Model Derivation

From Requirements to Models

What?

How?

Examples?

Lecture Outline

- What?
  - Entities, relationships and behavior
  - xUML model
- How?
  - Linguistic Analysis
  - Object Behavior Analysis
  - Use cases, activity diagrams, etc.
- Examples
  - Simple Microwave Oven
  - Miscellaneous illustrations

Elements of xUML Models

- Systems = Domains and Bridges
- Domains = Class Diagrams
- Bridges = Interactions Among Domains
- Class Diagrams = Classes + Relationships
- Class = Attributes + State Machine + Constraints
- State Machine = Events (Signals) + Actions

What? - Class Diagram

- Identify entities in specification. Entities are classes
- Identify attributes of entities -> attributes of classes
- Identify relationships among classes
  - “has a”
  - “is a”
  - Associative
- Identify constraints on the possible values of attributes.

What? - Determine Behaviors of Entities

- Construct the lifecycle (state machine) which controls the behavior of each entity.
- Construct the state transition table for each entity.
- Design the action to be executed in each state of the state machine.

What? – System Behavior

- Identify and record the communication among the entities
- Identify a set of use cases which define the environment in which the system will execute
- Define a class or classes which implement these use cases.

How? – Derivation Process

1. **Derive Class Diagram**
    1. **Define classes and select attributes**
    2. **Define associations/relationships among classes**
    3. **Construct associative classes**
    4. **Iterate steps 1, 2 & 3 until consistent**
2. **Construct State Models**
    1. **Construct state model for each object with multiple states**
    2. **For each state model, define actions effecting state changes**
3. **Iterate until consistent**

How? – Class Diagram

Methods for identifying classes, attributes and relationships

- Linguistic analysis of requirements specification - textbook
- Object Behavior Analysis – Rubin and Goldberg paper (related to Use Case analysis)
- Use Case Analysis

Practical Approach - Apply multiple methods and compare resulting class diagram

How? - Class Diagrams via Linguistic Analysis

<u>Identify the classes</u> . The classes derive from noun phrases. Go through the requirements statement and pick out all of the important nouns. Categorize these nouns into tangible items or devices, physical classes, roles, interactions, instance specifications, etc.. Decide which ones are significant and which ones are redundant and select classes.

<u>Identify attributes for each object</u>. Attributes come from possessive phrases, as descriptions of the nouns. Recall that the attributes define the identity and the state of an object.

<u>Identify relationships</u>. Relationships can be derived by looking at the verb phrases of the requirements analysis. Verb phrases include such things as the PC board "is made up of" chips and connectors, etc..

<u>Specialize and generalize classes</u> into subtypes and supertypes and create associative, create object definitions for m to n associations or dynamic associations which fall under the heading of events, interactions which have to be remembered.

Classes

- A class is an abstraction from a set of conceptual entities in a domain.
- An object is an instance of a class.
- They all share the same characteristics.
- They all behave according to the same rules and policies.
- These rules and policies may include *constraints* which supplement the defined behaviors.

Identifying classes

- Tangible Things
- Roles played by people or organizations
- Incidents
- Specifications
- Etc.

Identifying Classes

Classes Are Akin To Pornography Or Beauty

tangible entity or device - airplane

role - professor, student

incident or persistent event - registration of automobile

interaction - contract terms

specification – sets of entities with related characteristics

organization - university

external systems - sensor drives

Identifying Classes

- Which Nouns are Classes?
- Not all nouns are classes
  - Does it have interesting state? Qualified by attributes (adjectives) defining state.
  - Does it do anything?
  - Does it store data or information accessed by other classes?

Specifications for the Control Software for a One-Button Microwave

The microwave is powered by a powertube with a wattage rating and a part number, it incorporates: an interior light with a specified wattage and part number, a beeper which has a specified part number and a control button. The door of the oven is latched by a friction catch. In the current product the powertube consumes 600 watts and light consumes 40 watts.

This simple oven has a single control button. When the oven door is closed and the user presses the button, the oven will cook (that is, energize the power tube) for 1 minute.

There is a light inside the oven. Any time the oven is cooking, the light must be turned on, so you can peer through the window in the oven's door and see if your food is bubbling. Any time the door is open, the light must be on, so you can see your food or so you have enough light to clean the oven.

When the oven times out (cooks until the desired preset time), it turns off both the power tube and the light. It then emits a warning beep to signal that the food is ready.

The user can stop the cooking by opening the door. Once the door is opened, the timer resets to zero.

Closing the oven door turns out the light.

Linguistic Analysis – Microwave Oven

Noun or Noun Phrase	Type (Tangible, role, specification, etc)	Is It a Class	Why or Why Not
microwave	tangible	No	Same concept as oven
powertube	Tangible	Yes	Has attributes, states and actions
light	Tangible	Yes	Has attributes, states and actions
wattage rating	Specification	No	Is an attribute
Part number	Specification	No	Is an attribute
beeper	Tangible	Yes	Has attributes, states and actions
Control button	Tangible and Role	yes	Has state and sends signals to other entities.
door	Tangible	yes	Has state – sends signals to other entities
Oven	Tangible	Yes	Same as microwave so we choose one of the two.
Product	Role	No	Same as oven or microwave
watts	Specification	No	Attribute

Attributes

- Attribute is an abstraction of a single characteristic of the entity abstracted into a class.
- Attributes have types: roles and data types.
- Types of Attributes
  - Descriptive – describes intrinsic characteristics of a thing.
  - Naming – name used to refer to a thing.
  - Referential – provides information about links and composition – arise in “has a” relationships.
  - State or status – names of states of state machine

Attributes

Adjective or Qualifying Phrase	Noun Qualified	Is it an attribute?	Justification
wattage	powertube	Yes	Property
wattage	light	Yes	property
Serial number	oven	yes	property

Entities/Classes with States [attributes]

