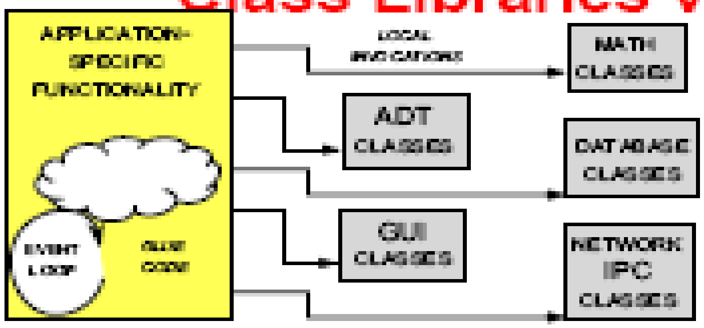
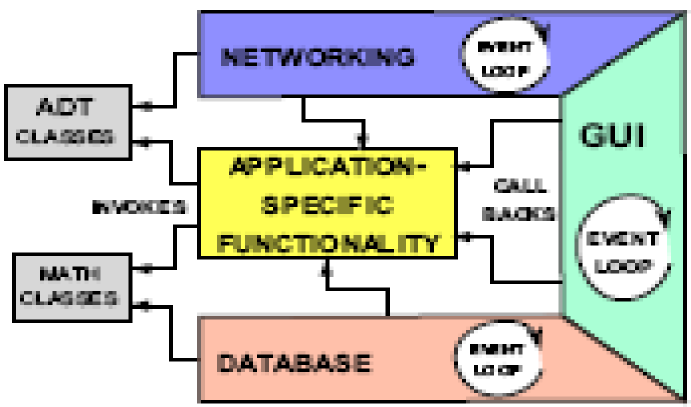
References:

- Applying UML and patterns
  Craig Larman

Class Libraries vs. Frameworks vs. Patterns



(A) CLASS LIBRARY ARCHITECTURE



(B) FRAMEWORK ARCHITECTURE

Definition

- *Class libraries*
  - Self-contained, "pluggable" ADTs
- *Frameworks*
  - Reusable, "semi-complete" applications
- *Patterns*
  - Problem, solution, context

What are patterns?

- Principles and solutions codified in a structured format describing a problem and a solution
- A named problem/solution pair that can be applied in new contexts
- It is advice from previous designers to help designers in new situations

The idea behind design patterns is simple:

Write down and catalog common interactions between objects that programmers have frequently found useful.

Result:

Facilitate reuse of object-oriented code between projects and between programmers.

Some definitions of design patterns

- “Design patterns constitute a set of rules describing how to accomplish certain tasks in the realm of software development.” (Pree, 1994)
- “Design patterns focus more on reuse of recurring architectural design themes, while frameworks focus on detailed design… and implementation.” (Coplien & Schmidt, 1995).
- “A pattern addresses a recurring design problem that arises in specific design situations and presents a solution to it” (Buschmann, *et. al.* 1996)
- “Patterns identify and specify abstractions that are above the level of single classes and instances, or of components.” (Gamma, et al., 1993)

Characteristics of Good patterns

- It solves a problem
- It is a proven concept
- The solution isn't obvious
- It describes a relationship
- The pattern has a significant human component

Types of Design Pattern

- *Creational patterns*
  - Deal with initializing and configuring classes and objects
- *Structural patterns*
  - Deal with decoupling interface and implementation of classes and objects
- *Behavioral patterns*
  - Deal with dynamic interactions among societies of classes and objects

Types of patterns

Architectural Patterns

Expresses a fundamental structural organization or schema for software systems.

Design Patterns

Provides a scheme for refining the subsystems or components of a software system, or the relationships between them.

Idioms

An idiom describes how to implement particular aspects of components or the relationships between them using the features of the given language.

Describing patterns

Name : It must have a meaningful name.

Problem: A statement of the problem.

Context: This tells us the pattern's applicability.

Forces: A description of the relevant forces and constraints and how they interact/conflict with one another..

Solution: Static relationships and dynamic rules describing how to realize the desired outcome.

Consequences: Implications(good and bad) of using the solution.

Examples: One or more sample applications of the pattern .

GRASP Patterns

Which class, in the general case is responsible?

- 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.

GRASP patterns

General Responsibility Assignment Software Patterns

- Expert
- Creator
- Low Coupling
- High Cohesion
- Controller
- Polymorphism
- Pure Fabrication
- Indirection
- Protected Variations
- Law of Demeter

Expert

Problem:

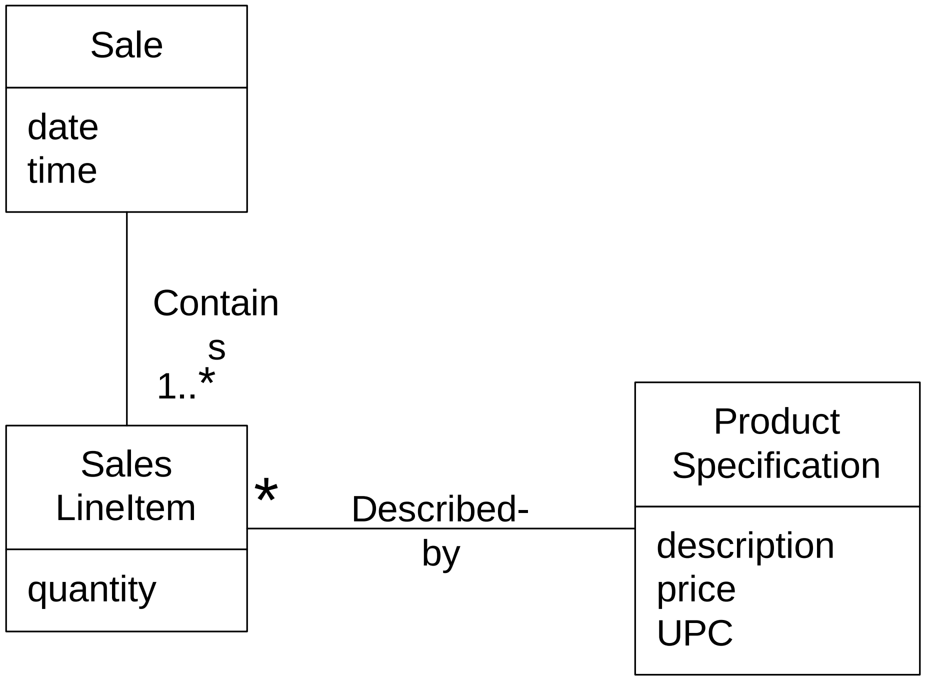
What is the most basic principle by which responsibilities are assigned in object-oriented design?

Solution:

Assign a responsibility to the class that has the information necessary to fulfil the responsibility.

Expert : Example

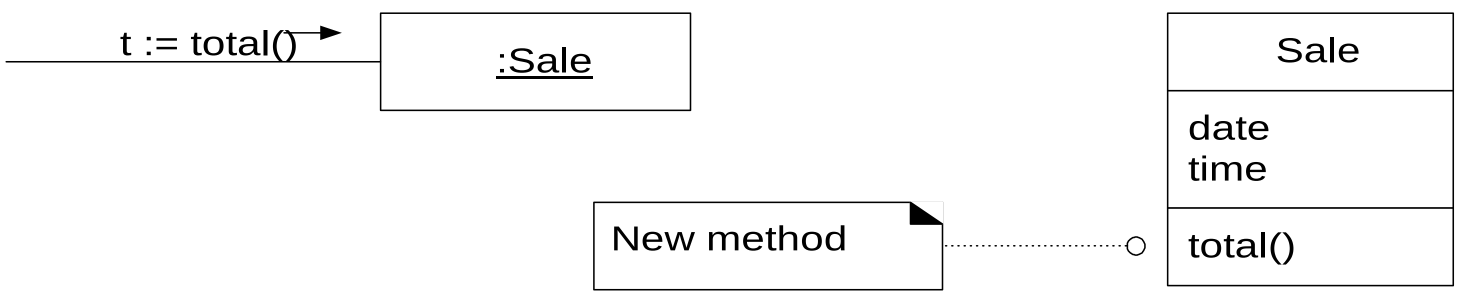
Who is responsible for knowing the grand total of a sale in a typical Point of Sale application?



Expert : Example

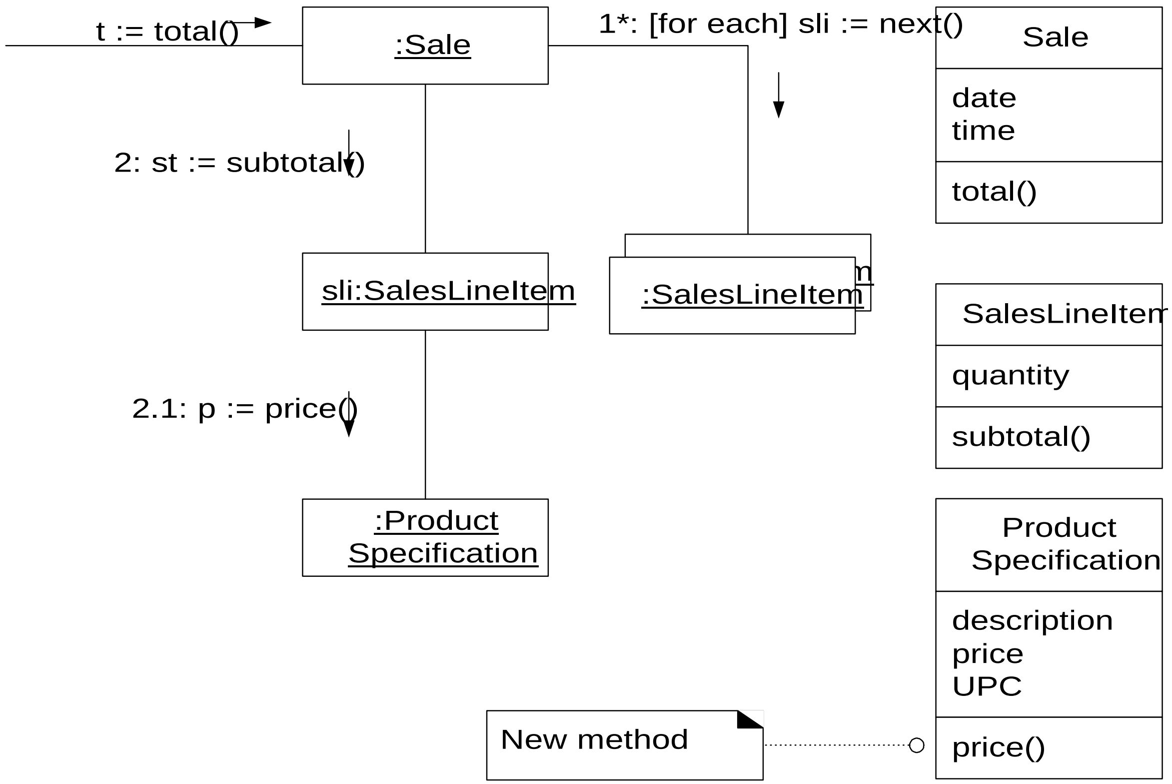
Need all *SalesLineItem* instances and their subtotals. Only *Sale* knows this, so *Sale* is the information expert.

Hence



Expert : Example

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



Expert : Example

Hence responsibilities assign to the 3 classes.

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

Expert

- Maintain encapsulation of information
- Promotes low coupling
- Promotes highly cohesive classes
- Can cause a class to become excessively complex

Creator

Problem:

Assign responsibility for creating a new instance of some class?

Solution:

Determine which class should create instances of a class based on the relationship between potential creator classes and the class to be instantiated.

Creator

who has responsibility to create an object?

By creator, assign class B responsibility of creating instance of class A if

B *aggregates* A objects

B *contains* A objects

B *records* instances of A objects

B *closely* uses A objects

B *has the initializing data* for creating A objects

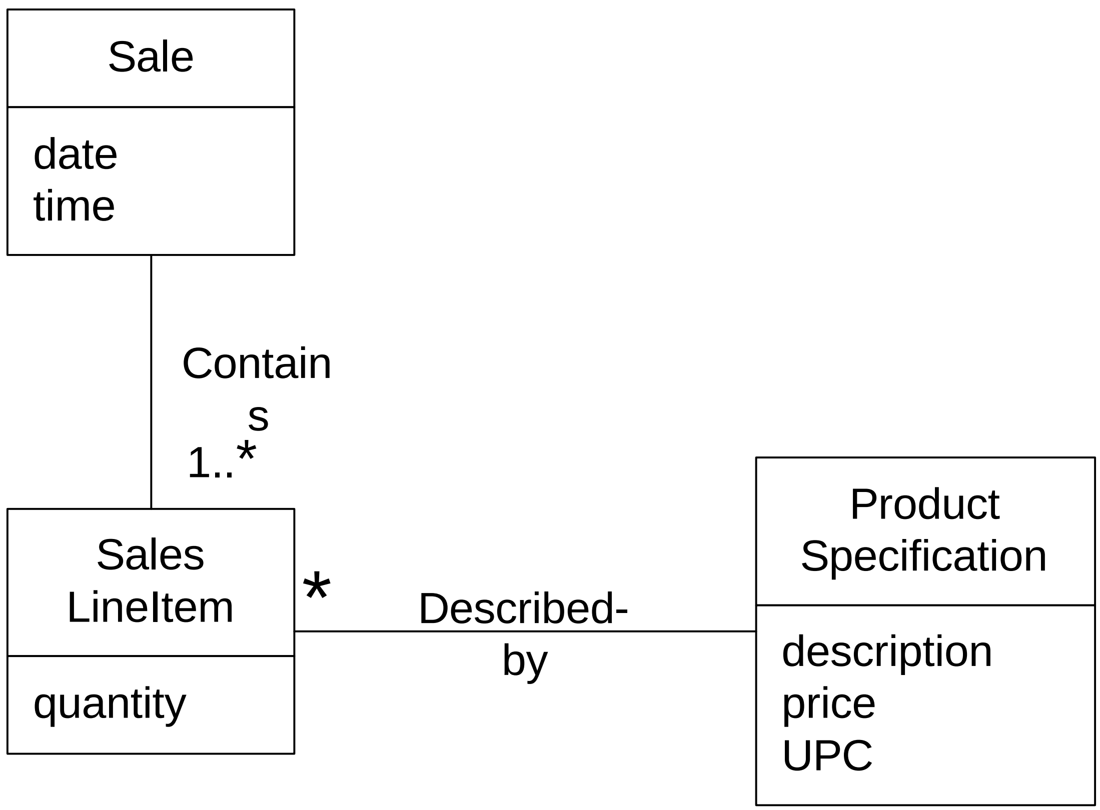
where there is a choice, prefer

B *aggregates* or *contains* A objects

Creator : Example

Who is responsible for creating *SalesLineItem* objects?

