Unified Modeling Language

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sources: UML Distilled, Fowler ad Scott, 2nd Ed., Addison-Wesley, and UML 簡述，陳盈志

Contents

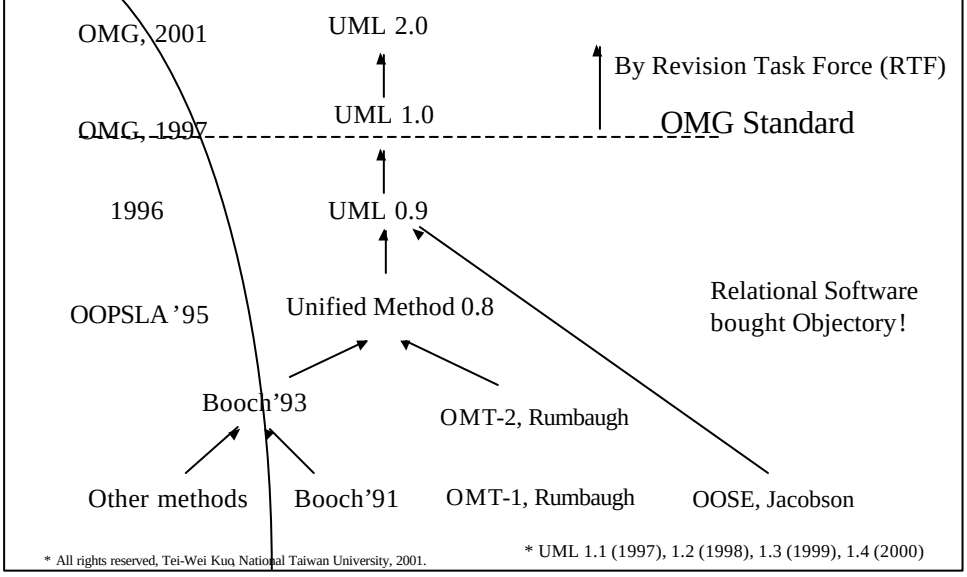
Introduction

- Unified Modeling Language
  - Object-Oriented Analysis and Design (OOA&D)
  - Specifying, Visualing, and Documenting Computer Systems.
- Important Contributors:
  - Grady Booch, Jim Rumbaugh, and Ivar Jacobson
  - Object Management Group (OMG)

Introduction

- Development of Object-Oriented Methods
  - Simmla 67 Language (Ole-Jone Dahl in 1967), Smalltalk, C++, etc.
  - OO Methods, 1980's, 1990's
    - OOADA, Booch
    - OOA/OOD, Coad and Yourdon
    - OMT, Rumbaugh
    - OOAD, Odell
    - OOSE, Jacobson

Introduction



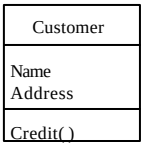
* UML 1.1 (1997), 1.2 (1998), 1.3 (1999), 1.4 (2000)

Introduction

- UML - A Modeling Language
  - Notations
- Modeling Methods
  - A modeling language
  - A process
    - What steps to take in doing a design!
- Rational Unified Process (RUP)
  - By Booch, Rumbaugh, and Jacobson

Introduction

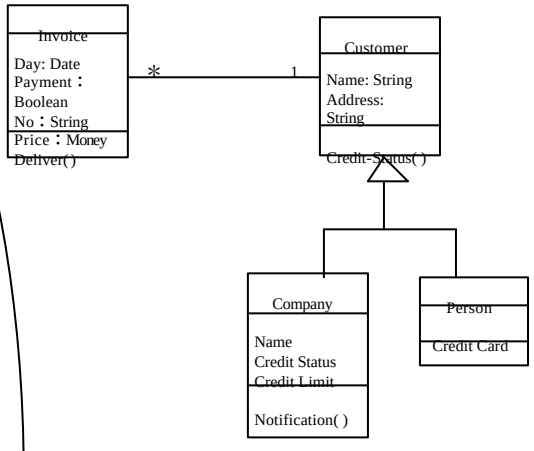
- Notations
  - Graphical stuff
    - Syntax of the language, e.g., class



- Meta-Models
  - Diagrams, e.g., class diagrams

Introduction

- A Class-Diagram Example



Introduction

- OO Method vs Formal Specification/Design Language
  - Less rigorous, easy understanding and manipulation

$$? i,[@(?_j, i ? 1) ? @(?_j, i)] ? P_j$$

- Standard vs Nonstandard Methods
  - Flexibility, Automatic Analysis, and Info/Code Exchanging

Introduction

- Why do analysis and design?
  - Communication
    - Code is precise but too detailed.
    - E.g., package diagrams to show the major system components.
  - Learning OO
    - Help people to do good OO.
  - Communicating with Domain Experts
    - Understanding of users' world
      - Use Cases and Class Diagrams!

Introduction

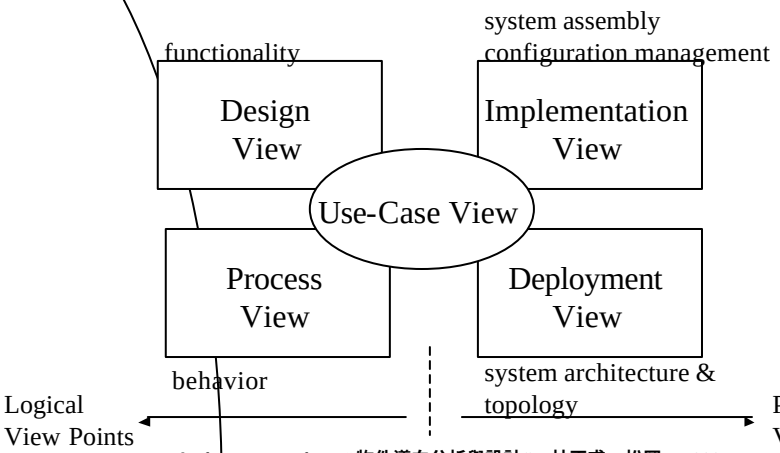
- Why “Unified”?
  - Across historical methods and notations
  - Across the development lifecycle
  - Across application domains
  - Across implementation languages and platforms
  - Across development process
  - Across internal concepts

Introduction

- Objectives of UML
  - Specifying, Visualing, and Documenting Computer Systems.
  - Elements -> Vocabularies
  - Design Guidelines and Experience Rules -> Grammar

Introduction

- Five UML View-Points



* The figure comes from "物件導向分析與設計", 林正甫, 松岡, 2000.

Introduction

- Use-Case View
  - Specify system functionality for users, designers, and test engineers.
  - Diagrams: use cases, sequence, collaboration, state, activity diagrams.
- Design View
  - Specify detailed design of the system's internal functionality, including use-cases and actors.
  - Diagrams: Class, Object, State, Sequence, collaboration, activity diagrams

Introduction

- Implementation View
  - Specify how to split the system into software components and do implementation.
  - Diagrams: state, sequence, collaboration, activity diagrams.
- Process View
  - Specify the operation of the entire system
  - Diagrams: component, state, sequence, collaboration, activity diagrams.

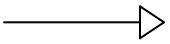
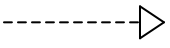
Introduction

- Deployment View
  - Specify the architecture of the system hardware and the deployment of software processes.
  - Diagrams: deployment, state, sequence, collaboration, activity diagrams.

Introduction

- UML Vocabularies
  - Things
    - Structural things, e.g., classes, components, use cases.
    - Behavioral things, e.g.,Interaction and state machine.
    - Grouping of things, e.g., package.
    - Annotational things, e.g., notes.

Introduction

- Relationships
  - Dependency
  - Association
  - Generalization 
  - Realization 
- Diagrams
  - Use case, class, object, sequence, collaboration, state, activity, component, deployment.

