

# GRASP Principles

UA.DETI.PDS - 2024/25

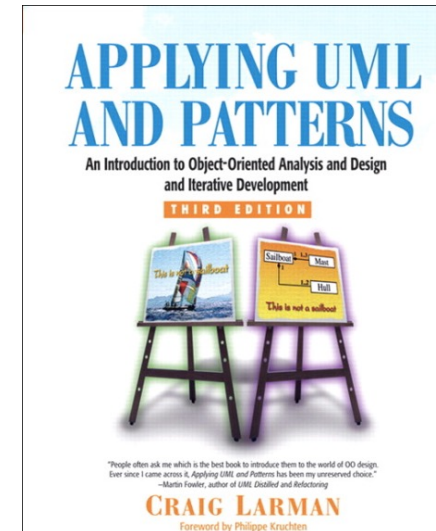
José Luis Oliveira

# Resources & Credits

## ❖ Applying UML and Patterns

Craig Larman

Chapters 16 & 22



- GRASP – General Responsibility Assignment Software Patterns Explained
  - <http://www.kamilgrzybek.com/design/grasp-explained/>

# GRASP

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## ❖ General Responsibility Assignment Software Patterns

- Name chosen to suggest the importance of grasping fundamental principles to successfully design object-oriented software

## ❖ Describe fundamental principles of object design and responsibility

## ❖ For instance ...

- You want to assign a **responsibility** to a class
- You want to avoid or minimize additional **dependencies**
- You want to maximise **cohesion** and minimise **coupling**
- You want to increase **reuse** and decrease **maintenance**
- You want to maximise **understandability**
- .....etc.

# Conducting example 1 - POS

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## ❖ Point of Sale / Point of Sale Terminal:

- Application for a shop, restaurant, etc. that registers **sales**.
- Each sale is of one or more **items** of one or more product types, and happens at a certain date.
- A **product** has a specification including a description, unitary price and identifier.
- The application also registers payments (say, in cash) associated to sales.
- A **payment** is for a certain amount, equal or greater than the total of the sale.



# POS - A simple model

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**Register**

**Sale**

-date: Date

**SalesLineItem**

-quantity: int

**Payment**

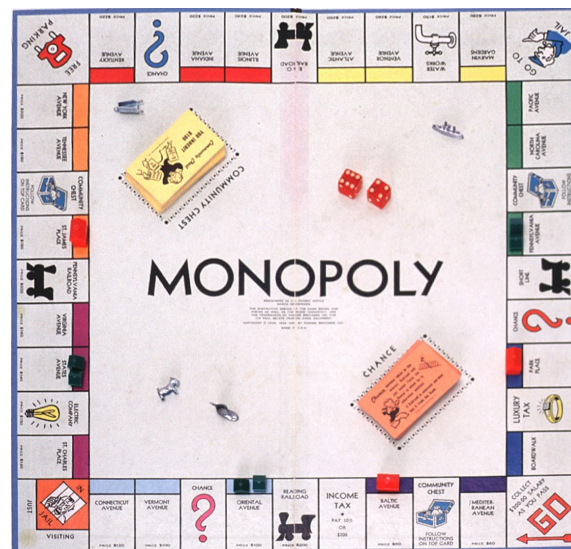
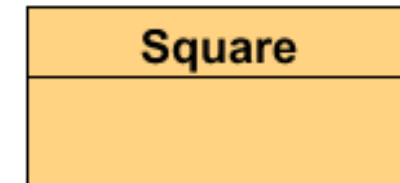
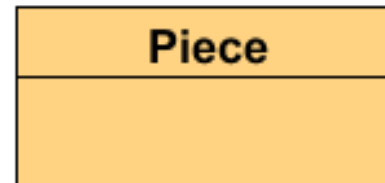
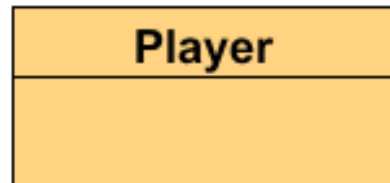
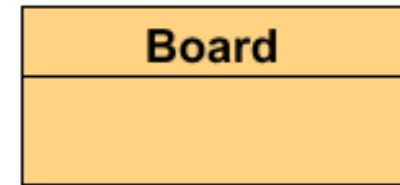
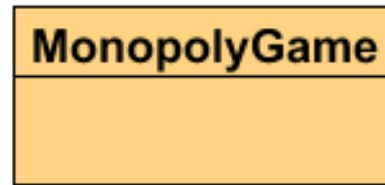
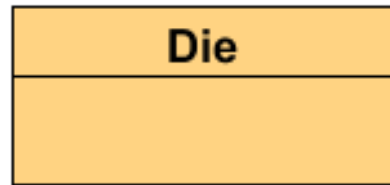
-amount: double

**ProductSpecification**

-description: String  
-itemID: int  
-price: double

# Conducting example 2: Monopoly

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# GRASP principles

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- ❖ Creator
- ❖ Information Expert
- ❖ Low Coupling
- ❖ High Cohesion
- ❖ Controller
- ❖ Polymorphism
- ❖ Pure Fabrication
- ❖ Indirection
- ❖ Protected Variations

# GRASP principles

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# Creator

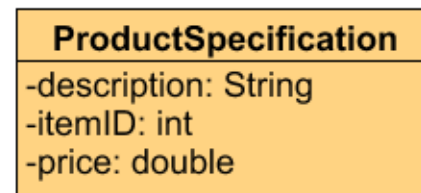
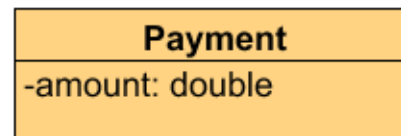
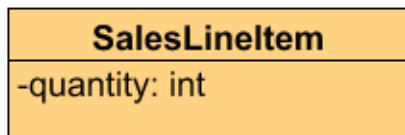
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- ❖ Name: Creator
- ❖ Problem: Who creates an instance of A?
- ❖ Solution: Assign class B the responsibility to create an instance of class A if one of these is true (the more the better):
  - B contains or aggregates A (in a collection)
  - B records A
  - B closely uses A
  - B has the initializing data for A

# Creator: example

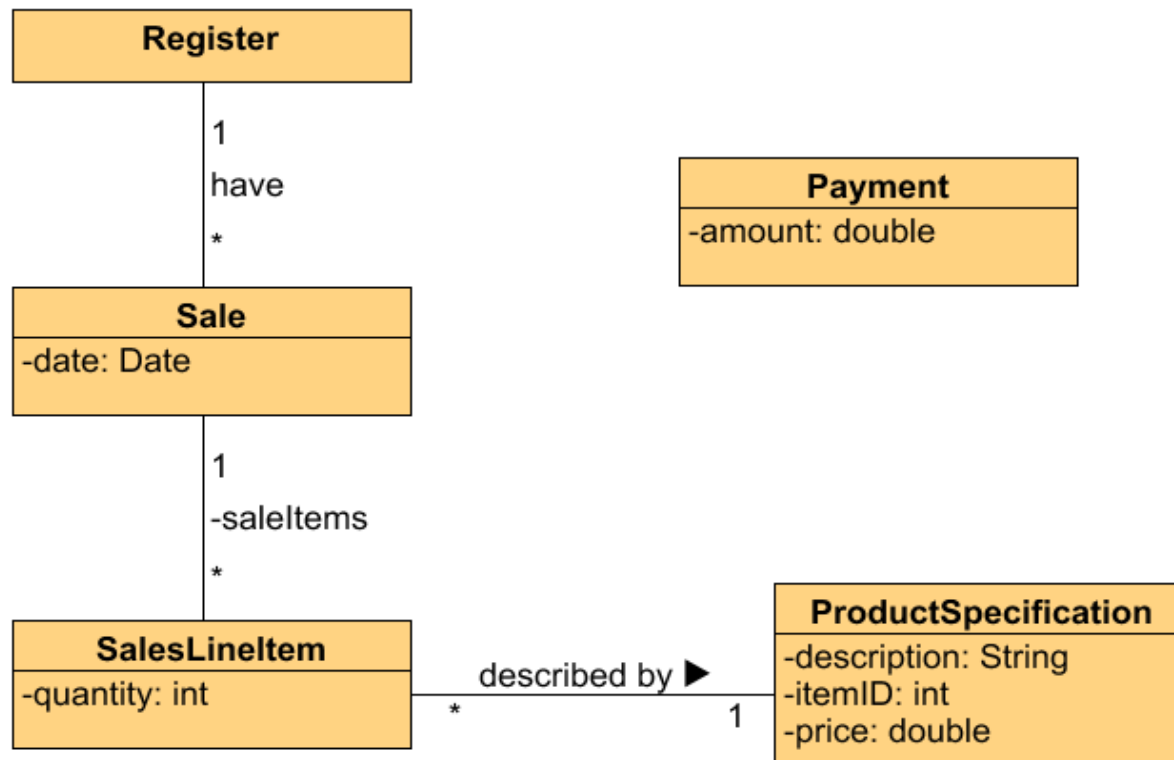
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- ❖ Who is responsible for creating SalesLineItem objects, from an itemID and a quantity?



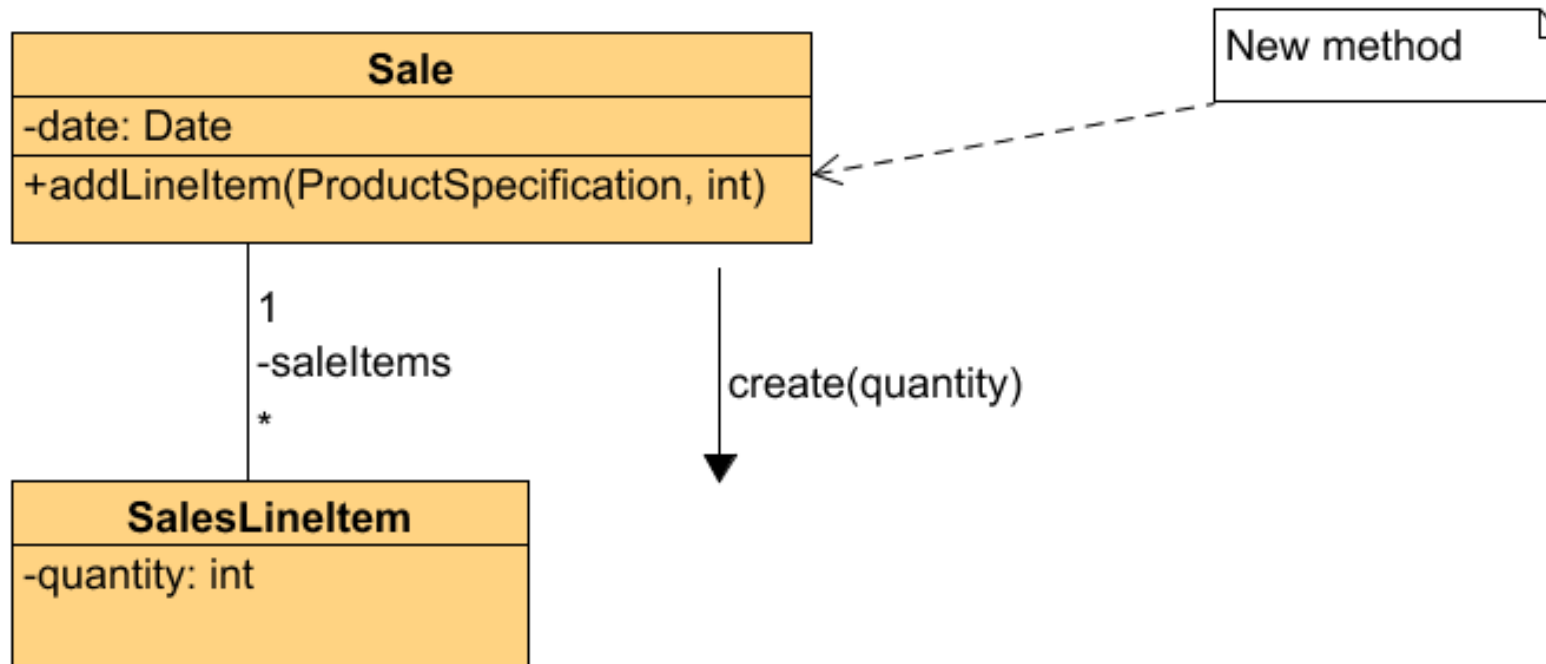
# Creator: example

- ❖ Who is responsible for creating SalesLineItem objects, from an itemID and a quantity?
- ❖ Look for a **class that aggregates or contains** SalesLineItem objects.

