STATE TRANSITION TESTING

Reference: Software Testing Course

@ Lonsdale System

Outline

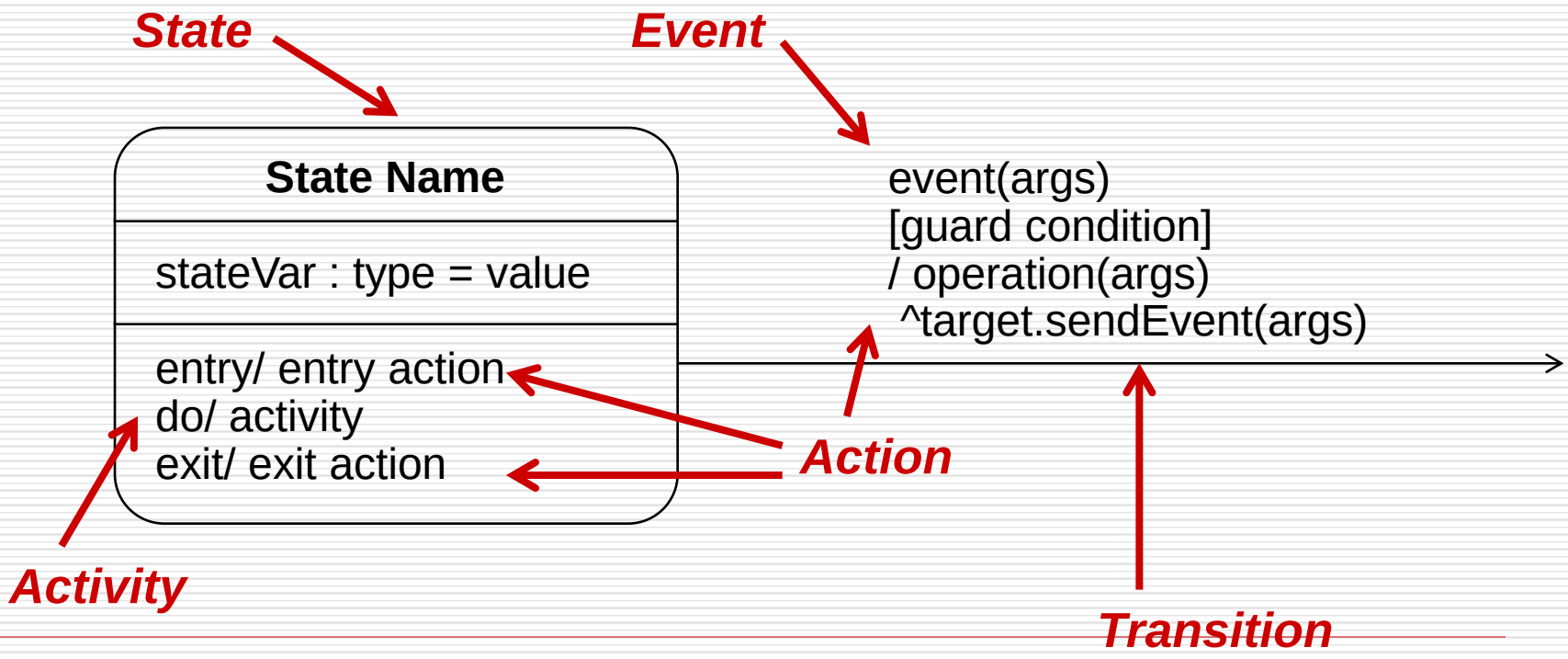
- Generating State Transition Diagrams
- State-Transition Tables
- Creating Test Cases
- Other examples

Define States

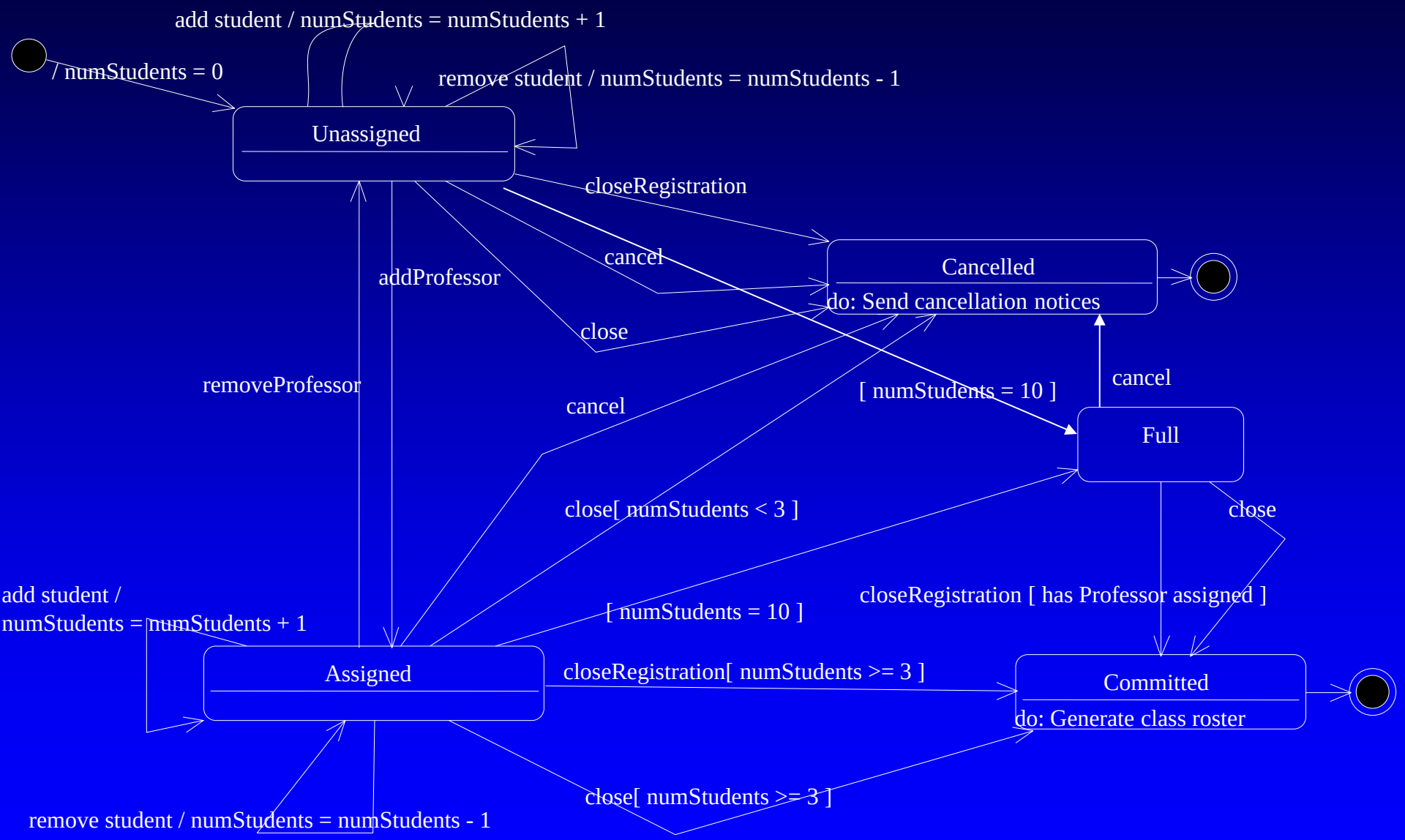
- Purpose
  - Design how an object's state affects its behavior
  - Develop statecharts to model this behavior
- Things to consider :
  - Which objects have significant state?
  - How to determine an object's possible states?
  - How do statecharts map to the rest of the model?

What is a Statechart?

- A directed graph of states (nodes) connected by transitions(directed arcs)
- Describes the life history of a reactive object



Statechart for Course Offering



State-Transition Testing Example

- State-Transition diagrams are an excellent tool to capture certain types of system requirements and to document internal system design.

- These diagrams document the events that come into and are processed by a system as well as the system's responses.

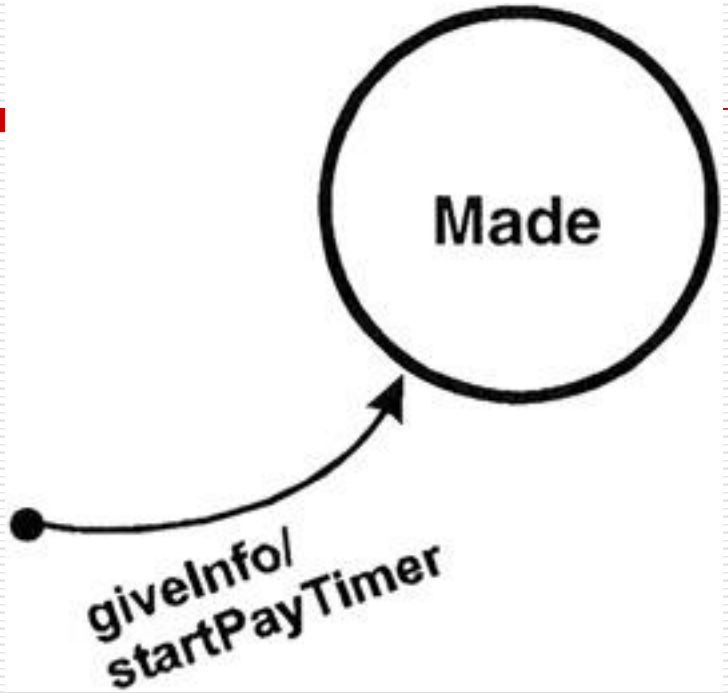
Reservation System Example

1- Make a reservation

- Provide information including departure and destination cities, dates, and times.
- A reservation agent uses that information to make a reservation.
- At that point, the **Reservation** is in the **Made** state.

  The system creates and starts a timer.
- If this **timer expires** before the **reservation is paid** for, the reservation **is cancelled** by the system.

