Some Object-Oriented Design Principles

Naming Conventions

- Some of these have standard names, and some I just made up.

Uniform Access Principle

- The interface for getting information from an object should be the same regardless of whether the information is:
  - stored, vs.
  - computed
- Related idea: Information hiding

UAP Corollary

- Don't allow public access to data members.

Centralization Principle

- Don't implement the same functionality in more than one place.
- Corollary: Don't cut-and-paste code.

Single-Choice Principle
(Bertrand Meyer)

- An exhaustive list of alternatives should reside in only one place.

Robert C. Martin

- Robert Martin, in his articles, and recent book "Agile Software Development" has thought deeply about the principles needed to permit a software design to evolve rapidly (as implied by "agile").
- We will mention several of his principles here. They are not limited to agile processes.
- These ideas also tie in with "Design Patterns", as originated by Gamma, et al.
- In some cases, one principle may be seen to generalize another.

Design Smells: The Odors of Rotting Software (Robert C. Martin)

- Software is "rotting" when it starts to exhibit any of the following "odors":
  - **Rigidity**: The system is hard to change, because every change forces many other changes.
  - **Fragility**: Changes cause the system to break in places that have no conceptual relationship to the part that was changed.
  - **Immobility**: It is hard to disentangle the system into components that can be reused in other systems [or in a new iteration of the same system].
  - **Viscosity**: Doing things right is harder than doing them wrong.

Design Smells, continued

- **Needless Complexity**: The design contains infrastructure that adds no direct benefit.
- **Needless Repetition**: The design contains repeating structures that could be unified under a single abstraction.
- **Opacity**: Code is hard to read and understand. It does not express its intent well.

- These ideas are also related to "anti-patterns" discussed later.

Single-Responsibility Principle (SRP)
(Robert C. Martin)

- "A class should have only one [responsibility, i.e.] reason to change."
- This seems to be the extreme of saying that a class should not have too many responsibilities:
  It should only have ***one***.
- Having more than one responsibility in a class effectively **couples** those responsibilities, when they should be separate.
- For example, in changing code that supports one responsibility, we don't want to have to separate out code supporting a different responsibility. We'd like class structure to do this for us.

An Earlier Concept

- "Separation of Concerns", Dijkstra, 1976
- Examples:
  - Design software (such as an OS) in layers.
  - Keep requirements separate from design decisions.

Responsibilities in What Sense?

- We encountered responsibilities with CRC cards.
- It appears that Martin's sense of a responsibility might lump some of the CRC-level responsibilities together.
- Maybe "area of responsibility" would be better?

Example of the SRP

- A Rectangle might be used in two different applications:
  - A geometric reasoning application
  - A graphical (drawing) application
- The reasoning application may need to do operations such as **change the size** of the rectangle.
- The graphical application may need to **draw it** (*and* change its size).
- These dual responsibilities should somehow reside in separate classes. [But obviously, there must be *some* connection, because there is only *one* rectangle in the second case.]

Rectangle, continued

- What are some ways in which the SRP could be followed in the Rectangle example?

Possible approaches

- Inheritance
- Delegation
- Multiple interfaces for a single implementation class

Martin's approach (not UML yet?)

