Overview Lecture

Course - CS371S

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Course Overview

Model Driven Development Overview

Executable UML Overview

Tool Overview

Course Overview

- Design of Software Systems
- Analysis of Software Systems
- Topics
  - Design Representations
  - Design Extraction and Refinement
  - Design Capture
  - Design Analysis
- Key Concept – Executable Design Specifications

Issues to be Resolved

- What is a software system?
- How will we represent a software system?
- How will we analyze our system to be sure it is does what it is supposed to do?
- How will we maintain and extend our software system?
- How will we connect with mainstream languages and systems?

Issues to be Resolved

- What is a software system?
  - Answer – A set of interacting entities.
- What must we specify?
  - The entities and their interactions

Issues to be Resolved

- How will we represent a software system?
  - Answer – In a language which captures the states and behaviors of entities
- What are examples of such languages?
  - Executable UML is one.
  - There are several others

Issues to be Resolved

- How will we analyze our system to be sure it is does what it is supposed to do?
  - We will state a set of properties the system must have and the set of environments in which the system will exhibit these behaviors.
- How will we represent properties and environments?
  - In the same language as the design capture language.

Issues to be Resolved

- How will we maintain and extend our software system?
  - In the same way we developed it.

Issues to be Resolved

- How will we connect with mainstream languages and systems?
  - Compile the design representation to a conventional imperative language such as Java or C++.

Problems with Conventional Approach

- Representation is has low level semantics conceptually far removed from application domains. Which means that:
  - Executable representation is not readily readable or analyzable.
  - Analysis for properties is in low level terms.
  - Human understandable representations must be created separately.

Approach of this Course

- Represent system in executable design level representation.
  - Design capture is direct from requirements
  - Design representation and executable representation are one and the same.
  - Analysis is of the design.
  - Maintenance and extension are in design representation.

Illustration

- You have graduated and are at work. Your boss gives you an English requirements specification and says “ Develop a system in Java implementing these specifications. Provide documentation which is understandable to those who don’t read code. Prove to me it is correct. ”

Illustration - Requirements

- **Reservation System for Avis Rent a Car**
- Avis has a set of offices in a set of cities. Each city/office pair has a set of cars available for rental. Each car is belongs to a rental class. A rental class has a model name, a manufacturer and a base daily rental price. Each car belongs to some rental location but may at any given time be in some other location.
- Avis is putting in a web-based reservation system. Customers request a reservation for a specific class of car in some city at some location for some span of dates and specifying a location to which to return the car. Many customers may be simultaneously attempting to make reservations. Requests are accepted in FIFO order. A customer either gets the class of car desired or a notification that a car in the rental class he/she requested is not available. The customer will sometimes then request another class of car. If the customer accepts the available rental car then he/she then presents a credit card against which the rental charges will be made. The system obtains an authorization from the credit card company for the expected charge. The rental is denied if the credit card company refuses to authorize the charge.
- If a customer has requested to return the rental car to a location different from the renting location then the system will choose a car belonging to the return site if one is available at the rental site.
- A reservation may be cancelled before its initiating date and time. When the customer picks up the car a rental is initiated. A rental may be extended while the customer is in possession of the car. If a car has not been returned 24 hours after the scheduled date and the customer has not requested an extension the car is reported to the local Police Department of the location as being missing or stolen.
- Each customer belongs to an organization, for example, AAA or AARP. Each organization has a discount percentage for each car class. Rental rates are determined by the organization to which a customer belongs. The discounts are revised fairly often as a function of contracts and competitive pressures.
- The software system you are to develop should support making and canceling of reservations in a fair and orderly manner. It should also keep track of when cars are returned and create a bill for the rental of each car and send copies of that bill to the organization and the customer. Your software should cover the cases when a car is not available and where a given class of car is not available. The software should keep track of the number of rental days for each class of cars by manufacturer to enable optimization of the mix of cars in the rental fleet. The GUI is a separate domain with which your system exchanges messages. The credit card company is also a separate domain with which your system exchanges messages.

Illustration – Design Extraction

- What is the first thing you should do?

Illustration – Design Extraction – Step 2

- Now What??

Model Driven Paradigm for Software Development

The steps in the development cycle are:

a) The system is defined as an executable specification which is an object-oriented analysis model.

b) The system is validated at the analysis model level.

c) A software and execution architecture is defined as a set of class templates in an object-oriented programming system.

d) The executable system is realized by compilation of the validated analysis model to the software execution architecture.

Why

Using models to design complex systems is standard practice in traditional engineering disciplines. No one would imagine constructing an edifice as complex as a bridge or an automobile without first constructing a variety of specialized system models. from using models and modeling techniques. Models help us understand a complex problem and its potential solutions through abstraction. Therefore, it seems obvious that software systems, which are often among the most complex engineering systems, can benefit greatly.

Why

MDD's defining characteristic is that software development's primary focus and products are models rather than computer programs.The major advantage of this is that we express models using concepts that are much less bound to the underlying implementation technology and are much closer to the problem domain relative to most popular programming languages. This makes the models easier to specify, understand, verify and maintain.

Requirement - Code Generation

If models are merely documentation, they are of limited value, because documentation all too easily diverges from reality. A key premise behind MDD is that programs are automatically generated from their corresponding models.

Therefore

Models must be executable.

Further

The resulting executable must be reasonably competitive wrt resource consumption.

Overview Lecture

This course is about designing, constructing, validating and verifying executable models which can be compiled to procedural code such as C++ or Java.

- Modeling Language – xUML
- Design Principles and Paradigms – textbook and example papers
- Validation and verification
- Tools – BridgePoint, iUMLite, Rational Rose, etc.
- Evaluation of MDD process

Course Work Requirements

This is essentially a laboratory class. The lectures will cover the xUML and the executable specification based development method in detail and other methods as alternatives. The main goal of the course will be to carry through a complete development of a small software system using object-oriented development methods. There will also be periodic laboratory exercises to develop skills before projects are started.

