6

Advanced State Modeling

6.1   The headlight (Figure A6.1) and wheels (Figure A6.2) each have their own state diagram. Note that the stationary state for a wheel includes several substates.

We have shown default initial states for the headlight and wheels. The actual initial state of the wheels may be arbitrary and could be any one of the power off states. The system operates in a loop and does not depend on the initial state, so you need not specify it. Many hardware systems have indeterminate initial states.
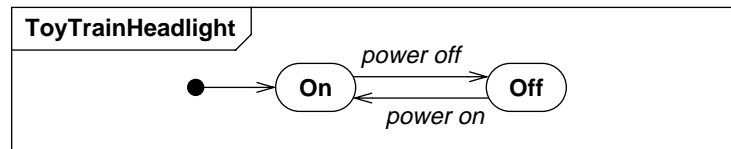

Figure A6.1   State diagram for a toy train headlight

6.2   Figure A6.3 extends Figure A5.2 for rapid setting of time. *B* means press button B while $\overline{B}$ means to release it. $B\overline{B}$ means to press and release it. (Instructor's note: you may want to give the students a copy of our answer to Exercise 5.2.)

6.3   Figure A6.4 adds *Motor On* to capture the commonality of the starting and running state. We have shown a transition from the *Off* state to the *Starting* state. We could instead have shown a transition from *Off* to *Motor On* and made *Starting* the initial state of *Motor On*. Note that the activity *apply power to run winding* has been factored out of both starting and running states. (Instructor's note: you may want to give the students a copy of our answer to Exercise 5.6.)
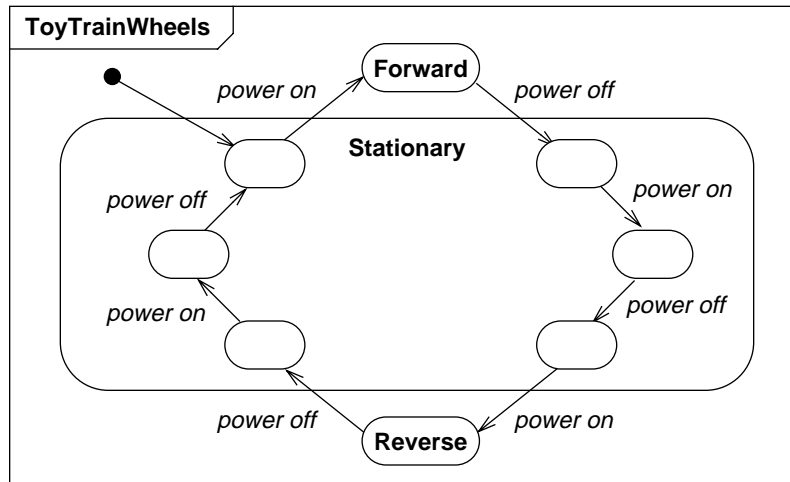
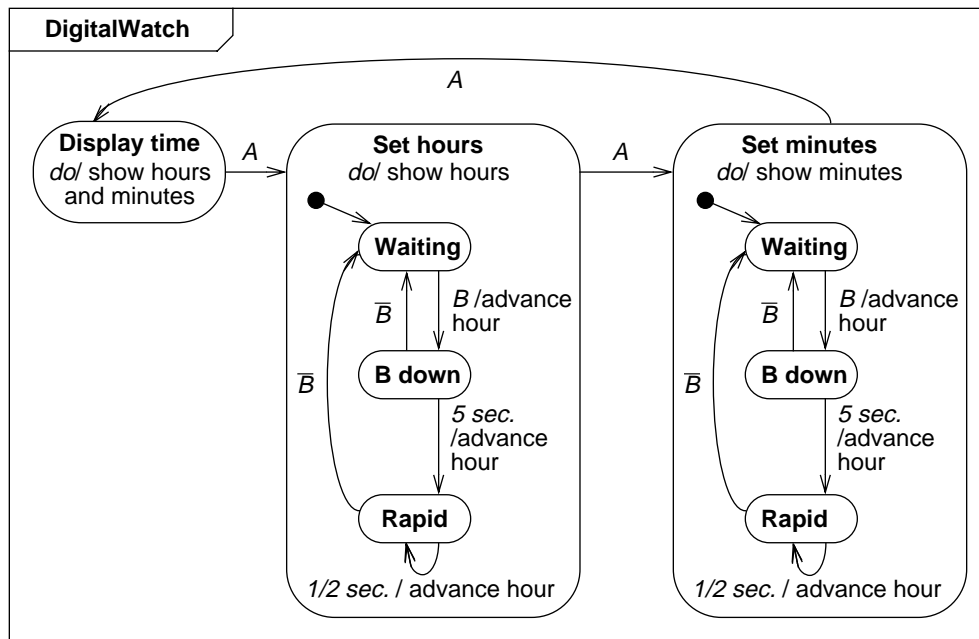**Figure A6.2** State diagram for the wheels of a toy train