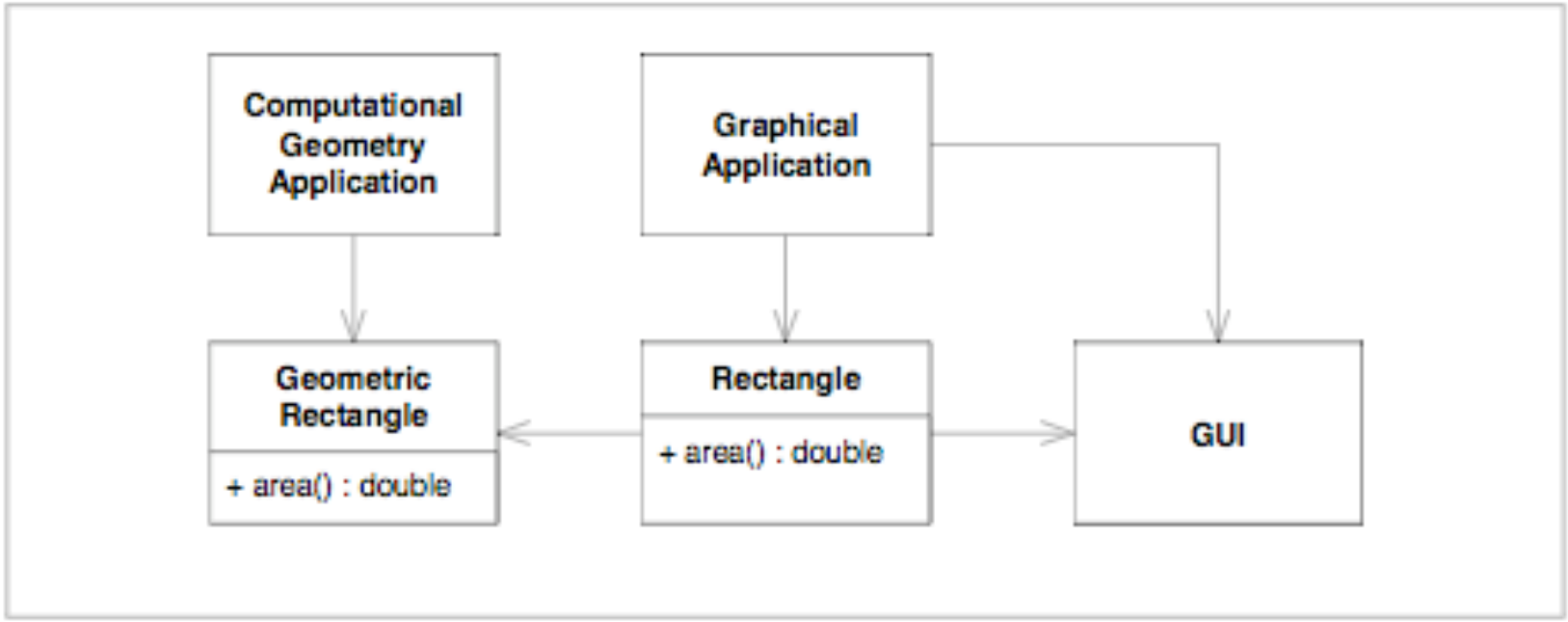


Figure 9-2
Separated Responsibilities

Another Martin example

Listing 9-1

```
Modem.java -- SRP Violation
interface Modem
{
  public void dial(String pno);
  public void hangup();
  public void send(char c);
  public char recv();
}
```

