Chapter 2: Object Oriented Analysis

1.0 Building Domain/Conceptual Models

The Object oriented analysis can be performed at different level of abstractions such as:

1. ENTERPRISE LEVEL
2. BUSINESS AREA LEVEL
3. APPLICATION LEVEL

The analysis we are dealing is the middle level of abstraction i.e Business Area level (Domain level) .One of the most important activities involved is domain analysis, which is performed when an organization wants to create a library of reusable classes that will be broadly applicable to an entire category of applications.

The domain analysis can be viewed as an umbrella activity for the software process, which states that domain analysis is an ongoing software engineering activity that is not connected to any one software project. The immediately apparent benefits derived from the reuse are consistency, and familiarity. Patterns within the software will become more consistent, leading to better maintainability. The Fig below shows input and output of domain analysis:

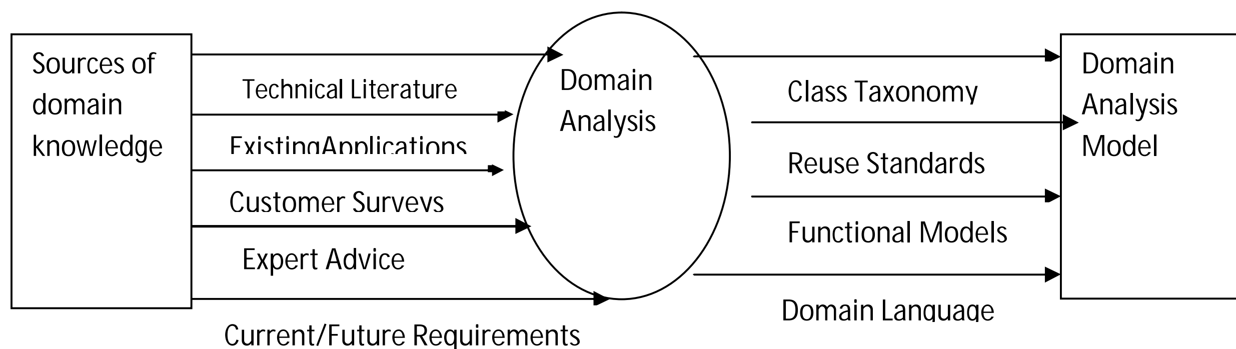


Fig 1: Input/ Output diagram for domain analysis

A domain model is the most important and classic model in OO *analysis*. It illustrates noteworthy concepts in a domain. It can act as a source of inspiration for designing some software objects and will be an input to several artifacts explored in the case studies. This chapter also shows the value of OOA/D knowledge over UML notation; the basic notation is trivial, but there are subtle modeling guidelines for a useful model expertise can take weeks or months.

A **domain model** is a *visual* representation of conceptual classes or real-situation objects in a domain. Domain models have also been called **conceptual models** (the term used in the first edition of this book), **domain object models**, and **analysis object models**.

In the UP, the term "Domain Model" means a representation of real-situation conceptual classes, not of software objects. The term does not mean a set of diagrams describing software classes, the domain layer of a software architecture, or software objects with responsibilities.

More precisely, the UP Domain Model is a specialization of the UP **Business Object Model** (BOM) "focusing on explaining 'things' and products important to a business domain". That is, a Domain Model focuses on one domain, such as POS related things.

Applying UML notation, a domain model is illustrated with a set of **class diagrams** in which no operations (method signatures) are defined. It provides a *conceptual perspective*. It may show:

- domain objects or conceptual classes
- associations between conceptual classes
- attributes of conceptual classes

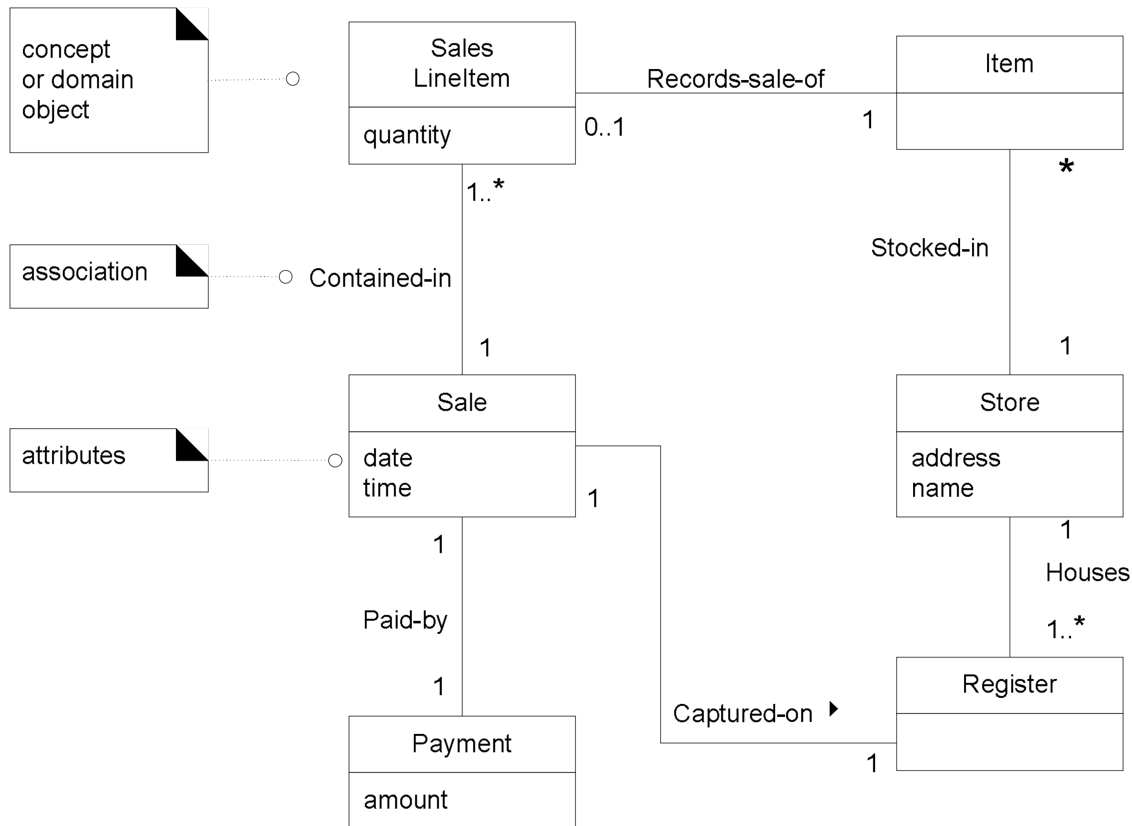


Fig 2: Simple Domain class model

The goal of the domain analysis, as mentioned above ,to find or create those classes that are broadly applicable ,so that they may be reused ,is characterized by a number of steps as enumerated below:

a. Define the domain to be investigated
b. Categorize the items extracted from the domain
c. Collect a representative sample of applications in the domain
d. Analyze each application in the sample
e. Develop an analysis model for the objects

The responsibility of domain analysis falls on the domain analyst. Besides the above steps ,the domain analyst should also create a set of reuse guidelines and develop an example that illustrates how the domain objects could be used to create a new application.

Why Call a Domain Model a "Visual Dictionary"?

Please reflect on Figure 2 for a moment. See how it visualizes and relates words or concepts in the domain. It also shows an *abstraction* of the conceptual classes, because there are many other things one could communicate about registers, sales, and so forth.

The information it illustrates (using UML notation) could alternatively have been expressed in plain text (in the UP Glossary). But it's easy to understand the terms and especially their relationships in a visual language, since our brains are good at understanding visual elements and line connections. Therefore, the domain model is a ***visual dictionary*** of the noteworthy abstractions, domain vocabulary, and information content of the domain.

Is a Domain Model a Picture of Software Business Objects?

A UP Domain Model, as shown in Figure 3, is a visualization of things in a real-situation domain of interest, *not* of software objects such as Java or C# classes, or software objects with responsibilities (see Figure 3).

Therefore, the following elements are not suitable in a domain model:

- Software artifacts, such as a window or a database, unless the domain being modeled are of software concepts, such as a model of graphical user interfaces.
- Responsibilities or methods.

