class should have one, and only one, reason to change”.
- OCP: “You should be able to extend a class’s behavior, without modifying it”
- LSP: “Derived classes must be substitutable for their base classes.”
- ISP: “Make fine grained interfaces that are client specific.”
- DIP: “Depend on abstrations, not on concretions.”

SRP: Single Responsibility Principle



- Example: Rectangle class with draw() and area()
- Computational geometry now depends on GUI, via Rectangle.
- Any changes to Rectangle due to Graphical application necessitates rebuild, retest, etc. of Comp. geometry app.

SRP: Cont’d



- Solution: Take the purely computational part of the Rectangle class and create a new class “Geometric Rectangle”.

- All changes regarding graphical display can then be localized into the Rectangle class.

SRP: Another example

- Modem: dial(), hangup(), send(), recv(), ...
- However, there are two separate kinds of functions that can change for different reasons:
  - Connection-related
  - Data communication-related
- These two should be separated.
- Recall that “Responsibility” == “a reason to change”.

SRP: Summary

- “SRP is the simplest of the principles, and one of the hardest to get right.”
- We tend to join responsibilities together.
- SRP says we need to go against this tendency.

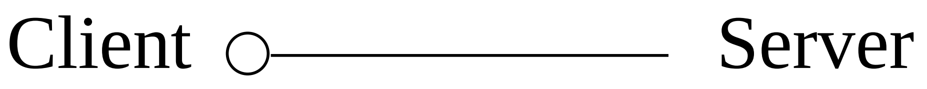
OCP: Open-Closed Principle

- “All systems change during their life cycles.” (Ivar Jacobson).
- “Software entities should be open for extension, but closed for modification.” (variation on Bertrand Meyer’s idea).
- Goal: avoid a “cascade of changes to dependent modules”.
- When requirements change, you extend the behavior, not changing old code.

OCP: Abstraction is Key

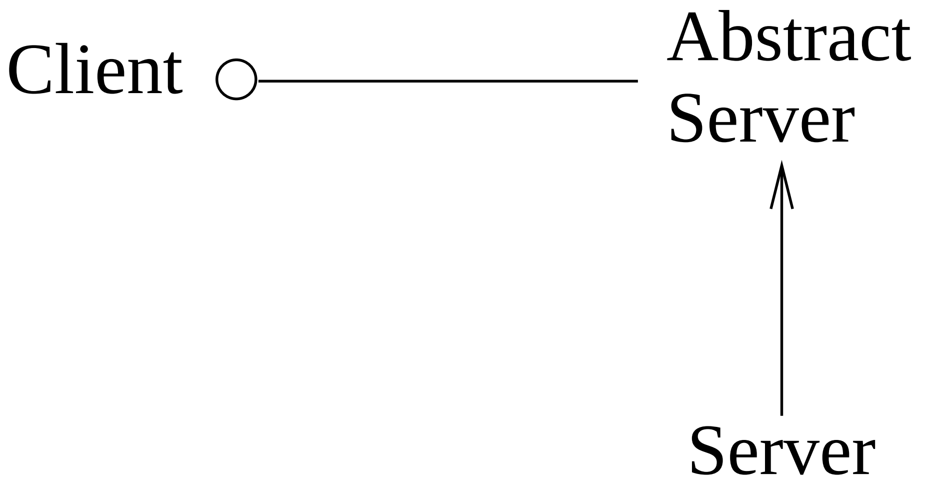
- Bad design: need to

  change client code when new kinds of server needed.



- Good design: can extend

  to new types of servers without modifying client code.



OCP: Data-Driven Approach

- In many cases, complete closure (closure to modification) may not possible.
- Data-driven approach can be taken to minimize and localize changes to a small region of code that only contain data, not code.
- For example, there can be a table that contains a specific ordering based on the requirements, where the requirements are expected to change.

OCP: Foundation for Many Heuristics

OCP leads to many heuristics and conventions.

- Make all member variables private.
- No global variables, EVER.
- Run time type identification (e.g., dynamic cast) is dangerous.
- etc.

OCP: Summary

- OCP is “at the heart of OOD”.
- Simply using an OOP is not enough: Need dedication to apply abstraction.
- OCP can greatly enhance reusability and maintainability.

LSP: Liskov Substitution Principle

- “Functions that use pointers or references to base classes must be able to use objects of derived classes without knowing it.” (original idea due to Barbara Liskov).
- Violation means the user class’s need to know ALL implementation details of the derived classes of the base class.
- Violation of LSP leads to the violation of OCP.

LSP: Example

Rectangle Class $\longleftarrow$ Square Class

- Problem: setWidth(), setHeight() in Rectangle class assumes w and h are independently settable.
- When Square class is used where Rectangle class is called for, behavior can be unpredictable, depending on implementation.
- Want either setWidth() or setHeight() to set both width and height in the Square class.
- LSP is violated when adding a derived class requires modifications of the base class.

LSP: Lessons Learned

- Cannot assess vailidty of a class by just looking inside a class: We must see how it is used.
- “ISA relationship pertains to *behavior*”, extrinsic, public behavior!
  - Square is a Rectangle, but they behave differently, seen from the outside.
- For LSP to hold, ALL derived classes should conform to the behavior that the clients expect of the base classes.