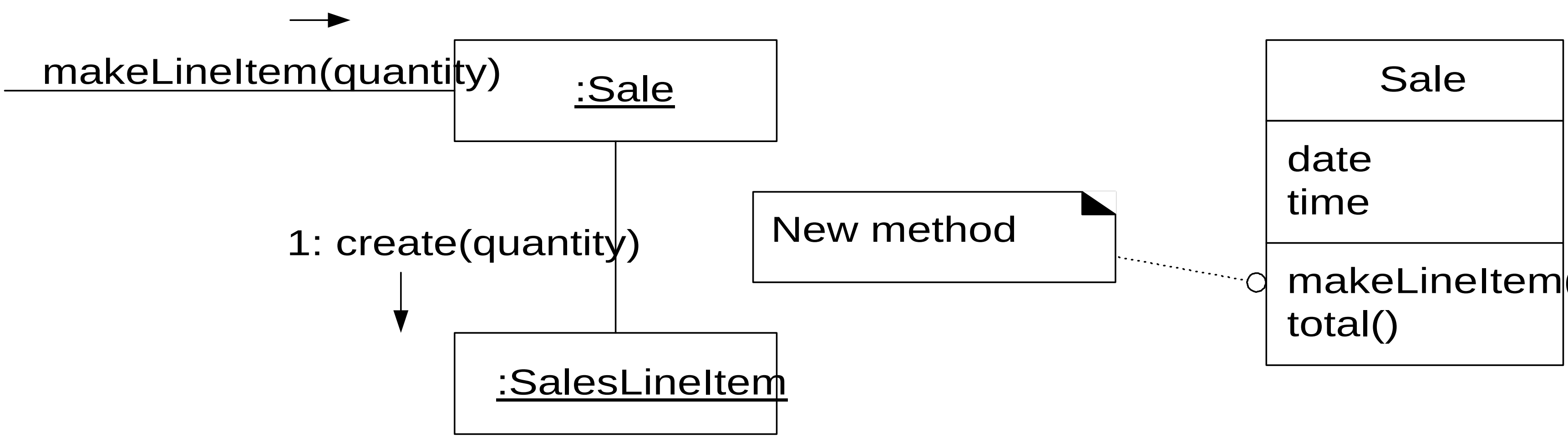
Look for a class that aggregates or contains *SalesLineItem* objects.



Creator : Example

Creator pattern suggests Sale.

Collaboration diagram is



Creator

- Promotes low coupling by making instances of a class responsible for creating objects they need to reference
- By creating the objects themselves, they avoid being dependent on another class to create the object for them

Low Coupling

Problem:

To support low dependency and increased reuse?

Solution:

Assign responsibilities so that coupling remains low.

In object oriented languages, common form 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.

Low coupling

- Classes are easier to maintain
- Easier to reuse
- Changes are localised

Low Coupling

How can we make classes independent of other classes?

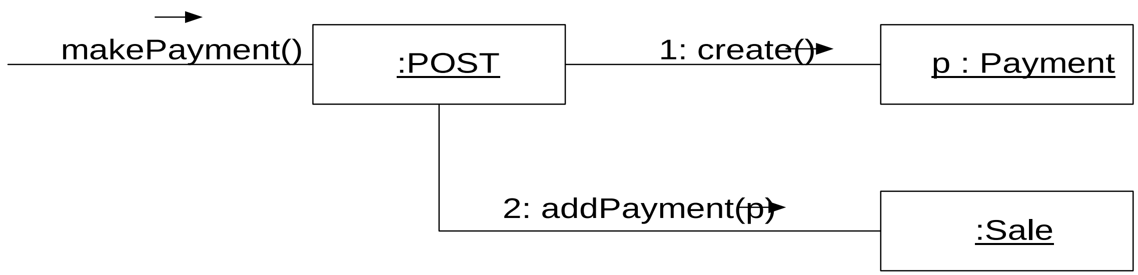
changes are localised
easier to understand
easier to reuse

Who has responsibility to create a *payment*?

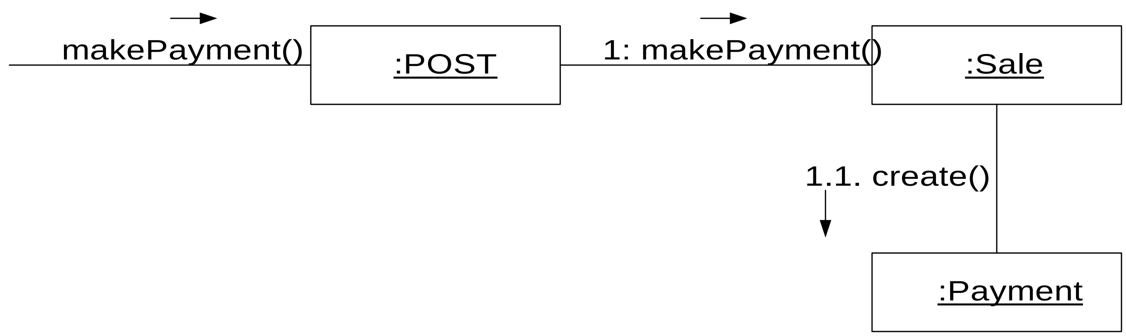
Low Coupling

Two possibilities:

1. Post



2. Sale



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

High Cohesion

Problem:

To keep complexity manageable?

Solution:

Assign responsibilities so that cohesion remains high.

Some examples:

- Very Low Cohesion: A Class is solely responsible for many things in very different functional areas
- Low Cohesion: A class has sole responsibility for a complex task in one functional area.
- High Cohesion. A class has moderate responsibilities in one functional area and collaborates with classes to fulfil tasks.

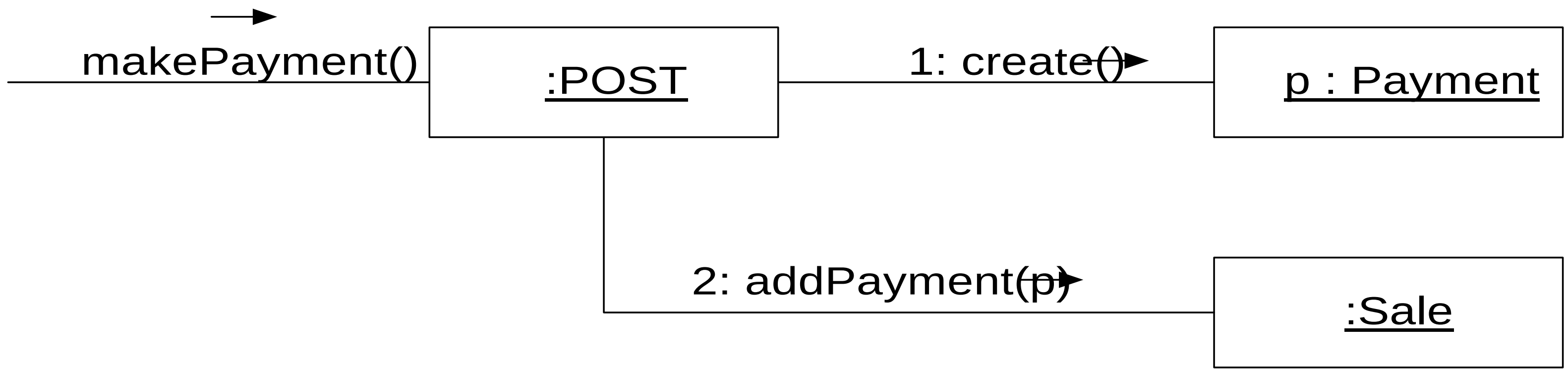
High cohesion

- Classes are easier to maintain
- Easier to understand
- Often support low coupling
- Supports reuse because of fine grained responsibility

High Cohesion

Who has responsibility to create a *payment*?

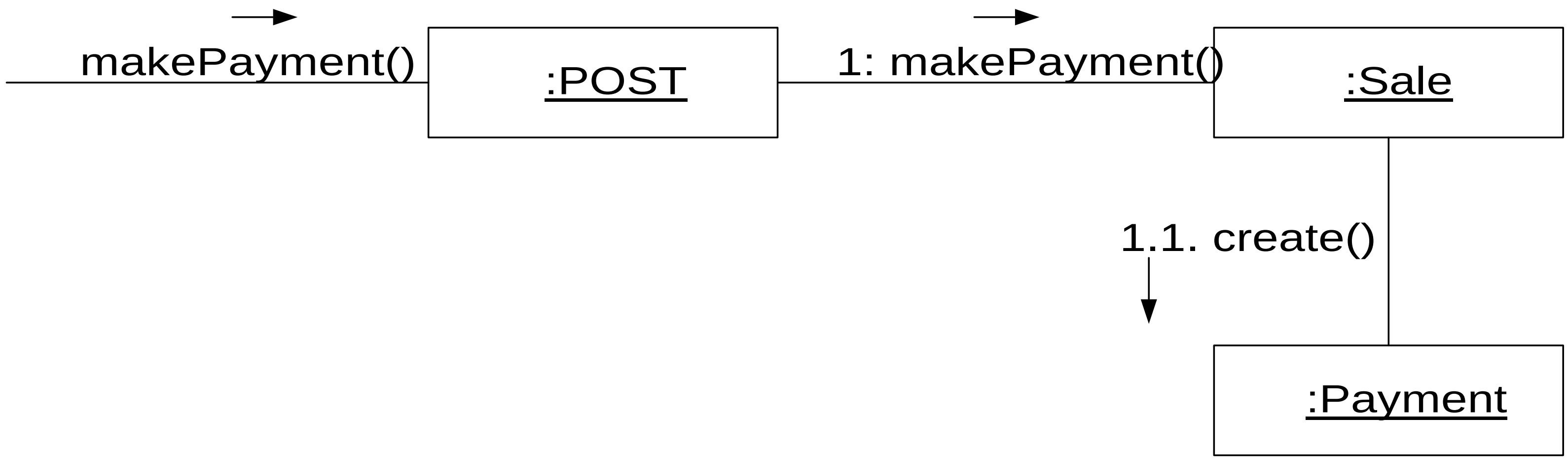
1.Post



looks OK if *makePayement* considered in isolation, but adding more system operations, *Post* would take on more and more responsibilities and become less cohesive.

High Cohesion

Giving responsibility to *Sale* supports higher cohesion in *Post*, as well as low coupling.



This design supports low coupling and high cohesion so it is desirable

Controller

Problem:

To assign responsibility for handling a system event?

Solution:

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

The Controller pattern provides guidance for generally acceptable choices.

Assign the responsibility for handling a system event message to a class representing one of these choices:

1. The business or overall organization (a façade controller).
2. The overall "system" (a façade controller).
3. An animate thing in the domain that would perform the work (a role controller).
4. An artificial class (Pure Fabrication representing the use (a use case controller).

Benefits:

Increased potential for reuse. Using a controller object keeps external event sources and internal event handlers independent of each other's type and behaviour.

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.

Controller : Example

System events in Buy Items use case

enterItem()

endSale()

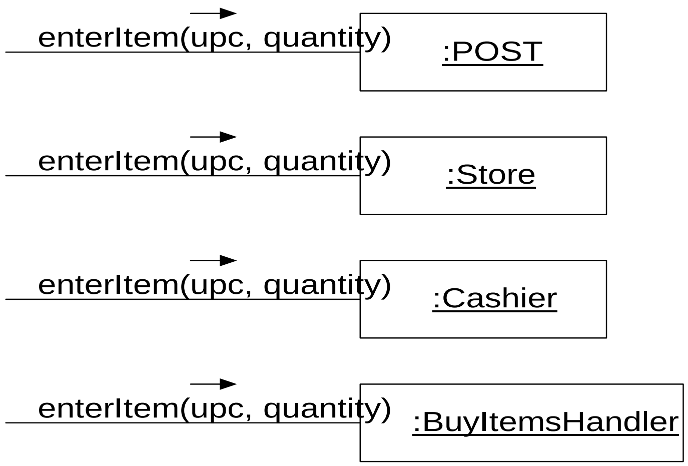
makePayment()

who has the responsibility for *enterItem()*?

Controller : Example

By controller, we have 4 choices

the overall system	Post
the overall business	Store
someone in the real world who is active in the task	Cashier
an artificial handler of all system events of a use case	BuyItemsHandler



The choice of which one to use will be influenced by other factors such as cohesion and coupling

Who should be the controller for system events such as *enterItem* and *endSale*?