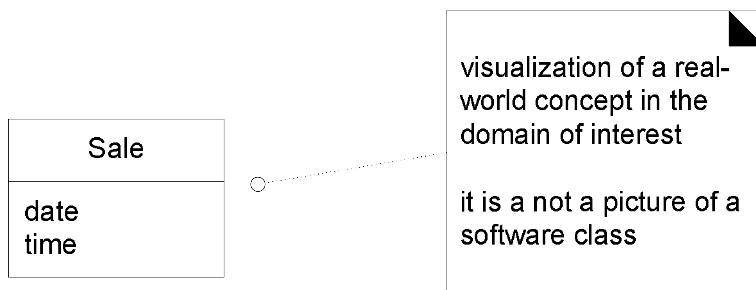


Fig 3: A domain model shows real-situation conceptual classes, not software classes.

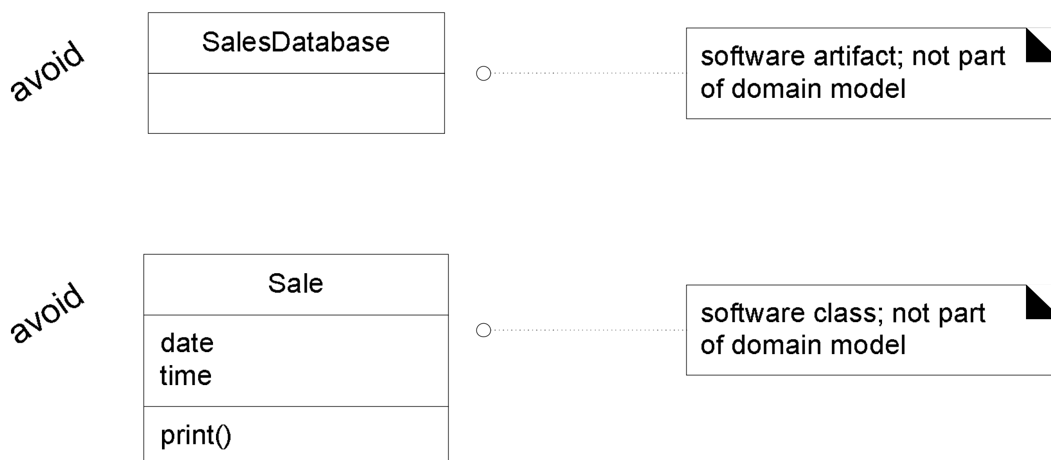


Fig 4: A domain model does not show software artifacts or classes.

hpokhrel24@gmail.com

What are Two Traditional Meanings of "Domain Model"?

"Domain Model" is a conceptual perspective of objects in a real situation of the world, not a software perspective. But the term is overloaded; it also has been to mean "the domain layer of software objects." That is, the layer of software objects below the presentation or UI layer that is composed of domain objects software objects that represent things in the problem domain space with related **"business logic" or "domain logic"** methods. For example, a *Board* software class with a *getSquare* method.

What are Conceptual Classes?

The domain model illustrates conceptual classes or vocabulary in the domain. Informally, a **conceptual class** is an idea, thing, or object. More formally, a conceptual class may be considered in terms of its symbol, intension, and extension (see Figure 5).

- **Symbol** words or images representing a conceptual class.
- **Intension** the definition of a conceptual class.
- **Extension** the set of examples to which the conceptual class applies.

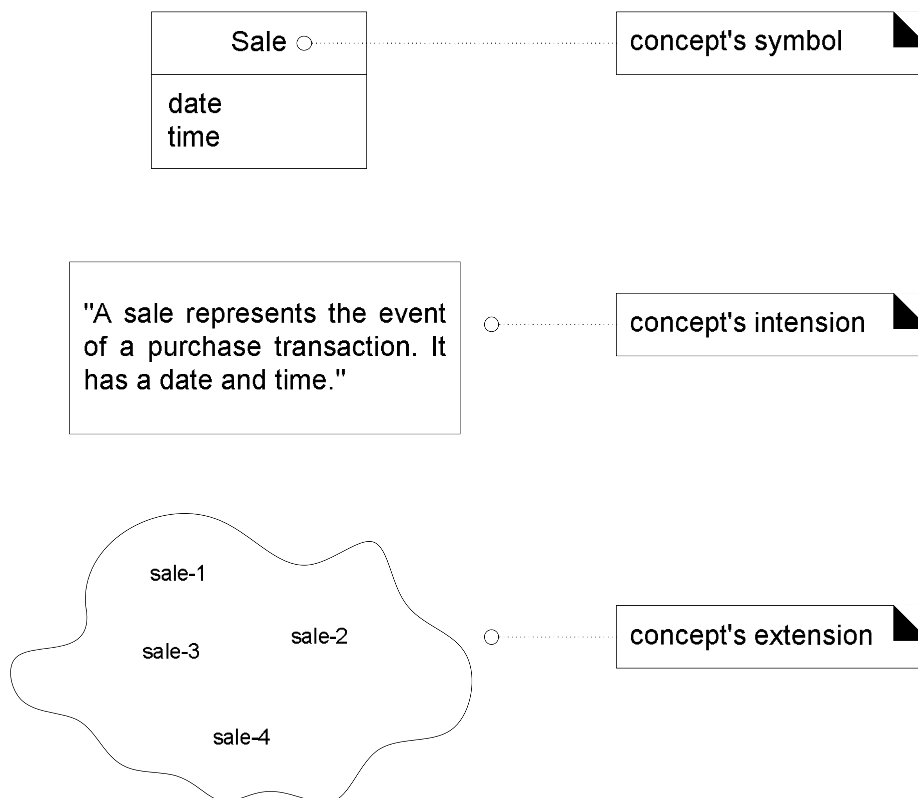


Fig 5: A conceptual class has a symbol, intension, and extension.

For example, consider the conceptual class for the event of a purchase transaction. I may choose to name it by the (English) symbol *Sale*. The intension of a *Sale* may state that it "represents the

hpokhrel24@gmail.com

event of a purchase transaction, and has a date and time." The extension of *Sale* is all the examples of sales; in other words, the set of all sale instances in the universe.

Are Domain and Data Models the Same Thing?

A domain model is not a **data model** (which by definition shows persistent data to be stored somewhere), so do not exclude a class simply because the requirements don't indicate any obvious need to remember information about it (a criterion common in data modeling for relational database design, but not relevant to domain modeling) or because the conceptual class has no attributes. For example, it's valid to have attributed less conceptual classes, or conceptual classes that have a purely behavioral role in the domain instead of an information role.

How to Create a Domain Model?

Bounded by the current iteration requirements under design:

1. Find the conceptual classes (see a following guideline).
2. Draw them as classes in a UML class diagram.
3. Add associations and attributes.

How to Find Conceptual Classes?

What are Three Strategies to Find Conceptual Classes?

1. **Reuse or modify existing models.**
    a. This is the first, best, and usually easiest approach, and where I will start if I can. There are published, well-crafted domain models and data models (which can be modified into domain models) for many common domains, such as inventory, finance, health, and so forth..
2. **Use a category list.**
3. **Identify noun phrases.**

Reusing existing models is excellent, but outside our scope. The second method, using a category list, is also useful.

Method 2: Use a Category List

We can kick-start the creation of a domain model by making a list of candidate conceptual classes. Table 9.1 contains many common categories that are usually worth considering, with an emphasis on business information system needs. The guidelines also suggest some priorities in the analysis. Examples are drawn from the 1) POS, 2) Monopoly, and 3) airline reservation domains.

Table 9.1. Conceptual Class Category List.

