状态机图

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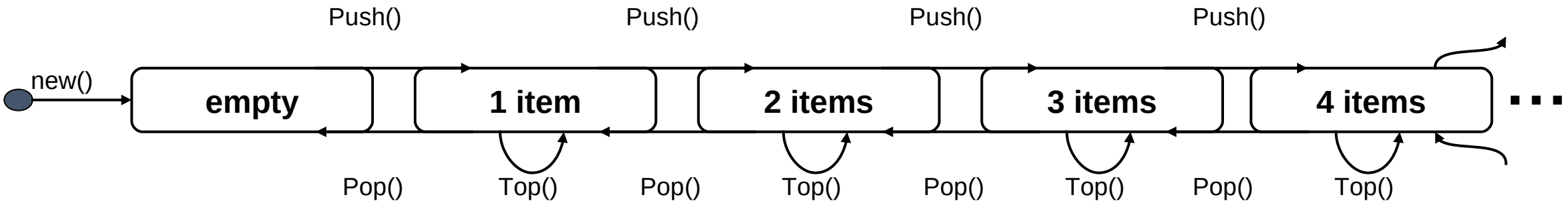
Modelling "State"

- What is State?
  - State space for an object
  - concrete vs. abstract states
- Finite State Machines
  - states and transitions
  - events and actions
- Modularized State machine models: Statecharts
  - superstates and substates
  - Guidelines for drawing statecharts

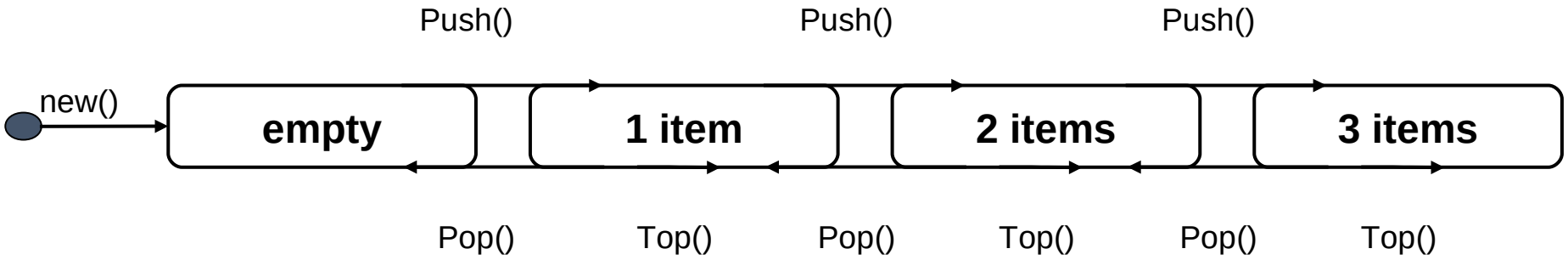
Getting objects to behave

- All objects have "state"
  - The object either exists or it doesn't
  - If it exists, then it has a value for each of its attributes
  - Each possible assignment of values to attributes is a "state"
    - (and non-existence of the object is also a state)
- E.g. For a stack object



What does the model mean?

- Finite State Machines
  - There are a finite number of states (all attributes have finite ranges)
    - E.g. imagine a stack with max length = 3



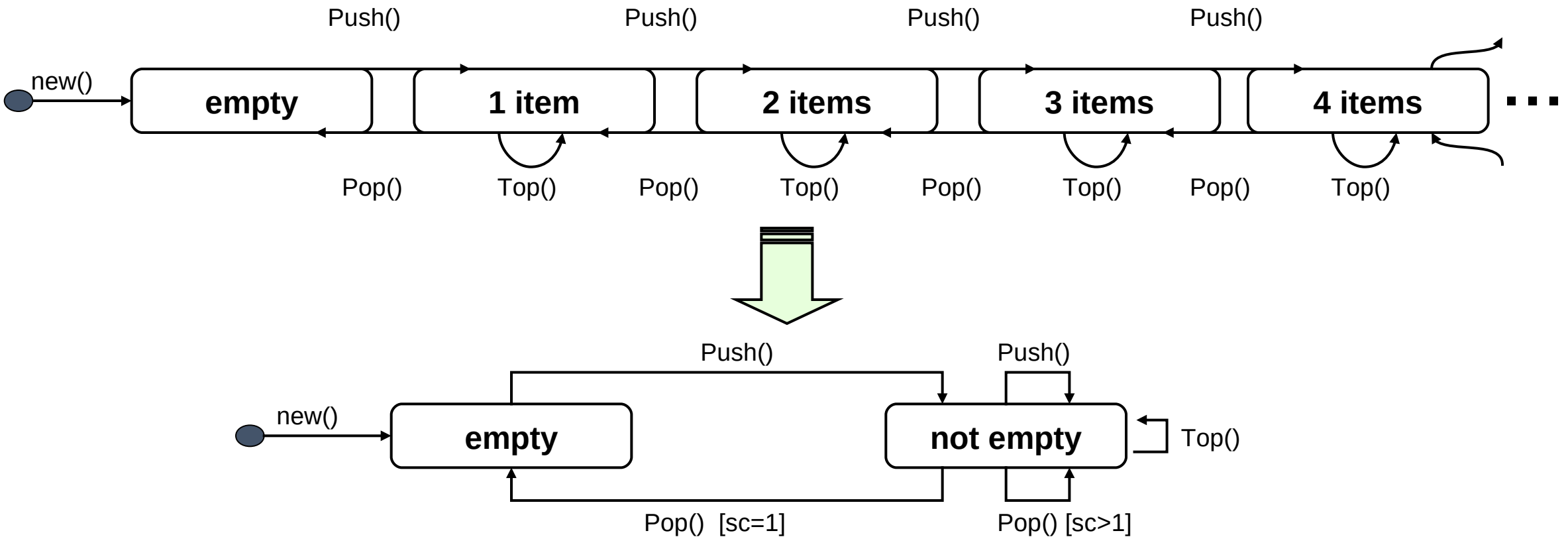
  - The model specifies a set of traces
    - E.g. new();Push();Push();Top();Pop();Push()…
    - E.g. new();Push();Pop();Push();Pop()…
    - There may be an infinite number of traces (and traces may be of infinite length)
  - The model excludes some behaviours
    - E.g. no trace can start with a Pop()
    - E.g. no trace may have more Pops than Pushes
    - E.g. no trace may have more than 3 Pushes without a Pop in between

Abstraction

- The state space of most objects is enormous
  - State space size is the product of the range of each attribute
    - E.g. object with five boolean attributes: 2^5+1 states
    - E.g. object with five integer attributes: $(maxint)^5+1$ states
    - E.g. object with five real-valued attributes: …?
  - If we ignore computer representation limits, the state space is infinite

- Only part of that state space is "interesting"
  - Some states are not reachable
  - Integer and real values usually only vary within some relevant range
  - Often, we're only interested in certain thresholds:
    - E.g. for Age, we may be interested in age<18; 18≤age≤65; and age>65
    - E.g. for Cost, we may want to distinguish cost≤budget, cost=0, cost>budget, and cost>(budget+10%)

Collapsing the state space



- The abstraction usually permits more traces
  - E.g. this model does not prevent traces with more pops than pushes
  - But it still says something useful

What are we modelling?

(D) Observed states of an application domain entity?

- E.g. a phone can be idle, ringing, connected, …

- Model shows the states an entity can be in, and how events can change its state
- This is an indicative model

(R) Required behaviour of an application domain entity?

- E.g. a telephone switch shall connect the phones only when the callee accepts the call

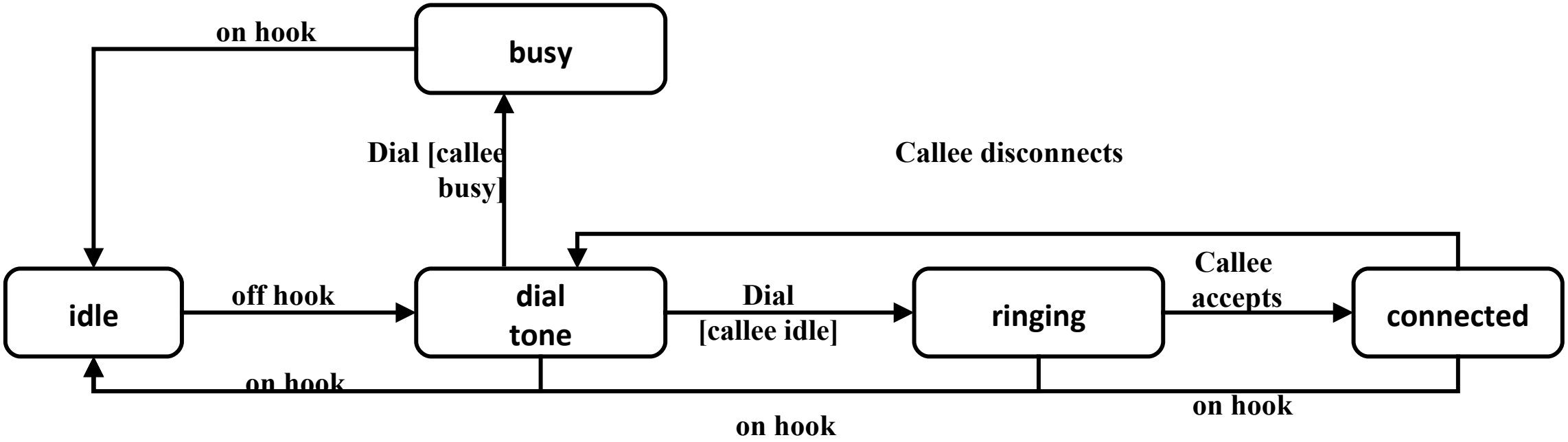
- Model distinguishes between traces that are desired and those that are not
- This is an optative model

(S) Specified behaviour of a machine domain entity?

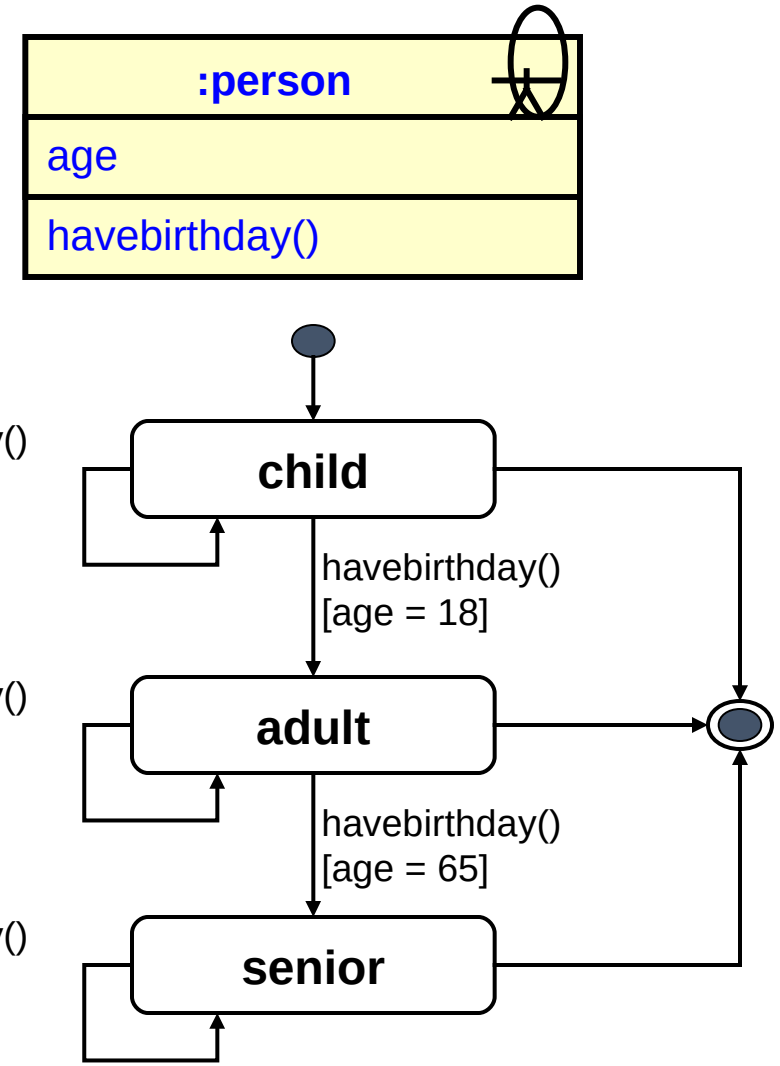
- E.g. when the user presses the 'connect' button the incoming call shall be connected

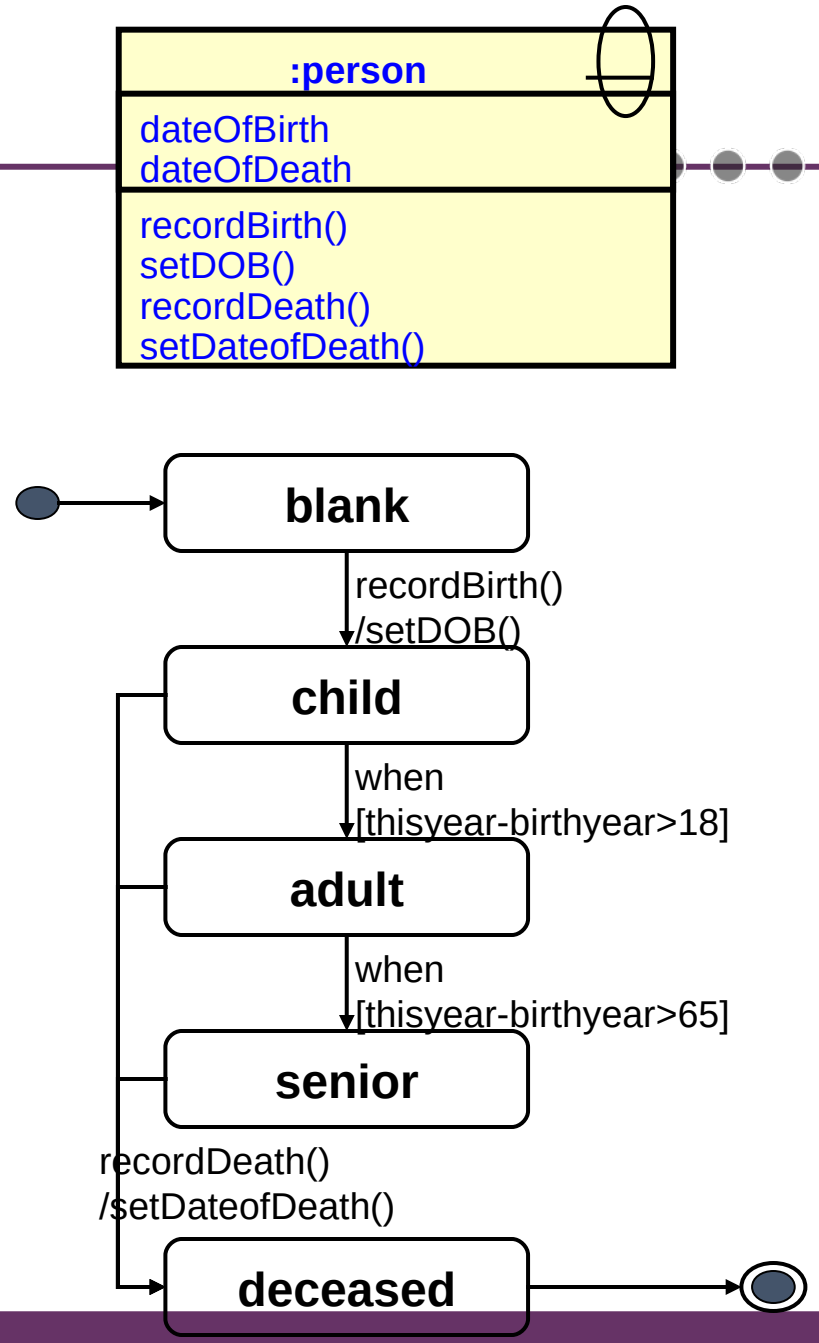
- Model specifies how the machine should respond to input events
- This is an optative model, in which all events are shared phenomena

Is this model indicative or optative?



the world vs. the machine





StateCharts

- States
  - "interesting" configurations of the values of an object's attributes
  - may include a specification of action to be taken on entry or exit
  - States may be nested
  - States may be "on" or "off" at any given moment
- Transitions
  - Are enabled when the state is "on"; disabled otherwise
  - Every transition has an event that acts as a trigger
  - A transition may also have a condition (or guard)
  - A transition may also cause some action to be taken
  - When a transition is enabled, it can fire if the trigger event occurs and its guard is true
  - Syntax: event [guard] / action
- Events
  - occurrence of stimuli that can trigger an object to change its state
  - determine when transitions can fire

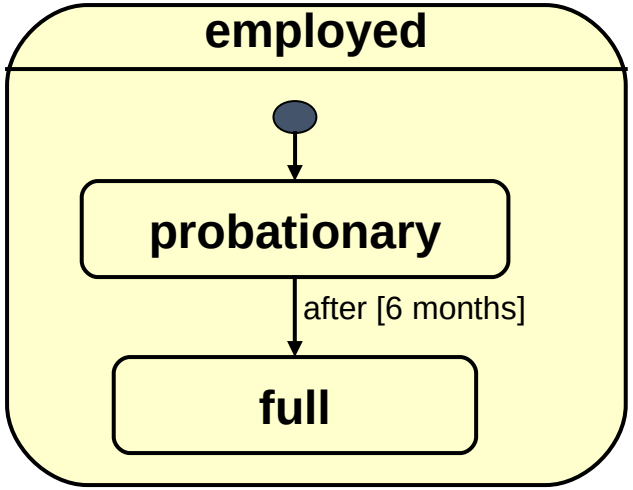
Superstates

States can be nested, to make diagrams simpler

- *A superstate consists of one or more states.*
- *Superstates make it possible to view a state diagram at different levels of abstraction.*

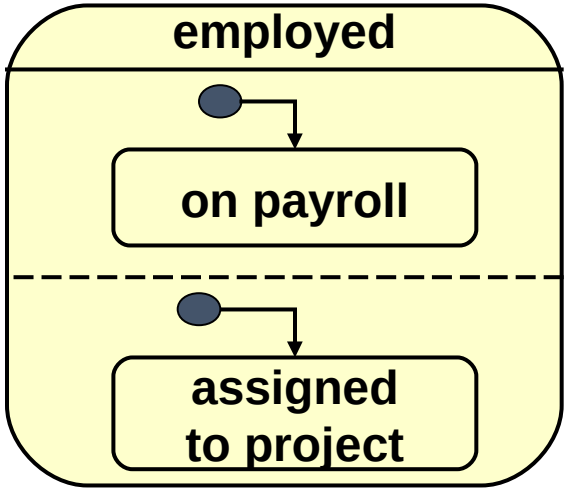
OR superstates

- when the superstate is "on", only one of its substates is "on"

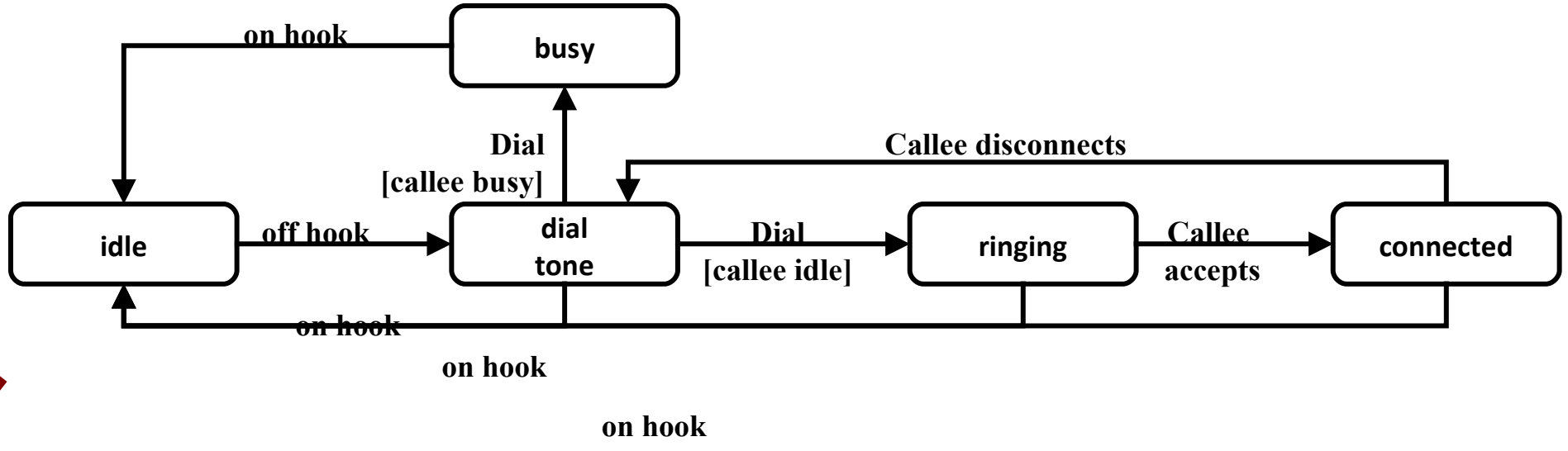


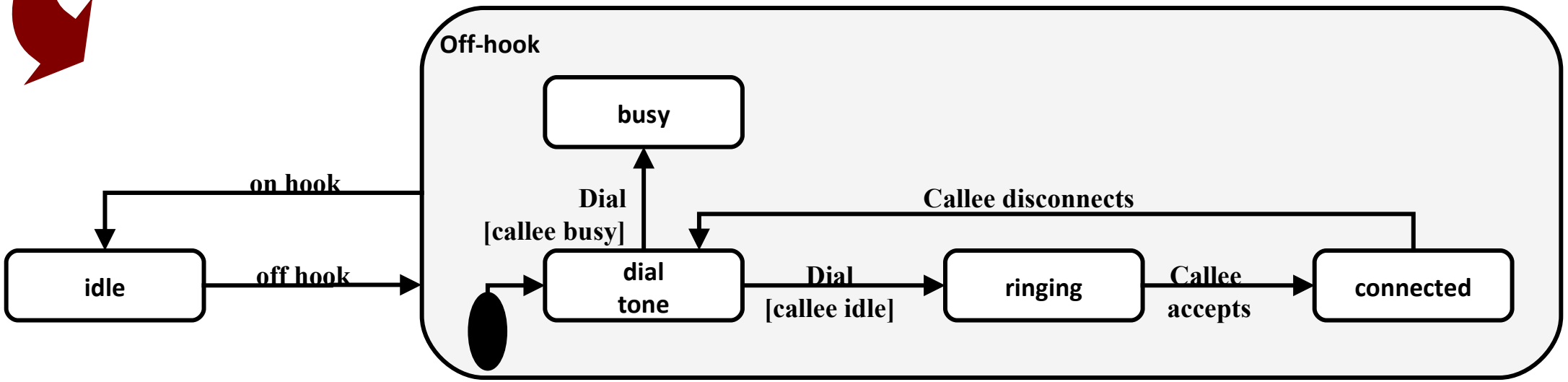
AND superstates (concurrent substates)

- When the superstate is "on", all of its states are also "on"
- Usually, the AND substates will be nested further as OR superstates

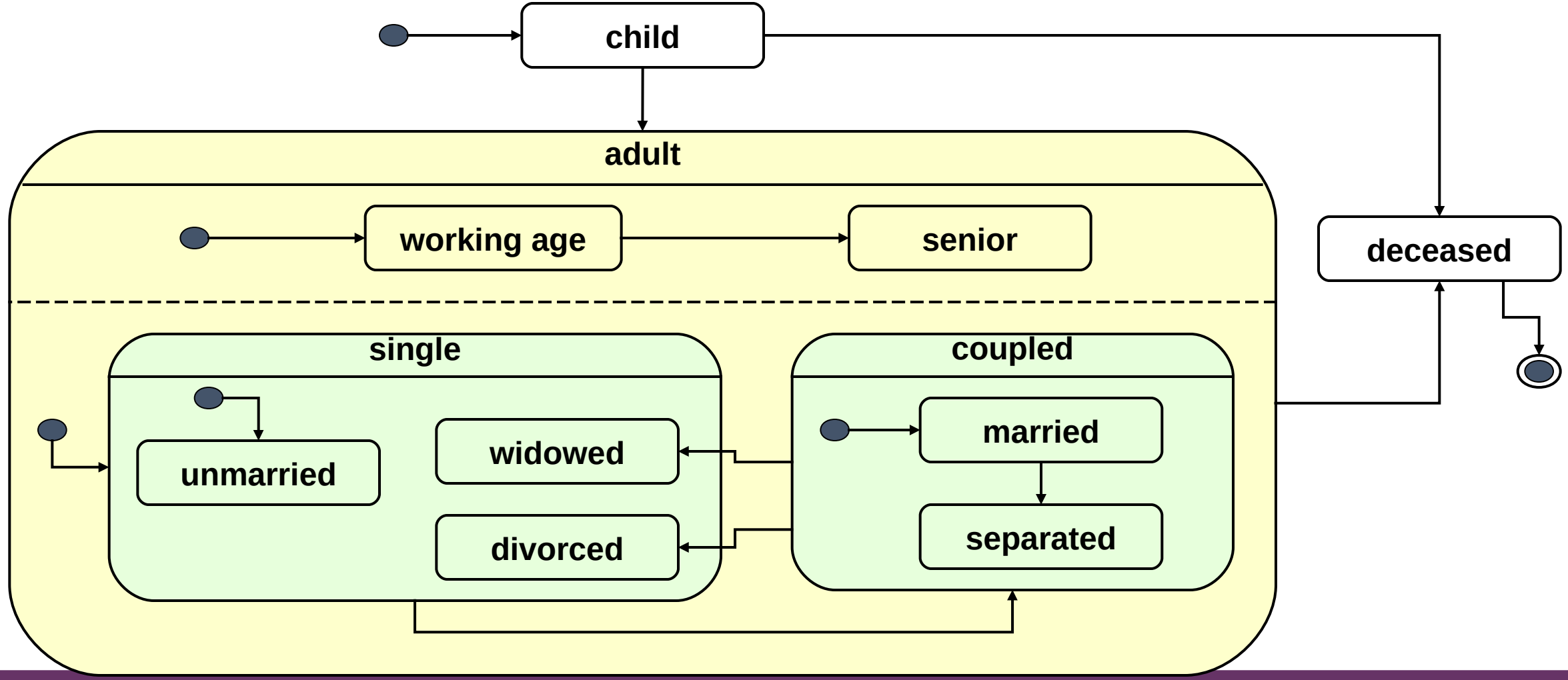


Superstates example





A more detailed example



States in UML

- A state represents a time period during which
  - A predicate is true
    - e.g. (budget - expenses) > 0,
  - An action is being performed, or an event is awaited:
    - e.g. checking inventory for order items
    - e.g. waiting for arrival of a missing order item
- States can have associated activities:
  - do/activity
    - carries out some activity for as long as the state is "on"
  - entry/action and exit/action
    - carry out the action whenever the state is entered (exited)
  - include/stateDiagramName
    - "calls" another state diagram, allowing state diagrams to be nested

Events in UML

- Events are happenings the system needs to know about
  - Must be relevant to the system (or object) being modelled
  - Must be modellable as an instantaneous occurance (from the system's point of view)
    - E.g. completing an assignment, failing an exam, a system crash
  - Are implemented by message passing in an OO Design
- In UML, there are four types of events:
  - *Change events* occur when a condition becomes true
    - denoted by the keyword 'when'
    - e.g. when[balance < 0]
  - *Call events* occur when an object receives a call for one of its operations to be perfomed
  - *Signal events* occur when an object receives an explicit (real-time) signal
  - *Elapsed-time events* mark the passage of a designated period of time
    - e.g. after[10 seconds]

(1) **Call event**: The event of receiving a call for an operation that is implemented by actions on state machine transitions.