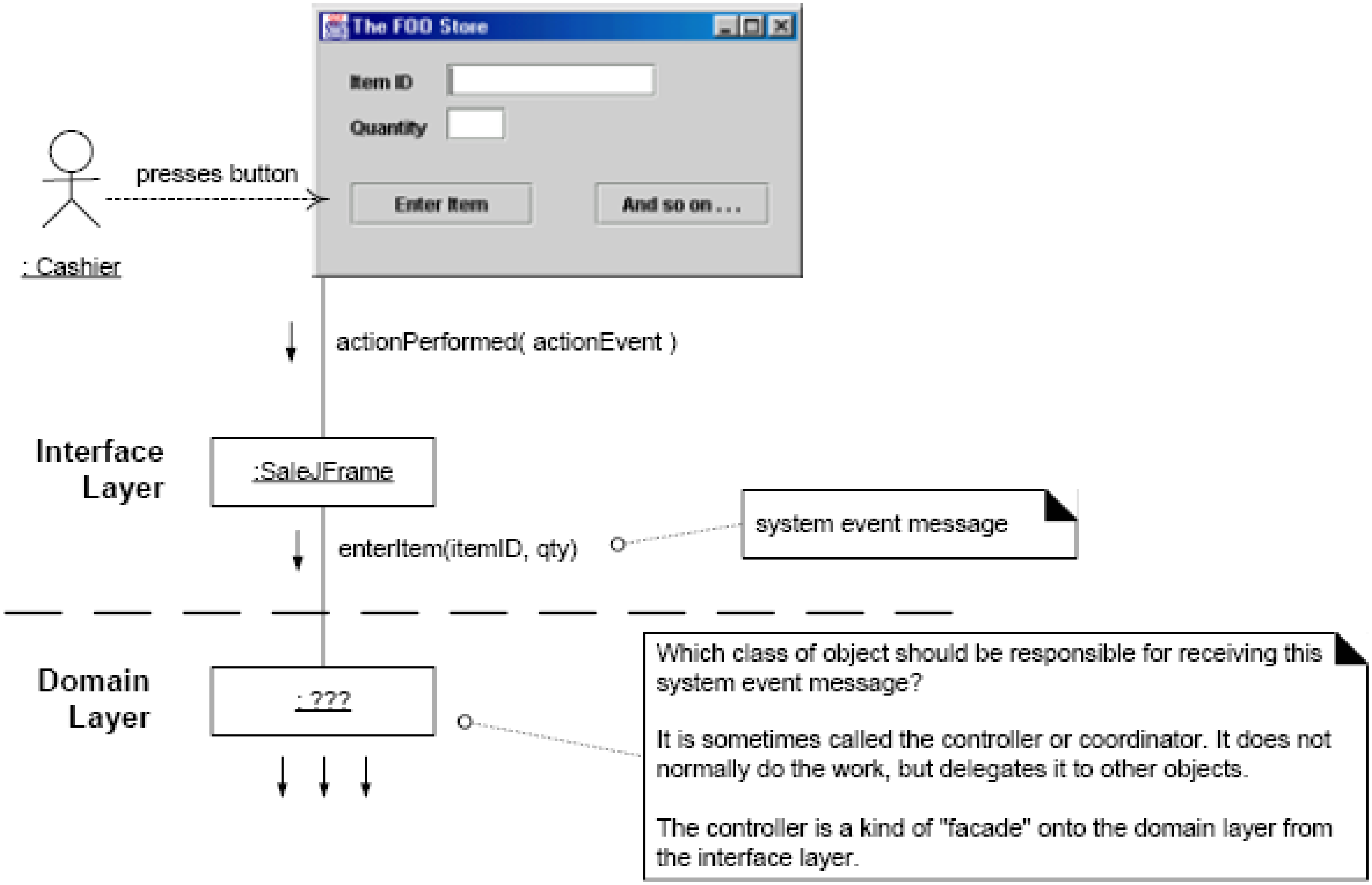
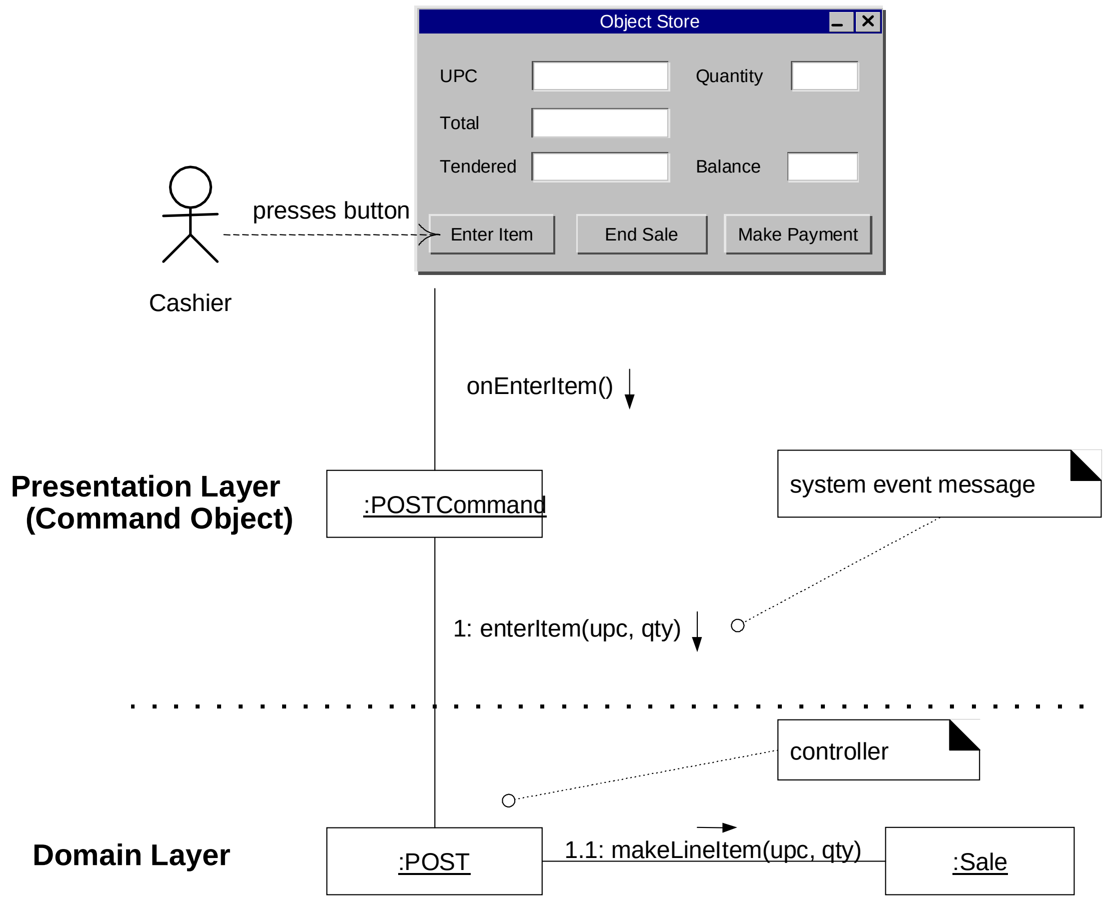
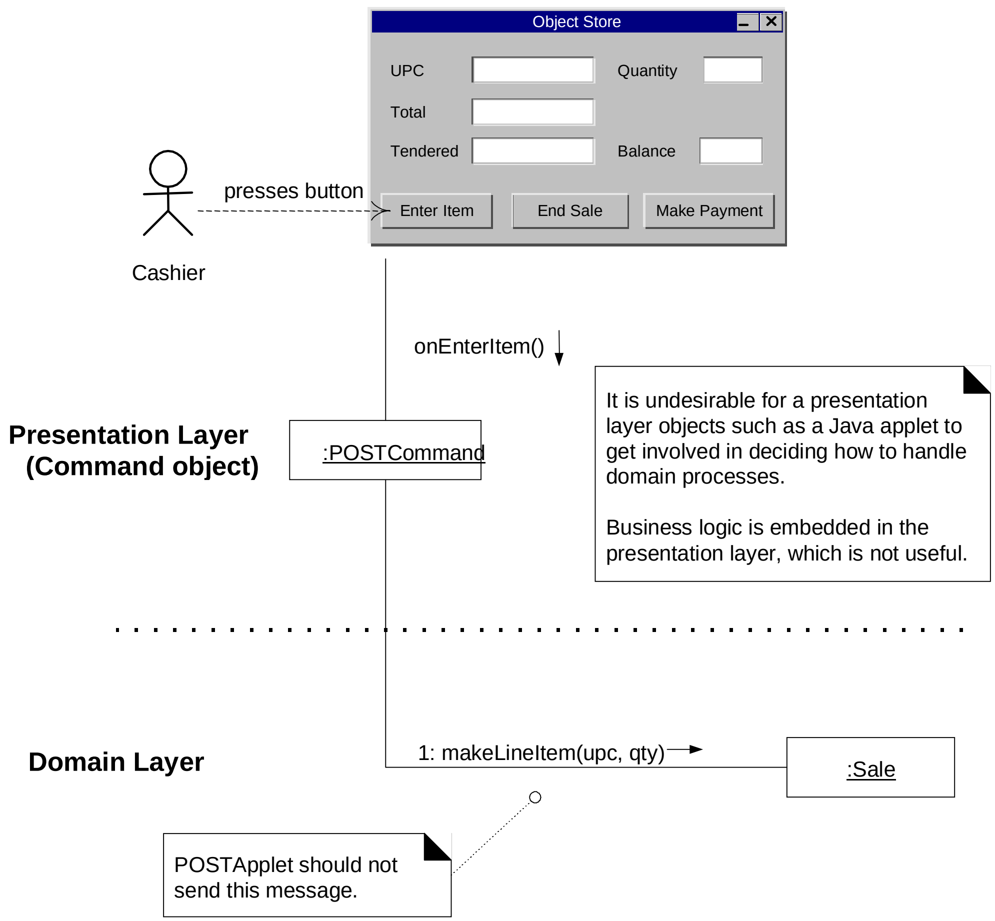


Figure 16.14 Controller for enterItem?

Good design
- presentation layer decoupled from problem domain



Bad design
– presentation layer coupled to problem domain



Controller

- Using a controller object keeps external event sources and internal event handlers independent of each other’ type and behaviour
- The controller objects can become highly coupled and uncohesive with more responsiblities

Polymorphism

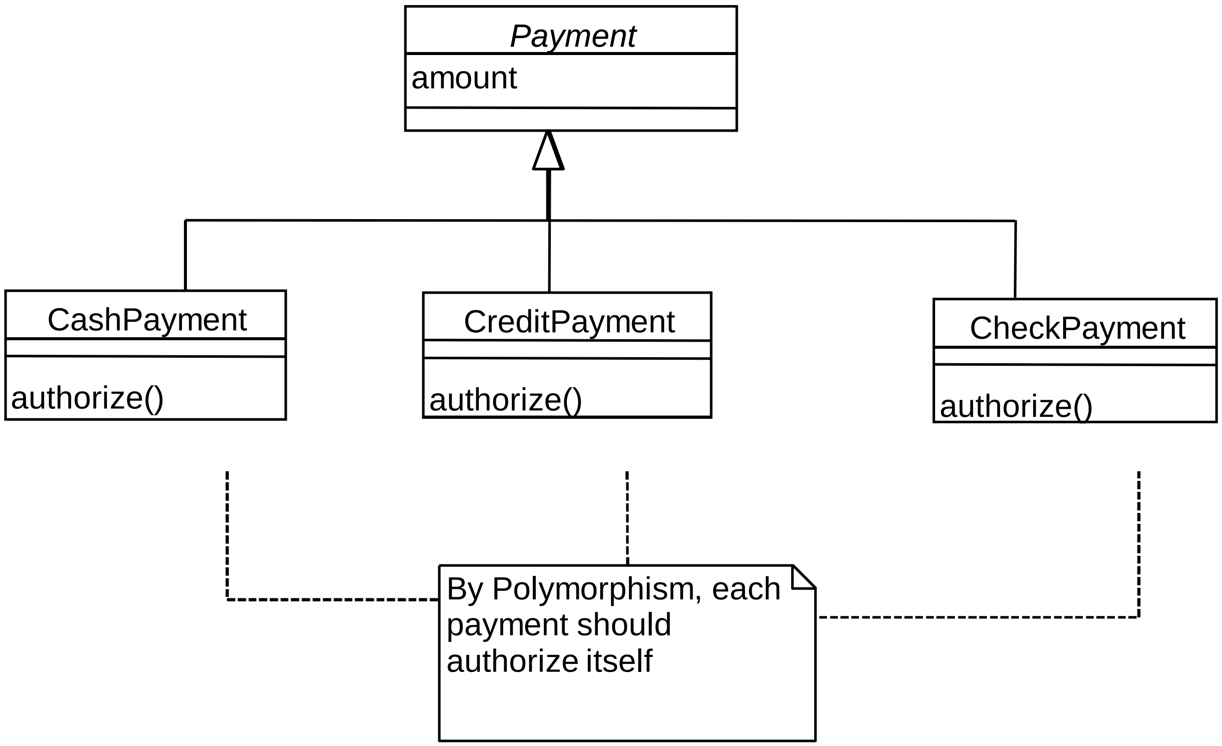
Problem:

To handle alternatives based on types?

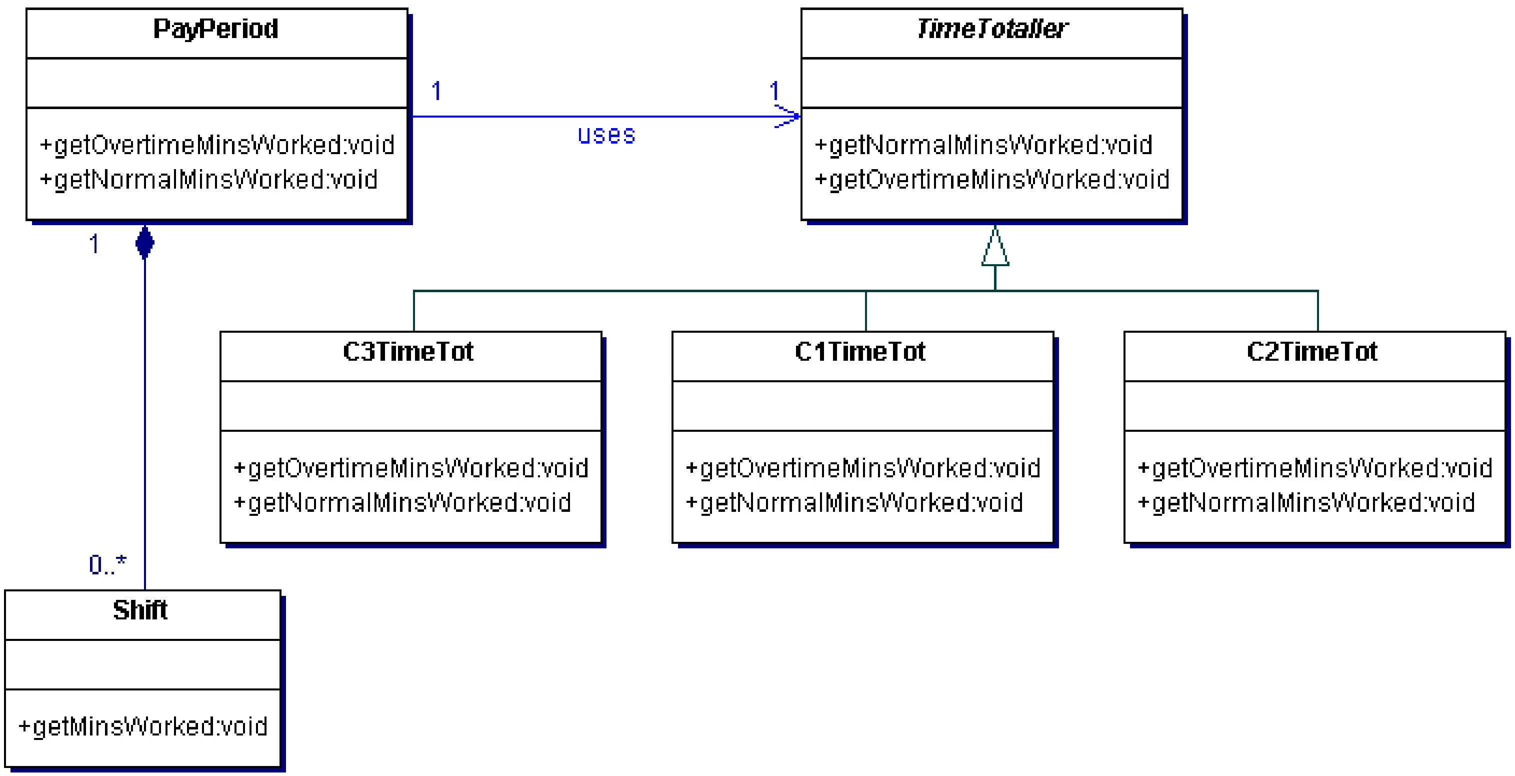
Solution:

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.