Conceptual Class Category	Examples
business transactions *Guideline*: These are critical (they involve money), so start with transactions.	*Sale, Payment* *Reservation*
transaction line items *Guideline*: Transactions often come with related line items, so consider these next.	*SalesLineItem*
product or service related to a transaction or transaction line item *Guideline*: Transactions are *for* something (a product or service). Consider these next.	*Item* *Flight, Seat, Meal*
where is the transaction recorded? *Guideline*: Important.	*Register, Ledger* *FlightManifest*

Conceptual Class Category	Examples
roles of people or organizations related to the transaction; actors in the use case *Guideline*: We usually need to know about the parties involved in a transaction.	*Cashier, Customer, Store MonopolyPlayer Passenger, Airline*
place of transaction; place of service	*Store* *Airport, Plane, Seat*
noteworthy events, often with a time or place we need to remember	*Sale, Payment MonopolyGame Flight*
physical objects *Guideline*: This is especially relevant when creating device-control software, or simulations.	*Item, Register Board, Piece, Die Airplane*
descriptions of things *Guideline*: See p. 147 for discussion.	*ProductDescription* *FlightDescription*
catalogs *Guideline*: Descriptions are often in a catalog.	*ProductCatalog* *FlightCatalog*
containers of things (physical or information)	*Store, Bin Board Airplane*
things in a container	*Item Square (in a Board) Passenger*
other collaborating systems	*CreditAuthorizationSystem* *AirTrafficControl*
records of finance, work, contracts, legal matters	*Receipt, Ledger* *MaintenanceLog*
financial instruments	*Cash, Check, LineOfCredit* *TicketCredit*
schedules, manuals, documents that are regularly referred to in order to perform work	*DailyPriceChangeList* *RepairSchedule*

Method 3: Finding Conceptual Classes with Noun Phrase Identification

Another useful technique (because of its simplicity) suggested in is **linguistic analysis**: Identify the nouns and noun phrases in textual descriptions of a domain, and consider them as candidate conceptual classes or attributes. Nevertheless, linguistic analysis is another source of inspiration. The fully dressed use cases are an excellent description to draw from for this analysis. For example, the current scenario of the *Process Sale* use case can be used.

Main Success Scenario (or Basic Flow):

1. **Customer** arrives at a **POS checkout** with **goods** and/or **services** to purchase.
2. **Cashier** starts a new **sale**.
3. **Cashier** enters **item identifier**.

hpokhrel24@gmail.com

4. System records **sale line item** and presents **item description, price**, and running **total**. Price calculated from a set of price rules.

Cashier repeats steps 2-3 until indicates done.

5. System presents total with **taxes** calculated.
6. Cashier tells Customer the total, and asks for **payment**.
7. Customer pays and System handles payment.
8. System logs the completed **sale** and sends sale and payment information to the external **Accounting** (for accounting and **commissions**) and **Inventory** systems (to update inventory).
9. System presents **receipt**.
10. Customer leaves with receipt and goods (if any).

Extensions (or Alternative Flows):

. . .

7a. Paying by cash:

- Cashier enters the cash **amount tendered**.
- System presents the **balance due**, and releases the **cash drawer**.
- Cashier deposits cash tendered and returns balance in cash to Customer.
- System records the cash payment.

Example: Find and Draw Conceptual Classes

Case Study: POS Domain

From the category list and noun phrase analysis, a list is generated of candidate conceptual classes for the domain. Since this is a business information system, focus first on the category list guidelines that emphasize business transactions and their relationship with other things. The list is constrained to the requirements and simplifications currently under consideration for iteration-1, the basic cash-only scenario of *Process Sale*.

iteration-1 requirements

Sale	*Cashier*
CashPayment	*Customer*
SalesLineItem	*Store*
Item	*ProductDescriptior*
Register	*ProductCatalog*
Ledger	

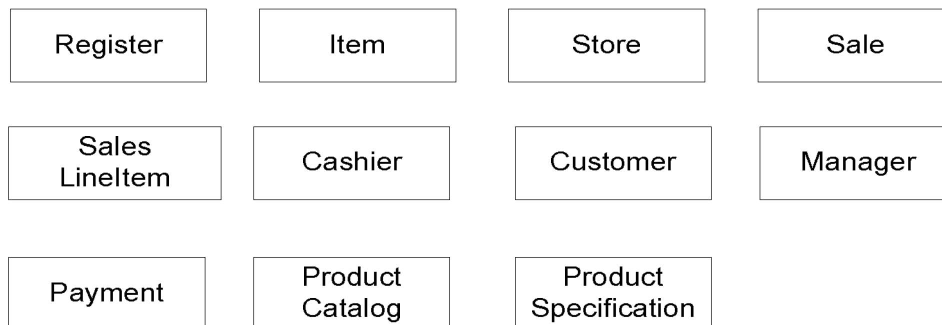


Fig 6: Initial POS Domain Model

hpokhrel24@gmail.com

2.0 Adding Associations and Attributes

2.1 Adding Associations

An association is a relationship between classes (more precisely, instances of those classes) that indicates some meaningful and interesting connection

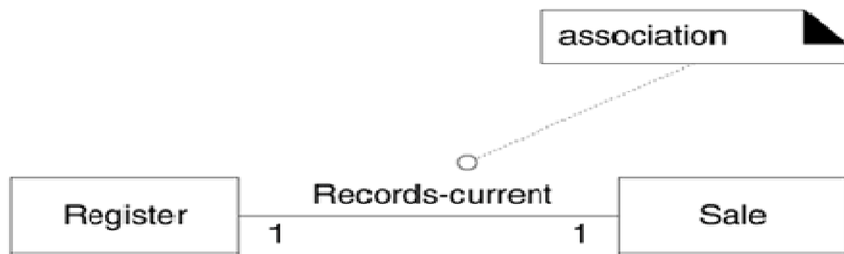
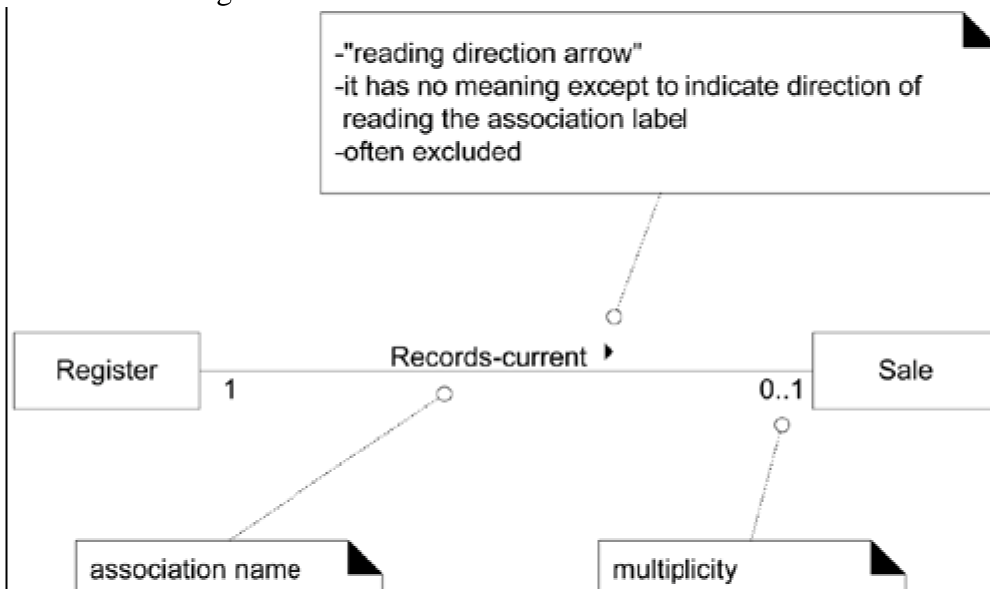


Fig 7 : Example of Associations

In the UML, associations are defined as "the semantic relationship between two or more classifiers that involve connections among their instances."

The ends of an association may contain a multiplicity expression indicating the numerical relationship between instances of the classes.
The association is inherently bidirectional, meaning that from instances of either class, logical traversal to the other is possible. This traversal is purely abstract; it is *not* a statement about connections between software entities.

An optional "reading direction arrow" indicates the direction to read the association name; it does not indicate direction of visibility or navigation. If the arrow is not present, the convention is to read the association from left to right or top to bottom, although the UML does not make this a rule. See figure below



hpokhrel24@gmail.com

Fig 8: The UML notation for associations.
Note: The reading direction arrow has no meaning in terms of the model; it is only an aid to the reader of the diagram.

How to Name an Association in UML?

Name an association based on a *ClassName-VerbPhrase-ClassName* format where the verb phrase creates a sequence that is readable and meaningful. Simple association names such as "Has" or "Uses" are usually poor, as they seldom enhance our understanding of the domain.
For example,

- *Sale Paid-by CashPayment*
    - bad example (doesn't enhance meaning): *Sale Uses CashPayment*
- *Player Is-on Square*
    - bad example (doesn't enhance meaning): *Player Has Square*

Association names should start with a capital letter, since an association represents a classifier of links between instances; in the UML, classifiers should start with a capital letter. Two common and equally legal formats for a compound association name are:

- *Records-current*
- *RecordsCurrent*

Roles :

Each end of an association is called a **role**. Roles may optionally have:

- multiplicity expression name
- navigability
- Multiplicity is examined next.