Reservation System Example

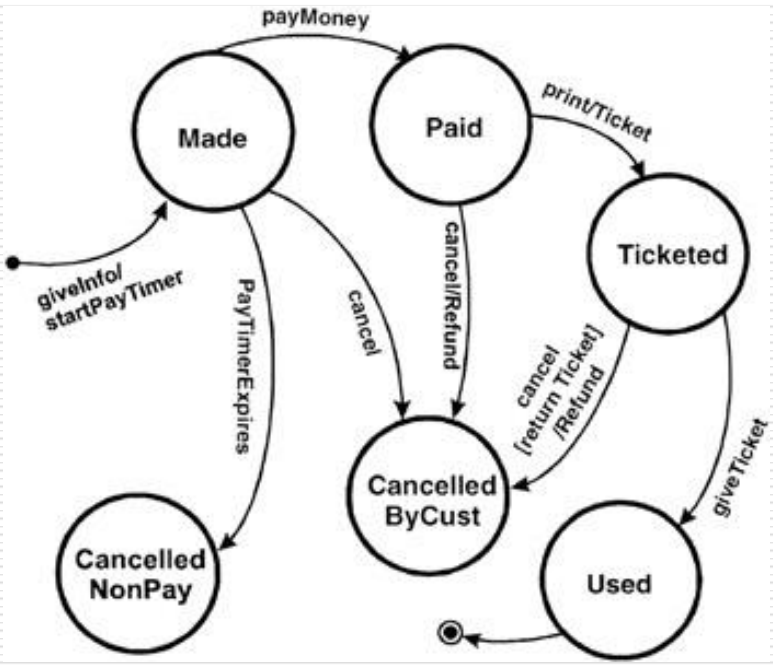


giveInfo, is an **event** that comes into the system from the outside world.

The command after the "/" denotes **an action** of the system; in this case **startPayTimer.**

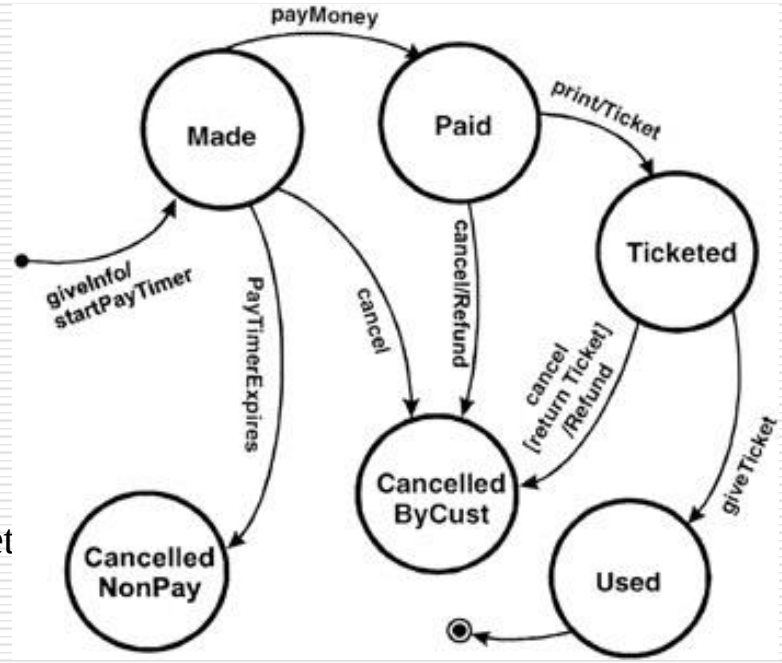
Reservation System Example

- When money is paid, through initiation of the PayMoney action, the system goes into the "Paid" state.
  - Events may have parameters associated with them. For example, **Pay Money** may indicate **Cash, Check, Debit Card,** or **Credit Card**
- When the ticket is printed, the system goes into the Ticketed State
- Upon boarding the plane, the customer gives the boarding pass along with the ticket, which signals that the ticket has been Used.
  - Anything else after this state?

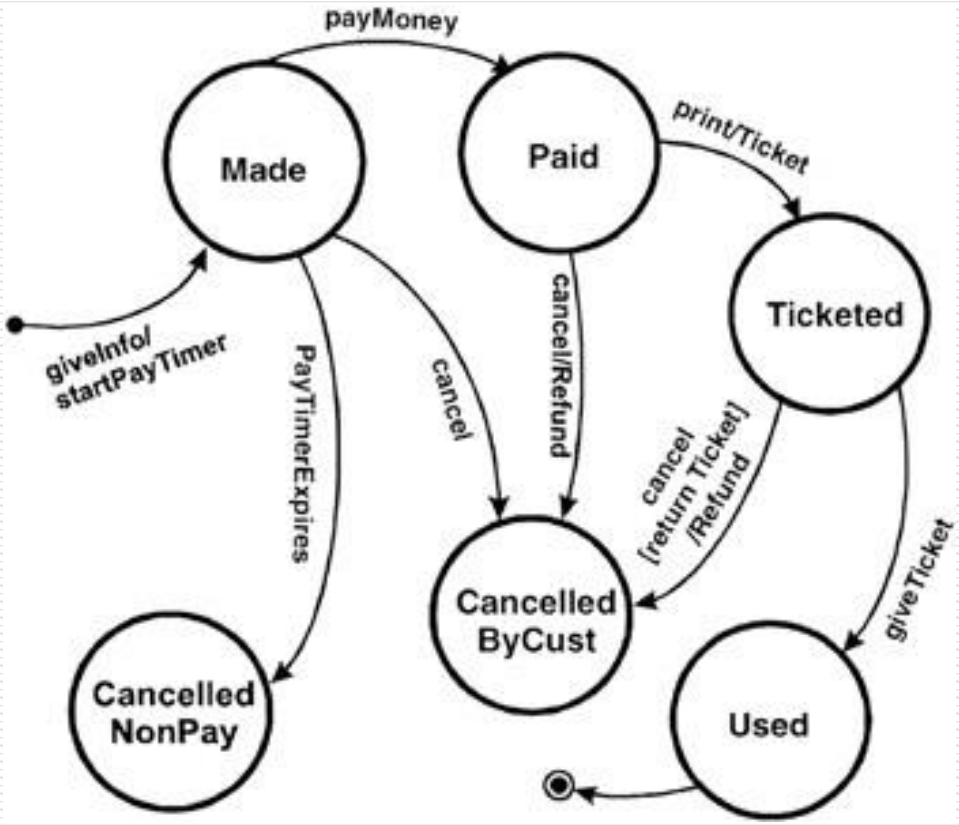


Reservation System Example

- If the **Reservation** is not paid on time, the **PayTimer** expires and the Reservation is **cancelled** for non-payment.
- A reservation may become cancelled if the customer wishes to do so.
  - This can happen prior to payment or after payment.
  - If after payment, a refund needs to be generated.
  - If the customer had the tickets with him, a refund cannot be given unless the printed ticket itself is returned to the agent.
    - This introduces one new notational element—square brackets [] that contain a conditional that can be evaluated either **True** or **False.**
      - This conditional acts as a guard allowing the transition only if the condition is true.



State Transition Diagram of the Reservation System



State-Transition Tables

- State-transition tables may be easier to use in a complete and systematic manner.
- State-transition tables consist of four columns—Current State, Event, Action, and Next State.
- Build the state-transition table as follows

For each state of the system

For each event/trigger of the system

Find the corresponding (Action, Next State) [if any]

Document (state, event, action, next state)

State-Transition table for Reservation.

Current State	Event	Action	Next State
null	giveInfo	startPayTimer	Made
null	payMoney	--	null
null	print	--	null
null	giveTicket	--	null
null	cancel	--	null
null	PayTimerExpires	--	null

Made	giveInfo	--	Made
Made	payMoney	--	Paid
Made	print	--	Made
Made	giveTicket	--	Made
Made	cancel	--	Can-Cust
Made	PayTimerExpires	--	Can-NonPay
Paid	giveInfo	--	Paid
Paid	payMoney	--	Paid
Paid	print	Ticket	Ticketed
Paid	giveTicket	--	Paid
Paid	cancel	Refund	Can-Cust
Paid	PayTimerExpires	--	Paid

Ticketed	giveInfo	--	Ticketed
Ticketed	payMoney	--	Ticketed
Ticketed	print	--	Ticketed
Ticketed	giveTicket	--	Used
Ticketed	cancel	Refund	Can-Cust
Ticketed	PayTimerExpires	--	Ticketed

Used	giveInfo	--	Used
Used	payMoney	--	Used
Used	print	--	Used
Used	giveTicket	--	Used
Used	cancel	--	Used
Used	PayTimerExpires	--	Used

Can-NonPay	giveInfo	--	Can-NonPay
Can-NonPay	payMoney	--	Can-NonPay
Can-NonPay	print	--	Can-NonPay
Can-NonPay	giveTicket	--	Can-NonPay
Can-NonPay	cancel	--	Can-NonPay
Can-NonPay	PayTimerExpires	--	Can-NonPay
Can-Cust	giveInfo	--	Can-Cust
Can-Cust	payMoney	--	Can-Cust
Can-Cust	print	--	Can-Cust
Can-Cust	giveTicket	--	Can-Cust
Can-Cust	cancel	--	Can-Cust
Can-Cust	PayTimerExpires	--	Can-Cust

State-Transition Tables (Cont.)

- The advantage of a state-transition table is that it lists all possible state-transition combinations, not just the valid ones.
- When testing critical, high-risk systems such as avionics or medical devices, testing every state-transition pair may be required, including those that are not valid.
- Creating a state-transition table often unearths combinations that were not identified, documented, or dealt with in the requirements. It is highly beneficial to discover these defects before coding begins.

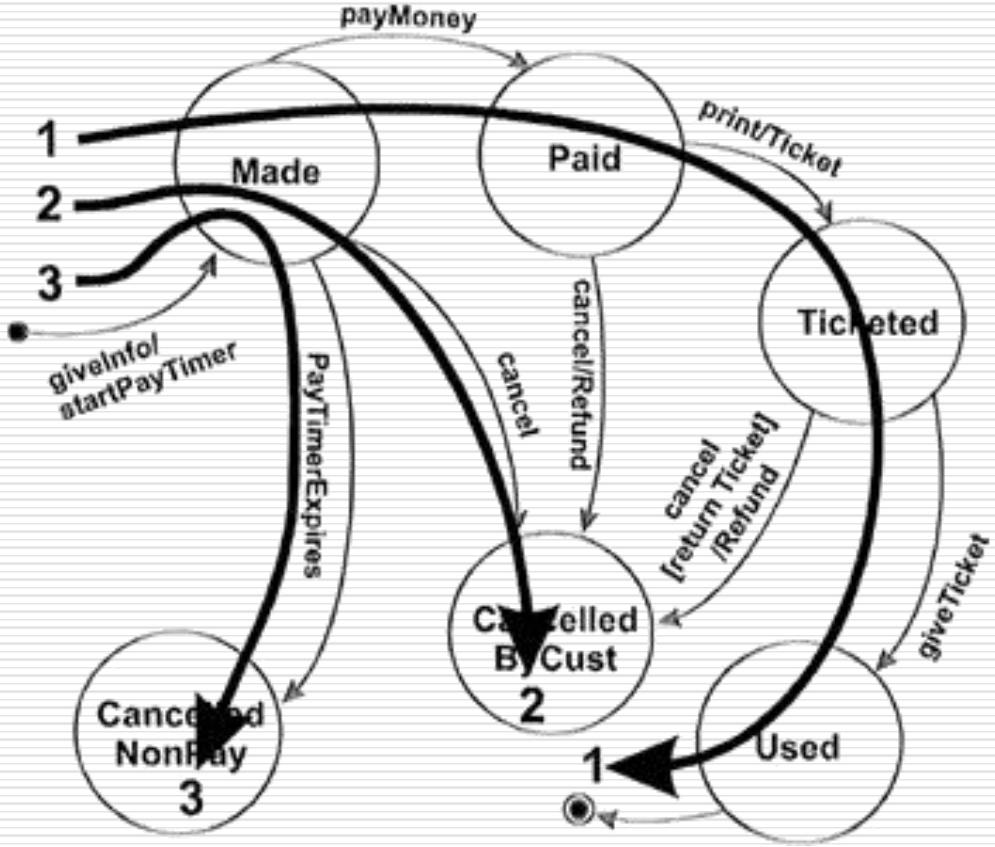
State-Transition Tables (Cont.)

