SWE 621:
Software Modeling and Architectural Design

Lecture Notes on Software Design

Lecture 5- Finite State Machines and Statecharts

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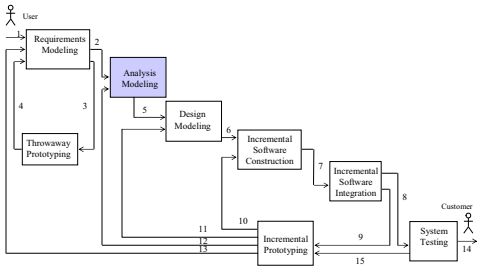
Steps in Using COMET/UML

1 Develop Software Requirements Model

2 **Develop Software Analysis Model**

- Develop static model of problem domain (Chapter 7)
- Structure system into objects (Chapter 8)
- **Develop statecharts for state dependent objects (Chapter 10)**
- Develop object interaction diagrams for each use case (Chapter 9, 11)

3 Develop Software Design Model



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Finite State Machines and Statecharts

5. Section FSM

Hassan Gomaa

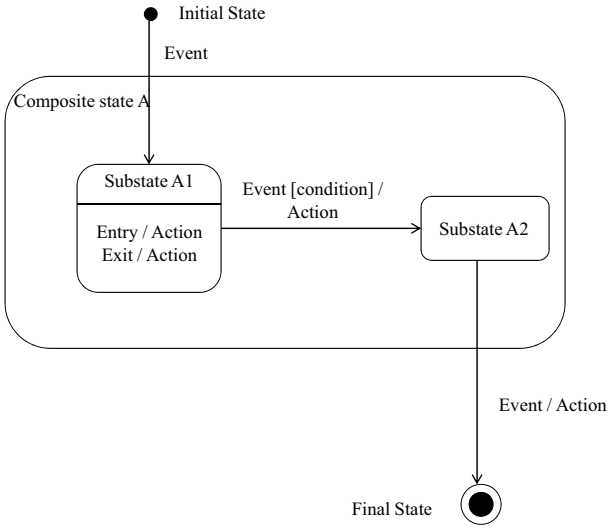
References: H. Gomaa, Chapter 10 - *Software Modeling and Design*, Cambridge University Press, February 2011

H. Gomaa, Chapter 10 - *Designing Concurrent, Distributed, and Real-Time Applications with UML*, Addison Wesley Object Technology Series, July, 2000

Finite State Machines and Statecharts

- Many information and real-time systems are state dependent
  - Action depends not only on input event
  - Also depends on state of system
- Finite State Machine
  - Finite number of states
  - Only in one state at a time
- Statechart
  - Graphical representation of finite state machine
  - States are rounded boxes
  - Transitions are arcs
- Statechart relates events and states

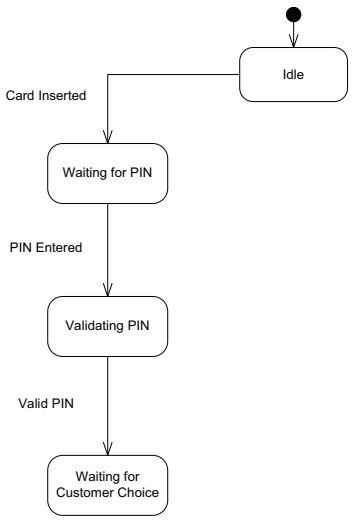
Figure 2.7 UML notation for statechart: composite state with sequential substates



States and Events

- State
  - A recognizable situation
  - Exists over an interval of time
  - Represents an interval between successive events
- Event
  - A discrete signal that happens at a point in time
  - Also known as a stimulus
  - Has no duration
  - Causes change of state
    - Referred to as state transition

Figure 10.1 Example of Events and States



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Events and Conditions

- State transition label
  - Event [Condition]
- Condition is a Boolean function
  - Conditions are optional on statecharts
  - Condition is true for finite period of time
- When event occurs, condition must be *true* for state transition to occur.
- If condition is *false*, state transition does not occur