Multiplicity:

Multiplicity defines how many instances of a class *A* can be associated with one instance of a class *B*

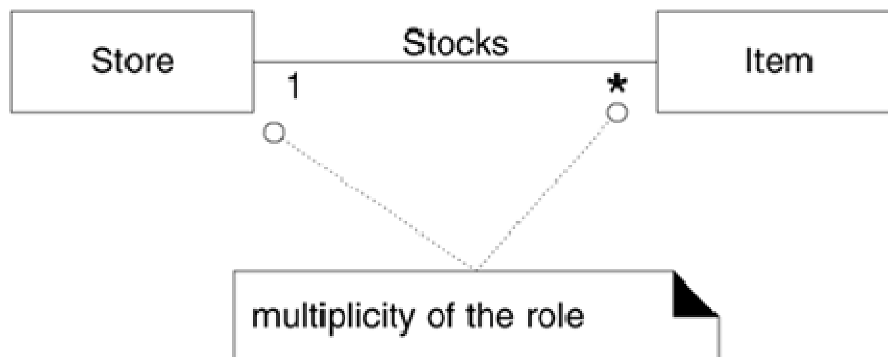


Fig 9: Multiplicity in Association

hpokhrel24@gmail.com

For example, a single instance of a *Store* can be associated with "many" (zero or more, indicated by the *) *Item* instances.
Some examples of multiplicity expressions are shown in Figure 10

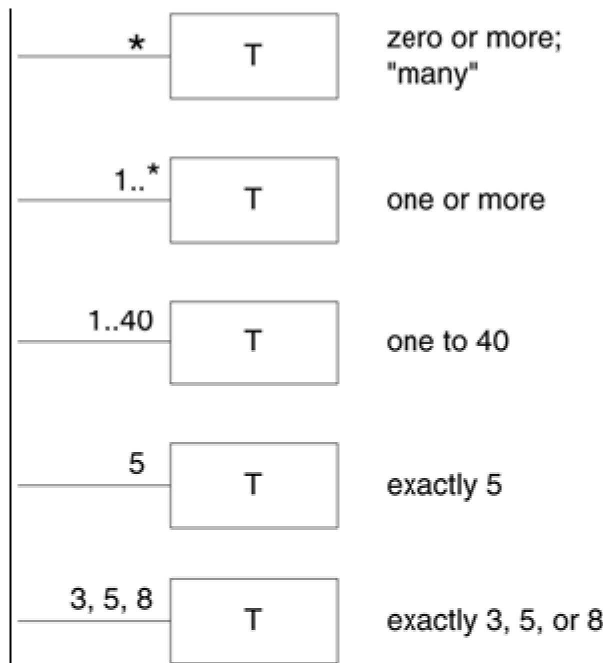
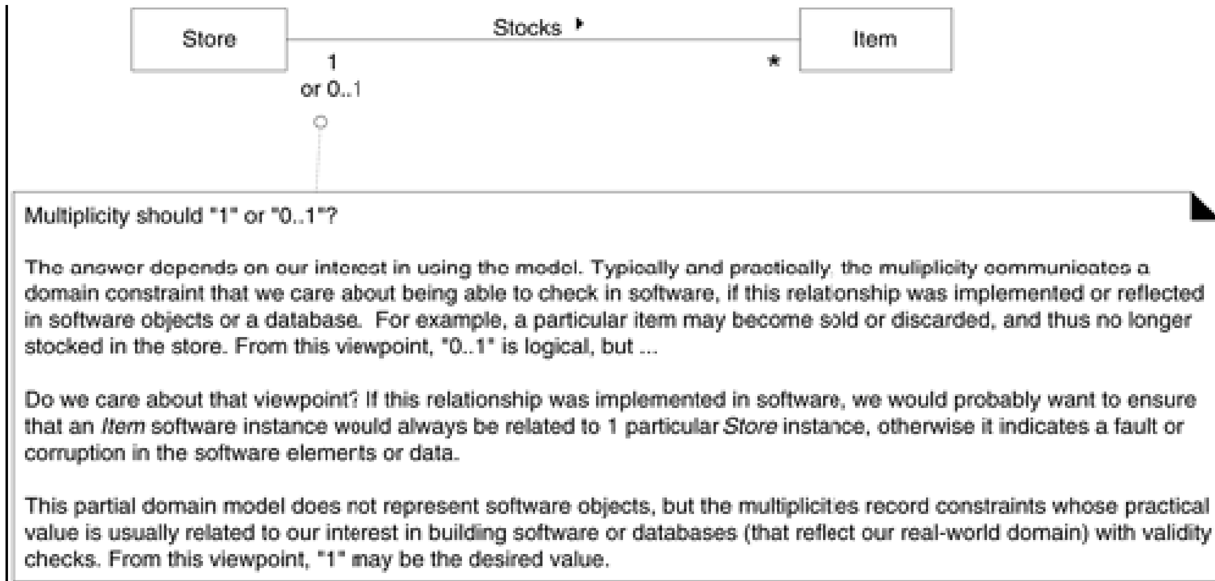


Fig 10: Multiplicity values.

The multiplicity value communicates how many instances can be validly associated with another, at a particular moment, rather than over a span of time.
For example, it is possible that a used car could be repeatedly sold back to used car dealers over time. But at any particular moment, the car is only *Stocked-by* one dealer. The car is not *Stocked-by* many dealers at any particular moment. Similarly, in countries with monogamy laws, a person can be *Married-to* only one other person at any particular moment, even though over a span of time, that same person may be married to many persons.
The multiplicity value is dependent on our interest as a modeler and software developer, because it communicates a domain constraint that will be (or could be) reflected in software. See Figure for low an example and explanation.



Multiple Associations Between Two Classes:

Two classes may have multiple associations between them in a UML class diagram; this is not uncommon. There is no outstanding example in the POS or Monopoly case study, but an example from the domain of the airline is the relationships between a *Flight* (or perhaps more precisely, a *FlightLeg*) and an *Airport* (see Figure); the flying-to and flying-from associations are distinctly different relationships, which should be shown separately.

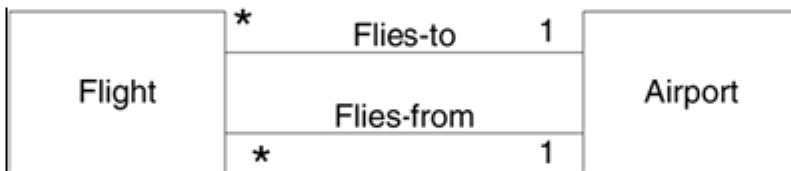


Fig: Multiple Associations

Example: Associations in the Domain Models

Case Study: NextGen POS

The domain model in Figure shows a set of conceptual classes and associations that are candidates for our POS domain model. The associations are primarily derived from the "need-to-remember" criteria of these iteration requirements, and the Common Association List. Reading the list and mapping the examples to the diagram should explain the choices.

For example:

Transactions related to another transaction *Sale Paid-by CashPayment*.

Line items of a transaction *Sale Contains SalesLineItem*.

Product for a transaction (or line item) *SalesLineItem Records-sale-of Item*.