Polymorphism : Example



Example : Polymorphism



Polymorphism

- Easier and more reliable then using explicit selection logic
- Easier to add additional behaviours later on
- Increased the number classes in a design
- May make the code less easier to follow

Pure Fabrication

Problem:

To not violate High Cohesion and Low Coupling?

Solution:

Assign a highly cohesive set of responsibilities to an artificial class that does not represent anything in the problem domain, in order to support high cohesion, low coupling, and reuse.

Benefits:

High cohesion is supported because responsibilities are factored into a class that only focuses on a very specific set of related tasks.

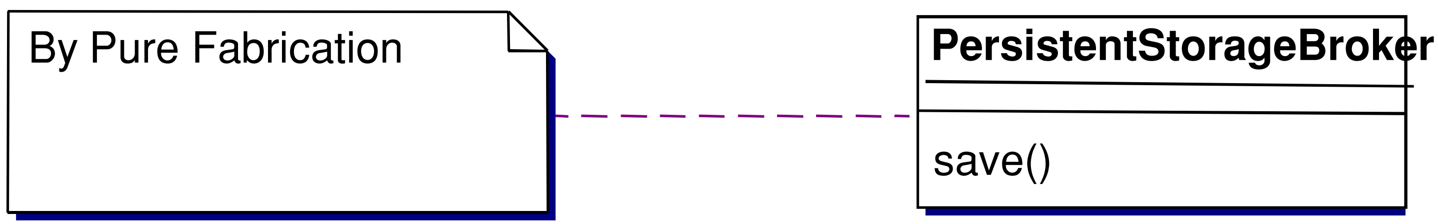
Reuse potential may be increased because of the presence of fine grained Pure Fabrication classes.

Example

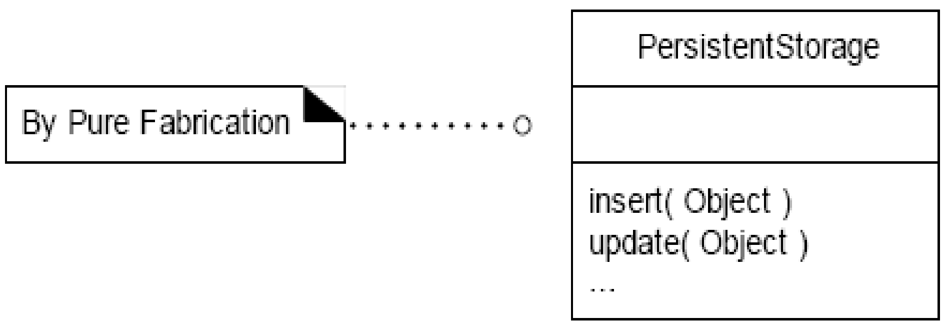
Suppose, in the point of sale example, that support is needed to save Sale instances in a relational database. By Expert, there is some justification to assign this responsibility to Sale class. However.

- The task requires a relatively large number of supporting database-oriented operations and the Sale class becomes incohesive.
- 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 or lots of duplication in other classes that do the same thing.

Pure Fabrication : Example



- 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

- Preserves low coupling and high cohesion of classes
- Improve reusability of classes

Indirection

Problem:

To avoid direct coupling?

To de-couple objects so that Low coupling is supported and reuse potential remains high?

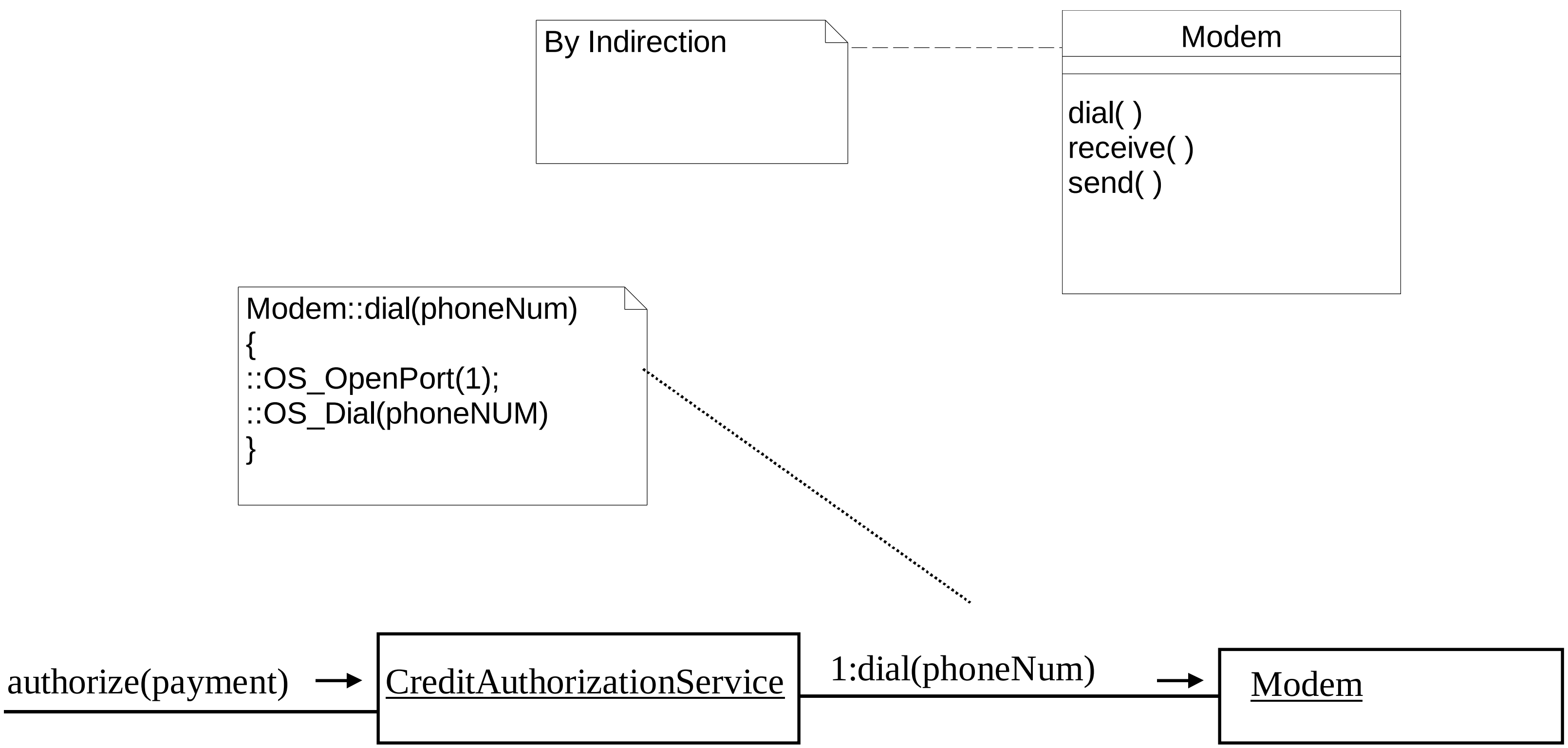
Solution:

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

Example : PersistentStorageBroker

The Pure fabrication example of 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



- Assume that :

- A point-of-sale terminal application needs to manipulate a modem in order to transmit credit payment request
- The operating system provides a low-level function call API for doing so.
- A class called CreditAuthorizationService is responsible for talking to the modem

- If CreditAuthorizationService invokes the low –level API function calls directly, it is highly coupled to the API of the particular operating system. If the class needs to be ported to another operating system, then it will requiure modification.
- Add an intermediate Modem class between the CreditAuthorizationService and the modem API. It is responsible for translating abstract modem requests to the API and creating an Indirection between the CreditAuthorizationService and the modem.

Indirection

- Low coupling
- Promotes reusability

Law of Demeter

Problem:

To avoid knowing about the structure of indirect objects?

Solution:

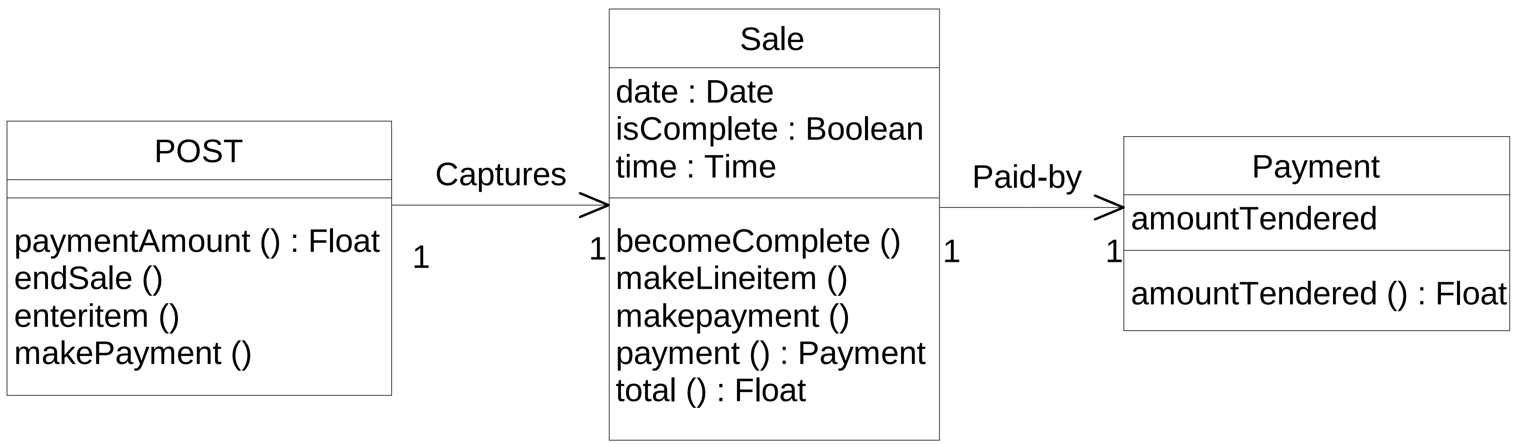
If two classes have no other reason to be directly aware of each other or otherwise coupled, then the two classes should not directly interact.

Law of Demeter

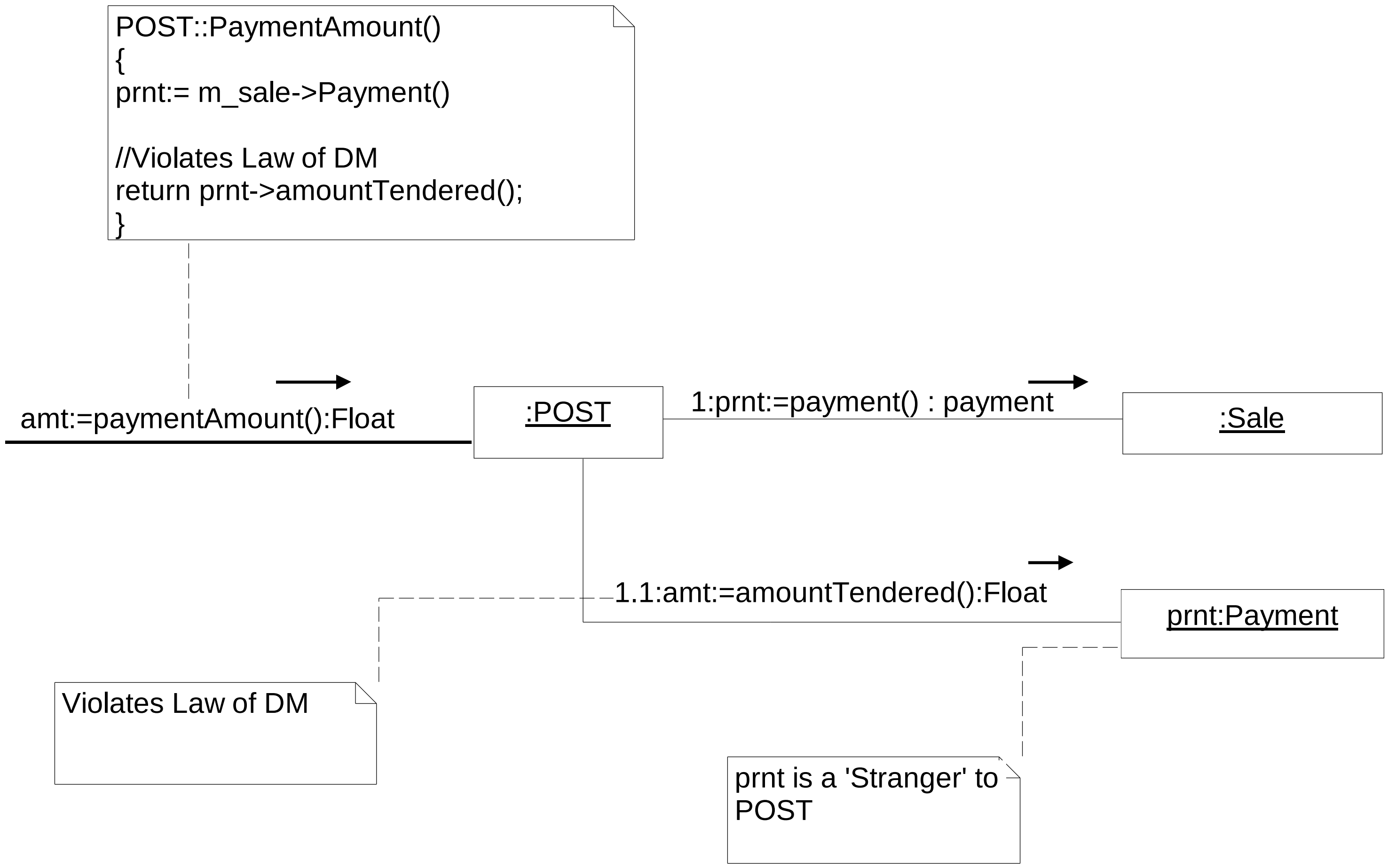
It states that within a method, messages should only be sent to the following objects:

- 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

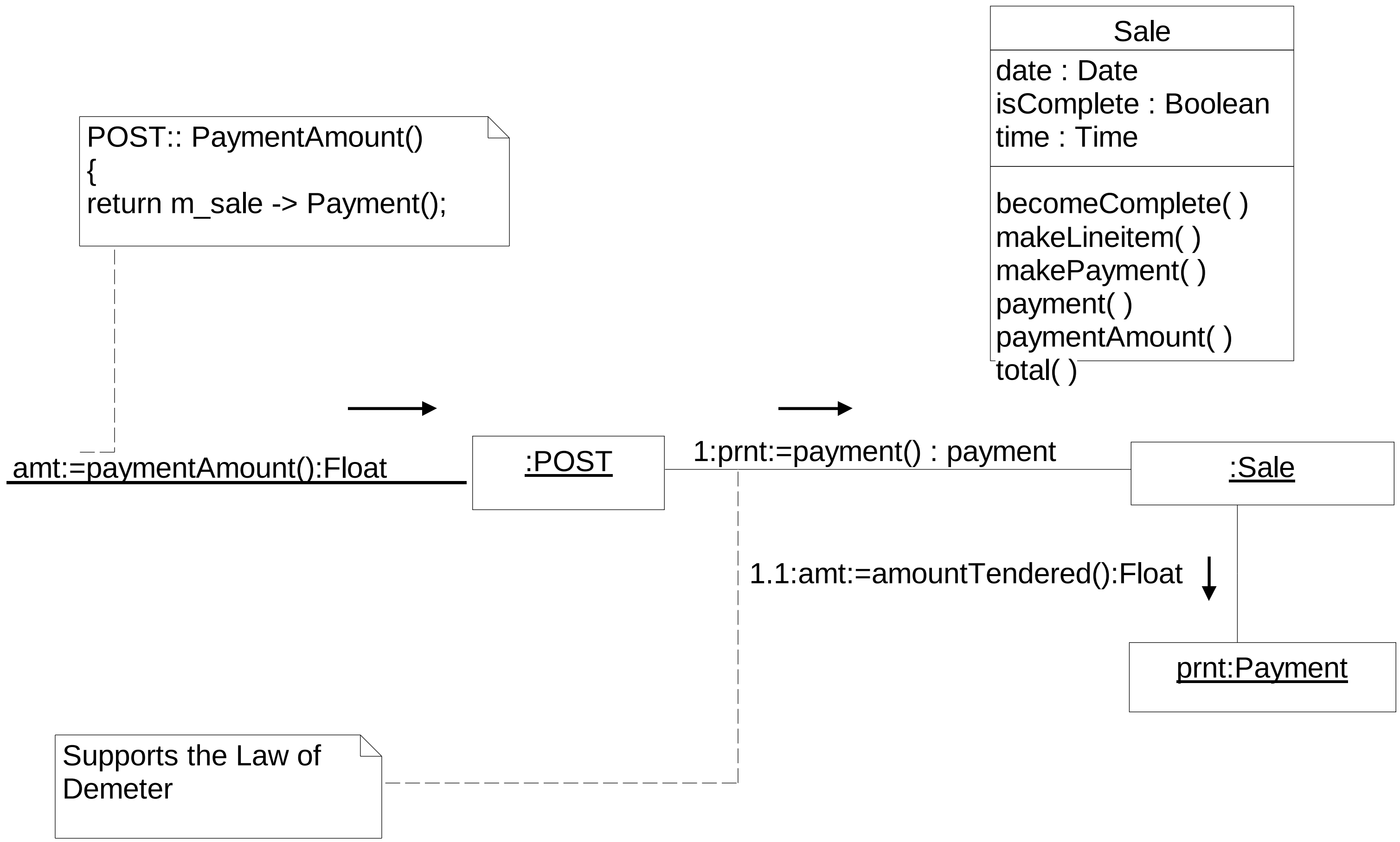
Law of Demeter : Example



Violates Law of Demeter : Example



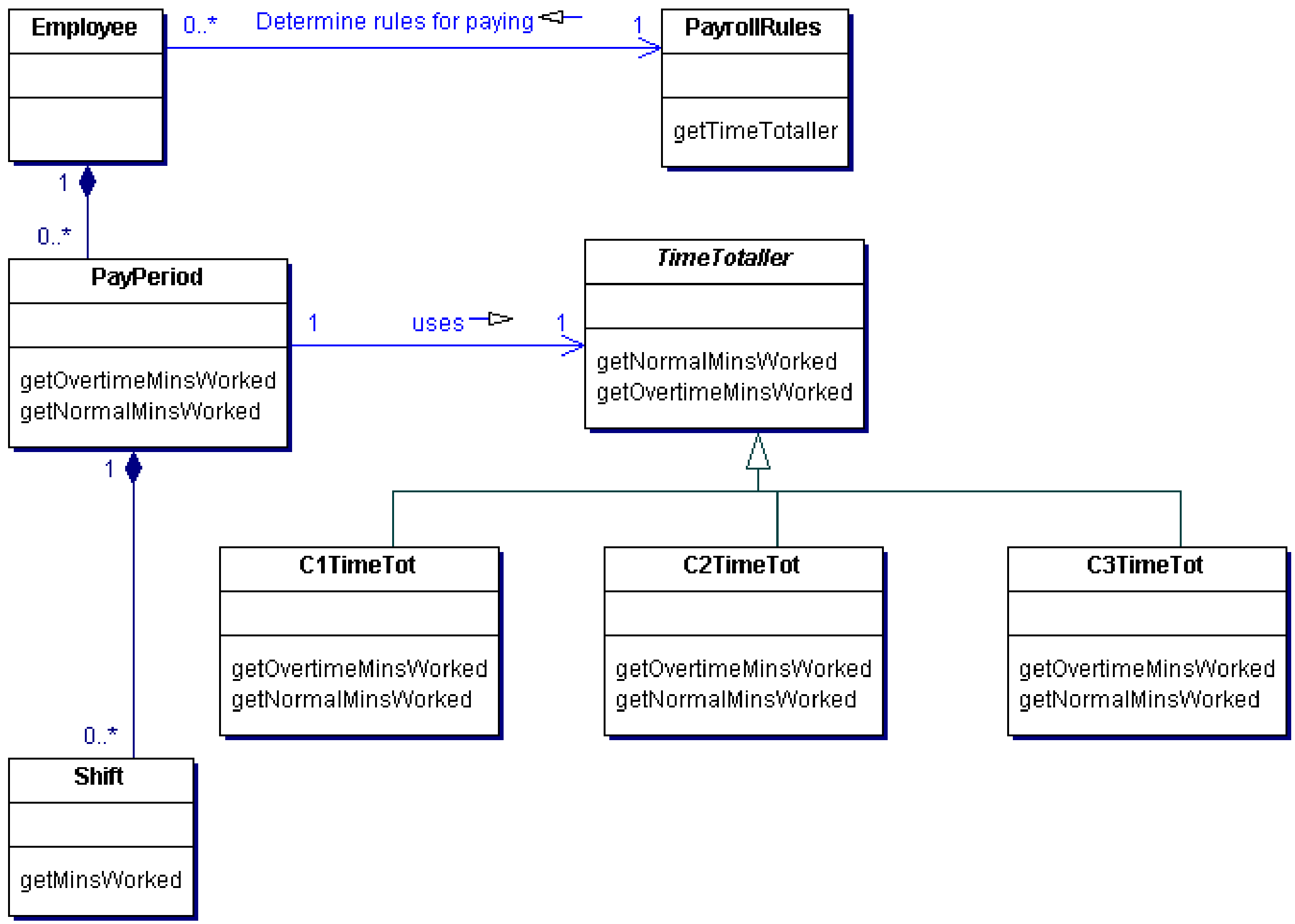
Support Law of demeter



Law of Demeter

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

Law of Demeter – Time totalling example



Time totalling example

Employee - Instances of the Employee class represent an employee.

PayrollRules – The rules for paying an employee vary with the laws that apply to the location where the employee works. Instances of the PayrollRules class encapsulate the pay rules that apply to an employee.

PayPeriod – Instances of the Payperiod class represent a range of days for which an employeee is paid in the same pay slip.

Shift – Instances of the Shift class represent ranges of time that the employee worked.

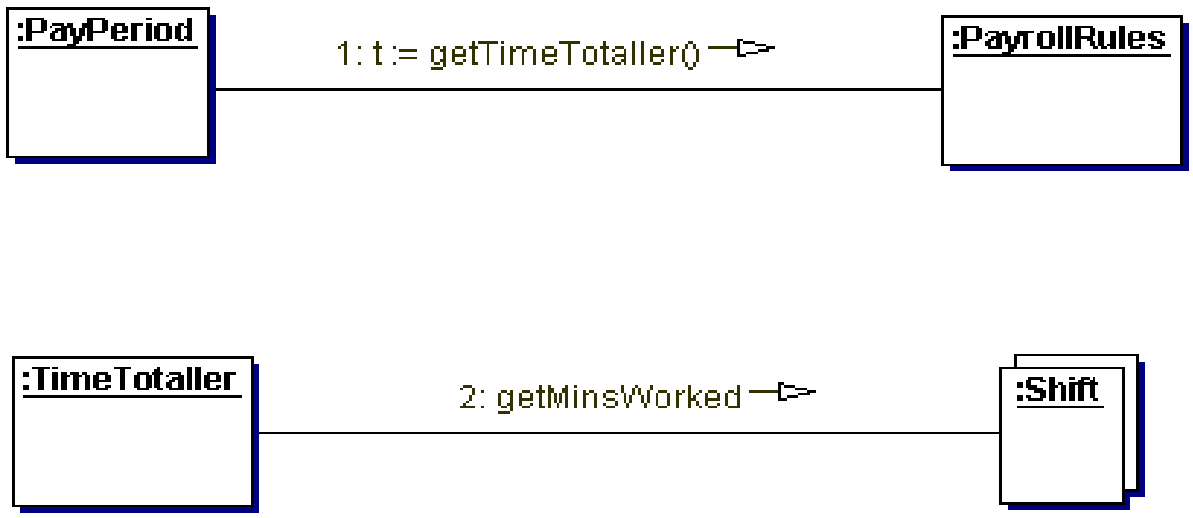
TimeTotaller – The Timetotaller class is an abstract class that the PayPeriod class uses to break the total hours worked during a pay period into normal and overtime minutes.

C1TimeTot,C2TimeTot,C3TimeTot – Concrete subclasses for different location of TimeTotaller that encapsulate the rules for breaking total minutes worked into normal and overtime minutes worked.

The following interaction must occur:

- The pay period must become associated with an instance of the subclasss of TimeTotaller appropriate for the employee when the PayPeriod object is created.
- The TimeTotaller object must be able to examine each shift in the pay period to learn the number of minutes worked in each shift.

Bad time-totalling collaboration



PayPeriod class has no reason to know anything about the PayrollRules class

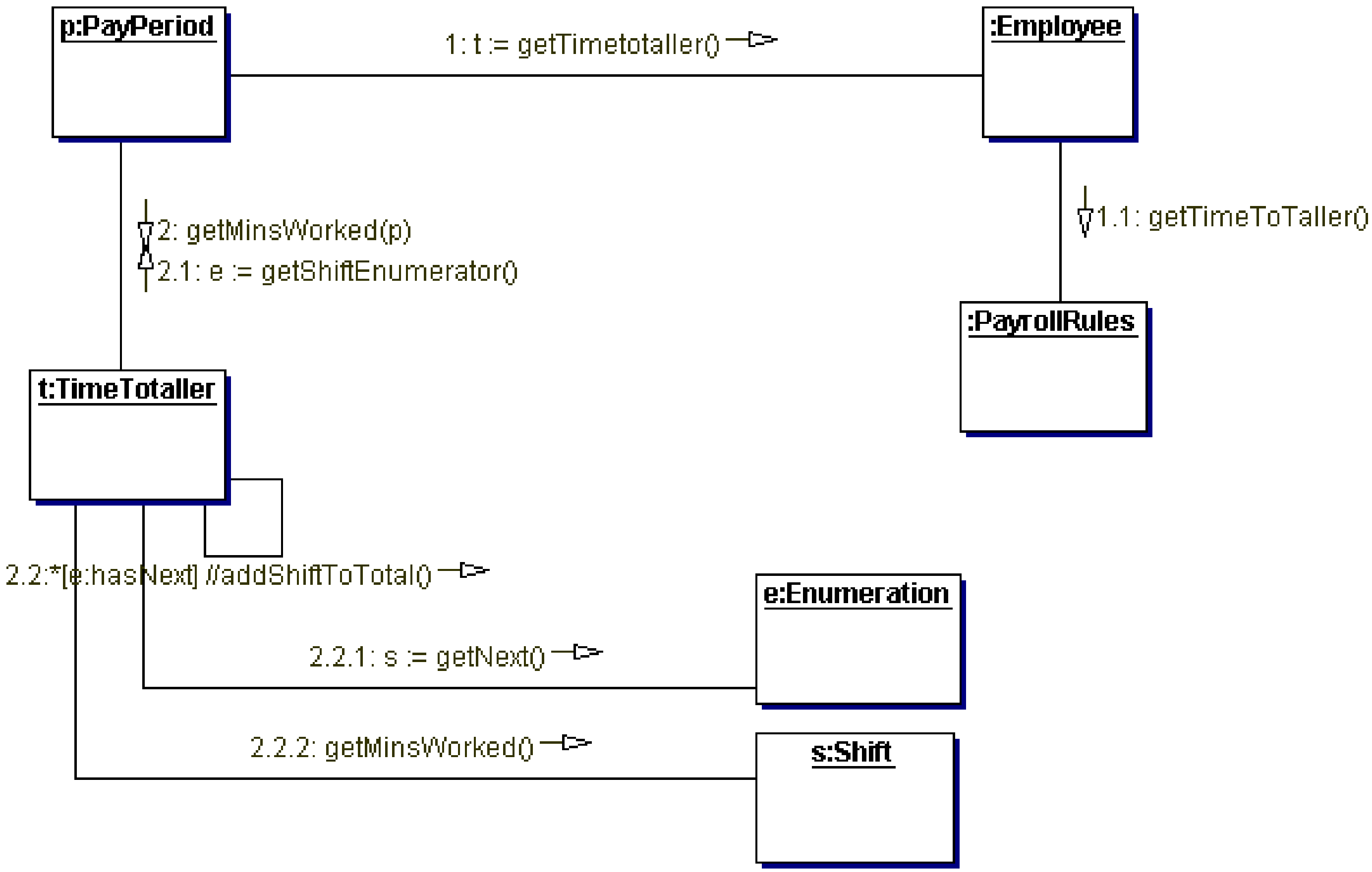
For TimeTotaller to have direct access to the collection of shifts that it needs implies violation of the Shift class's encapsulation of how it aggregates Collection of shifts -- resulting in higher level of coupling