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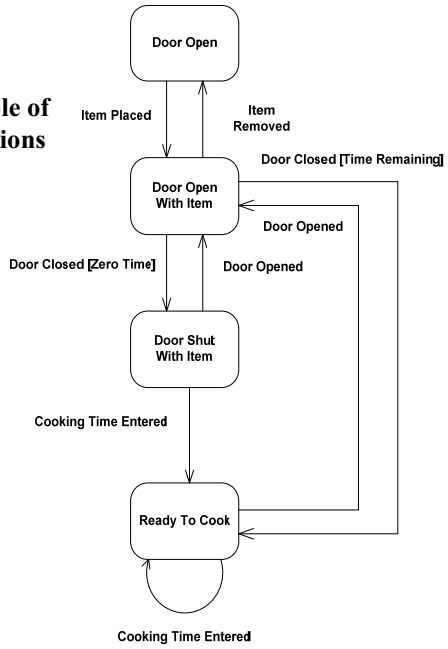
Figure 10.6 Example of Events and Conditions



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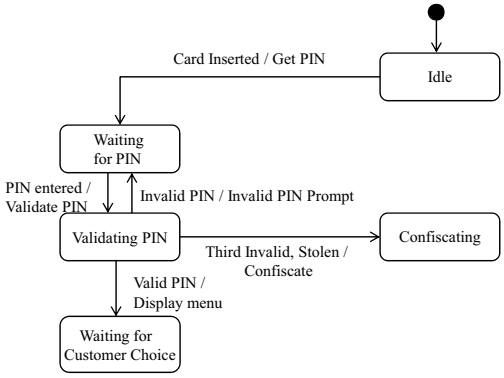
Actions

- State transition label
  - Event / action(s)
  - Event [condition] / action(s)
- Action
  - Executed as a result of state transition
  - Executes instantaneously at state transition
  - Terminates itself
  - Is optional

Figure 10.8 Example of actions



Entry and Exit Actions

- Entry action
  - Action executed on entry into state
    - Entry / action
  - E.g., Start Cooking
- Exit action
  - Action executed on exit from state
    - Exit / action
  - E.g, Stop Cooking

Figure 10.10 Example of entry action

Fig. 10.11a: Actions on state transitions

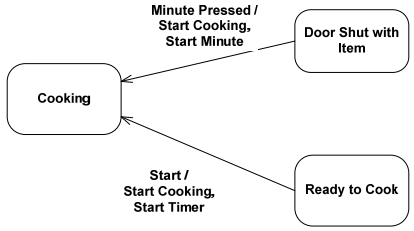


Fig. 10.11b: Entry action

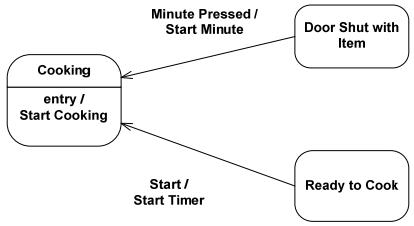


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Figure 10.11 Example of exit action

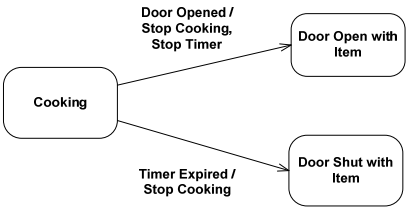

Fig. 10.11a Actions on state transitions

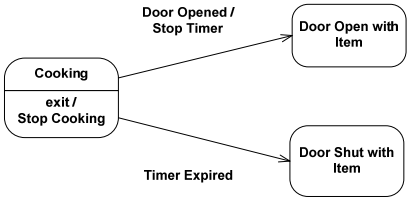

Fig. 10.11b: Exit action

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Hierarchical Statecharts

- Disadvantages of State Transition Diagrams and Flat Statecharts
  - Complex State Transition Diagrams get very cluttered
  - Limited capability for managing complexity
- Hierarchical Statecharts
  - Based on Harel Statecharts
  - Notation for hierarchical decomposition of state transition diagrams
    - Composite state decomposed into substates
    - Default entry states
    - Transition out of composite state corresponds to transition out of every substate