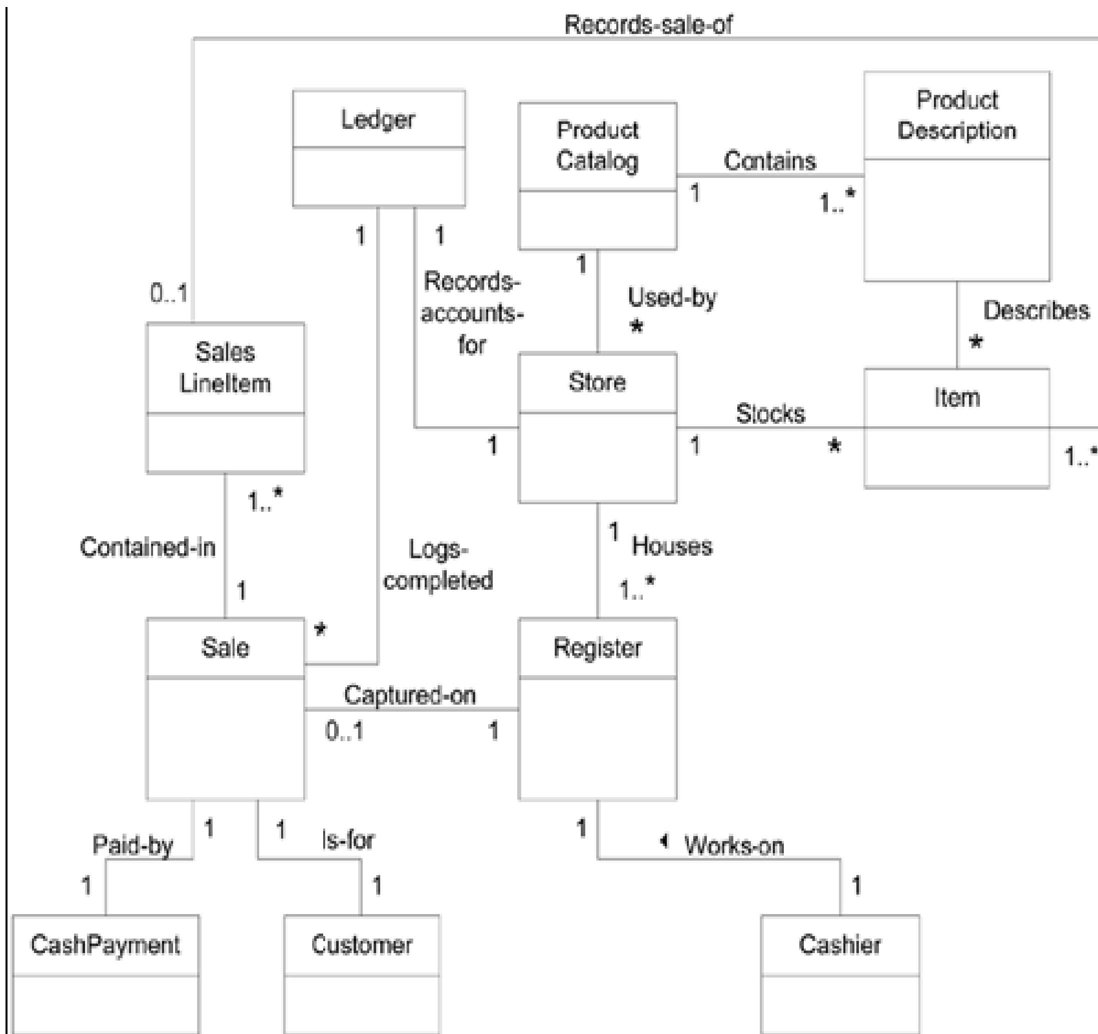
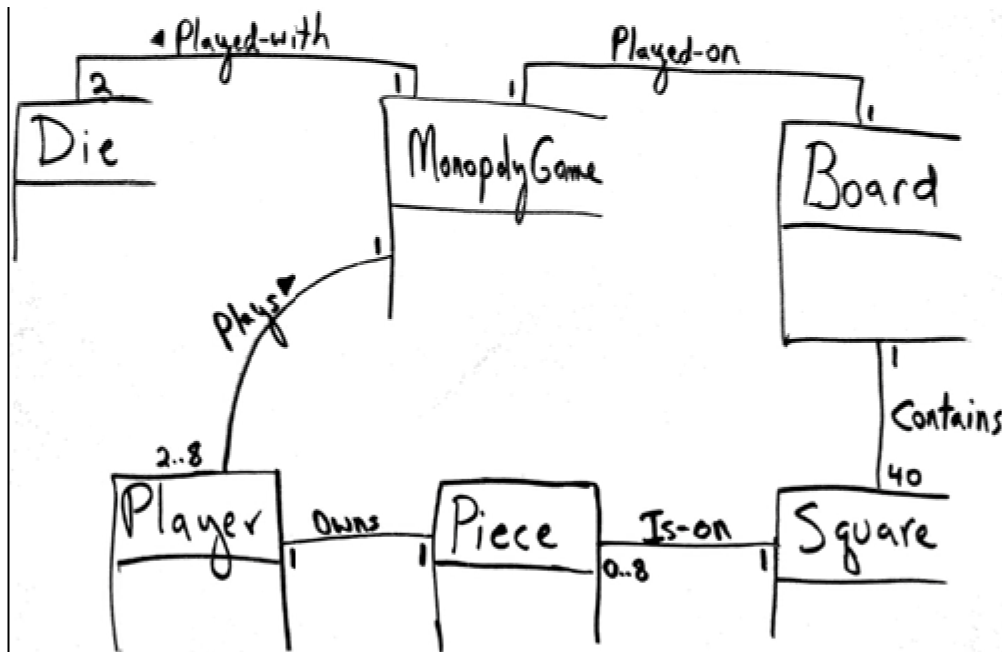


Fig: **NextGen POS partial domain model.**

Example: Monopoly Game

hpokhrel24@gmail.com



2.2 Adding Attributes

It is useful to identify those attributes of conceptual classes that are needed to satisfy the information
requirements of the current scenarios under development. An **attribute** is a logical data value of an object.

When to Show Attributes?

Include attributes that the requirements (for example, use cases) suggest or imply a need to remember information.

For example, a receipt (which reports the information of a sale) in the *Process Sale* use case normally includes a date and time, the store name and address, and the cashier ID, among many other things.

Therefore,

- *Sale* needs a *dateTime* attribute.
- *Store* needs a *name* and *address*.
- *Cashier* needs an *ID*.

Attribute Notation in UML

Attributes are shown in the second compartment of the class box (see Figure). Their type and other information may optionally be shown.

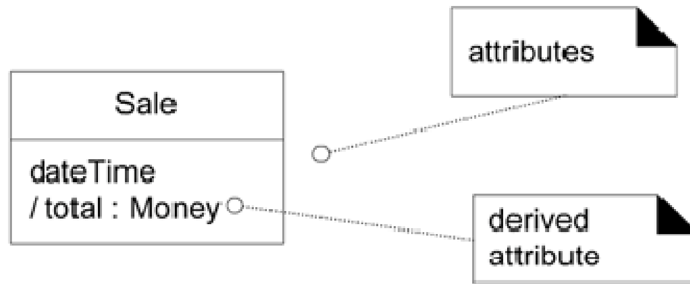


Fig: Class an Attributes

More Notation

The full syntax for an attribute in the UML is:

visibility name : type multiplicity = default {property-string}

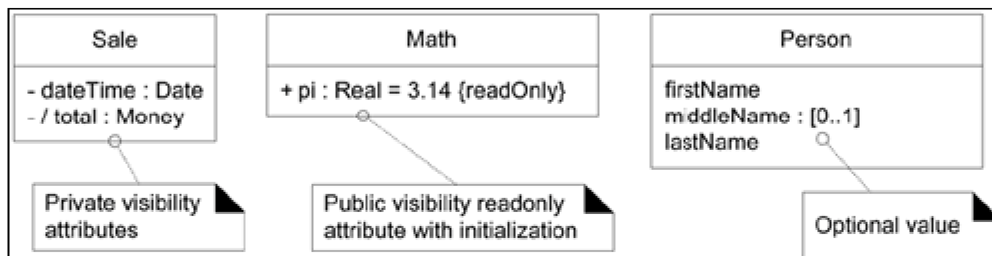


Fig: attribute notation in UML

As a convention, most modelers will assume attributes have private visibility (-) unless shown otherwise, so I don't usually draw an explicit visibility symbol.
{readOnly} is probably the most common property string for attributes.
Multiplicity can be used to indicate the optional presence of a value, or the number of objects that can fill a (collection) attribute. For example, many domains require that a first and last name be known for a person, but that a middle name is optional. The expression *middleName : [0..1]* indicates an optional value0 or 1 values are present.