Resolution using Interfaces

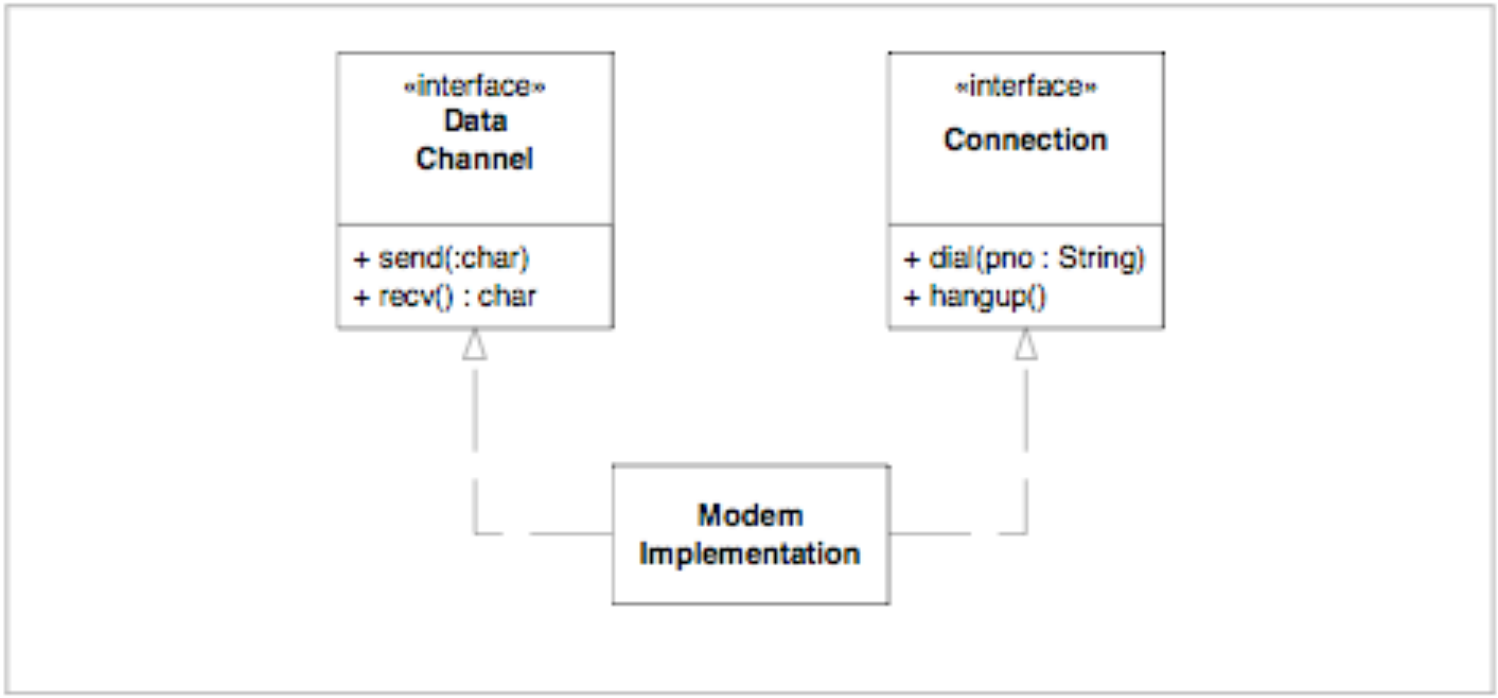


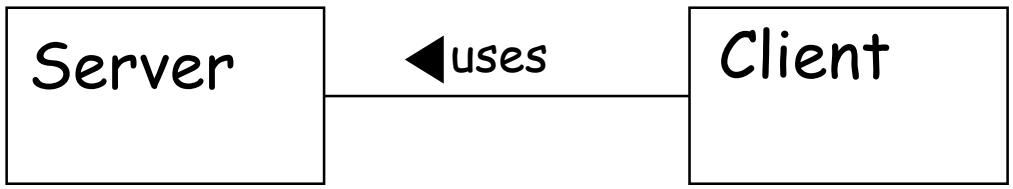
Figure 9-3
Separated Modem Interface

Open/Closed Principle (OCP)
(Bertrand Meyer, then Robert C. Martin)

- "Classes should be both 'open' and 'closed'."
  - **Open**: in the sense that the class can be **extended** through inheritance.
  - **Closed**: in the sense that the functionality of a class, once set, should not be modified retroactively.
- In other words, add functionality by **inheriting from**, not rewriting, existing code.