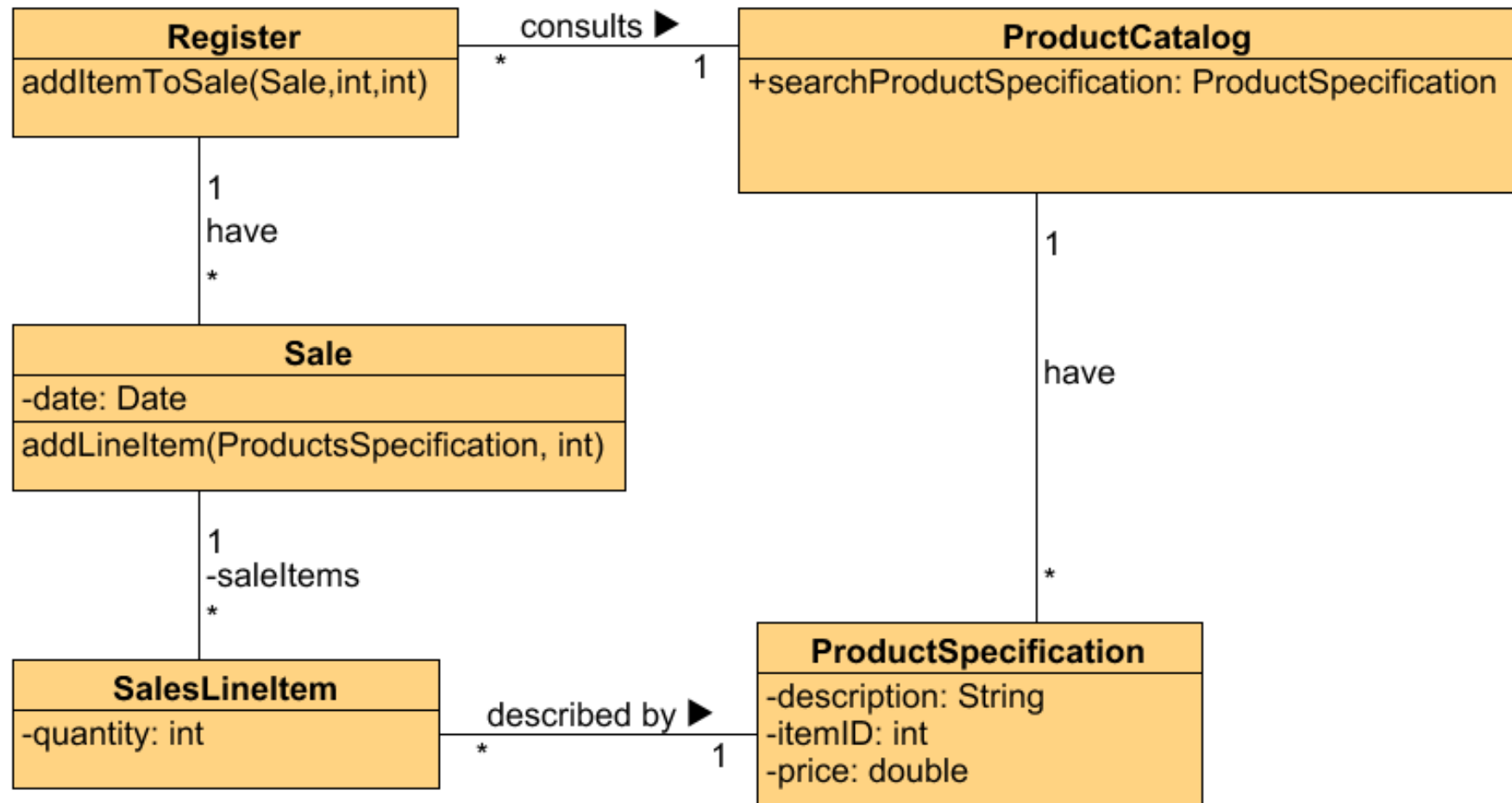


# Creator: example

- ❖ Creator pattern suggests Sale.
- ❖ Collaboration diagram is



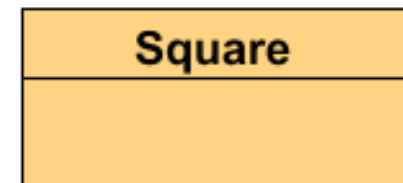
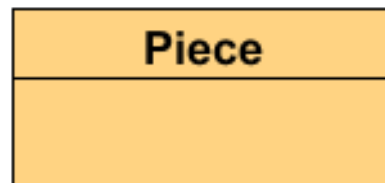
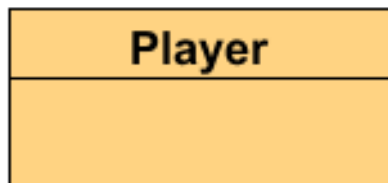
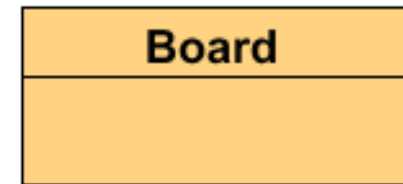
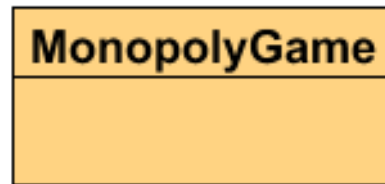
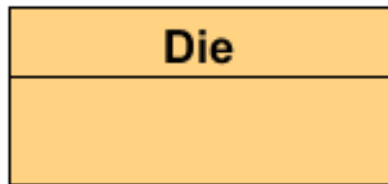
# Creator: example



# Creator: another example

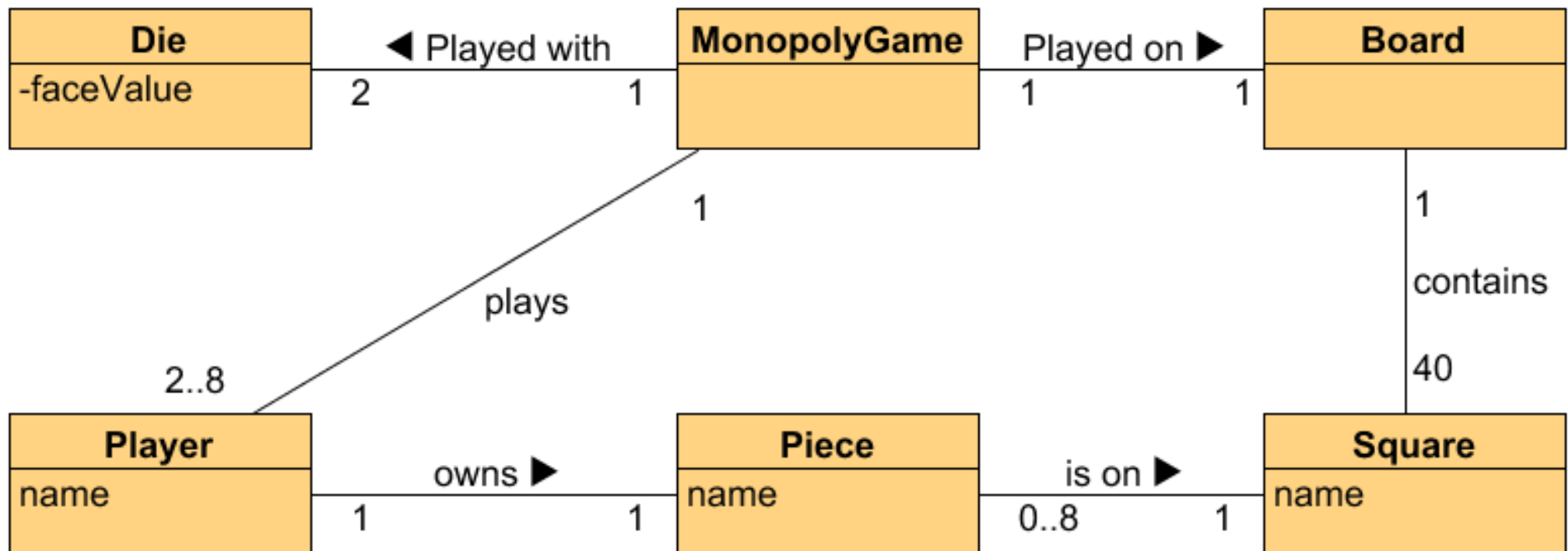
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❖ Who creates what?



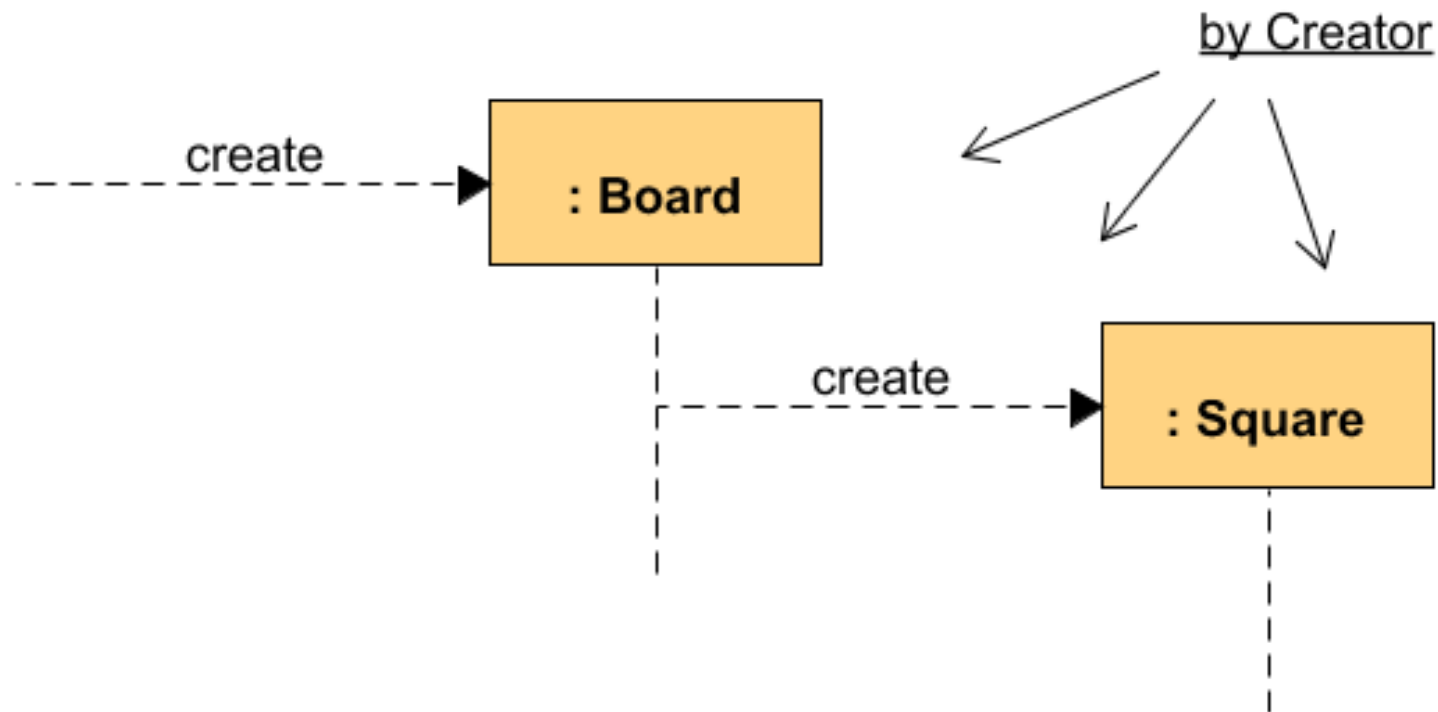
# Creator: another example

❖ Who creates the Squares?



# Creator pattern

- ❖ How does Create pattern lead to this partial Sequence diagram?

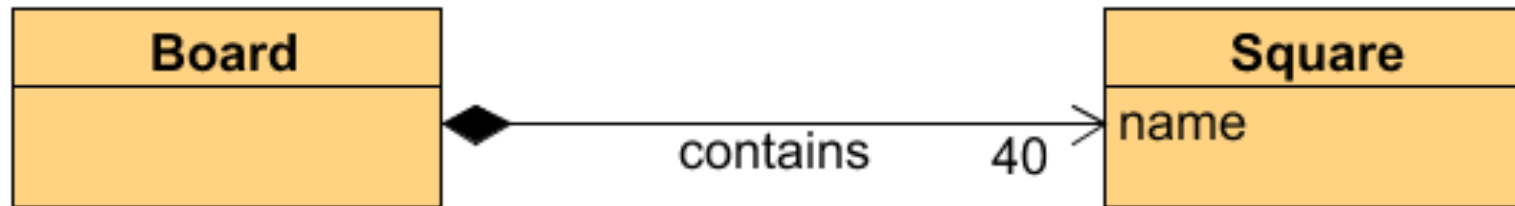




# Creator pattern

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- ❖ How does Create pattern develop this design class diagram?



- ❖ Board has a composite aggregation relationship with Square
  - I.e., Board contains a collection of Squares

# Discussion of Creator pattern

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- ❖ Promotes low coupling by making instances of a class responsible for creating objects they need to reference
- ❖ Connect an object to its creator when:
  - Aggregator aggregates Part
  - Container contains Content
  - Recorder records
  - Initializing data passed in during creation

# Contraindications or caveats

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- ❖ Creation may require significant complexity:
  - recycling instances for performance reasons
  - conditionally creating instances from a family of similar classes
- ❖ In these instances, other patterns are available...
  - We'll learn about Factory and other patterns later...