- Call event 的语法格式如下：

  事件名（[逗号分隔的参数列表]）

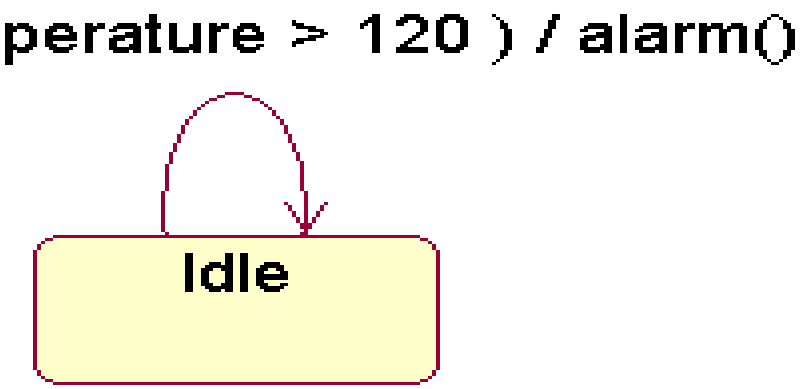
其中参数列表中的参数格式为：

  参数名：类型

例：

(2) **Change event**: The event of a Boolean expression becoming satisfied because of a change to one or more of the values it references.

- Change event 用关键字 when 表示。例

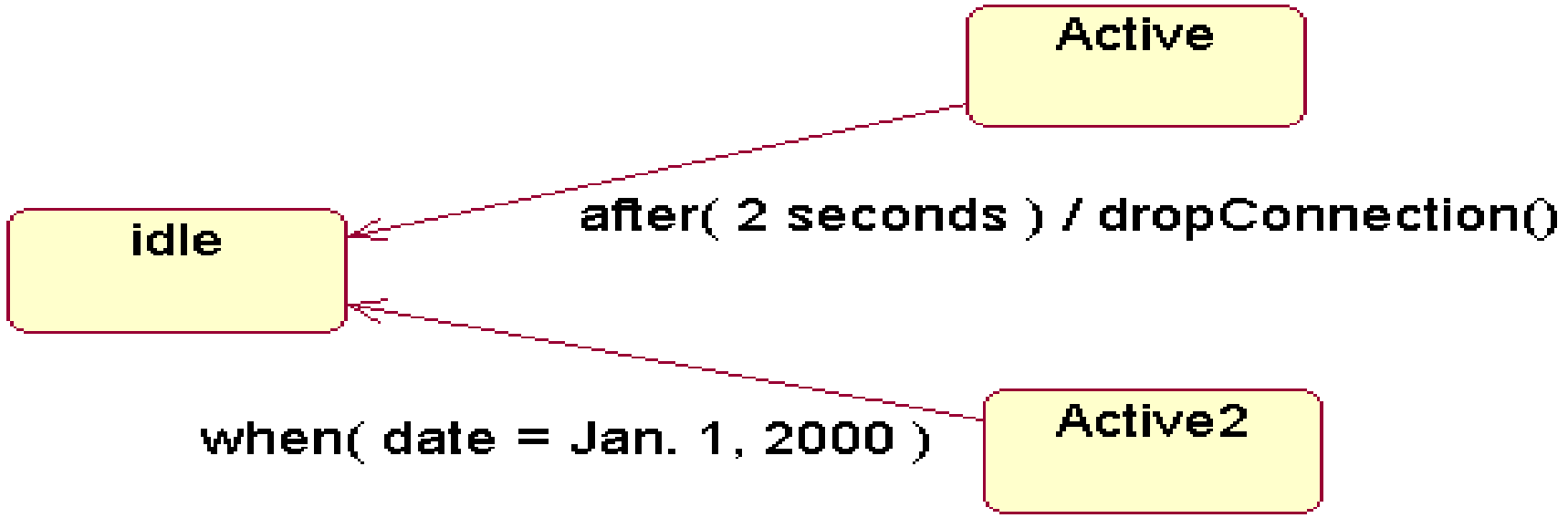


- Change event 和警戒条件 (guard condition) 的区别：
  - 警戒条件只在所相关的事件出现后计算一次，如果值为 false，则不进行状态转移。

(3) **Time event**: An event that denotes the satisfaction of a time expression, such as the occurrence of an absolute time or the passage of a given amount of time after an object enters a state.

- Time event 用关键字 after 或 when 表示。

例：



(4) **Signal event**: An event that is the receipt by an object of a signal sent to it, which may trigger a transition in its state machine.

- Signal event 的语法格式和 Call event 一样。

- 信号事件是一个异步事件，调用事件一般是一个同步事件。

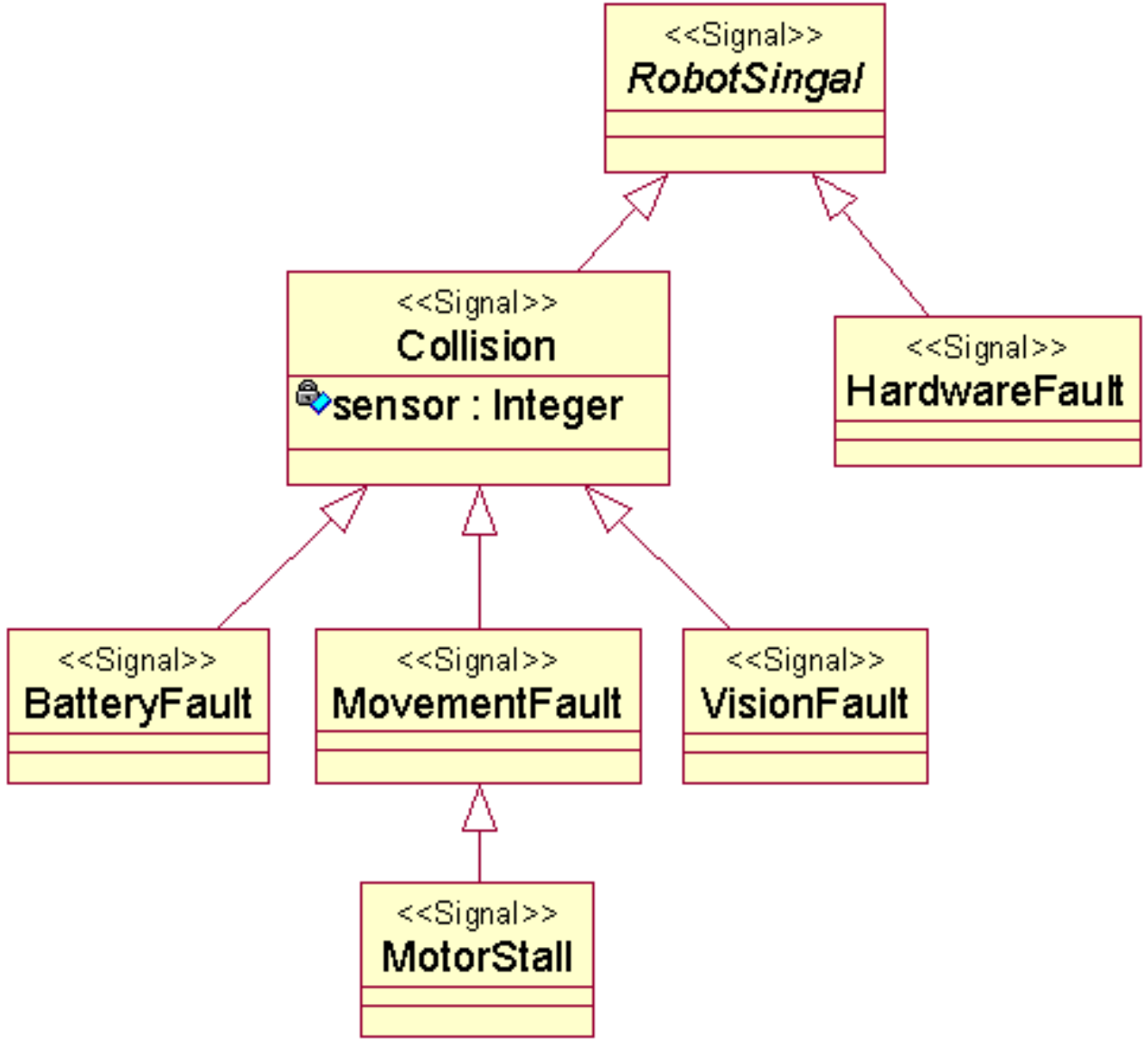
Signal(信号)

- 信号表示由一个对象异步地发送、并由另一对象接收的一个已命名的对象。
- A signal is a kind of event that represents the specification of an asynchronous communication between objects.

说明：

- 信号用版型为 <<signal>> 的类图标表示。
- 信号之间可以具有泛化关系，形成层次结构。
- 在 UML 中，例外 (exception) 是信号的一种。

- 例：信号之间泛化关系的例子。



Checking your Statecharts

- Consistency Checks
  - All events in a statechart should appear as:
    - operations of an appropriate class in the class diagram
  - All actions in a statechart should appear as:
    - operations of an appropriate class in the class diagram
- Style Guidelines
  - Give each state a unique, meaningful name
  - Only use superstates when the state behaviour is genuinely complex
  - Do not show too much detail on a single statechart
  - Use guard conditions carefully to ensure statechart is unambiguous
    - Statecharts should be deterministic (unless there is a good reason)
- You probably shouldn't be using statecharts if:
  - you find that most transitions are fired "when the state completes"
  - many of the trigger events are sent from the object to itself
  - your states do not correspond to the attribute assignments of the class

Statecharts & Relationship to Other Diagrams

- Events on the statechart diagram should appear as an incoming message for the appropriate object on a sequence and collaboration diagram.

  状态图中的事件应为顺序图 / 交互图中该对象的输入消息

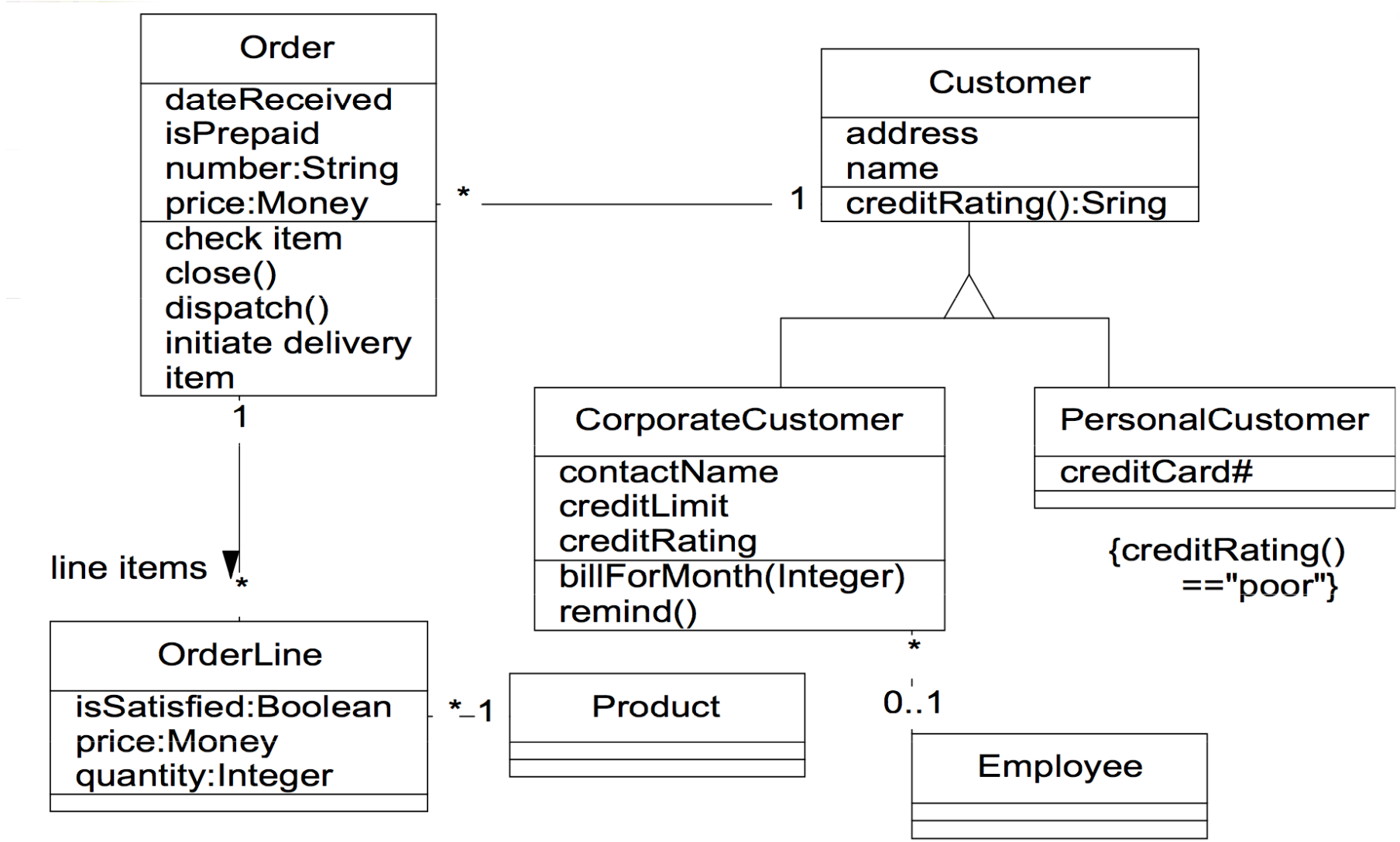
- A statechart diagram is prepared for every object class in the Class Diagram with non-trivial behaviour.

  状态图应针对类图中具有重要行为的类进行建模

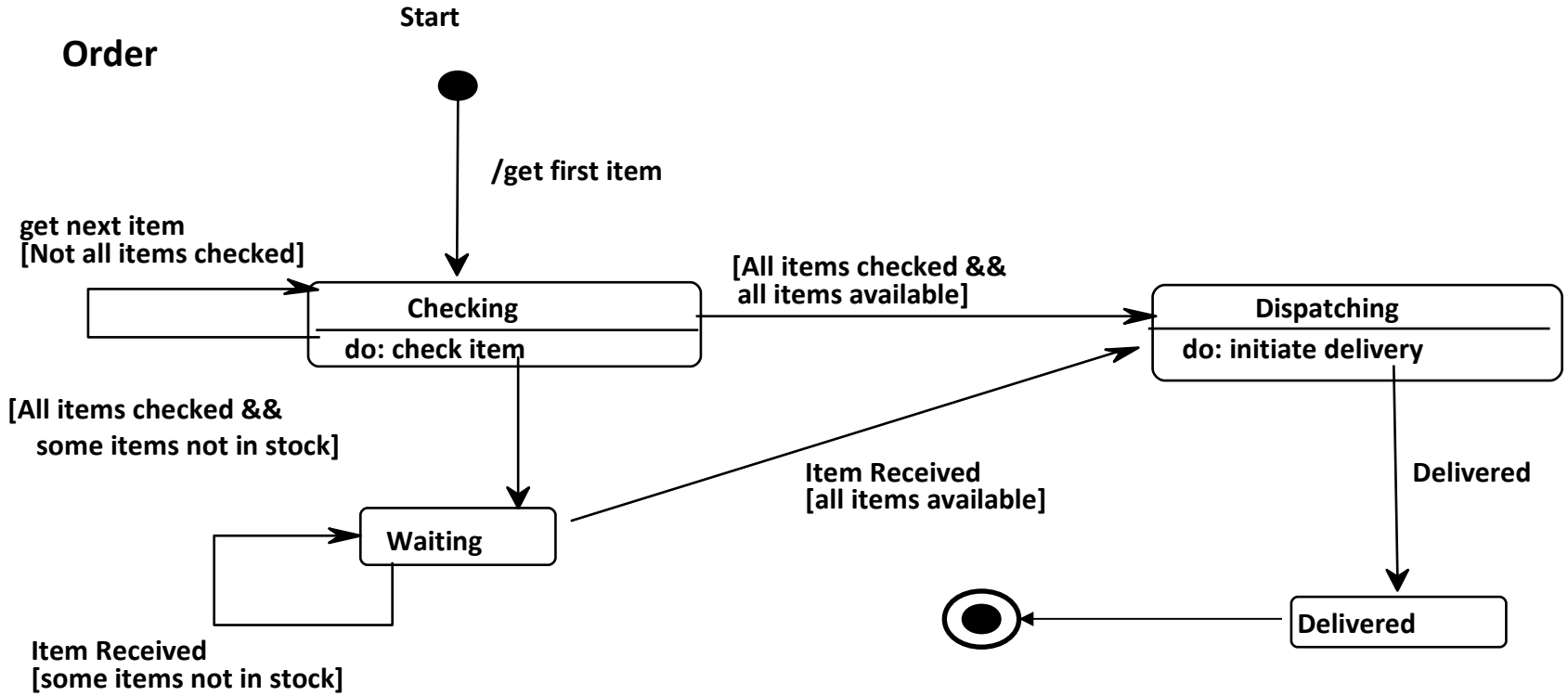
- Every event should correspond to an operation on the appropriate class.

  每个事件均映射为相应类的一个动作

Class Diagram: Order Processing



Order Statechart Diagram



Add a new state and separate transitions to the diagram to show that an order can be cancelled at any point before it is delivered.

Supertransition 超级迁移

- Where transitions may occur from several states to a single state the Statechart Diagram may show this single state as a *Supertransition*

  可将由多个状态发出的指向同一个状态的迁移定义为超级迁移

  - e.g. a Purchase Order may be cancelled at any point prior to delivery.

- This may be drawn with several transitions or by creating a Superstate.

  超级迁移可图形表示为多条迁移，或为之创建一个超级状态

Complex Statechart Transitions

- Transition to superstate boundary ≡ transition to initial state of the superstate.

  指向组合状态边界的迁移等价于指向该组合状态初态的迁移

  - entry actions of all regions entered are performed

    所有属于该组合状态的入口条件将被执行

- There may also be transitions directly into a complex state region (like program "gotos").