- Door (open, closed)
- Power tube (on, off)[wattage, etc]
- Light (on, off) [wattage, etc]
- Timer (on and counting down, off and zero)
- Beeper (on, off) – Ignore beeper for now
- Button – Event generator
- Oven Controller - Program

Associations - Relationships Among Classes

Hierarchical Structure among Classes – Generalization and Specialization

***Definition*: An *association* is the abstraction of a set of domain relationships that hold systematically between different kinds of conceptual entities, abstracted as *classes,* in the domain.**

Associations have:

- **Names**
- **Roles or reciprocal functions (verb phrases)**
- **Multiplicities**
  - **1…1 – Mandatory, exactly 1 to 1**
  - **1…* - Mandatory, perhaps 1 to n**
  - **0…1 – Conditional but not more than 1**
  - **0…* - Conditional perhaps more than 1**

(Figures 6.1, 6.2, and 6.3. pp84-85)

Associative Classes – Define M to N relationships

Associations Represented by Classes

Definition: An association class is an abstraction, as a class, of an association that may have its own attributes, other associations and behavior.

1. **Association classes arise from relationships among classes which have semantic content that cannot be expressed by simple verb phrases and/or multiplicity.**
2. **Association classes can participate in associations other than those which cause their definition.**
3. **An instance of an association class exists only if the instances of the classes it couples exists.**
4. **Association classes very often model contention for resources.**

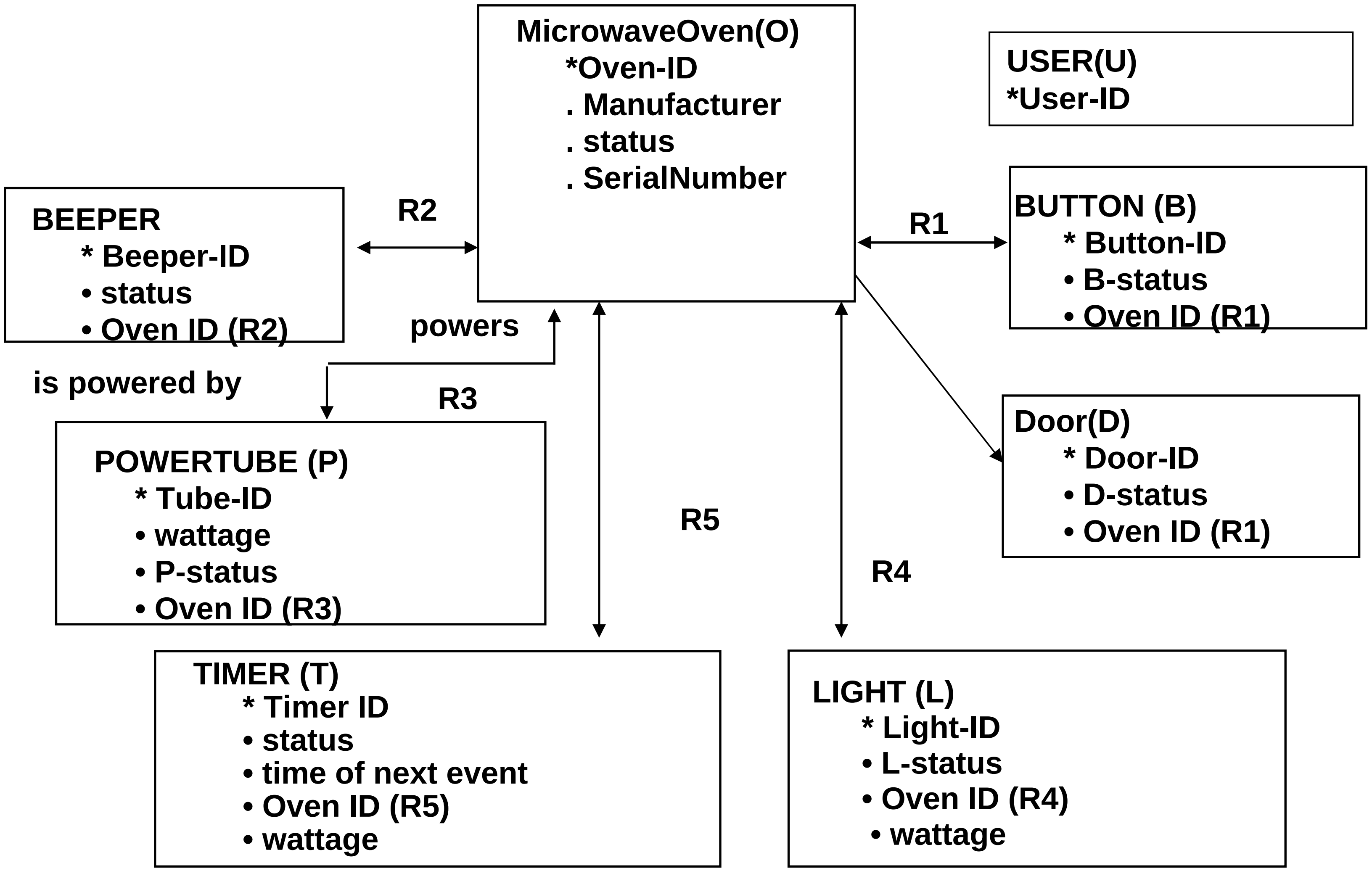
Identification of Relationships

- Relationships can be derived by looking at the verb phrases of the requirements analysis. Verb phrases include such things as Universities have departments, departments have professors, professors advise students.

Relationships

Verb Phrase	Relationship or Action	Classes Related	Type of Relationship
Microwave is powered by a powertube	relationship	Oven/powertube	Referential attribute
It incorporates a ..light ..	relationship	Oven/light	Referential attribute
It incorporates a … control button	relationship	Oven/control button	Referential attribute
It incorporates a .. ….beeper …	relationship	Oven/beeper	Referential attribute
The door of the oven is latched	relationship	Oven/door	Referential attribute

Class Diagram - Cheap Microwave Oven Controller



Properties

Specifications for what the system should do and not do.