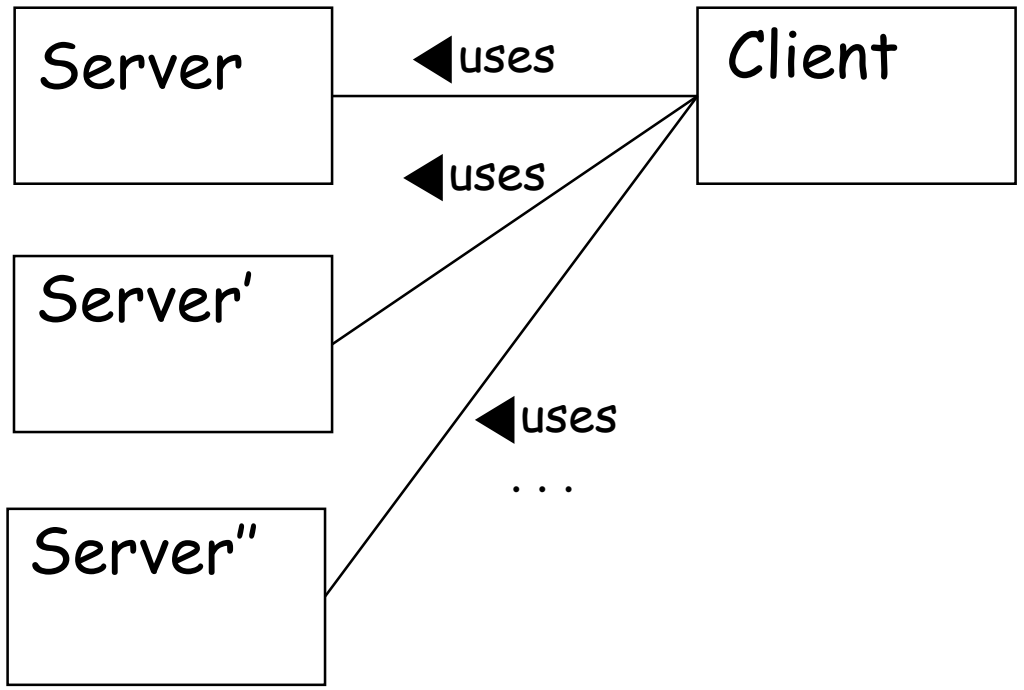
OCP Generic Example

- Having a **client** class that can interact with a **fixed** server class tends to **violate** OCP:



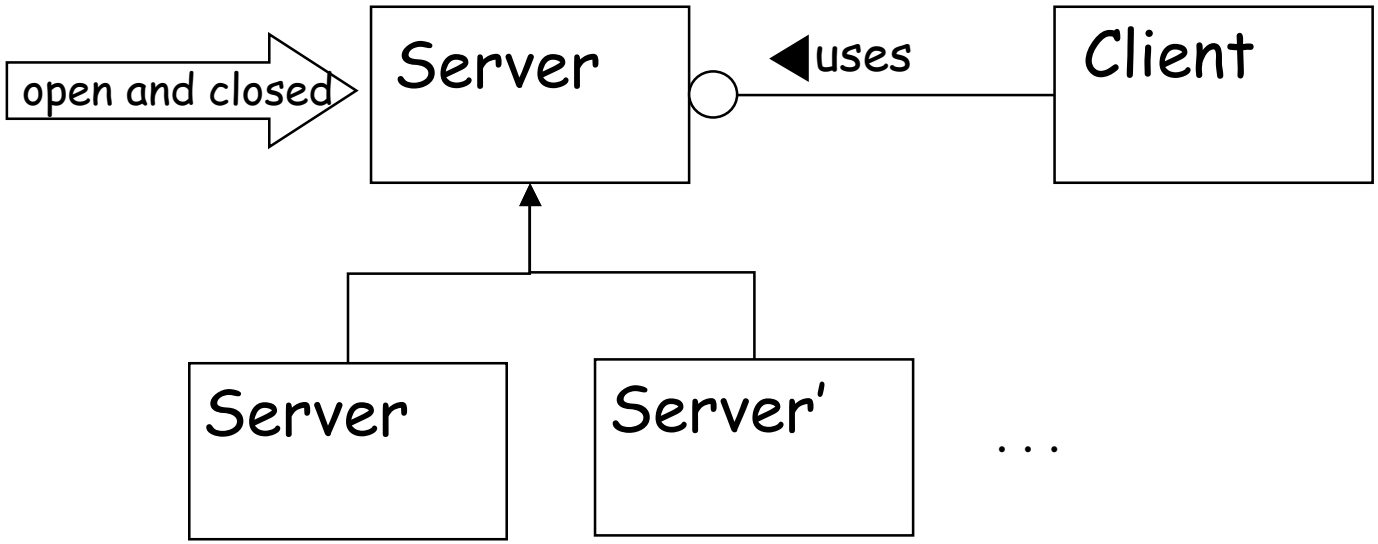
OCP Generic Example

A Client cannot use a different server, Server', without some rewrite of the Client (i.e. Client is **not closed**).



OCP Generic Example

- The correction is to define an abstract Server class, or an **interface**, and derive concrete servers from it.