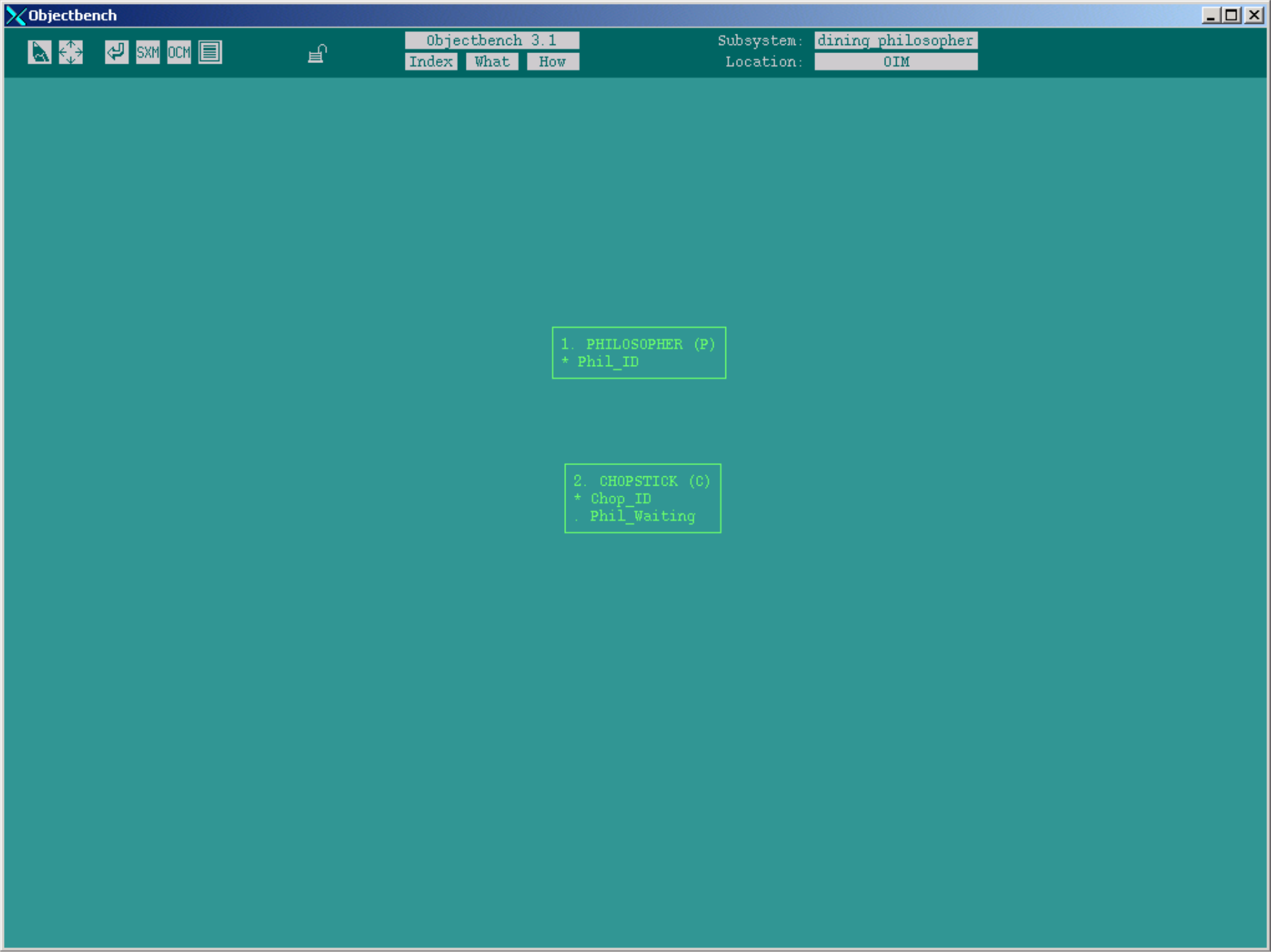
There will be two class examinations but no final examination.

Project Specifications

The project will be development of a small software system through the executable specification development methodology. The projects will be executed by small teams of co-workers. I have a set of possible projects. Each team will do a different project. A team can suggest a project of their own definition by preparing a requirements specification and getting it approved.

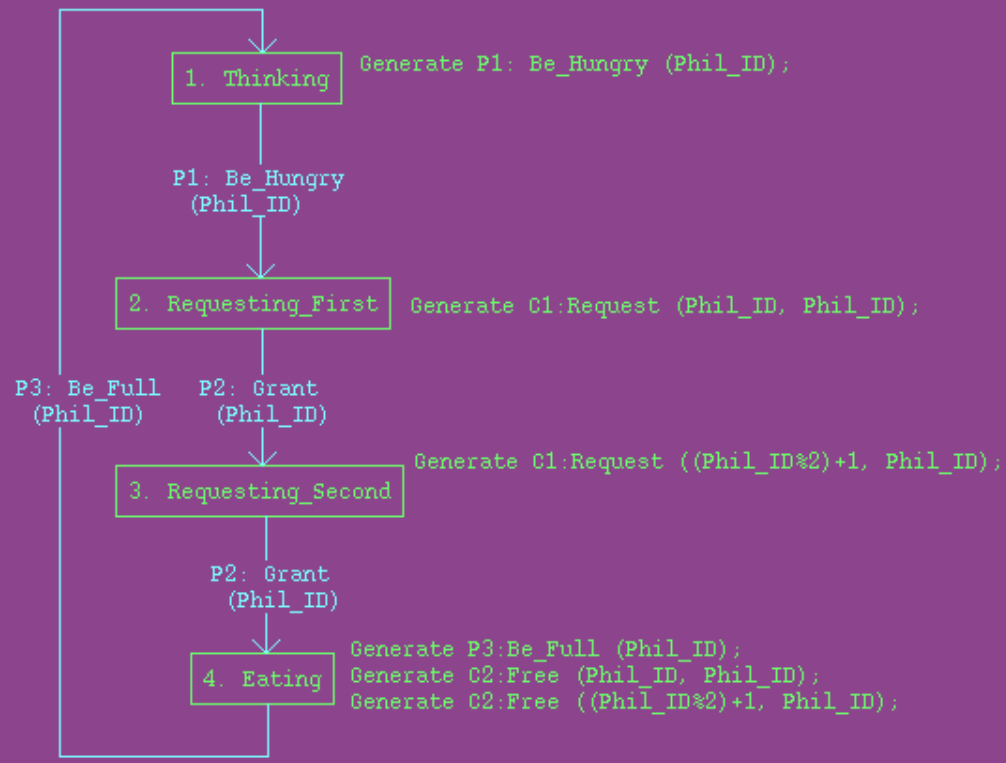
Glimpse at an IDE – Objectbench

1. Graphical capture
2. Execution by discrete event simulator interpretation of program.
3. Early dialect of xUML
4. Dining Philosophers Problem