Safety properties – States which the system should never reach.

Liveness properties – States the system should always reach from specified initial states.

Properties

- Pushing the button while the Door is closed
- turns on the Light and the Tube for one
- minute
- Pushing the button while the Tube is on,
- extends the cooking period by one minute.
- If the Door is open then the Light is on
- If the Door is open then the Tube is off
- If the Light is on then the Door is open or
- the Tube is on

Lifecycles

- Each active object (instance of a class) in the domain has a behavior (lifecycle).
- Lifecycle sequences the actions the object performs.
- Lifecycles in xUML are modeled as state machines.
- UML state charts used to graphically represent state machines.

State Machines

- Lifecycle formally expressed as a state machine.
- State machine is comprised of

1. States – each stage of the object lifecycle.
2. Events – trigger.
3. Transitions – specifies the new state given current state and event received.
4. Procedures – specifies the actions that an object performs when it arrives in a state. Specified using an action language.

Events - Use Cases – Environment Specification

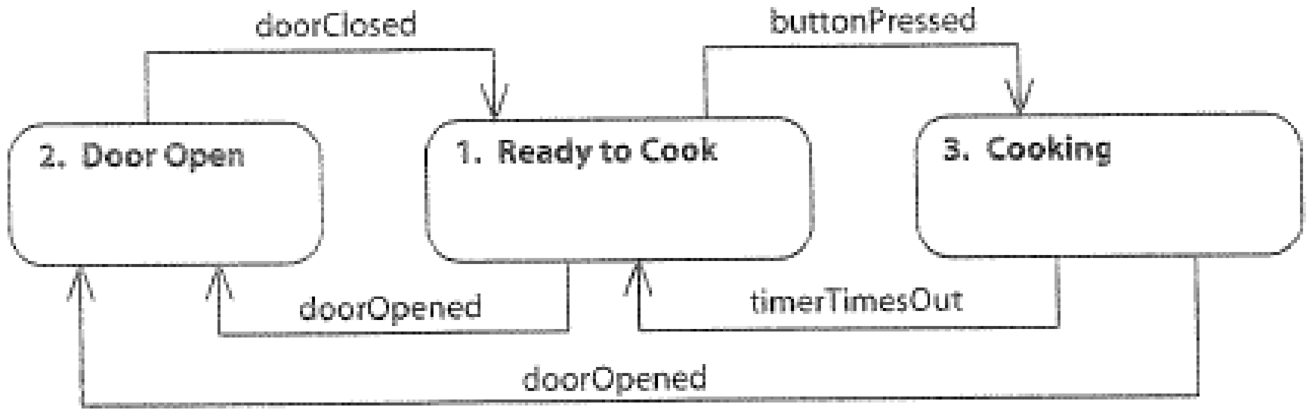
Door is opened

Door is closed

Button is pushed

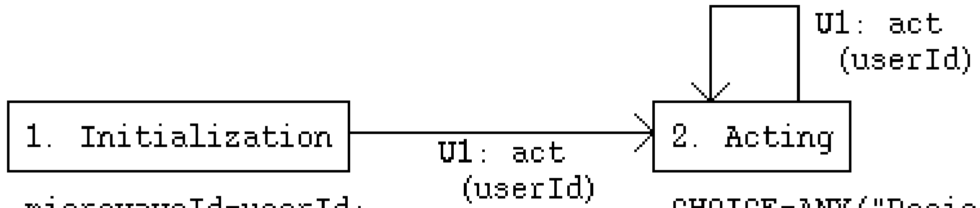
Timer completes cooking period.