Another Common Type of OCP Violation

Listing 1

Procedural Solution to the Square/Circle Problem

```
enum ShapeType {circle, square};

struct Shape
{
  ShapeType itsType;
};

struct Circle
{
  ShapeType itsType;
  double itsRadius;
  Point itsCenter;
};
```

Listing 1 (Continued)

Procedural Solution to the Square/Circle Problem

```
struct Square
{
  ShapeType itsType;
  double itsSide;
  Point itsTopLeft;
};

//
// These functions are implemented elsewhere
//
void DrawSquare(struct Square*)
void DrawCircle(struct Circle*);

typedef struct Shape *ShapePointer;

void DrawAllShapes(ShapePointer list[], int n)
{
  int i;
  for (i=0; i<n; i++)
  {
    struct Shape* s = list[i];
    switch (s->itsType)
    {
    case square:
      DrawSquare((struct Square*)s);
    break;

    case circle:
      DrawCircle((struct Circle*)s);
    break;
    }
  }
}
```

Why is this a violation?

How is it fixed?

Counter SRP?

- What about the "You aren't gonna need it." principle in agile design?
- What about "Do the simplest thing that could possibly work."?

Occam's Razor

- Also spelled "Ockham", attributed to William of Ockham, 1285-1349.
- "Entities shall not be multiplied beyond necessity."
- Don't invent a new concept to explain something when an existing one will do just as well.
- Related: KISS principle.
- Misinterpretation: The simplest solution/explanation is usually the right one.

Liskov Substitution Principle (LSP)

As popularly stated:

A member of a derived class must also make sense when used as a member of the base class.

For example, if a method has an object of a class as an argument, the same method should be able to work with an object of a derived class.

As originally stated:

1. INTRODUCTION

What does it mean for one type to be a subtype of another? We argue that this is a semantic question having to do with the behavior of the objects of the two types: the objects of the subtype ought to behave the same as those of the supertype as far as anyone or any program using supertype objects can tell.

For example, in strongly typed object-oriented languages such as Simula 67[Dahl,

B. Liskov and J. Wing, A behavioral notion of subtyping, ACM TOPLAS, **16**, 6 (Nov. 1994), 1811-1841.

(Prof. Barbara Liskov, M.I.T.)

Clarification

- LSP applies to **behavioral**, rather than structural, properties of objects.

Behavioral vs. Structural Sub-Typing

- Consider two classes:
  - Array
  - Stack
- Which is reasonably a sub-class of the other, if either?

LSP **Corollary** (Robert C. Martin)

- Functions that use *pointers* or *references* to base classes must be able to use objects of derived classes **without differentiation** of whether the referenced object is base vs. derived.

Examples

- Suppose we have a class RealValuedFunction and a sub-class DifferentiableFunction. How would these be tied together or differentiated?

- Should a class Bird have a method flyDistance()?

- Suppose we have a class Year.
  Should we have a subclass LeapYear?

- Suppose we have a class FacultyMember having methods
  hire()
  fire()

  Should we have a sub-class TenuredFacultyMember?

Notes

- See "Agile Software Development" p 124:
  - Degenerate Function in a Derivative
  - Throwing exceptions from Derivatives:
    - A derived class should not throw an exception that a client of the base class cannot handle.

Examples

- Suppose we have two kinds of Employee:
  - Agent
  - LotAttendant

  Should both of these be classes extending a common base class: Employee?

- Should class Square be derived from class Rectangle; or vice-versa?

- Should class Circle be derived from class Ellipse; or vice-versa?

Martin's Rectangle & Square, v1

```
class Rectangle
{
  public:
    void   SetWidth(double w)  {itsWidth=w;}
    void   SetHeight(double h) {itsHeight=w;}
    double GetHeight() const   {return itsHeight;}
    double GetWidth() const    {return itsWidth;}
  private:
    double itsWidth;
    double itsHeight;
};
```

```
void Square::SetWidth(double w)
{
  Rectangle::SetWidth(w);
  Rectangle::SetHeight(w);
}

void Square::SetHeight(double h)
{
  Rectangle::SetHeight(h);
  Rectangle::SetWidth(h);
}
```

LSP violation in v1

```
void f(Rectangle& r)
{
  r.SetWidth(32); // calls Rectangle::SetWidth
}
```