Derived Attributes

The *total* attribute in the *Sale* can be calculated or derived from the information in the *SalesLineItems*. When we want to communicate that 1) this is a noteworthy attribute, but 2) it is derivable, we use the UML convention: a /symbol before the attribute name.
As another example, a cashier can receive a group of like items (for example, six tofu packages), enter the *itemID* once, and then enter a quantity (for example, six). Consequently, an individual *SalesLineItem* can be associated with more than one instance of an item.
The quantity that is entered by the cashier may be recorded as an attribute of the *SalesLineItem*

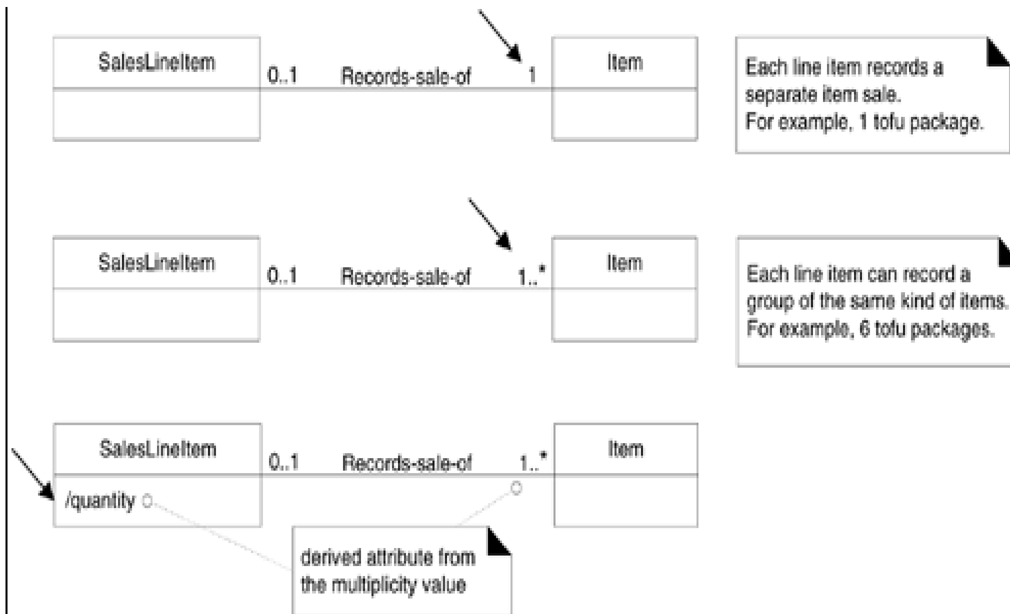


Fig: **Recording the quantity of items(derived items) sold in a line item.**

What are Suitable Attribute Types?

Focus on Data Type Attributes in the Domain Model

Informally, most attribute types should be what are often thought of as "primitive" data types, such as numbers and booleans. The type of an attribute should *not* normally be a complex domain concept, such as a *Sale* or *Airport*.

For example, the *currentRegister* attribute in the *Cashier* class in Figure 9.22 is undesirable because its type is meant to be a *Register*, which is not a simple data type (such as *Number* or *String*). The most useful way to express that a *Cashier* uses a *Register* is with an association, not with an attribute.

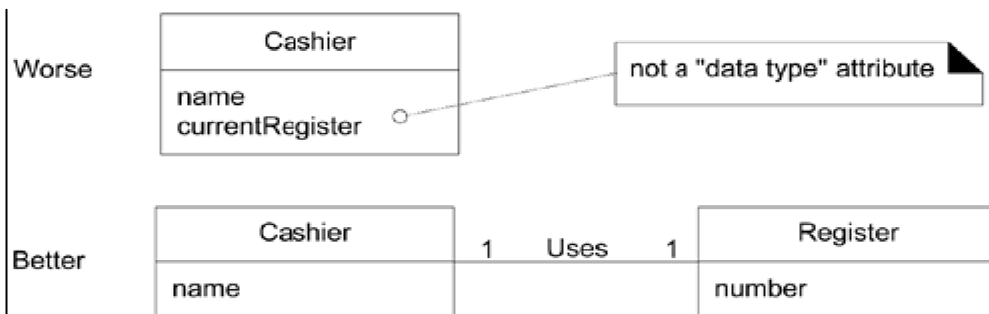


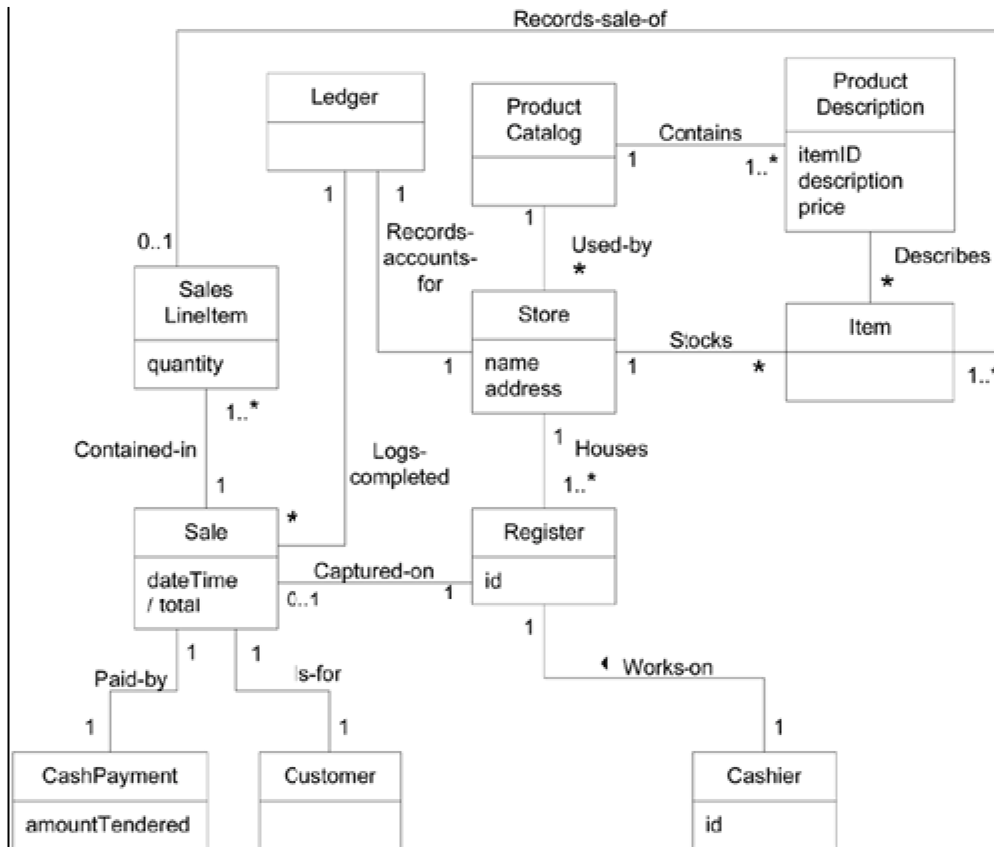
Fig: **Relate with associations, not attributes.**

Data Types

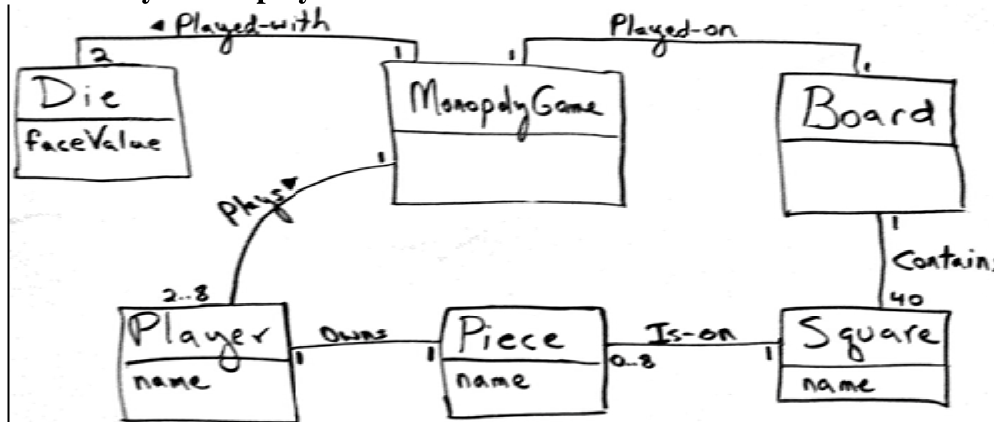
As said, attributes in the domain model should generally be **data types**; informally these are "primitive" types such as number, boolean, character, string, and enumerations (such as Size = {small, large}). More precisely, this is a UML term that implies a set of values for which unique identity is not meaningful (in the context of our model or system). Said another way, equality tests are *not* based on identity, but instead on value.

For example, it is not (usually) meaningful to distinguish between:
In Java, for example, a value test is done with the *equals* method, and an identity test with the == operator.
Separate instances of the *Integer* 5.
Separate instances of the *String* 'cat'.
Separate instance of the *Date* "Nov. 13, 1990".