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Figure 10.9 Example of same event and action on different state transitions

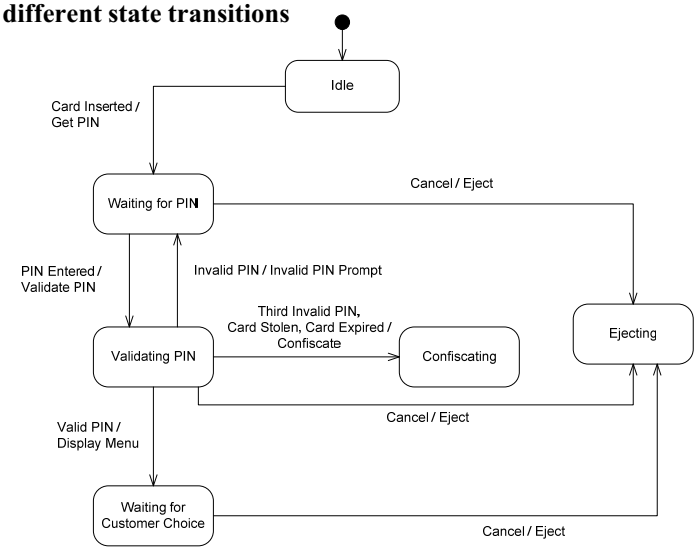

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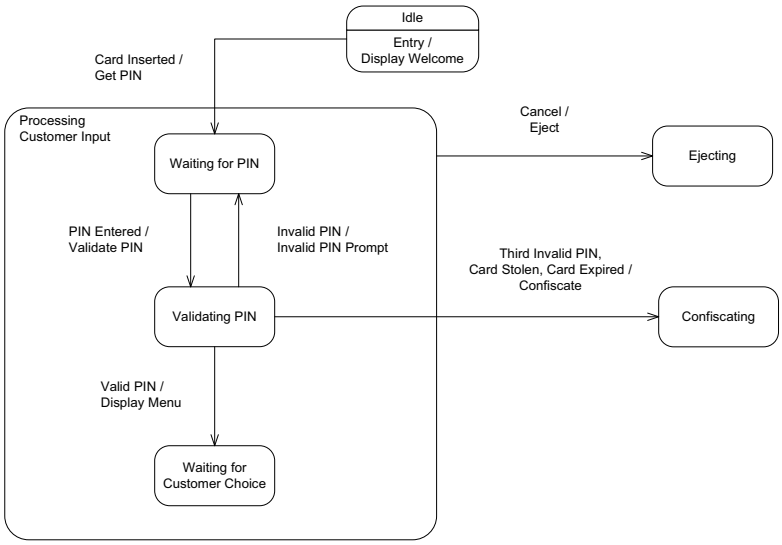
Figure 10.12 Example of hierarchical statechart showing composite state and substates



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Hierarchical Statecharts

- **Sequential** decomposition
  - When object is in composite state
    - It is in one and only one of substates
  - Transition into composite state
    - Must be to one and only one of substates
- Aggregation of state transitions
  - If same event causes transition out of every substate
  - Then aggregate into transition out of composite state

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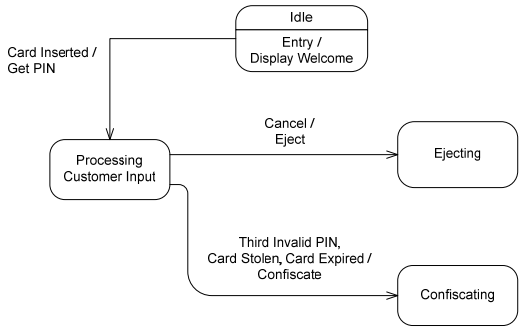
Figure 10.12 Example of hierarchical statechart showing composite state without substates