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- Development Process
- Use Cases
- Class Diagrams & Object Diagrams
- Interaction Diagrams
- Packages and Collaborations
- State Diagrams, Activity Diagrams, Physical Diagrams
- Misc

Development Process

- UML - A Modeling Language
  - Notations
- Modeling Methods
  - A modeling language
  - A process
    - What steps to take in doing a design!
- Rational Unified Process (RUP)
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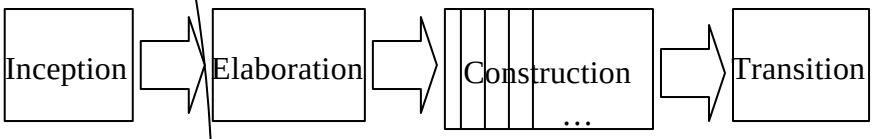
Overview

- An iterative and incremental development process:
  - Each construction iteration
    - Analysis, design, implementation, testing, and integration.



Overview

- Keep a ceremony to a minimum!
  - A lot of formal paper deliverables, formal meetings, formal sign-offs for high-ceremony projects.
- Possible iterations in all phases!

Inception

- Goal:
  - Establish the business rationale for the project.
  - Decide the scope of the project.
- Forms:
  - Informal chatting
  - Full-pledged feasibility study
- What should be done?
  - Work out the business case – cost and income!

Elaboration

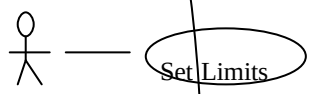
- Want to get a better understanding of the problem:
  - What is it you are actually going to build?
  - How are you going to build it?
- Contents:
  - Collect more detailed requirements.
  - Do high-level analysis and design to establish a baseline architecture.
  - Create the plan for construction.

Elaboration

- Risks:
  - Requirement Risks
  - Technical Risks
  - Skill Risks
  - Political Risks

Elaboration – Requirement Risks

- Requirement Risks
  - Q:
    - Will we build a wrong system?
  - Starting points:
    - Use cases
      - A typical interaction that a user has with the system in order to achieve a goal!



Elaboration – Requirement Risks

- The usage of use cases
  - Indicate a function that users can understand and that has a value for users.
  - No too much detailed!
- Domain Model
  - A model whose primary subject is the world the computer system is supporting!

Elaboration – Requirement Risks

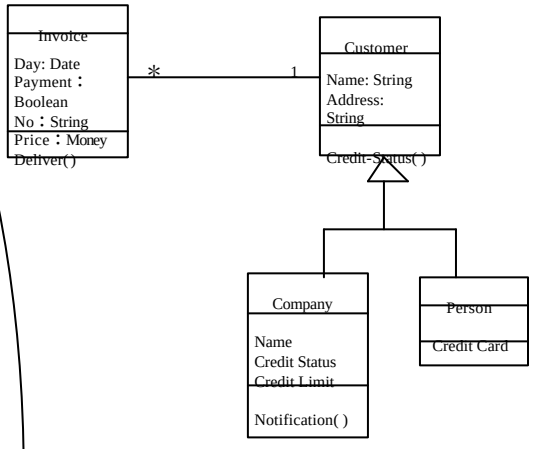
- Important tasks for elaboration
  - Get all potential use cases,especially the most important and riskiest ones.
  - Come out the skeleton of the conceptual model of the domain:
    - How the business operates?
    - Lays a foundation for the object model that will represent objects supported by the system.

Elaboration – Requirement Risks

- UML Techniques for Conceptual Domain Model:
  - Class Diagram
    - Definitions of vigorous vocabulary about the domain.
  - Activity Diagram
    - Encouraging the finding of parallel processes.
  - Interaction Diagram
    - Exploring different roles interact in the business

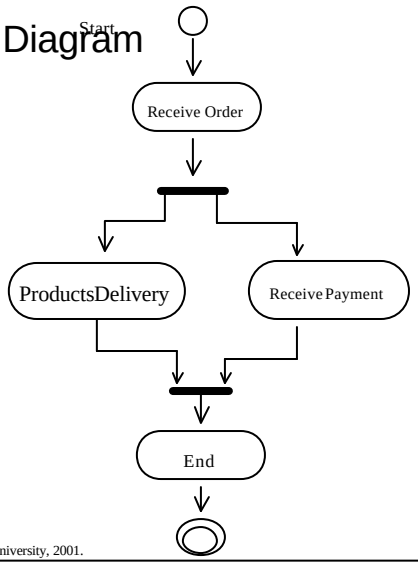
Elaboration – Requirement Risks

- A Class-Diagram Example



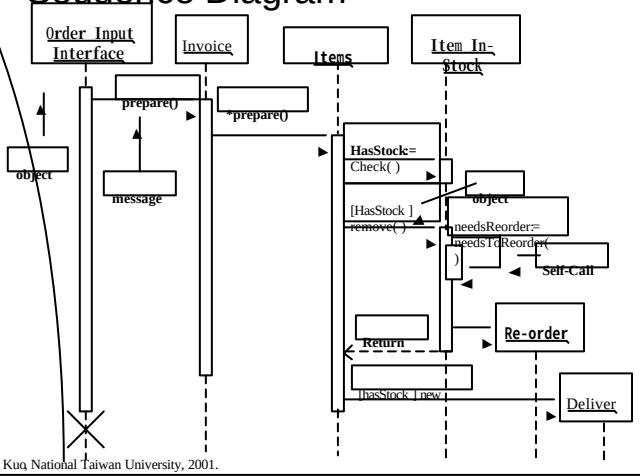
Elaboration – Requirement Risks

- An Activity Diagram Example



Elaboration – Requirement Risks

- An Interaction Diagram Example – Sequence Diagram

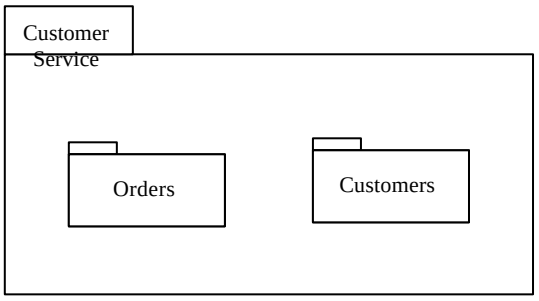


Elaboration – Requirement Risks

- Remark
  - Use minimum notation
  - Focus on important issues and risky areas
  - A starting point for building classes in the construction phase
    - Use package diagrams if needed
  - A skeleton – concentrate on important details, instead of all.

Elaboration – Requirement Risks

- A Package Diagram Example



Elaboration – Requirement Risks

- Remark
  - A small team in building the domain model
  - Build a prototype of any tricky parts of the use cases.
  - Get access to domain experts!

Elaboration – Technological Risks

- Technological Risks
  - Q:
    - Will the selecting technology actually do the job for us?
    - Will the various pieces fit together?
  - Possible solution:
    - Build prototypes to try out technology!

Elaboration – Technological Risks

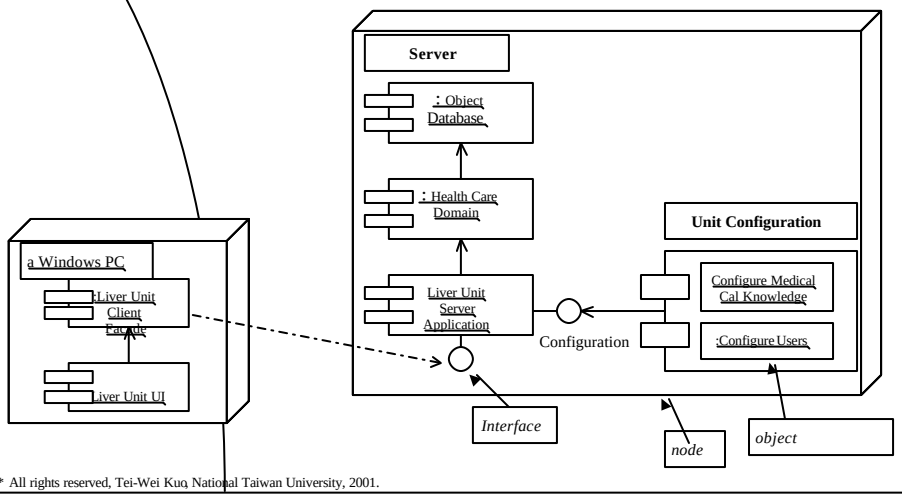
- Biggest Challenge:
  - How the components of a design fit together?
    - E.g., Java + database + session + …
- Must:
  - Address any architecture design decisions!
    - Especially for distributed systems!