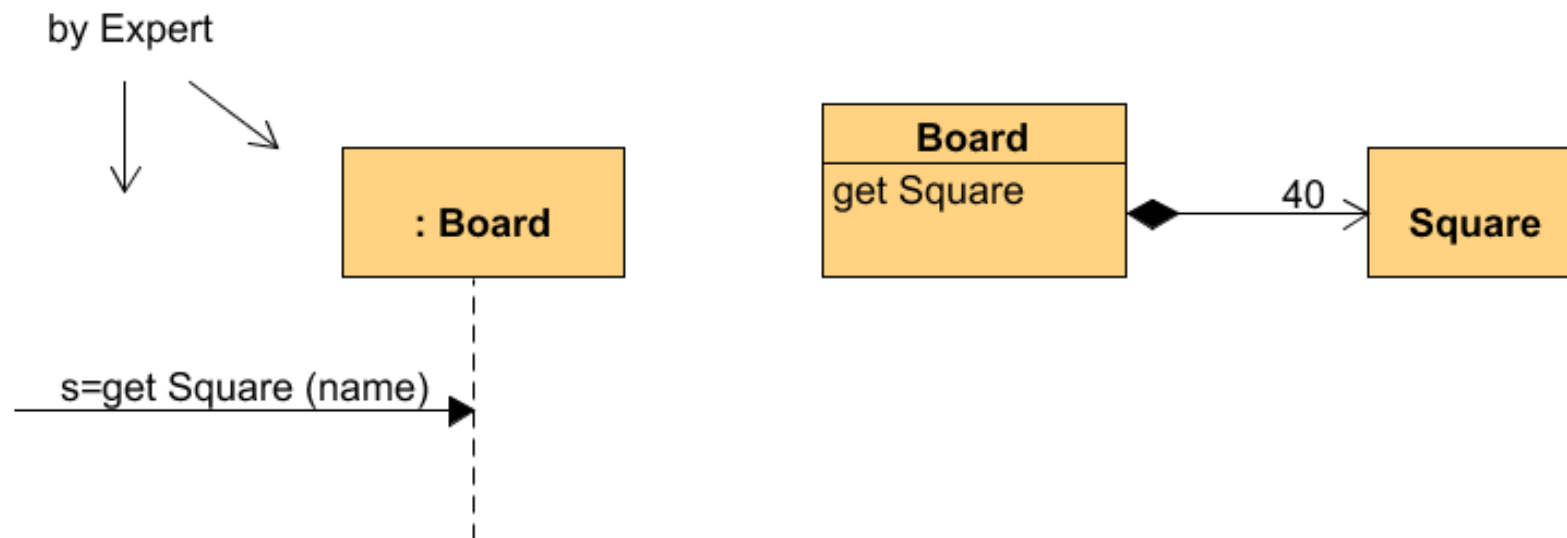
# GRASP

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- ❖ Creator
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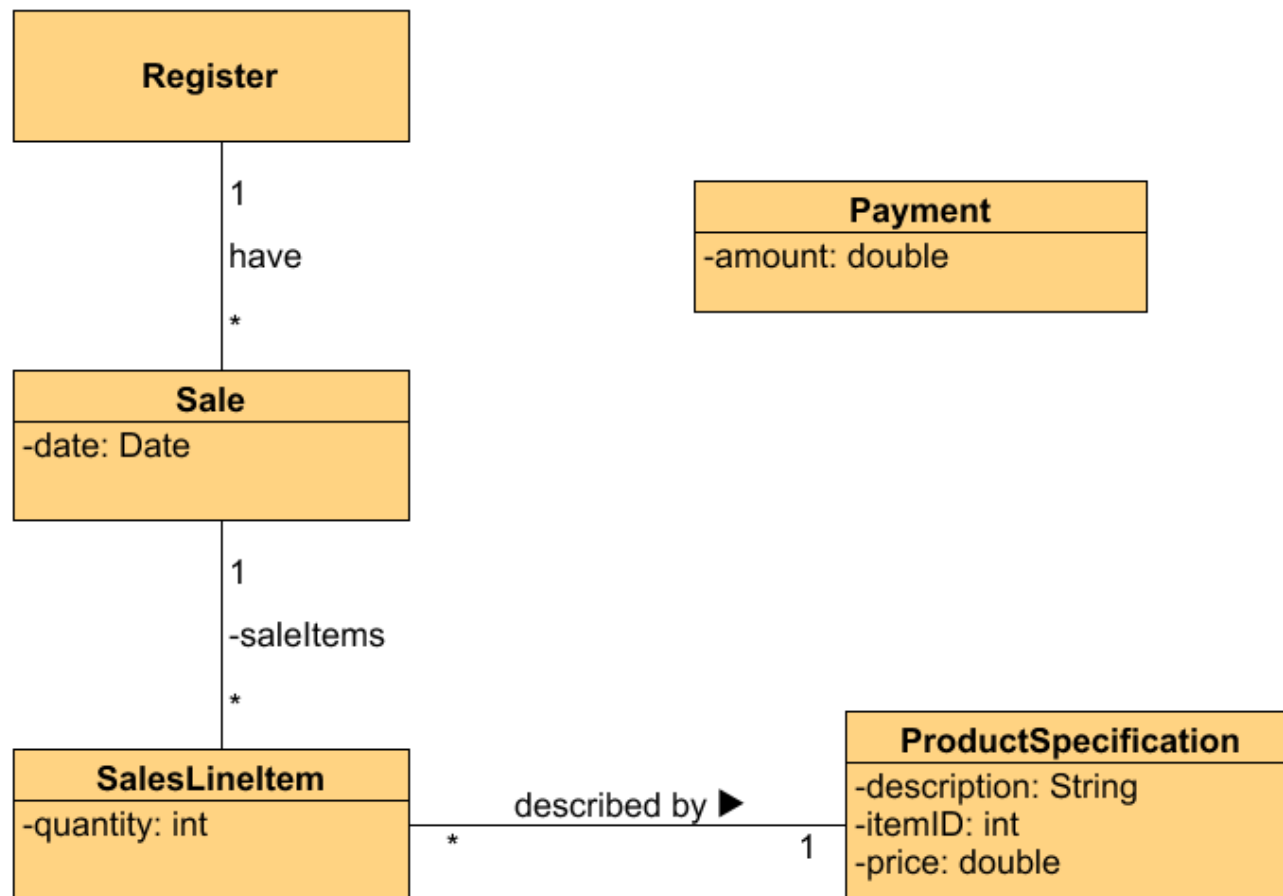
# Information Expert principle

- ❖ Name: Information Expert
- ❖ Problem: How to assign responsibilities to objects?
- ❖ Solution: Assign responsibility to the class that has the information needed to fulfill it?
- ❖ E.g., *Board* information needed to get a *Square*



# Information Expert: another example

- ❖ Who is responsible for knowing the grand total of a sale in a typical Point of Sale application?



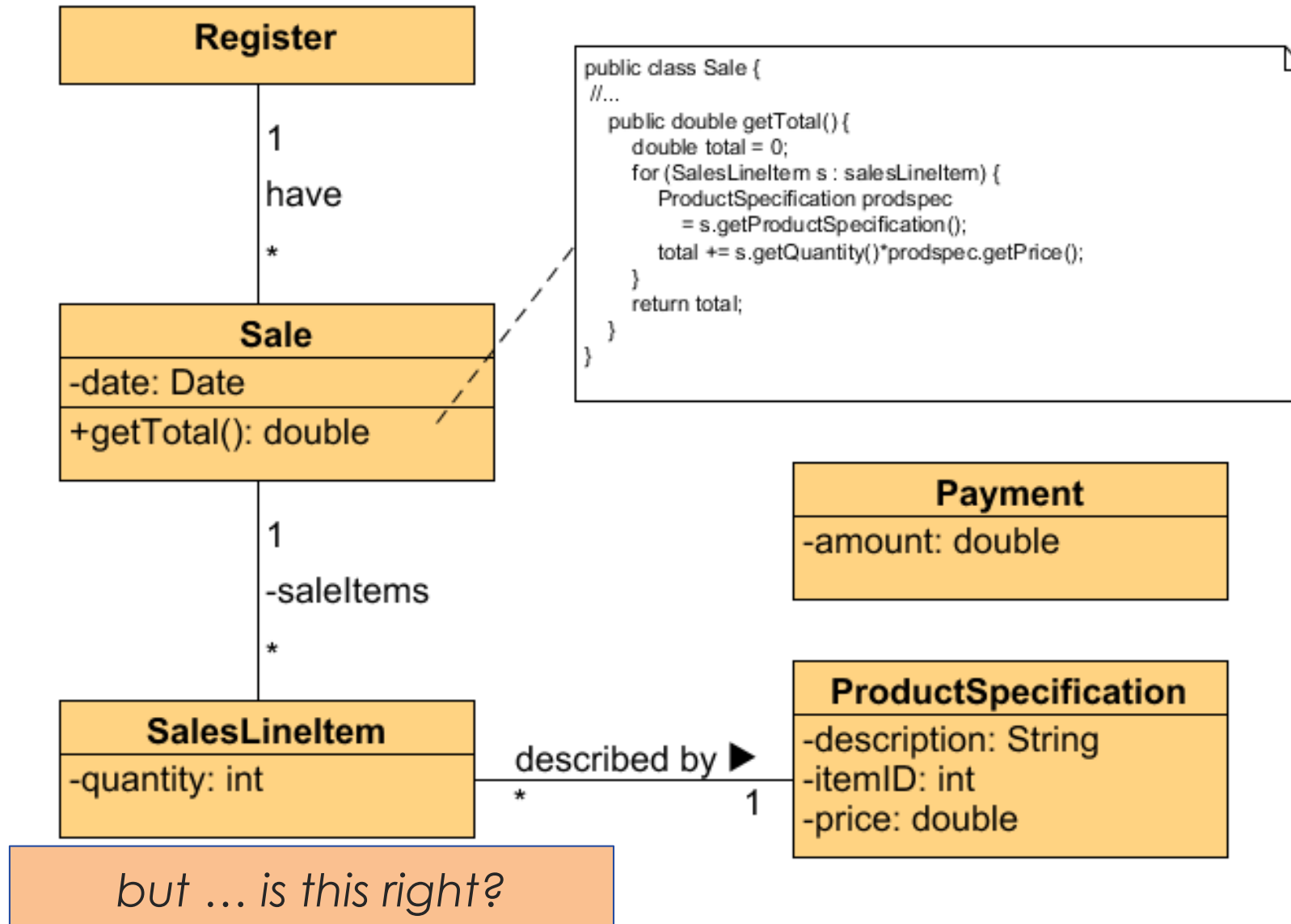
# Information Expert: example

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- ❖ Need all *SalesLineItem* instances and their subtotals. Only *Sale* knows this, so *Sale* is the information expert.
- ❖ Hence

Sale
-date: Date
+getTotal(): double

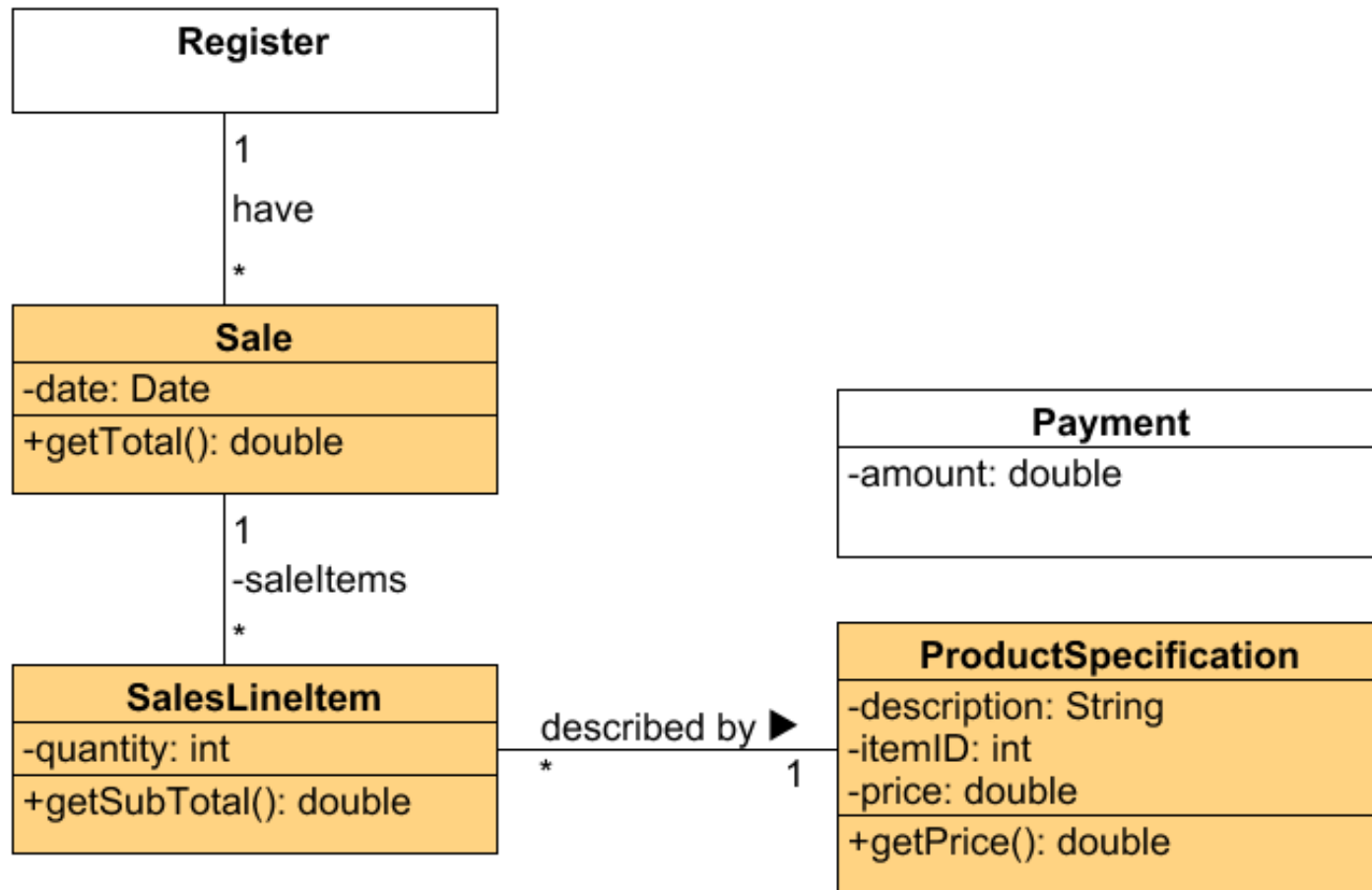
# Information Expert: example





# Information Expert: example

- ❖ But subtotals are needed for each line item.
  - By Expert, *SalesLineItem* is expert, knows quantity and has association with *ProductSpecification* which knows price.