If a Square is passed for r,
the width is set, but not the height.
The resulting shape might not be a square any longer, even though it is called one.
That is, the "square invariant" is violated.
[This is an issue in C++, but not in Java.]

```
void Square::SetWidth(double w)
{
  Rectangle::SetWidth(w);
  Rectangle::SetHeight(w);
}

void Square::SetHeight(double h)
{
  Rectangle::SetHeight(h);
  Rectangle::SetWidth(h);
}
```

v2 to "fix" v1 problems, using **virtual** methods in C++

```
class Rectangle
{
  public:
    virtual void SetWidth(double w)  {itsWidth=w;}
    virtual void SetHeight(double h) {itsHeight=h;}
    double       GetHeight() const   {return itsHeight;}
    double       GetWidth() const    {return itsWidth;}
  private:
    double itsHeight;
    double itsWidth;
};

class Square : public Rectangle
{
  public:
    virtual void SetWidth(double w);
    virtual void SetHeight(double h);
};

void Square::SetWidth(double w)
{
  Rectangle::SetWidth(w);
  Rectangle::SetHeight(w);
}

void Square::SetHeight(double h)
{
  Rectangle::SetHeight(h);
  Rectangle::SetWidth(h);
}
```

The OCP was violated.
We had to recode Rectangle.

An anomaly with v2

```
void g(Rectangle& r)
{
  r.SetWidth(5);
  r.SetHeight(4);
  assert(r.GetWidth() * r.GetHeight()) == 20);
}
```

The assertion will always succeed for a Rectangle, but will fail for a Square, a violation of LSP.

LSP and Design by Contract (DbC)

- DbC (Bertrand Meyer) says that each method has:
  - An assumed pre-condition
    (ensured by the caller)
  - A guaranteed post-condition
    (ensured by the method)
- A derived class can have:
  - weaker pre-condition (assume less)
  - stronger post-condition (guarantee more)

  but never the other way around, lest the LSP be violated.

More on DbC

- DbC is the opposite of defensive programming.
- Methods do not check whether their arguments satisfy the precondition; they assume it.
- This cuts down on multiple coverage.

- The rectangle/square problem can be seen as a violation of LSP/DbC, since various square methods make **stronger** assumptions than do rectangle methods.

Dependency-Inversion Principle (DIP)
(Robert C. Martin)

- **Details should depend on abstractions;**
  Abstractions should not depend on details, but
  at most on other abstractions.

- High-level modules should not depend on low-level modules; both should depend on abstractions.

- In other words, don't let low-level modules "call the shots" for high-level ones. The high-level ones are where policies should be set.

- Succinctly: ***Specify the interface first***, then implement.

Conventional

- Utility layer implements utility classes and methods.
- Mechanism layer uses utilities to provide mechanisms.
- Policy layer uses mechanism to implement policies.
- [Example? Dikjstra: "The T.H.E. Multiprogramming System"]

Inversion

- See p. 129 of Martin:
- Policy layer should define (and use) interfaces that the Mechanism layer implements.
- Mechanism layer should define (and use) interfaces that the Utility layer implements.

DIP

- Followed literally, the DIP forbids:
  - Deriving a class from another concrete (rather than abstract) class.
  - A variable from referencing a concrete class.
  - Overriding a method in a concrete base class.
- Some exceptions are allowed if the base class is a stable utility.

Exercise

- Design a simple class structure (use UML) for
  switches (e.g. button, toggle, pull-chain, …) and
  devices (e.g. lamp, motor, radio, …).
- Every device has some kind of on-off switch.
- Different kinds of switches should be usable with a given type of device.
- Where are abstract classes vs. interfaces appropriate?
- Extend to the case where devices are operated by **relays**, e.g. for noise or power isolation purposes.
- [A relay is a device that serves as a switch, but which can be activated by a different switch.]

More Named Principles (1)

(cf. Martin book + http://c2.com/cgi/wiki?PrinciplesOfObjectOrientedDesign)

- **Note that not all principles are without controversy.**
- **The Interface Segregation Principle**: The dependency of one class to another one should depend on the smallest possible interface.
  - Clients should not be forced to depend on unused aspects of interfaces.
  - Having multiple client-specific interfaces is better than having one general purpose (aka "all-singing, all-dancing") interface.
- **The Reuse/Release Equivalence Principle**: The granule of reuse is the same as the granule of release. Only components that are released through a tracking system can be effectively reused.
- **The Common Reuse Principle**: Classes that tend not to be reused together should not be grouped together in the same package.
- **The Common Closure Principle**: Classes that tend to change together, belong together in the same package. [Is this different from Common Reuse?]