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Guidelines on Statecharts

- State name must be passive not active
  - Represents time period when something
    - is happenING, e.g., Waiting for PIN
    - Identifiable situation, e.g., Idle, Initial
- State names must be unique
- Must be able to exit from every state
- Flat statechart
  - Statechart is only in one state at a time
- Hierarchical statechart
  - **sequential** decomposition
    - Statechart is only in one substate at a time

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Guidelines on Statecharts

- Event is the cause of the state transition
  - Event happens at a moment in time
  - Event name indicates something has just happened
    - e.g, Card Inserted, Door Closed
- Action is the result of the state transition
  - Action is a command, e.g., Dispense Cash, Start Cooking
  - Action executes instantaneously
  - Activity executes throughout a given state
- More than one action possible with a state transition
  - No sequential dependency between actions
- Condition is a Boolean value
  - Event [Condition]
  - State transition only occurs if
    - Event happens & Condition is True
  - Condition is True over some interval of time
- Actions, Activities and Conditions are optional

Developing Statechart from Use Case

- Develop state dependent use case
- Start with scenario (one path through use case)
  - Consider sequence of interactions between actor and system
- Consider sequence of external events
  - Input event from external environment
  - Causes state transition to new state
  - Action may result from state transition
- Initially develop flat statechart

Figure 19.1 Banking System use case model

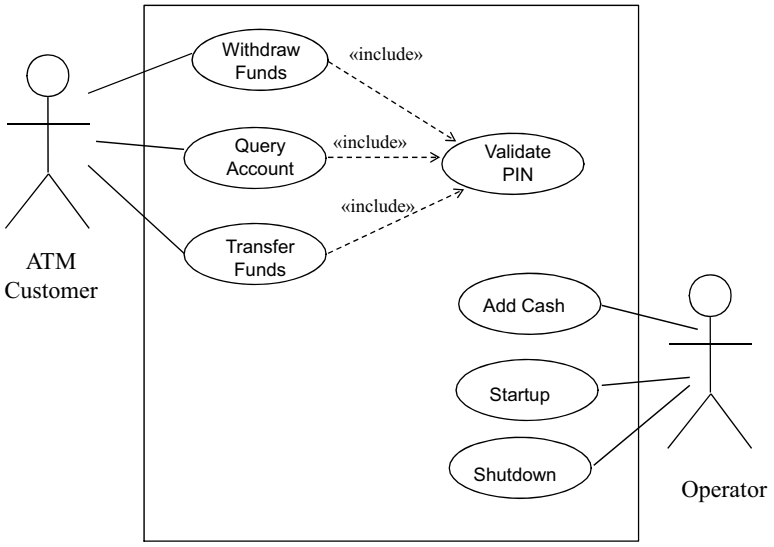

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Figure 10.14 Statechart for ATM Control - Validate PIN use case