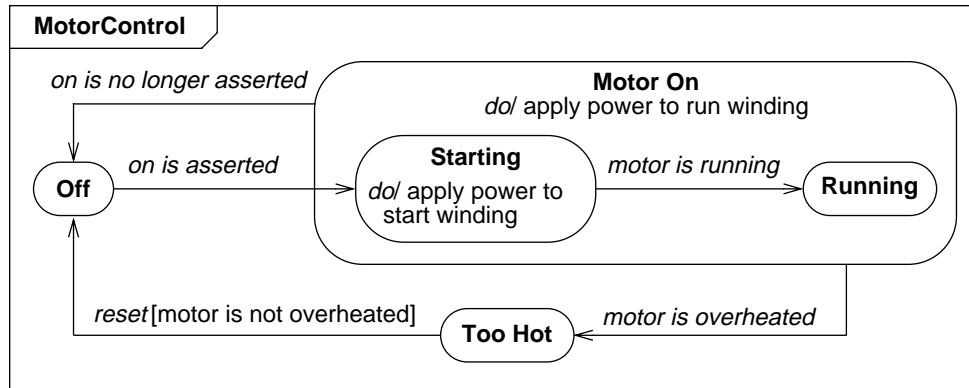**Figure A6.3** Extended state diagram for a digital watch

Figure A6.4 State diagram for a motor control using nested states

6.4   Figure A6.5 revises the motor state diagram. Note that a transition from *Off* to either *Forward* or *Reverse* also causes an implicit transition to *Starting,* the default initial state of the lower concurrent subdiagram. An off request causes a transition out of both concurrent subdiagrams back to state *Off.*
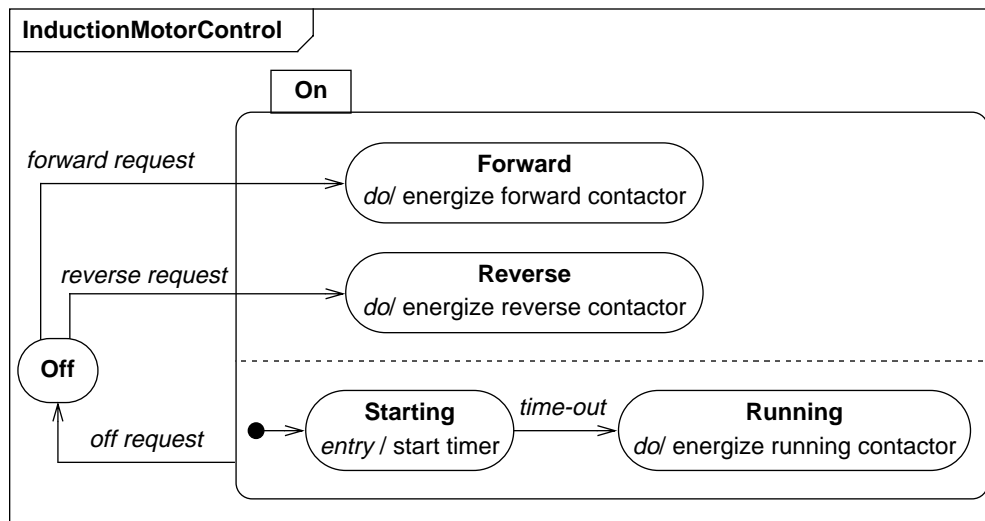

Figure A6.5 Revised state diagram for an induction motor control

6.5 a. Add an arrow labeled "[overheating detected]" from each non-*Off* state to state *Off*.

   b. Add an arrow labeled "[overheating detected]" from state *On* to state *Off*. Because state *On* has nested states, the transition applies to them.