# Information Expert: example

```
class Register {
    List<Sale> sales = new ArrayList<>();
    //...
    public void addItemToSale(Sale sale, int itemID, int quantity) {
        ProductSpecification prodSpec =
            ProductCatalog.searchproductSpecification(itemID);
        sale.addLineItem(prodSpec, quantity);
    }
}

class Sale {
    List<SalesLineItem> salesLineItem = new ArrayList<>();
    //...
    public void addLineItem(ProductSpecification prodSpec, int quantity) {
        salesLineItem.add(new SalesLineItem(prodSpec, quantity));
    }
}
```

# Information Expert: example

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- ❖ Hence responsibilities assign to the 3 classes.

Class	Responsibility
Sale	knows sale total
SalesLineItem	knows line item subtotal
ProductSpecification	knows product price

- ❖ Fulfillment of a responsibility may require information spread across different classes, each expert on its own data.
  - Real world analogy: workers in a business, bureaucracy, military. “Don’t do anything you can push off to someone else”.

# Benefits and Contraindications

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- ❖ Facilitates information encapsulation
  - Classes use their own info to fulfill tasks - highly cohesive classes
  - Code easier to understand just by reading it
- ❖ Promotes low coupling
  - *Sale* doesn't depend on *ProductSpecification*

But:

- ❖ Can cause a class to become excessively complex
  - e.g. who is responsible to save *Sale* in a database? *Sale* is the information expert, but with this decision, then each class has its own services to save itself in a database.
  - This needs another kind of separation – domain and persistence

# GRASP

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# Low Coupling pattern

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- ❖ Name: Low Coupling
- ❖ Problem: How to reduce the impact of change and encourage reuse?
- ❖ Solution: Assign a responsibility so that coupling (linking classes) remains low. Try to avoid one class to have to know about many others.
  - changes are localised
  - easier to understand
  - easier to reuse

# Low Coupling pattern

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- ❖ Coupling measures of how strongly a class is connected, depends, relies on, or has knowledge of objects of other classes.
- ❖ Classes with strong coupling
  - suffer from changes in related classes
  - are harder to understand and maintain
  - are more difficult to reuse
- ❖ But coupling is necessary if we want classes to exchange messages!
  - The problem is too much of it and/or too unstable classes.

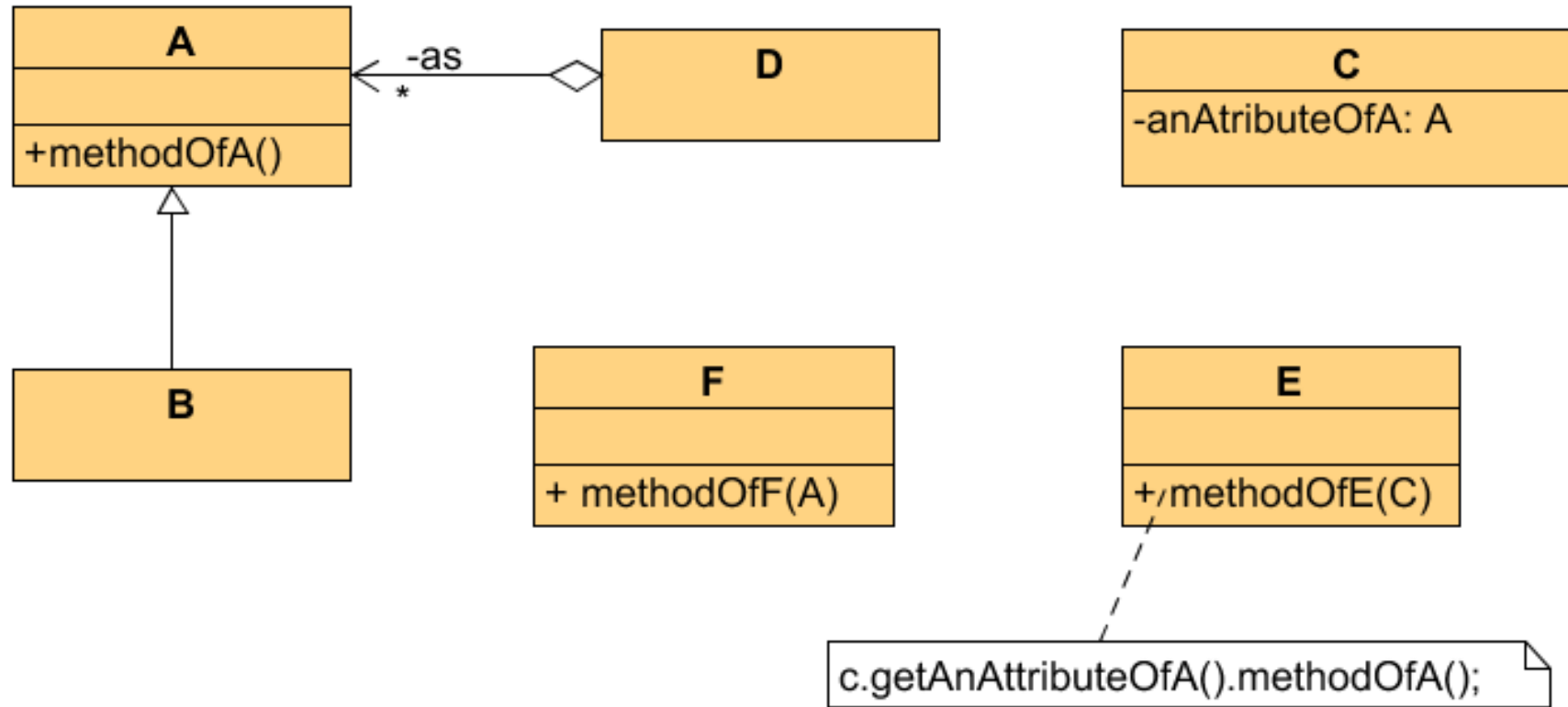
# Entities coupling

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- ❖ In object-oriented languages, common forms of coupling from TypeX to TypeY include:
  - TypeX has an **attribute** (data member or instance variable) that refers to a TypeY instance, or TypeY itself.
  - TypeX has a **method** which references an instance of TypeY, or TypeY itself, by any means. These typically include a parameter or local variable of type TypeY, or the object returned from a message being an instance of TypeY.
  - TypeX is a direct or indirect **subclass** of TypeY.
  - TypeY is an **interface**, and TypeX implements that interface.

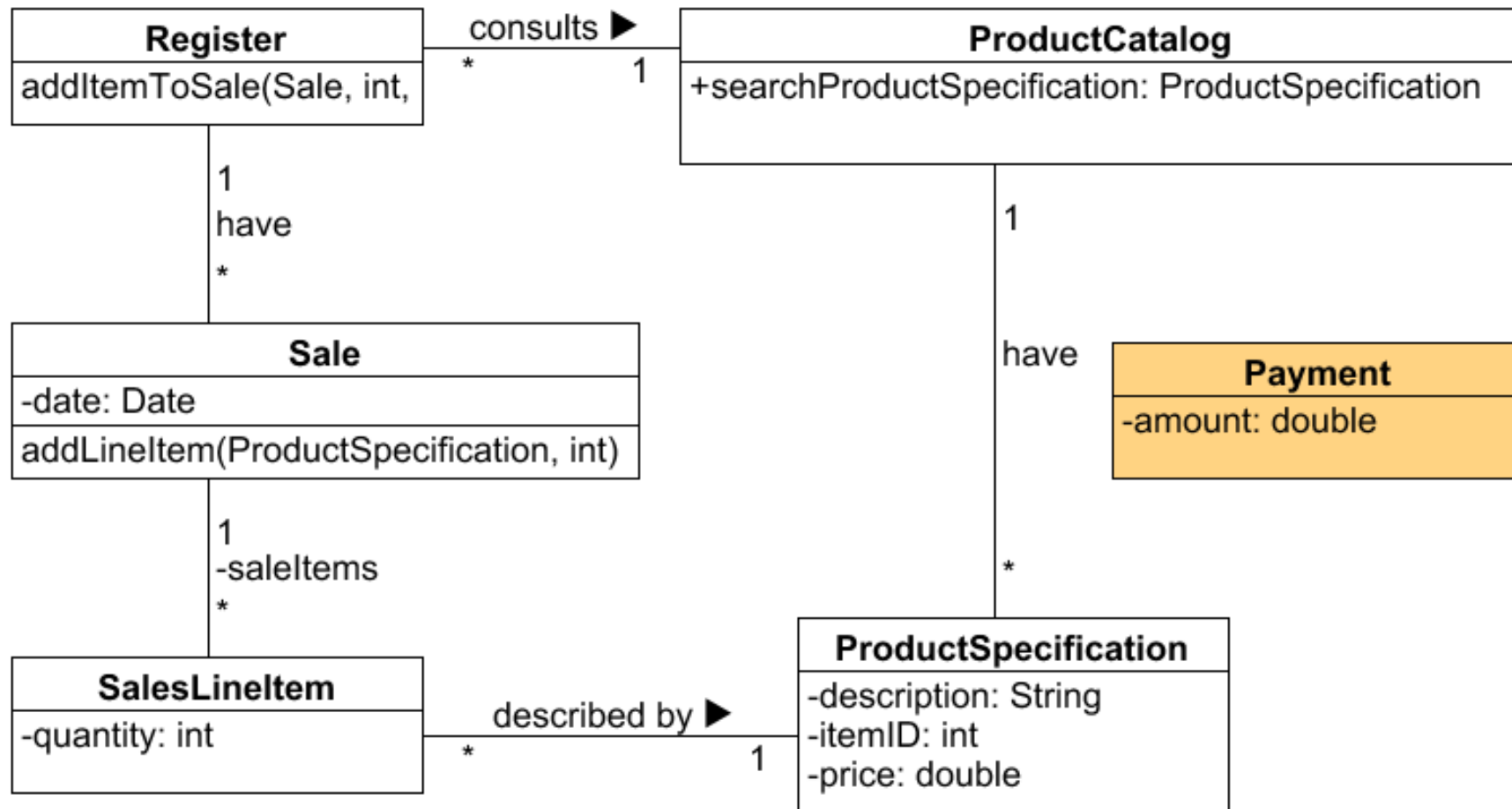


# Entities coupling



# Low Coupling: example

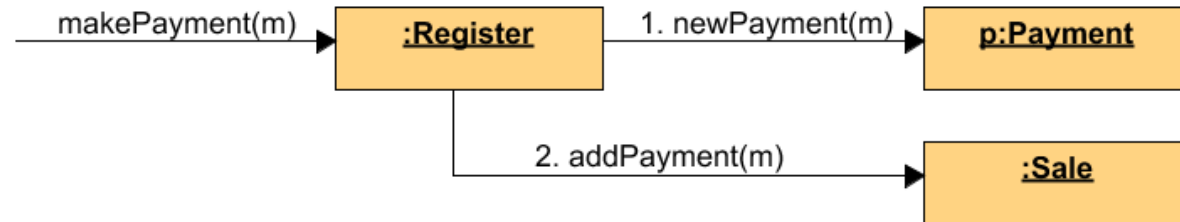
❖ Who has responsibility to create a payment?