State Machine View of Use Cases



External View of the Microwave Oven

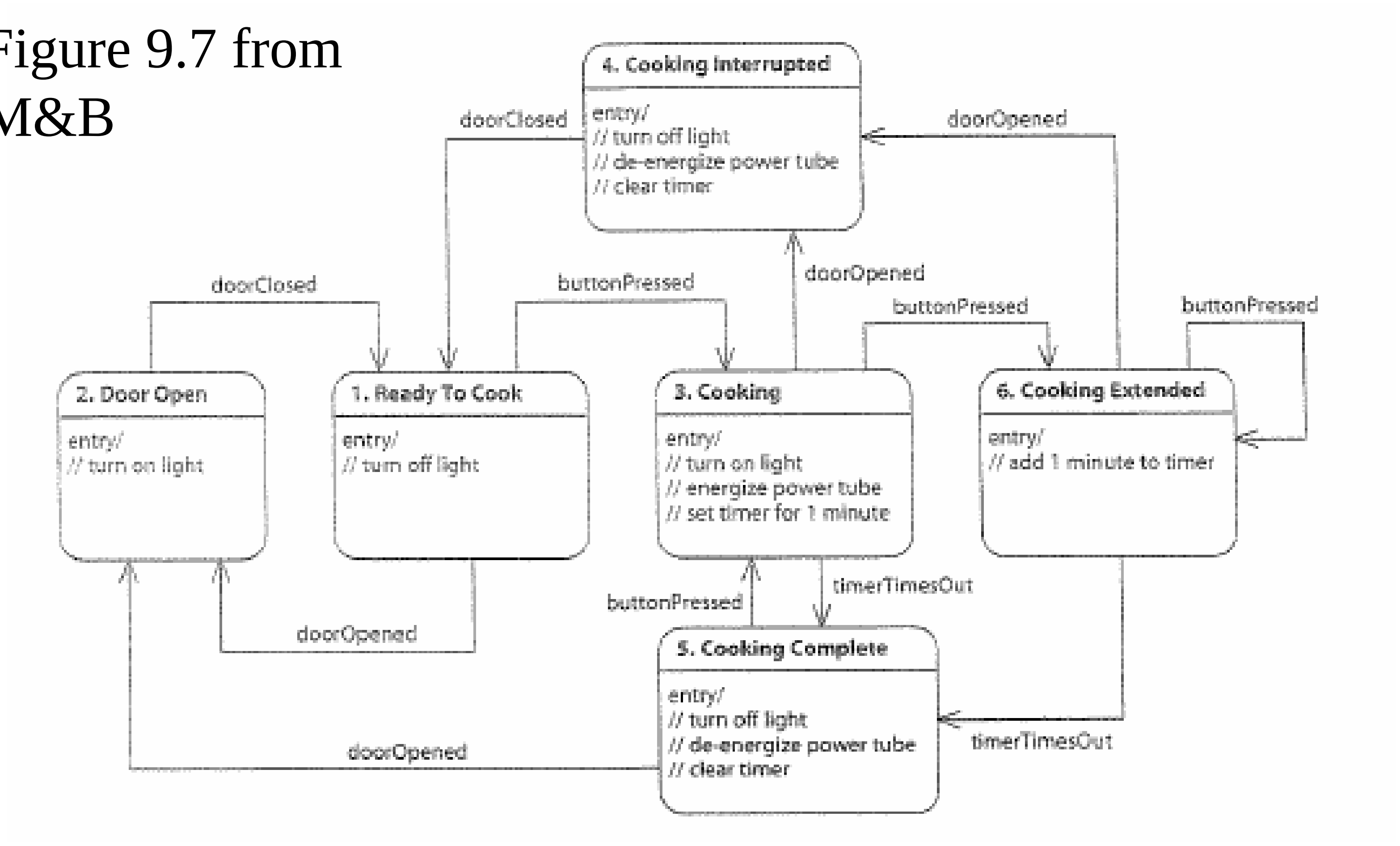
User-Environment with actions



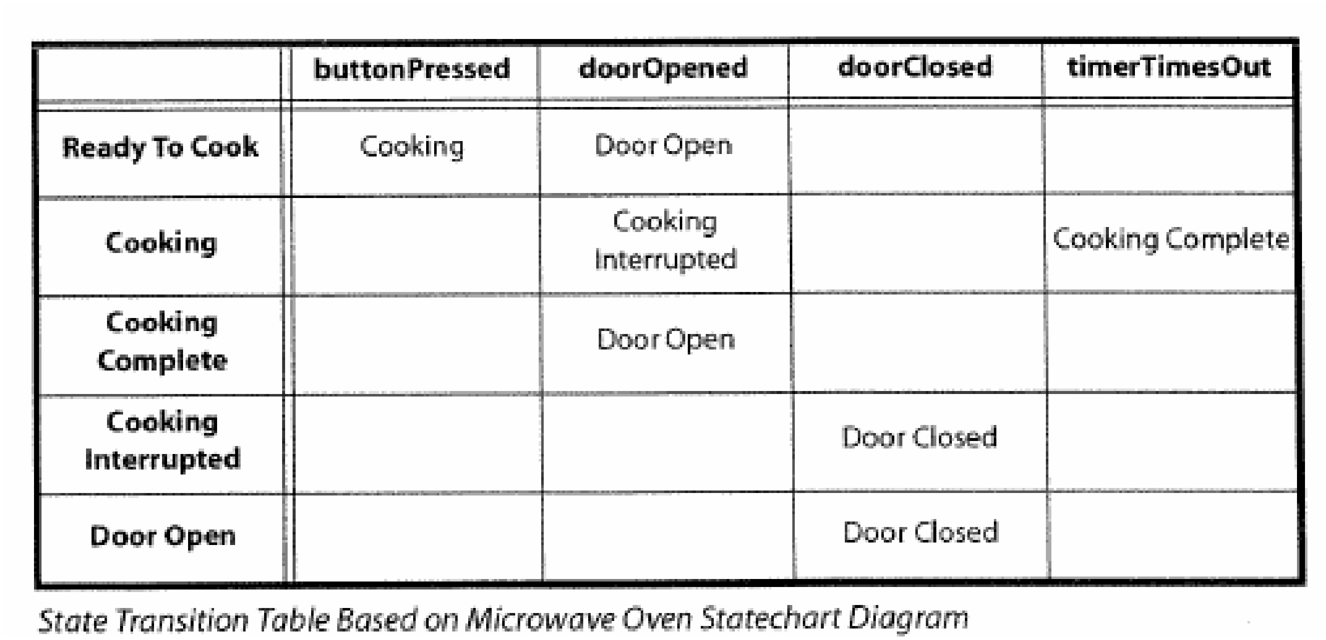
```
microwaveId=userId;
actionsRemaining=5;
Generate U1: act (userId);
```

```
CHOICE=ANY("Decision_Type");
if(CHOICE==1)
    Generate MW1: buttonPressed (microwaveId);
else if(CHOICE==2)
{
    if(Microwave(microwaveId).doorOpen)
        Generate MW3: doorClosed (microwaveId);
    else
        Generate MW2: doorOpened (microwaveId);
}
else
    if(Microwave(microwaveId).tubeOn)
        Generate MW4: timerTimesOut (microwaveId);
actionsRemaining=actionsRemaining-1;
if(actionsRemaining>0)
    Generate U1: act (userId);
```