- Using a state-transition table can help detect defects in implementation that enable invalid paths from one state to another.
- The disadvantage of such tables is that they become very large very quickly as the number of states and events increases.
- In addition, the tables are generally sparse; that is, most of the cells are empty.

Creating Test Cases

1. **Create a set of test cases such that all states are "visited" at least once under test**. The set of three test cases shown below meets this requirement. Generally this is a weak level of test coverage.

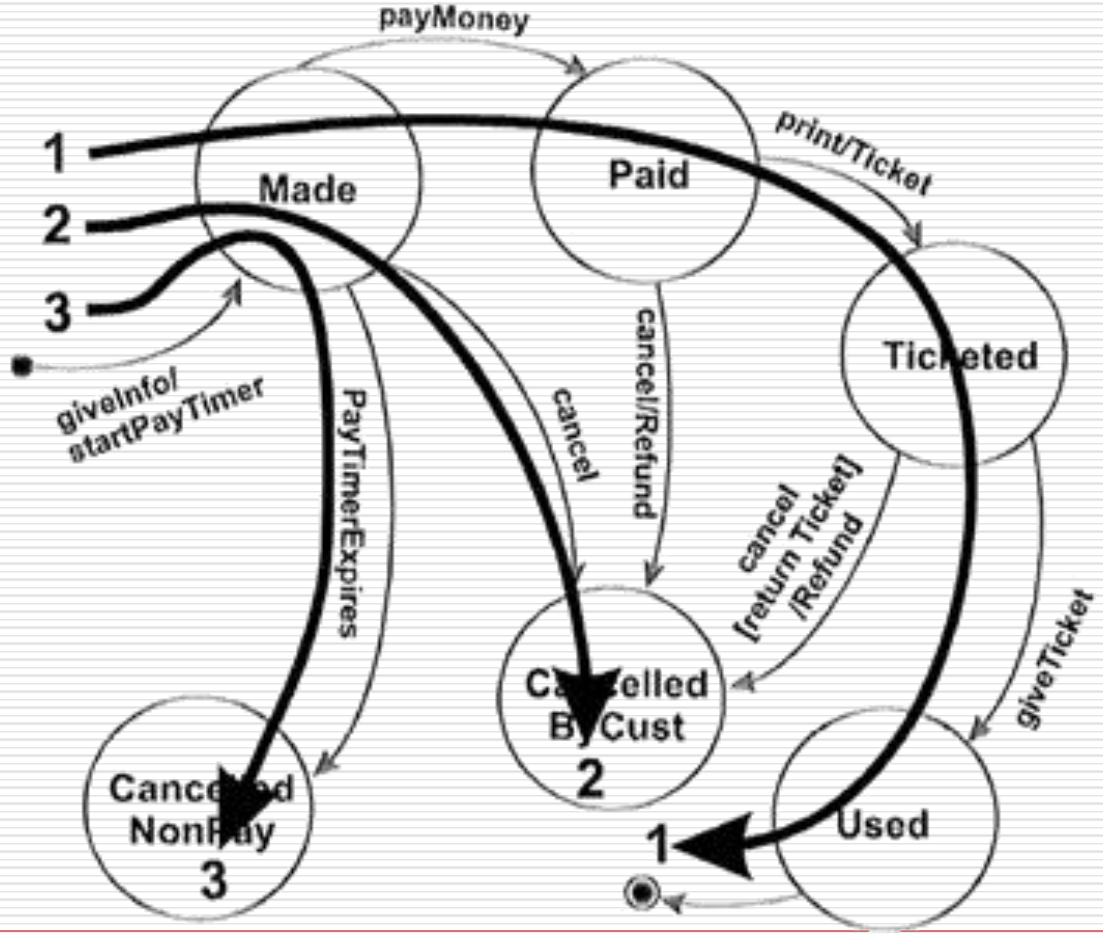
A set of test cases that "visit" each state



Creating Test Cases (Cont.)

2. **Create a set of test cases such that all events are triggered at least once under test.** Note that the test cases that cover each event can be the same as those that cover each state. Again, this is a weak level of coverage.

A set of test cases that trigger all events at least once



Creating Test Cases (Cont.)

3. Create a set of test cases such that all paths are executed at least once under test.

- While this level is the most preferred because of its level of coverage, it may not be feasible.
- If the state-transition diagram has loops, then the number of possible paths may be infinite.

  For example, given a system with two states, A and B, where A transitions to B and B transitions to A. A few of the possible paths are:

  - A→B
  - A→B→A
  - A→B→A→B→A→B
  - A→B→A→B→A→B→A
  - …
  - and so on forever.

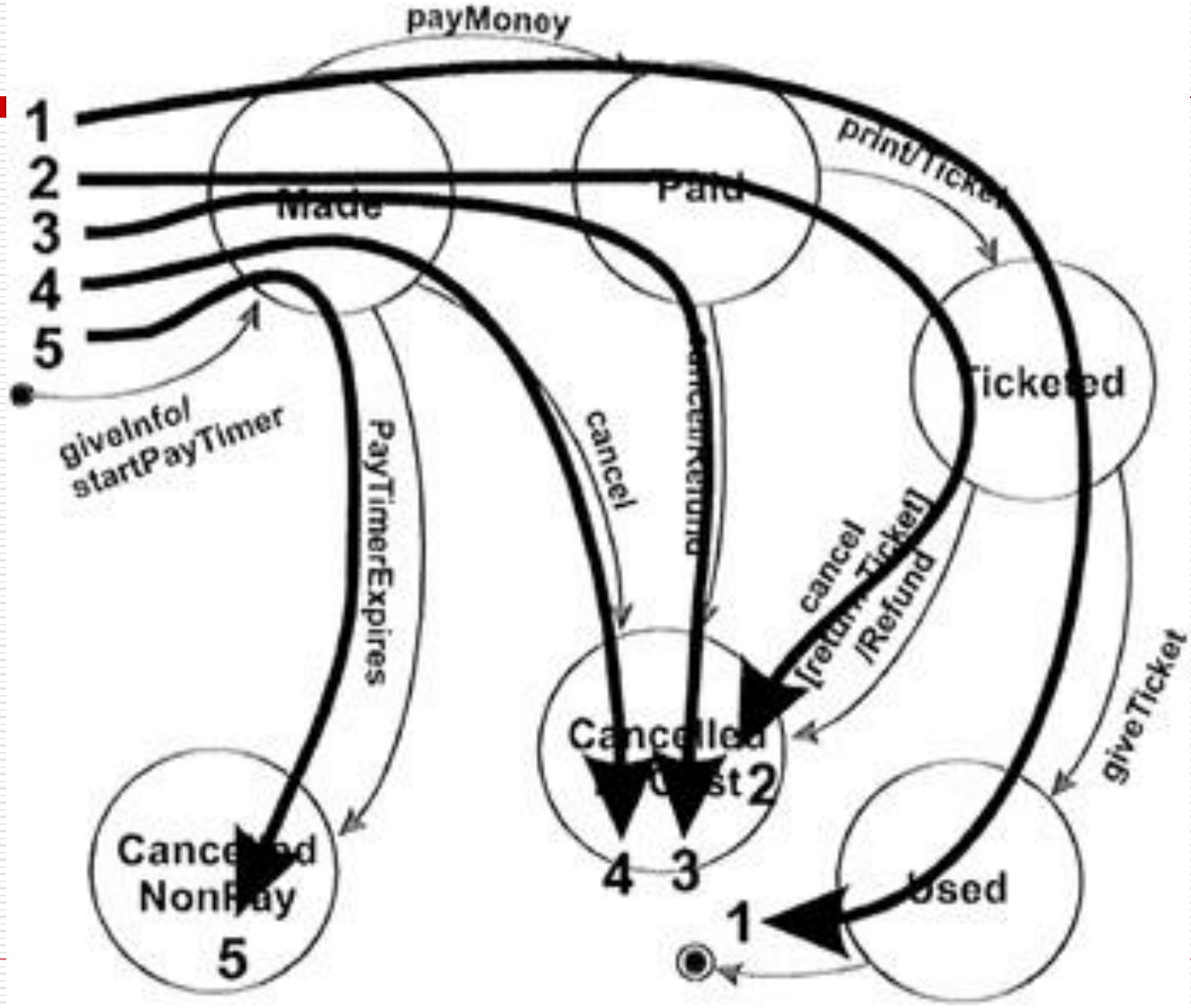
3. Create a set of test cases such that all paths are executed at least once under test (Cont.)

- Testing of loops such as this can be important if they may result in accumulating computational errors or resource loss (locks without corresponding releases, memory leaks, etc.).

Creating Test Cases (Cont.)

4. Create a set of test cases such that all transitions are exercised at least once under test. This level of testing provides a good level of coverage without generating large numbers of tests. This level is generally the one recommended.

A set of test cases that trigger all transitions at least once



4. A set of test cases that trigger all transitions at least once (Cont.)

- Test cases can also be read directly from the state-transition table. The gray rows in the following table show all the valid transitions.