Elaboration – Technological Risks

- Questions: How can we change the elements of the design relatively easy?
  - What will happen if a piece of technology doesn't work?
  - What if we can't connect two pieces of the puzzle?
  - What is the likelihood of something going wrong?
- Look at use cases to do assessment!
  - Class diagrams,interaction diagrams, package diagrams,deployment diagrams.

Elaboration – Technological Risks

- A Deployment Diagram Example:



Elaboration – Skills Risks

- Skill Risks
  - Can you get the staff and expertise you need?
    - Always little experience and thought
- Solutions
  - Short training
  - Mentoring
  - Project reviewing every specific period of time
  - Reading
  - Pattern learning

Elaboration – Political Risks

- Political Risks
  - Are the political forces that get in the way and seriously affect your project?
    - Internal
    - External
- Solutions
  - Find good ones to do it if you cannot!

Elaboration

- Duration
  - A fifth of the total length of the project.
- Events to signal the termination
  - Developers feel comfortable providing estimates to the person-week effort.
  - All significant risks have been identified, and how you intend to deal with them are known.

Planning of the Construction Phase

- Goal
  - Be aware of progress
  - Signal progress through the team
- Essence
  - Set up a series of iteration
  - Define the functionality to deliver in each iteration

Planning of the Construction Phase

- Method
  - Customer vs Developer
    - Customer
      - Assess the business value of a use case.
    - Developer
      - Build the system

Planning of the Construction Phase - Steps

- Steps
  - Categorize use cases according to the business value and development risks!
  - Determine your iteration length
    - A fixed iteration with a handful of case uses being implemented.
    - project velocity
      - Developer-week per iteration = (#developers*iteration-length)/load-factor
    - Iteration#
      - (Development-time of all use cases / Developer-week per iteration) + 1

Planning of the Construction Phase - Steps

- Assign use cases to iterations
  - Do not put off risk until the end!
- Contingency Factor
  - 10~20 percent of the construction time.
- Transition
  - 10~35 percent of the construction time for tuning and packaging
- Ready for a release plan!

Construction

- Goal
  - Build the system in a series of iterations.
  - Demo and confirm the implementation.
    - Reduce risk!
- Iterations within construction are both incremental in function and iterative in the code base!
- Refactoring!
- Integration!

Remark

- Self-Testing Software
  - Testing as a continuous process!
  - Unit test code by the developers
  - Function test code developed by a separate team
- When the plan goes away!
  - Time-boxed!
  - Redo the plan!

Remark

- Refactoring – a couple of small steps
  - Rewriting vs redesigning
  - Never refactor a program and add functionality to it at a time.
  - Have a good test in-place before refactoring
  - Take short, deliberate steps
    - Avoid debugging!

Using UML in the Construction

- Add a use case
  - Check class diagrams to see how they fit the software been built!
- How classes collaborate to implement the functionality required by each use case
  - Try interaction diagrams!
  - If the change is serious, use the notations to discuss with colleagues!

Using UML in the Construction

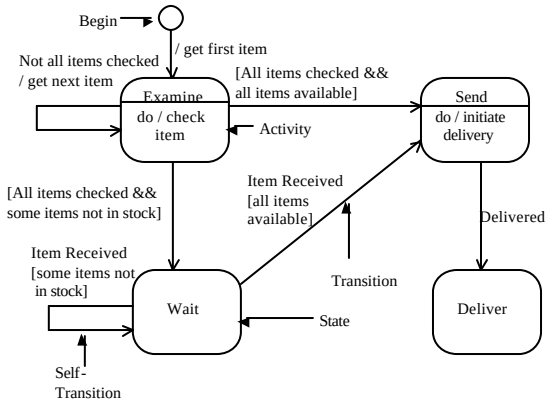
- Use UML to help document what is built!
  - Detailed documentation should be from the code! (+ additional doc)
- Use package diagrams as the logical road map of the system!
  - Dependencies of logical pieces
- Use deployment diagrams to show the high-level physical picture!

Using UML in the Construction

- For a class with a complex behavior
  - Use state diagrams to describe it!
  - Use iteration diagram to describe complicated interactions among classes
- When a complex algorithm is involved
  - Use activity diagram to understand the code!

Using UML in the Construction

- An State Diagram Example



Transition

- Goal:
  - Development to fix bugs!
    - No additional of substantial functionality!
    - Beta-testing, performance tuning, user training, etc.
- Why iterative development?
  - Do the development process regularly!
  - Get used to deliver finished code!
- Tradeoff
  - Meet users' requirements
  - Optimize code!

When To Use iterative Development

- Only on projects you want to succeed!

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Use Cases

- Why use cases?
  - People need a way to communicate in project development and planning.
- Scenarios – those behind use cases
  - A sequence of steps describing an interaction between a user and a system.

  The customer browses the catalog and adds desired items to the shopping basket. When the customer wishes to pay, the customer describes the credit and shopping info and confirms the sale. The system check the authorization on the credit card and confirms the sale both immediately and with a follow-up email.

Use Cases

- A use case is a set of scenarios tied together by a common user goal!
- Buy a Product – Use-Case Text:
  1. *Customer browses the catalog and selects items to buy.*
  2. *Customer goes to check out.*
  3. *Customer fills up in the shipping information.*
  4. *System presents full pricing information, including shopping.*
  5. *Customer fills in credit card information.*
  6. *System authorizes purchase.*
  7. *System confirms sale immediately.*
  8. *System sends confirming email to customer.*
- *Alternative: Authorization Failure*
  - *At Step 6, if the authorization fails,let customer try again!*

Use Cases

- How to create a use case?
  - Describe the primary scenario and alternatives as variations on that sequence!
    - The existence of preconditions!
  - Divide up use cases
    - E.g., Regular Customer – skip steps 3, 4, and 5 when info is already there.
  - Need an amount of detail depending on the risk in each use case!

Use Case Diagrams

- Introduced by Jacobson in 1994
  - Show what needed to build in each iteration!
  - Example – Trading (Chp3)
- Primary Elements:
  - Actor
    - A role that a user or an external system plays with respect to the system!
    - A user can play more than one role.
    - Actors, who carry out use cases, are useful when trying to come up with the use cases.

Use Case Diagrams

- Situations worth tracking the actors later:
  - Need configuring for various of users.
  - Help in negotiating priorities among various actors.
- Remark:
  - Use cases may not have clear links to specific actors.
  - A good source for identifying use cases is external events!

Use Case Diagrams

- From the external point of view
  - It describes what use cases are.
    - Scope and Constraints
  - What users really want!
- From the internal point of view
  - It describes how use cases operate.

Use Case Relationships

- Include
  - Occur when you want to avoid repetition.
  - E.g., Analyze-Risk and Price-Deal "include" Valuation.
- Generalization
  - Describe a variation on normal behavior (casually).
  - Override the base use case!
  - E.g., Limits-Exceeded is "generalized" into "Capture-Deal".

Use Cases Diagrams

- Extend
  - Similar to generalization but with more rules to it.
  - Extension points for adding behavior to the base use case.
  - Example – Buy-a-Product and Regular Customer
- Generalization and Extend may cause the splitting of complicated use cases.