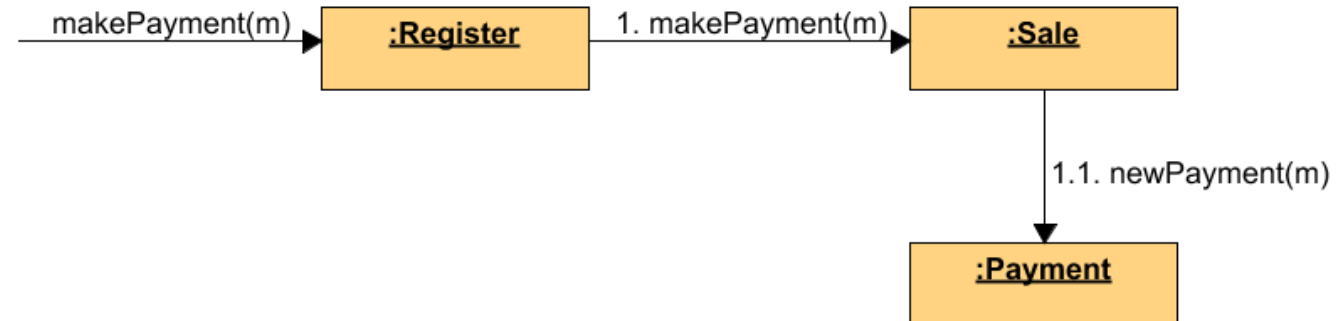
# Low Coupling: example

❖ Two possibilities:

– Register



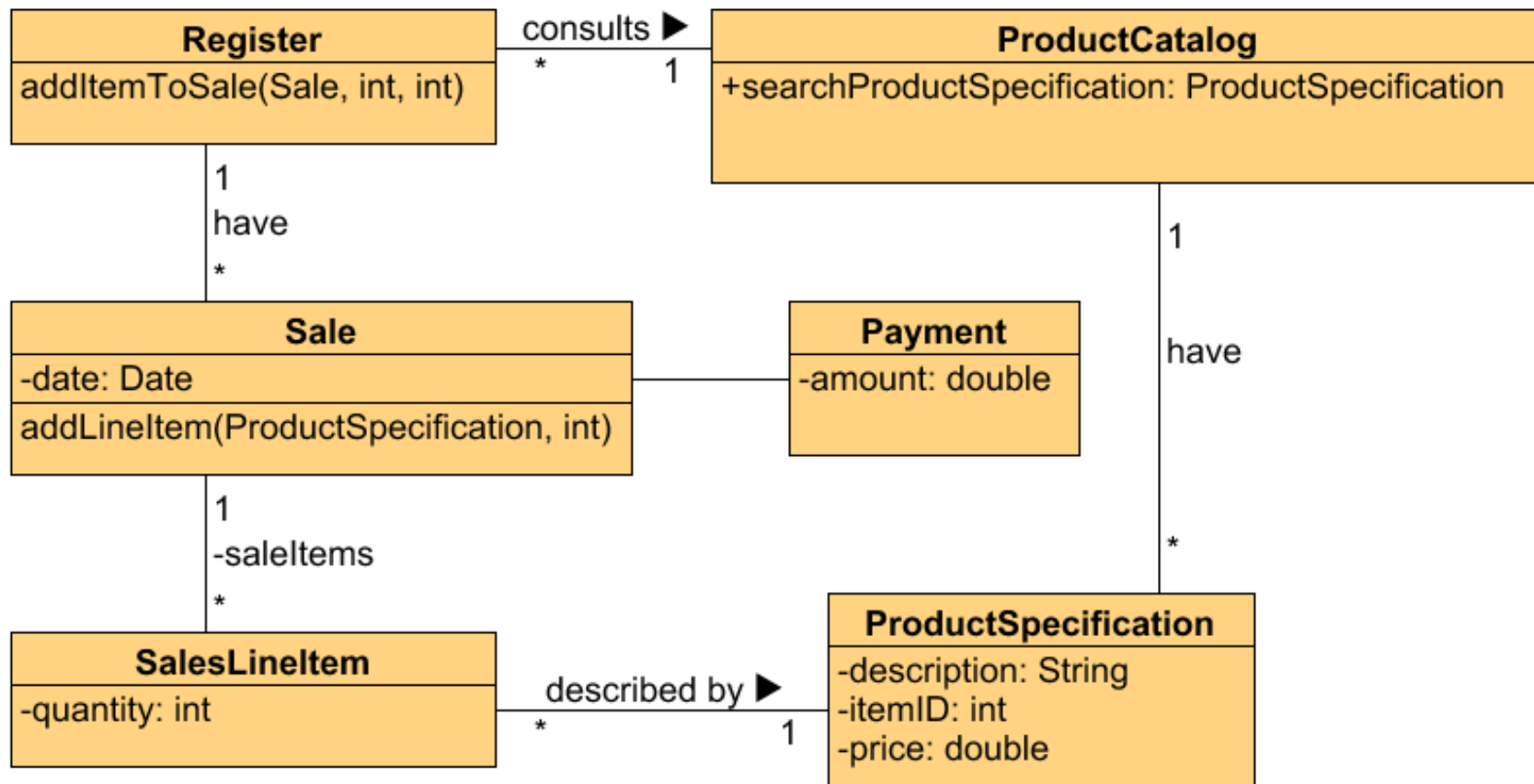
– Sale



– Low coupling suggests *Sale* because *Sale* must be coupled to *Payment* anyway (*Sale* knows its *total*).

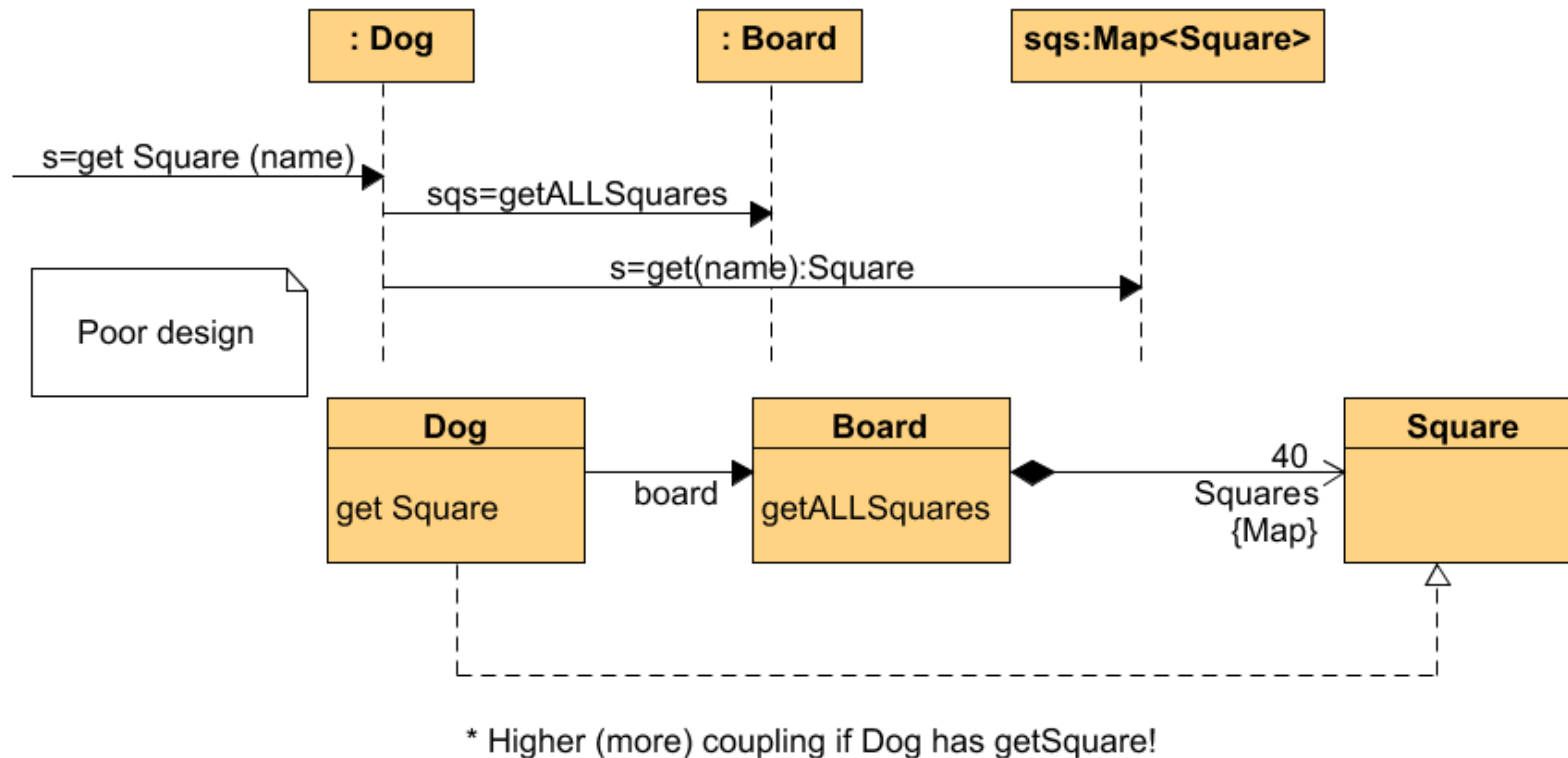
# Low Coupling: example

- ❖ Who should own the method *getBalance()* that computes payment amount - total of sale?



# Low Coupling: monopoly

- ❖ Why does the following design violate Low Coupling?



- Why is a better idea to leave getSquare responsibility in Board?

# Benefits & Contraindications

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- ❖ Understandability: Classes are easier to understand in isolation
- ❖ Maintainability: Classes aren't affected by changes in other components
- ❖ Reusability: easier to grab hold of classes

But:

- ❖ A higher coupling to stable classes is not a big issue
  - e.g., libraries and well-tested classes

# GRASP

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# High Cohesion pattern

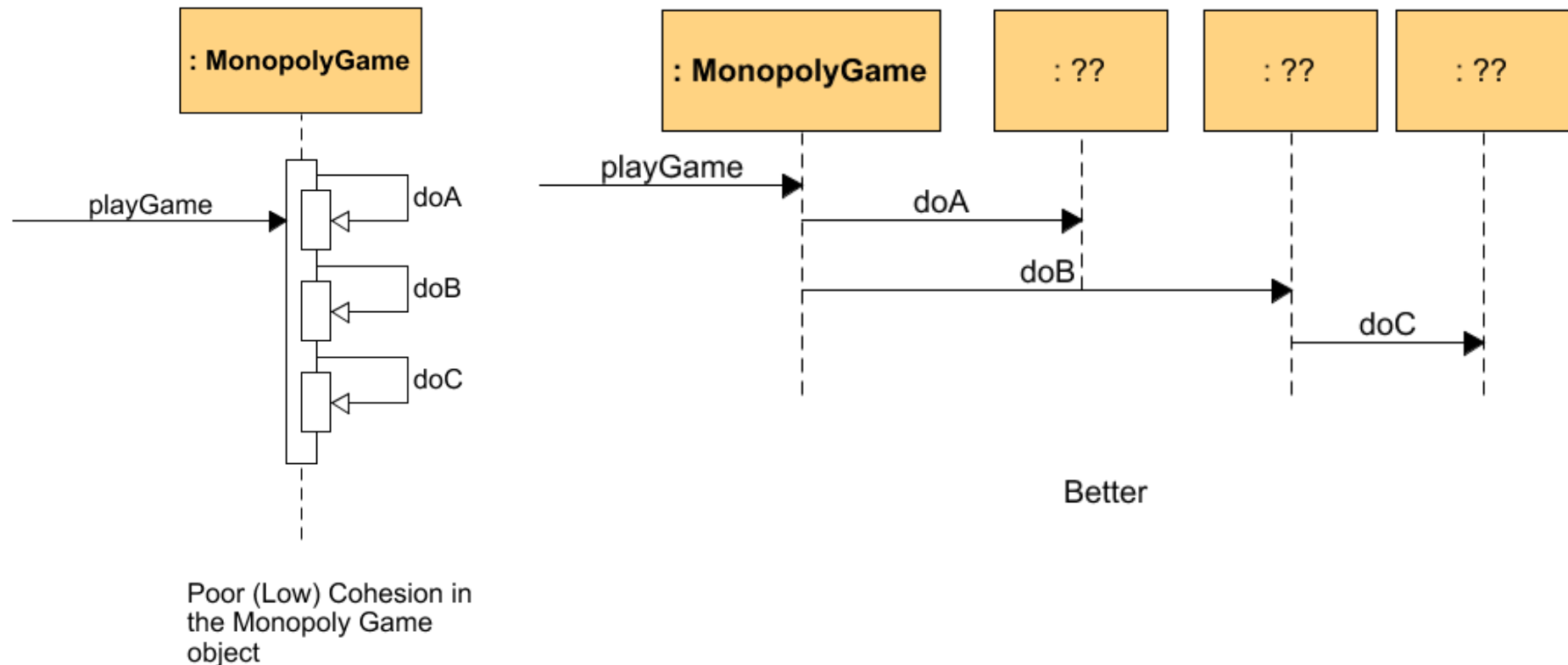
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- ❖ Cohesion measures how strongly related and focused are the responsibilities of an element
- ❖ Name: High Cohesion
- ❖ Problem: How to keep classes focused and manageable?
- ❖ Solution: Assign responsibility so that cohesion remains high.



# High Cohesion

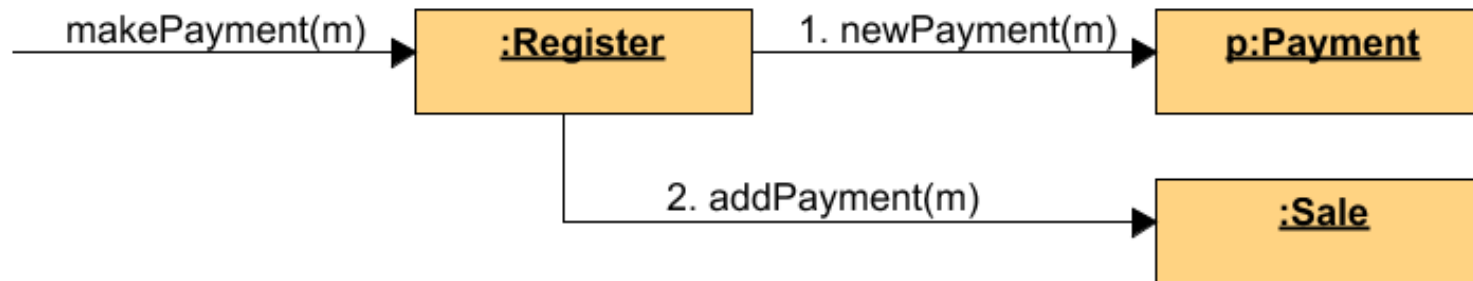
- ❖ How does the design on right promote high cohesion?