  迁移可直接指向组合状态的子状态

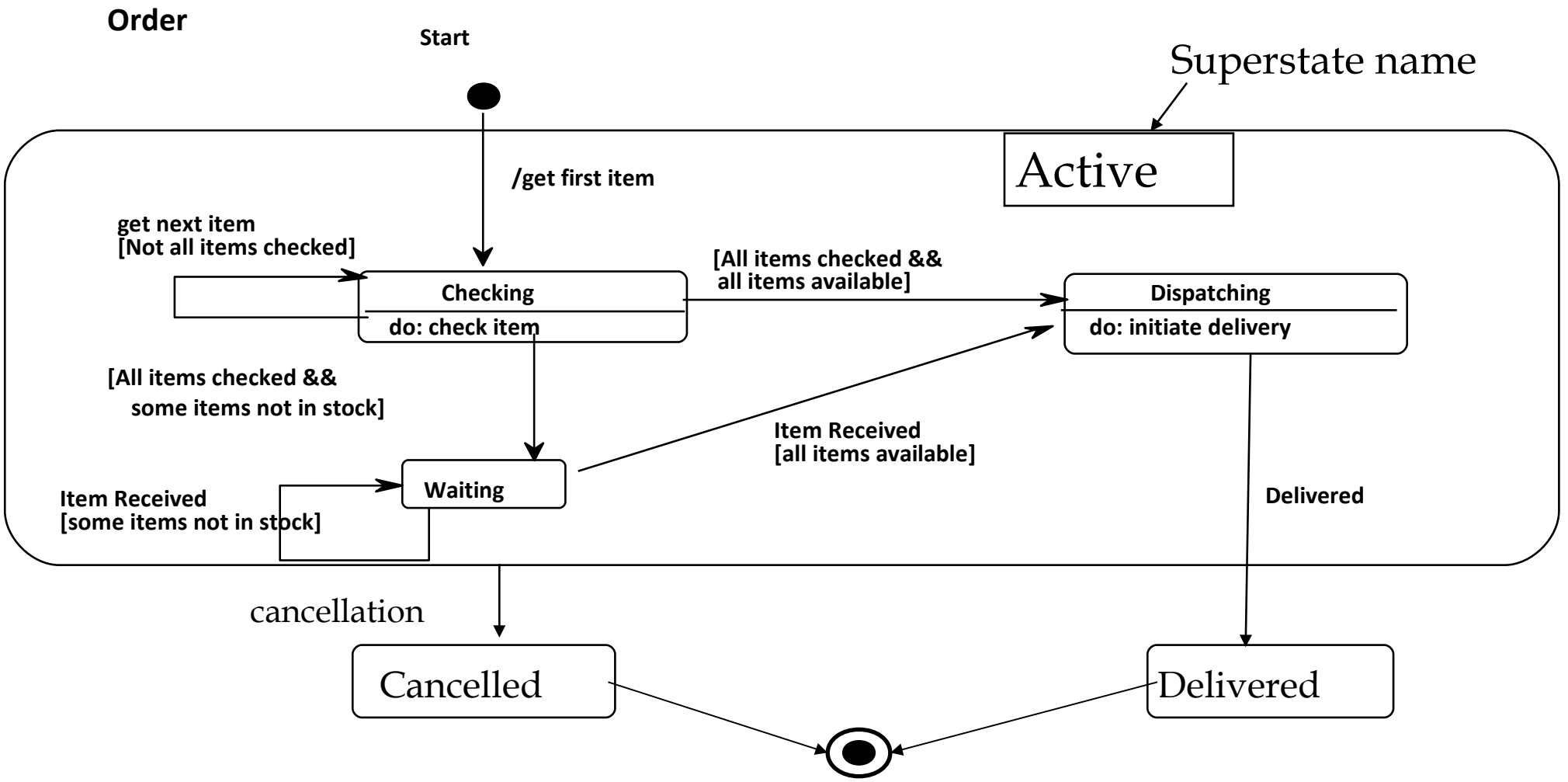
- Transition from a superstate boundary ≡ transition from the final state of the superstate

  从组合状态边界转出的迁移等价于从该组合状态的终态发出迁移

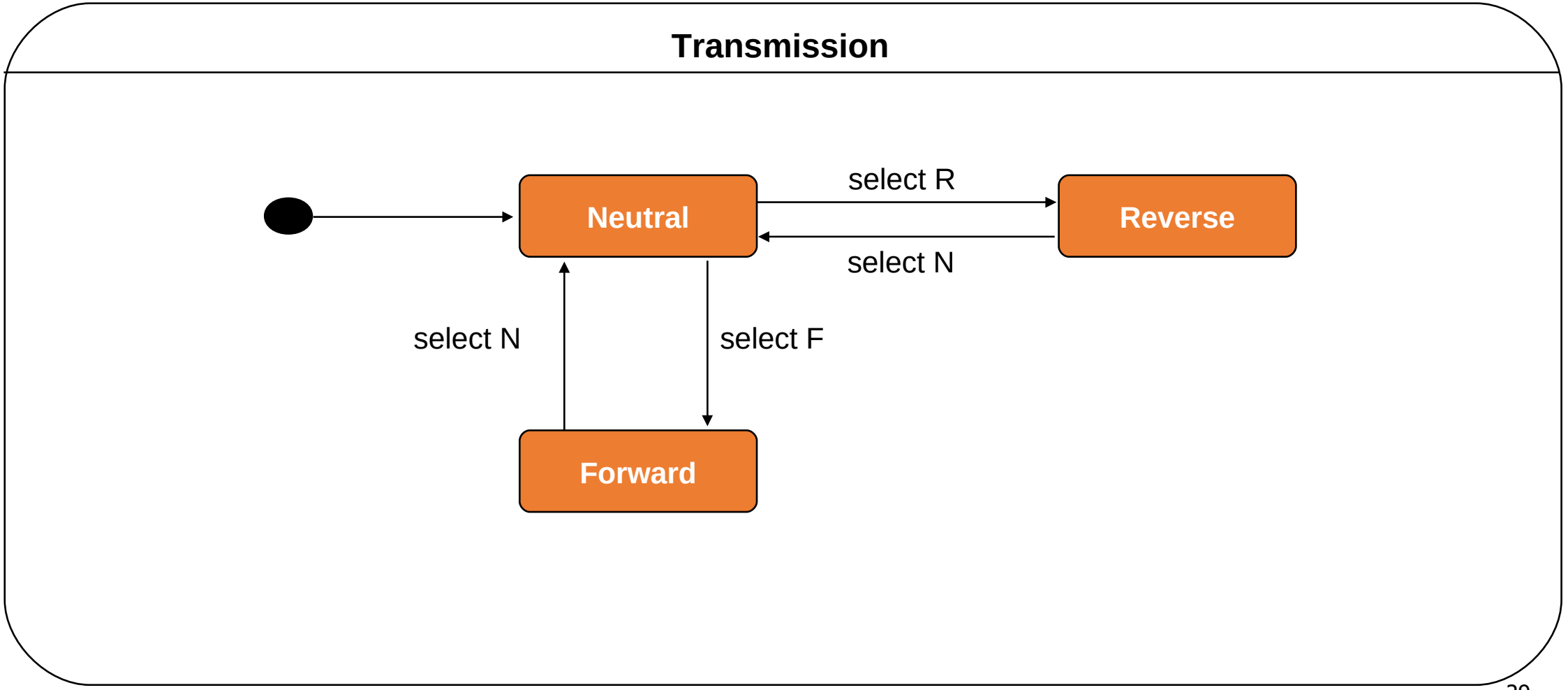
  - exit actions of all regions exited are performed

    所有出口条件均将被执行

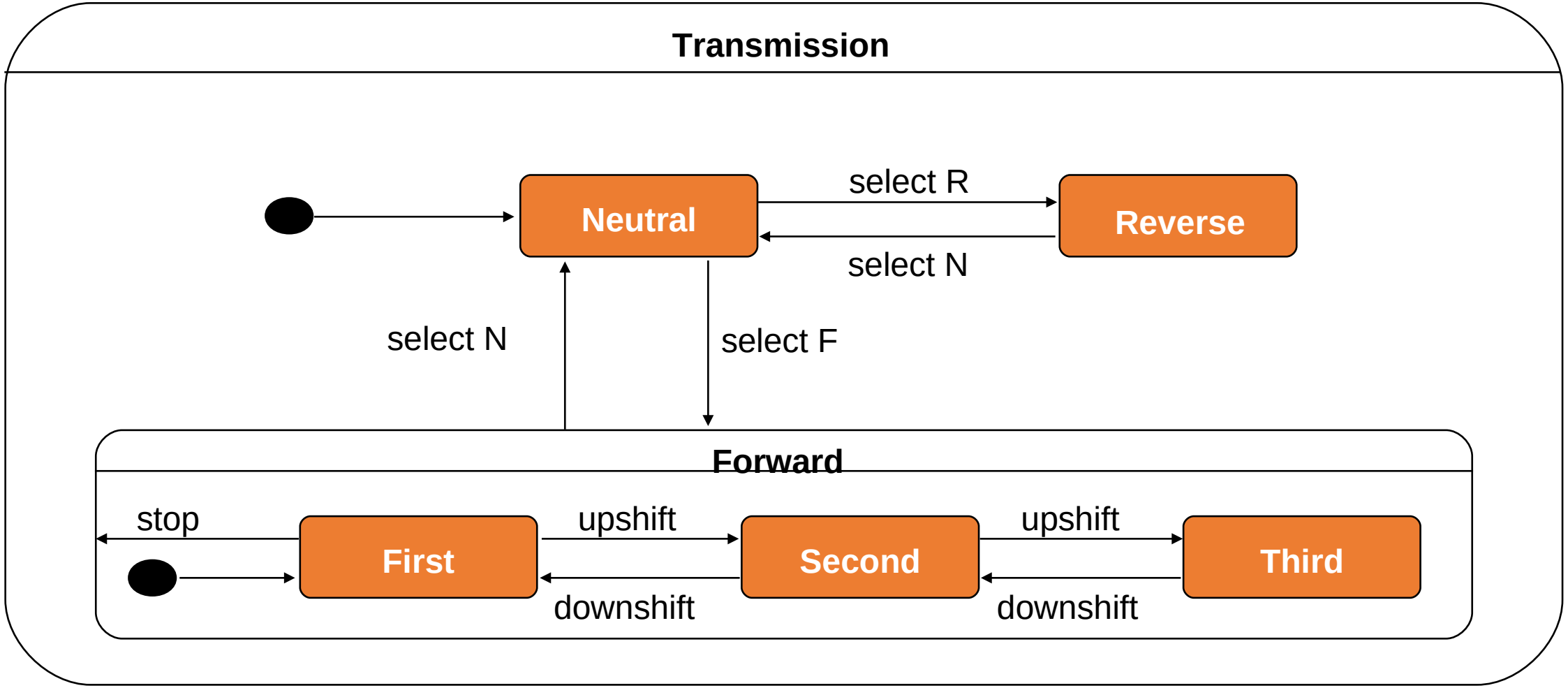
Order Statechart Diagram: Superstates & Supertransition



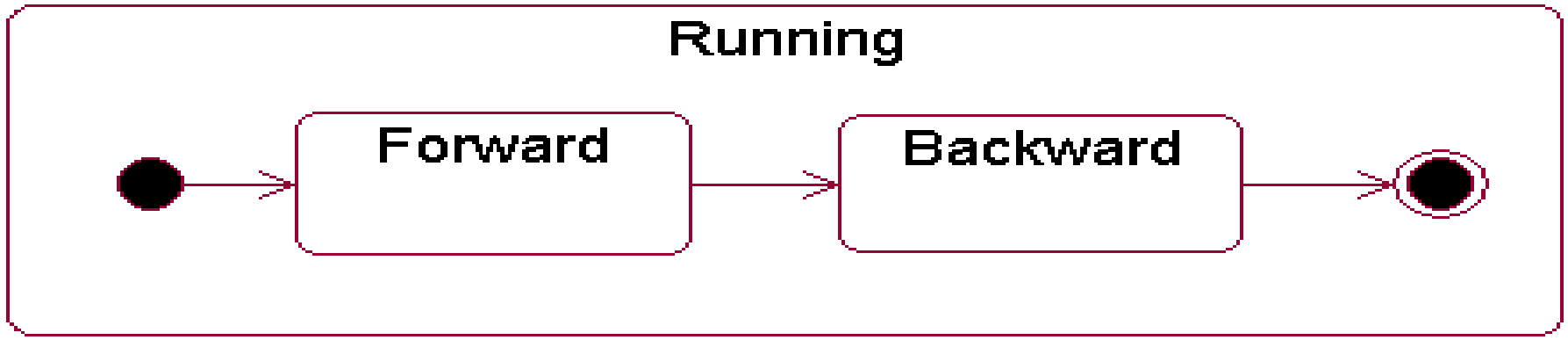
Nested (Super) States



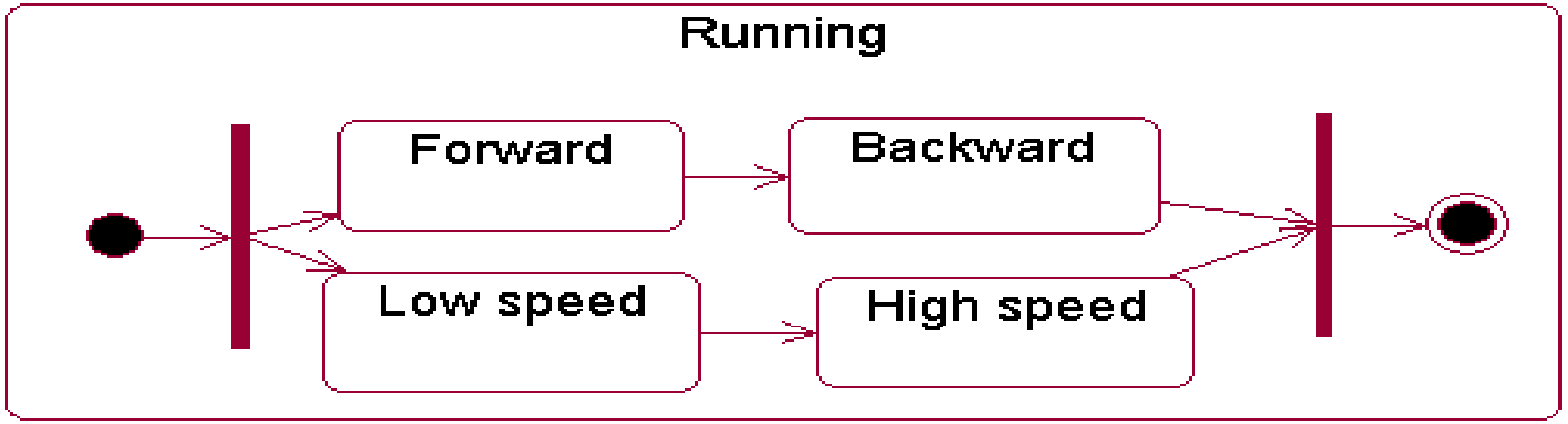
Nested (Super) States



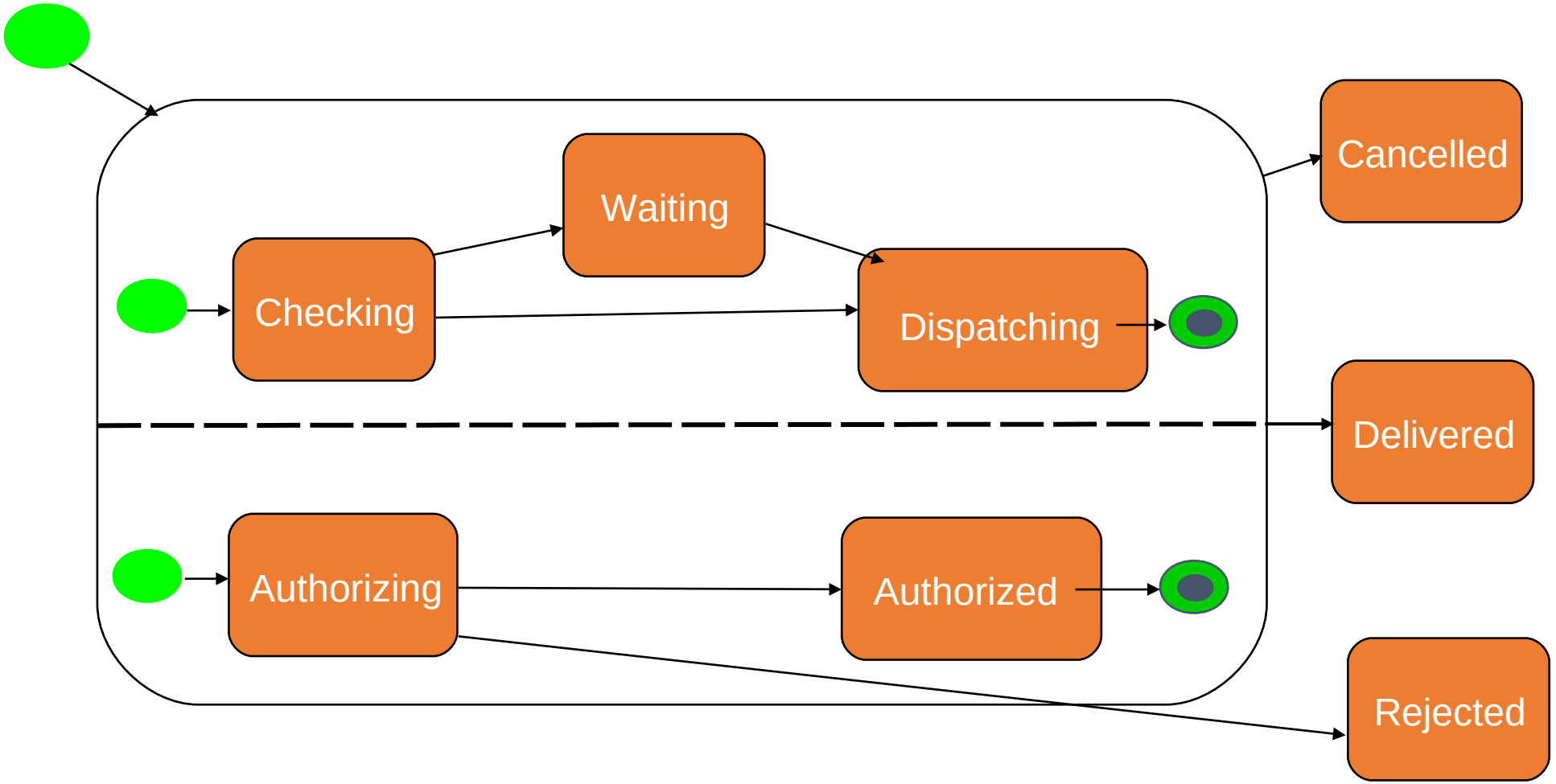
例 1 ： 子状态之间 “ or” 关系的例子。



例 2 ： 子状态之间 “ and” 关系的例子。



Concurrent States:Order

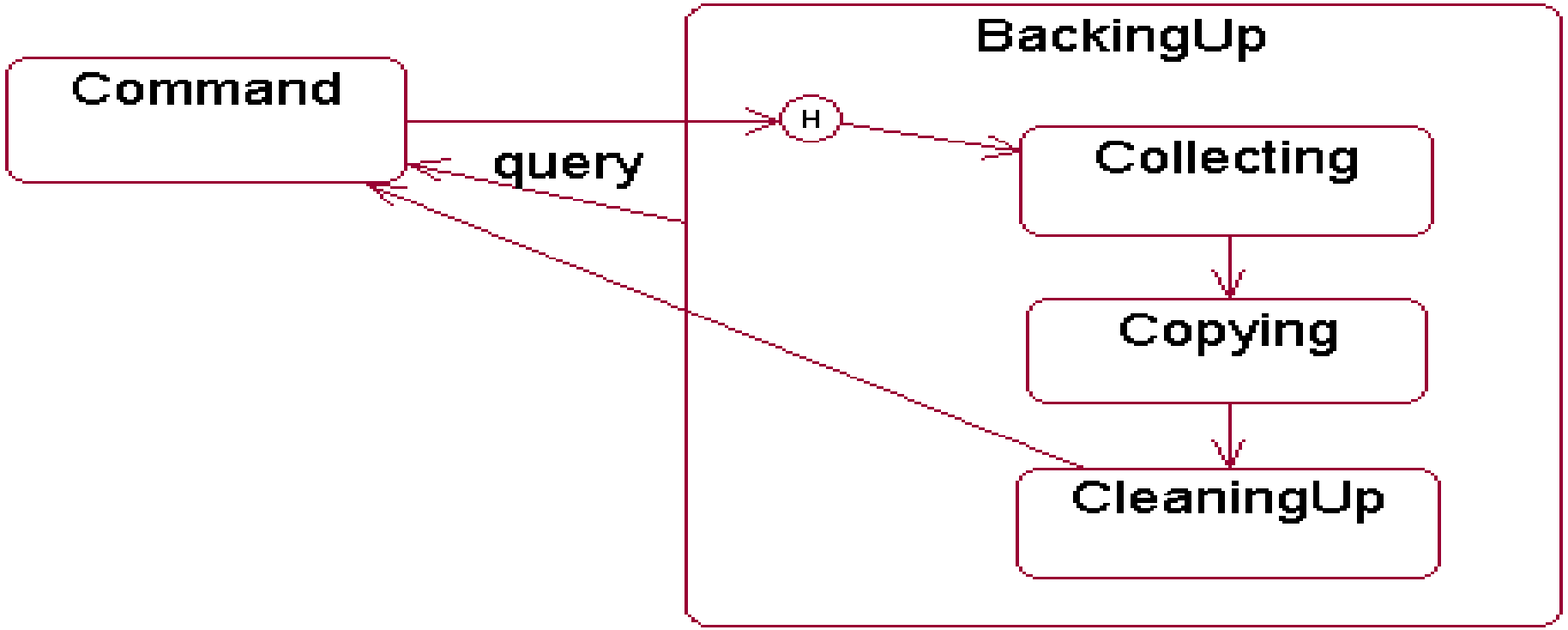


History State(历史状态)

- History State: A pseudostate whose activation restores the previously active state within a composite state.
- 使用历史状态，可以记住从组合状态中退出时所处的子状态，当再次进入组合状态时，可直接进入到这个子状态，而不是再次从组合状态的初态开始。

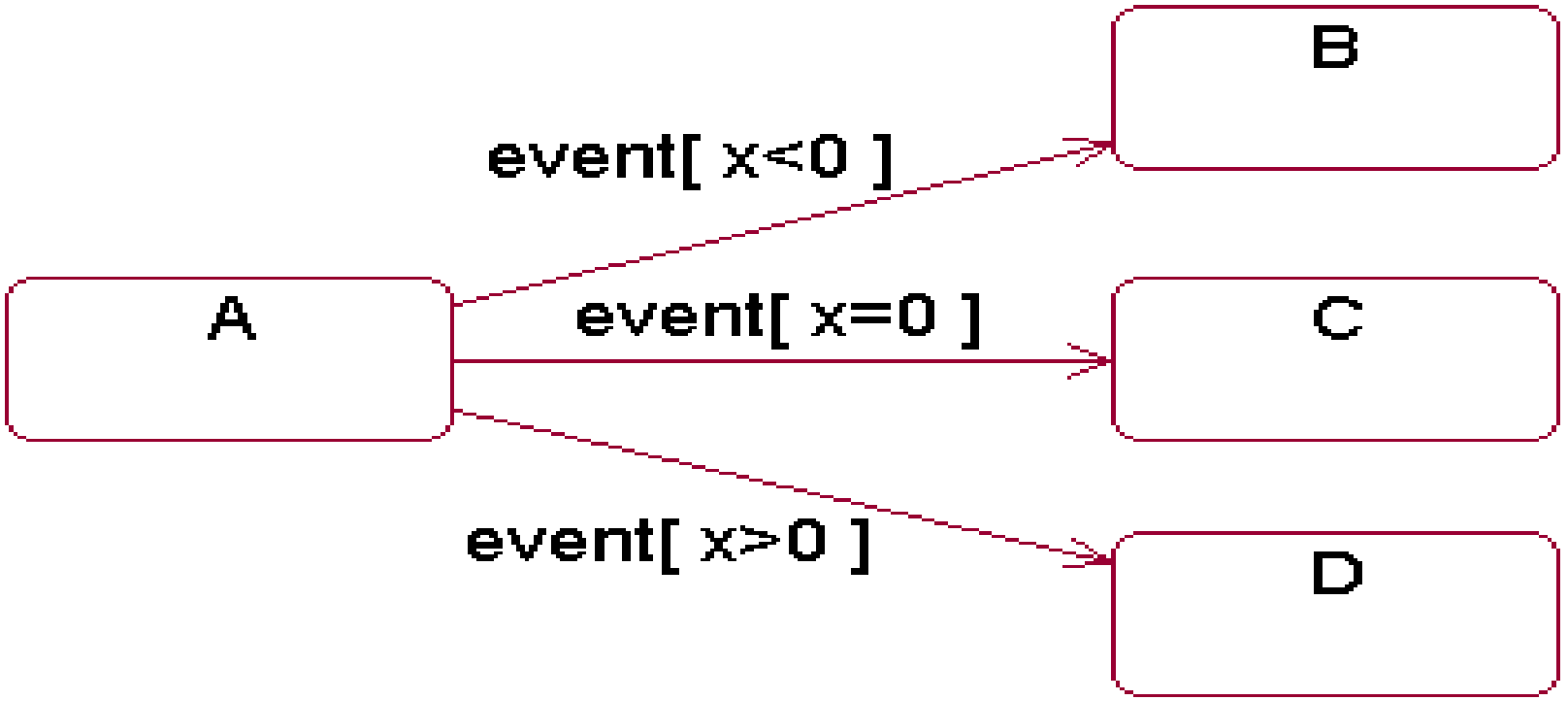
- H 和 H* 的区别：
  - H 只记住最外层的组合状态的历史。
  - H* 可记住任何深度的组合状态的历史。

例：历史状态的例子。



- 一个转移包括五部分： source state, event trigger, guard condition, action, target state.
- 对于一个给定的状态，最终只能产生一个转移，因此从相同的状态出来的、事件相同的几个转移之间的条件应该是互斥的。

例：



Action(动作)

- An action(动作) is an executable atomic computation.
- 一个动作是一个可执行的原子计算。

说明：

- 动作是原子的，不可被中断的，其执行时间可忽略不计的。
- UML 并没有规定描述 action 的语言格式，一般建模时采用实际的程序设计语言来描述。

- 两种特殊的动作：entry action(进入动作) 和 exit action(退出动作) 。
  - Entry 动作：进入状态时执行的活动，格式如下：

    'entry' '/'action-expression
  - Exit 动作：退出状态时执行的活动，格式如下：

    'exit' '/'action-expression

  (其中 action-expression 可以用到对象本身的属性和输入事件的参数)

Statecharts & Relationship to Other Diagrams

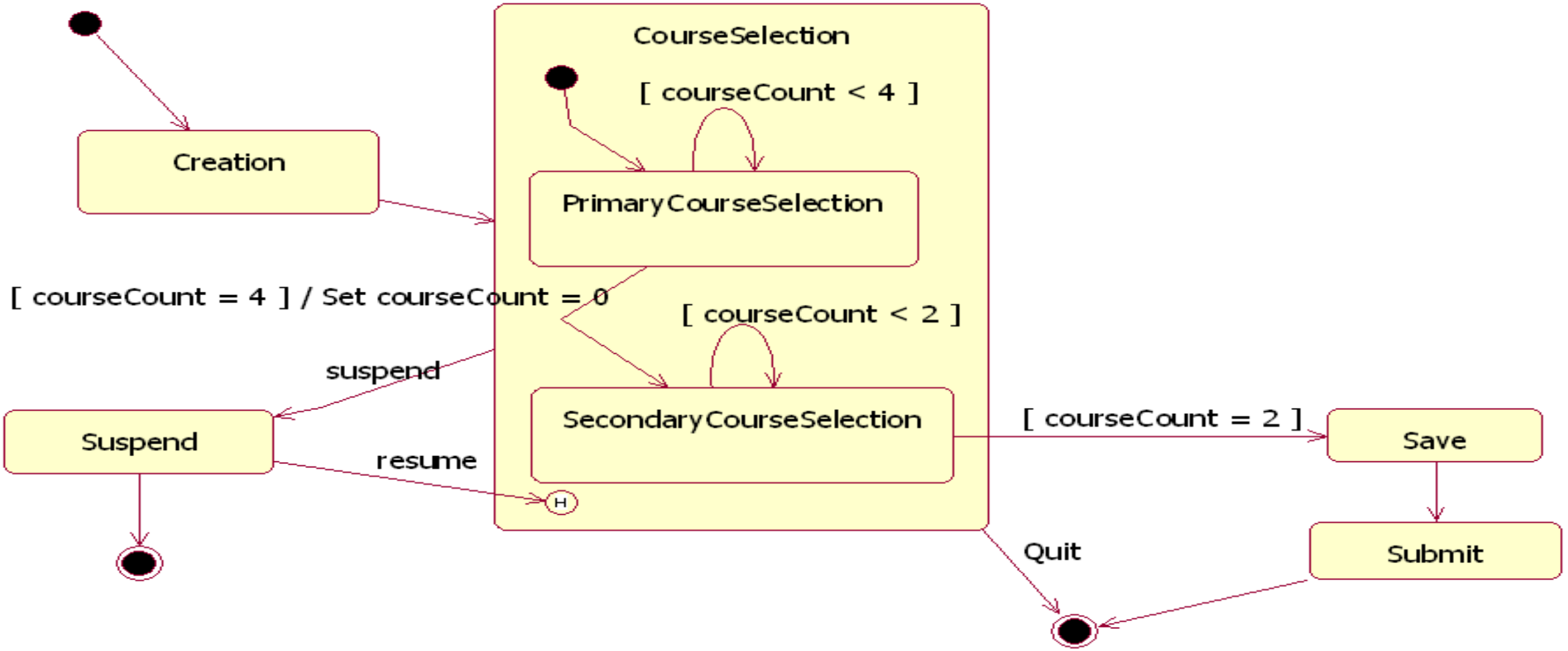
- Every action should correspond to the execution of an operation on the appropriate class.