Use Cases

- System Use Cases
  - An interaction with the software.
    - E.g., text copying and style def. functionality
- Business Use Cases
  - How a business responds to a customer or an event.
    - E.g., unifying text formats.
- Order in Elaboration
  - Business use cases first
  - System use cases to satisfy business use cases
  - Use cases represent an external view.

Use Case Diagrams

- Use Case Boundary
  - To identify what is external or internal
  - Typical system boundaries
    - HW/SW boundary of a device or computer system
    - Dept of an organization
    - Entire organization
- Examples
  - Wire in paychecks

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Class Diagrams

- Why Class Diagrams?
  - Central within object-oriented methods in modeling systems and the relationship among their components.
- Usages of Class Diagrams
  - Types, attributes, operations of objects
  - Static relationship among them
    - Association
    - Subtypes, etc.

Class Diagrams

- Three Perspectives in Drawing Class Diagrams (Cook and Daniels, 1994):
  - Conceptual – << type >>
    - Represent the concepts in the domain under study – maybe no direct mapping to classes
    - Should be language-independent
  - Specification – << type >>
    - Consider software and the interfaces of the software
      - No implementation should be considered.

Class Diagrams

- Implementation – << implementation class >>
  - Lay down the implementation bare
- Lines between perspectives are not sharp; however, it is important to separate the specification perspective and implementation perspective!!
- Perspectives are no part of the formal UML but are useful in modeling.

Class Diagrams

- Association
  - Relationship between instances of classes.
  - Association Ends – Roles!
  - Multiplicity – *, 1..n, etc.
  - Navigability
    - Order -> Customer
  - Naming
    - Associations – verbs
    - Roles – nouns

Class Diagrams

- Perspectives
  - Conceptual relationships between classes.
  - Within specification perspective
    - Associations represent responsibilities – Queries and Updates

```
Class Order {
        Public Customer getcustomer();
        ...
```

    - The diagram indicates only the interface – nothing more!

Class Diagrams

- In implementation model
  - Pointers in both directions between the related classes.

```
class Order {
    private Customer _customer;
    private Set _OrderLines;
    ...
```

- Navigability!
  - Unidirectional/Bidirectional Associations
    - Inverse Constraints

Attributes

- Attributes denote the status and characteristics of classes
  - Single valued
  - *visibility name:type = default-value*
  - Optional, e.g., dateReceived[0..1]:Date
- Perspectives
  - At the conceptual level
    - Simply notations
  - At the specification level
    - A way to set values
  - At the implementation
    - A field for a attribute

Operations

- Definition:
  - Operations are processes that a class knows to carry out.
  - Operations correspond to the methods on a class.
- Perspectives
  - At the conceptual level,
    - The principal responsibilities of classes
  - At the specification level,
    - Methods on a class

Operations

- At the implementation level,
  - Private (-), public (+), and protected (#) operations, as well:

    visibility name (parameter-list): return-type-expression [property-string]
    - + balanceOn (date:Date): Money
    - Parameter
      - *Direction name:type = default-value*

        (direction: in, out, inout)

Operations

- Types – constraints
  - Queries
    - Marked as *{ query }*
  - Modifiers
  - Getting/Setting Methods (internal knowledge)
- Operations vs Methods
  - The body of a procedure – method (body)
  - Method call/declaration – operation
  - e.g., polymorphism – subtyping

Generalization

- Definition
  - "Super-type" – inverse of specialization
- Perspectives
  - At the conceptual level,
    - Everything about a "super-type" is true for a "subtype".
  - At the specification level,
    - The interface of a "subtype" must conform to that of a "super-type".

Generalization

- Substitutability of code
  - polymorphism
- At the implementation level,
  - Inheritance in programming languages
  - Subclassing is one way to implement subtyping but not the only way.
- Stability of Generalization

Constraints Rules

- Constraints { } on attributes, associations, generalization, etc.
- Format:
  - Informal English statements
  - Object Constraint Language (OCL)

    flight.pilot.training_hour >=
    flight.plane.minimum_hours

Class Diagrams

- When to use them?
  - Do not try to use all the notations available to you.
  - Fit the perspective from which you are drawing the models to the stage of the project:
    - Concept model – analysis
    - Specification model – software
    - Implementation model – illustrate implementation techniques
  - Concentrate on key areas

Design by Contract (Bertrand Meyer)

- Assertions
  - A Boolean statement that should never be false.
- Types:
  - Pre-conditions – checked by callers
    - What we expect!
  - Post-conditions – checked by operations
    - What we do! (e.g., square-root)
  - Invariants – constraint rules on class diagrams
    - May be false during the execution on a method (e.g., balance ==sum(entries.amount()).

Design by Contract (Bertrand Meyer)

- Assertions
  - Subclassing
    - Strengthen the invariants or post-conditions!
    - Weakening the pre-conditions!
      - Substitution
  - Ideally as a part of the code!
  - Invariants are equivalent to constraint rules on class diagrams!

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Interaction Diagrams

- Purpose:
  - Models that describe how groups of objects collaborate in some behavior.
  - Capturing of the behavior of a single use case typically.
- Types:
  - Sequence Diagrams
  - Collaboration Diagrams

Sequence Diagrams

- A Object – A Box
- Lifeline – Object's Life
- Message
  - An arrow between the lifelines of two objects
  - Message Order (top to bottom)
  - Labeled with a name, arguments, control information, etc.
  - A Self-Call

Sequence Diagrams

- Control Information
  - A condition, e.g., [needsReorder]
  - An iteration marker, e.g., *[for all order lines]
- Return
  - A return from a message – a dashed line
- Asynchronous Message – do not block the caller
  - Create a new thread or a new object
  - Communicate with a thread that is running.

Sequence Diagrams

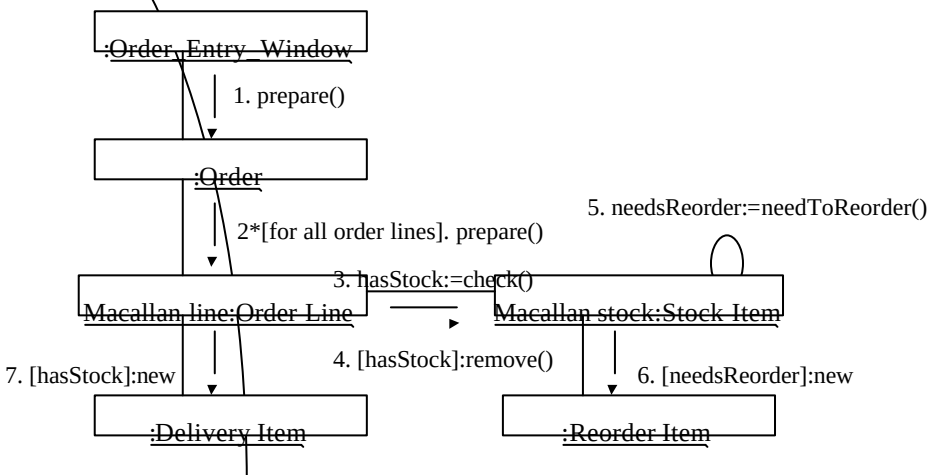
- Object Deletion 
- Why Sequence Diagrams?
  - Emphasize on sequence
  - Capture the overall flow of control!
  - Show concurrent processes!

Collaboration Diagrams

- An Interaction Diagram which provide the spatial layout of objects!
- Notation
  - objectName:ClassName
- Numbering of Messages
  - Simple Numbering
  - Decimal Numbering
    - Which operation is calling which operation!