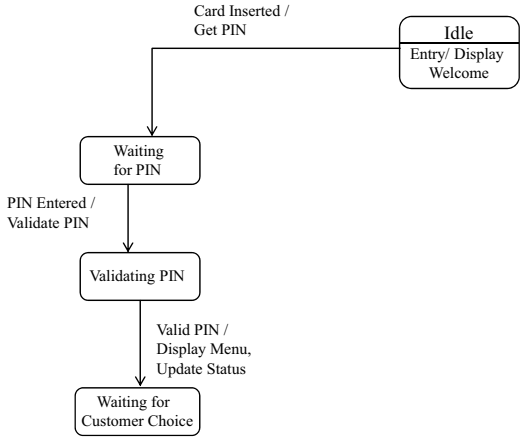

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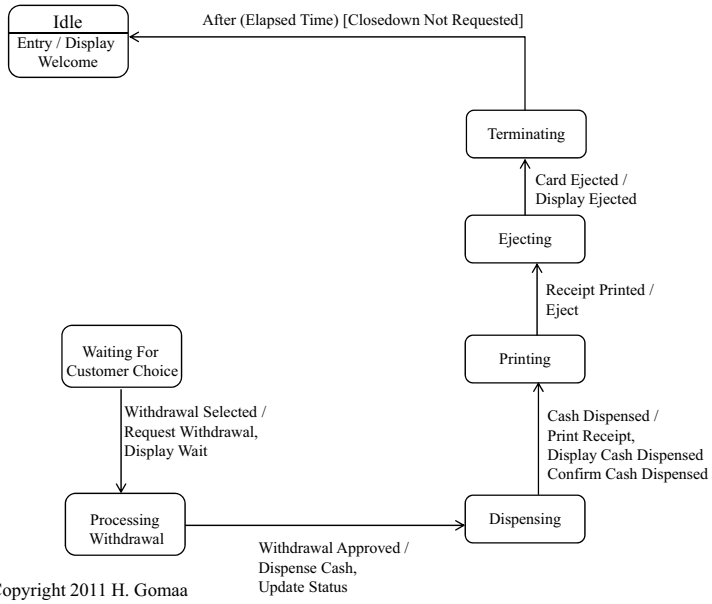
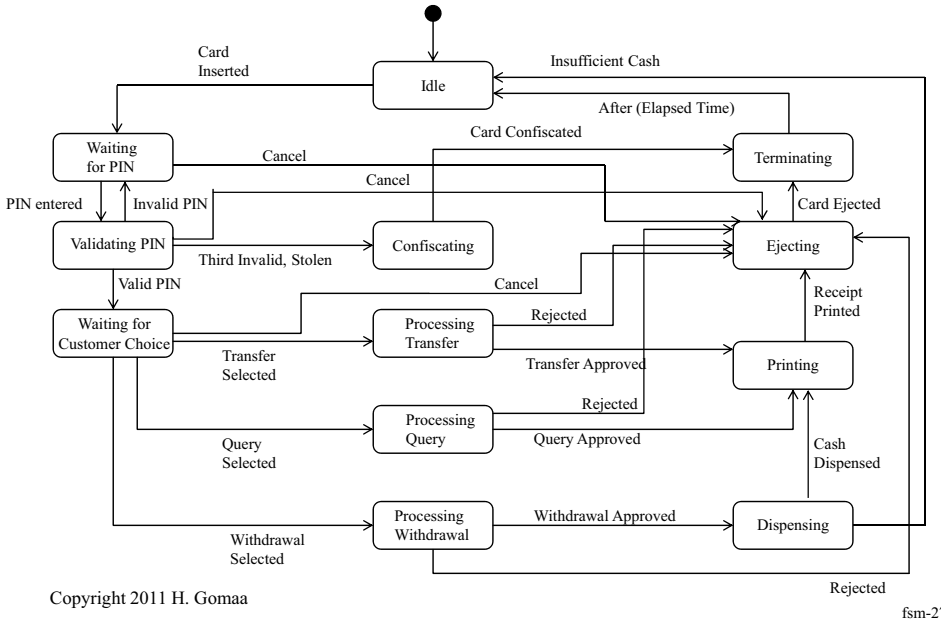
Figure 10.15 Statechart for ATM Control - Withdraw Funds use case



Developing Statechart from Use Case
(continued)

- Consider alternative external events
  - Could result in additional states
  - Could result in additional state transitions
- Develop hierarchical statechart
  - States that can be aggregated to form composite state
  - Event causing transition from several states
    - Create composite state with one transition out of composite state
    - Instead of many transitions out of substates

Example of integrated statechart



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Example of hierarchical statechart