Testing all valid transitions from a State-transition table.			
Current State	Event	Action	Next State
null	giveInfo	startPayTimer	Made
null	payMoney	--	null
null	print	--	null
null	giveTicket	--	null
null	cancel	--	null
null	PayTimerExpires	--	null

Made	giveInfo	--	Made
Made	payMoney	--	Paid
Made	print	--	Made
Made	giveTicket	--	Made
Made	cancel	--	Can-Cust
Made	PayTimerExpires	--	Can-NonPay
Paid	giveInfo	--	Paid
Paid	payMoney	--	Paid
Paid	print	Ticket	Ticketed
Paid	giveTicket	--	Paid
Paid	cancel	Refund	Can-Cust
Paid	PayTimerExpires	--	Paid

Ticketed	giveInfo	--	Ticketed
Ticketed	payMoney	--	Ticketed
Ticketed	print	--	Ticketed
Ticketed	giveTicket	--	Used
Ticketed	cancel	Refund	Can-Cust
Ticketed	PayTimerExpires	--	Ticketed
Used	giveInfo	--	Used
Used	payMoney	--	Used
Used	print	--	Used
Used	giveTicket	--	Used
Used	cancel	--	Used
Used	PayTimerExpires	--	Used

Can-NonPay	giveInfo	--	Can-NonPay
Can-NonPay	payMoney	--	Can-NonPay
Can-NonPay	print	--	Can-NonPay
Can-NonPay	giveTicket	--	Can-NonPay
Can-NonPay	cancel	--	Can-NonPay
Can-NonPay	PayTimerExpires	--	Can-NonPay
Can-Cust	giveInfo	--	Can-Cust
Can-Cust	payMoney	--	Can-Cust
Can-Cust	print	--	Can-Cust
Can-Cust	giveTicket	--	Can-Cust
Can-Cust	cancel	--	Can-Cust
Can-Cust	PayTimerExpires	--	Can-Cust

State-Transition Testing (Cont.)

- In addition, depending on the system risk, you may want to create test cases for some or all of the invalid state/event pairs to make sure the system has not implemented invalid paths.

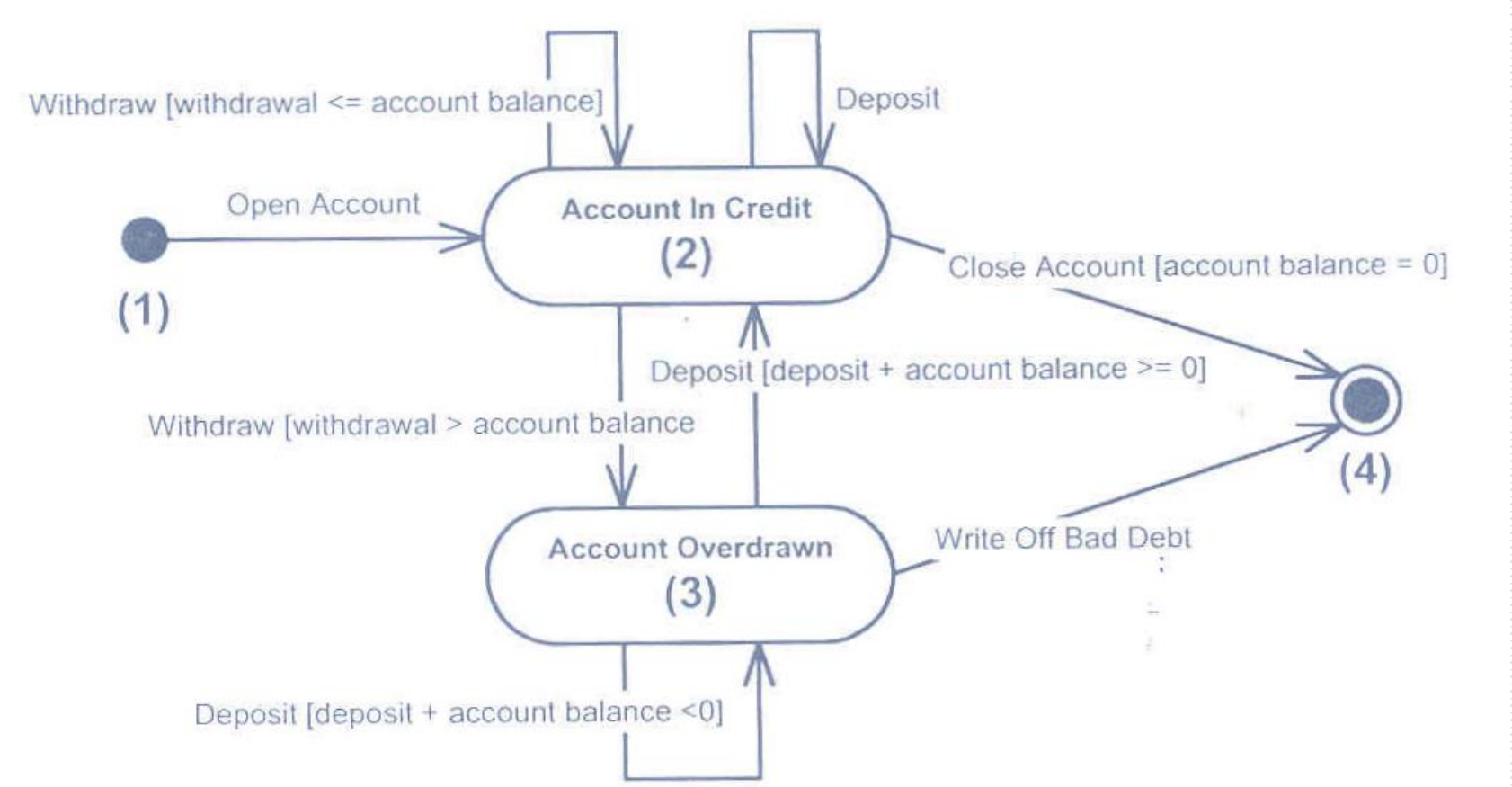
- ***Applicability and Limitations***
  - State-Transition diagrams are excellent tools to capture certain system requirements, namely those that describe states and their associated transitions. These diagrams then can be used to direct our testing efforts by identifying the states, events, and transitions that should be tested.
  - State-Transition diagrams are not applicable when the system has no state or does not need to respond to real-time events from outside of the system.

    An example is a payroll program that reads an employee's time record, computes pay, subtracts deductions, saves the record, prints a paycheck, and repeats the process.

Key Points

- State-Transition diagrams direct our testing efforts by identifying the states, events, actions, and transitions that should be tested. Together, these define how a system interacts with the outside world, the events it processes, and the valid and invalid order of these events.
- A state-transition diagram is not the only way to document system behaviour. They may be easier to comprehend, but state-transition tables may be easier to use in a complete and systematic manner.
- The generally recommended level of testing using state-transition diagrams is to create a set of test cases such **that all transitions are exercised** at least once under test.
- In high-risk systems, you may want to create even more test cases, approaching all paths if possible.

State Transition for a Bank Account



Prior State	New State	Valid Transition	Comment
1	1	N	
1	2	Y	New account
1	3	N	Possible negative test case
1	4	N	
2	1	N	
2	2	Y	Deposit and withdraw [withdrawal <= account balance]
2	3	Y	Withdraw [withdrawal > account balance]
2	4	Y	Closed account [account balance=0]
3	1	N	
3	2	Y	Deposit [deposit + account balance >= 0]
3	3	Y	Deposit [deposit + account balance < 0]
3	4	Y	Write Off Bad Debt [account balance < 0]
4	1	N	
4	2	N	Possible negative test case
4	3	N	Possible negative test case
4	4	N	Possible negative test case