LSP: Summary

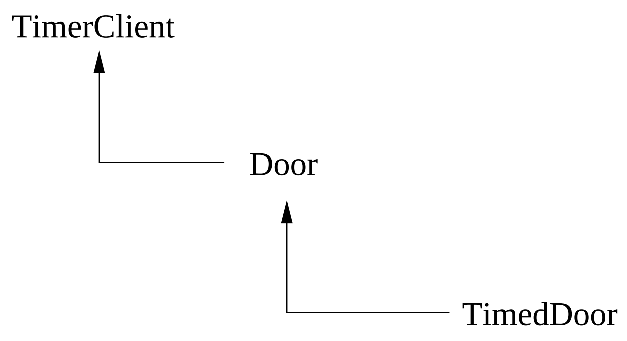
- LSP is an important property that holds for all programs that conform to the Open-Closed principle.
- LSP encourages reuse of base types, and allows modifications in the derived class without damaging other components.

ISP: Interface Segregation Principle

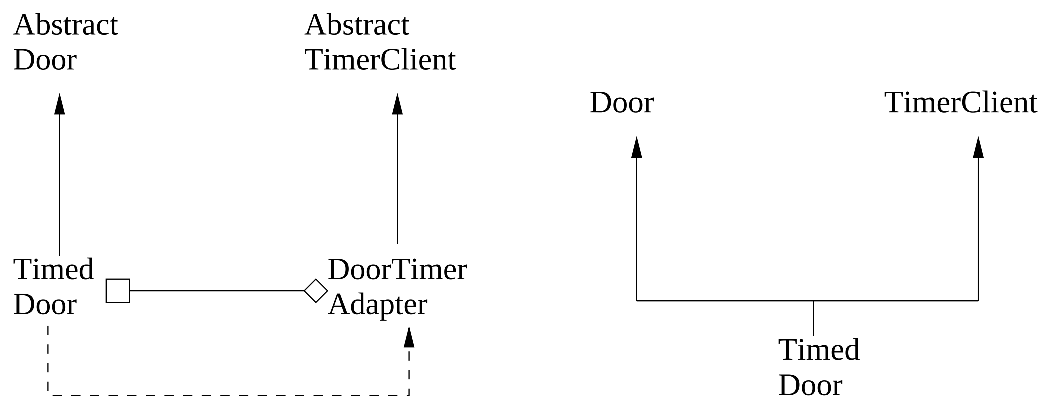
- “Clients should not be forced to depend upon interfaces that they do not use.”
- Avoid “fat interfaces”.
- Fat interfaces: interfaces of a class that can be broken down into groups that serve different set of clients.
- Clients depending on a subset of interfaces need to change when other clients using a different subset changes.

ISP: Example

- Bad design



- Good design



Clients that use Door or TimerClient access only those speficied interfaces.

ISP: Example – Explained

- Bad design: To provide access to time server, Door class inherits from TimerClient unnecessarily.
- Good design 1: TimedDoor creates DoorTimerAdapter, which includes reference back to TimedDoor, so when triggered, it can send close signal.
- Good design 2: Multiple inheritance.

ISP: Summary

- Should avoid interfaces that are not specific to a single client.
- Fat interfaces cause inadvertant coupling between unrelated clients.

DIP: Dependency Inversion Principle

- “A. High level modules should not depend upon low level modules. Both should depend upon abstractions.”
- “ B. Abstractions should not depend upon details. Details should depend upon abstractions.”
- DIP is an out-growth of OCP and LSP.
- “Inversion”, because standard structured programming approaches make the higher level depend on lower level.

DIP: The Problem

- Bad design:
  - Hard to change (rigidity)
  - Unexpected parts break when changing code (fragility)
  - Hard to reuse (immobility)
- Cause of bad design:
  - Interdependence of the modules
  - Things can break in areas with NO conceptual relationship to the changed part.
  - Dependent on unnecessary detail.

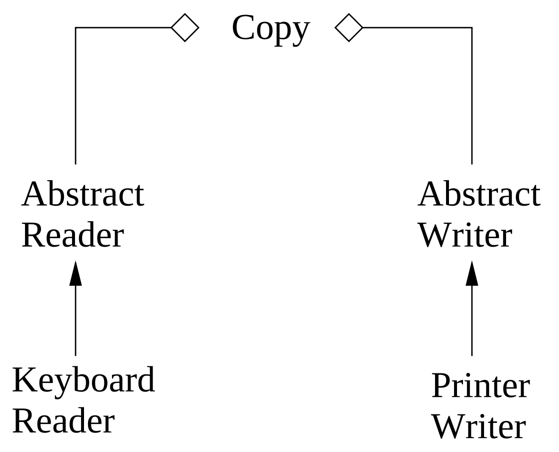
DIP: Example

Copy(): uses ReadKeyboard() and WritePrinter(char c);

- Copy() is a general (high-level) functionality we want to reuse.
- The above design is tied to the specific set of hardware, so it cannot be reused to copy over diverse hardware components.
- Also, it needs to take care of all sorts of error conditions in the keyborad and printer component (lots of unncessary details creep in).