Figure 9.7 from M&B



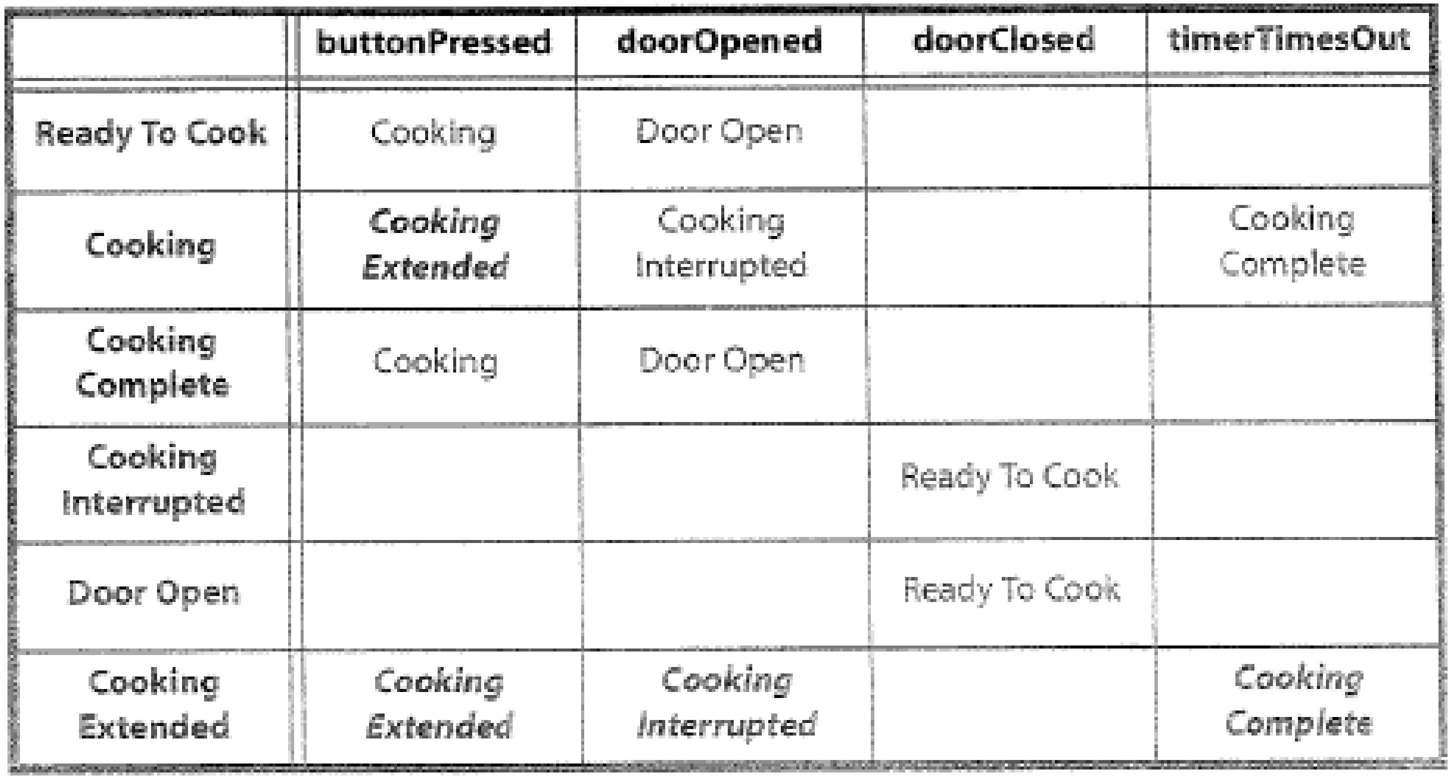
State Transition Table – Figure 9.4 from M&B



	buttonPressed	doorOpened	doorClosed	timerTimesOut
Ready To Cook	Cooking	Door Open		
Cooking		Cooking Interrupted		Cooking Complete
Cooking Complete		Door Open		
Cooking Interrupted			Door Closed	
Door Open			Door Closed	

State Transition Table Based on Microwave Oven Statechart Diagram

Figure 9.7 from M&B



	buttonPressed	doorOpened	doorClosed	timerTimesOut
Ready To Cook	Cooking	Door Open		
Cooking	***Cooking Extended***	Cooking Interrupted		Cooking Complete
Cooking Complete	Cooking	Door Open		
Cooking Interrupted			Ready To Cook	
Door Open			Ready To Cook	
Cooking Extended	*Cooking Extended*	*Cooking Interrupted*		*Cooking Complete*