Table 1: State Table for a Bank Account

Ba

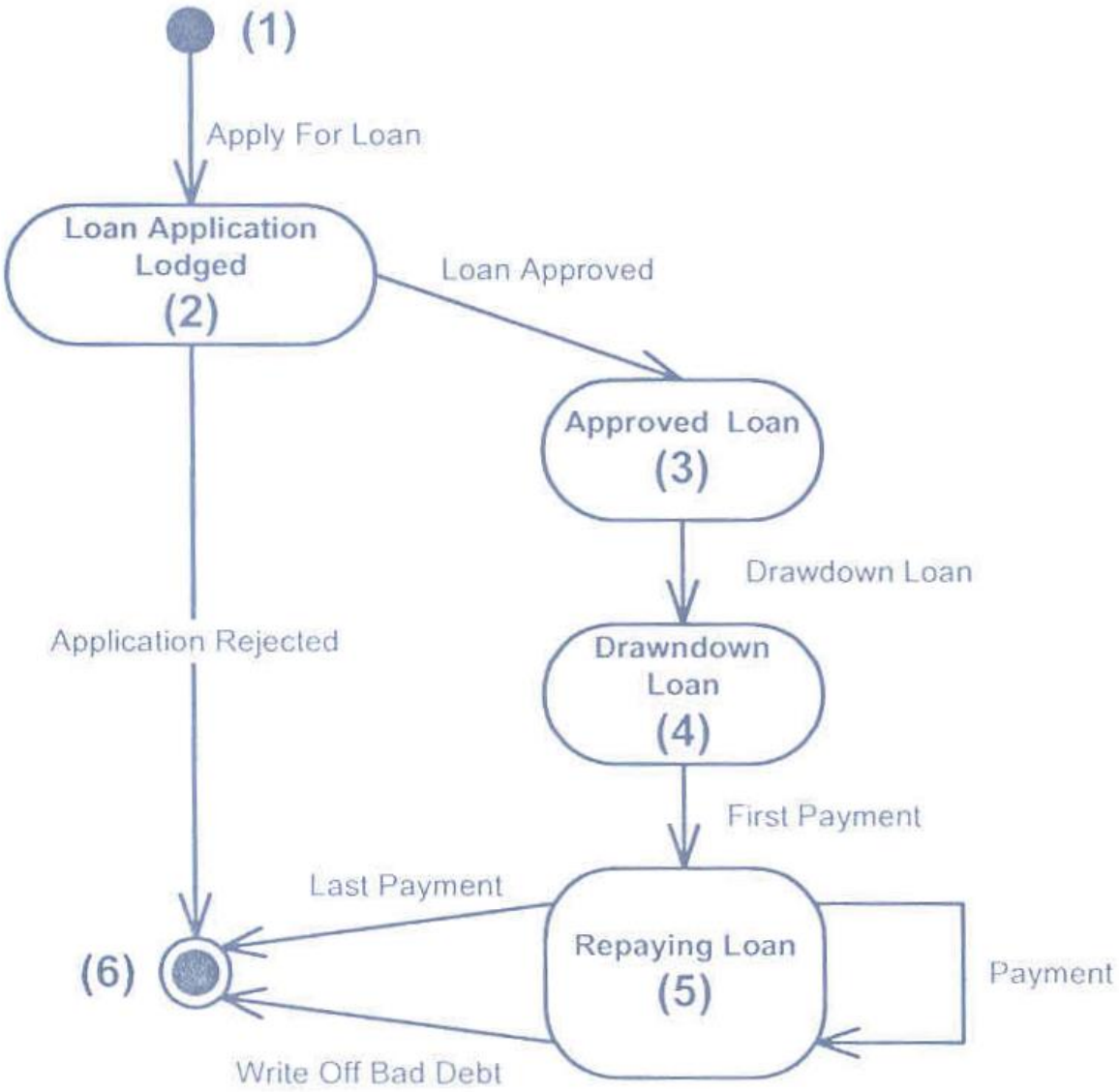


Figure 4: State transition diagram for a Bank Loan

Prior State	New State	Valid Transition	Comment
1	1	N	
1	2	Y	New loan application
1	3	N	
1	4	N	
1	5	N	
1	6	N	
2	1	N	
2	2	N	
2	3	Y	Loan approval
2	4	N	This tests that un-approved loans cannot be drawn down
2	5	?	Is there an application fee?
2	6	Y	Loan rejection
3	1	N	
3	2	?	Can approved loans be reconsidered?
3	3	N	
3	4	Y	Drawdown of loan
3	5	?	Can pre-payments be accepted?
3	6	N	
4	1	N	
4	2	?	Can a drawdown loan be reconsidered?
4	3	N	
4	4	?	Are multiple draw downs allowed?
4	5	Y	First Payment
4	6	?	Can a loan be written of before any payments have been made?
5	1	N	
5	2	N	
5	3	N	
5	4	?	Are multiple draw downs allowed?
5	5	Y	Payment during life of loan
5	6	Y	If account balance = 0, loan discharged If account balance < 0, loan default
6	1	N	
6	2	?	Can rejected loans be reconsidered
6	3	?	Can rejected loans be approved?
6	4	N	
6	5	?	Can written off loans be reinstated?
6	6	N	

Table 2: State Table for a Bank Loan

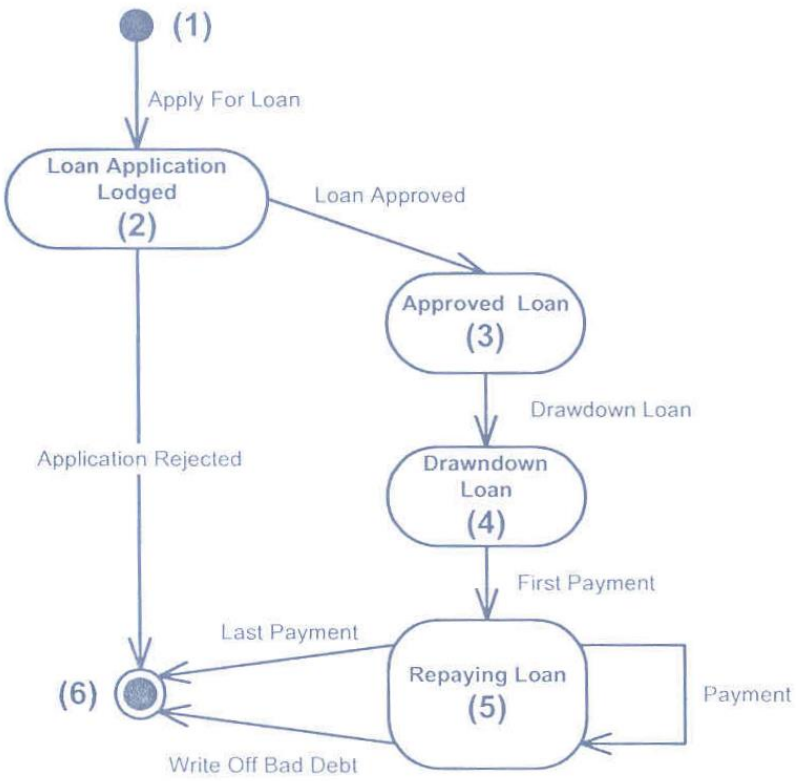
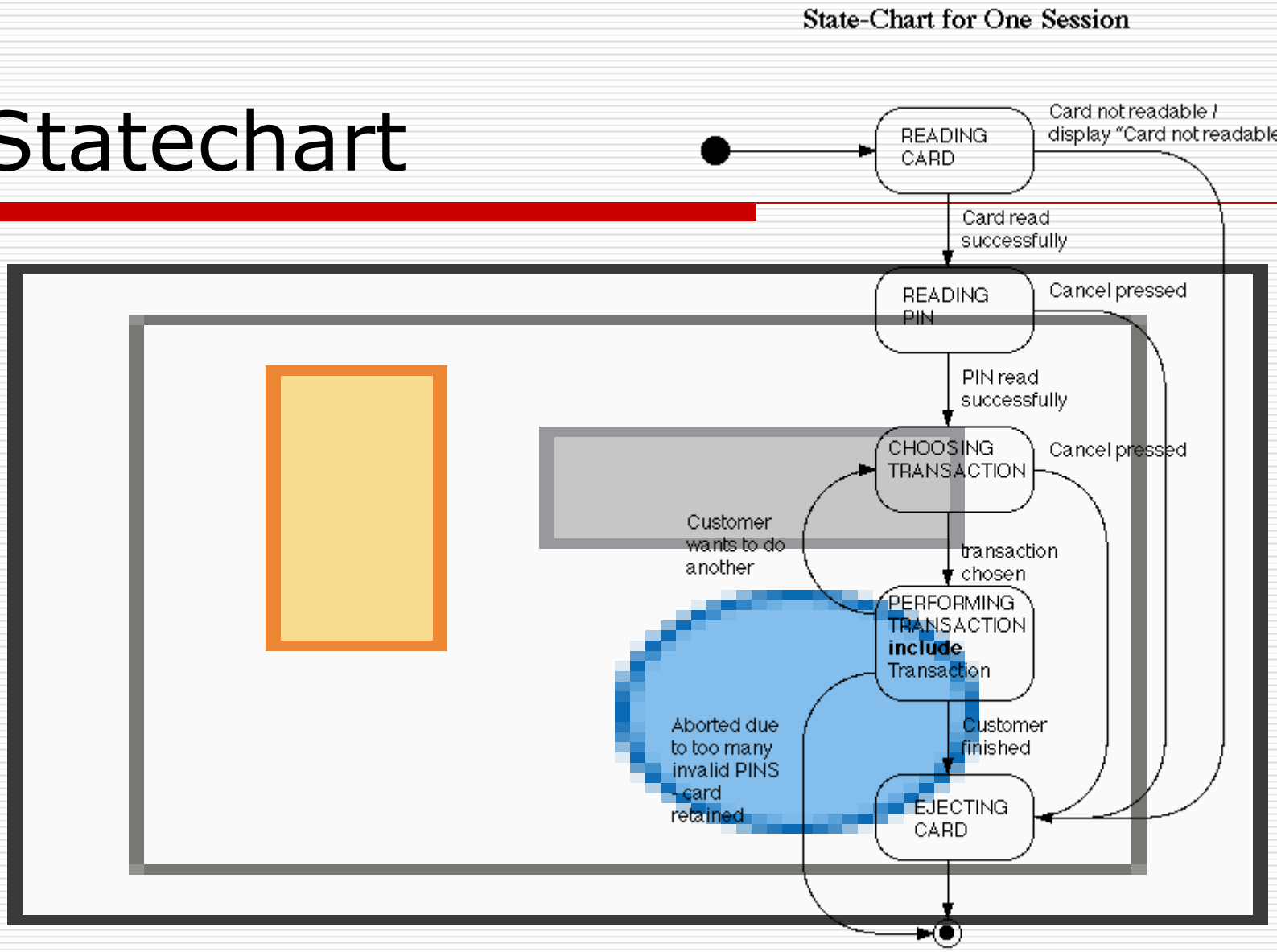
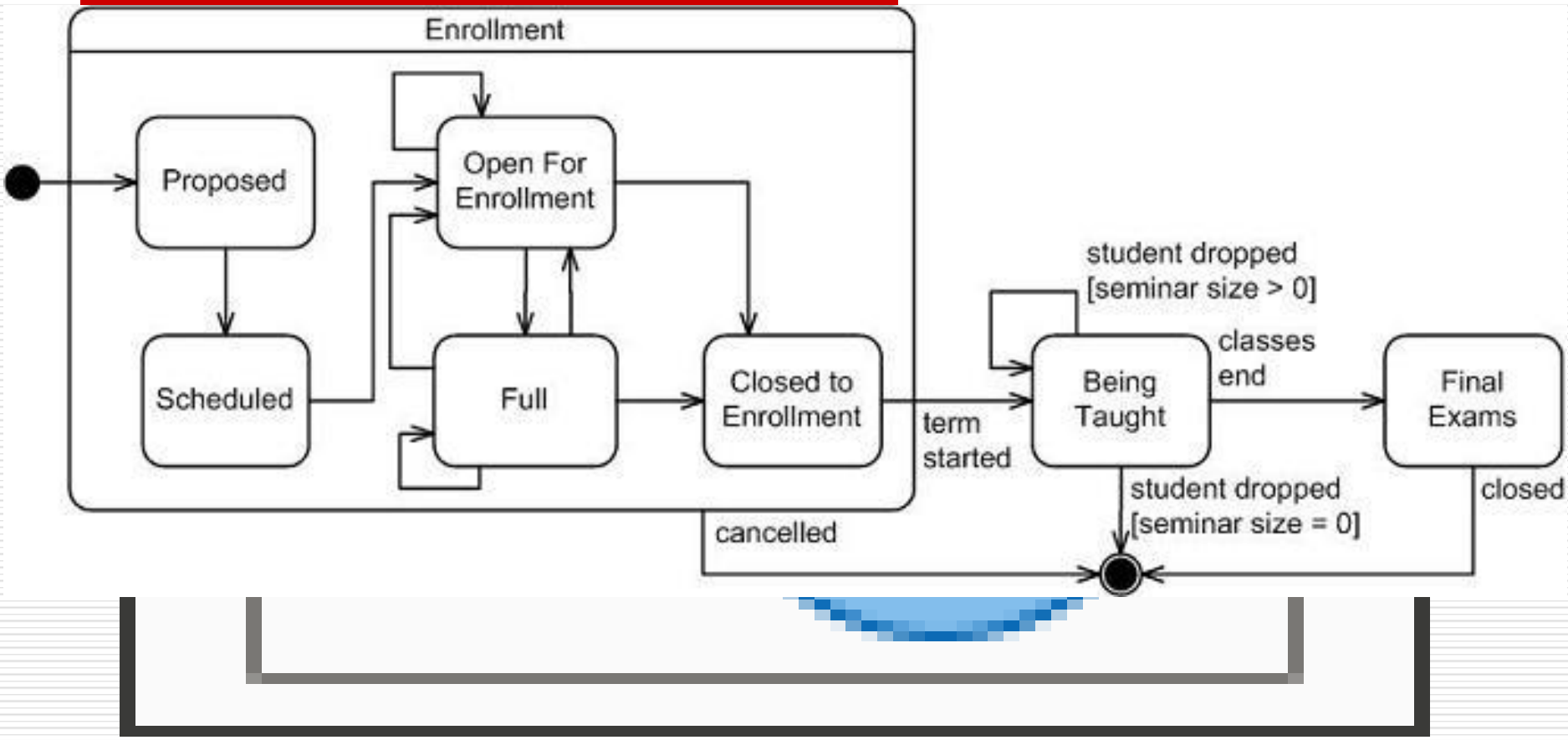
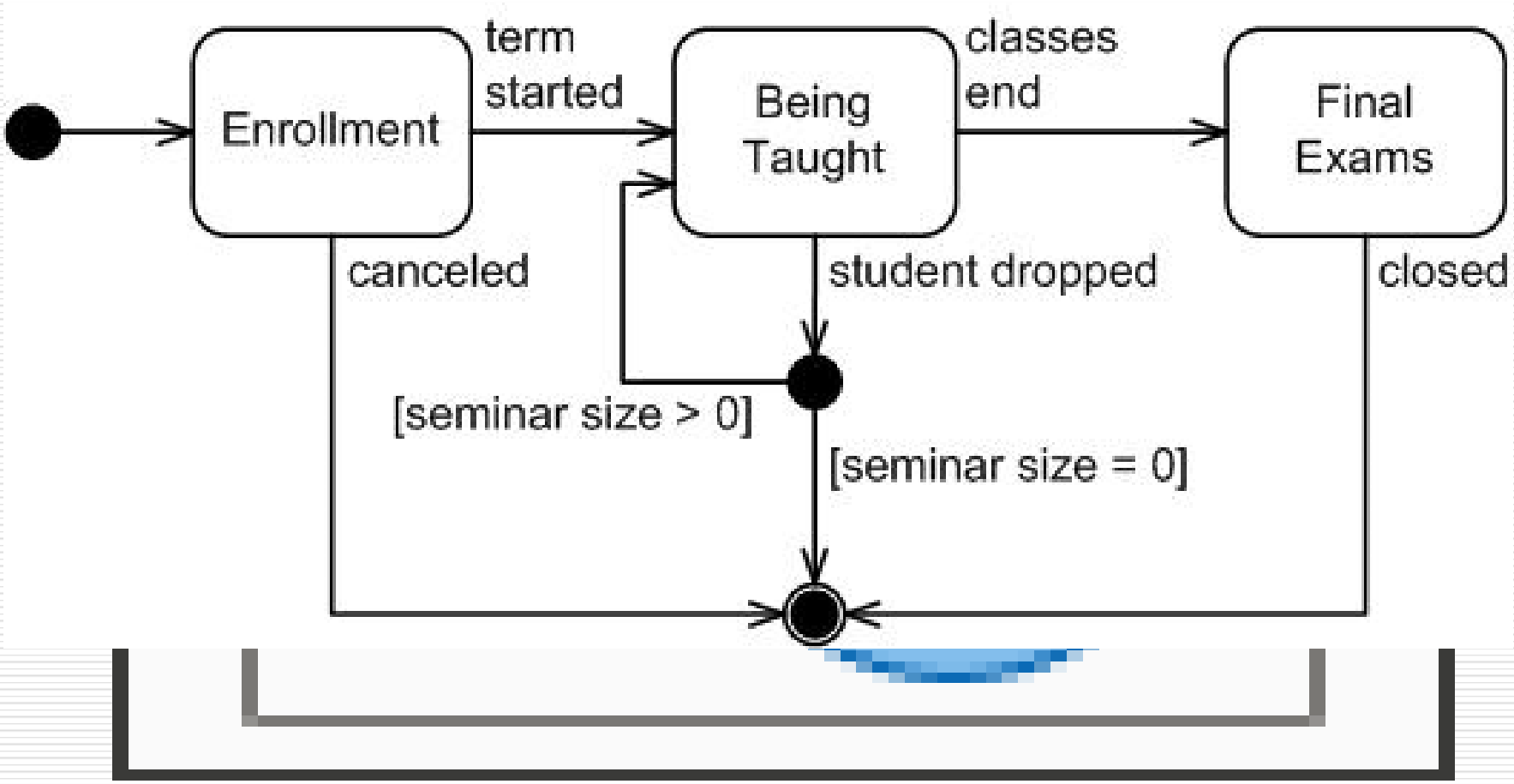