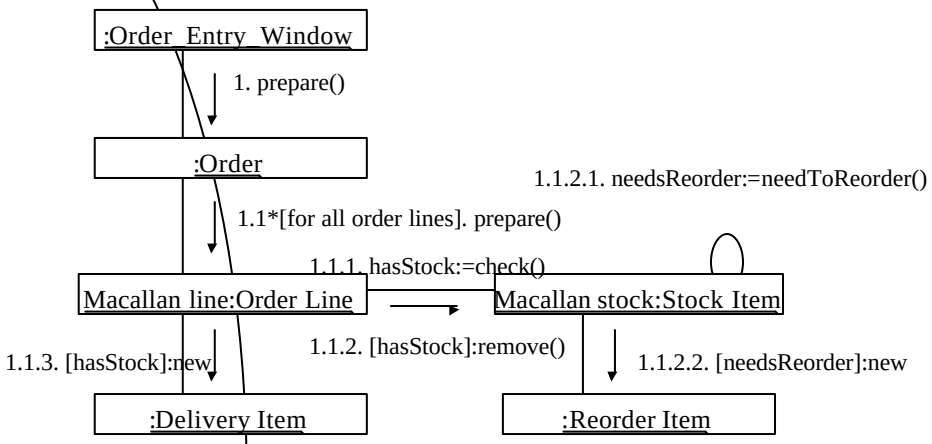
Collaboration Diagrams

- Collaboration Diagrams with Simple Numbering



Collaboration Diagrams

- Collaboration Diagrams with Decimal Numbering



Interaction Diagrams

- Why Collaboration Diagrams?
  - Use the layout to indicate how objects are statically connected.
- When to use Interaction Diagrams?
  - Behavior of several objects within a single use case typically – simplicity!
  - Collaborations among the objects
- When alternatives are considered?

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- Introduction
- Development Process
- Use Cases
- Class Diagrams & Object Diagrams
- Interaction Diagrams
- Packages and Collaborations
- State Diagrams, Activity Diagrams, Physical Diagrams
- Misc

Class Diagrams: Advanced Concepts

- Class Diagrams
  - Central within object-oriented methods in modeling systems and the relationship among their components.
- Many more notations:
  - Stereotypes
    - Core extension mechanism of UML
      - Subtypes of Class, Association, and Generalization

Class Diagrams

- Interface
  - An example of Stereotypes!
  - A class that has only public operations with no method bodies or attributes
    - <<interface>>
- Profile
  - Extend a part of UML with stereotypes for a particular purpose.

Object Diagrams

- A snapshot of the objects in a system at a point in time.
  - An instance diagram
  - *instance name: class name*
    - Both are optional – :Person
  - A collaboration diagram without messages

Class Diagrams

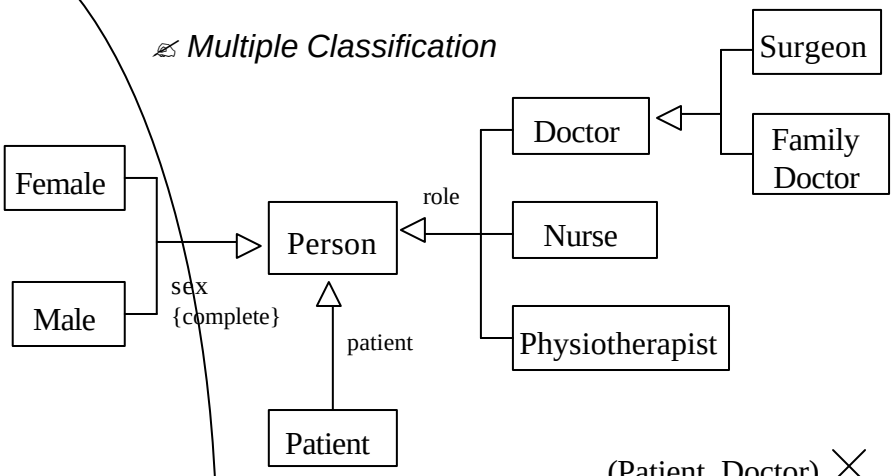
- Class Scope Operations and Attributes
  - Class Scope vs Instance Scope
- Classification
  - Relationship between an object and its type
  - Single vs Multiple Classification
    - Single Classification:
      - An object belongs to a single type, which may inherit from supertypes.

Class Diagrams

- Multiple Classification
  - An object may have any of these types assigned to it in any allowable combination.
  - Discriminator
    - An indication of the basis of the subtyping – disjoint!
  - Constraint {complete}
    - An instance of the superclass must be an instance of one of the subtypes of a group.

Class Diagrams

- *Multiple Classification*

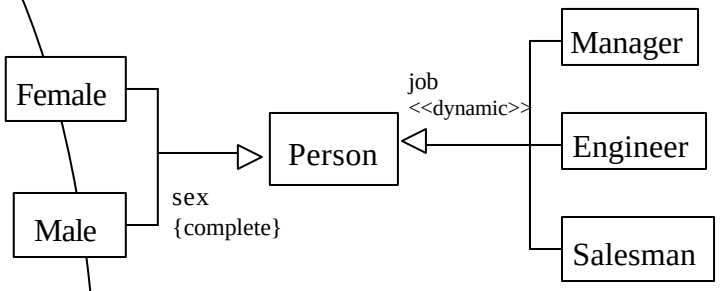


Class Diagrams

- Static vs Dynamic Classification
  - Dynamic Classification
    - Change objects' type within the subtyping structure.
- Multiple, Dynamic Interface
  - Additional behavior

Class Diagrams

- *Multiple, Dynamic Classification*

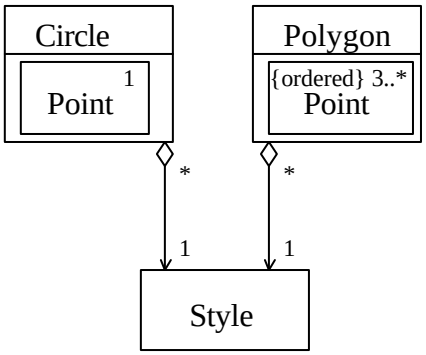


Aggregation and Composition

- Aggression
  - A part-of relationship
    - E.g.
      - car and engine
      - A style instance may be shared by a polygon and a circle.
- Composition
  - A stronger variety of aggression
  - The parts are usually expected to live or die with the whole.
    - E.g., a point must belong to a polygon!

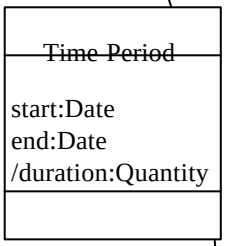
Aggregation and Composition

- Alternative Notation:



Derived Associations and Attributes

- Derived Features
  - Derived from others on a class diagram
    - Conceptual Perspective
      - Confirm with the domain experts
    - Specification Perspective
      - Constraints between values – age
    - Implementation Perspective
      - Caching for performance reasons

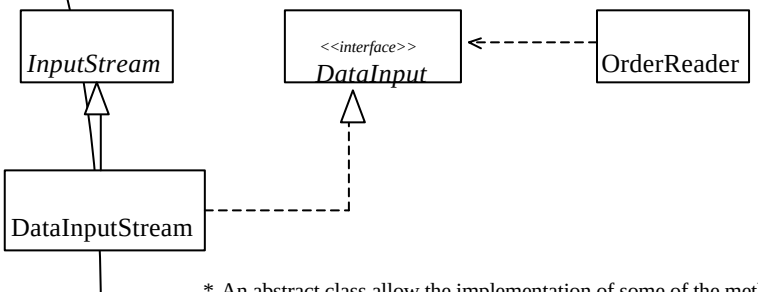


Interfaces and Abstract Classes

- Interface
  - Abstract Class: A class with no implementation (fields and method bodies) but operation declarations
  - Italicize the abstract item name and label it with the { abstract } constraints
- Realization
  - One class implements behavior specified by another – confirm to the interface without using inheritance!
  - Subtyping in a specification model!

Interfaces and Abstract Classes

- Dependency
  - If one changes, then anyone which depends on the former must change accordingly.