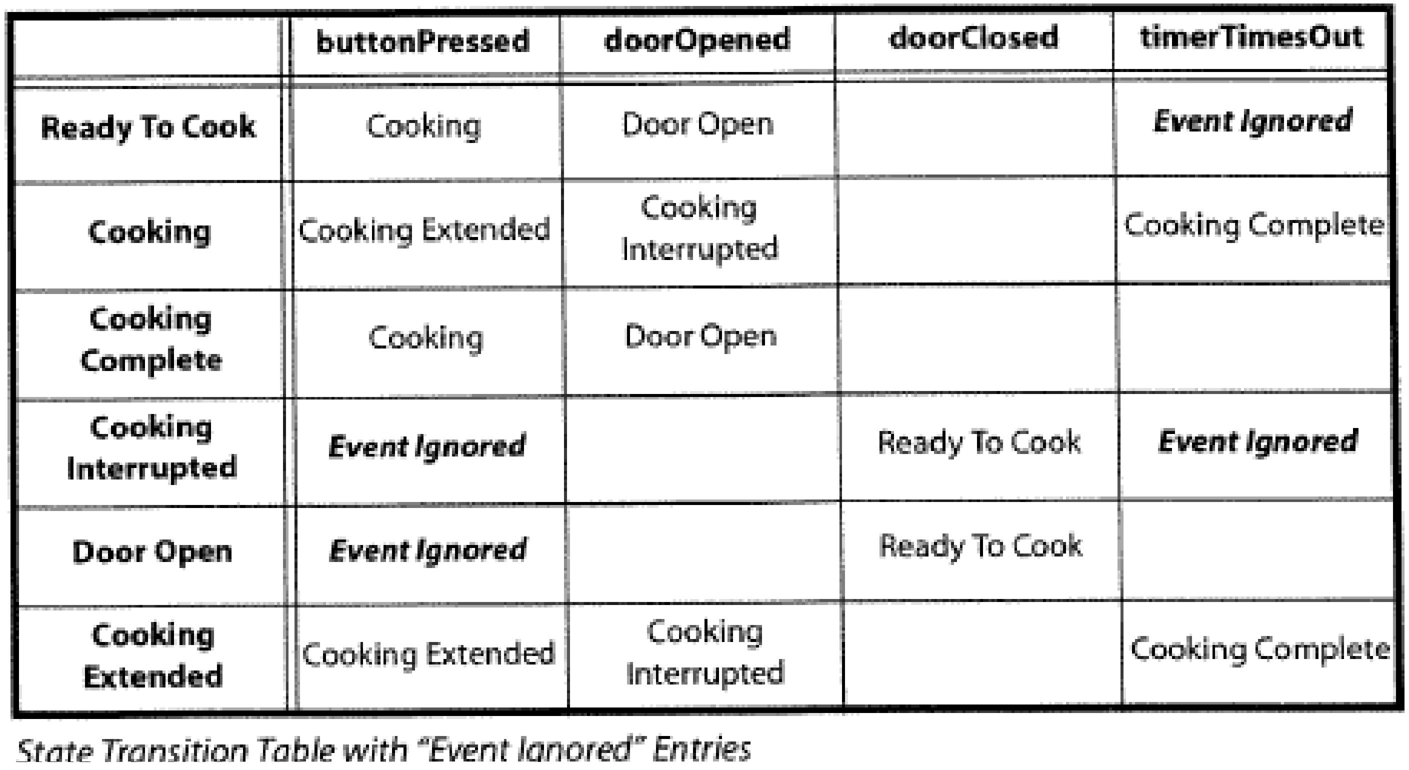
Event Ignored cell entry

When a certain event can happen but causes no effect, the STT cell is filled in as "Event Ignored." In the case of the oven, pressing the button when the door is open has no effect. Figure 9.8 shows the state transition table with Event Ignored entries added.

When an event is ignored, the object stays in the same state it is in and *does not* re-execute the procedure. In this way, an Event Ignored is different from a transition to the same state.

Although the event is ignored in the sense of not causing a transition, it has been detected and consumed by the state machine. The event is not held until the object arrives in a state where the event can cause a transition.

Figure 9.8 from M&B



	buttonPressed	doorOpened	doorClosed	timerTimesOut
Ready To Cook	Cooking	Door Open		***Event Ignored***
Cooking	Cooking Extended	Cooking Interrupted		Cooking Complete
Cooking Complete	Cooking	Door Open		
Cooking Interrupted	***Event Ignored***		Ready To Cook	***Event Ignored***
Door Open	***Event Ignored***		Ready To Cook	
Cooking Extended	Cooking Extended	Cooking Interrupted		Cooking Complete

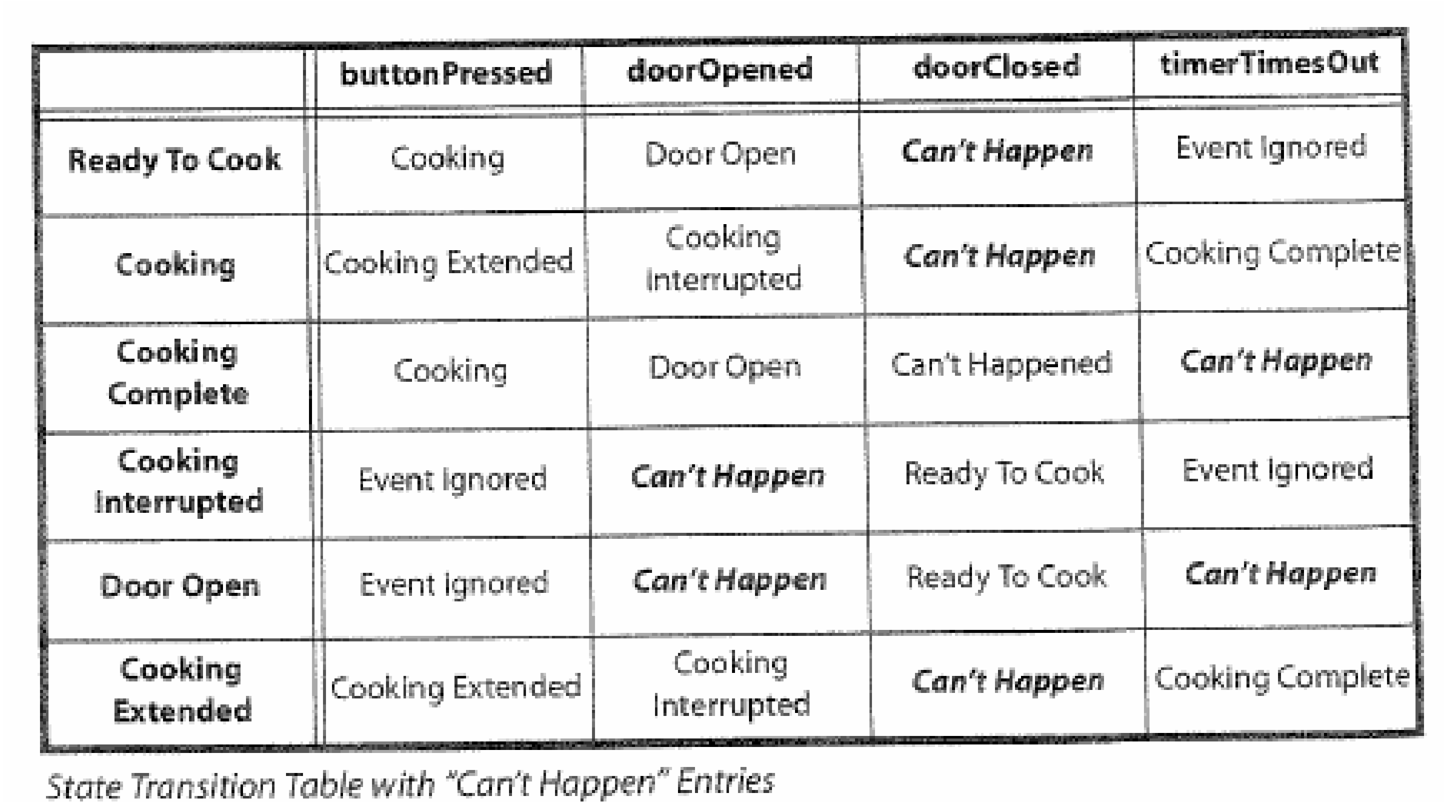
State Transition Table with "Event Ignored" Entries