Good time-totalling collaboration

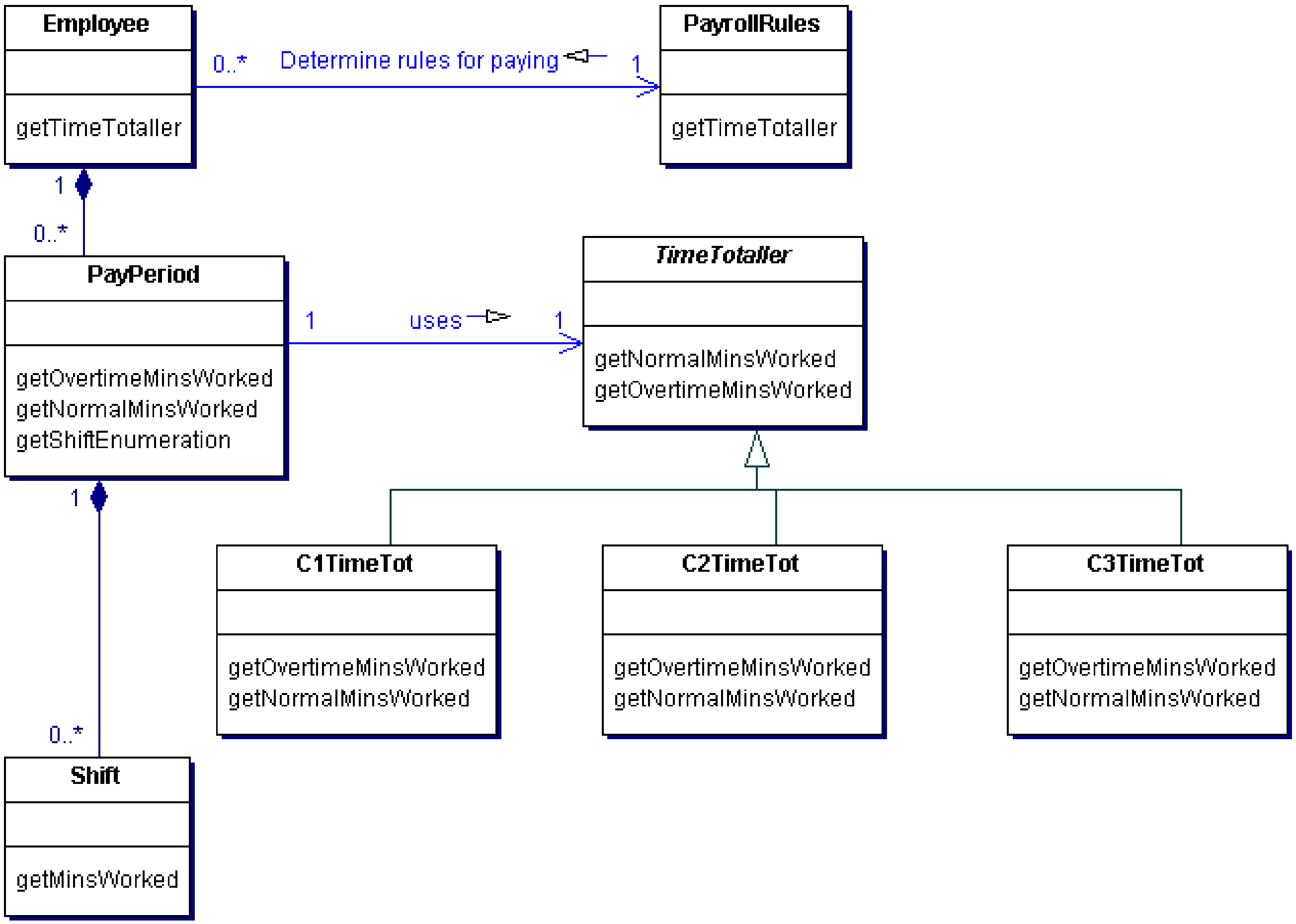
To preserve the level of cohesion and coupling a less direct interaction may be used.

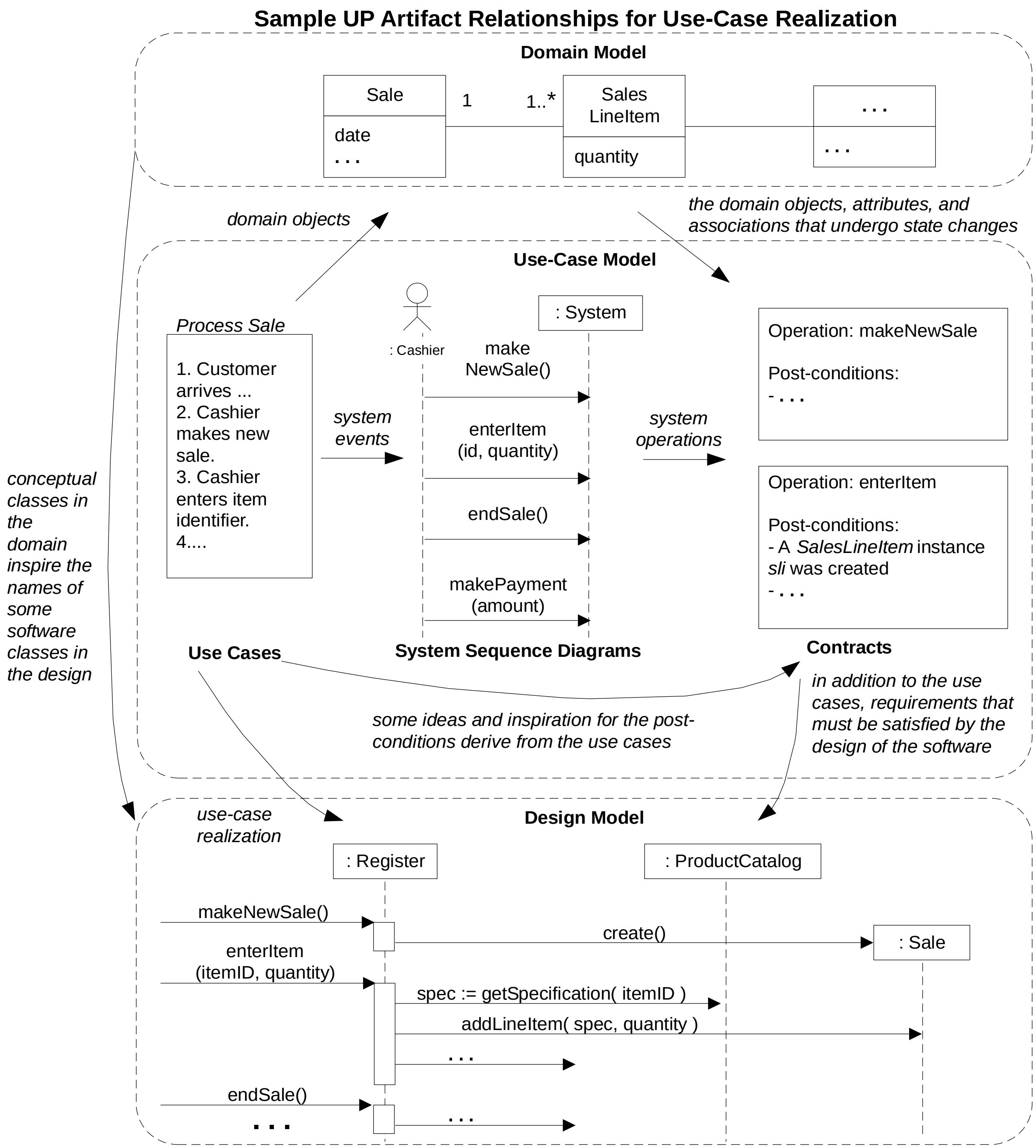
This is done as shown by the following collaboration diagram and the creation of additional methods.

Good time-totalling collaboration

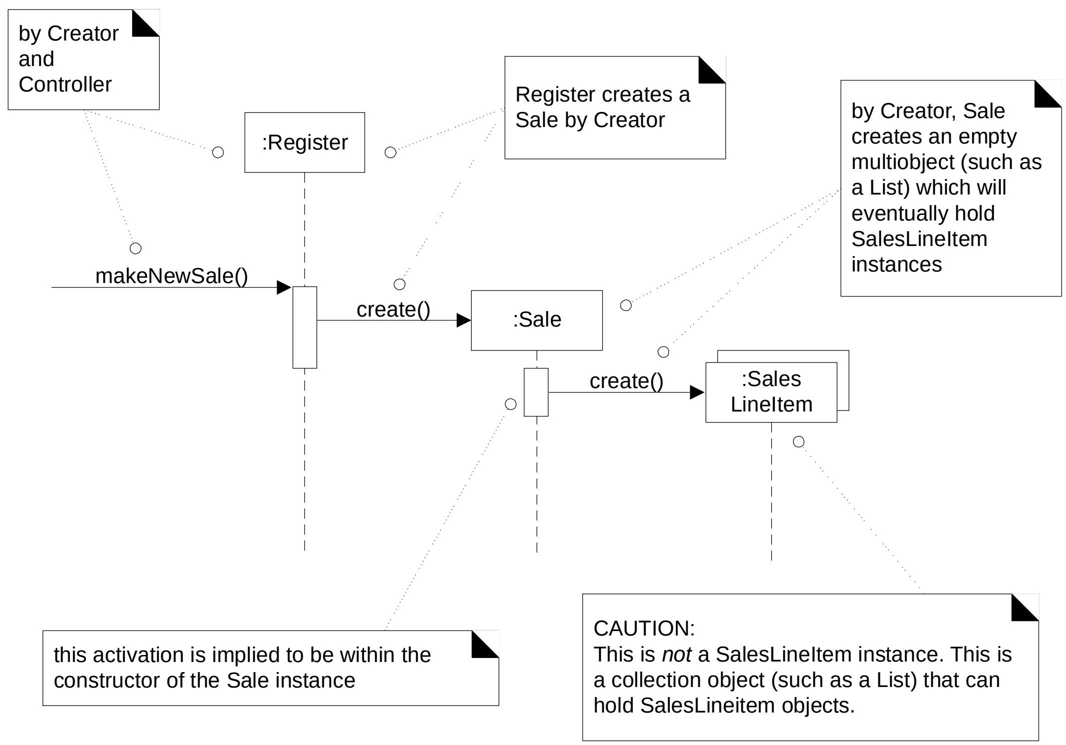


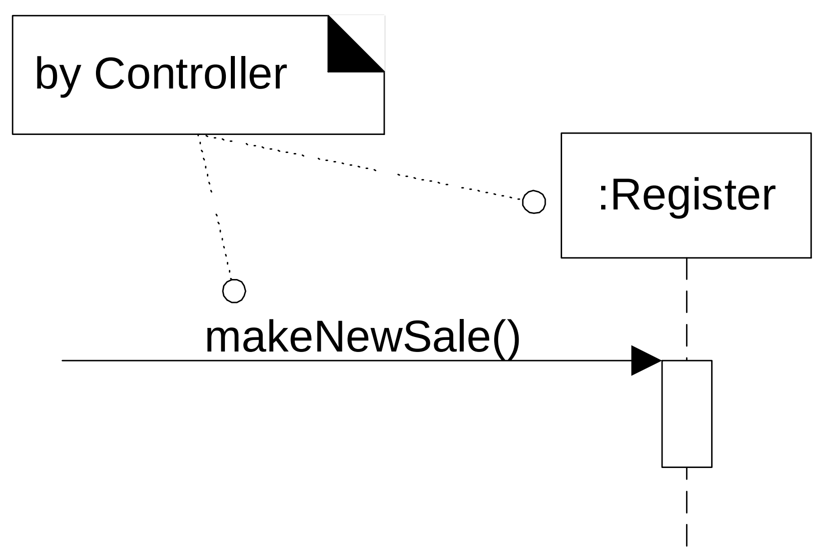
Law of Demeter – Time totalling example with added operations