* An abstract class allow the implementation of some of the methods

Reference Objects and Value Objects

- Reference Objects
  - An object with an identity and can be referenced – no copies (change synchronization)!
  - E.g., Customer
- Value Objects
  - Values without identities, e.g., date.
  - Immutable built-in values of the type system (cause of confusion in UML)

Multivalued Association Ends

- A Multivalued End
  - Whose multiplicity's upper bound is greater than 1, e.g., *.
  - Constraint
    - Sets – basic type
    - { ordered }
    - { bag } – multi-set
    - { hierarchy }
    - { dag }

Frozen Constraint

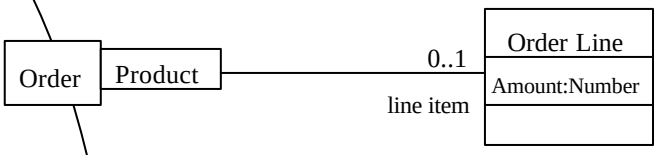
- Frozen Constraint
  - Attribute – no change on values, value set at the object creation time.
    - { frozen } vs { read only }
  - Association End – the association end on a class could not be changed.

Associations

- Classification
  - The object Shep is an instance of the type Border Collie
- Generalization – being transitive
  - The type Border Collie is a subtype of the type Dog
- Quantified Associations
  - Specification Perspective – imply an interface!
  - Implementation Perspective – The use of a data structure to hold data

Associations

- A Qualified Association

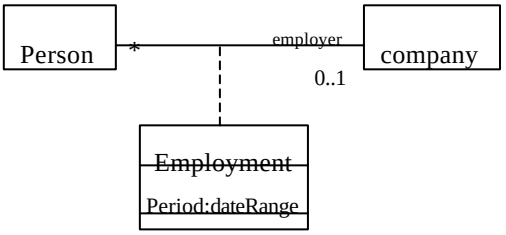



```
class Order {
   public OrderLine getLineitem(Product aProduct);
   ….

class Order {
   private Map _lineItems;
```


Associations

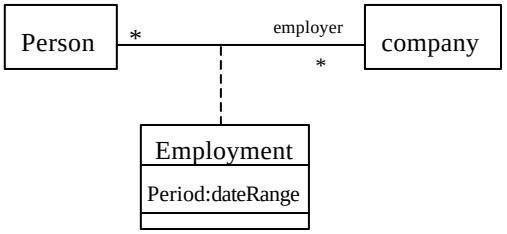
- Association Classes
  - Add attributes, operations, and other features to associations – one instance from each side!



- Another notation: promoting…

Associations

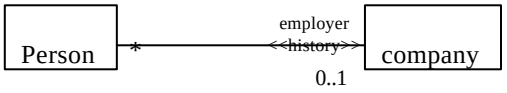
- An Illegal Association Class (Although it seems fine)



- Another Solution: Promote the association class into a “full” class!

Associations

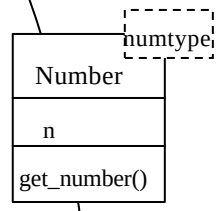
- Use Stereotypes
  - <<history>>




```
class Person {
  Company getEmployer();
  Company getEmployer(Date)
  void changeEmployer(Company newEmployer,
            Date changeDate
  void leaveEmployer (Date changeDate);
```

Parameterized Class

- Parameterized Class
  - Template in C++

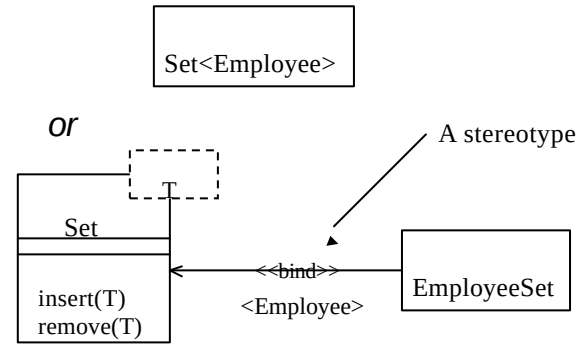



```
template <class numtype>
class number
{
        private:
                numtype n;
        public:
                number () { n = 0; }
                void get_number() { cin >> n; }
}
```

```
int main {
    number<int> ni;
    nc.get_number();
    …
```

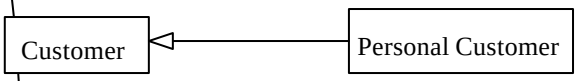

Parameterized Classes

- A Bound Element
  - *Set<Employee>*



Visibility

- Different languages have different rules in “+private”, “-public”, and “#protected”!!
  - C++
    - Public Member: visible to anywhere!
    - Private Member: used only by the class that defines it!
    - Protected Member: (a) used only by the class that defines it or (b) a subclass of that class!



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Package Diagrams

- How do you break down a large system into smaller systems?
  - Functional Decomposition
    - Separation of functions and data
  - UML Package Diagrams
    - A OO Grouping Mechanism

Package Diagrams

- Definition: Package Diagrams
  - Class Diagrams that only show packages and dependencies
- Packages
  - Group of Classes or Packages
- Dependencies
  - A dependency exists between two elements if changes to the definition of one element may cause changes to the other element.

Package Diagrams

- Why Changes Propagate?
  - One class sends messages to another.
  - One class has another as part of its data.
  - One mentions another as a parameter to an operation.

Interface changes!

Package Diagrams

How to minimize dependencies?

- UML Dependency vs Compilation Dependency?
  - Why no transitivity?
    - Similar to a layered architecture!
- Example: Package Diagram

Package Diagrams

- Class Types inside a Package:
  - Private, Public, or Protected
    - Sharing/Dependency of the Public Methods of Public Classes!
  - Reducing of the Interface of a Package
    - Facades
- Another Objective for Package Diagrams:
  - Help to see what dependencies are!

Package Diagrams

- Containment of Packages or Classes
  - Key Classes
- Dependency of Packages That Contain Sub-packages
  - Summaries of Low-Level Dependency
- <<global>> Package
  - Global Dependency
- <<abstract>> Package
  - Generalization – Dependency Implication

Package Diagrams

- Rules of Thumb
  - Minimize dependencies
    - Refactoring!
  - Remove cycles in the dependency structure as much as possible!
    - Contain them in a large containing package!
    - Eliminate them from the interactions between the domain and external interfaces!

Package Diagrams

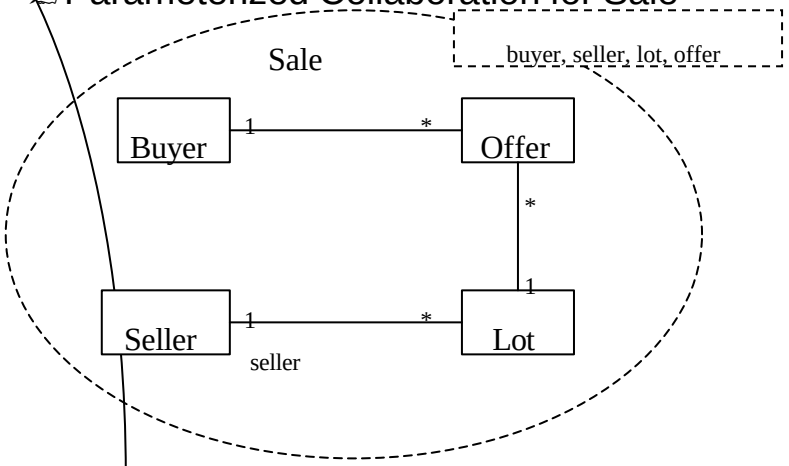
- Collaboration
  - The interaction among two or more classes
    - Show the implementation of an operation or the realization of a use case.
  - May include class diagrams and interaction diagrams
  - Use for classes inside a package or common behavior across packages