Example: Attributes in the Domain Models



Case Study: Monopoly



hpokhrel24@gmail.com

3.0 Representations of System Behavior

System behavior is a description of *what* a system does, without explaining how it does it. One part of that description is a system sequence diagram. Other parts include the use cases and system operation contracts. Before proceeding to a detailed design of how a software application will work, it is useful to investigate and define its behavior as a "black box."

An interesting and useful question in software design is this: *What events are coming in to our system*? Why? Because we have to design the software to handle these events (from the mouse, keyboard, another system,) and execute a response.
Basically, a software system reacts to three things:

1) external events from actors (humans or computers),
2) timer events, and
3) faults or exceptions (which are often from external sources).

Therefore, it is useful to know what, *precisely*, are the external input events the **system events**. They are an important part of analyzing system behavior.

System behavior can be represented by using following:

a. Use cases
b. System Sequence diagrams,Collaboration Diagrams
c. Operation contracts

System Sequence Diagram

An SSD shows, for a particular course of events within a use case, the external actors that interact directly with the system, the system (as a black box), and the system events that the actors generate (see Figure).
Time proceeds downward, and the ordering of events should follow their order in the scenario.
For a use case scenario, an SSD shows:

1. The System (as a black box)
2. The external actors that interact with System
3. The System events that the actors generate
4. SSD shows operations of the System in response to events, in temporal order
5. Develop SSDs for the main success scenario of a selected use case, then frequent and salient alternative scenarios

From Use case to SSD

How to construct an SSD from a use case:

1. Draw System as black box on right side
2. For each actor that directly operates on the System, draw a stick figure and a lifeline.
3. For each System events that each actor generates in use case, draw a message.
4. Optionally, include use case text to left of diagram.

Example: Use Case: Order Entry

1) An Order Entry window sends a “prepare” message to an Order

2) The Order sends “prepare” to each Order Line on the Order
3) Each Order Line checks the given Stock Item
4) Remove appropriate quantity of Stock Item from stock
5) Create a deliver item

Alternative: Insufficient Stock
3a) if Stock Item falls below reorder level, then Stock Item requests reorder

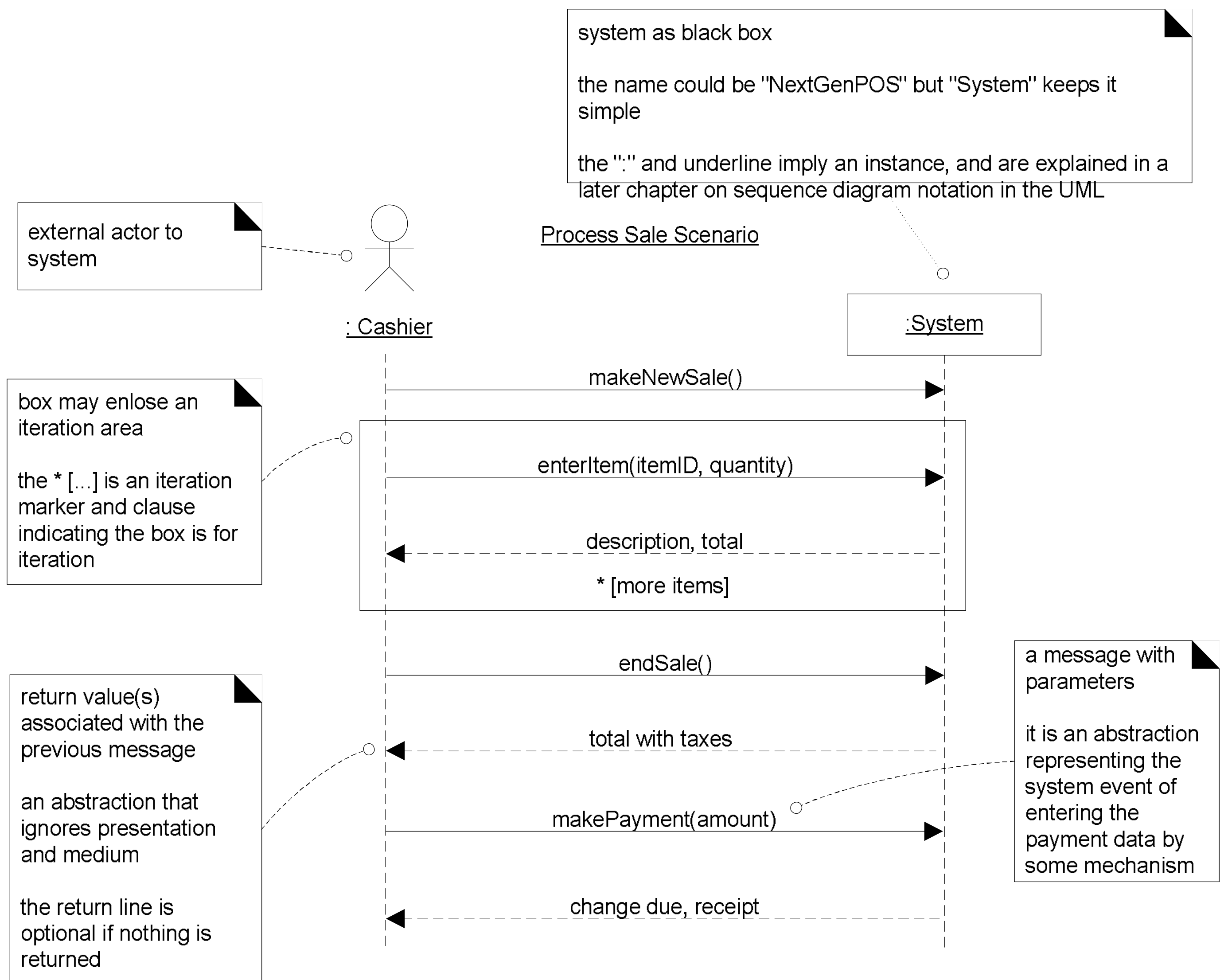


Fig: SSD for a Process Sale scenario.

Use cases describe how external actors interact with the software system we are interested in creating. During this interaction an actor generates **system events** to a system, usually requesting some **system operation** to handle the event. For example, when a cashier enters an item's ID, the cashier is requesting the POS system to record that item's sale (the *enterItem* event). That event

initiates an operation upon the system. The use case text *implies* the *enterItem* event, and the SSD makes it concrete and explicit.

The UML includes **sequence diagrams** as a notation that can illustrate actor interactions and the operations initiated by them.

A **system sequence diagram** is a picture that shows, *for one particular scenario of a use case*, the events that external actors generate, their order, and inter-system events. All systems are treated as a black box; the emphasis of the diagram is events that cross the system boundary from actors to systems. Draw an SSD for a main success scenario of each use case, and frequent or complex alternative scenarios.

What is the Relationship Between SSDs and Use Cases?

An SSD shows system events *for one scenario of a use case*, therefore it is generated from inspection of a use case. SSDs are derived from use cases; they show one scenario.