Objectbench
SXM
OCM
Objectbench 3.1
Index
What
How
Subsystem:
dining_philosopher
Location:
OIM
1. PHILOSOPHER (P)
* Phil_ID
2. CHOPSTICK (C)
* Chop_ID
. Phil_Waiting

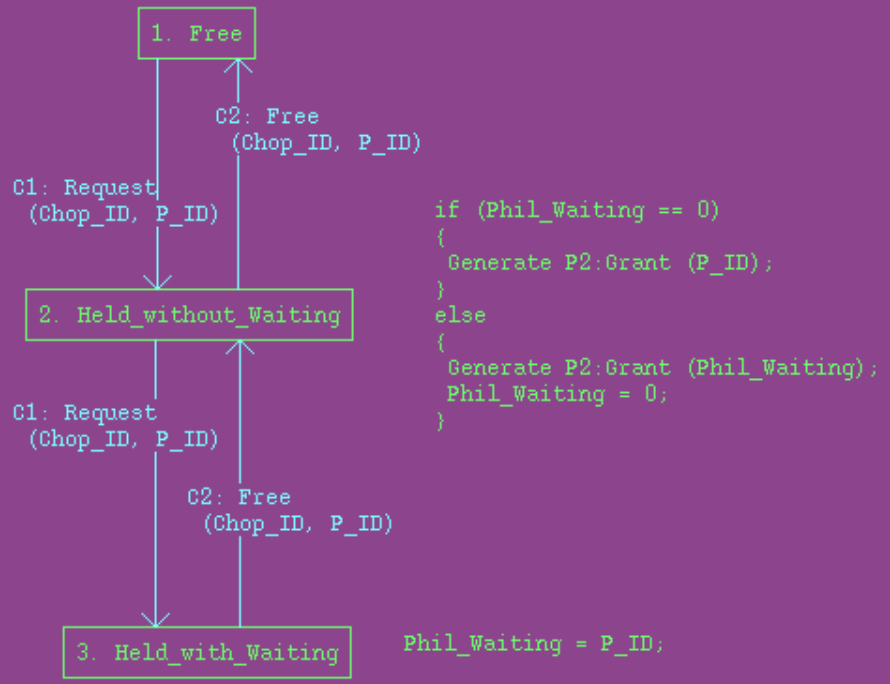
Objectbench

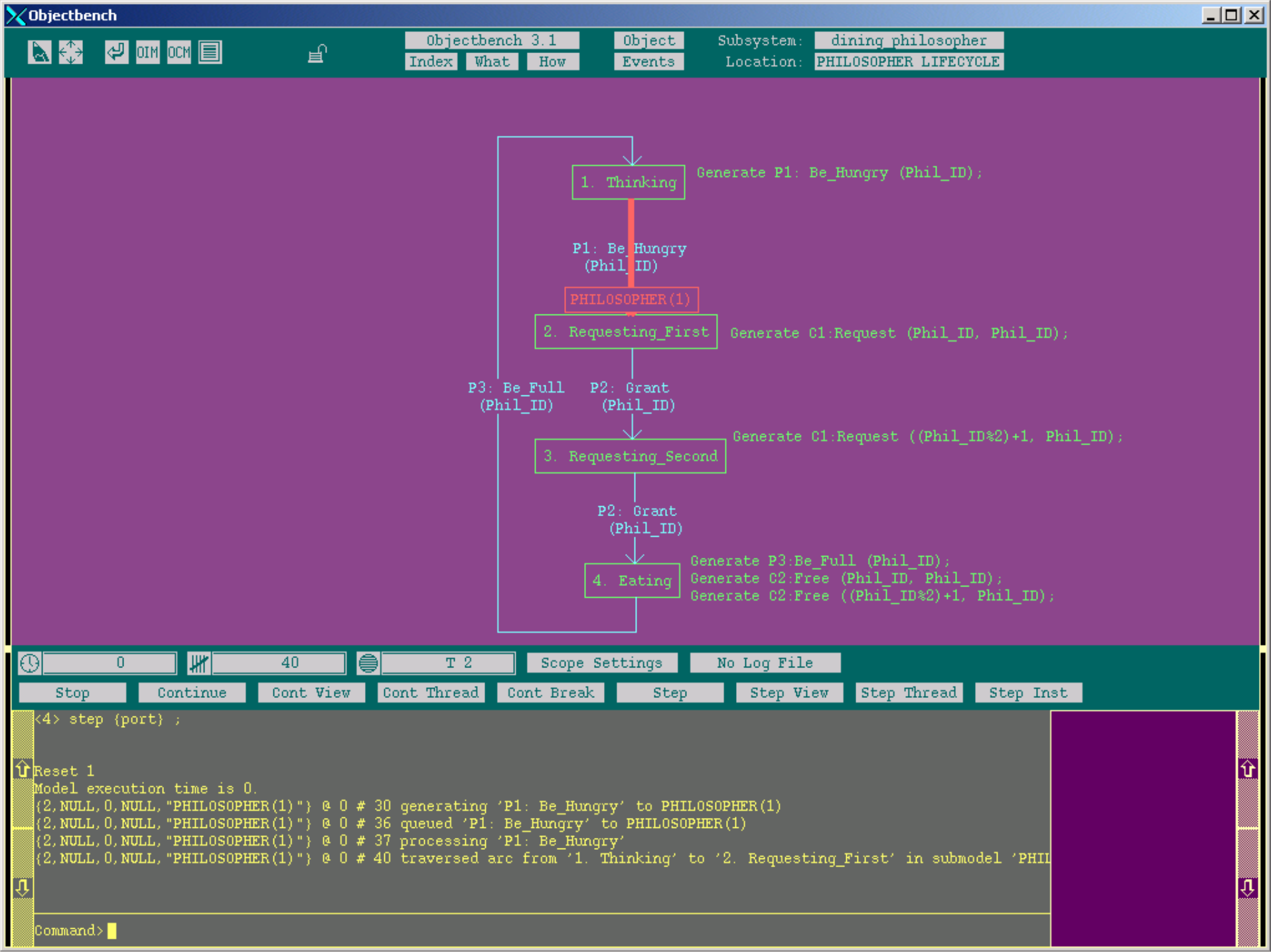
Objectbench 3.1 | Object | Subsystem: dining_philosopher
Index | What | How | Events | Location: PHILOSOPHER LIFECYCLE