Package Diagrams

- Parameterizing of Collaboration
  - Same collaboration for different classes
  - Roles (Collaboration) vs Classes
  - Pattern
- Example: Collaboration for Sale

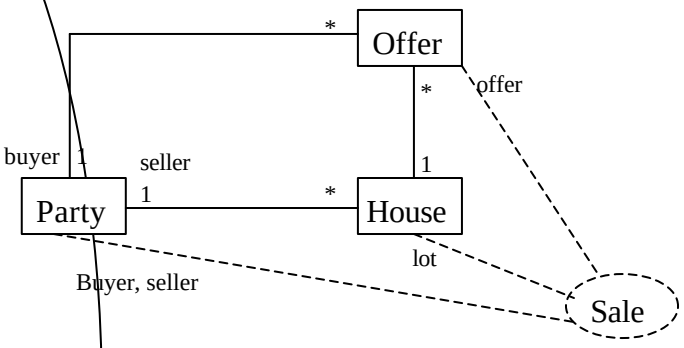
Package Diagrams

- Parameterized Collaboration for Sale



Package Diagrams

- Using the Sale Collaboration



Package Diagrams

- When to Use Package Diagrams
  - Whenever a class diagram that encompasses the whole system is no longer legible on a A4 sheet of paper!
    - Useful for testing as well!
- When to use Collaboration?
  - Refer to a particular interaction
  - Parameterized collaboration

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State Diagrams

- Why State Diagrams?
  - Describe the behavior of a system.
  - Describe all of the possible states that a particular object can get into and how the object's state changes as a result of events that reach the object.
  - Based on statechart by David Harel (1987)

State Diagrams

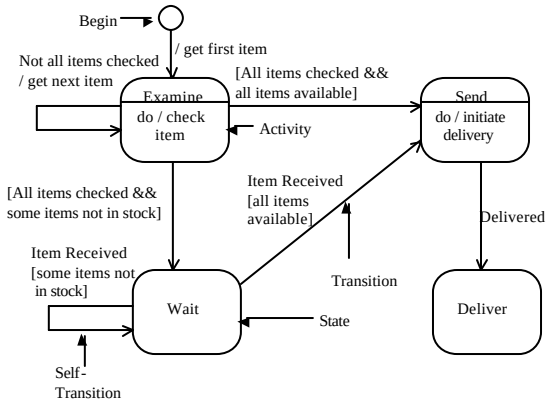
- Syntax
  - *Event [Guard] / Action*
  - *do / activity*
  - Start point
- Action
  - Be associated with a transition
  - Occur quickly and is not interruptible.
- Activity
  - Be associated with a state
  - May be interrupted by some event.

State Diagrams

- Guard
  - A logical condition
  - Guards from the same state should be mutually exclusive
  - A transition should occur as soon as the corresponding event happens.
- A state could have no activity!
- Superstate

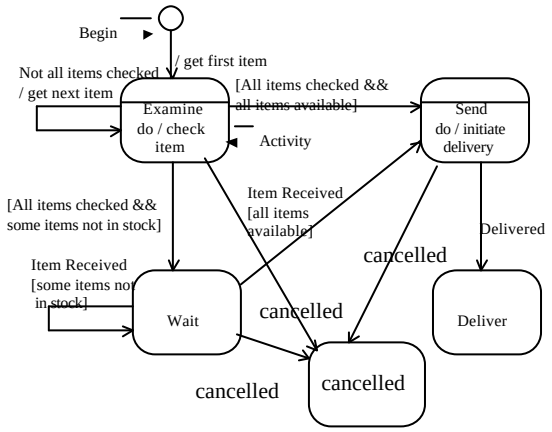
State Diagrams

An State Diagram Example



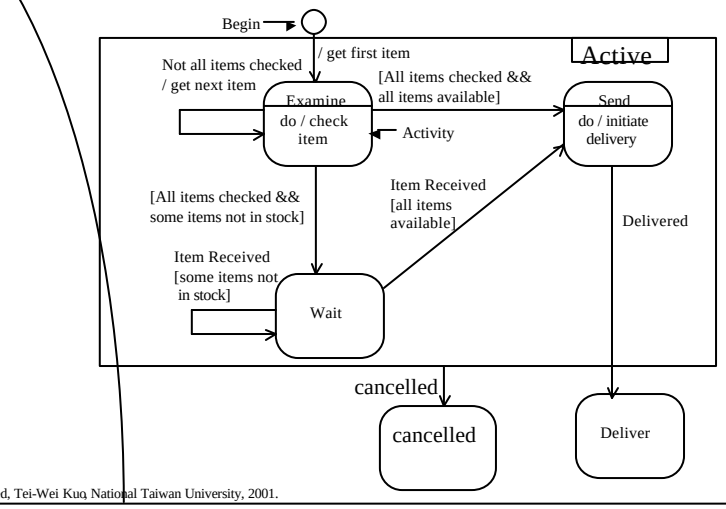
State Diagrams

An State Diagram Example



State Diagrams

- An State Diagram Example - Superstate

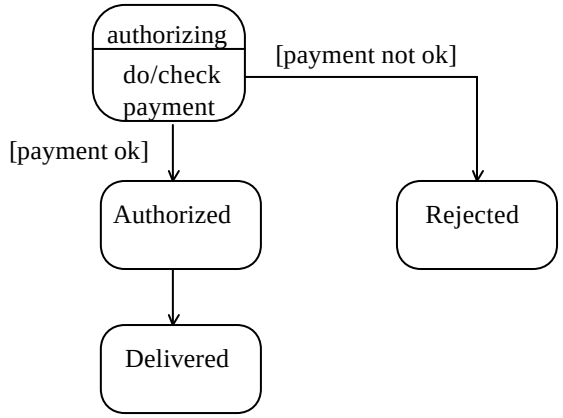


State Diagrams

- Other Event Types
  - No-state transition event
    - eventName / actionName
  - After Event
    - after (20 minutes)
  - When Event
    - when (temperature > 100 degrees)
  - Entry/Exit Event

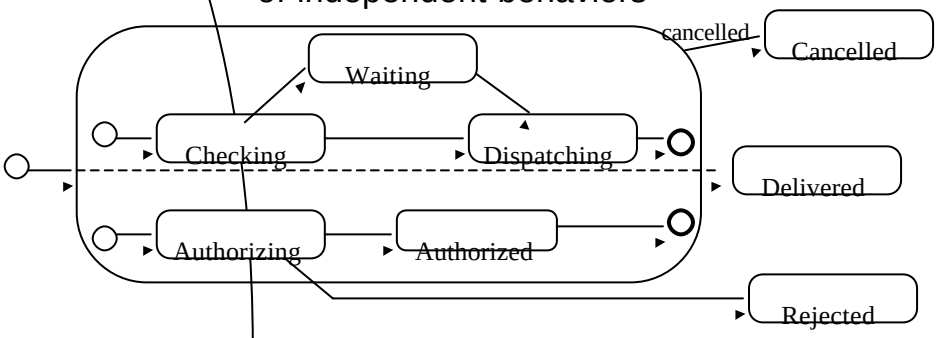
State Diagrams

- Example: Payment authorization



State Diagrams

- Concurrent State Diagrams
  - More than one state at any point
  - Good when a given object has sets of independent behaviors



State Diagrams

- When to Use State Diagrams?
  - Describe the behavior of an object across several use cases.
    - Use interaction diagrams or activity diagrams if needed
  - Only classed exhibiting interesting behavior!
- Do not draw state diagrams for every class!

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Activity Diagrams

- Why Activity Diagrams?
  - Useful in connection with workflow and in describing behavior that has a lot of parallel processing.
  - Describing the sequencing of activities with support for both conditional and parallel behavior.
  - Origin:
    - Event diagrams (Jim Odell), state modeling techniques, workflow modeling, Petri nets.