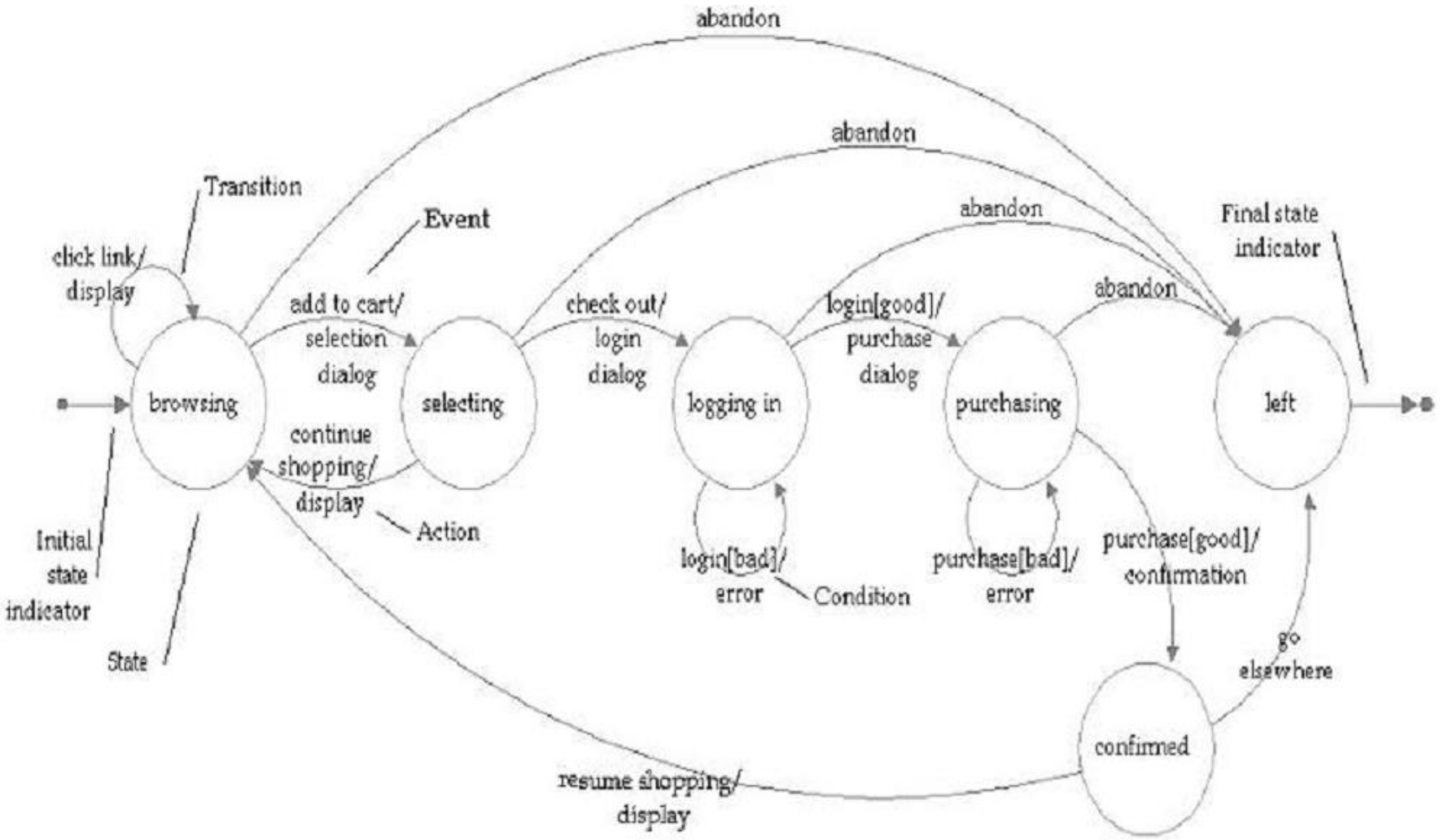
Figure 4: State transition diagram for a Bank Loan

Statechart


State-Chart for One Session
READING CARD
Card not readable / display "Card not readable"
Card read successfully
READING PIN
Cancel pressed
PIN read successfully
CHOOSING TRANSACTION
Cancel pressed
Customer wants to do another
transaction chosen
PERFORMING TRANSACTION include Transaction
Aborted due to too many invalid PINS card retained
Customer finished
EJECTING CARD


Enrollment
Proposed
Open For Enrollment
Scheduled
Full
Closed to Enrollment
cancelled
term started
student dropped
[seminar size > 0]
Being Taught
classes end
Final Exams
student dropped
[seminar size = 0]
closed