Can't Happen cell entry

If the event cannot happen when the object is in a particular state, record the fact by entering "*Can't Happen*" in the cell.

The *Can't Happen* entry is reserved for occasions when the event simply cannot occur according to the rules and policies of the domain. For example, the oven cannot receive a door Closed event when the oven is cooking. The door is already closed in this state; detecting this event in this state makes no sense.

Figure 9.9 from M&B



	buttonPressed	doorOpened	doorClosed	timerTimesOut
Ready To Cook	Cooking	Door Open	***Can't Happen***	Event Ignored
Cooking	Cooking Extended	Cooking Interrupted	***Can't Happen***	Cooking Complete
Cooking Complete	Cooking	Door Open	Can't Happened	***Can't Happen***
Cooking Interrupted	Event Ignored	***Can't Happen***	Ready To Cook	Event Ignored
Door Open	Event Ignored	***Can't Happen***	Ready To Cook	***Can't Happen***
Cooking Extended	Cooking Extended	Cooking Interrupted	***Can't Happen***	Cooking Complete

State Transition Table with "Can't Happen" Entries

Actions

- Turn on the light
- Turn off the light
- Energize the power tube
- De-energize the power tube
- Set the timer for 1 minute
- Add 1 minute to the timer
- Clear the timer

State Machine with Actions

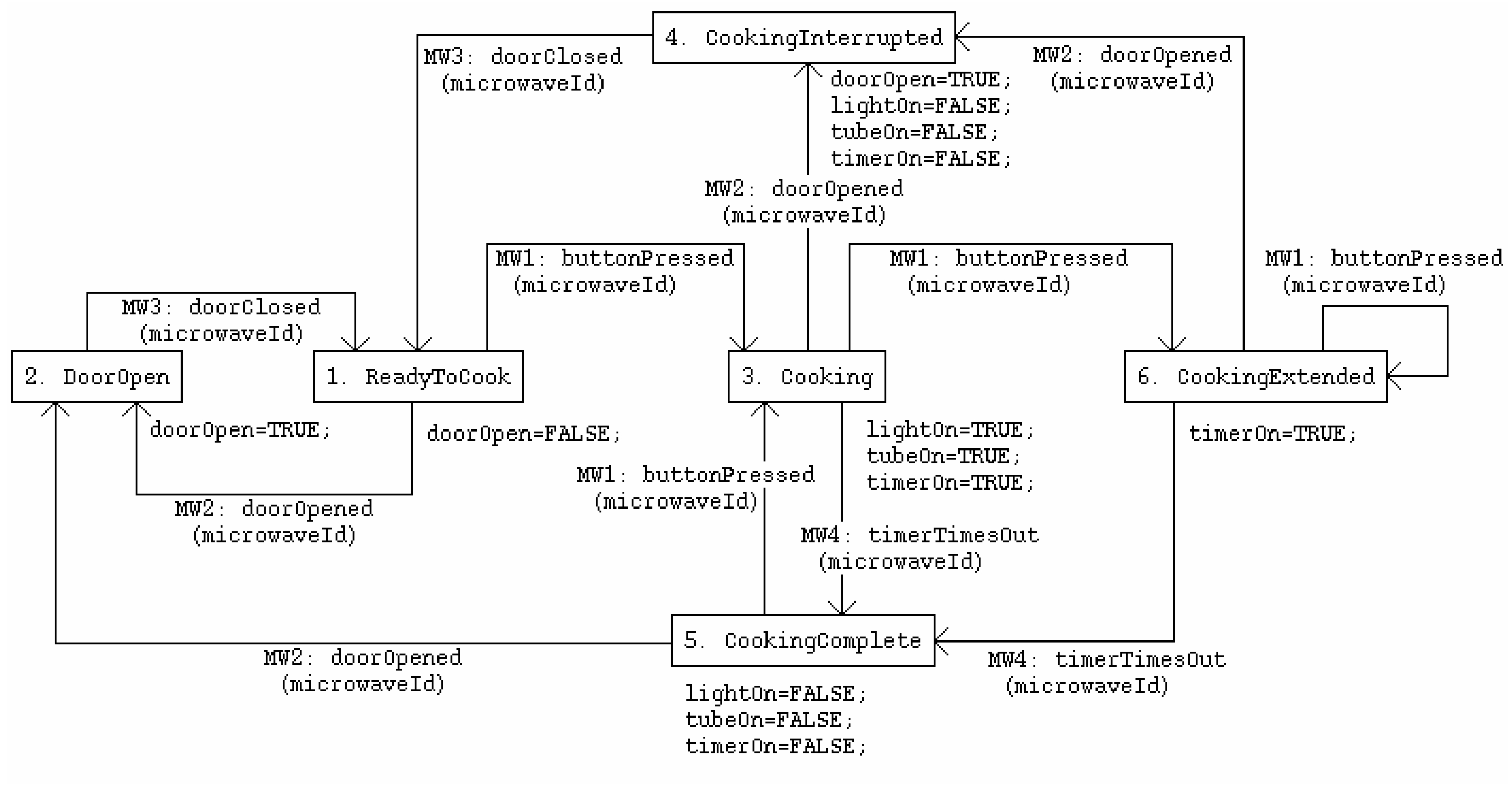