Activity Diagrams

- Core Symbols
  - Activity State or Activity

  - Conditional Behavior

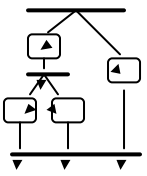
    - Branch
      - Exclusive on “Transitions”
      - Guard [condition], e.g., [else]
    - Merge
      - Marks the end of conditional behavior started by a branch.

Activity Diagrams

- Parallel Behavior
  - Fork
    - Interleaving semantics
      - Sequence of “parallel” activities is irrelevant!
    - Difference from flowchart
      - Limited to sequential processes in flowcharts
  - Join
    - The outgoing transition is taken only if all of the states on the incoming transitions have completed their activities.

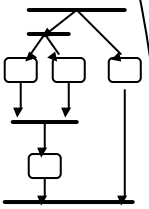
Activity Diagrams

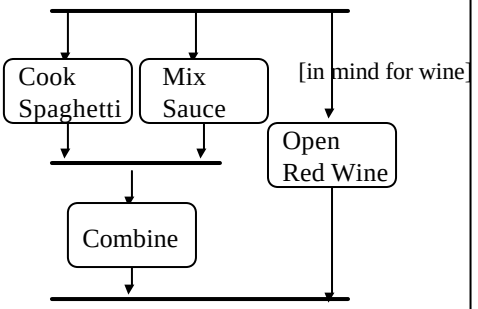
- Why Parallelism?
  - Improving the efficiency and responsiveness of business processes
    - Remove unnecessary sequence and spot opportunities for parallelism.
- Forks and joins must match except:
  1. Threads fork threads



Activity Diagrams

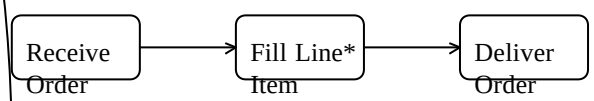
2. Notational shorthand to remove clutter from the diagram.
3. Sync state and conditional threads





Activity Diagrams

- Decomposing an Activity
  - Break an activity down into subactivities.
    - The explicit start and end states are good for the usage of the subactivity in other contexts.
- Dynamic Concurrency
  - Multiplicity Marker *



Activity Diagrams

- Swimlanes
  - Why?
    - Activity diagrams tell you what happens, but they do not convey which class is responsible for each activity!
    - Label each activity with the responsible class or human is too tedious.
  - Combine the activity diagram's depiction of logic with the interaction diagram's depiction of responsibility
    - Linear or nonlinear zones!

Activity Diagrams

- When to use activity diagrams?
  - Analyze a use case
    - Action and behavior dependency
  - Understand workflow
  - Describe a complicated sequential algorithm
  - Deal with multi-threaded applications
- Good for considering parallel behavior or multi-threaded programming.

Activity Diagrams

- When not to use them?
  - Try to see how objects collaborate
    - Interaction diagrams
  - Try to see how an object behaves over its lifetime
    - State diagrams
  - Represent complex conditional logic
    - Truth tables
- Disadvantage:
  - No link among actions and objects

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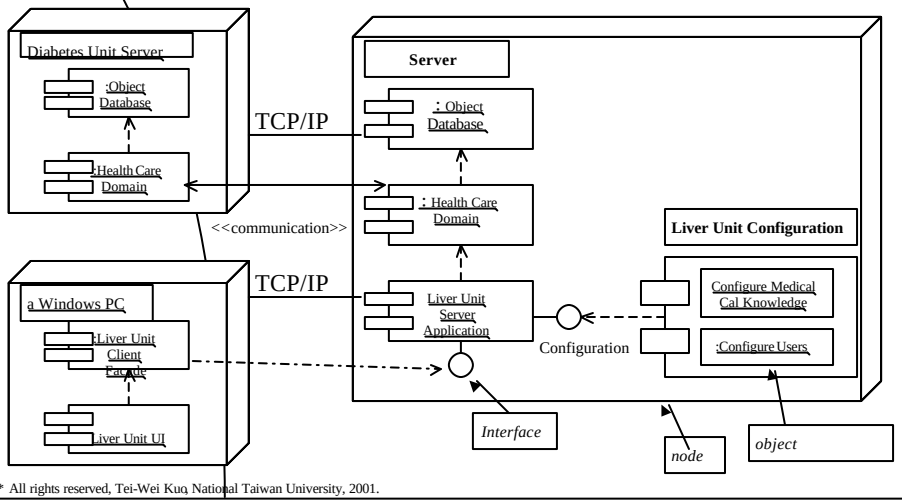
Physical Diagrams

- Physical Diagrams
  - Deployment Diagrams
    - Show the physical relationships among software and hardware components in the delivered system.
  - Component Diagrams
    - Show the various components in a system and their dependencies.

Deployment Diagrams

- Purpose:
  - Show how components and objects are routed and move around a distributed system.
- Node
  - Some kind of computational unit, e.g., a piece of hardware
- Connection
  - Communication paths over which the system will interact.

Deployment Diagram



Component Diagrams

- Purpose:
  - Show the various components in a system and their dependencies.
- Component
  - A physical module of code
    - Physical package of code
    - A class might appear in several components
- Dependency
  - Communication and compilation

Physical Diagrams

- Combining of Component and Deployment Diagrams
  - Show which components run on which nodes!
- When to use them?
  - Show the physical information of the system!

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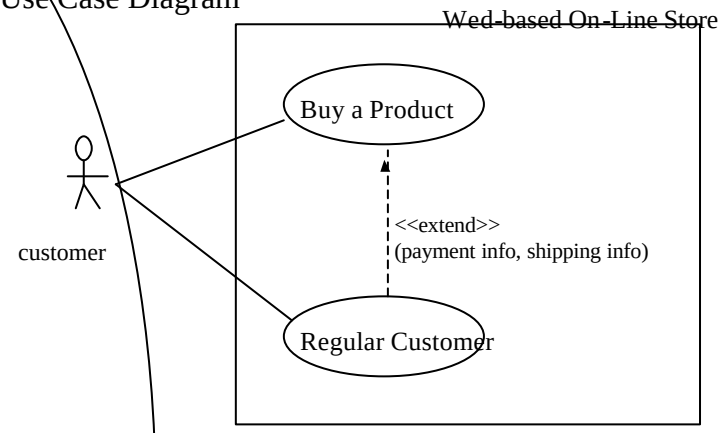
A Case Study – Buy a Product

- Buy a Product – Use-Case Text:
  1. *Customer browses the catalog and selects items to buy.*
  2. *Customer goes to check out.*
  3. *Customer fills up in the shipping information.*
  4. *System presents full pricing information, including shopping.*
  5. *Customer fills in credit card information.*
  6. *System authorizes purchase.*
  7. *System confirms sale immediately.*
  8. *System sends confirming email to customer.*
- *Alternative: Regular Customer*
  - *3.a system display current shipping information, pricing information, and last digits of credit card information*
  - *3.b Customer accept or override these defaults*
  - *Return to Step 6!*

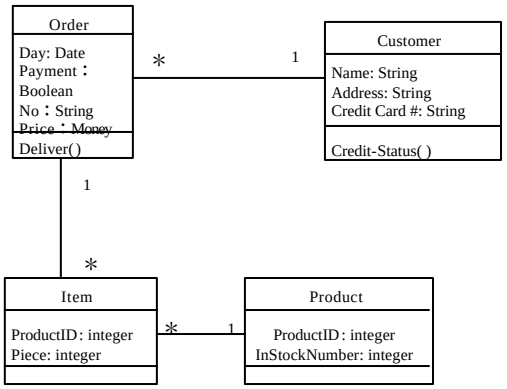
A Case Study – Buy a Product

A Use Case Diagram



A Case Study – Buy a Product

✍A Class-Diagram



A Case Study – Buy a Product

✍A Sequence Diagram