Objectbench

Objectbench 3.1 | Object | Subsystem: dining_philosopher
Index | What | How | Events | Location: CHOPSTICK LIFECYCLE




Objectbench
Objectbench 3.1
Index
What
How
Object
Events
Subsystem:
dining_philosopher
Location:
PHILOSOPHER LIFECYCLE
1. Thinking
Generate P1: Be_Hungry (Phil_ID);
P1: Be_Hungry
(Phil_ID)
PHILOSOPHER(1)
2. Requesting_First
Generate C1:Request (Phil_ID, Phil_ID);
P3: Be_Full
(Phil_ID)
P2: Grant
(Phil_ID)
3. Requesting_Second
Generate C1:Request ((Phil_ID%2)+1, Phil_ID);
P2: Grant
(Phil_ID)
4. Eating
Generate P3:Be_Full (Phil_ID);
Generate C2:Free (Phil_ID, Phil_ID);
Generate C2:Free ((Phil_ID%2)+1, Phil_ID);
0
40
T 2
Scope Settings
No Log File
Stop
Continue
Cont View
Cont Thread
Cont Break
Step
Step View
Step Thread
Step Inst
<4> step {port} ;
Reset 1
Model execution time is 0.
{2,NULL,0,NULL,"PHILOSOPHER(1)"} @ 0 # 30 generating 'P1: Be_Hungry' to PHILOSOPHER(1)
{2,NULL,0,NULL,"PHILOSOPHER(1)"} @ 0 # 36 queued 'P1: Be_Hungry' to PHILOSOPHER(1)
{2,NULL,0,NULL,"PHILOSOPHER(1)"} @ 0 # 37 processing 'P1: Be_Hungry'
{2,NULL,0,NULL,"PHILOSOPHER(1)"} @ 0 # 40 traversed arc from '1. Thinking' to '2. Requesting_First' in submodel 'PHIL
Command>

Executable UML

- What is Executable UML
- Executable UML Model
- Domain Modeling
- Classes
- Actions
- Constraints
- Lifecycles
- Signals and Events
- Synchronization
- Model Compilers
- Summary
- References

What is Executable UML?

- Executable UML is a program in a language more abstract than typical procedural languages.
- Subset of UML + Action Language Specification
- Describes data and the behavior
- Doesn’t make coding decisions
- Can be deployed in various software environments without change
- Makes use of model compiler to generate code

Executable UML Model

- An Executable UML model comprises:
  - UML class diagrams
  - UML state charts
  - Set of procedures, where each procedure is a set of actions.
- Other UML diagrams can be used to support the construction of Executable UML models.

Domain Modeling

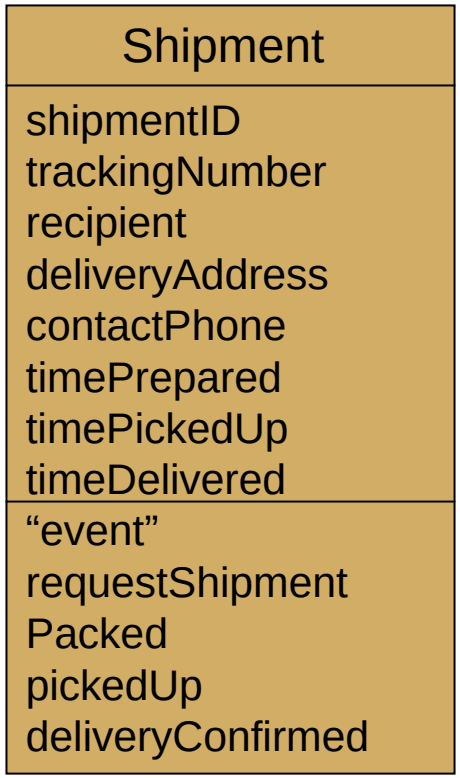
- An executable UML model is to be built for each subject matter, or domain in the system.
- The functional requirements of the system can be expressed in terms of use cases
- For a domain, a class diagram is defined comprising classes, attributes and associations and description for each element.
- A state machine formalizes a lifecycle of an object in terms of states, events, and transitions.
- Each state on the state chart diagram has an associated procedure.
- Each procedure comprises a set of actions.

Classes

- Class diagram in an xUML model comprises:
  - Classes: class's name, attributes, and events
  - Generalization and Specialization relationships
    - All superclasses are tagged {abstract}
    - All generalizations are tagged {disjoint, complete}
    - Multiple generalization is permitted, but no diamond generalizations
  - Associations: association's name, multiplicity, and roles.
    - There can be two or more associations between the same two classes.