  每个动作均对应于某个类操作的一次具体执行
- Entry/Action, Exit/Action and Do/Activity within a State will normally be equivalent to Operations in the Class Diagram.

  状态图中的操作定义等价于类图中的操作定义
- Every outgoing message sent from a statechart must corrrespond to an operation on another class.

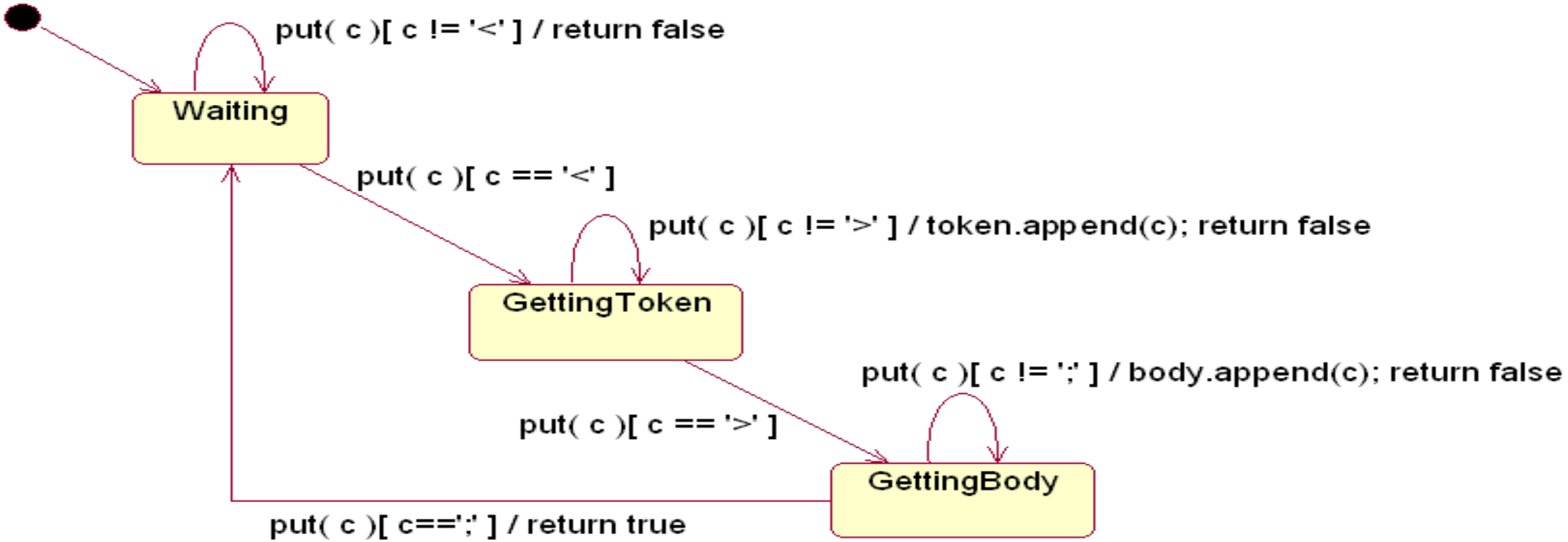
  状态图中的每个输出消息均对应于其他类的一个操作

类型为 RegistrationController 的对象的状态图：



状态图的工具支持

- 正向工程：根据状态图生成代码。例：



```
class MessageParser {
public boolean put(char c) {
    switch (state) {
        case Waiting:
            if (c == '<') {
                state = GettingToken;
                token = new StringBuffer();
                body = new StringBuffer();
            }
            break;
        case GettingToken :
            if (c == '>')
                state = GettingBody;
            else
                token.append(c);
            break;
        case GettingBody :
            if (c == ';') {
                state = Waiting;
                return true;
            }
            else
                body.append(c);
        }
        return false;
    }
public StringBuffer getToken() {
    return token;
}
public StringBuffer getBody() {
    return body;
}
private final static int Waiting = 0;
private final static int GettingToken = 1;
private final static int GettingBody = 2;
private int state = Waiting;
private StringBuffer token, body;
}
```

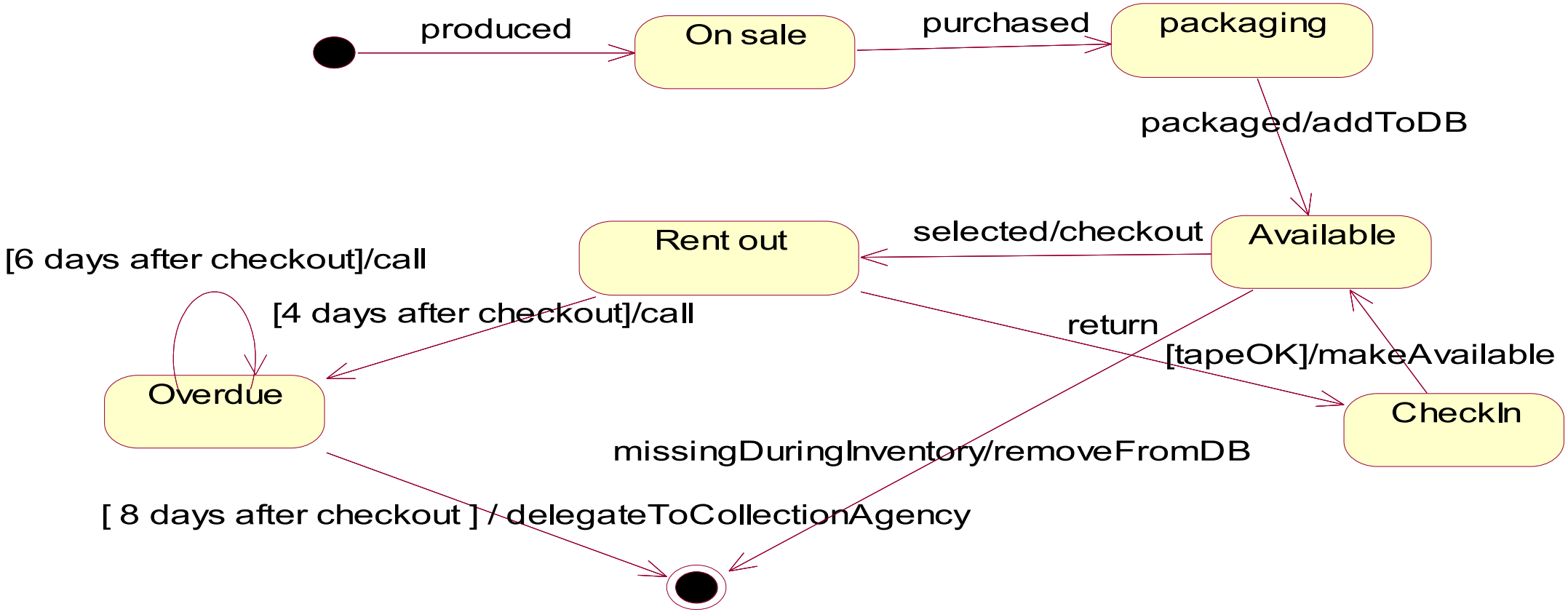
状态图建模风格

- 建模风格 1： 把初态放置在左上角；把终态放置在右下角。
- 建模风格 2： 用过去式命名转移事件。
  - 这样做是为了反映转移是事件的结果这个事实。也就是说，事件出现在转移之前，因此引用事件时要用过去式。
  - 例如：用 cancelled， closed， scheduled 等命名事件。

- 建模风格 3： 警戒条件不要重叠。
  - 从一个状态出来的相似转移上的警戒条件相互之间必须互斥。
  - 例如，像 x < 0 ， x = 0 和 x > 0 这样的警戒条件是互斥的，而像 x <= 0 和 x >= 0 这样的警戒条件是非互斥的。
- 建模风格 4： 不要把警戒条件置于初始转移上。
  - 当警戒条件为假的时候，这个对象做什么?

3. 画出描述录像带生命进程的状态图。（10分）

- 假定录像带首先被工厂生产出来，然后出售，被录像带商店购入后，进行适当的包装和编号，存入录像带商店的数据库，准备出租。顾客选中并准备租用时，在柜台取带，并于三天内归还。如果逾期不还，录像带商店将在次日打电话给顾客催还。两天后将再次打电话给顾客催还。如再过两天后仍未还带，商店将委托代理取带，并从数据库中清除该录像带。如果还回的录像带破损，也将从数据库中清除该带。如果在年度检查中发现该录像带从库存中遗失，也将被清除。
- 注意画出状态迁移的事件和条件。


produced
On sale
purchased
packaging
packaged/addToDB
Available
selected/checkout
Rent out
[6 days after checkout]/call
[4 days after checkout]/call
return
[tapeOK]/makeAvailable
Overdue
CheckIn
missingDuringInventory/removeFromDB
[8 days after checkout] / delegateToCollectionAgency

活动图

清华大学软件学院 刘璘

Activity Diagram(活动图)

- An activity diagram is a special case of a state diagram

  活动图是状态图的特例

- in which all (or at least most) of the states are action or sub-activity states

  状态为持续性的活动

- and in which all (or at least most) of the transitions are triggered by completion of the actions or sub-activities in the source states.

  迁移由活动的结束来触发

  (UML specification 1.5, pp3-156)

Activity Diagrams

- Activity diagrams describe activities which involve concurrency and synchronization.

  活动图用于描述并发和同步

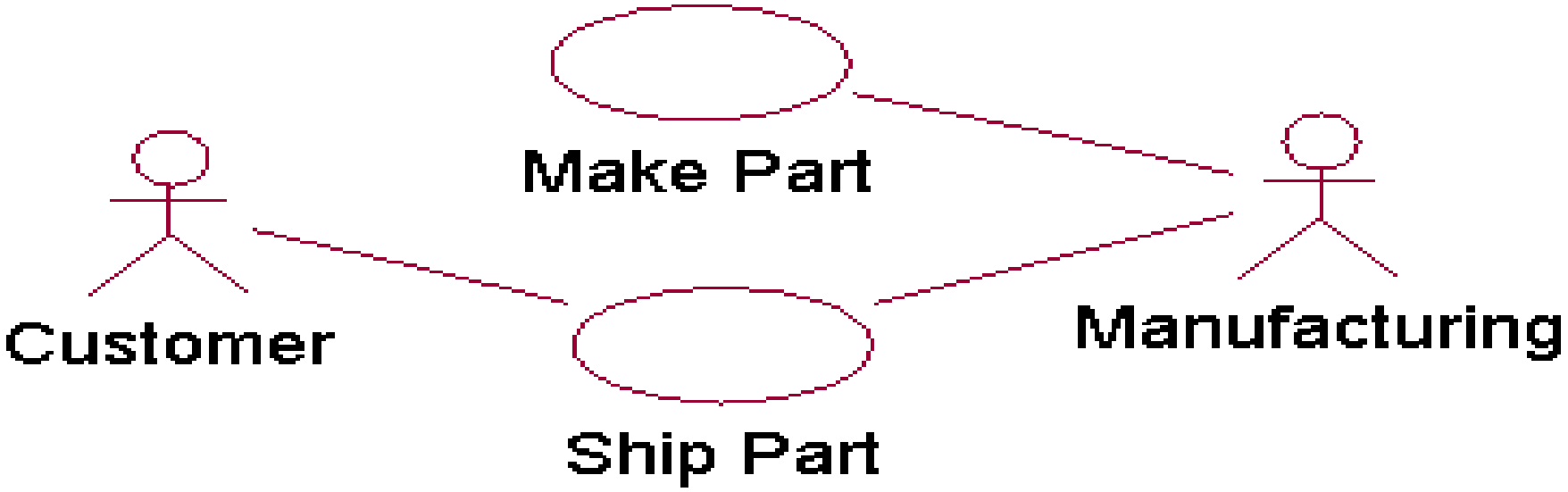
- Variation of Statecharts that focuses on a flow of activity driven by internal processing within an object rather than events that are external to it.

  与状态图的不同在于它关注对象内部的事务处理，而非外部的相关事件。

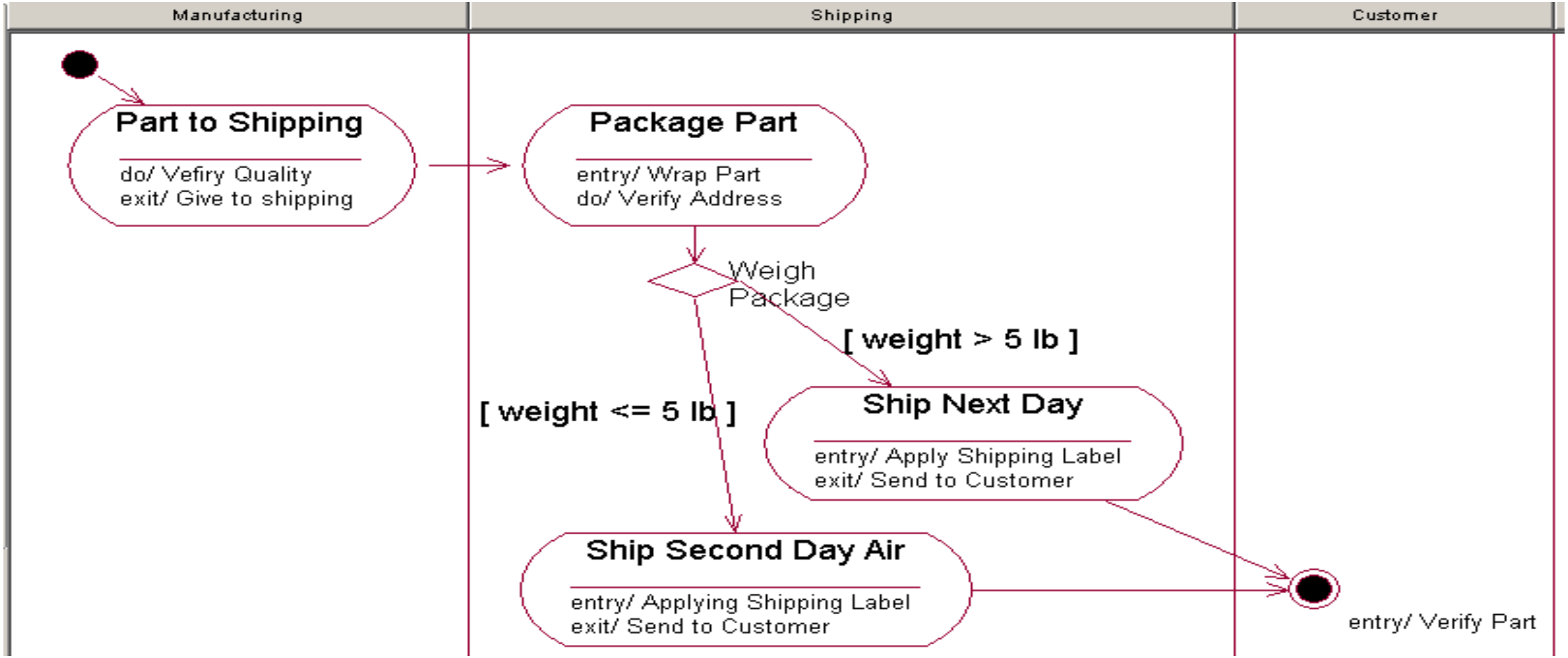
Activity Diagrams

- Can be used
  - To model business workflows (in business modeling for instance).
    对系统的工作流 (workflow) 建模，即对系统的业务过程建模。
  - To describe a system function that is represented within a use case or between use cases.
    对系统功能建模，尤其是那些表示为一个或一组用例的功能
  - In operation specifications, to describe the logic of an operation.
    对具体的操作建模，描述计算过程的细节。

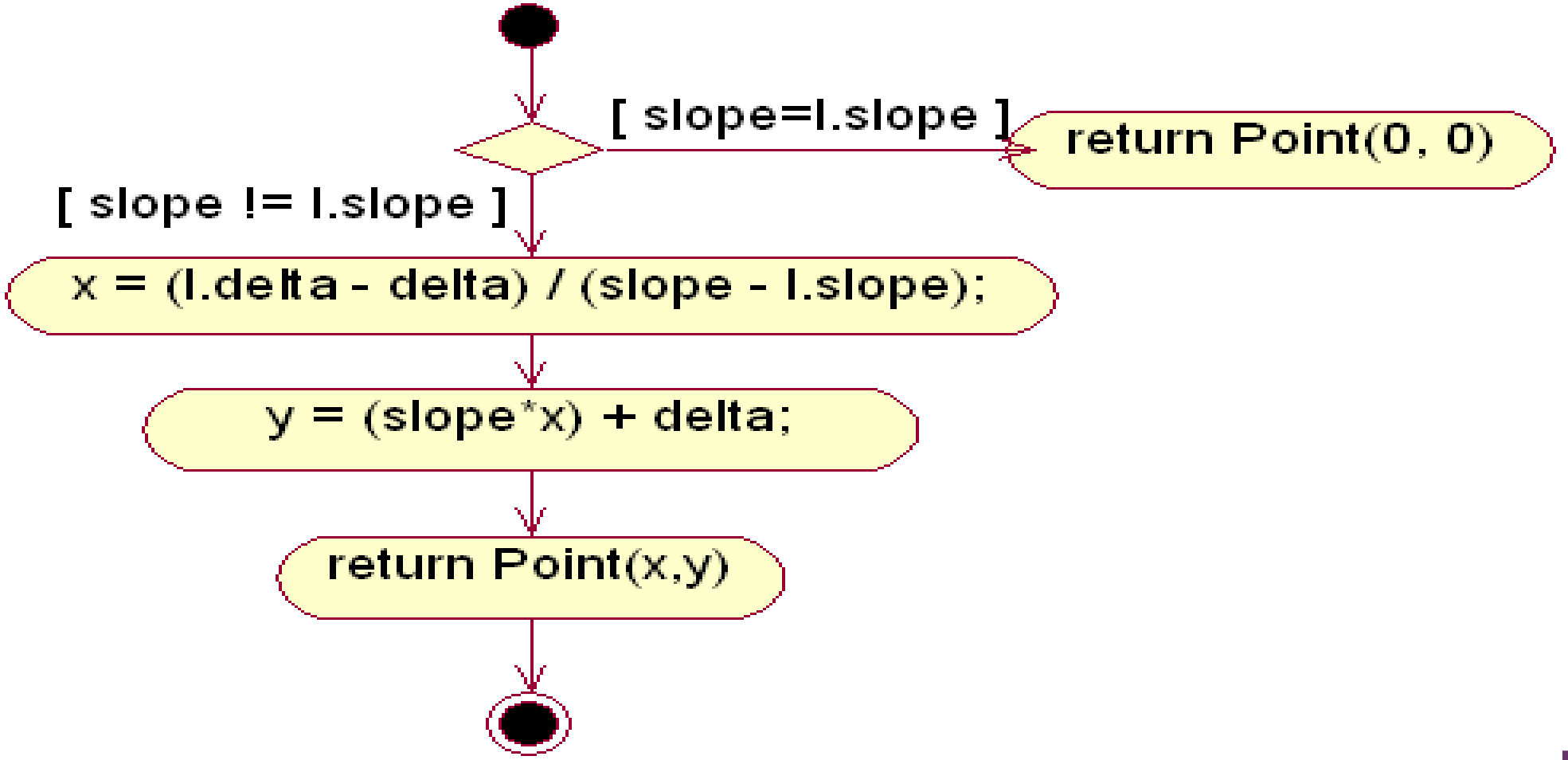
例 1： 用活动图对工作流程建模的例子。
(1)： 产品制造和发货的 use case 图。



(2). 用活动图来说明具体的工作流程。



例 2：用活动图对操作建模的例子：用活动图描述类 Line 的操作 intersection 的算法。



活动图中的基本概念

- Activity (活动)
- transition (转移)
- swimlane (泳道)
- branch (分支)
- fork and join (分叉和汇合)
- object flow (对象流)

activity(活动)

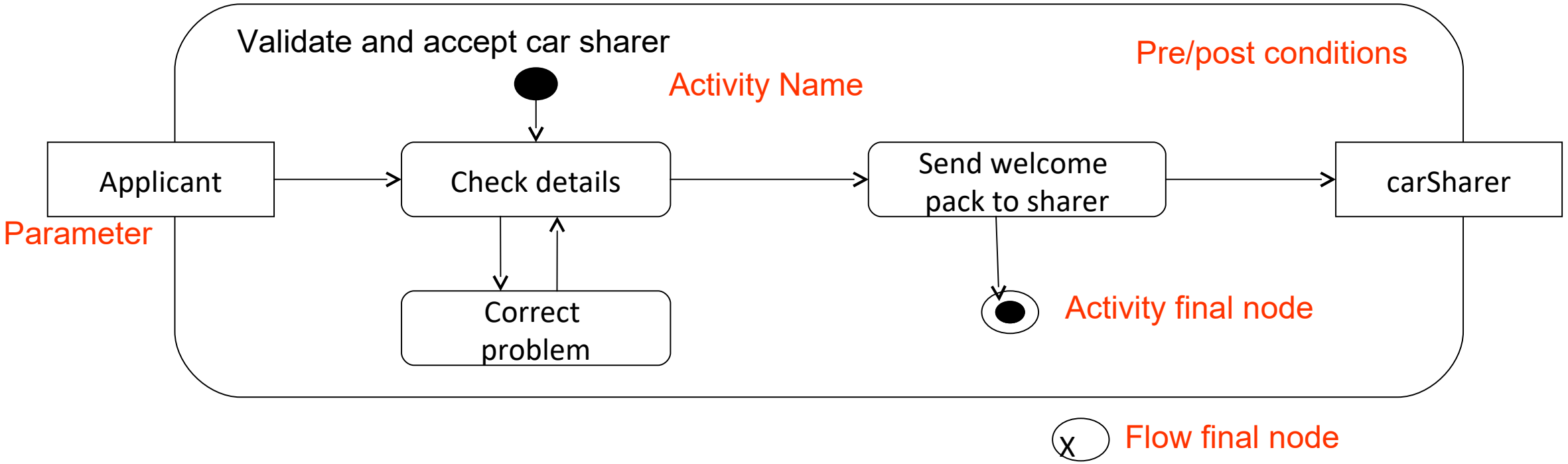
- An activity represents the performance of task or duty in a workflow. It may also represent the execution of a statement in a procedure.