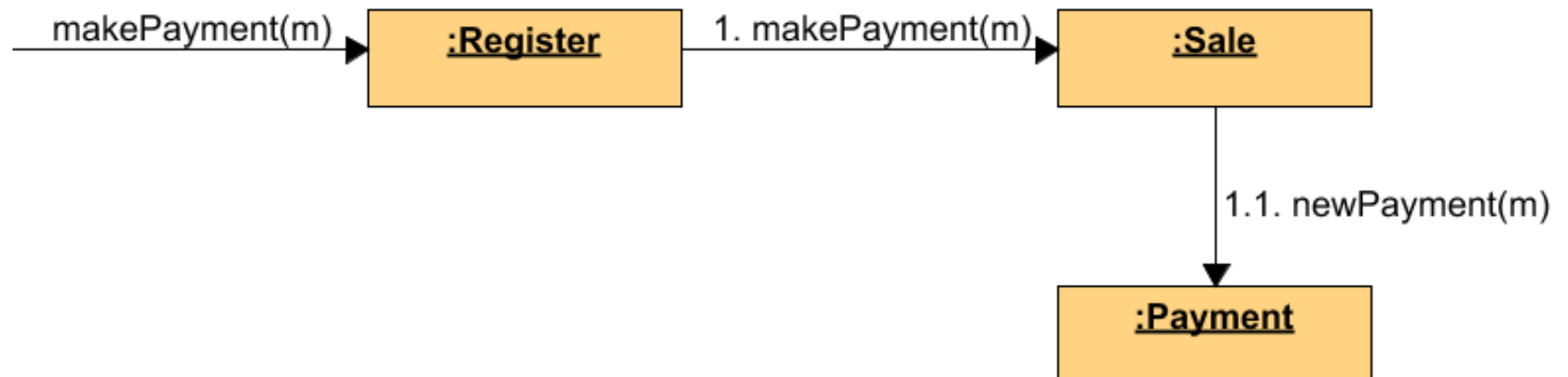
- ❖ Delegate responsibility & coordinate work

# High Cohesion

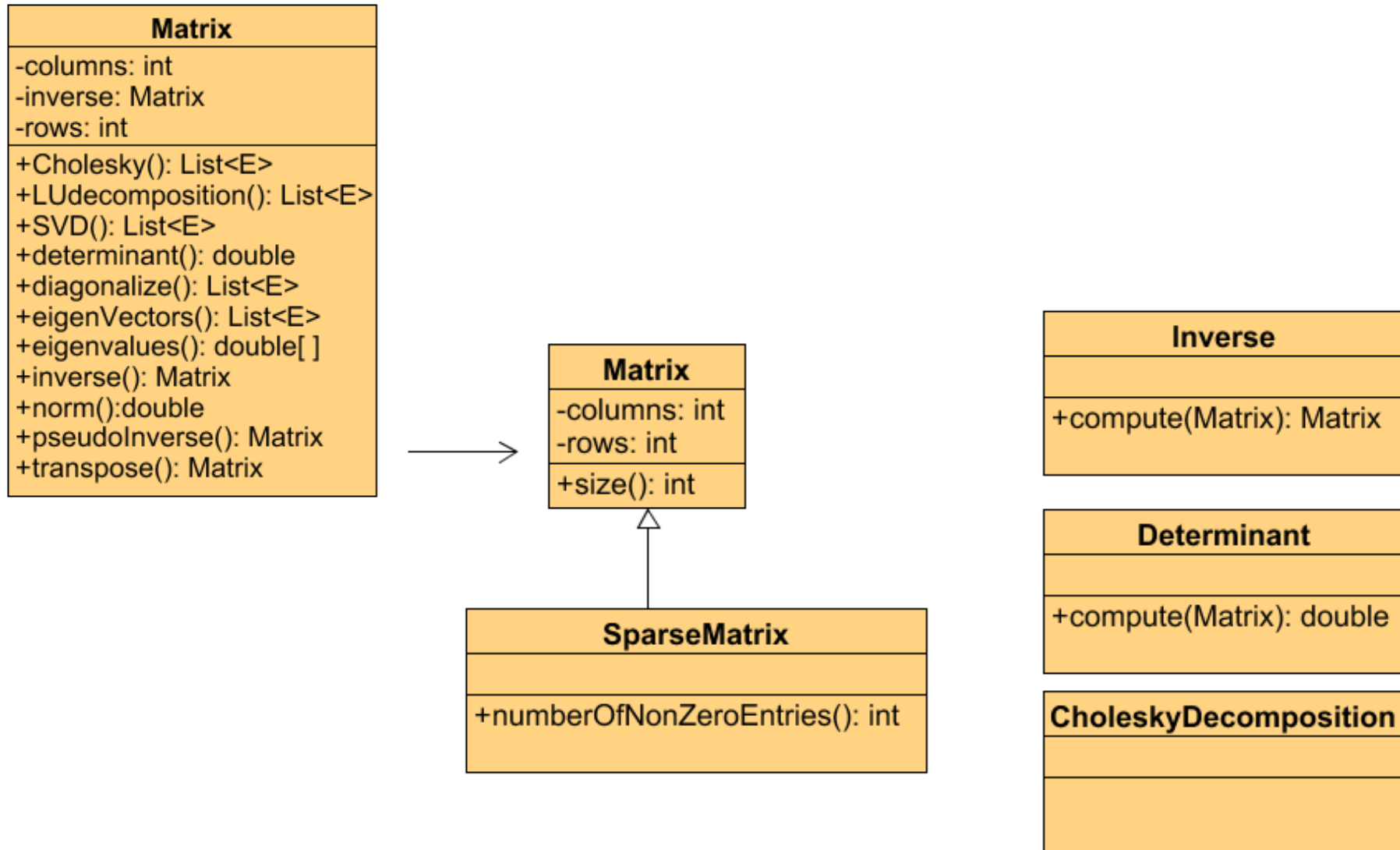
- ❖ *Register* would take on more and more responsibilities and become less cohesive.



- ❖ Giving responsibility to *Sale* supports higher cohesion in *Register*, as well as low coupling.



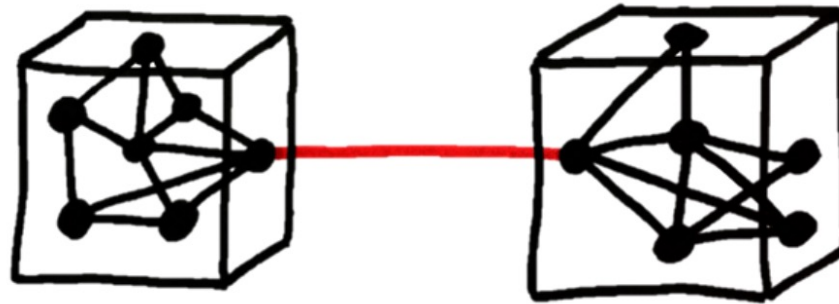
# High Cohesion



# Benefits & Contraindications

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- ❖ Understandability, maintainability
- ❖ Complements Low Coupling



But:

- ❖ Sometimes desirable to create less cohesive server objects
  - that provide an interface for many operations, due to performance needs associated with remote objects and remote communication

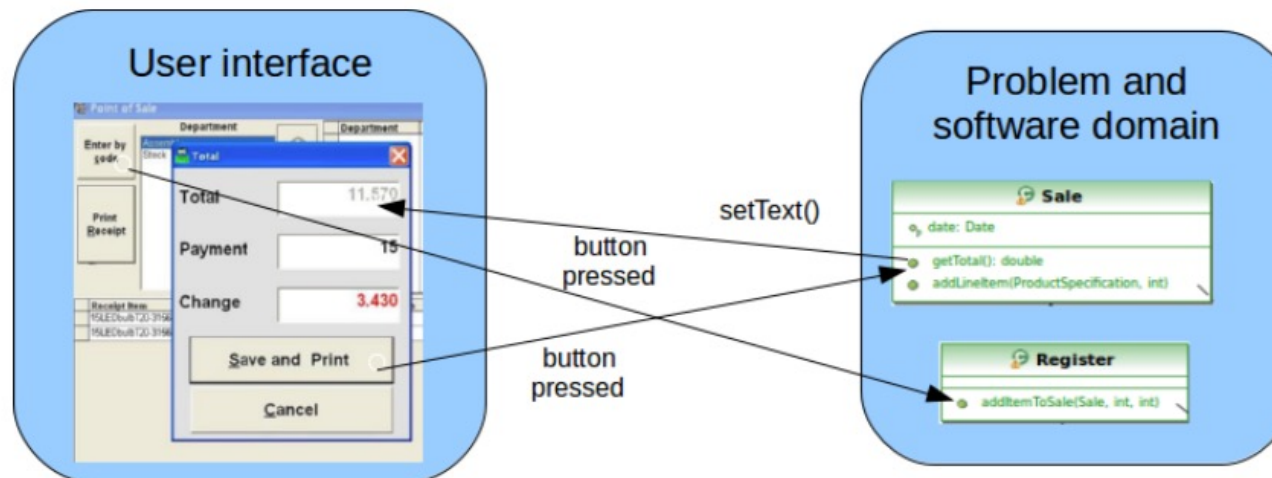
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# Controller

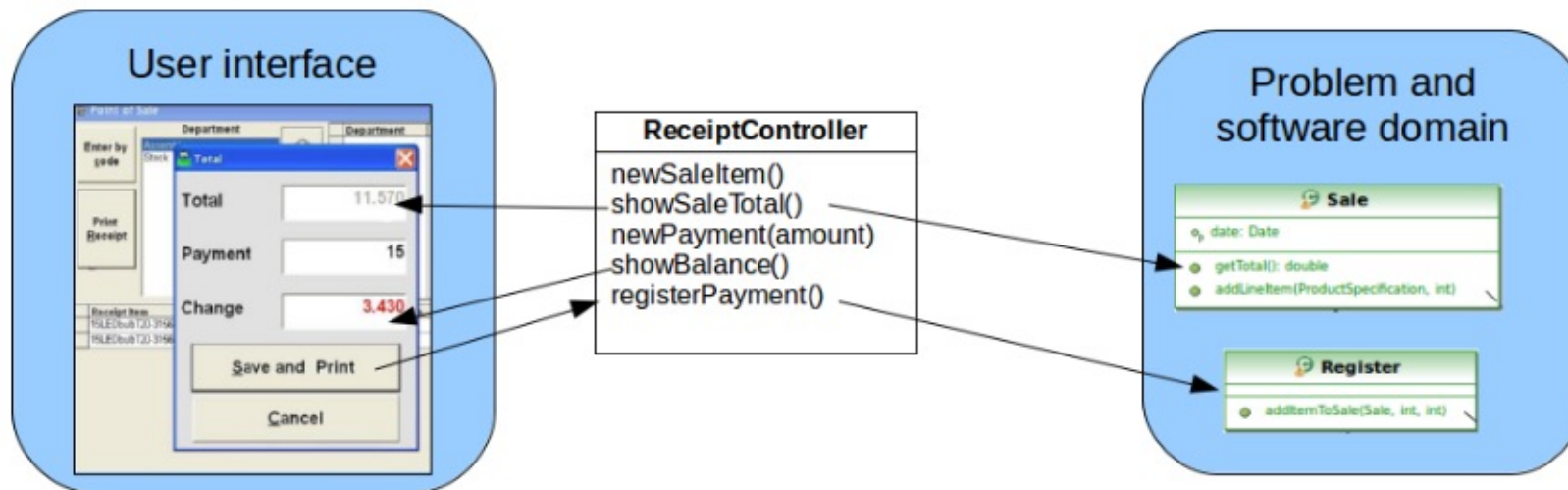
- ❖ Name: Controller
  - *(more on Model-View-Controller architecture)*
- ❖ Problem: Who should be responsible for UI events?



# Controller

## ❖ Solution:

- If a program receive events from external sources other than its GUI, add an event class to decouple the event source(s) from the objects that actually handle the events.



# Controller

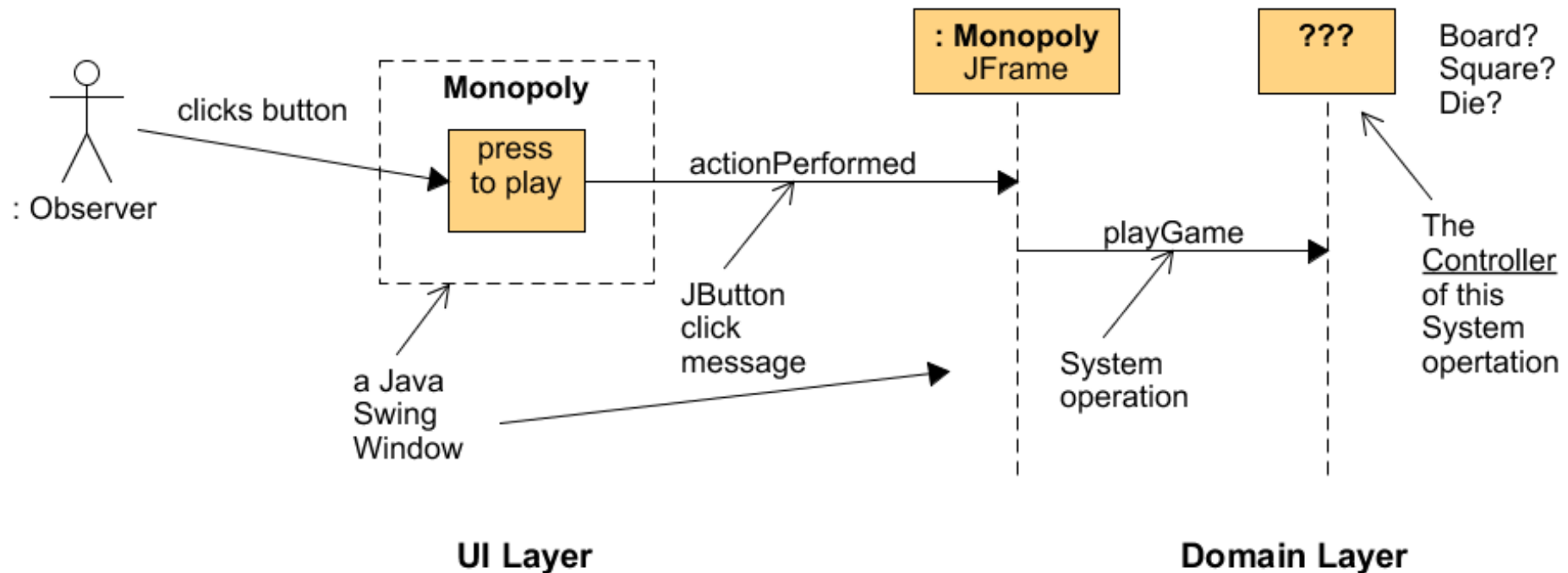
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- ❖ Assign the responsibility for handling a system event message to a class representing one of these choices:
  1. The business or overall "system"(a façade controller).
  2. An artificial class, Pure Fabrication representing the use case (a use case controller).