More Named Principles

(cf. http://c2.com/cgi/wiki?PrinciplesOfObjectOrientedDesign)

- **The Acyclic Dependencies Principle**: The dependency structure for released components (i.e. packages) should be acyclic.
- **The Stable Dependencies Principle**: Dependencies between released categories must run in the direction of stability. The dependee should be more stable than the depender.
- **The Stable Abstractions Principle**: The more stable a class category is, the more it should consist of abstract classes. A completely stable category should consist of nothing but abstract classes.

Law of Demeter

Law of Demeter

- This "law" seems generally worthwhile.
- It is not without controversy and difficulties in understanding, cf. http://c2.com/cgi/wiki?LawOfDemeterIsHardToUnderstand
- Therefore it should not be followed slavishly, but neither should it be ignored.

Law of Demeter (LoD)
colloquial version

- "Only talk to your immediate friends".
- [not meaning *friends* in the sense of C++ classes and methods]
- so named by Prof. Karl Lieberherr, Northeastern University:
- LoD home page:
  http://www.cs.neu.edu/home/lieber/LoD.html

Law of Demeter Principle as stated by its author

- Each unit [i.e. class, method] should only use a limited set of other units: only units "closely" related to the current unit.
- Main Motivation: Control information overload. We can only keep a limited set of items in our short-term memory.
- Secondary Motivation: maintainability: A class should not have to know much about distant classes.

Rumbaugh, Booch and the LoD

Rumbaugh: "Avoid traversing multiple links or methods. **A method should have limited knowledge of an object model.** A method must be able to traverse links to obtain its neighbors and must be able to call operations on them, but it should not traverse a second link from the neighbor to a third class."

Booch: "The basic effect of applying this Law is the creation of **loosely coupled classes**, whose implementation secrets are **encapsulated**. Such classes are fairly unencumbered, meaning that to understand the meaning of one class, you need not understand the details of many other classes."

LoD: More Specific OO Interpretation

- An object should only invoke methods of:
  - objects that are ***declared*** within the object's class
  - objects that are ***parameters*** *of the method*
  - ***itself***
  - objects that it ***creates***

- mnemonic DPIC ("depict")

Expressly Precluded by LoD

- Do not extract object B from an object A and perform an operation on it.
- Instead, **recast** what you want to do as an operation on A. That operation may call operations on B.

Example of Violating the Law of Demeter

- class Patron
  {
  void sendNotice();
  }

- class Book
  {
  Patron getBorrower();
  };

- class Library
  {
  map<Book> booksByTitle;

  Book getBook(string Title);
  };

```
library.getBook("Ulysses").getBorrower().sendOverdueNotice();
```

The above statement is considered bad:
The client of library has to *know about* books and borrowers just to send this notice.

Remedying the Violation

- class Library
  {
  map<Book> booksByTitle;

  void sendOverdueNotice(string Title);
  };

library.sendOverdueNotice(“Ulysses”);