说明:

- Action 和 activity 的区别:
  - Action 是原子的，而 activity 可进一步分解。

Activities (in UML 2.0)

Activities consists of action nodes, object nodes, and control nodes linked by activity edges.



Actions

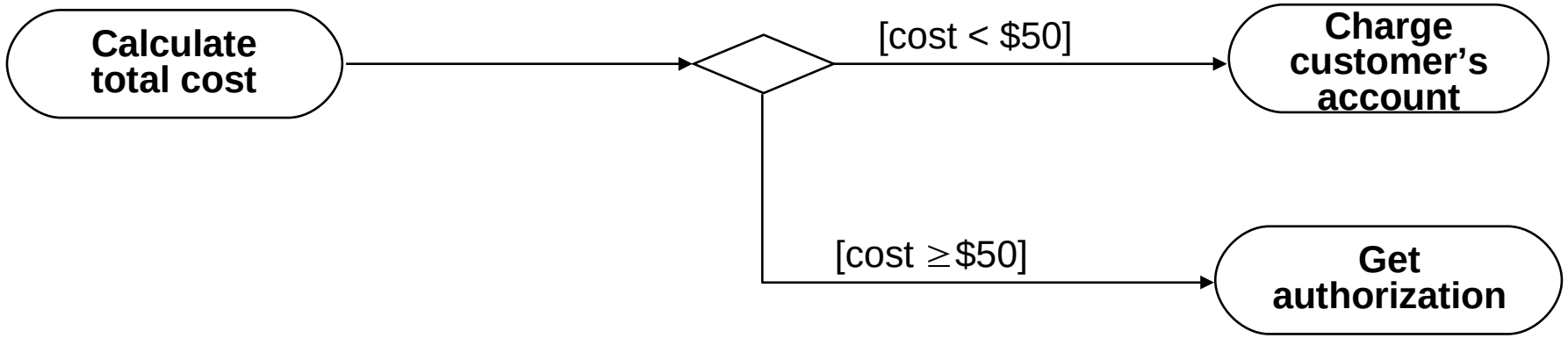
- An action represents an activity state in the execution of the activity. An activity state normally contains an action expression and usually has no associated name.

- Actions may be described by:
  - Natural language
  - Structured English
  - Pseudo-code
  - Programming language
  - Another activity diagram

- An action expression may only use attributes and links of the owning object.

More About Activity Diagrams

- **Decision point/node:**

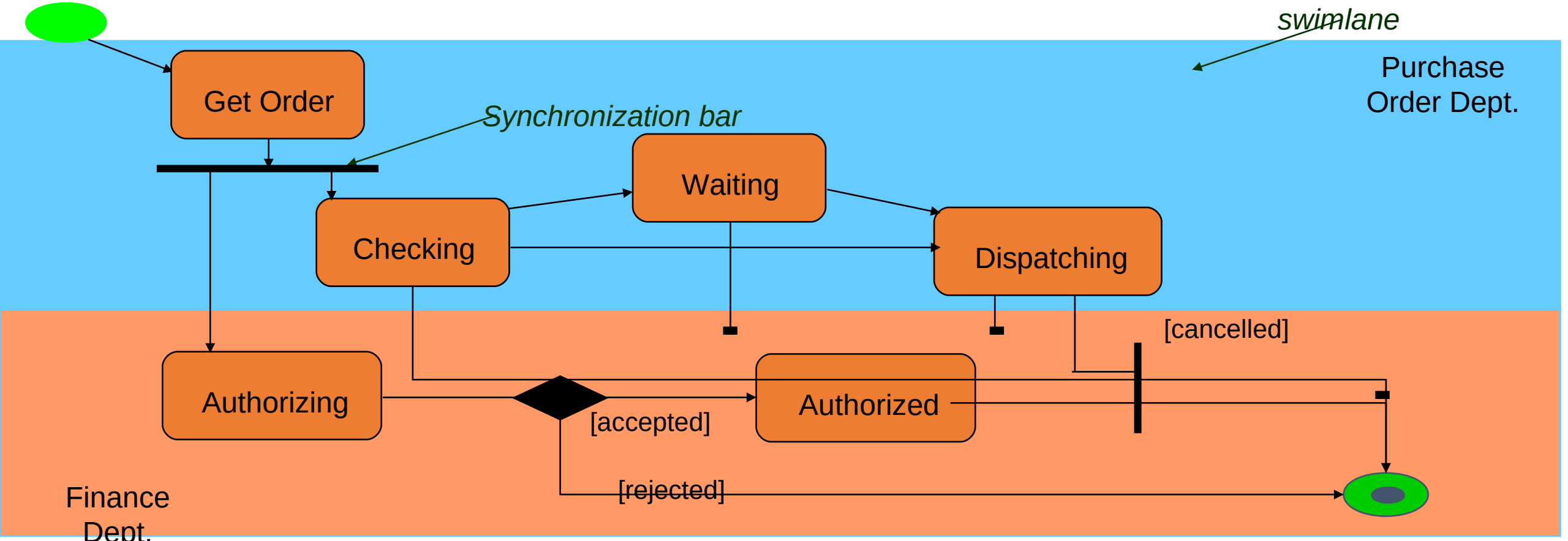


- **Dead end:** there may be transitions in an activity diagram with no destination state; this can mean that:
  - Not all processing has been specified,
  - Or, that another activity diagram will take over.

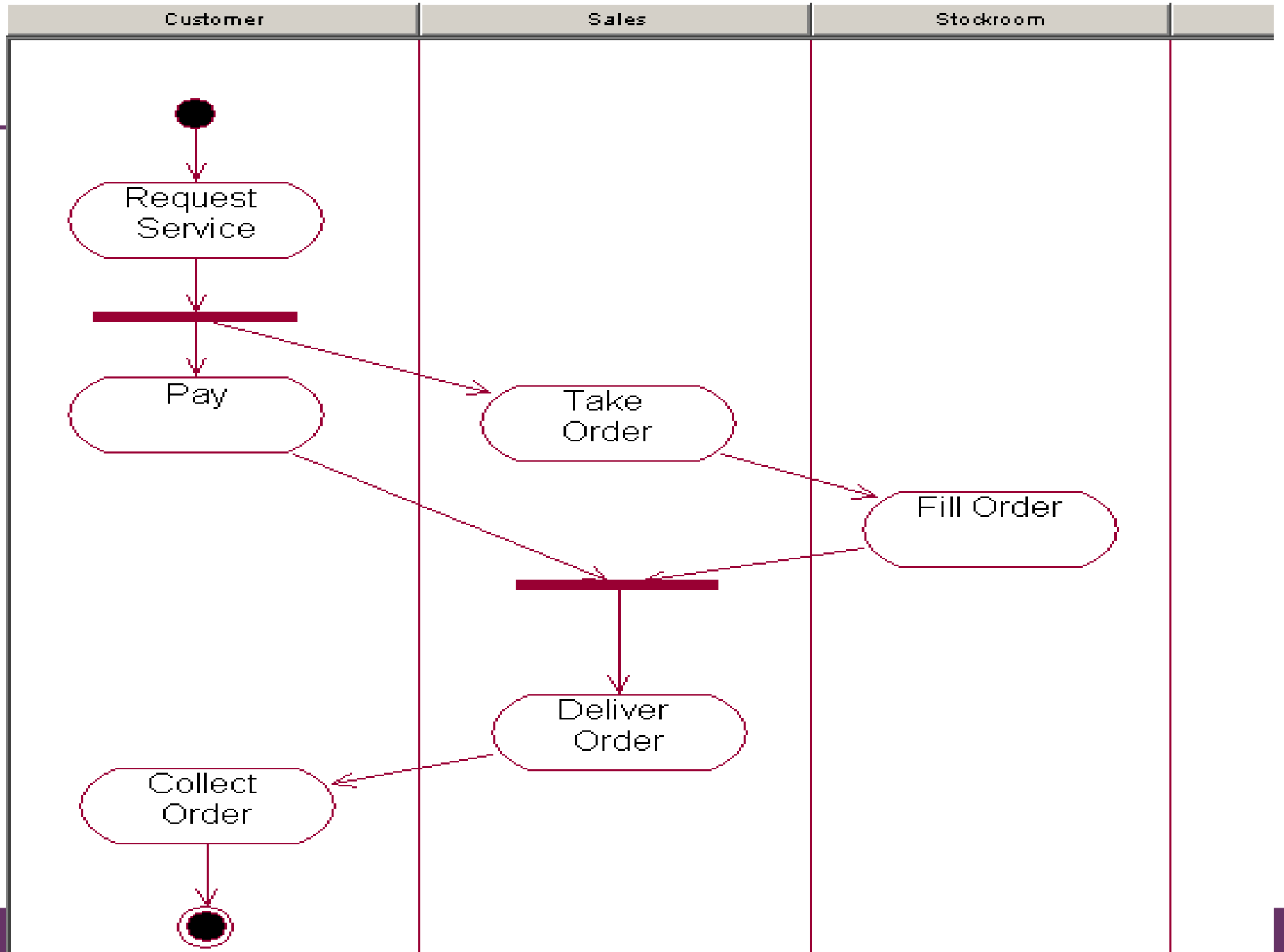
Swimlanes/ Activity Partition

- An activity diagram can be divided into swimlanes.
- A **swimlane** is a partition on activity graphs for organizing responsibilities for activities.
- Each swimlane:
  - Represents one focus of responsibility(责任区) in the activity.
  - May be handled by a distinct operation in one or more objects.
- The order of the swimlanes has no significance.

Swimlanes

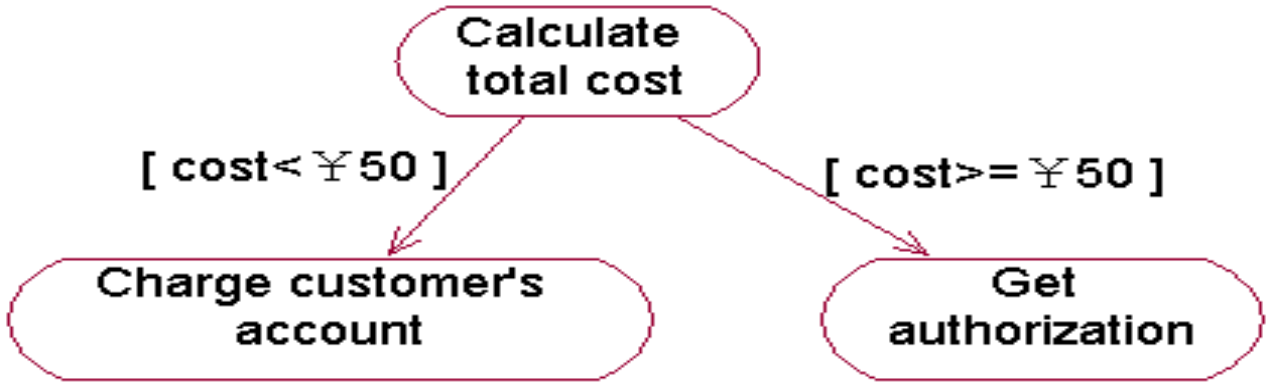

swimlane
Purchase Order Dept.
Get Order
Synchronization bar
Waiting
Checking
Dispatching
[cancelled]
Authorizing
[accepted]
Authorized
[rejected]
Finance Dept.

- 例：使用泳道的例子。

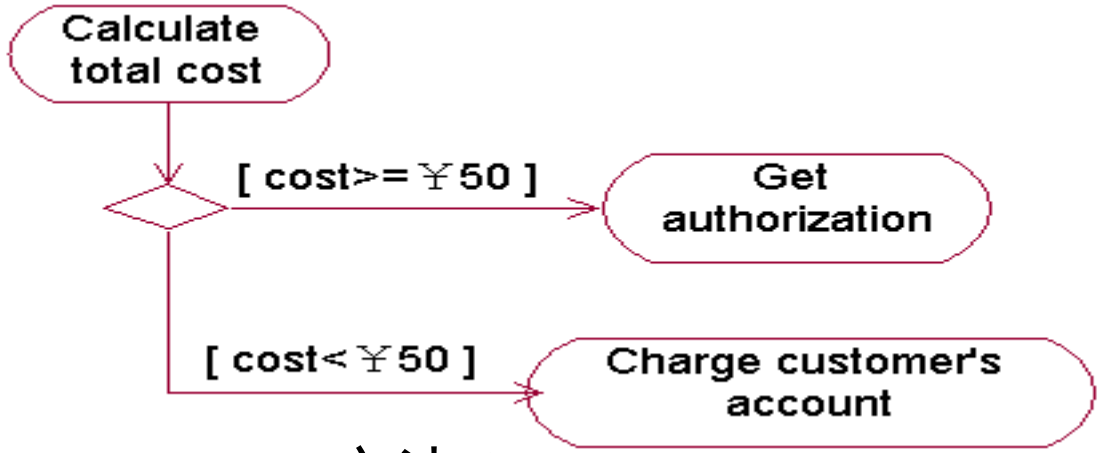

Customer
Sales
Stockroom
Request Service
Pay
Take Order
Fill Order
Deliver Order
Collect Order

branch(分支)

- A **branch** is an element in a state machine in which a single trigger leads to more than one possible outcome, each with its own **guard condition**.
- 表示分支的两种方法:



方法 1



方法 2

fork 和 join(分叉和汇合)

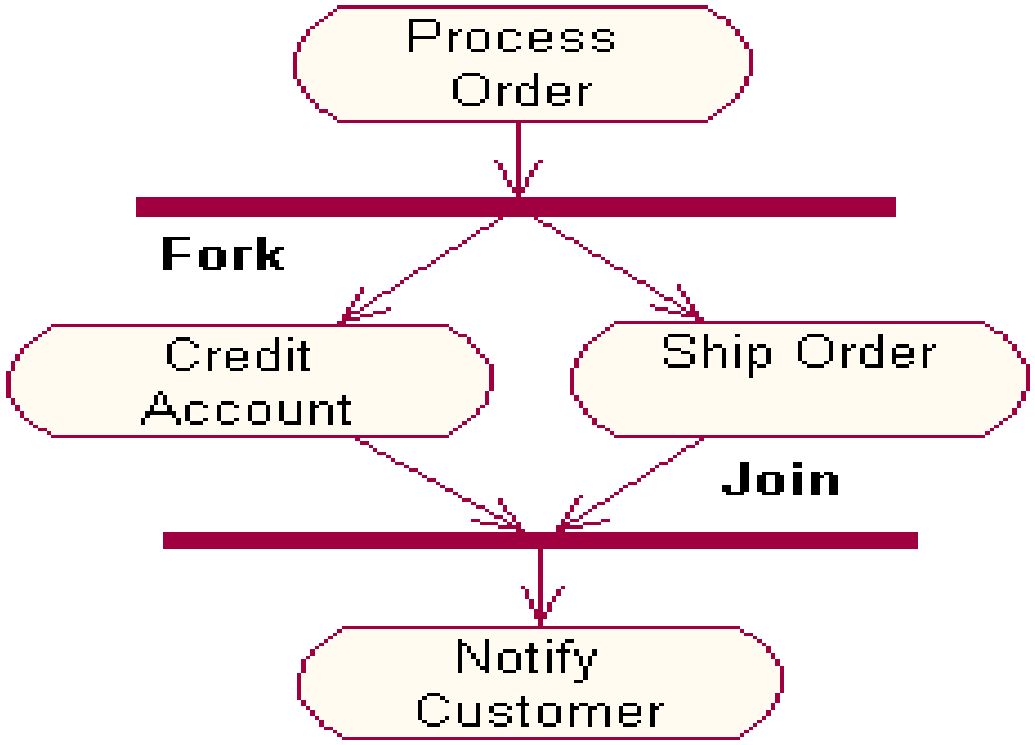
- A **fork** is a complex transition in which one source state is replaced by two or more target states, resulting in an increase in the number of active states.

- A **join** is a transition with two or more source states and one target state.

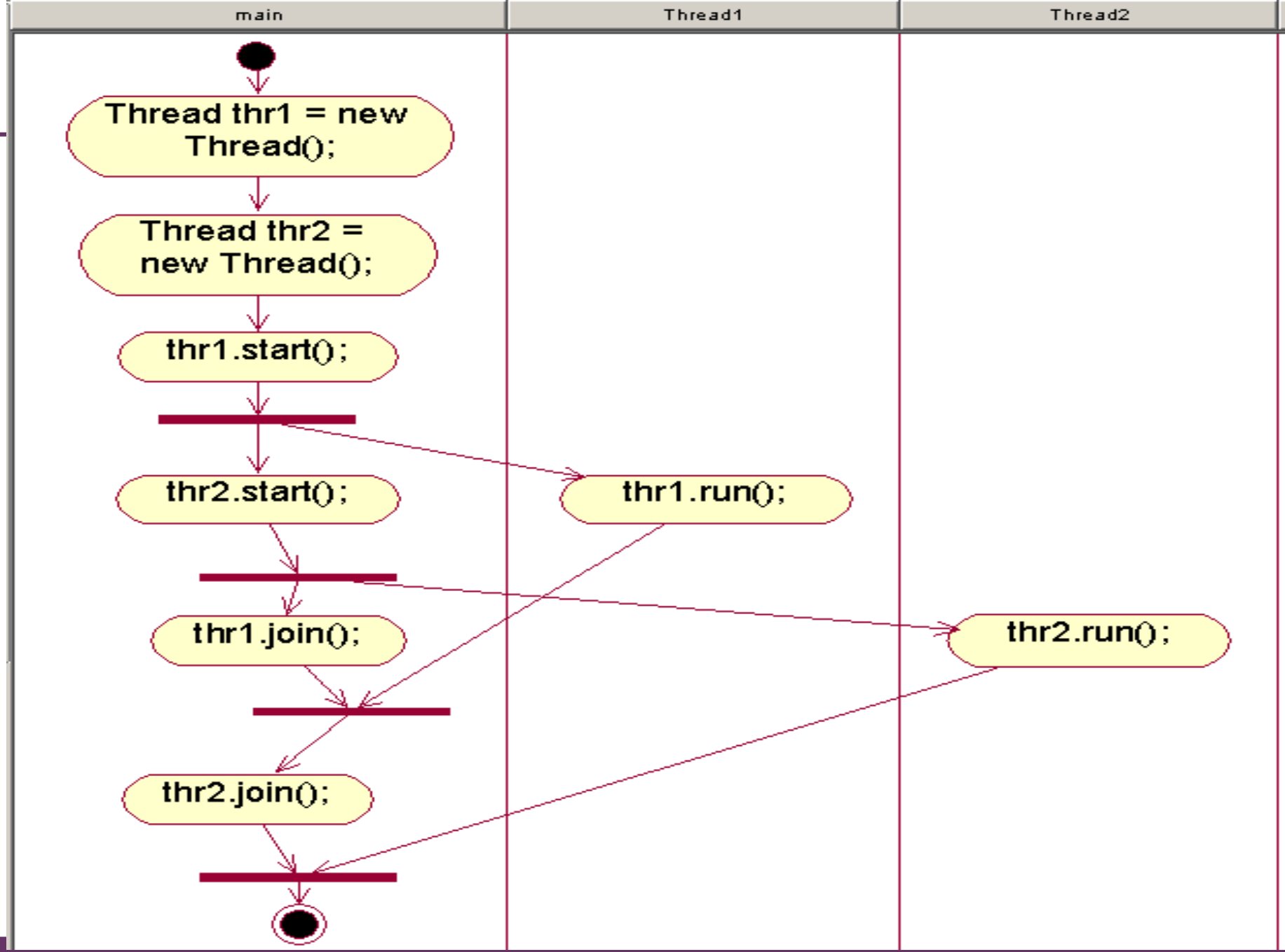
说明：

- 利用 fork 和 join 可以表示系统中或对象中的并发行为。

例： fork 和 join 的例子。



例：用活动图描述Java中使用多线程的过程。

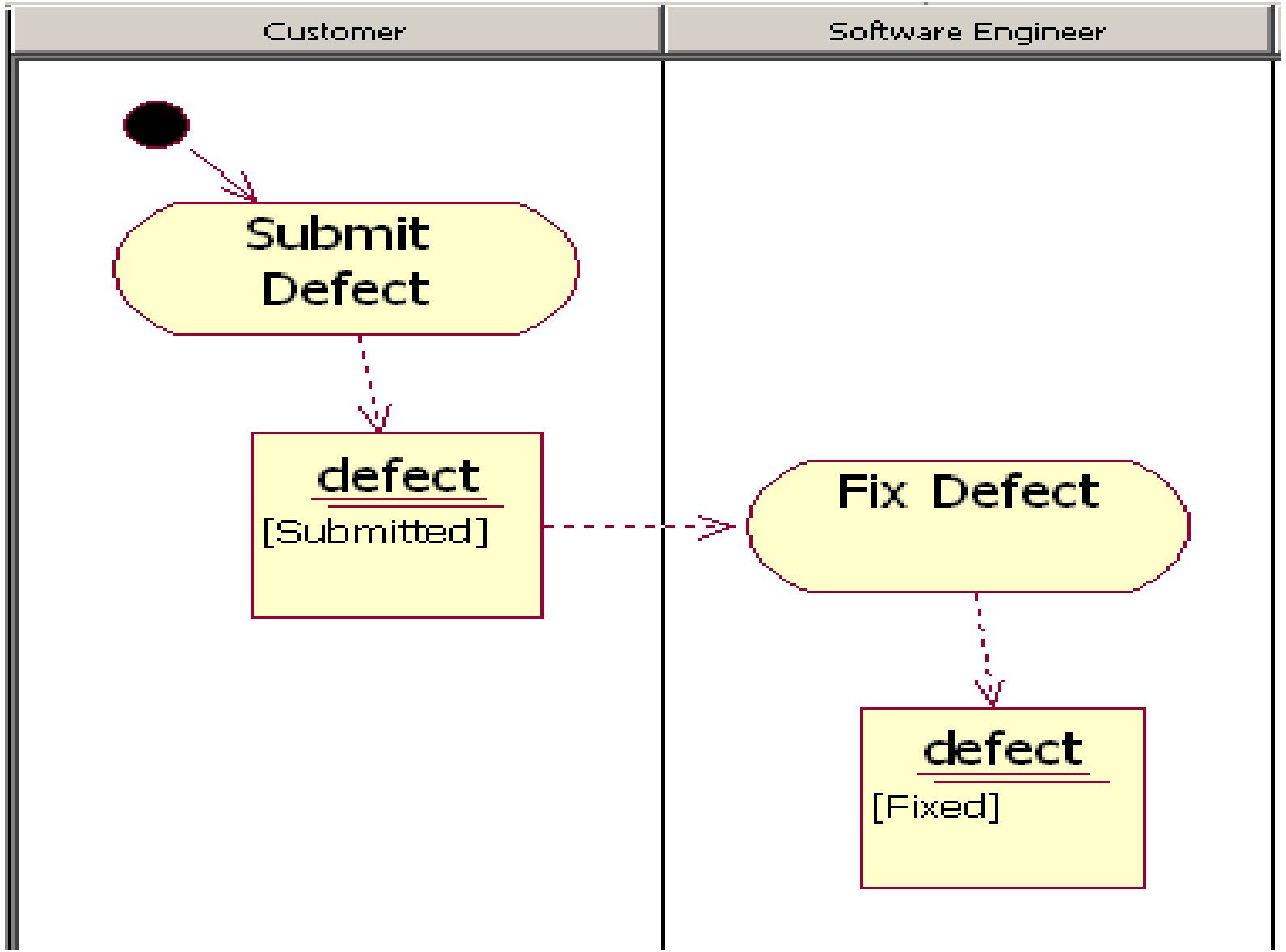


对象流

- 在活动图中可以出现对象。对象可以作为活动的输入或输出。

- An **object flow** on an activity diagram represents the relationship between an activity and the object that creates it (as an output) or uses it (as an input).