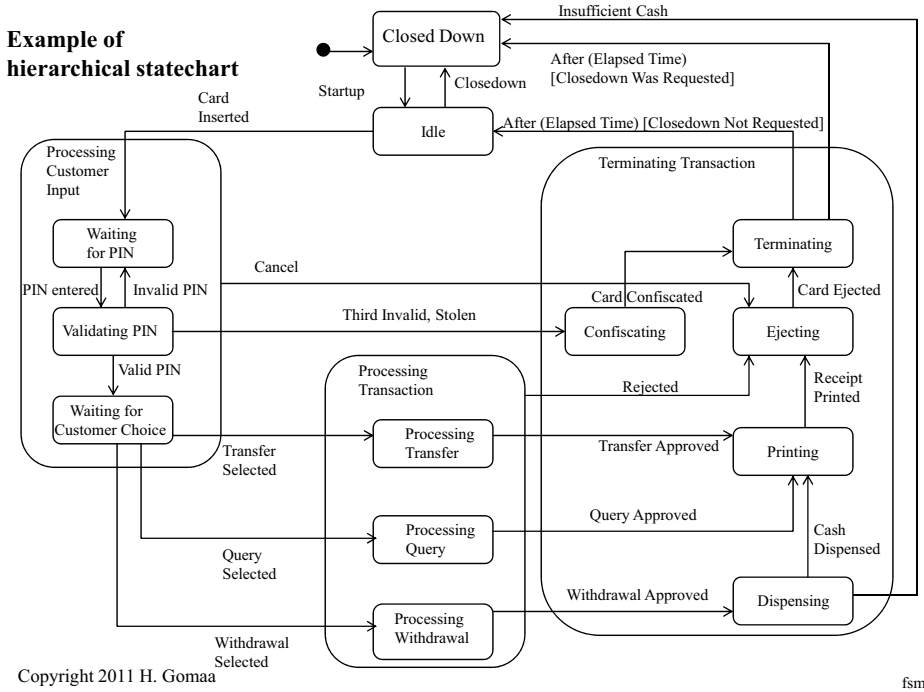

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Figure 10.18 Top level statechart for ATM Control

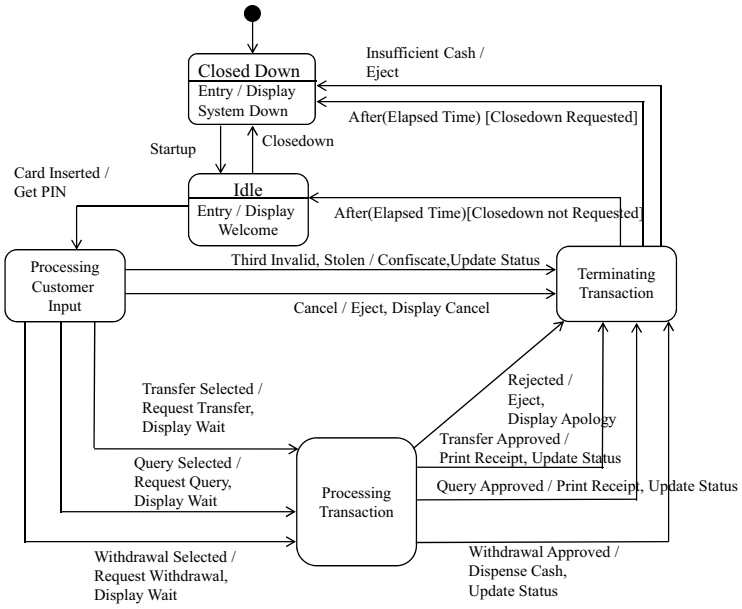

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Figure 10.19 Statechart for ATM Control - Processing Customer Input composite state

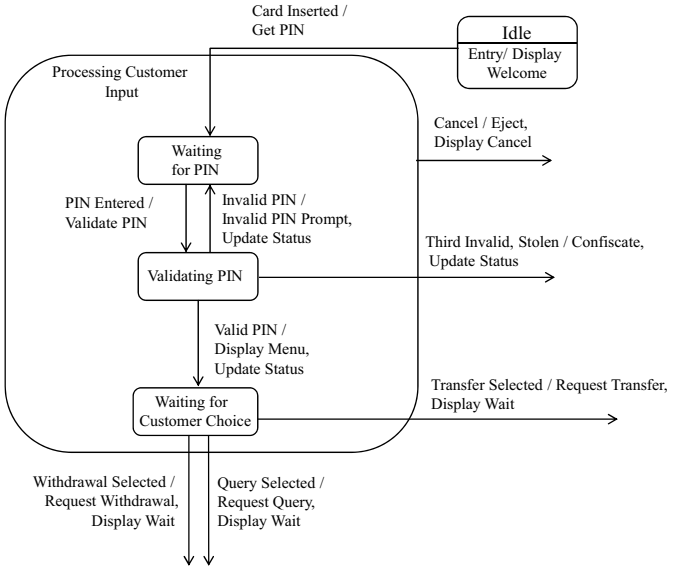

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Figure 10.20 Statechart for ATM - Processing Transaction composite state