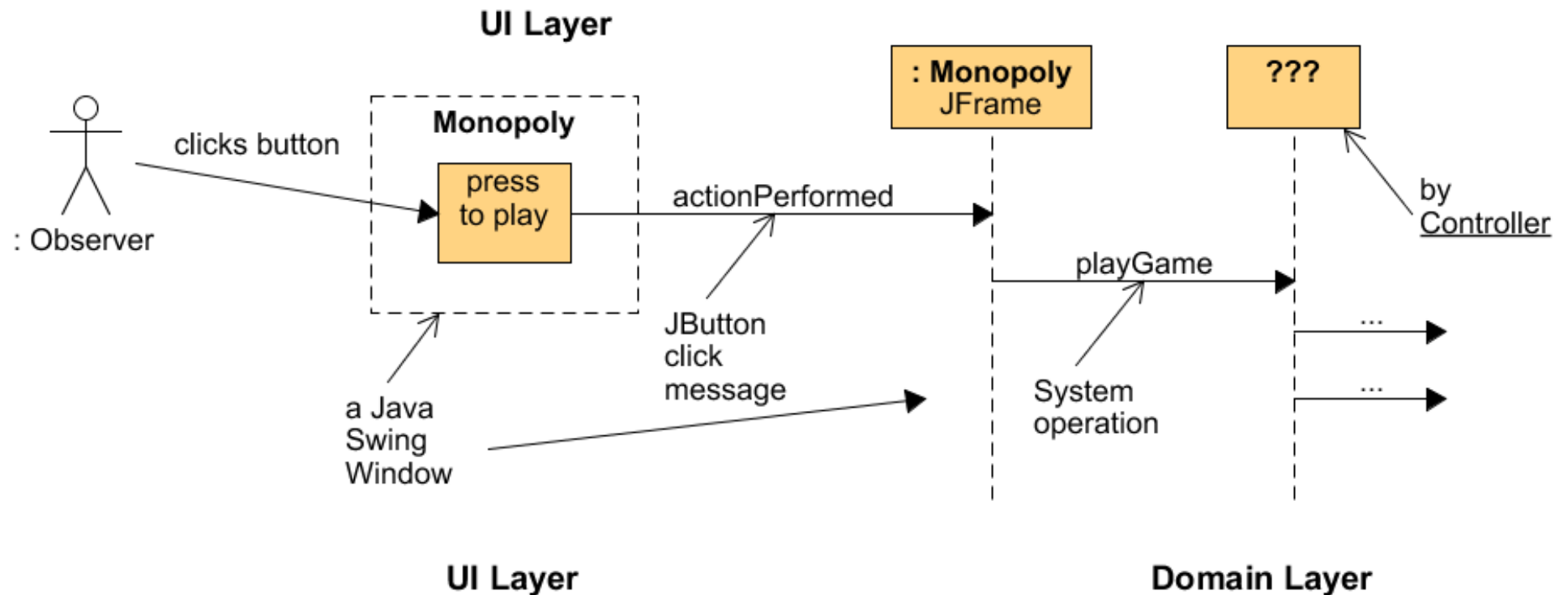
# Controller

❖ Who is the controller of playGame operation?



# Controller

- ❖ Separation between logical and UI views



# Benefits & Contraindications

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- ❖ Increased potential for reuse
  - Using a controller object keeps external event sources and internal event handlers independent of each other's type and behaviour.
  - either the UI classes or the problem/software domain classes can change without affecting the other side.
- ❖ Controller just forwards
  - event handling requests
  - output requests
- ❖ Reason about the states of the use case
  - Ensure that the system operations occurs in legal sequence, or to be able to reason about the current state of activity and operations within the use case.

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# Polymorphism

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## ❖ Problem:

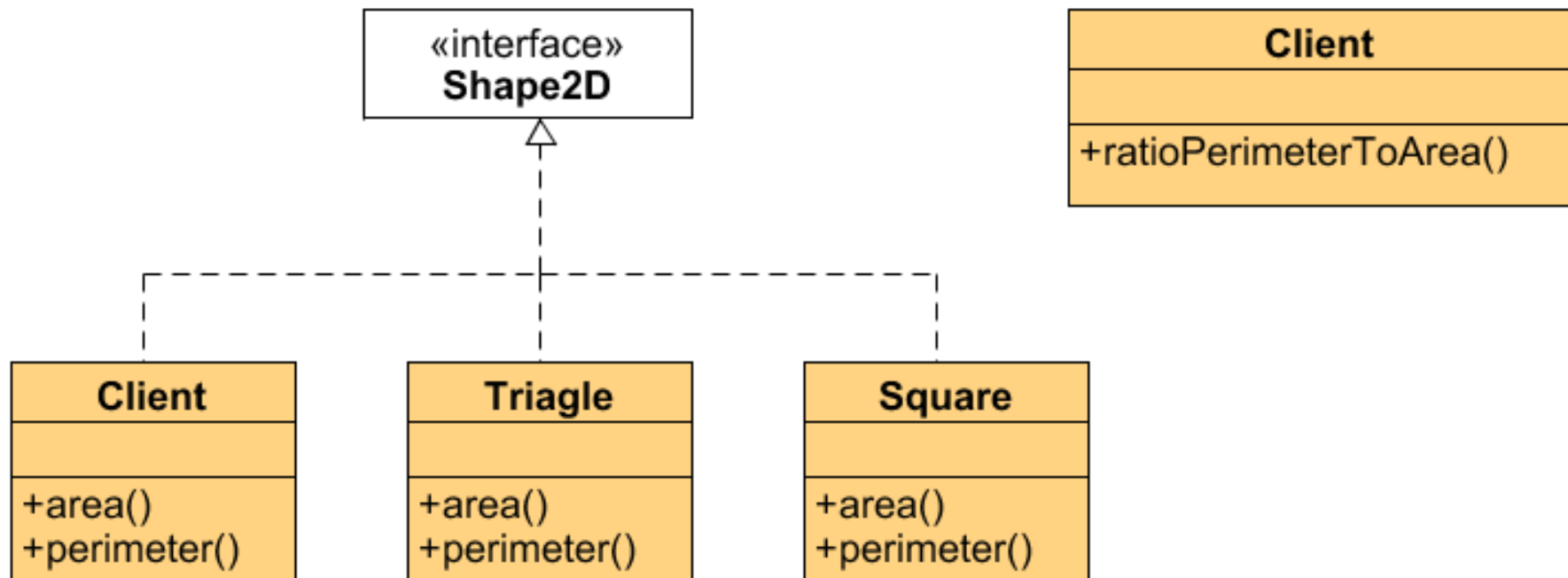
- How to handle behavior based on type (i.e., class) but not with an if-then-else or switch statement involving the class name or a tag attribute?

## ❖ Solution:

- When alternate behaviours are selected based on the type of an object, use polymorphic method call to select the behaviour, rather than using if statement to test the type.
- Polymorphic methods: giving the same name to (different) services in different classes. Services are implemented by methods.

# Example

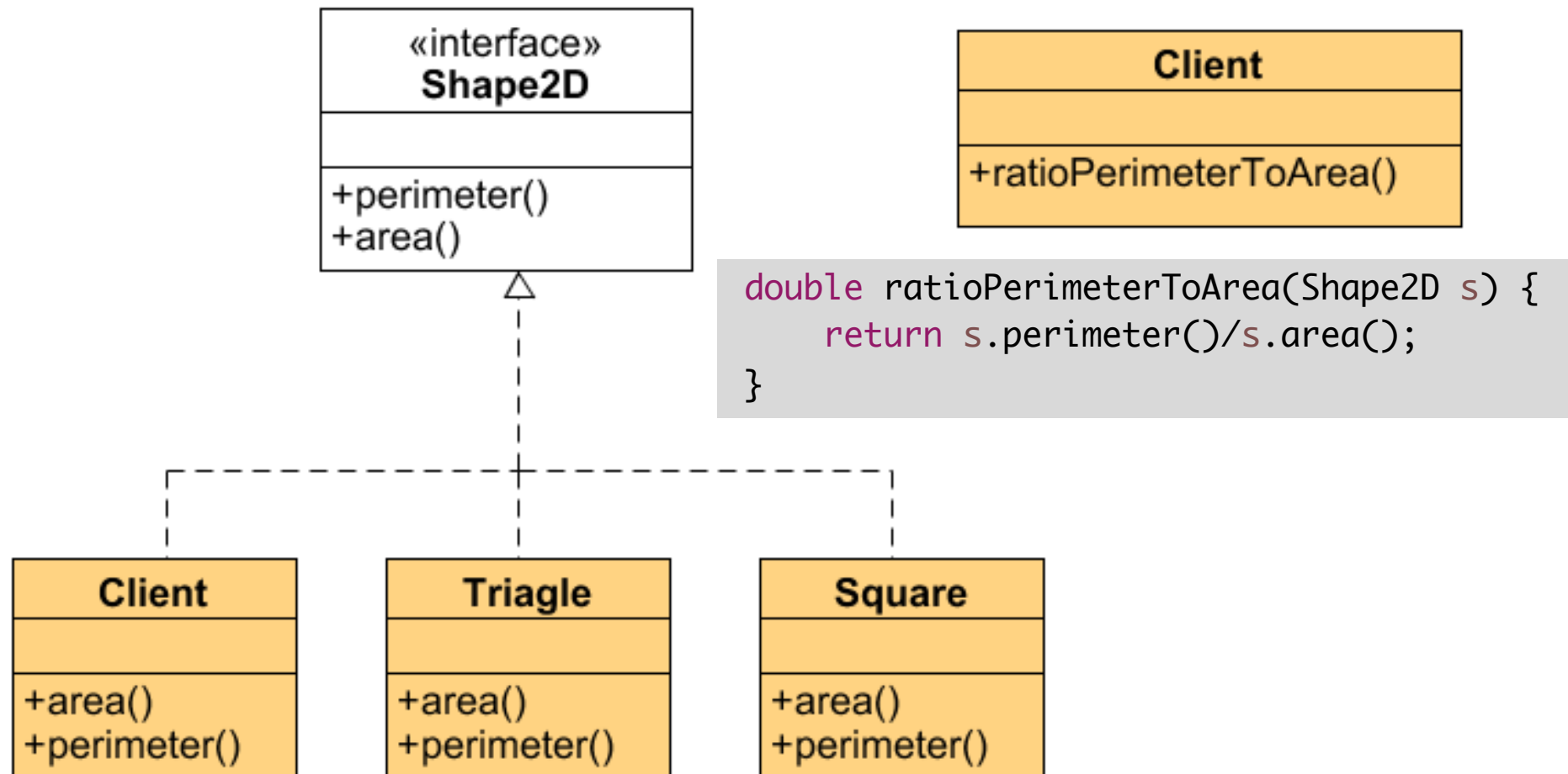
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# Example

```
double ratioPerimeterToArea(Shape2D s) {
    double ratio = 0.0;
    if (s instanceof Triangle) {
        // or String name = s.getClass().getName();
        // if (name=="Triangle") {
            Triangle t = (Triangle) s;
            ratio = t.perimeter()/t.area();
        } else if (s instanceof Circle) {
            Circle c = (Circle) s;
            ratio = c.perimeter()/c.area();
        } else if (s instanceof Square) {
            Square sq = (Square) s;
            ratio = sq.perimeter()/sq.area();
        }
    }
    return ratio;
}
```

# Example - Polymorphism





# Benefits & Contraindications

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- ❖ Easier and more reliable than using explicit selection logic.
- ❖ Easier to add additional behaviours later on.
- ❖ If polymorphism is not used, and instead the code tests the type of the object, then that section of code will grow as more types are added to the system.
  - This section of code becomes more coupled (i.e., it knows about more types) and less cohesive (i.e., it is doing too much).

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# Pure Fabrication

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## ❖ Problem:

- What object should have a responsibility when no class of the problem domain may take it without violating High Cohesion and Low Coupling?
- Not all responsibilities fit into domain classes, like persistence, network communications, user interaction, etc.

## ❖ Solution:

- Assign a highly cohesive set of responsibilities to an artificial class that does not represent anything in the problem domain.