- 对象流的例子
  -

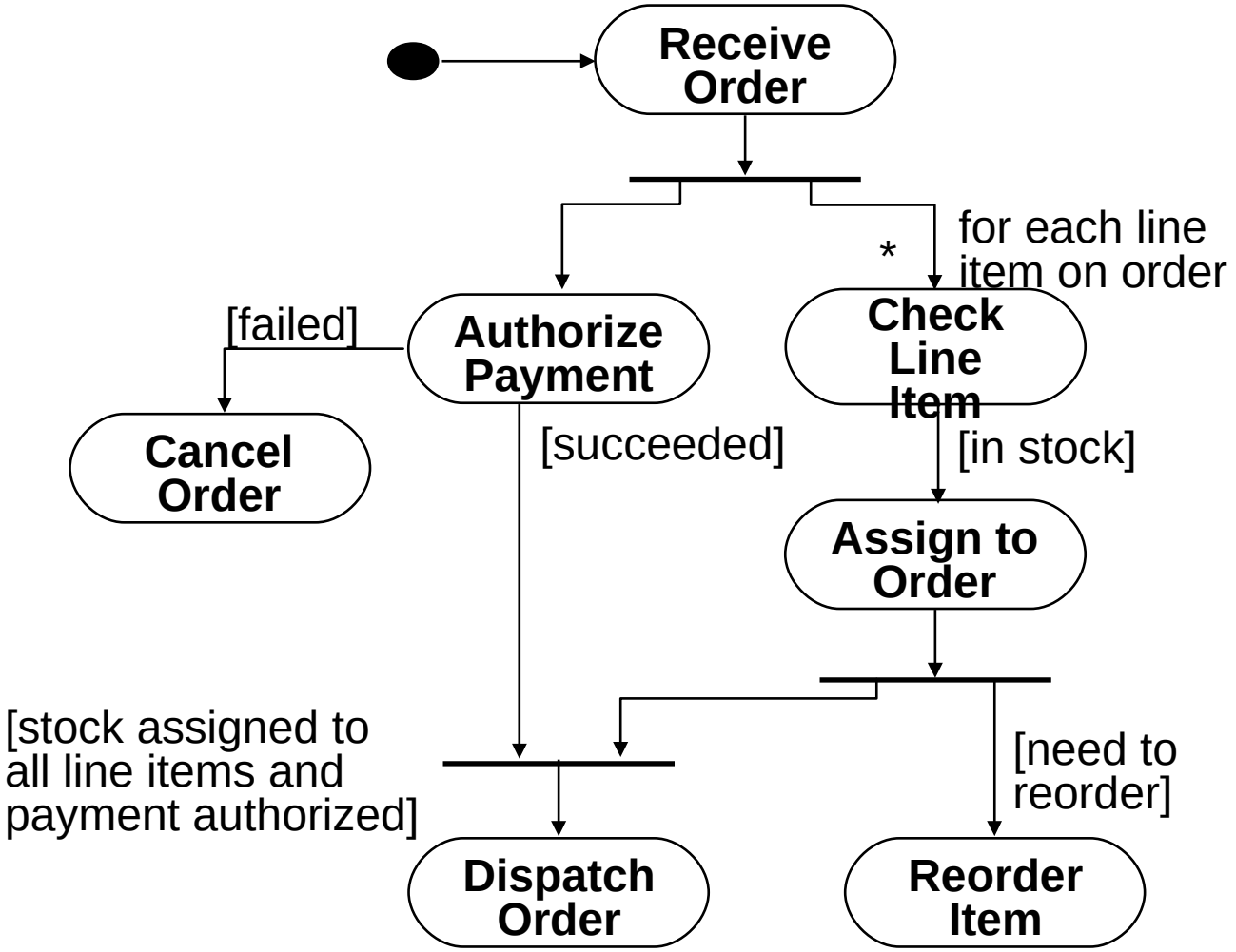

Customer
Software Engineer
Submit Defect
defect
[Submitted]
Fix Defect
defect
[Fixed]

Example: Order Processing

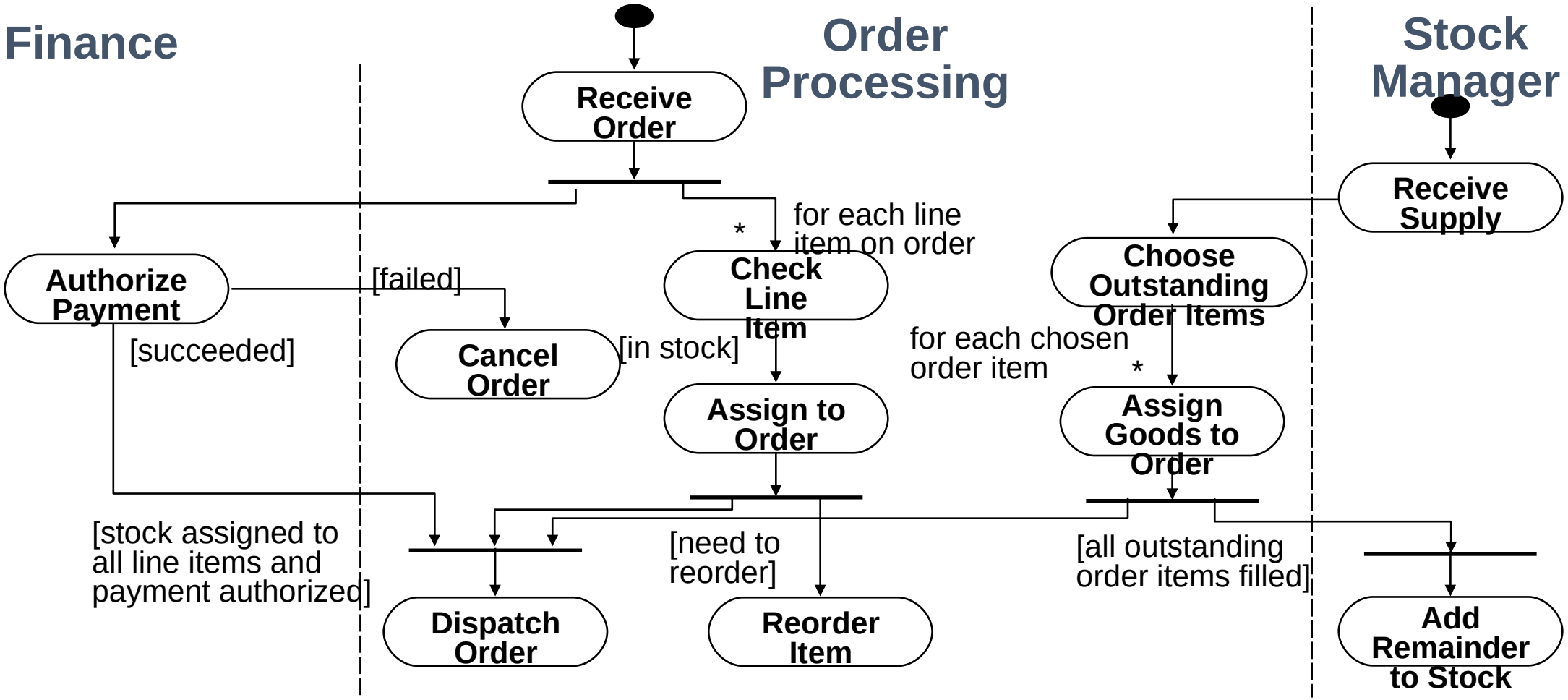
- The Process Order use case:

  "When we receive an order, we check each line item on the order to see if we have the goods in stock. If we do, we assign the goods to the order. If this assignment sends the quantity of those goods in stock below the reorder level, we reorder the goods. While we are doing this, we check to see if the payment is O.K. If the payment is O.K. and we have the goods in stock, we dispatch the order. If the payment is O.K. but we do not have the goods, we leave the order waiting. If the payment is not O.K., we cancel the order."

Order Processing Activity Diagram

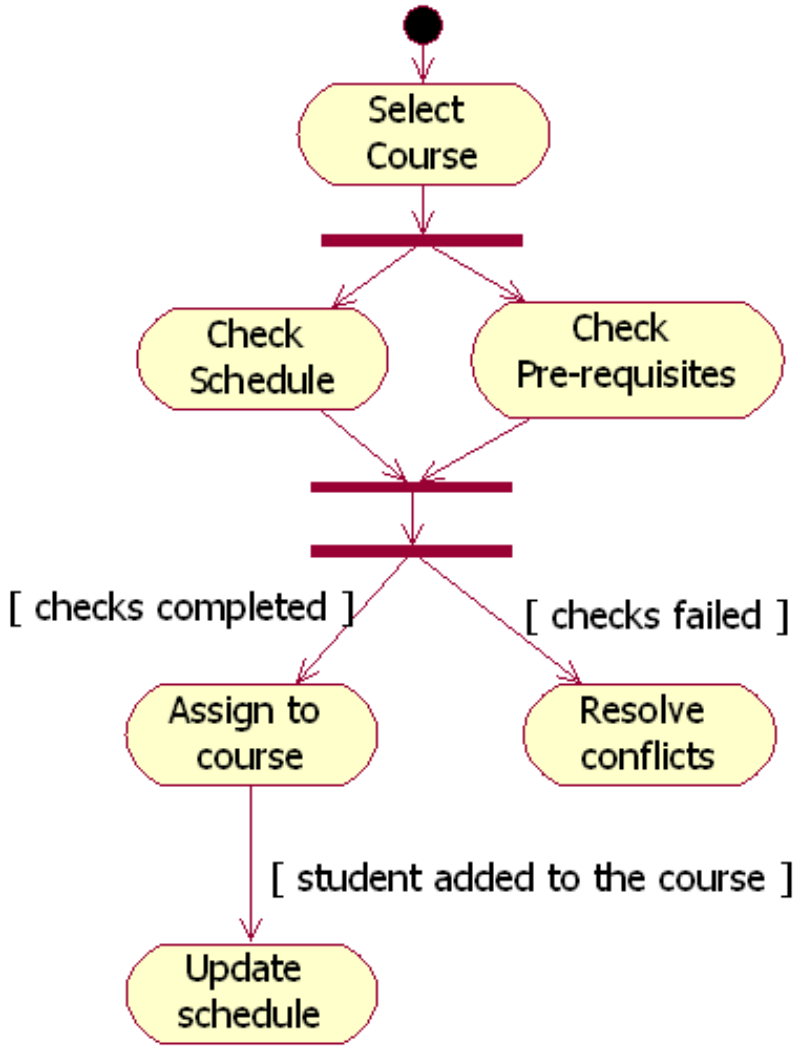


With Swimlanes



例 3 ：课程注册系统中的活动图例子

分析用例 Register for Courses 的活动图：



活动图的工具支持

- 正向工程：
  - 利用活动图产生代码，特别是对具体操作建模的活动图。
  - 例：根据 Slide 55 活动图生成的代码：

```
Point Line::intersection (l : Line) {
    if (slope == l.slope) return Point(0,0);
    int x = (l.delta - delta) / (slope - l.slope);
    int y = (slope * x) + delta;
    return Point(x, y);
}
```

活动图与状态图比较

1. 活动图和状态图描述的重点不同：
   - 活动图描述的是从 activity 到 activity 的控制流，而状态图描述的是对象的状态及状态之间的转移。
2. 活动图和状态图使用的场合不同：
   - 对于以下几种情况可以使用活动图：
     - 分析用例
     - **理解涉及多个用例的工作流**
     - 处理多线程应用
   - 对于下面的情况要使用状态图：
     - 显示一个对象在其生命周期内的行为。

说明：如果要显示多个对象之间的交互情况，可用顺序图或协作图。

活动图建模风格

- 建模风格 1： 确保从决策点出来的每个转移都有一个警戒条件。
  - 这可以确保建模人员已经考虑到这个决策点的所有可能情况。

- 建模风格 2： 确保决策点上的警戒条件形成一个完备集。
  - 不管什么情况，要一定能够可以从决策点离开。
  - 例如，像 x < 0 和 x > 0 这样的警戒条件是不完备的，因为当 x 等于 0 时会发生什么并不清楚。

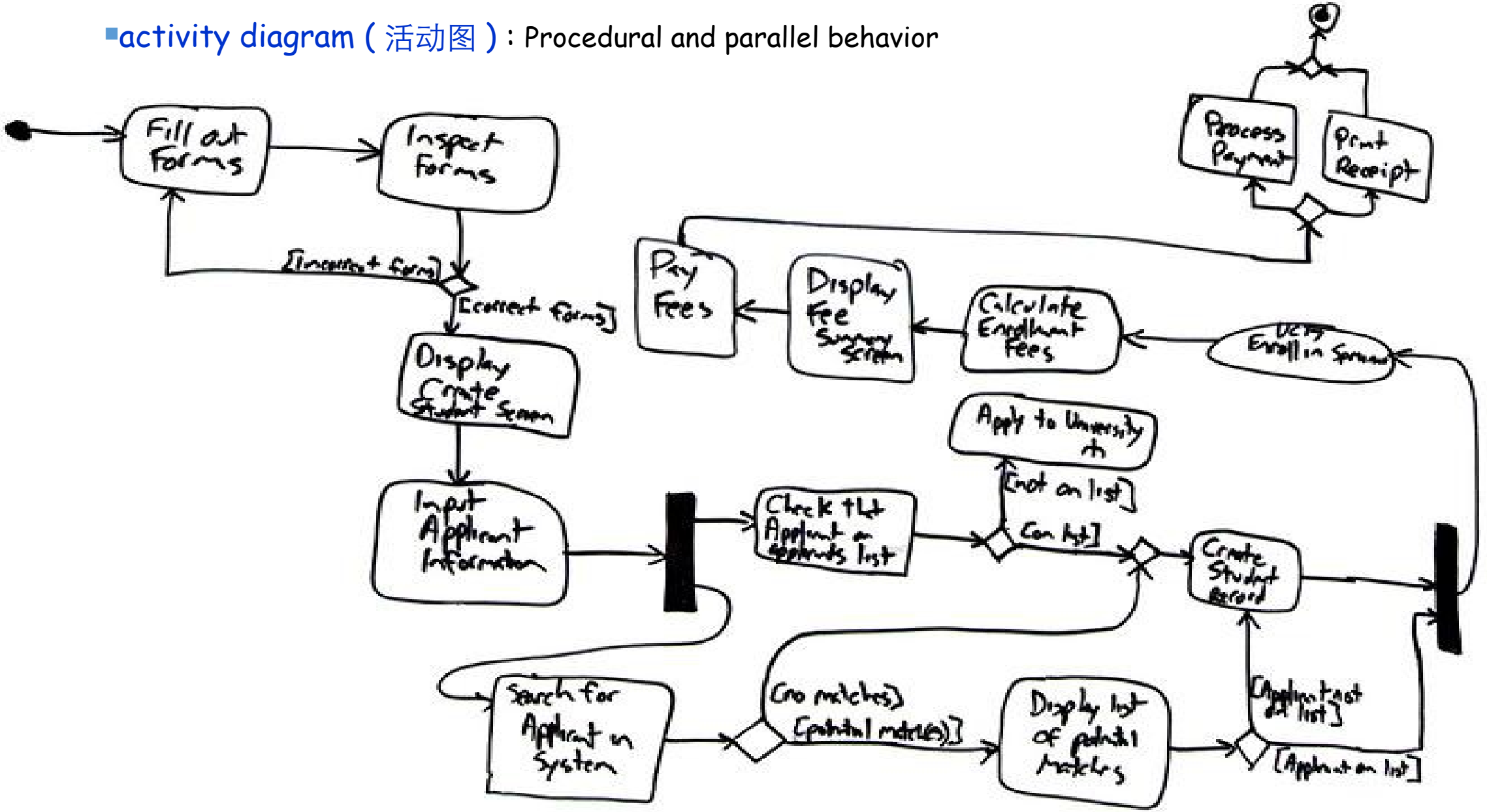
- 建模风格 3： 警戒条件不要重叠。

- 建模风格 4： 确保每个分叉只有一个进入转移。
  - 当发现需要几个转移到同一个分叉时，表明建模人员或者遗漏了一个活动，或者在该点事实上并不需要并发活动。
- 建模风格 5： 确保每个汇合只有一个退出转移。
  - 当某个汇合点需要多个退出转移时，表明仍然需要并发的活动，因此，把汇合点沿着总体活动过程向前移动。
- 建模风格 6： 要小于 5 条泳道。
  - 泳道的一个缺点是使得建模人员无法自由地在图中排列活动以节省空间，因此会增加图的大小。泳道数目越多，这个问题越严重。

Why Build Models?

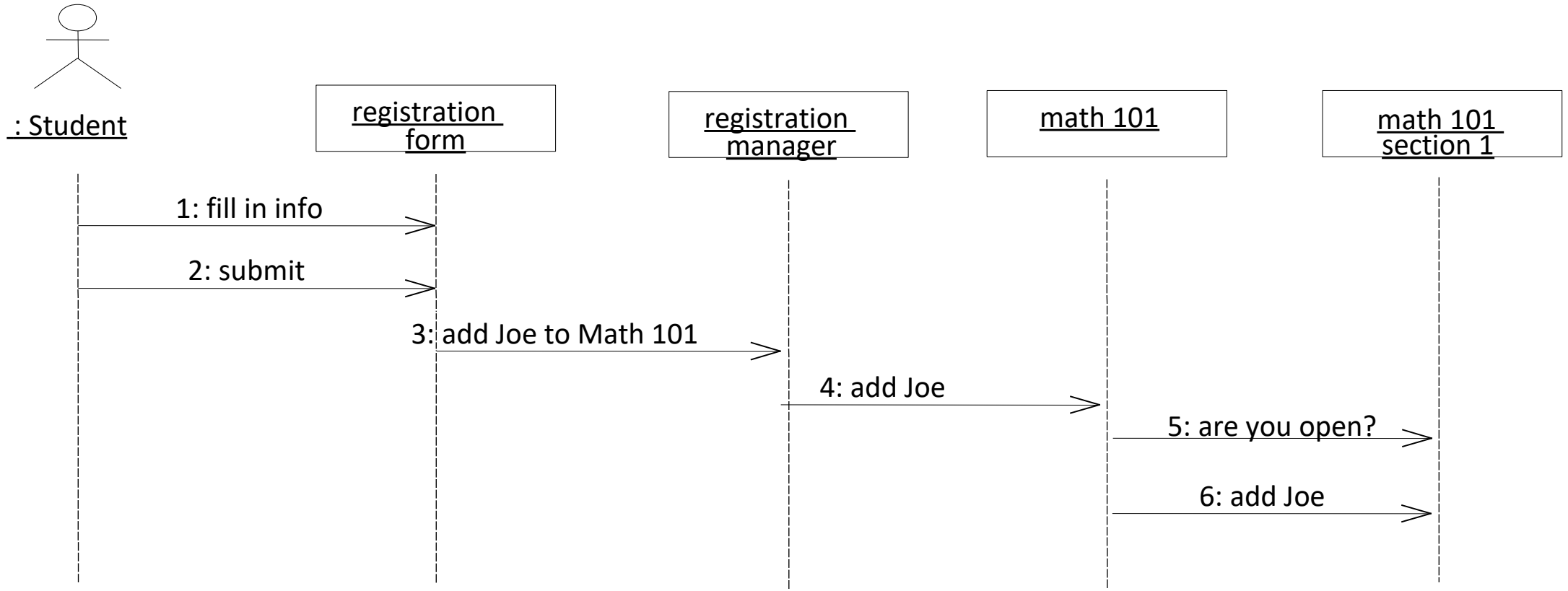
- To understand the problem better
- To communicate with other persons
- To find errors or omissions
- To plan out the design
- To generate code

- activity diagram (活动图) : Procedural and parallel behavior

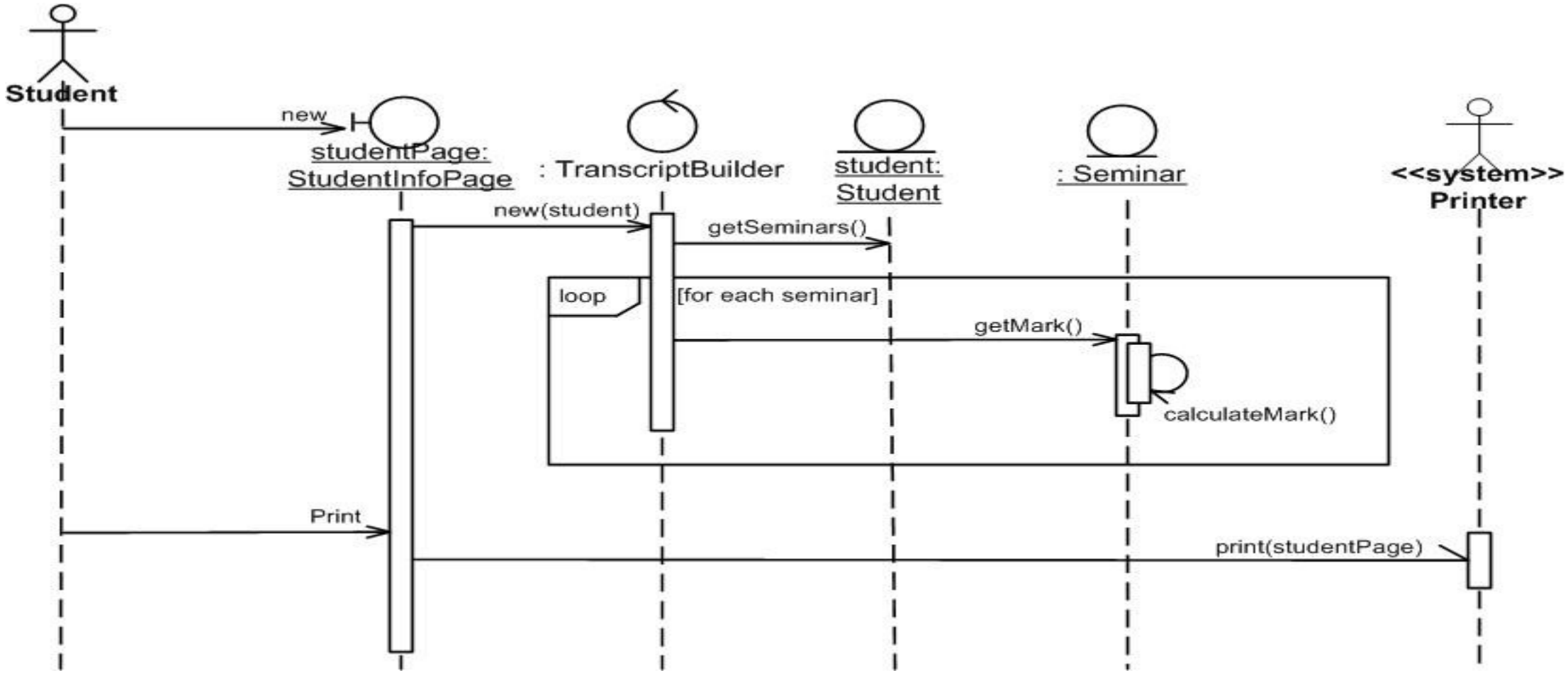


Sequence Diagram

- A sequence diagram shows step by step what must happen to accomplish a piece of functionality provided by the system.