Also called the "one-dot" rule

Prefer

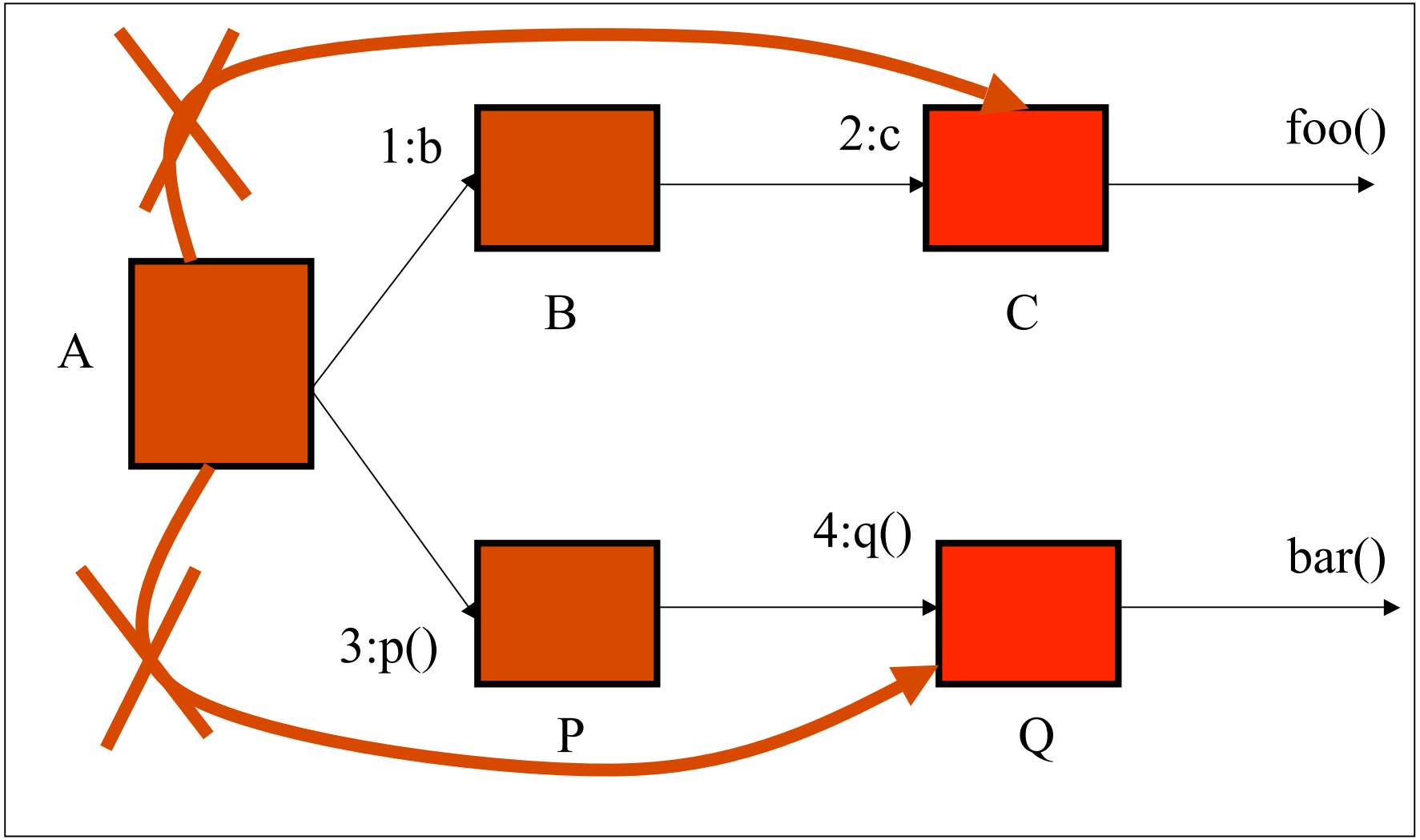
```
sendOverdueNotice("Ulysses");
```

to

```
library.getBook("Ulysses").getBorrower().sendOverdueNotice();
```

Violations: Dataflow Diagram

(slide from Lieberherr)



More on Following the LoD

- General idea: Keep the structure as **loose** as possible (known as "late binding" in conventional system design).

- Specific incarnations:
  "Adaptive Plug-and-Play Components" (Liberherr)

Further Guidelines
related to LoD
will be seen when we
discuss "Design Patterns"

Related Hot Topic

- Aspect-Oriented Programming
  - Program implementation is sliced up by "aspects" which tend to **cut across** class boundaries.
  - Aspects are addressed separately in programming, the **woven** together with a weaver, using "**join points**".
- *Aspect-Oriented Programming*, Gregor Kiczales, et al., Xerox PARC, 1997

Example of Aspects

- For a mail-order company
  - Ordering aspect
  - Customer service aspect
  - Shipping aspect
  - Inventory aspect
  - Pricing aspect
  - Marketing aspect
  - Accounting aspect
  - Shareholder aspect
- These aspects can largely be treated separately in an enterprise application, yet they have various *join points* at specific products, customers, etc.
- This seems related to the SRP.