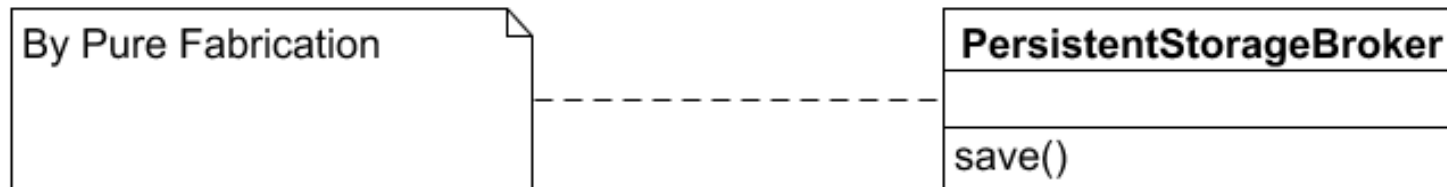
# Example

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- ❖ Suppose, in the point of sale example, that we need to save Sale instances in a relational database.
  - By Expert, there is some justification to assign this responsibility to Sale class.
- ❖ However..
  - The task requires a relatively large number of supporting database-oriented operations and the Sale class becomes not cohesive.
  - The sale class has to be coupled to the relational database increasing its coupling.
  - Saving objects in a relational database is a very general task for which many classes need support. Placing these responsibilities in the Sale class suggests there is going to be poor reuse.

# Pure Fabrication: example

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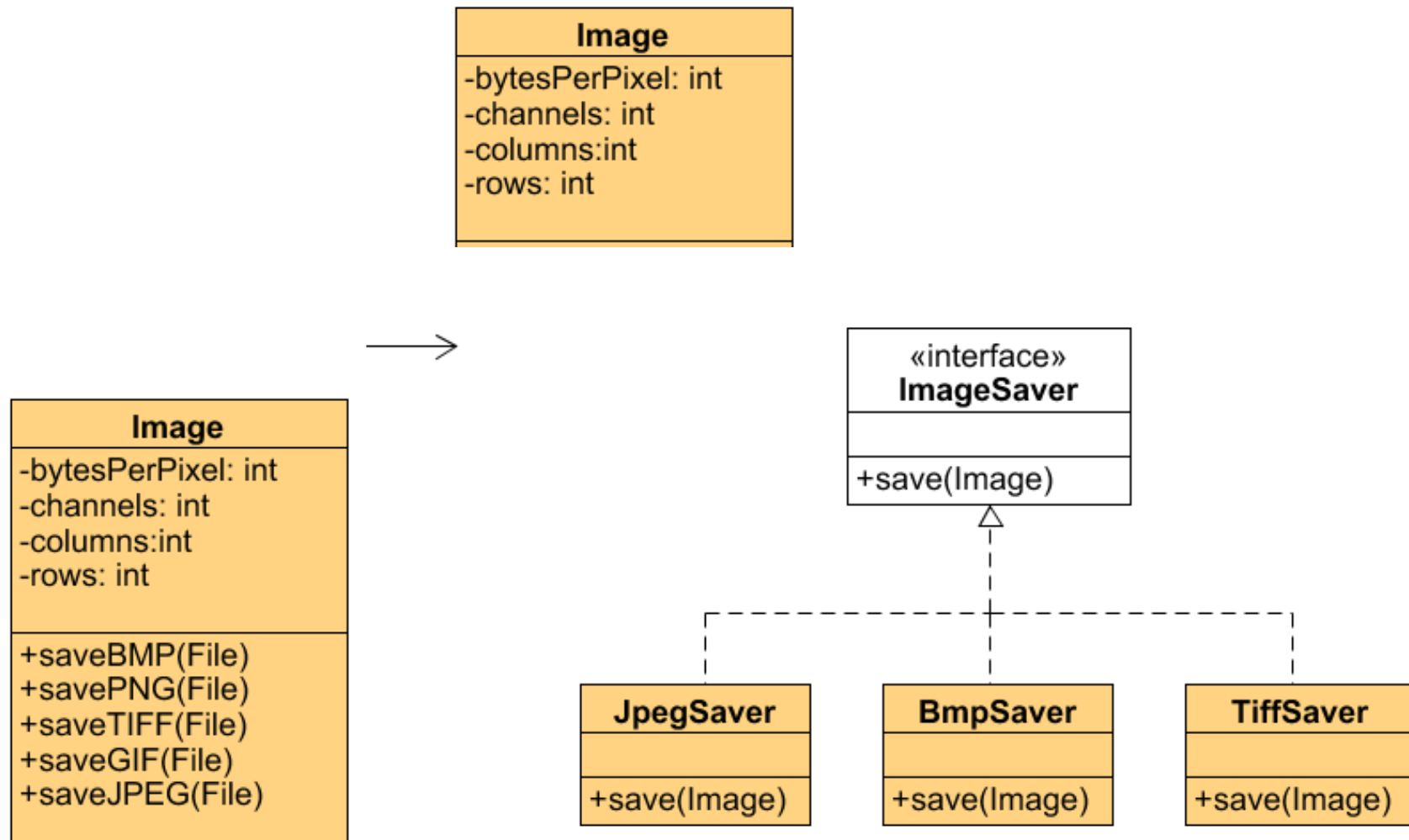
- The Sale remains well design, with high cohesion and low coupling
- The PersistentStorageBroker class is itself relatively cohesive
- The PersistentStorageBroker class is a very generic and reusable object

# Pure Fabrication: Another example

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Image
-bytesPerPixel: int -channels: int -columns: int -rows: int
+saveBMP(File) +savePNG(File) +saveTIFF(File) +saveGIF(File) +saveJPEG(File)

# Pure Fabrication: Another example



# Benefits & Contraindications

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- ❖ High cohesion is supported because responsibilities are factored into a class that only focuses on a very specific set of related tasks.
- ❖ Reuse potential may be increased because of the presence of fine grained Pure Fabrication classes.



# GRASP

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- ❖ Creator
- ❖ Information Expert
- ❖ Low Coupling
- ❖ High Cohesion
- ❖ Controller
- ❖ Polymorphism
- ❖ Pure Fabrication
- ❖ Indirection
- ❖ Protected Variations

# Indirection

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## ❖ Problem:

- How to avoid direct coupling?
- How to de-couple objects so that Low coupling is supported, and reuse potential remains high?

## ❖ Solution:

- Assign the responsibility to an intermediate object to mediate between other components or services, so that they are not directly coupled.

# Indirection

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- ❖ Indirection can be categorized into the following main groups:
  - Behavioural Extension.
  - Interface Modification.
  - Technology Encapsulation.
  - Complexity Encapsulation.

# Example: PersistentStorageBroker

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## ❖ The Pure fabrication example

- de-coupling the Sale from the relational database services through the introduction of a PersistentStorageBroker is also an example of assigning responsibilities to support Indirection.
- The PersistentStorageBroker acts as a intermediary between the Sale and database

# Indirection: example

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## ❖ Assume that :

- A point-of-sale terminal application needs to setup a specific communication channel in order to transmit credit payment request
- The operating system provides a low-level function call API for doing so.

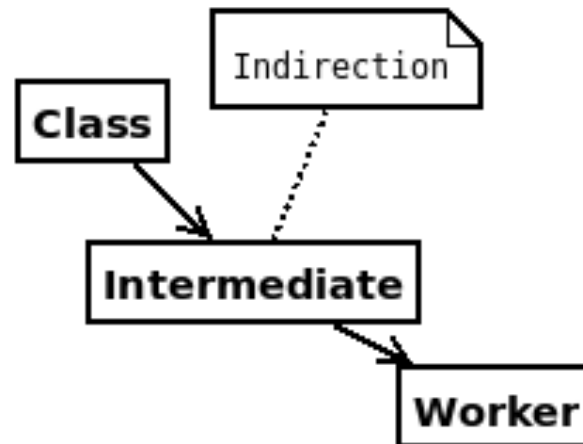
## ❖ How to?

- A class called CreditAuthorizationService is responsible for talking to the communication equipment

# Benefits & Contraindications

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- ❖ Low coupling
- ❖ Promotes reusability



# GRASP

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- ❖ Creator
- ❖ Information Expert
- ❖ Low Coupling
- ❖ High Cohesion
- ❖ Controller
- ❖ Polymorphism
- ❖ Pure Fabrication
- ❖ Indirection
- ❖ Protected Variations

# Protected Variations

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## ❖ Problem:

- How to design objects, subsystems, and systems so that variations or instabilities in some elements do not have an undesirable impact on other elements?

## ❖ Solution:

- Identify points of predicted variation or instability, assign responsibilities to create a stable interface around them.

## ❖ Protected Variations is a fundamental design principle which is the foundation for many design patterns



# Protected Variations

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## ❖ Mechanisms motivated by Protected Variations:

- Core PV mechanisms: data encapsulation, interfaces, polymorphism, indirection, standards
- Data-driven designs: style sheets, property files, other mechanisms for reading in configuration data at run time
- Service lookup including naming services (Java's JNDI) or traders (Java's Jini or UDDI for web services)
- Interpreter-driven designs
- Reflective or meta-level designs
- Uniform access – language support for uniform access to methods and data
- Liskov Substitution Principle (LSP) - *more following*
- Structure-hiding designs (Law of Demeter – "don't talk to strangers") - *more following*

# Liskov Substitution Principle (LSP)

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- ❖ Due to Barbara Liskov, Turing Award 2008
- ❖ LSP: a subclass B of A should be substitutable for superclass A, i.e., B should be a true subtype of A
- ❖ Reasoning at the specification level
  - B should not remove methods from A
  - For each B.m, which “substitutes” A.m, B.m’s specification is stronger than A.m’s specification
  - Client: A a; ... a.m(int x,int y);
  - Call a.m can bind to B’s m and B’s m should not surprise client

# Classic Example

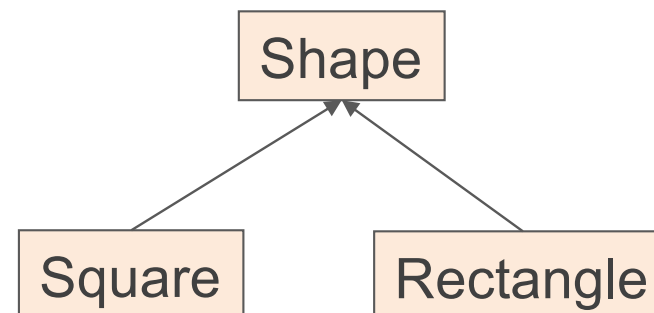
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- ❖ Every Square is-a Rectangle?
- ❖ Thus,
  - class Square extends Rectangle { ... }
- ❖ But is a Square a true subtype of Rectangle?
  - In other words, is Square substitutable for Rectangle in clients expecting a Rectangle?

# Every Square is-a Rectangle?

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- ❖ Square is not a true subtype of Rectangle
  - Rectangles are expected to have height and width that can change independently
  - Squares violate that expectation. Surprise clients
- ❖ And the opposite? Is Rectangle a true subtype of Square?
  - No. Squares are expected to have equal height and width. Rectangles violate this expectation
- ❖ One solution:
  - make them unrelated



# Law of Demeter (Don't talk to strangers)

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## ❖ Problem:

- How to avoid knowing about the structure of indirect objects?

## ❖ Solution:

- If two classes have no other reason to be directly aware of each other or otherwise coupled, then the two classes should not directly interact.
  - e.g., in A don't do `getB().getC().methodOfC()`
- Within a method, messages should only be sent to the following objects:
  - The `this` object (or `self`)
  - A parameter of the method
  - An attribute of `self`
  - An element of a collection which is an attribute of `self`
  - An object created within the method

# Law of Demeter: Example

```
class Company {  
    Collection<Department> departments = new ArrayList<>();  
}  
class Department {  
    private Employee manager;  
    public Employee getManager() {  
        return manager;  
    }  
}  
class Employee {  
    private double salary;  
    public double getSalary() {  
        return salary;  
    }  
}
```

Now *Company* needs to have the total of amount spend with Managers' salary. How?

# Law of Demeter: Example

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– Don't:

```
// within Company
for (Department dept : departments) {
    System.out.println( dept.getManager().getSalary() );
    // now Company depends on Employee
}
```

– Do:

```
class Department { //...
    double getManagerSalary() {
        return getManager().getSalary();
    }
}
// within Company
for (Department dept : departments) {
    System.out.println( dept.getManagerSalary() );
}
```

# Benefits & Contraindications

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- ❖ Keeps coupling between classes low and makes a design more robust
- ❖ Adds a small amount of overhead in the form of indirect method calls



# Others - SOLID principles

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- ❖ **S**ingle responsibility
  - *"every class should have a single responsibility, and that responsibility should be entirely encapsulated by the class"* (Robert Martin)
- ❖ **O**pen/closed (OCP)
  - *"software entities (classes, modules, functions, etc.) should be open for extension, but closed for modification"* (Bertrand Meyer)
- ❖ **L**iskov substitution (LSP)
- ❖ **I**nterface segregation
  - *"no client should be forced to depend on methods it does not use"* (similar to High Cohesion of GRASP)
- ❖ **D**ependency inversion
  - *"High-level modules should not depend on low-level modules. Both should depend on abstractions"*

# Others principles / jargons

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## ❖ Minimalism

- Keep it simple, stupid (KISS)
- Worse is better (Less is more)
- You aren't gonna need it (YAGNI)
- Principle of good enough (POGE)
- Quick-and-dirty

## ❖ Don't repeat yourself (DRY)

- *Cut and paste of code is evil.*

## ❖ Inversion of control (IoC)

## ❖ ... and many others

# Summary

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- ❖ Skillful assignment of responsibilities is extremely important in object-oriented design
- ❖ Patterns are named problem/solution pairs that codify good advice and principles related to assignment of responsibilities
- ❖ GRASP identifies several principles:
  - Creator, Information Expert, Controller, Low Coupling, High Cohesion, Polymorphism, Pure Fabrication, Indirection, Protected Variations