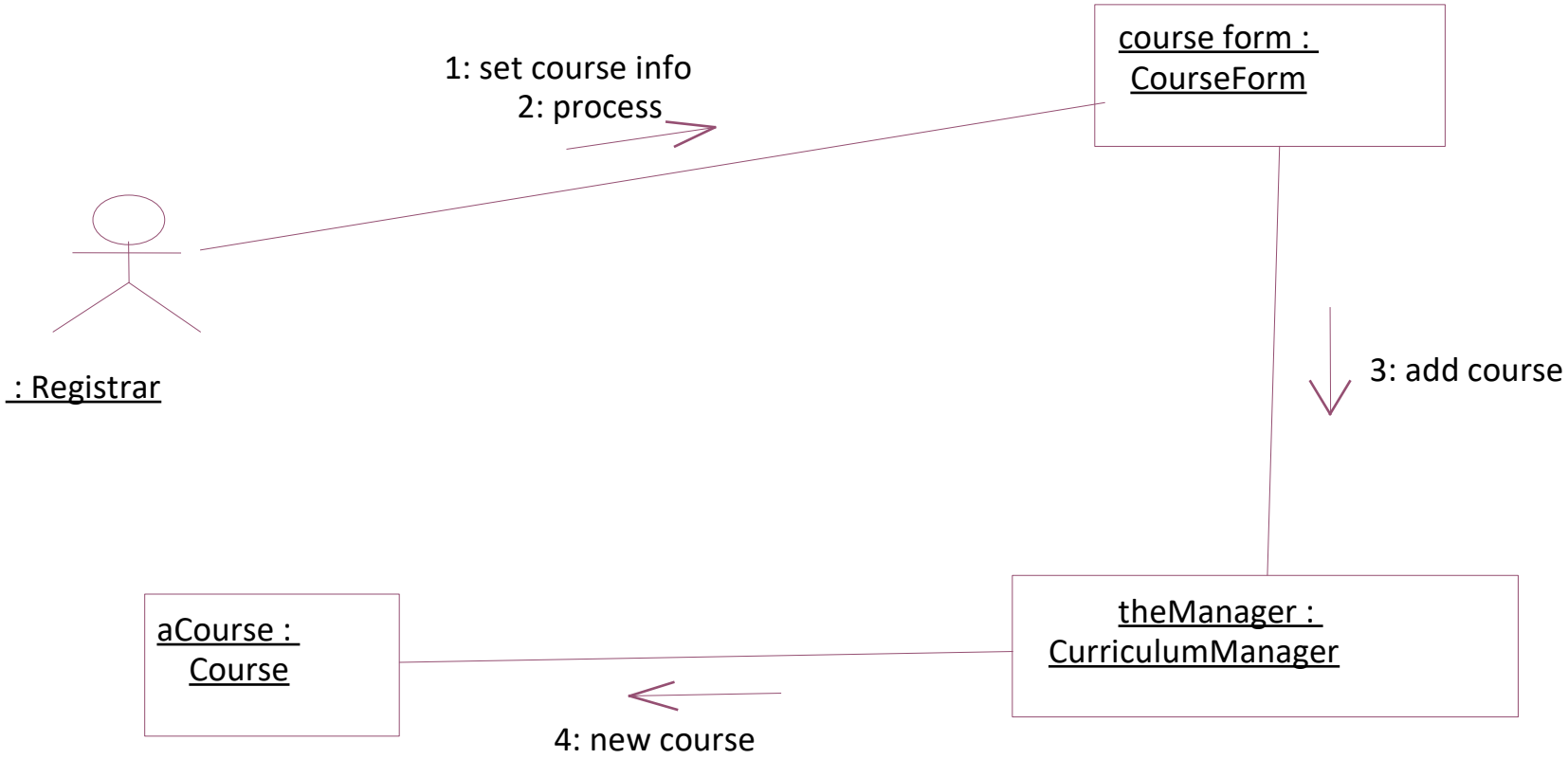


- **sequence diagram（顺序图）：**Interaction between objects;
  emphasis on sequences



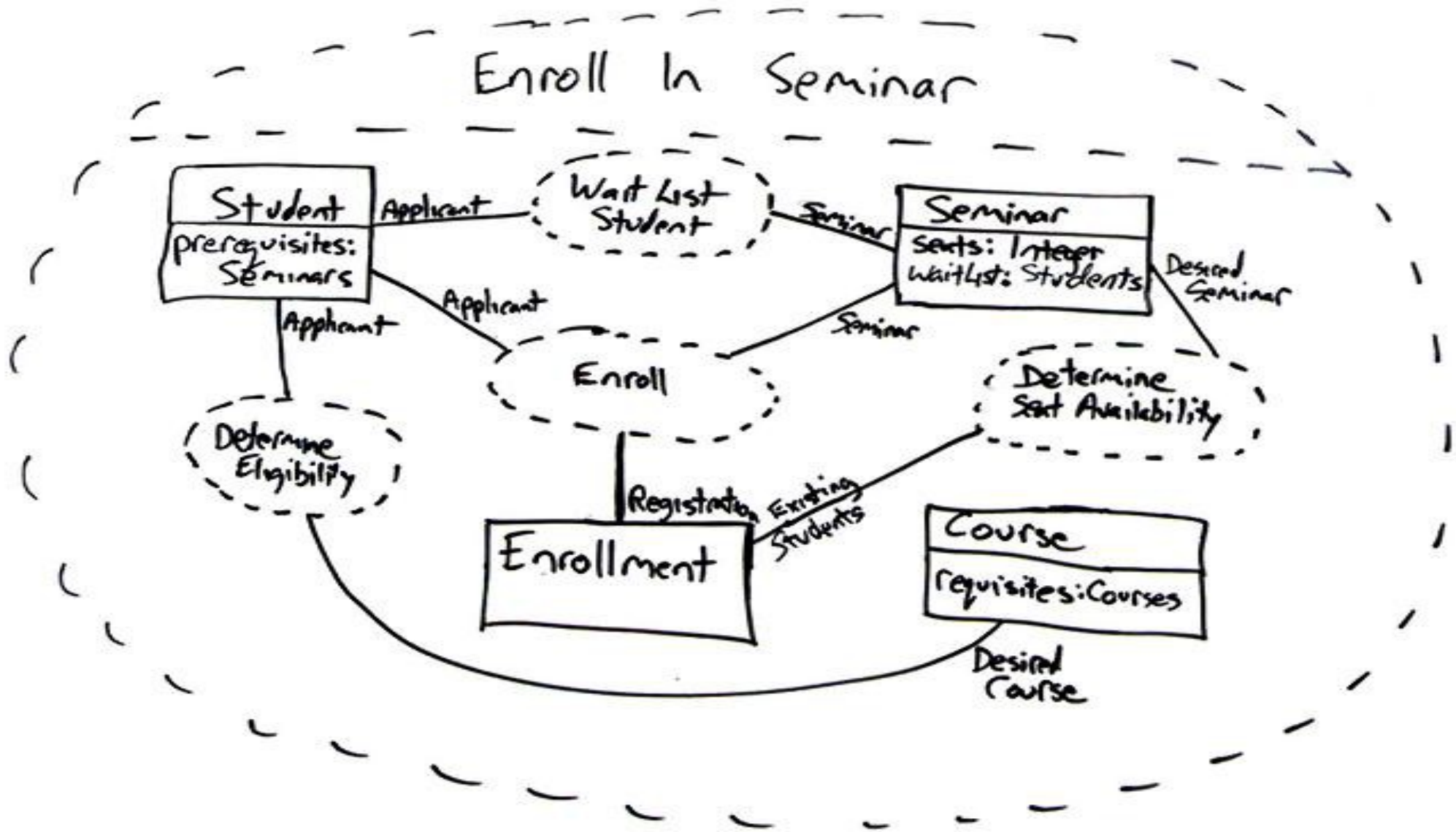
Collaboration Diagram

- A collaboration diagram displays object interactions organized around objects and their links to one another.



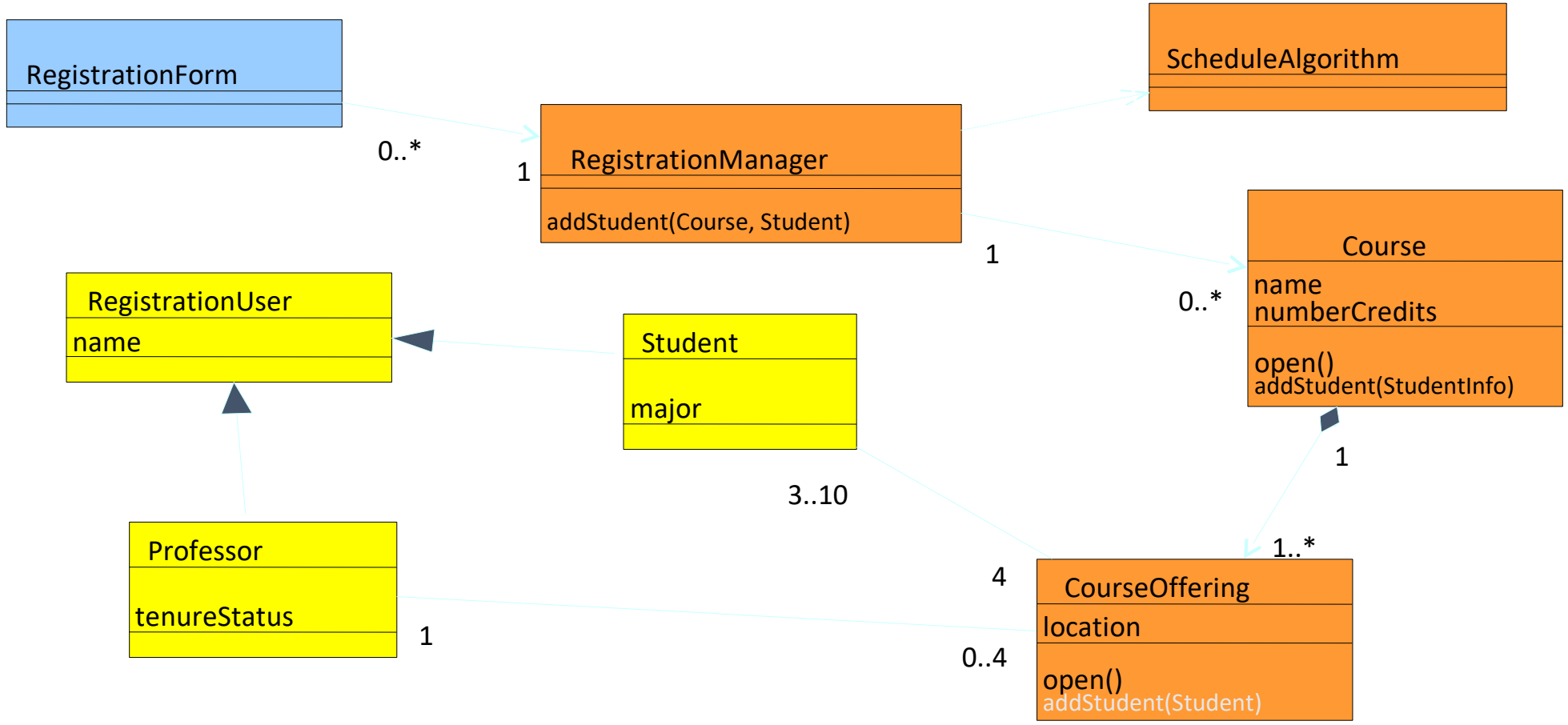
- **collaboration diagram（协作图）：**Interaction between objects;

  emphasis on links



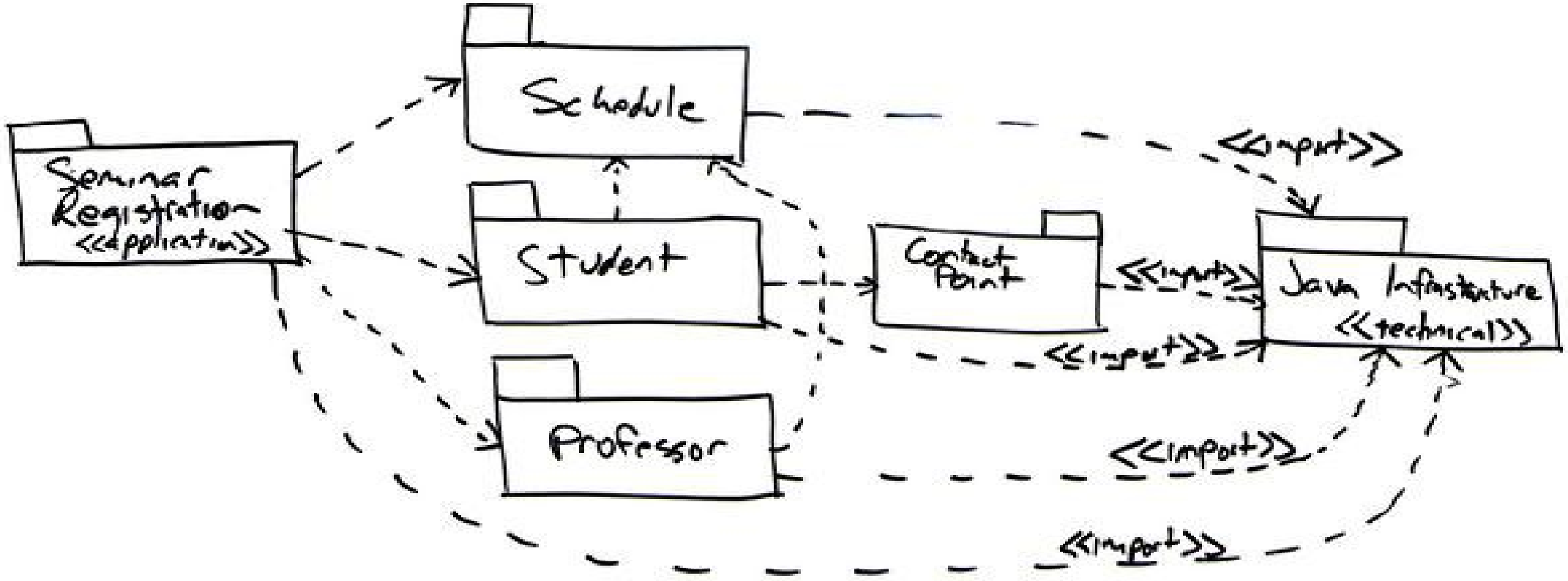
Class Diagram

- A class diagram shows the structure of your software.