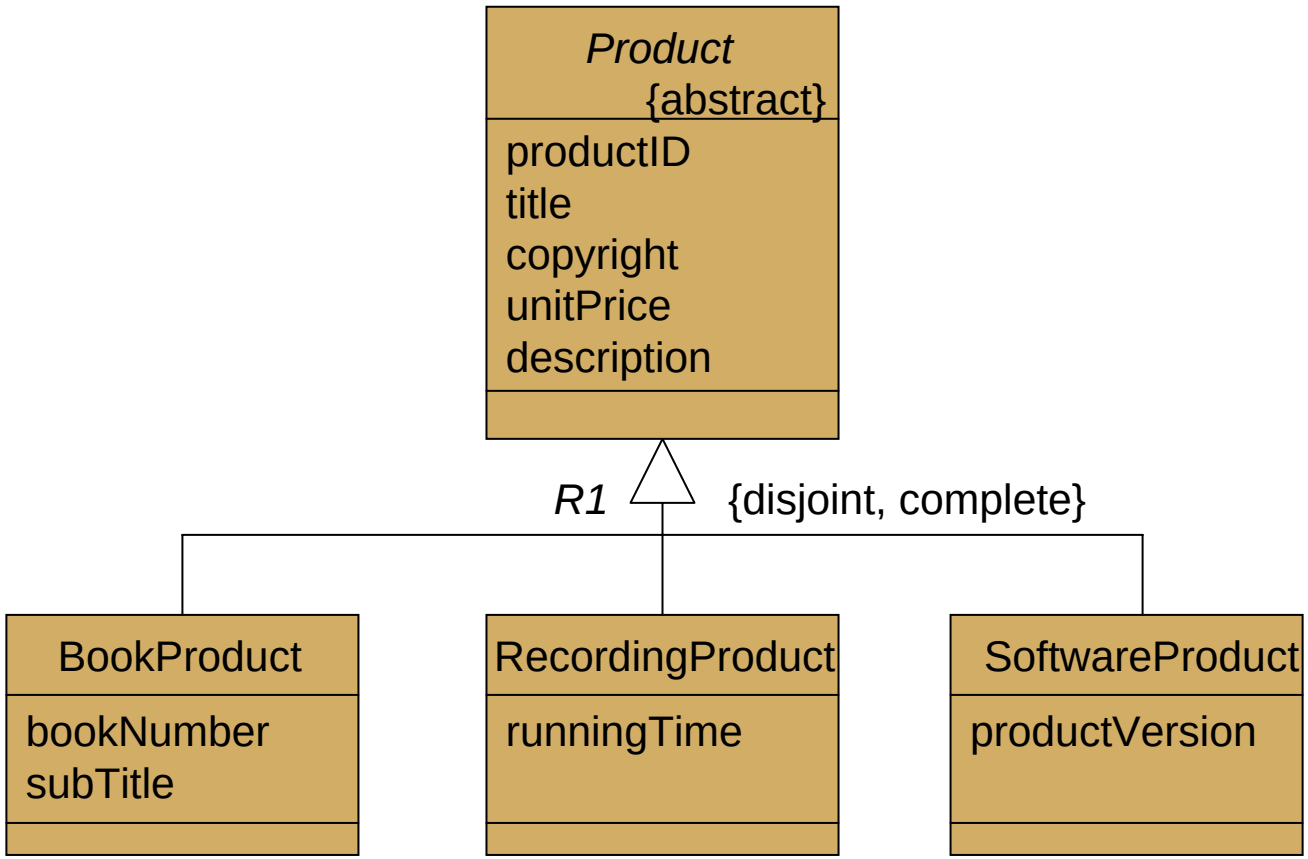
Examples

Class



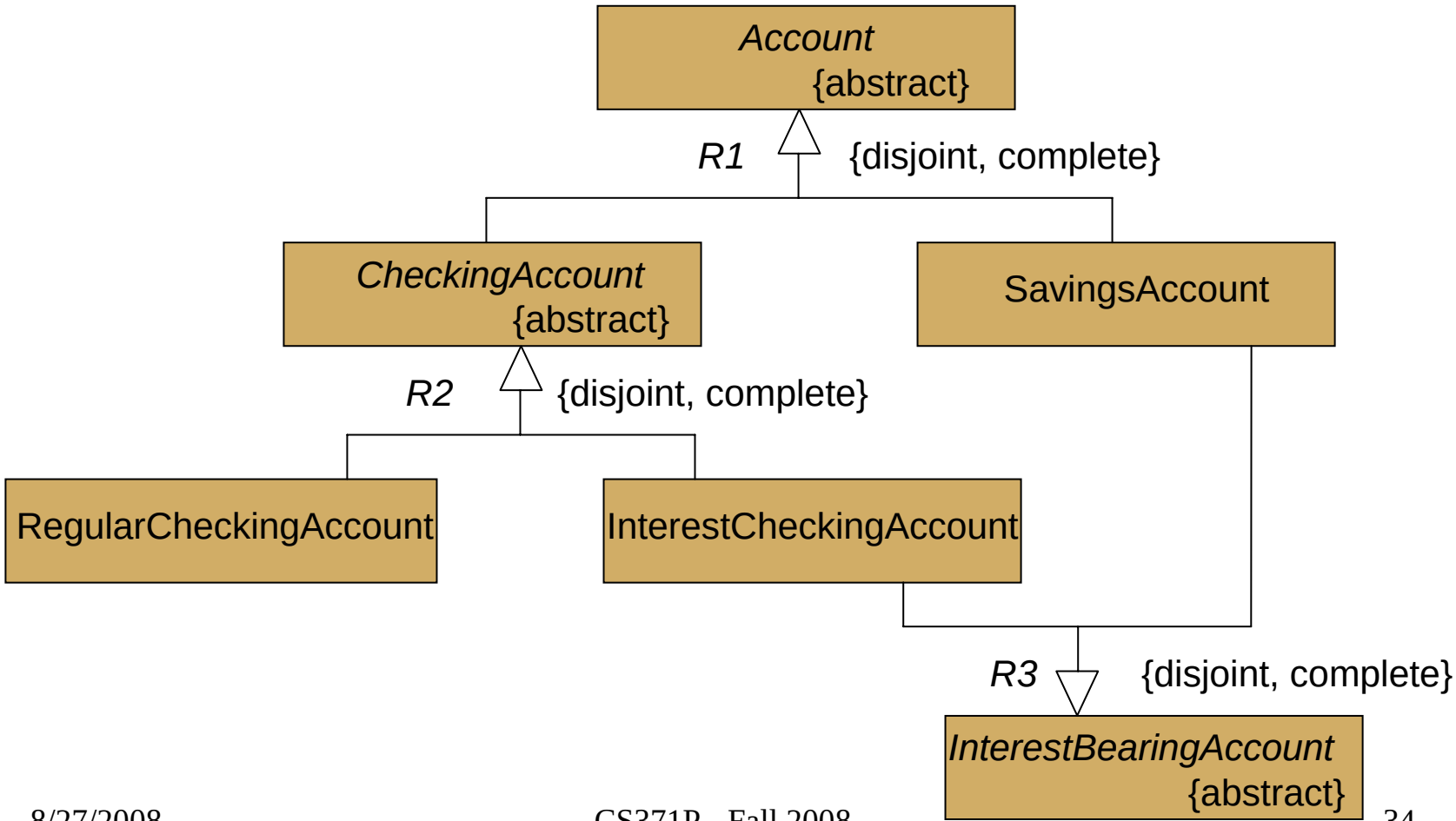
Examples

Generalization



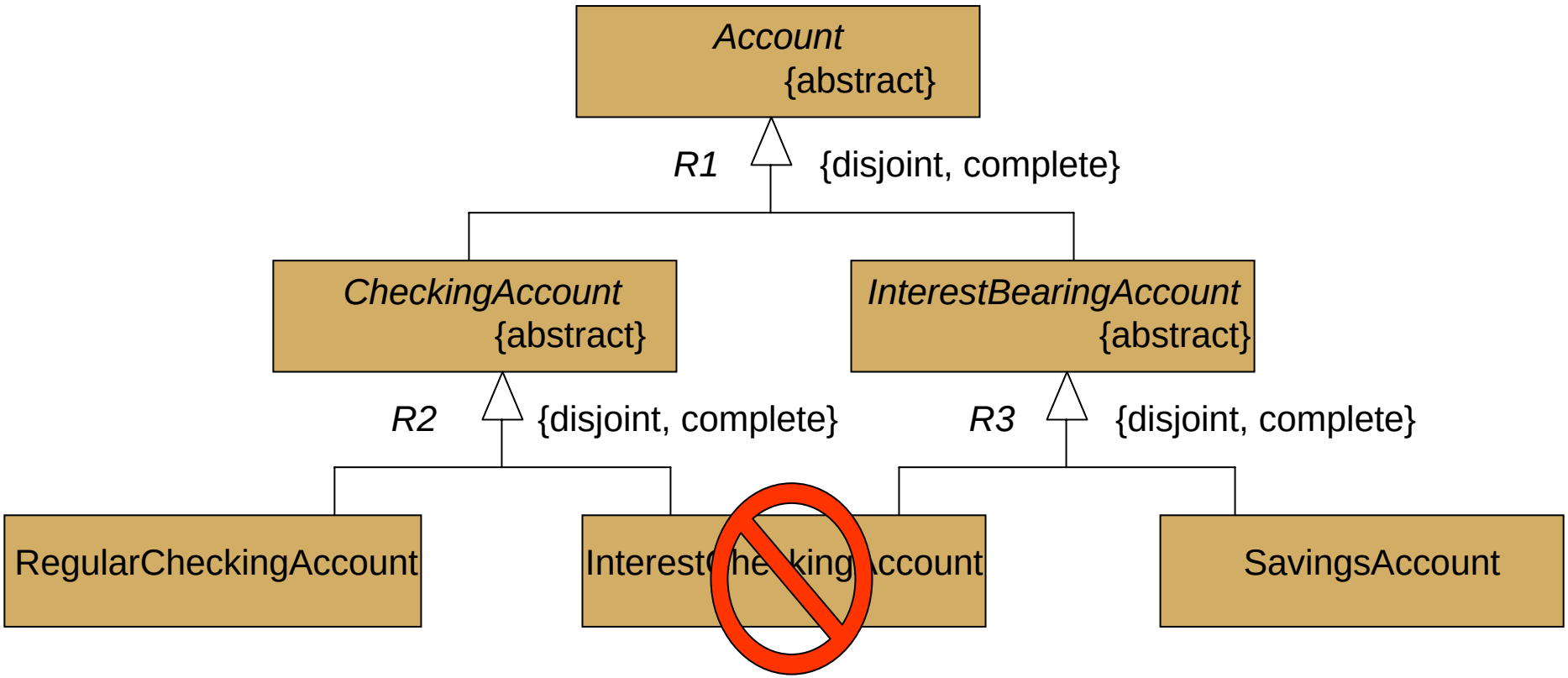
Examples

Multiple Generalization



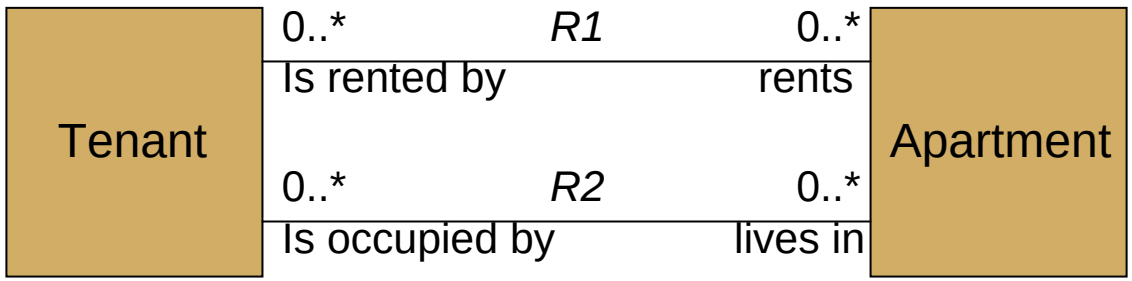
Examples

Improper Multiple Generalization



Examples

Associations



Actions

- An action is an individual operation that performs a single task on an element
- Executable UML relies on the Precise Action Semantics for UML adopted by OMG
- Different xUML versions use different Object Action Languages
- Classes as well as associations have actions for creating and deleting instances. A reclassification action allows a subclass to move from one leaf subclass in the specialization hierarchy to another

Representative Action Language Syntax

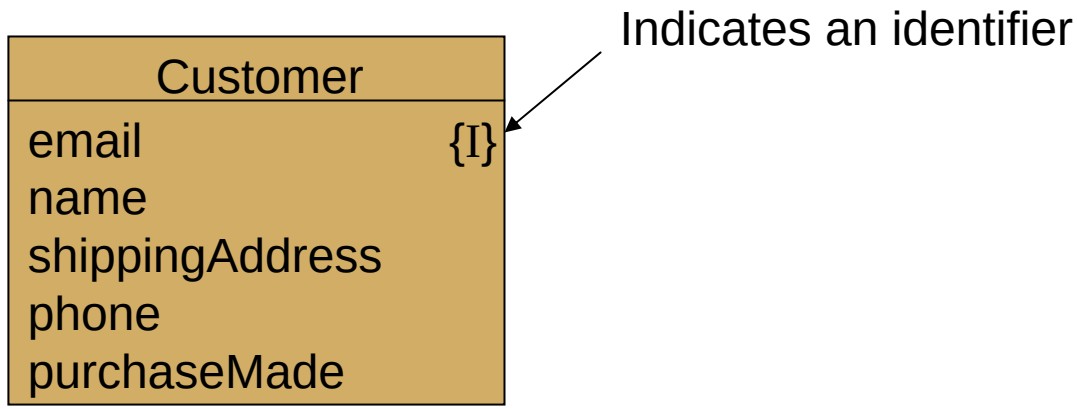
Action	Syntax
Create object	**create object instance** <object reference> **of** <class>;
Write attribute	<object reference>.<attribute name> = <expression>;
Delete object	**delete object instance** <object reference>;
Class extent	**select many** <object reference set> **from instances of** <class>;
Qualification (1)	**select any** <object reference> **from instances of** <class> **where** <clause>;
Qualification (+)	**select many** <object reference set> **from instances of** <class>**where**<clause>;
Loop	**for each** <object reference> **in** <object reference set> <statements> **end for**;
Create link	**relate** <object reference> **to** <object reference> **across** <association>;
Traverse link	**select [one|many]** <object reference> **related by** <object reference>-><class>[<association>];
Delete link	**unrelate** <object reference> **from** <object reference> **across** <associattion>;
Reclassify object	**reclassify object instance** <object reference> **from** <class> **to** <class>;