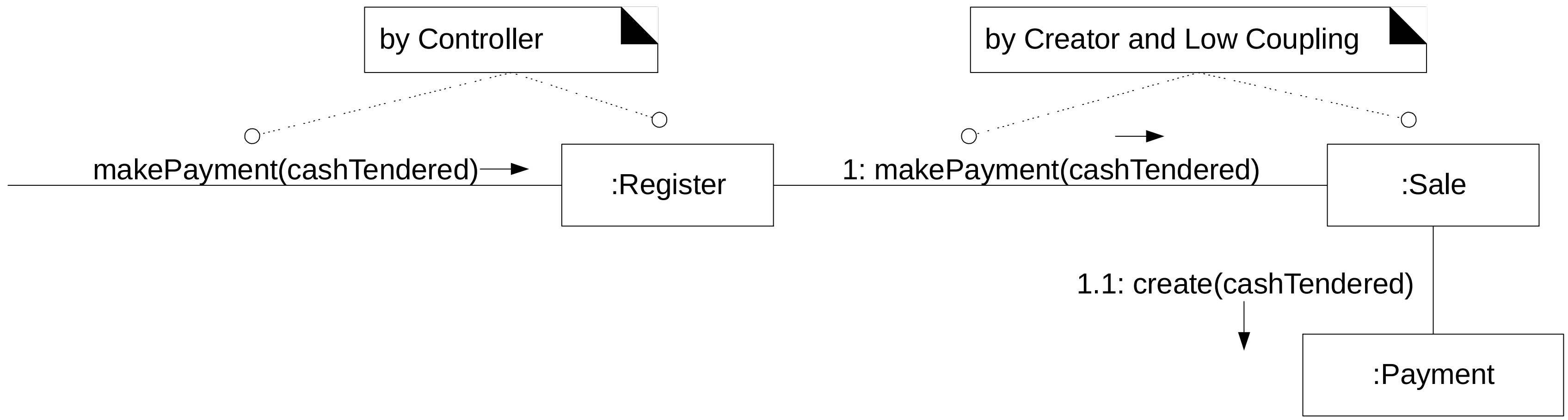


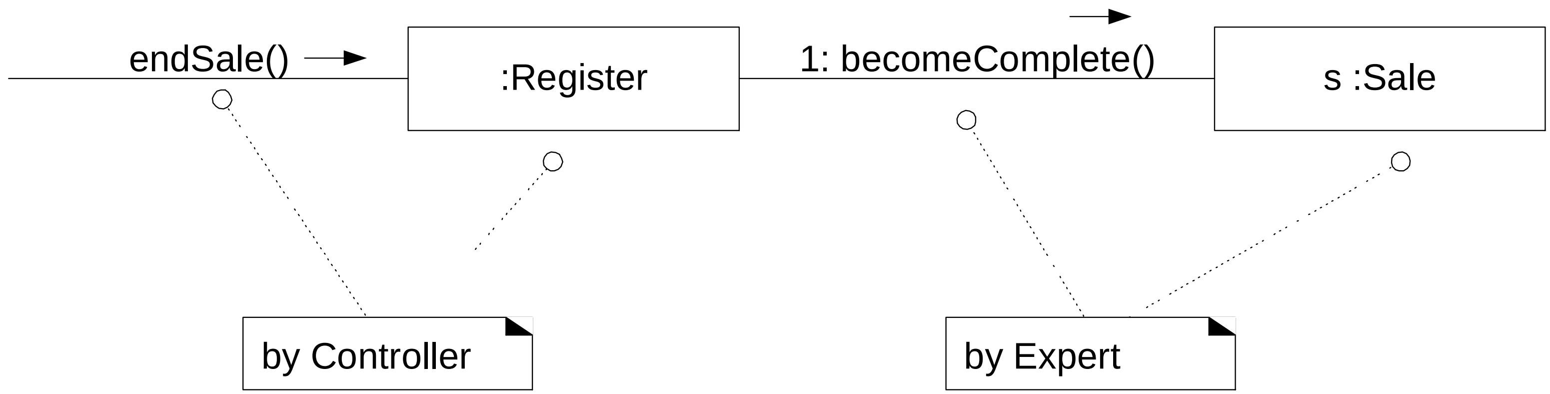


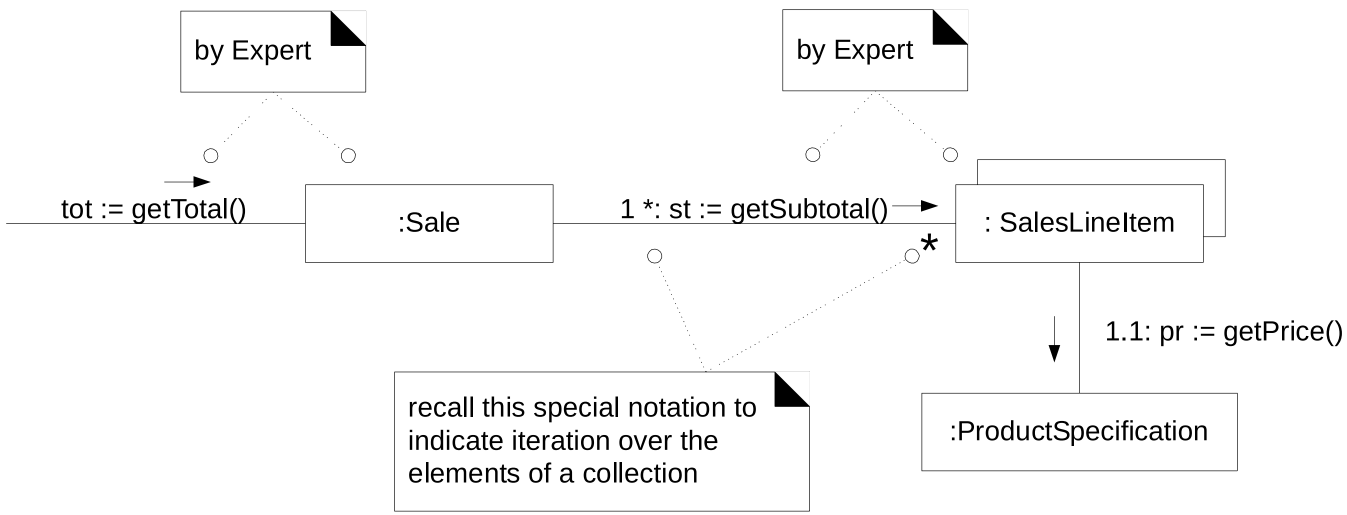
Sample UP Artifact Relationships for Use-Case Realization
Domain Model
Sale
date
. . .
1
1..*
Sales LineItem
quantity
. . .
. . .
domain objects
the domain objects, attributes, and associations that undergo state changes
Use-Case Model
Process Sale
1. Customer arrives ...
2. Cashier makes new sale.
3. Cashier enters item identifier.
4....
system events
: Cashier
: System
make NewSale()
enterItem (id, quantity)
endSale()
makePayment (amount)
system operations
Operation: makeNewSale
Post-conditions:
- . . .
Operation: enterItem
Post-conditions:
- A *SalesLineItem* instance *sli* was created
- . . .
conceptual classes in the domain inspire the names of some software classes in the design
Use Cases
System Sequence Diagrams
Contracts
in addition to the use cases, requirements that must be satisfied by the design of the software
some ideas and inspiration for the post-conditions derive from the use cases
use-case realization
Design Model
: Register
: ProductCatalog
makeNewSale()
create()
: Sale
enterItem (itemID, quantity)
spec := getSpecification(itemID)
addLineItem(spec, quantity)
. . .
endSale()
. . .
. . .

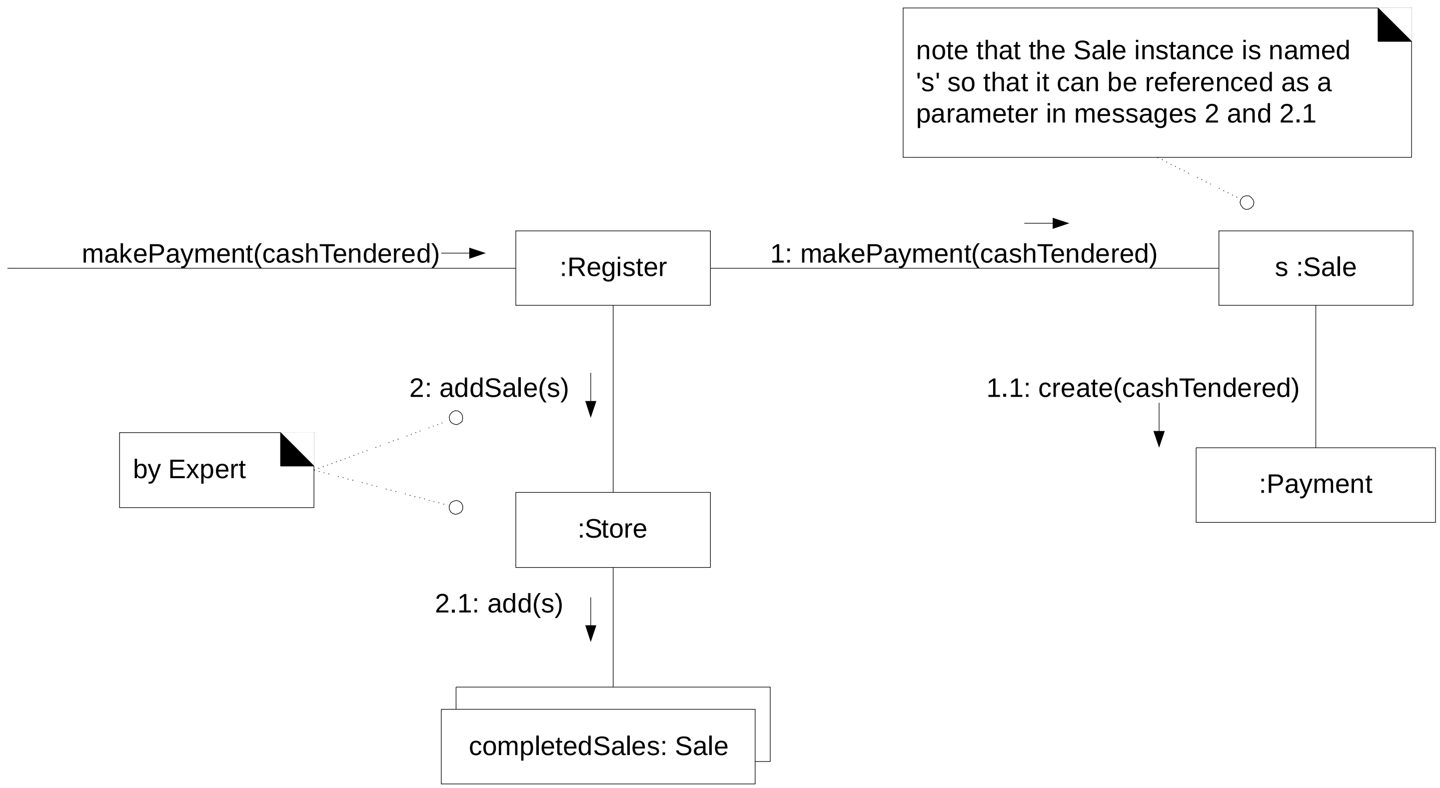

by Creator and Controller
Register creates a Sale by Creator
by Creator, Sale creates an empty multiobject (such as a List) which will eventually hold SalesLineItem instances
:Register
makeNewSale()
create()
:Sale
create()
:Sales LineItem
this activation is implied to be within the constructor of the Sale instance
CAUTION:
This is *not* a SalesLineItem instance. This is a collection object (such as a List) that can hold SalesLineitem objects.

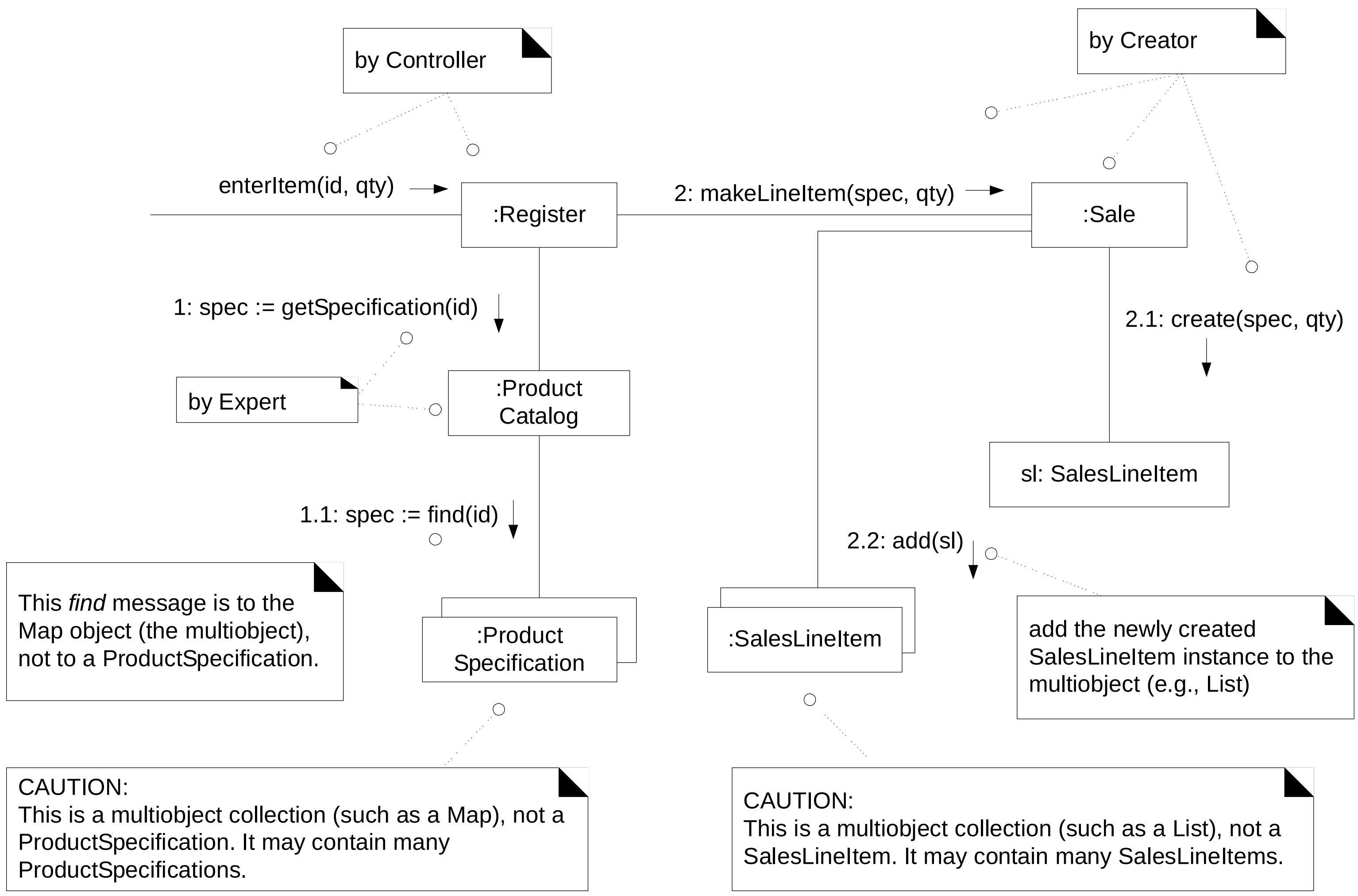

by Controller
:Register
makeNewSale()

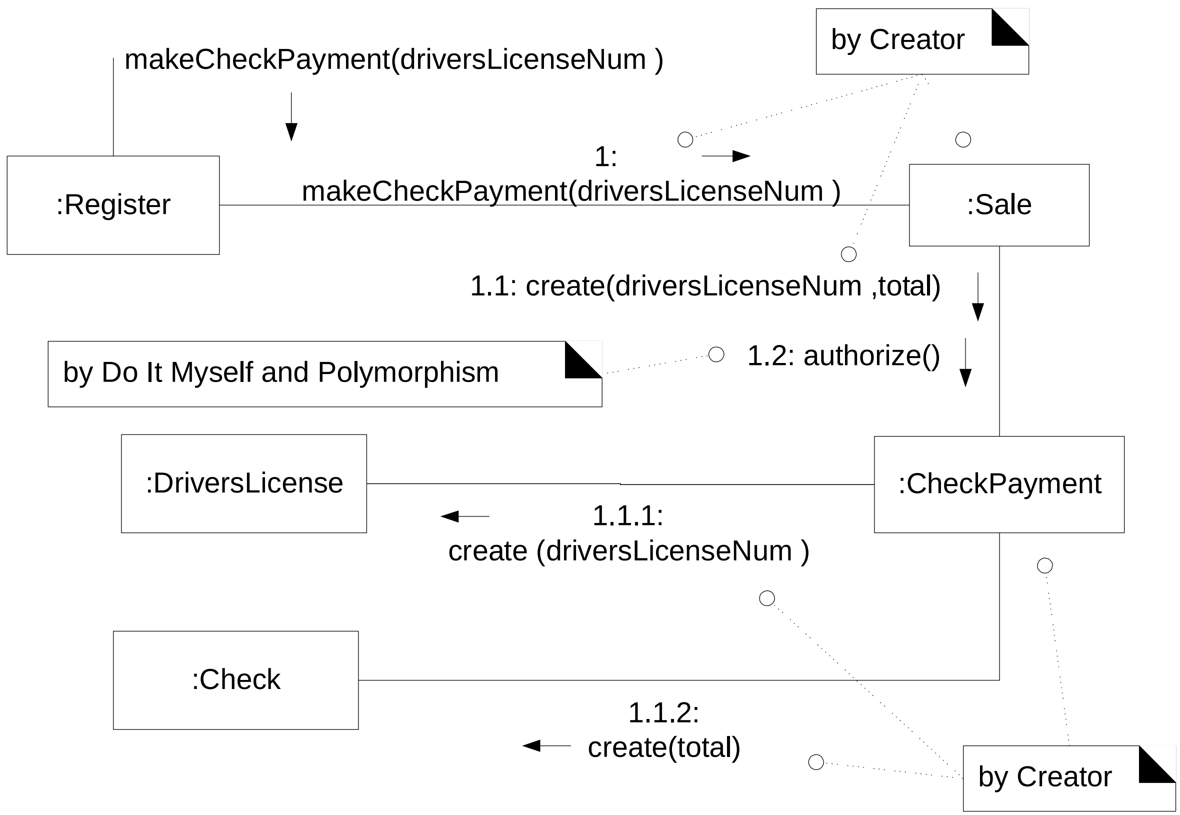

by Controller
by Creator and Low Coupling
makePayment(cashTendered)
:Register
1: makePayment(cashTendered)
:Sale
1.1: create(cashTendered)
:Payment