6.6   Figure A6.6 places the signal classes into a generalization hierarchy along with a few
sample signal attributes. Do not confuse *textPick* with *characterInput*. Often *character-
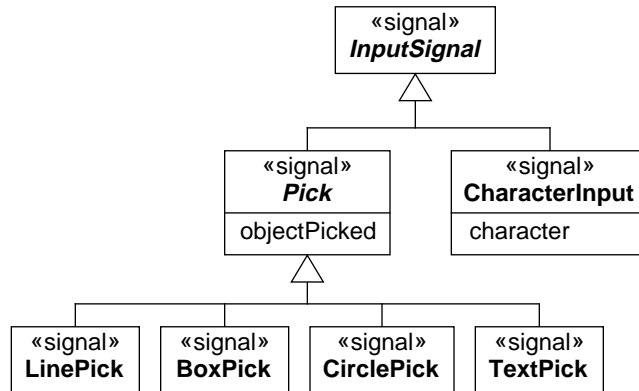Input* will follow a *textPick* event that indicates which input object receives the input
character.

Figure A6.6 A signal hierarchy

6.7   There would be one concurrent state machine for each room, plus one each for the fur-
nace control, blower control, and humidity control. They would have the following re-
sponsibilities:
   Room control. Measures temperature in the room. Requests heat if temperature is too
low. Cancels heat request if temperature is high enough. Controls flappers to the room
based on room temperature. Allows user to set target temperature.
   Furnace control. Turns on furnace if any room requests heat. Turns off furnace if no
room requests heat. Turns off furnace if furnace temperature is too high.
   Blower control. Turns on blower when furnace goes on. Turns off blower if furnace
is off and furnace is cool enough.
   Humidity control. Measures humidity and outside temperature. Allows user to set tar-
get humidity. Turns on humidifier if humidity is too low and blower is on.

6.8 a. Events are:
      selectpush select button
      on-offpush on-off button
      timedpush timed button
      autopush auto button
      setpush set button
      vcrpush vcr button
      time-outpreset recording time has expired
   Activities are:

display time   display current time of day in time display
display start time   display start recording time in time display
display stop time   display stop recording time in time display
flash day   flash day segment of time display
flash hour   flash hour segment of time display
flash minutes   flash minutes segment of time display
flash channel   flash channel display
initialize start time   set time setting display for start time to be current time
initialize stop time   set time setting display for stop time to be start time
next day   advance time setting display to next day of the week
next hour   advance time setting display to next hour
next minute   advance time setting display to next minute
next channel   advance channel setting display to next preset channel
more time   add fixed time increment to preset recording time
record   record the preset channel on the vcr tape
update time   change the time display as the current time changes
display "auto"   light the "auto" indicator on the display panel
vcr output   enable the vcr as the source of output (and disable the tv)
tv output   enable the tv as the source of output (and disable the vcr)

b. A synopsis of the user manual is as follows:

To set the clock, push SELECT successively to set the day of the week, the hour, and the minutes in turn. Within each setting, push SET to advance the respective setting by 1 unit (15 minutes for minutes).

To set the record timer, push ON/OFF. The time to start recording is displayed. It is initially set to the current time. The start time may be set using the SELECT and SET buttons as described for setting the clock to set the day, hour, minutes, and channel to begin recording.

When the recording start time and channel have been selected, press ON/OFF again to set the recording stop time. The stop time is displayed. It is initially set to be the same as the start time. Press SELECT and SET to set the hours and minutes of the stop time as described for setting the clock.

When the stop time has been set, press ON/OFF a final time to return to the time-of-day display. To enable the automatic recording mode, press AUTO. The "auto" indicator lights up. When the preset recording start time is reached, the vcr automatically switches to the preset channel and begins recording. When the preset recording stop time is reached, the vcr automatically stops recording. The current time is displayed continuously in automatic mode. To disable automatic recording mode, press AUTO again; if the vcr is recording, then recording will cease.