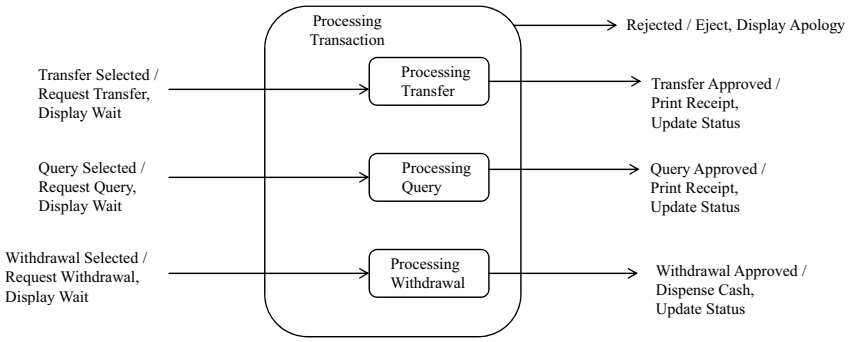

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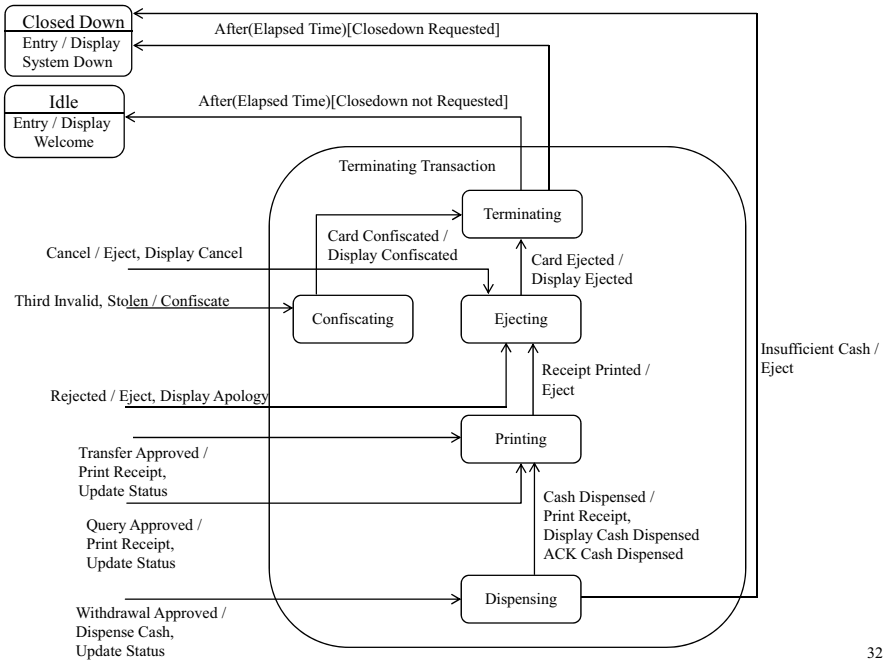
Figure 10.21 Statechart for ATM Control - Terminating Transaction composite state



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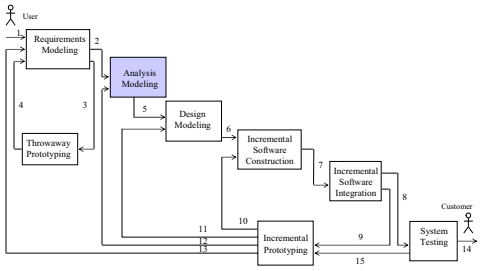

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