Constraints

- A constraint is a rule that restricts the value of attributes and/or associations in a model
- Constraints can be expressed in OCL, action language or graphical notation
- Unique Instance Constraints: An identifier is a set of one or more attributes that uniquely distinguishes each instance of a class:
  - Single Attribute Identifier
  - Multiple Attribute Identifier
- Referential Constraints: A referential attribute identifies the instance of associated class

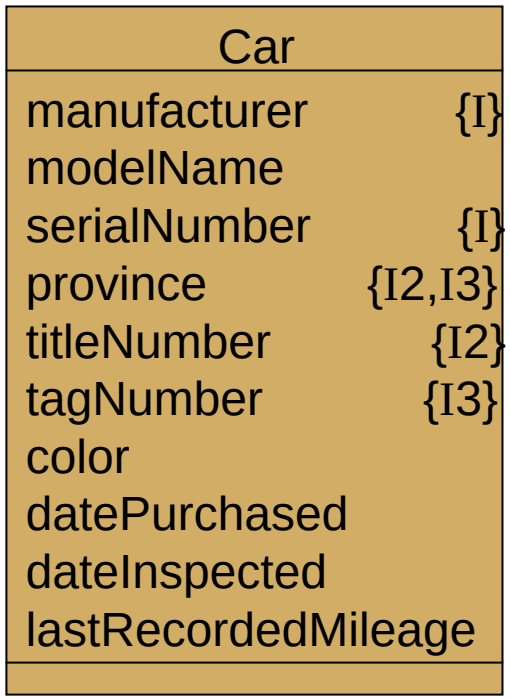
Examples

Single Attribute Identifier



Examples

Multiple Attribute Identifiers



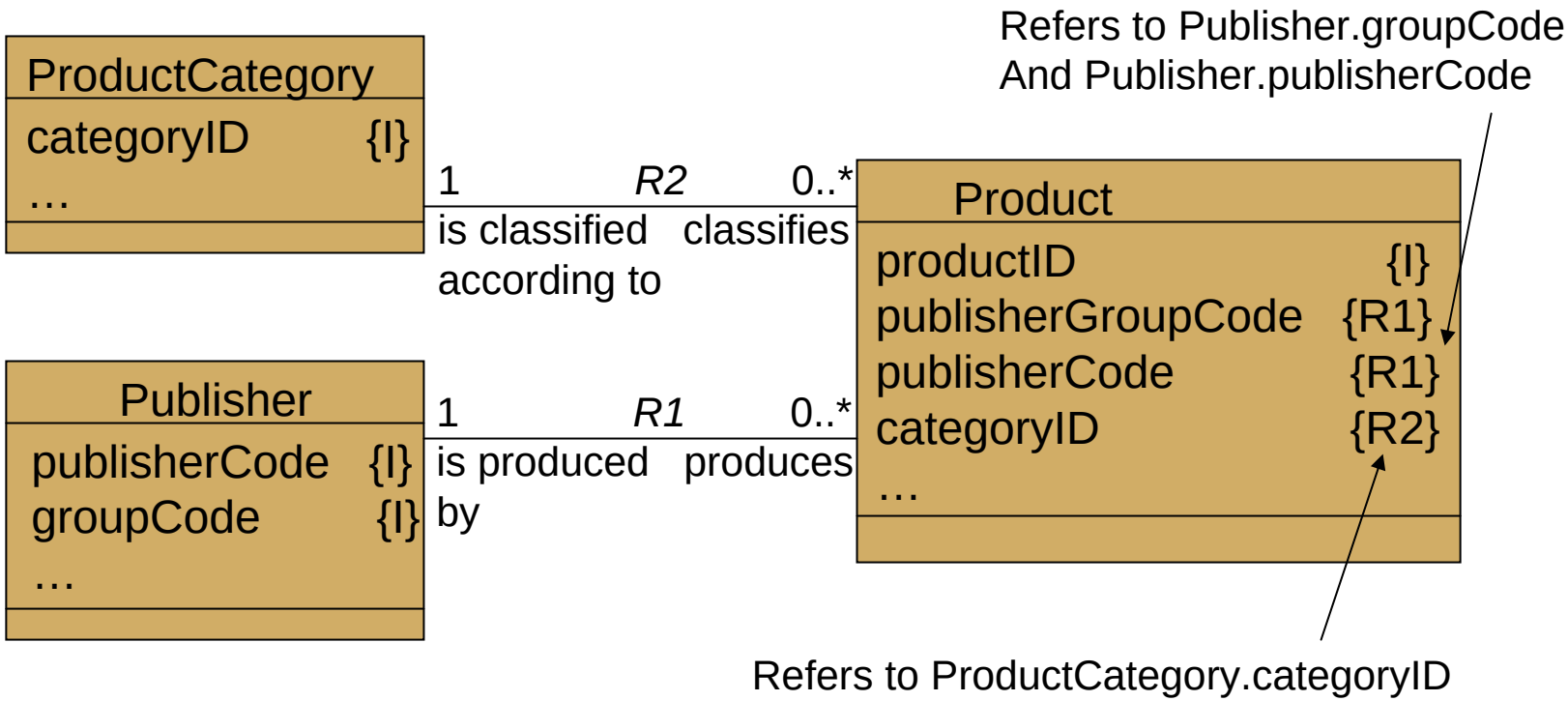
Identifier 1:
manufacturer + serial number