To record for 15 minutes starting immediately, press TIMED. The vcr begins recording on the current channel. To extend the recording time by an additional 15 minutes, press TIMED one or more times. [Note that there appears to be no way to cancel timed recording before time expires. This is a bug in the state diagram and would be extremely annoying to vcr owners.]
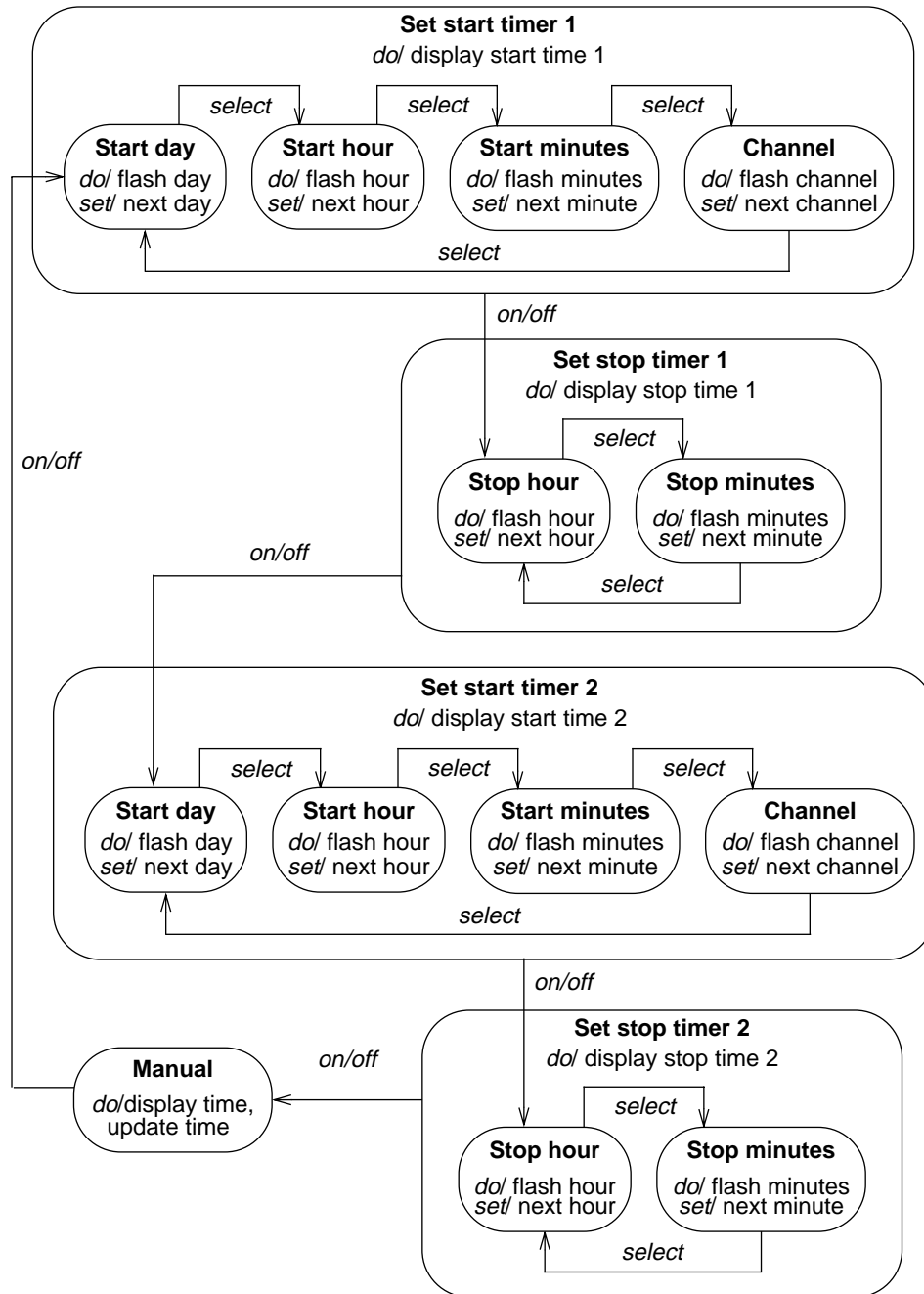
Figure A6.7 Adding a second start-stop timer for a vcr

Press the VCR button to toggle the output of the vcr between straight antenna input (to use the tuner on the TV set) and the output of the vcr (TV must be set on channel 3 or 4).