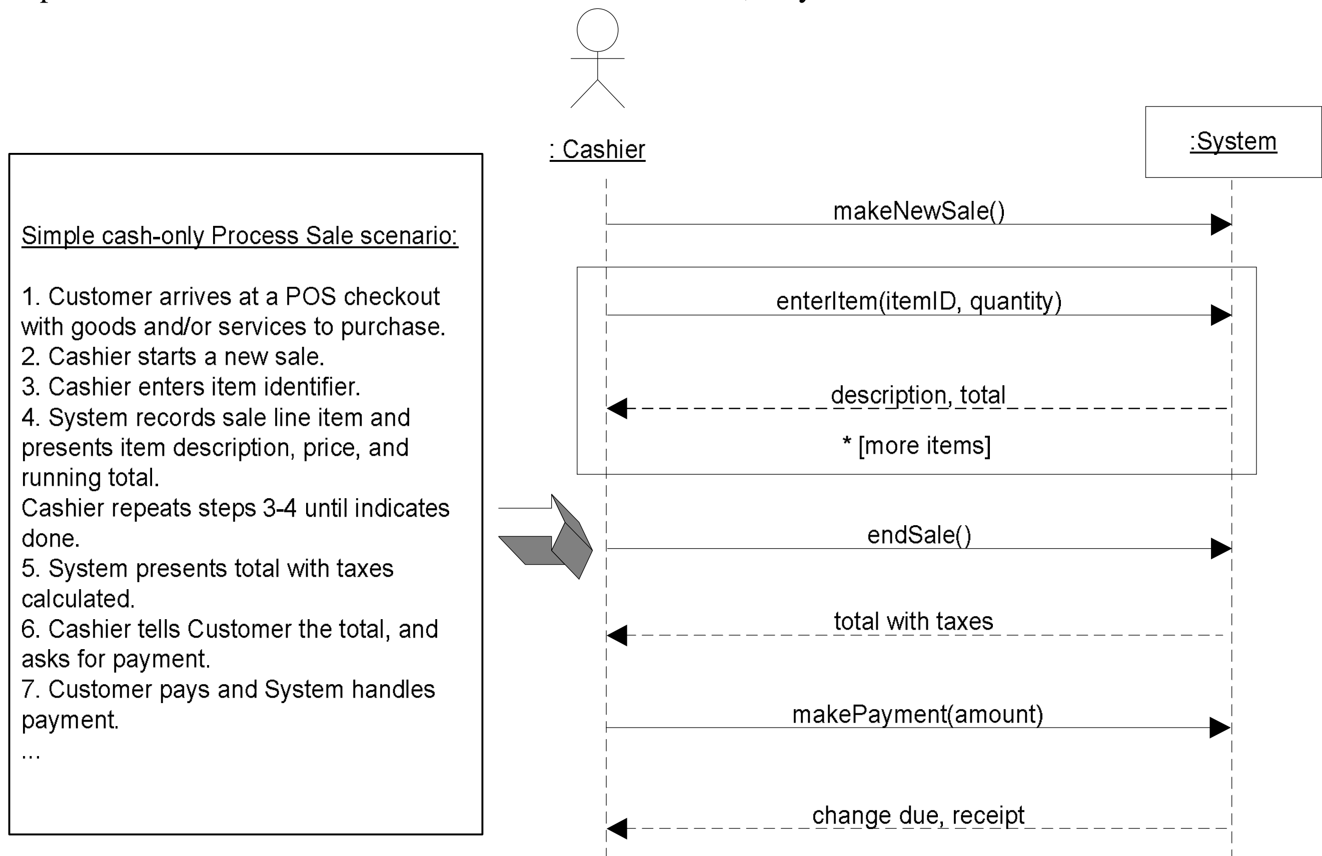


Fig: relation between use case and SSD

How to Name System Events and Operations?

Which is better, *scan(itemID)* or *enterItem(itemID)*?

System events should be expressed at the abstract level of intention rather than in terms of the physical input device.

Thus "enterItem" is better than "scan" (that is, laser scan) because it captures the *intent* of the operation while remaining abstract and noncommittal with respect to design choices about what

interface is used to capture the system event. It could by via laser scanner, keyboard, voice input, or anything.
It also improves clarity to start the name of a system event with a verb (add…, enter…, end…, make…), as in Figure below, since it emphasizes these are commands or requests.

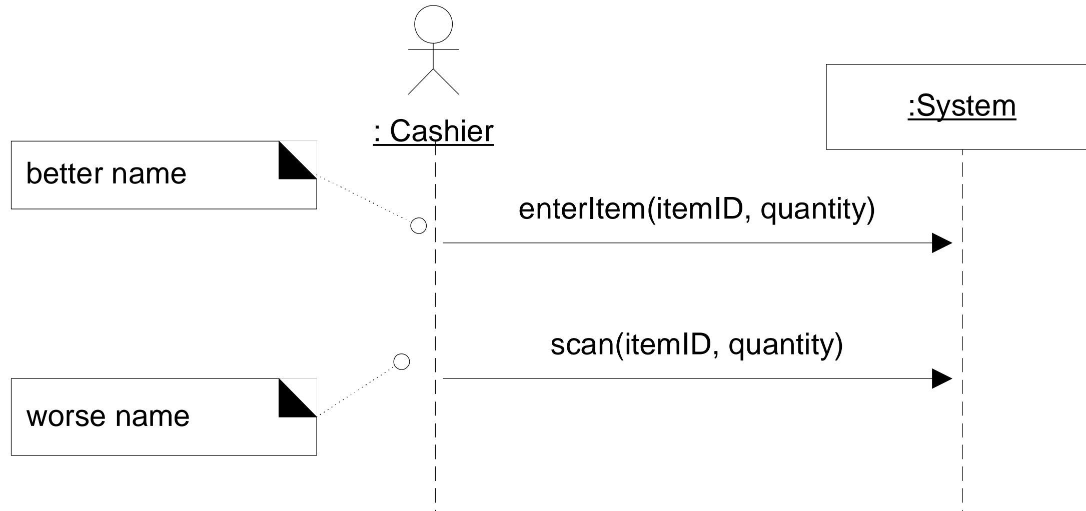


Fig: Showing Choose event and operation names at an abstract level.

Operation Contracts : Read from book

MathTrainer Requirement
MathTrainer *aids in perfecting the* ***mental arithmetic*** *of* ***elementary school students*** *.*
MathTrainer poses each student ten random ***arithmetical exercises****, which should be solved as fast and correct as possible. From the* ***responses scores*** *are collected which can be viewed by the* ***users*** *of MathTrainer.*
Teachers *can define* ***types of exercises*** *by determining* ***numerical ranges*** *and allowed* ***mathematical operations*** *. They can also delete types which were defined by themselves. Students are assigned to their teacher and can request exercises for an exercise type of their teacher.*
New teachers and students are able to apply as new MathTrainer users themselves by specifying username and ***password*** *– this is done in the* ***context*** *of the usual* ***user identification*** *. The password can be changed anytime.*
Teachers can delete the students which are assigned to them. During the ***realization*** *of a* ***test*** *(ten exercises) the* ***time*** *needed for each exercise is stopped. However, the scores are based on the* ***cumulative time .***

hpokhrel24@gmail.com

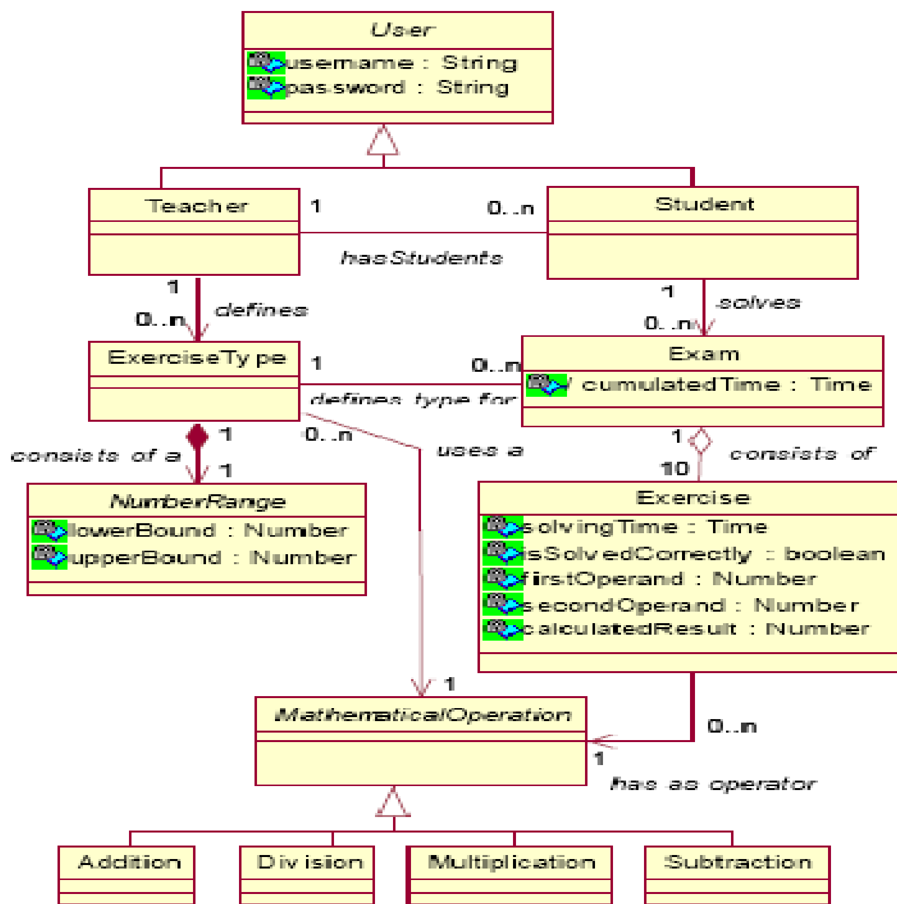


Fig: The domain model of the MathTrainer example.

hpokhrel24@gmail.com