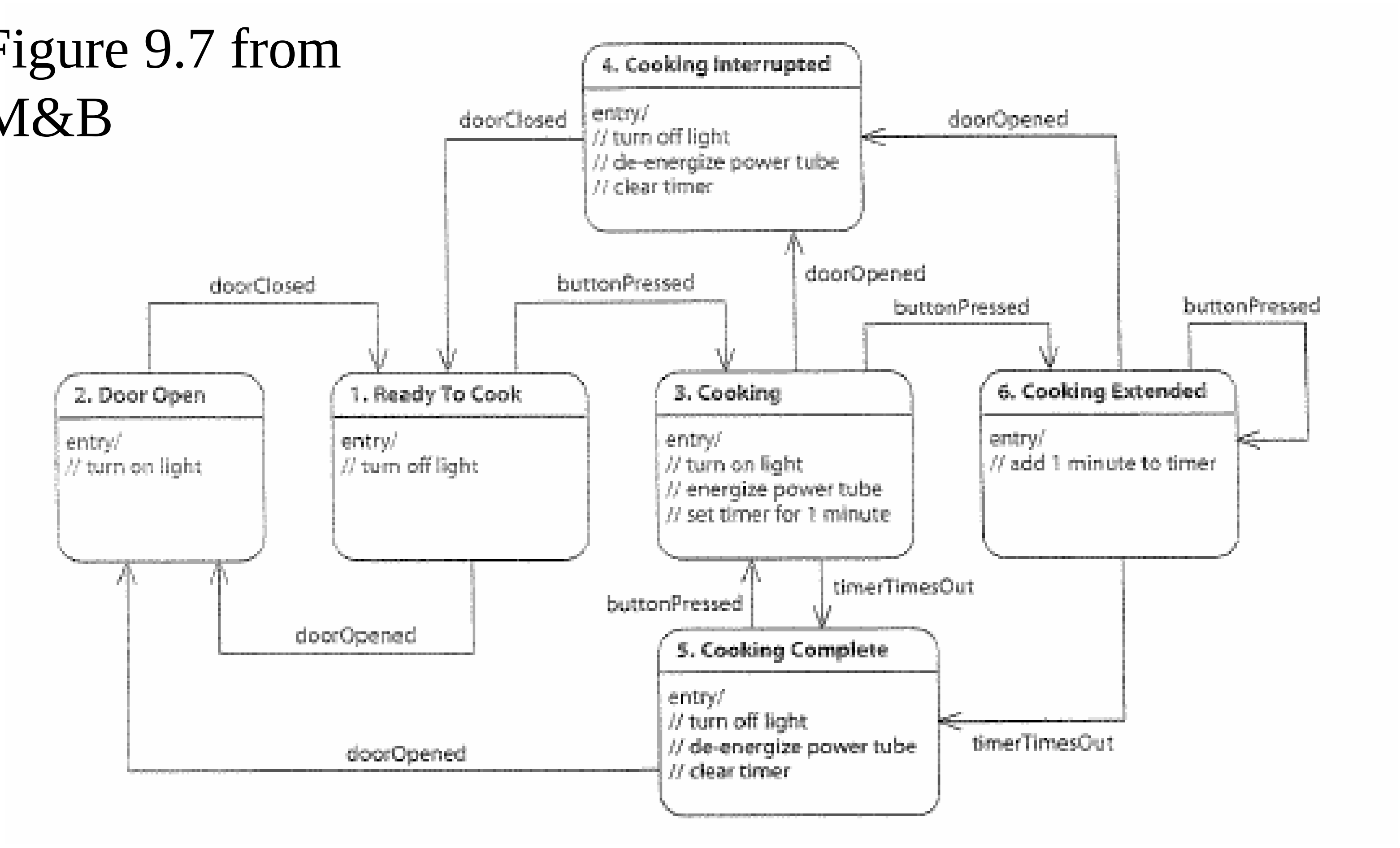

4. CookingInterrupted
MW3: doorClosed (microwaveId)
MW2: doorOpened (microwaveId)
doorOpen=TRUE; lightOn=FALSE; tubeOn=FALSE; timerOn=FALSE;
MW2: doorOpened (microwaveId)
MW1: buttonPressed (microwaveId)
MW1: buttonPressed (microwaveId)
MW1: buttonPressed (microwaveId)
MW3: doorClosed (microwaveId)
2. DoorOpen
1. ReadyToCook
3. Cooking
6. CookingExtended
doorOpen=TRUE;
doorOpen=FALSE;
lightOn=TRUE; tubeOn=TRUE; timerOn=TRUE;
timerOn=TRUE;
MW1: buttonPressed (microwaveId)
MW2: doorOpened (microwaveId)
MW4: timerTimesOut (microwaveId)
5. CookingComplete
MW2: doorOpened (microwaveId)
MW4: timerTimesOut (microwaveId)
lightOn=FALSE; tubeOn=FALSE; timerOn=FALSE;

Figure 9.7 from M&B


4. Cooking Interrupted
entry/
// turn off light
// de-energize power tube
// clear timer
doorClosed
doorOpened
doorClosed
buttonPressed
doorOpened
buttonPressed
buttonPressed
2. Door Open
entry/
// turn on light
1. Ready To Cook
entry/
// turn off light
3. Cooking
entry/
// turn on light
// energize power tube
// set timer for 1 minute
6. Cooking Extended
entry/
// add 1 minute to timer
buttonPressed
timerTimesOut
doorOpened
5. Cooking Complete
entry/
// turn off light
// de-energize power tube
// clear timer
doorOpened
timerTimesOut