[The user's manual would also include descriptions of the manual control buttons omitted from the state diagram. The state diagram also omits controls for setting the current channel.]

c. We added to the state diagram (Figure A6.7) by duplicating states *Set start time*r and *Set stop timer* for the second time and hooking the new states into the ON/OFF sequence. We have deleted the entry activity to initialize the start time and stop time, because the user would not want to lose a previously set time in using the second setting.

d. We could parameterize the states to avoid duplicating information in several places (Figure A6.8). As Section 6.1 explains, we would use event parameters and define submachines for states *Set start time*r and *Set stop timer*.
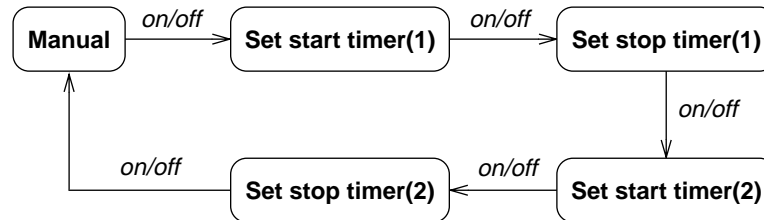

Figure A6.8 Using submachines to reduce the size of the vcr state diagram

6.9 Figure A6.9 uses nested states to repair the flaw in the state diagram for a copy machine. The power can be turned off at any time for the copy machine causing a transition to the off state.

6.10 Figure A6.10 shows the state diagram for *TableTennisGame*. This is the only class with important temporal behavior. Consequently this one state diagram constitutes the entire state model.

6.11 Figure A6.11 reifies class modeling concepts. An event within a state (entry event, exit event, or some other event) may or may not have an associated activity.

6.12 Figure A6.12 flattens the transmission state diagram. There are a few more transitions than for the nested state diagram. The increase in size would be more dramatic for a complex nested state diagram.

Note that we omit a self-transition from *First* to *First* upon *stop*. Such a behavior is included in Figure 6.5 and is a minor flaw of the diagram. The distinction between remaining in *First* and making a self-transition to *First* would be meaningful if activities were bound to the *stop* transition.
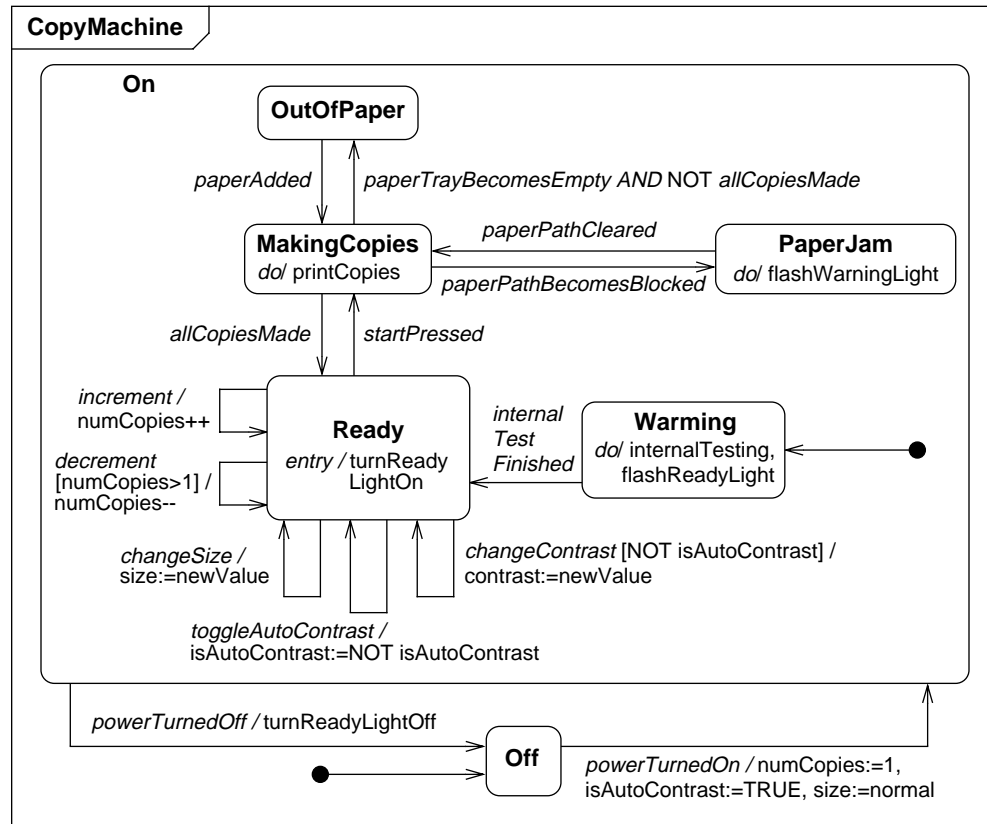
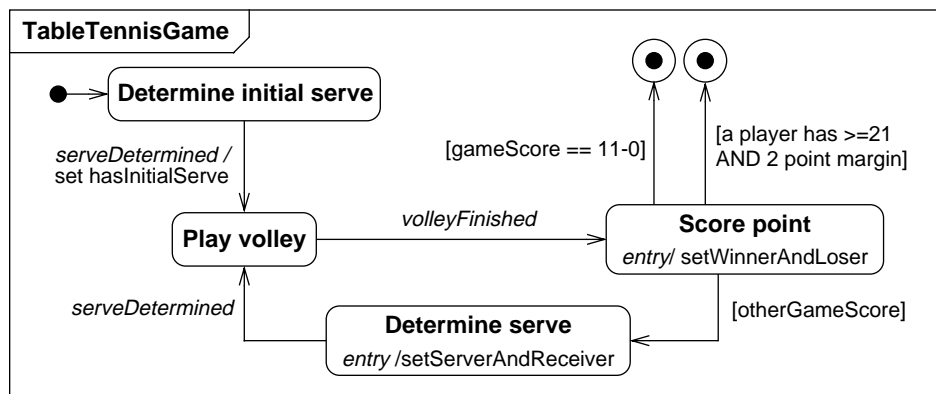**Figure A6.9** State diagram for copy machine with nested states