Enrollment
term started
Being Taught
classes end
Final Exams
canceled
student dropped
closed
[seminar size > 0]
[seminar size = 0]


abandon
abandon
abandon
abandon
Transition
Event
Final state
indicator
click link/
display
add to cart/
selection
dialog
check out/
login
dialog
login[good]/
purchase
dialog
browsing
selecting
logging in
purchasing
left
continue
shopping/
display
Action
Initial
state
indicator
State
login[bad]/
error
Condition
purchase[bad]/
error
purchase[good]/
confirmation
go
elsewhere
confirmed
resume shopping/
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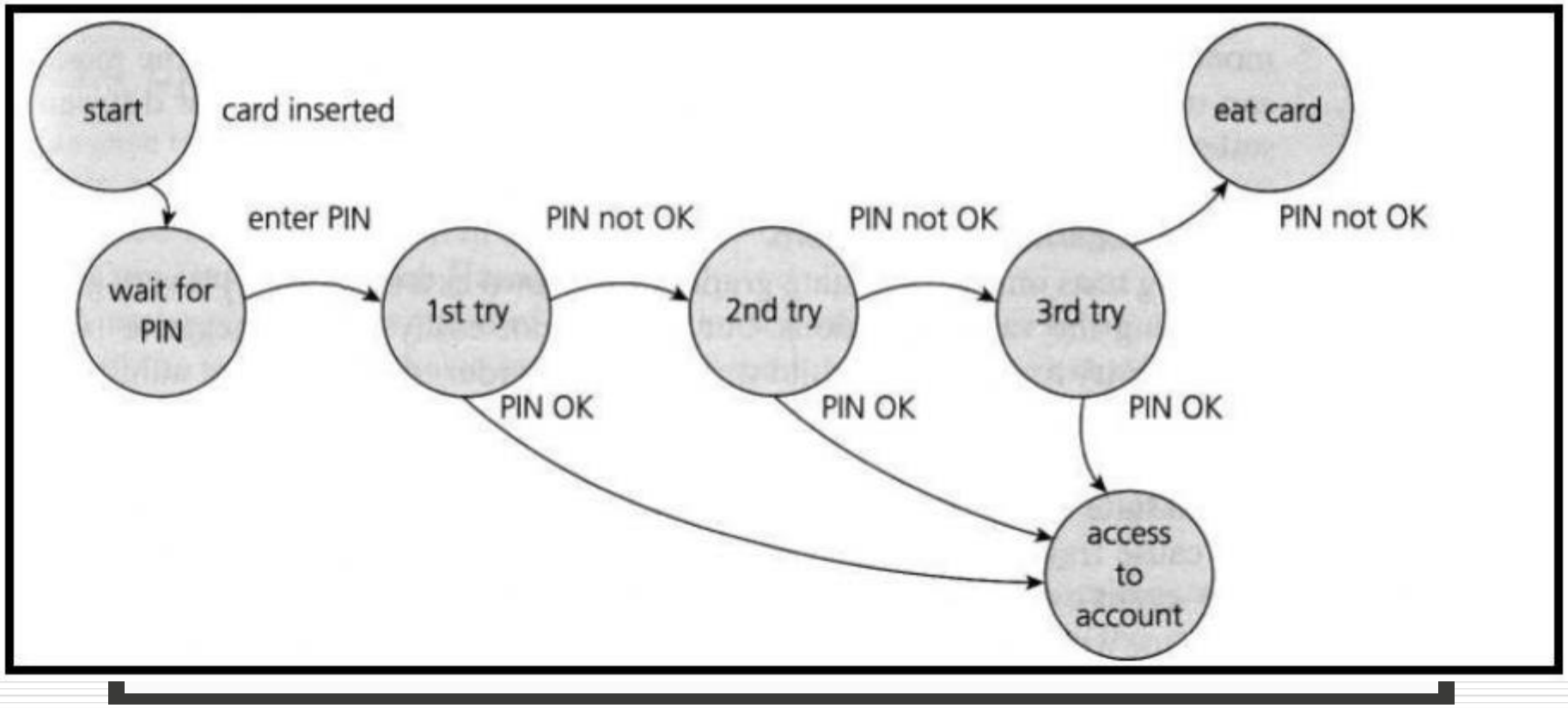
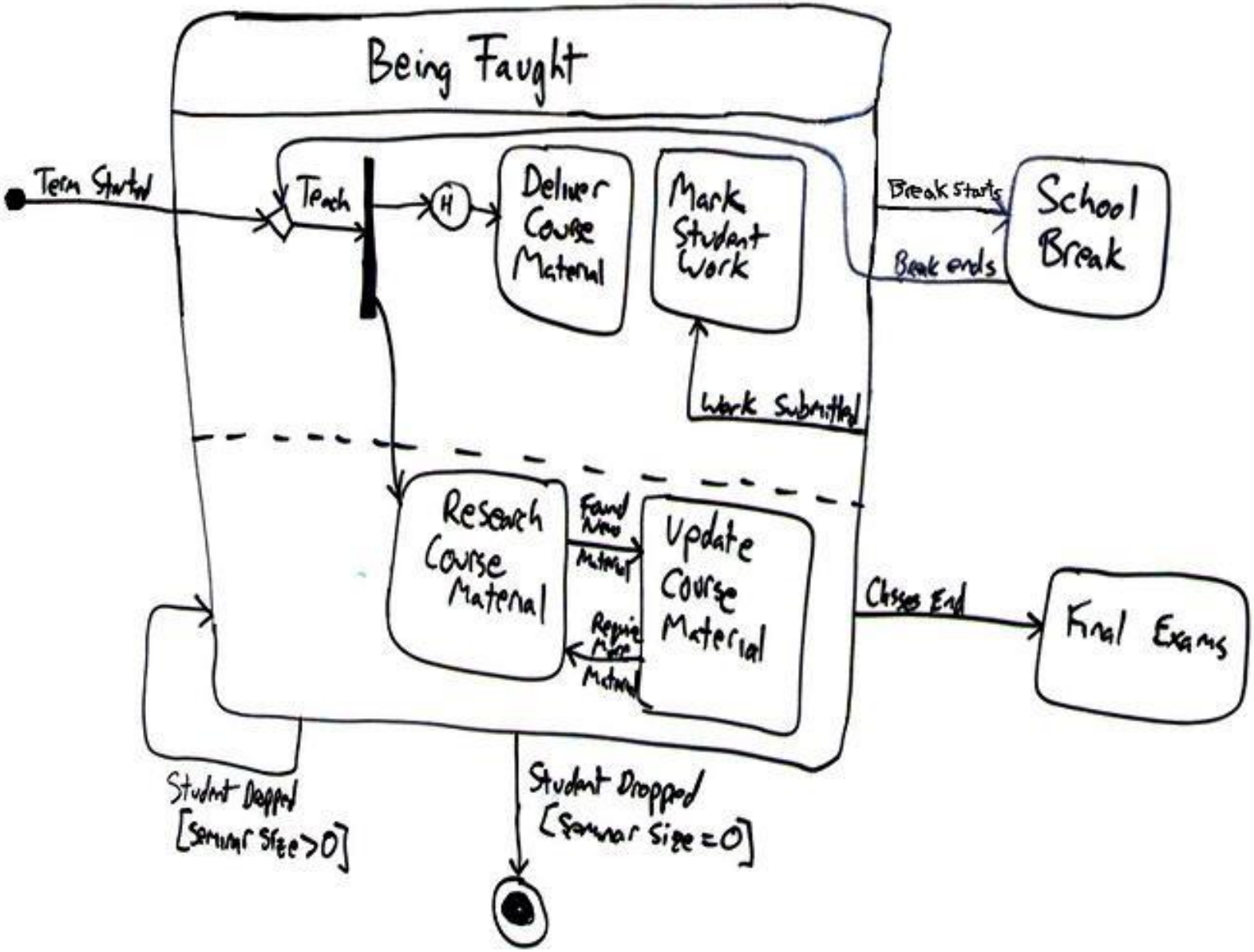

start
card inserted
wait for PIN
enter PIN
1st try
PIN not OK
2nd try
PIN not OK
3rd try
PIN not OK
eat card
PIN OK
PIN OK
PIN OK
access to account


Being Taught
Term Started
Teach
H
Deliver Course Material
Mark Student Work
Break starts
Break ends
School Break
Work Submitted
Research Course Material
Found New Material
Update Course Material
Require More Material
Classes End
Final Exams
Student Dropped
[Seminar Size>0]
Student Dropped
[Seminar Size=0]

Exercise

- Account mobifone
- ATM
- Moodle Assignment
- Student life cycle
- Bug life cycles

Assignment name* You must supply a value here.

Description*

Arial | 1 (8 pt) | Lang

Path:

Grade 100

Available from 6 February 2015 10 15 Disable

Due date 13 February 2015 10 15 Disable

Prevent late submissions Yes

Allow resubmitting No

Email alerts to teachers No

Maximum size 10MB

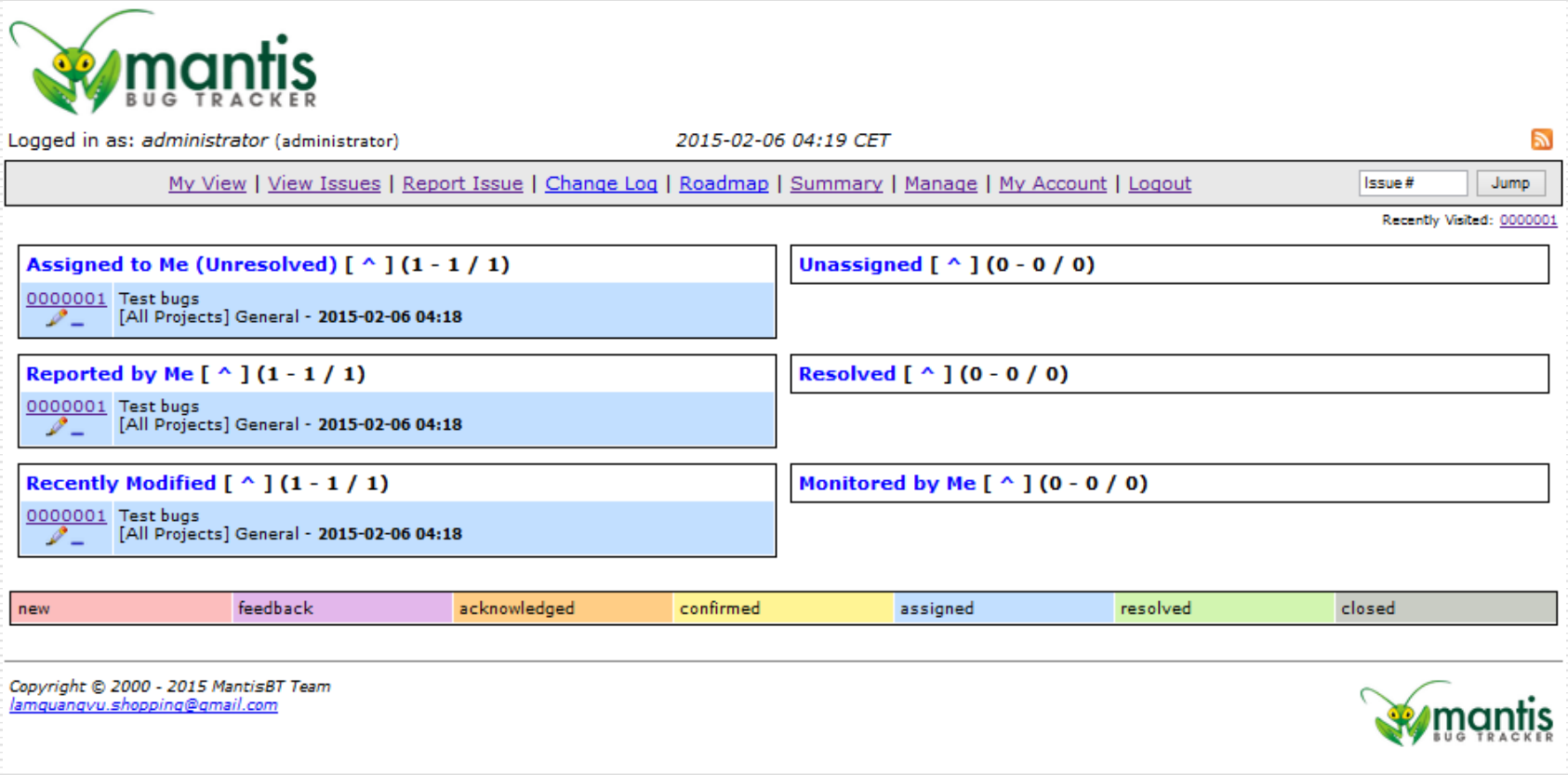
Group mode No groups

Visible Hide

ID number

Grade category Uncategorised

HCMU


mantis
BUG TRACKER
Logged in as: administrator (administrator)
2015-02-06 04:19 CET
My View | View Issues | Report Issue | Change Log | Roadmap | Summary | Manage | My Account | Logout
Issue #
Jump
Recently Visited: 0000001
Assigned to Me (Unresolved) [^] (1 - 1 / 1)
0000001
Test bugs
[All Projects] General - 2015-02-06 04:18
Unassigned [^] (0 - 0 / 0)
Reported by Me [^] (1 - 1 / 1)
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Test bugs
[All Projects] General - 2015-02-06 04:18
Resolved [^] (0 - 0 / 0)
Recently Modified [^] (1 - 1 / 1)
0000001
Test bugs
[All Projects] General - 2015-02-06 04:18
Monitored by Me [^] (0 - 0 / 0)
new
feedback
acknowledged
confirmed
assigned
resolved
closed
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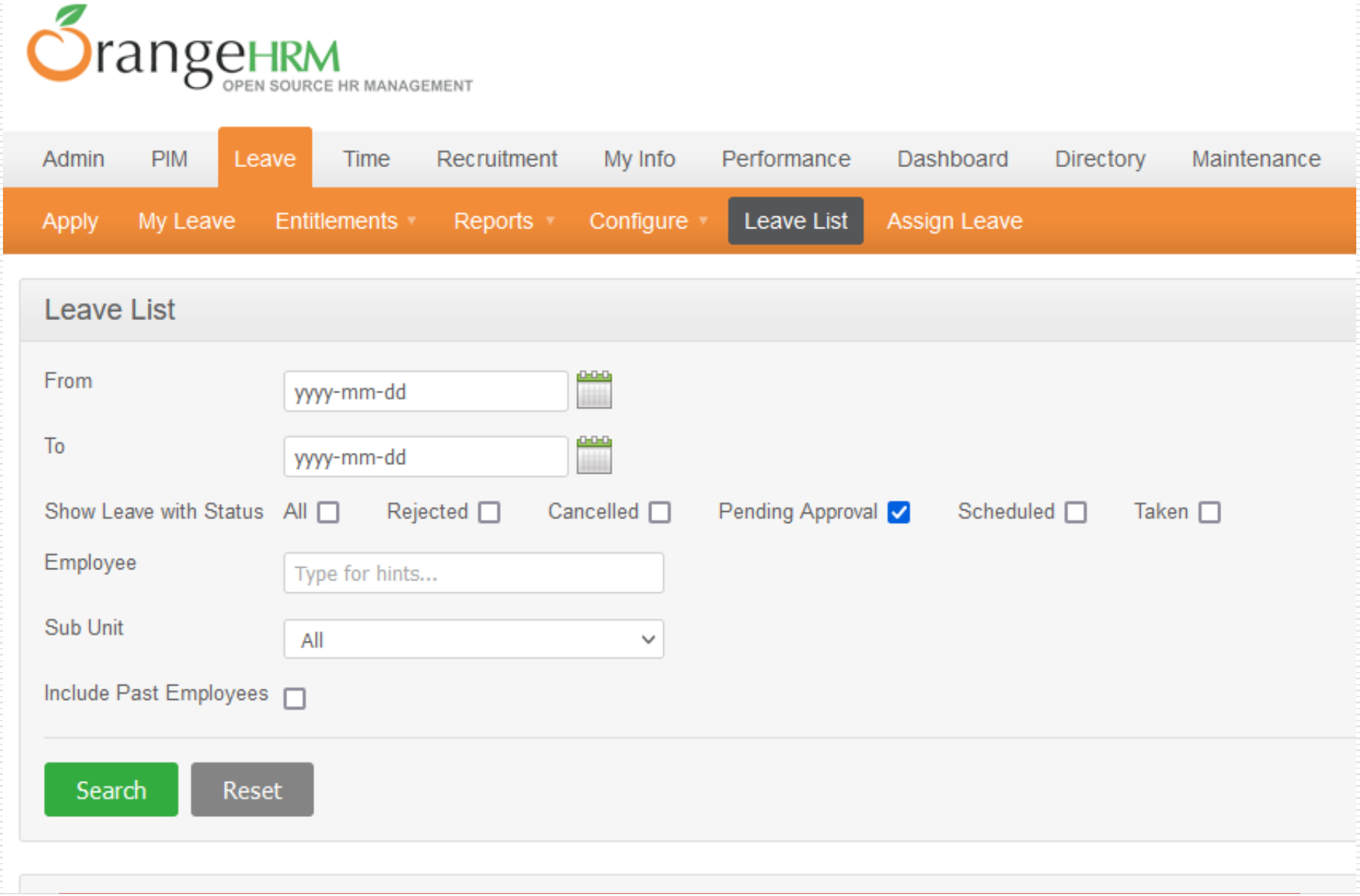
lamquangvu.shopping@gmail.com
mantis
BUG TRACKER


OrangeHRM
OPEN SOURCE HR MANAGEMENT
Admin
PIM
Leave
Time
Recruitment
My Info
Performance
Dashboard
Directory
Maintenance
Apply
My Leave
Entitlements
Reports
Configure
Leave List
Assign Leave
Leave List
From
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Sub Unit
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Search
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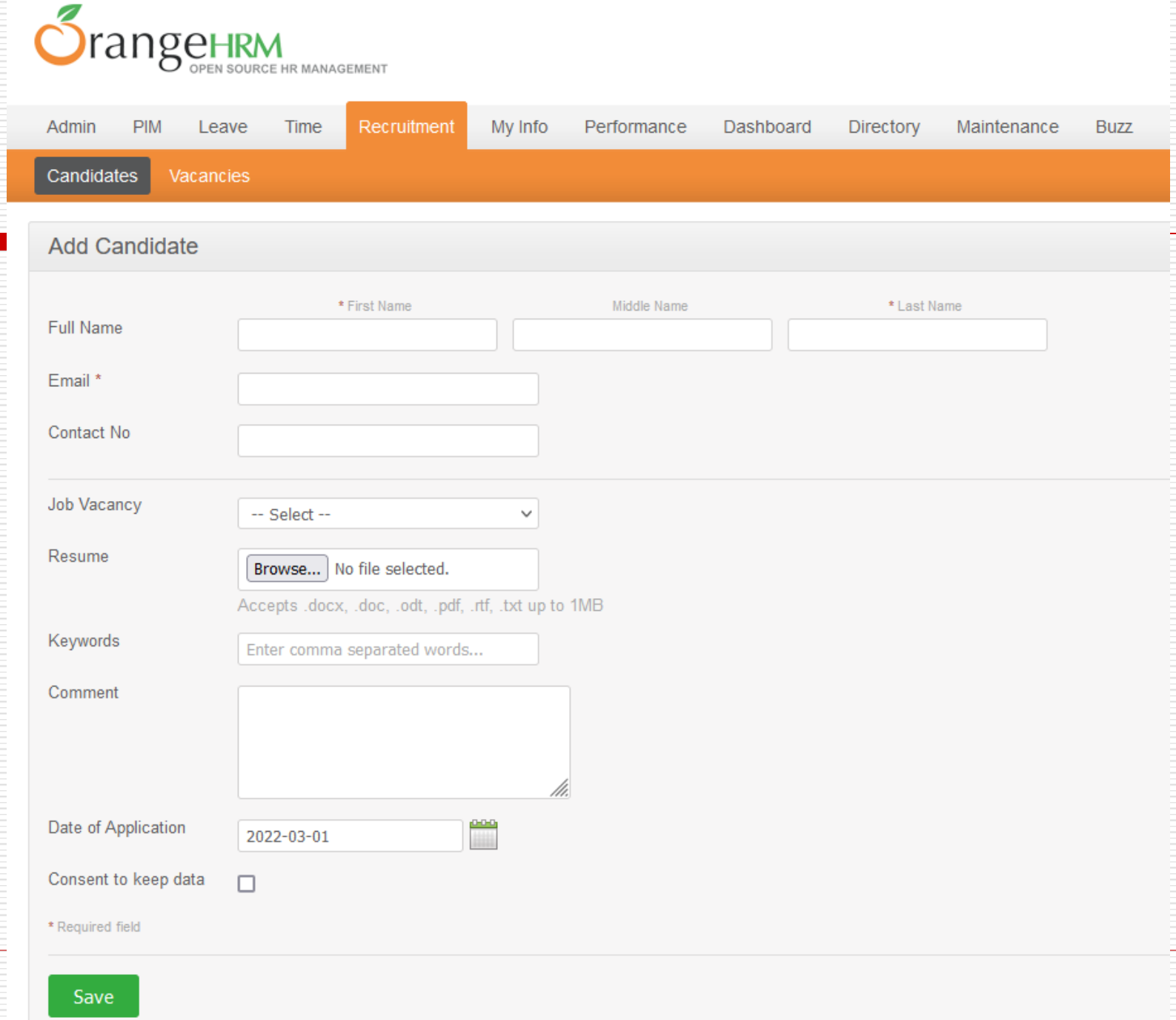
OrangeHRM
OPEN SOURCE HR MANAGEMENT
Admin
PIM
Leave
Time
Recruitment
My Info
Performance
Dashboard
Directory
Maintenance
Buzz
Candidates
Vacancies
Add Candidate
* First Name
Middle Name
* Last Name
Full Name
Email *
Contact No
Job Vacancy
-- Select --
Resume
Browse...
No file selected.
Accepts .docx, .doc, .odt, .pdf, .rtf, .txt up to 1MB
Keywords
Enter comma separated words...
Comment
Date of Application
2022-03-01
Consent to keep data
* Required field
Save