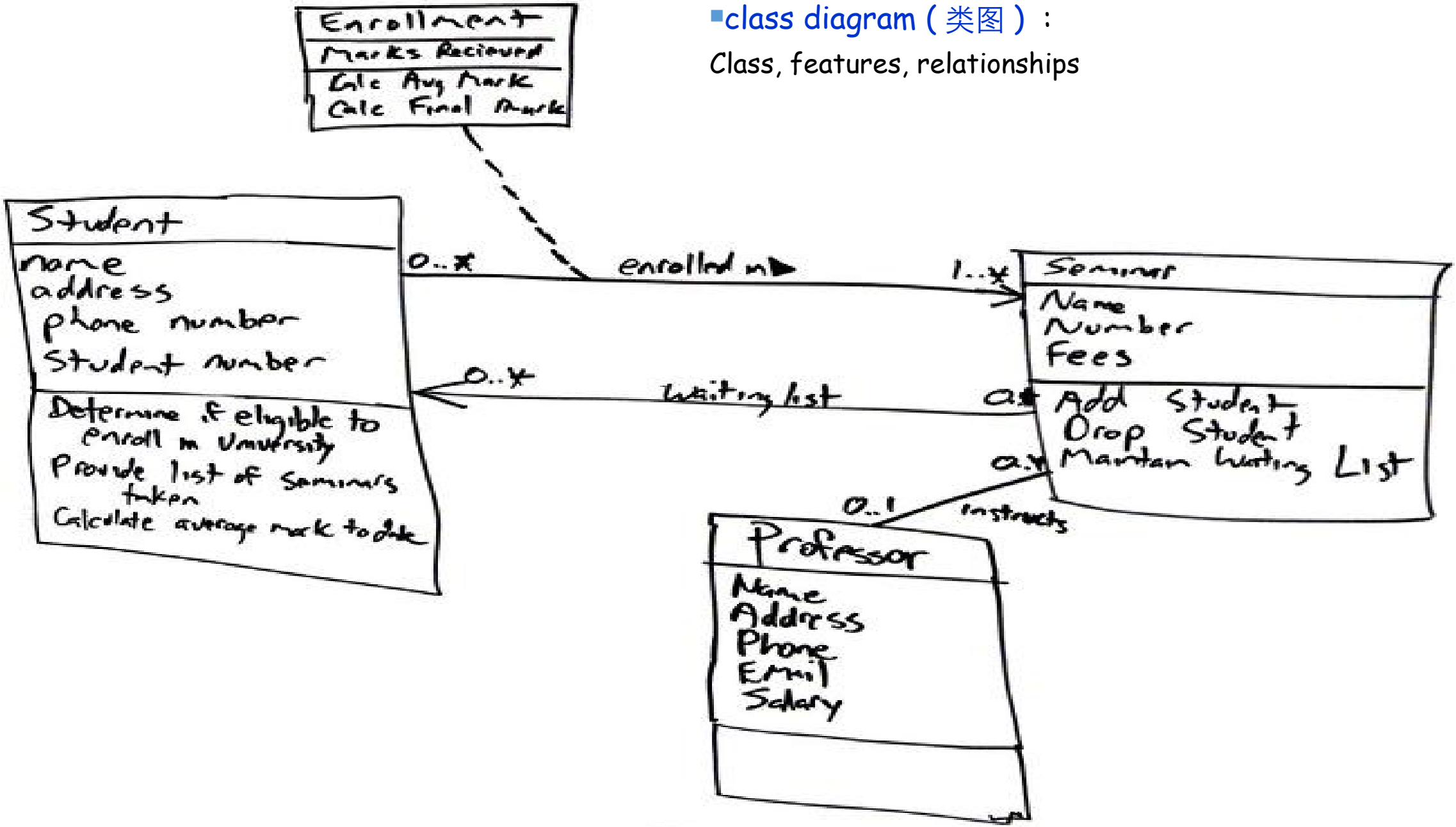
- Package Diagram

  Compile-time hierarchic structure

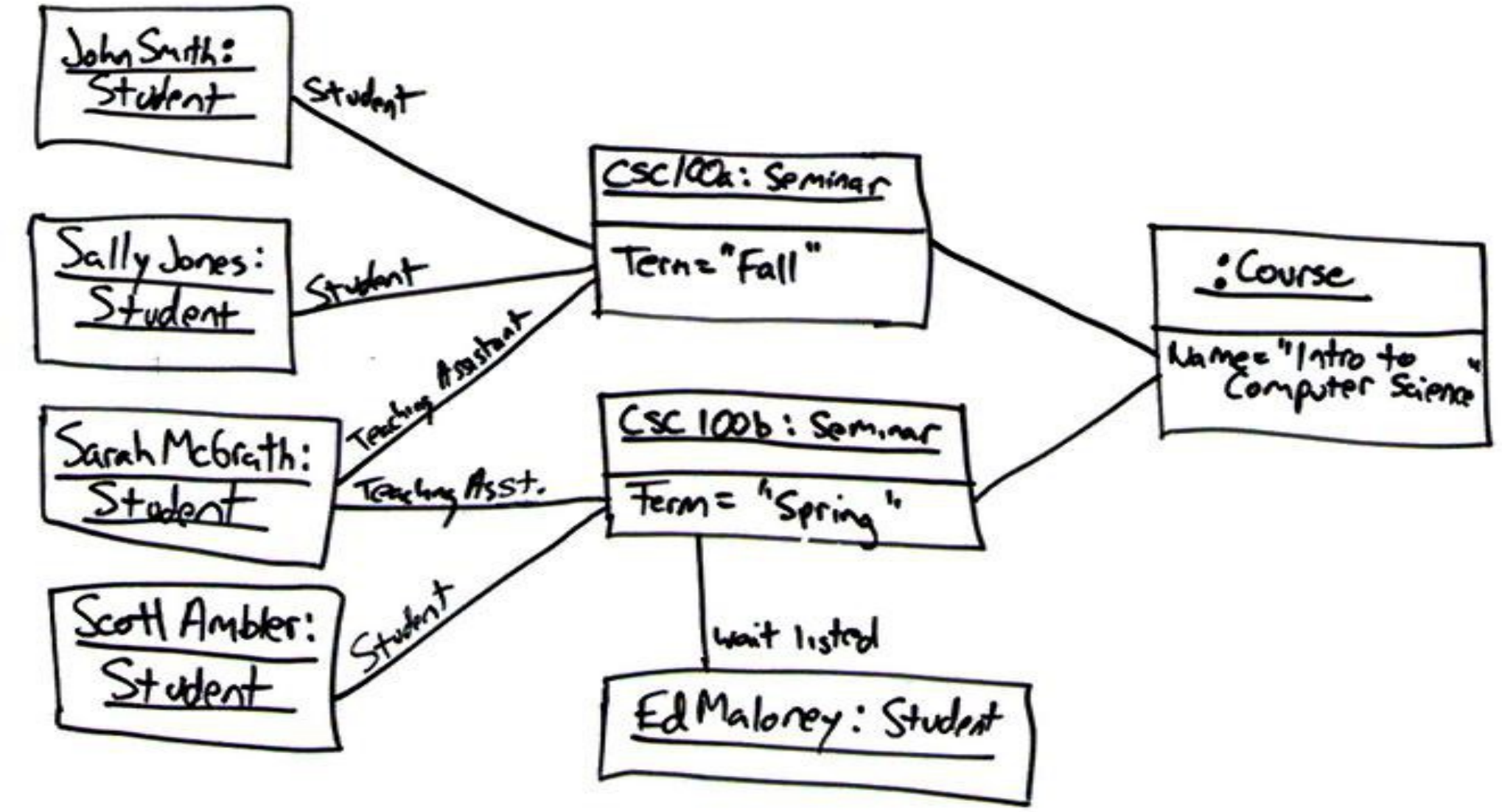


- class diagram (类图) ：

Class, features, relationships

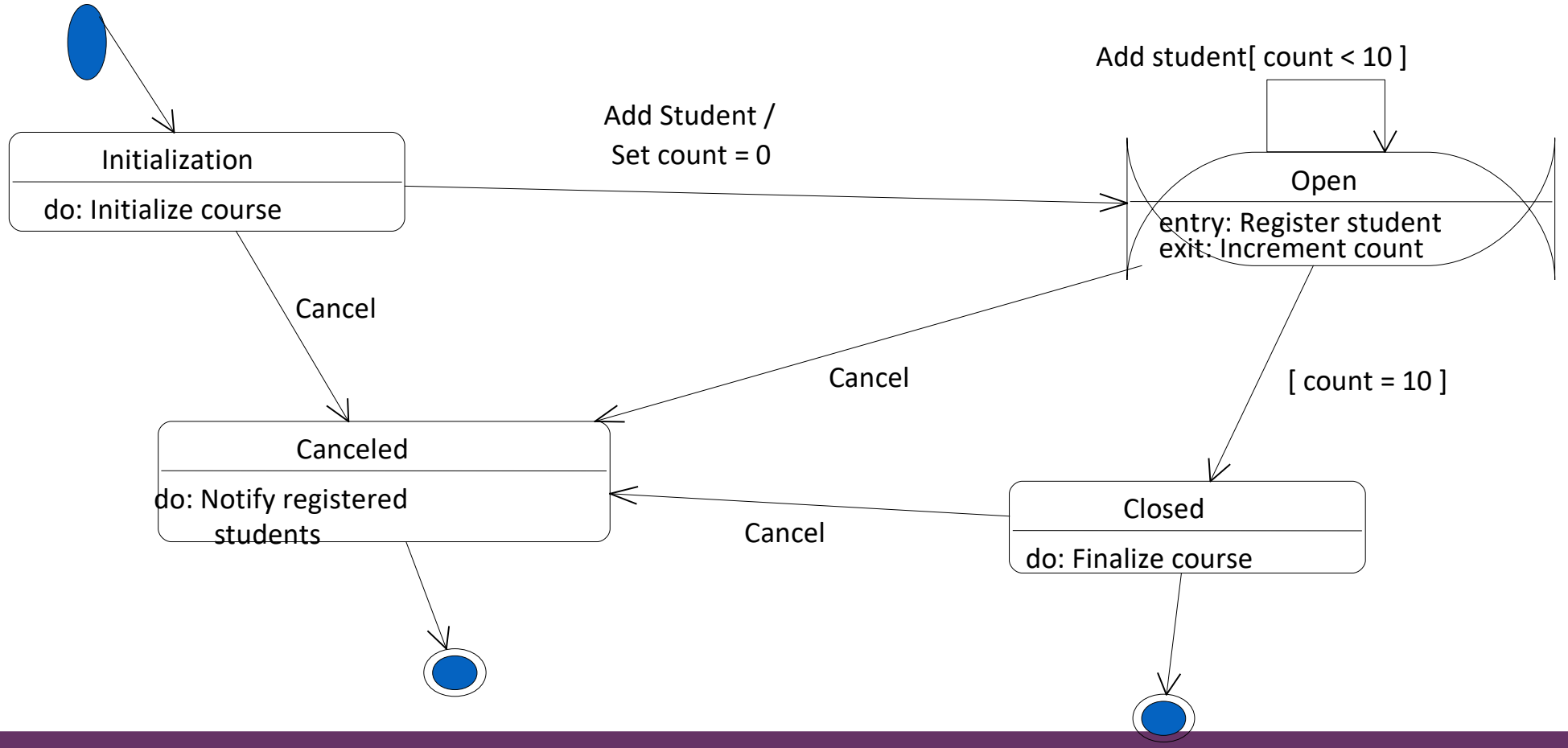


object diagram（对象图）：Example configurations of instances

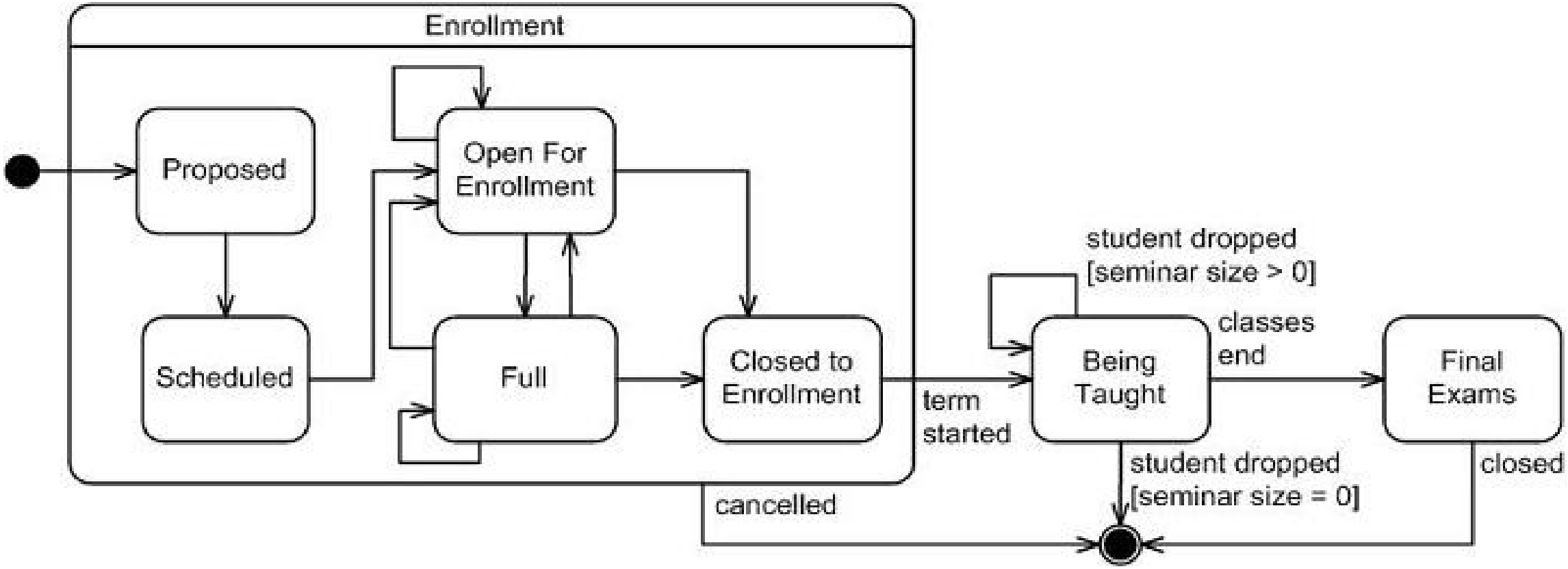


Statechart Diagram

- A statechart diagram shows the lifecycle of a single class.

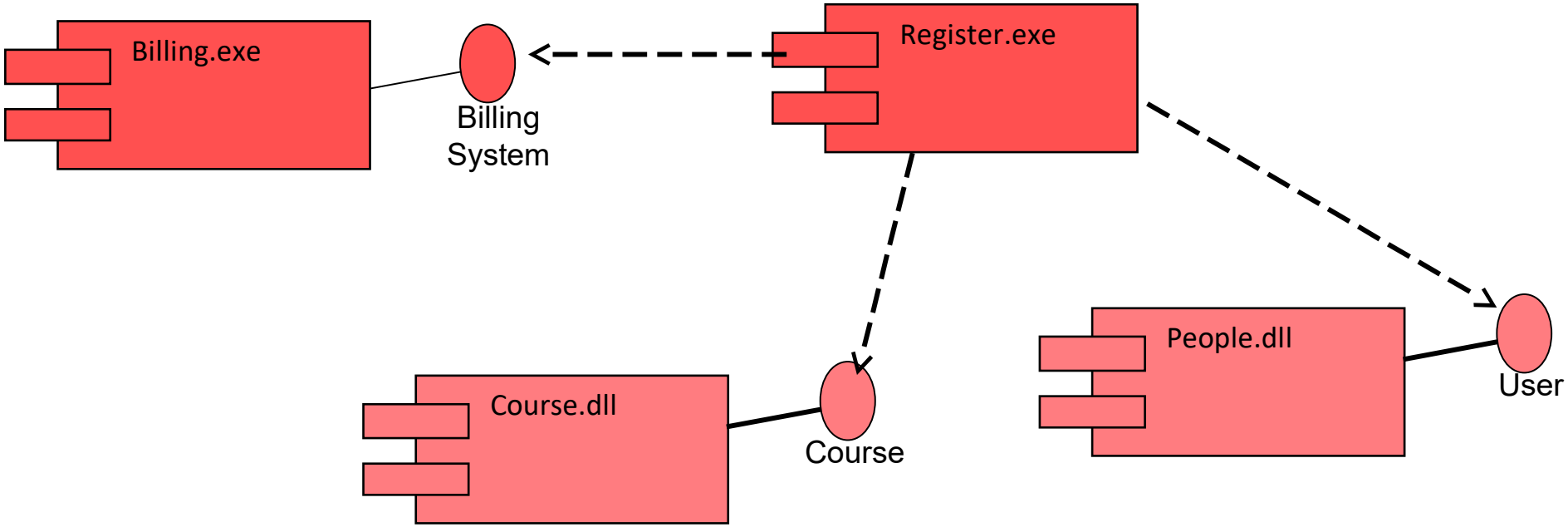


- **statecharts diagram（状态图）**：how events change an object over its life

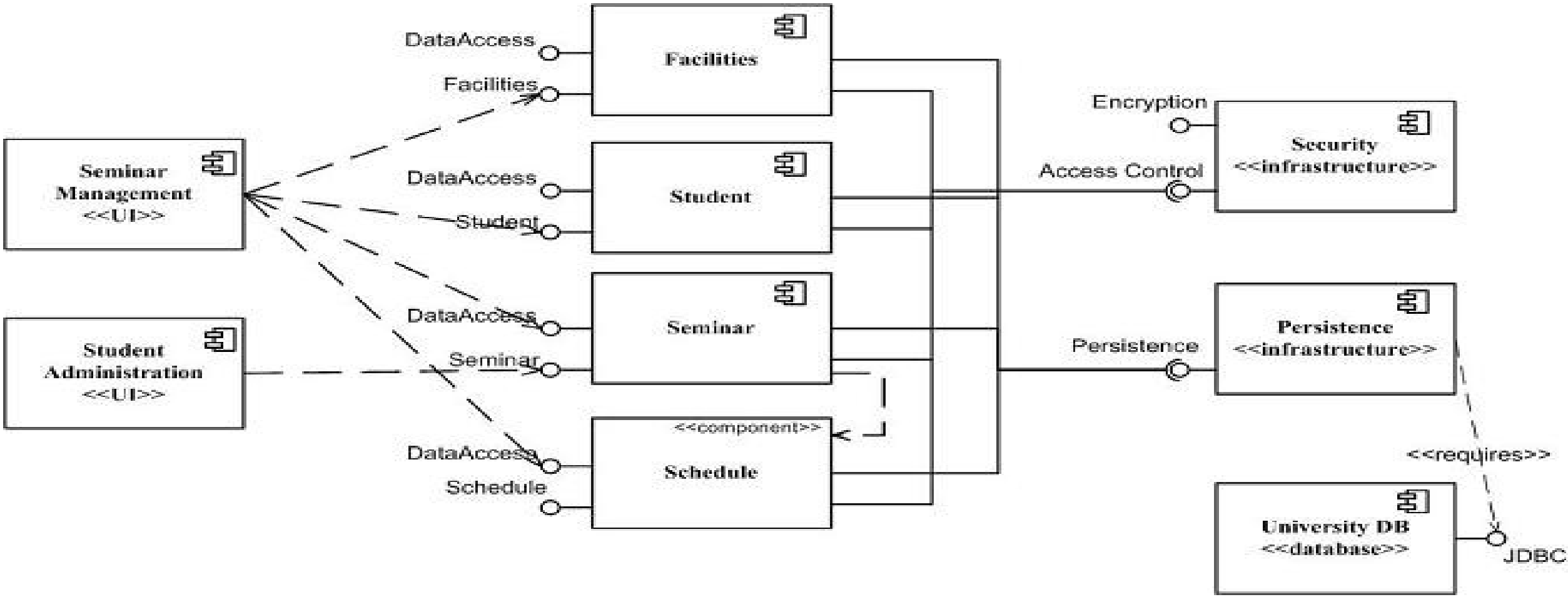


Component Diagram

- A component diagram illustrates the organization and dependencies among software components.

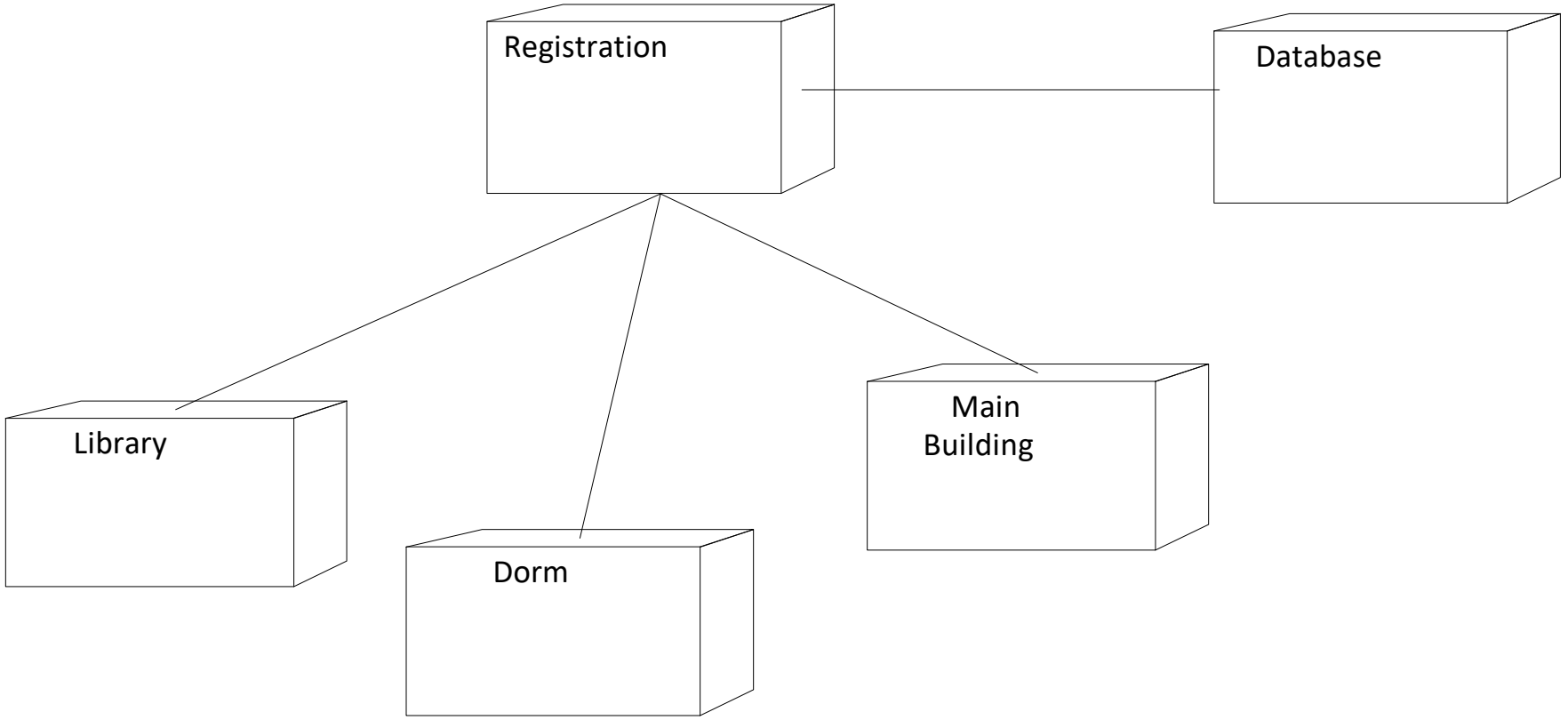


component diagram (构件图) : structure and connections of components

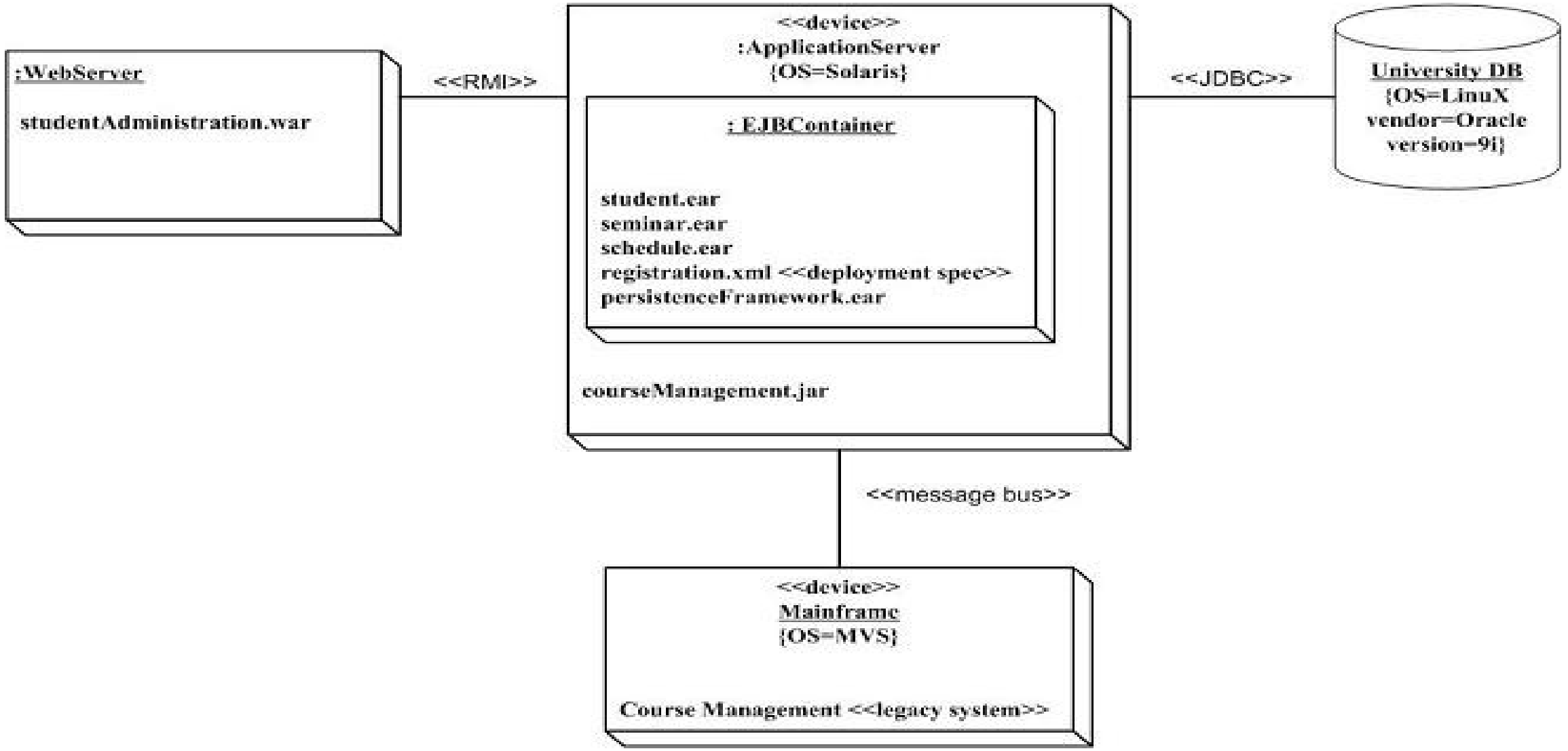


Deployment Diagram

- A deployment diagram visualizes the distribution of components across the enterprise.

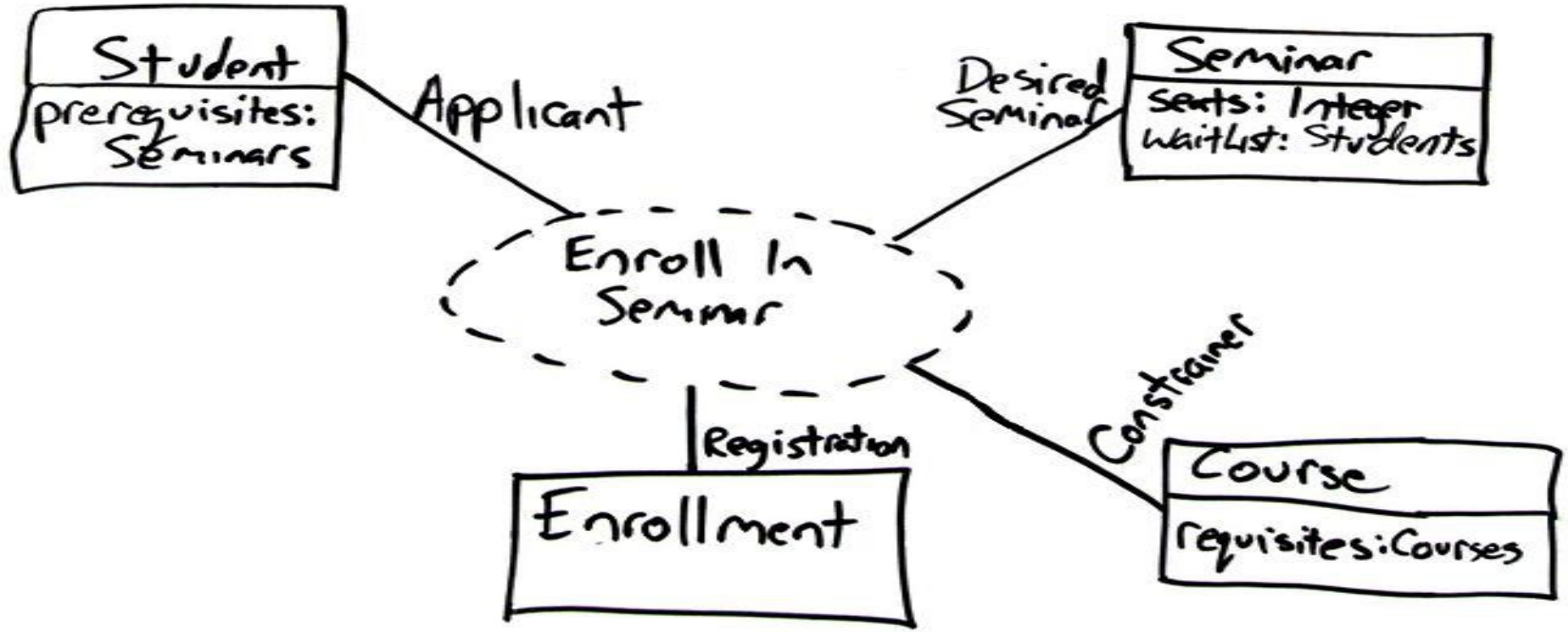


- **deployment diagram（部署图）**: deployment of artifacts to nodes



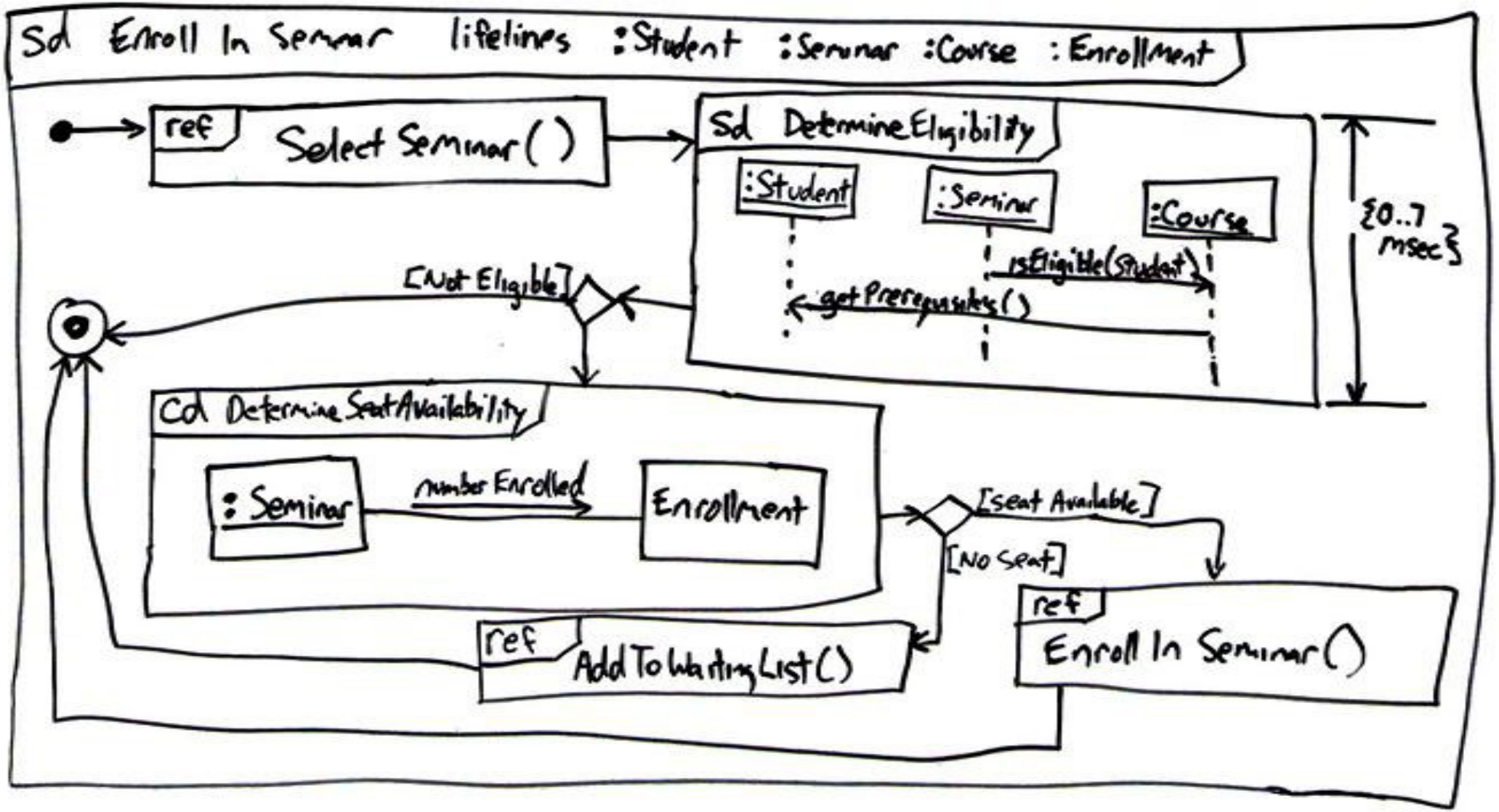
- **Composite Structure Diagram（组成结构图）**

  Runtime decomposition of a class



Interaction Overview Diagram（交互概要图）

Mix of sequence and activity diagram



Timing Diagram（定时图）

Interaction between objects; emphasis on timing