Identifier 2:
province + titleNumber

Identifier 3:
province + tagNumber

Examples

Referential Constraints

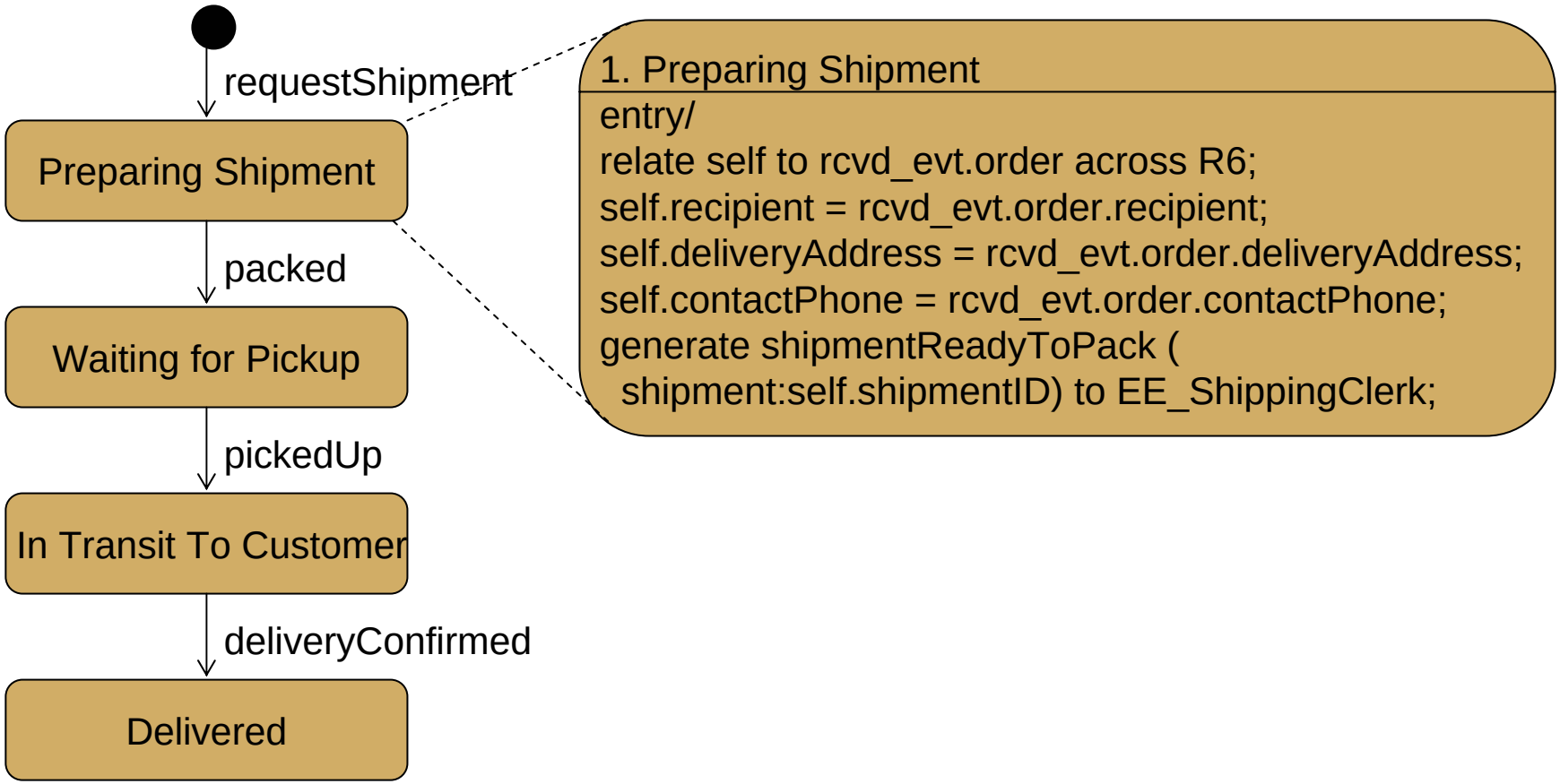


Lifecycles – State Machines

- Each instance of a class generally has a lifetime. Its behavior is a progression through various stages over time. This is known as the lifecycle of the object
- A lifecycle is formally expressed as a state machine comprising states, events, transitions and procedures
- A state machine can be expressed in terms of a State Transition Table where each row represents a state and each column an event.
- Filling the State Transition Table can result in discovering new states, events and/or transitions

Example

Shipment Class Lifecycle (state chart)



Signals and Events

- The behavior of the system is sequenced by signals between state machine instances
- Objects communicate as a result of state machine instances sending signals
- A signal is a message that carry data
- Signaling is asynchronous
- Once an event is detected by the receiver, a transition is made and the receiver executes a procedure
- Event parameters can be viewed as an object rcvd_evt created dynamically by the sender

Example

Signal with Parameter:
Generate addSelection(productID:rcvd_evt.productID,
quantity:rcvd_evt.quantity) to order;

Signal to external entity:
Generate requestChargeApproval(…) to EE_creditCardCompany;

Creating object by signaling:
generate requestShipment (order:self) to Shipment creator

Synchronization

- In executable UML time is local to each object
- There is no global time and no global synchronization mechanism
- An object synchronizes its behavior with another by sending signals
- Executable UML provides rules for signals and procedures that are designed to describe required synchronization between objects
- It’s the job of the model compiler to ensure these rules by whatever mechanism
- It’s the developer responsibility to avoid data access conflict by imposing some rules to the modeler or to the model compiler

Model Compilers

- An executable UML model compiler turns an executable UML model into an implementation using a set of decisions about the target hardware and software environment
- Model compilers can be extremely sophisticated
- There are many possible executable UML model compilers for different system architectures
- The choice of the model compiler can be based on the performance requirements and the environment of the application
- Example of an existing model compiler is the transaction safe system with rollback available from Kabira technologies
- A model compiler comprises a set of mechanisms that manages the runtime system, and a set of rules for how to weave the Executable UML models together

Summary

- Executable UML is a profile of UML
- The Executable UML presented here is not the only possible Executable UML
- Executable UML is not a standard
- It relies on model compilers to generate executable code
- Executable UML models are separate from any implementation, yet can readily be executed to test for completeness and correctness
- The choice of a model compiler affects the performance of the generated code