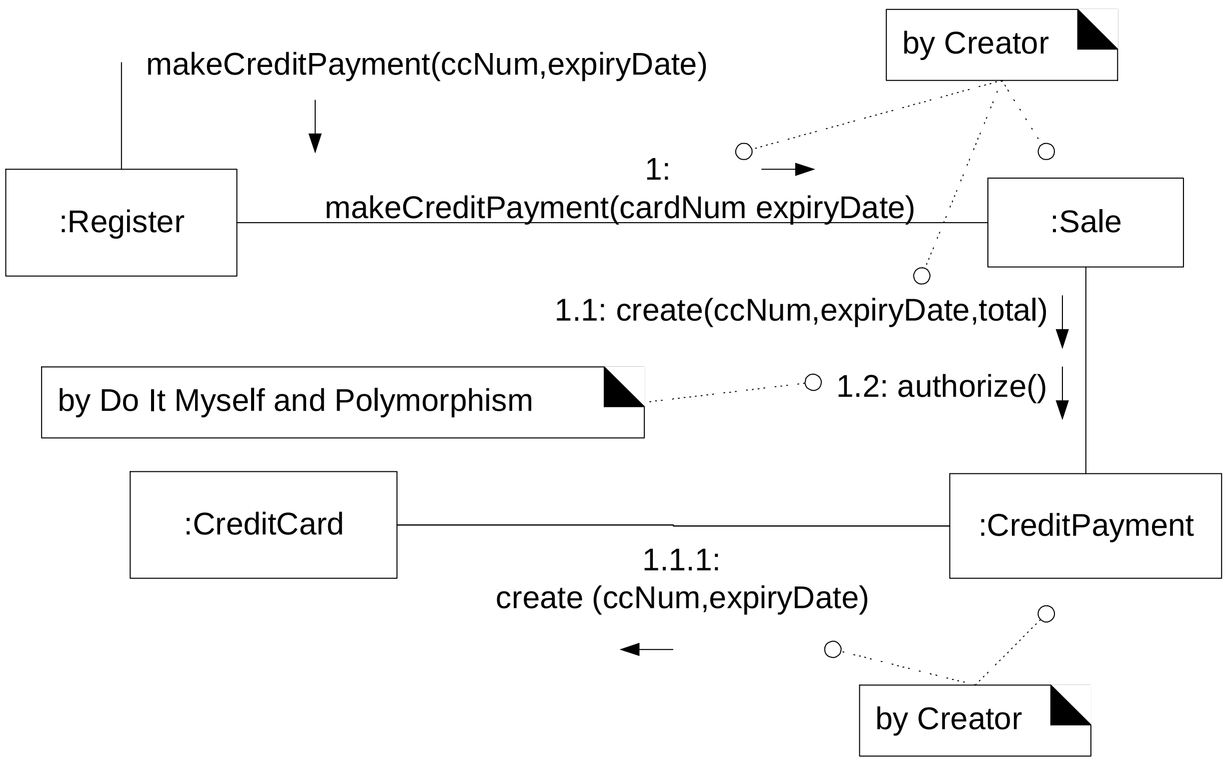

endSale()
:Register
1: becomeComplete()
s :Sale
by Controller
by Expert

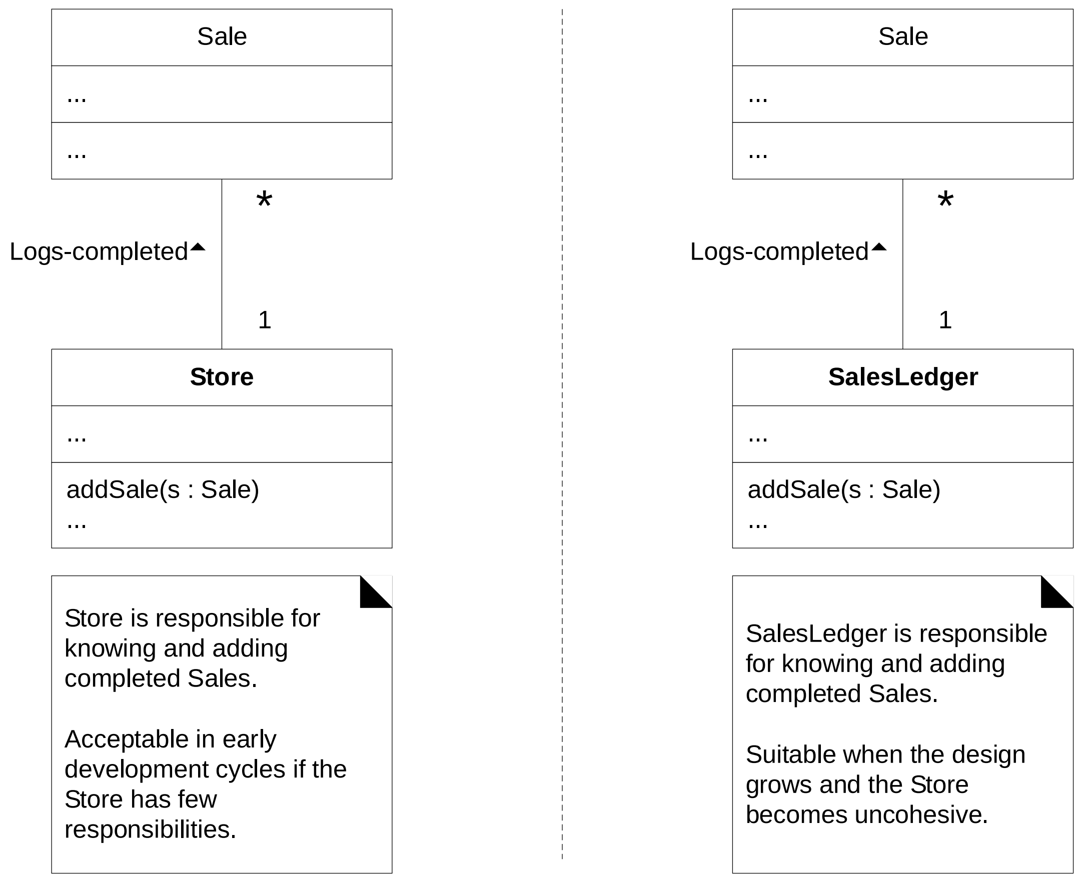

by Expert
by Expert
tot := getTotal()
:Sale
1 *: st := getSubtotal()
: SalesLineItem
*
1.1: pr := getPrice()
recall this special notation to indicate iteration over the elements of a collection
:ProductSpecification

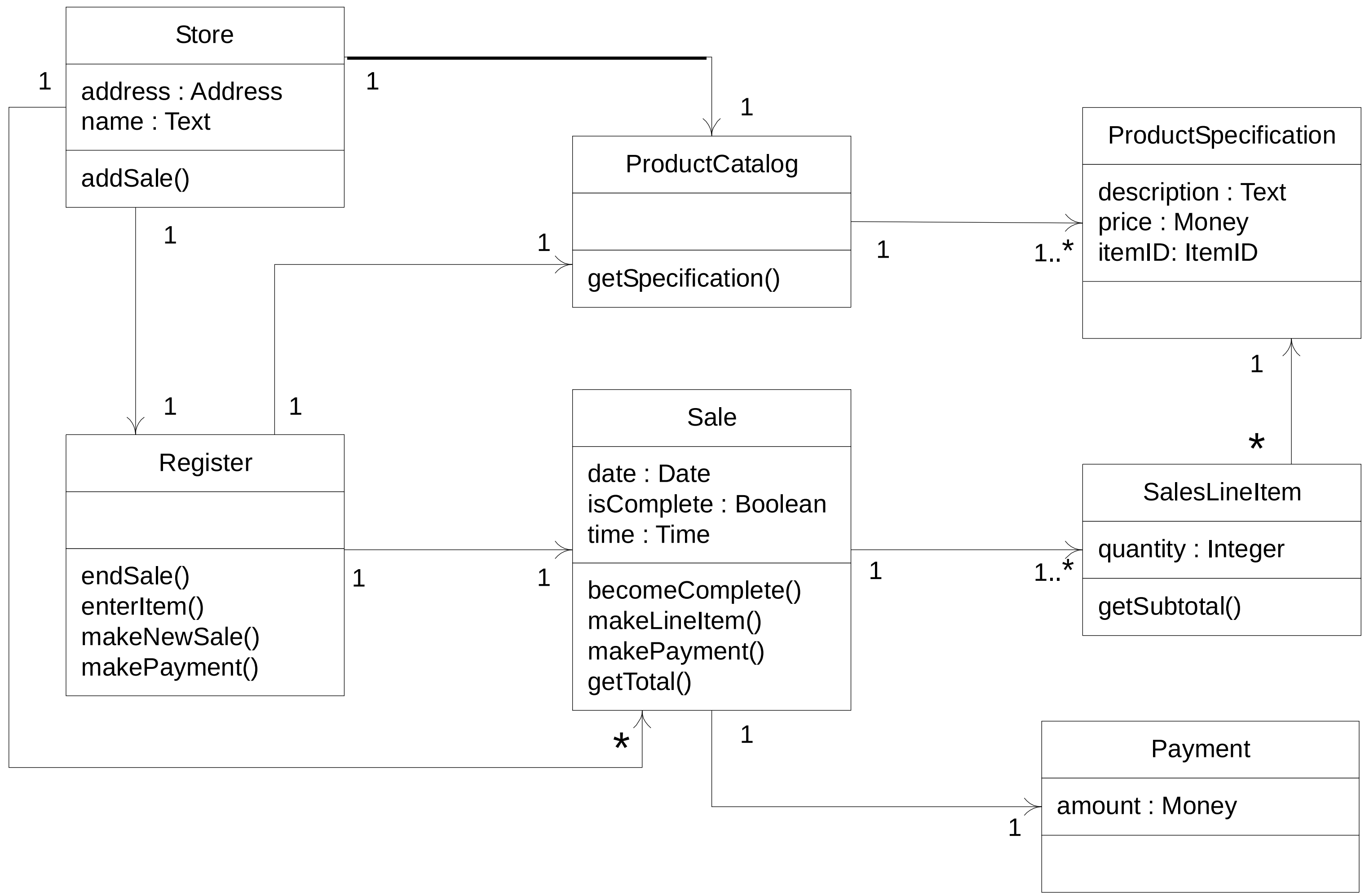

note that the Sale instance is named 's' so that it can be referenced as a parameter in messages 2 and 2.1
makePayment(cashTendered)
:Register
1: makePayment(cashTendered)
s :Sale
2: addSale(s)
1.1: create(cashTendered)
by Expert
:Payment
:Store
2.1: add(s)
completedSales: Sale


by Controller
by Creator
enterItem(id, qty)
:Register
2: makeLineItem(spec, qty)
:Sale
1: spec := getSpecification(id)
2.1: create(spec, qty)
by Expert
:Product Catalog
sl: SalesLineItem
1.1: spec := find(id)
2.2: add(sl)
This *find* message is to the Map object (the multiobject), not to a ProductSpecification.
:Product Specification
:SalesLineItem
add the newly created SalesLineItem instance to the multiobject (e.g., List)
CAUTION:
This is a multiobject collection (such as a Map), not a ProductSpecification. It may contain many ProductSpecifications.
CAUTION:
This is a multiobject collection (such as a List), not a SalesLineItem. It may contain many SalesLineItems.


makeCheckPayment(driversLicenseNum)
by Creator
:Register
1:
makeCheckPayment(driversLicenseNum)
:Sale
1.1: create(driversLicenseNum ,total)
by Do It Myself and Polymorphism
1.2: authorize()
:DriversLicense
:CheckPayment
1.1.1:
create (driversLicenseNum)
:Check
1.1.2:
create(total)
by Creator


by Creator
makeCreditPayment(ccNum,expiryDate)
1:
makeCreditPayment(cardNum expiryDate)
:Register
:Sale
1.1: create(ccNum,expiryDate,total)
by Do It Myself and Polymorphism
1.2: authorize()
:CreditCard
:CreditPayment
1.1.1:
create (ccNum,expiryDate)
by Creator


Sale
...
...
*
Logs-completed
1
Store
...
addSale(s : Sale)
...
Store is responsible for knowing and adding completed Sales.
Acceptable in early development cycles if the Store has few responsibilities.
Sale
...
...
*
Logs-completed
1
SalesLedger
...
addSale(s : Sale)
...
SalesLedger is responsible for knowing and adding completed Sales.
Suitable when the design grows and the Store becomes uncohesive.


Store
address : Address
name : Text
addSale()
ProductCatalog
getSpecification()
ProductSpecification
description : Text
price : Money
itemID: ItemID
Register
endSale()
enterItem()
makeNewSale()
makePayment()
Sale
date : Date
isComplete : Boolean
time : Time
becomeComplete()
makeLineItem()
makePayment()
getTotal()
SalesLineItem
quantity : Integer
getSubtotal()
Payment
amount : Money
1
1
1
1
1
1
1
1..*
1
*
1
1
1
1..*
*
1
1