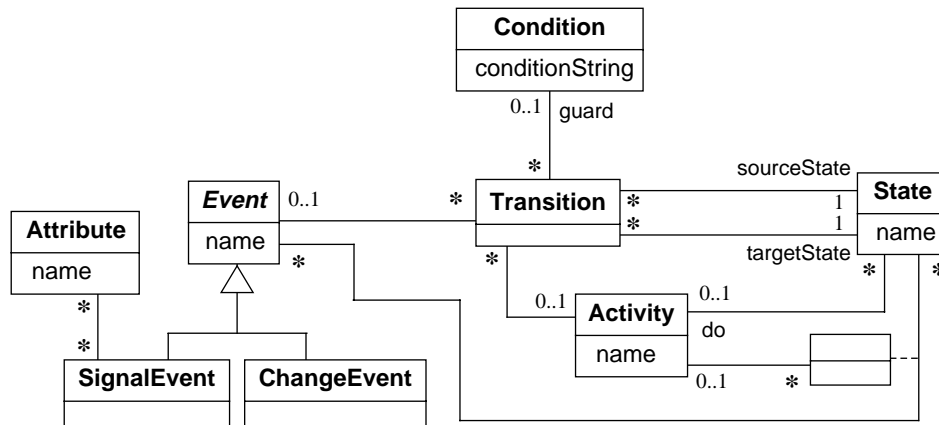**Figure A6.10** State diagram for *TableTennisGame*

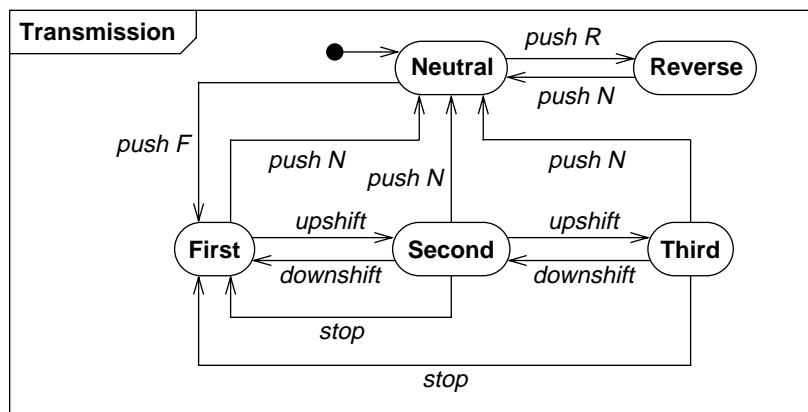**Figure A6.11** Class diagram that reifies state modeling concepts

Figure A6.12 Flat state diagram for a car transmission