DIP: Diagnosis of Copy()

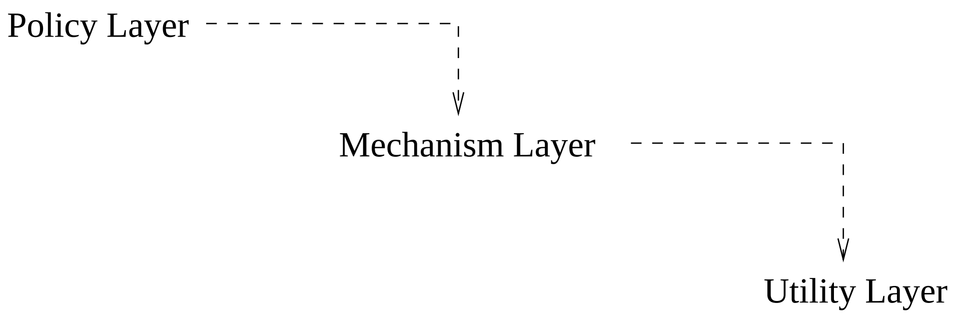
- Module containing high level policy (Copy) is dependent upon low level detailed modules it controls (WritePrinter, ReadKeyboard).
- Good design:



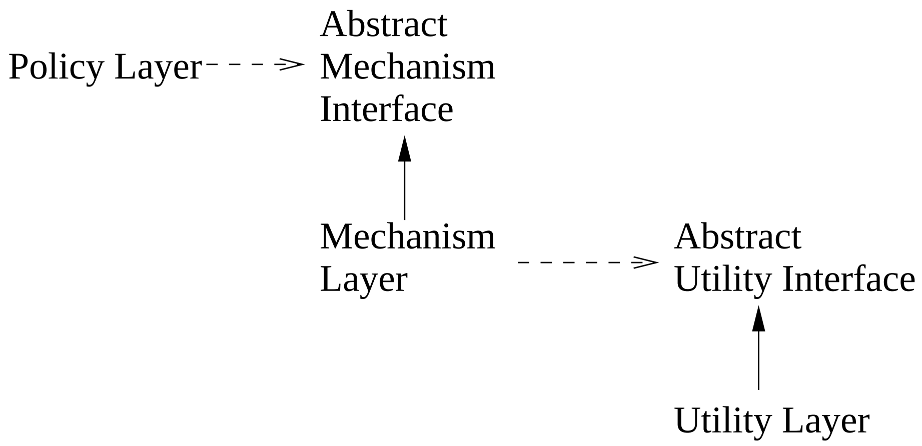
Encourages reuse of higher level policies.

DIP: Layering and Better Layering

- Bad Design



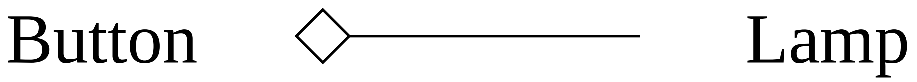
- Good Design



Policy layer not dependent on lower levels, thus can be reused.

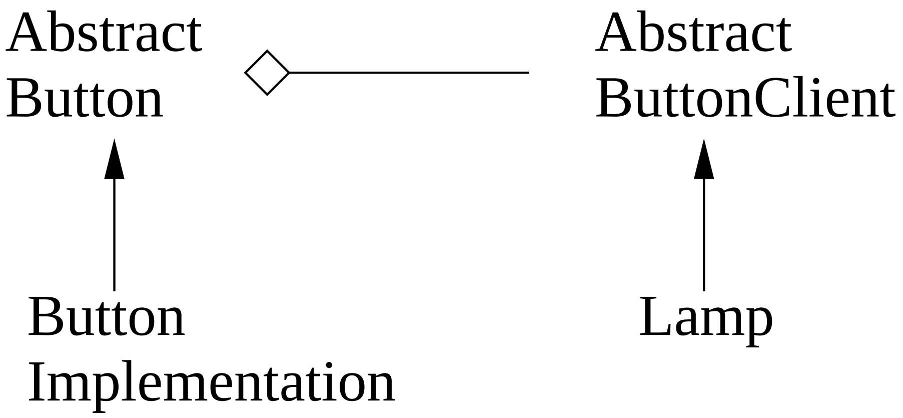
DIP: Another Example

- Bad Design



When button changes, lamp has to be at least recompiled. Cannot reuse button for different device.

- Good Design



Can further introduce LampAdapter.

Button Example – Explained

- Bad design: Button class includes private member Lamp, so that when pressed, it can turn the lamp off. This is bad. When lamp changes, Button is affected.
- Good design: Abstract Button class now containst Abstract Button Client only, so when Lamp changes, Button is not affected.

DIP: Summary

- DIP promises many benefits of OO paradigm.
- Reusability is greately enhanced by DIP.
- Code can be made resilient to change by using DIP.
- As a result, code is easier to maintain.

SOLID Principles: Summary

- Help manage dependency.
- Improved maintainability, flexibility, robustness, and reusability.
- Abstraction is important