Statechart to C++ Mapping

Introduction

Goal

This Technology Accelerator™ illustrates the use of Codagen Architect to map UML statechart diagrams into ANSI C++ source code.

Compatibility

This Codagen Technology Accelerator™ requires Codagen Architect version 3.0, Service Release1.

Overview

Reactive systems are best modeled with statecharts diagrams since the main focus of these diagrams is on the possible events that the system can respond to, and how the response is carried out. With these diagrams, we can visualize the behavior that the system will exhibit in response to a particular event according to its current state.

An interesting challenge is the transformation of these statecharts into manageable source code. Several patterns for mapping these statecharts into actual code have been published. In this Technology Accelerator™, we will use the "State" design pattern (from Gamma et al.) to derive ANSI C++ code from the model's class and state diagrams. The basic principle behind this pattern is that an object's behavior will change according to its current state, giving the appearance that its class has changed.

For each class possessing state diagrams (hereafter called a state-based class), the following subsystem is produced:

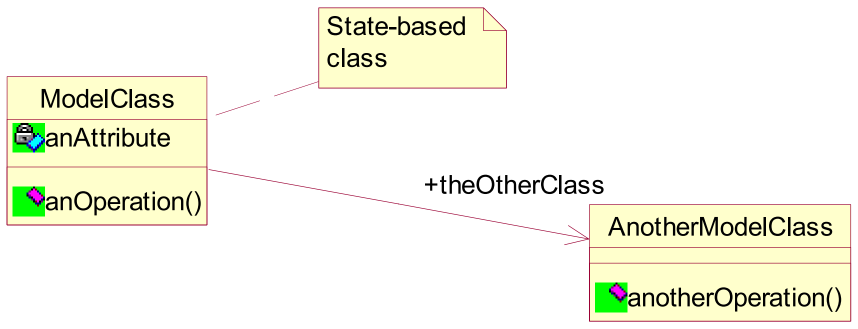
- a "context class" representing the subsystem's entry point, delegating all requests to the current "state class"
- an abstract "state interface" that defines the methods that each "state class" must implement
- a " state class" for each possible state that the state-based class can be in, encapsulating a specific behavior of this state-based class

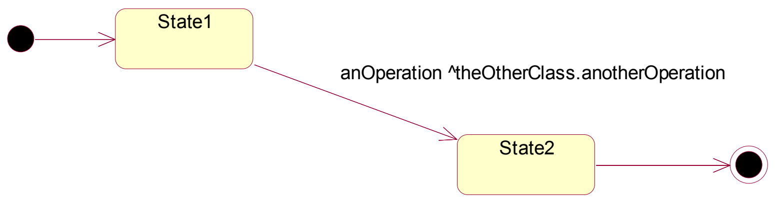
To illustrate the mapping from statechart diagrams to ANSI C++ code, this Technology Accelerator™ features a temperature control system that is reactive to the following external events: user commands (from a control panel, for example) and changes in the ambient temperature. This system is modeled as a collection of classes containing state diagrams to illustrate their state dependent behavior.

Application Model

This section takes a black-box approach: it describes the project's expected input and the produced output (the focus is on the "what"). In other words, it describes the nature of the platform-independent model (PIM) and the platform-dependent model (PSM).

Platform-Independent Model





Any model that possesses the following characteristics can be used as an input for the Technology Accelerator™ Architect project:

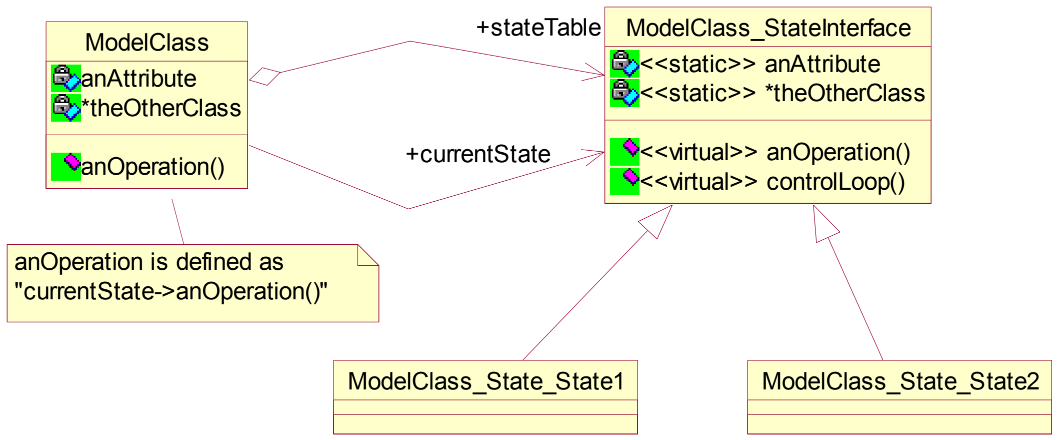
- Each association must have a role name for each navigable end.
- This role name must be used as the target name in the send events
- Each send event to a specific target class must correspond to a method in the target class interface.
- Each trigger on a transition in a class statechart must correspond to a method in the class interface.
- Each state in a class statechart must have a transition for each possible trigger (all methods in the class interface).

Architecture Specification

The following table lists the properties and the associated UML model elements, defined in the "HeatingSystem.csf" architecture specification file.

Layer/Issue/Property	**UML Element**	**Description**
Design Pattern		Generic Design Patterns
State		Allow an object to alter its behavior when its internal state changes. The object will appear to change its class.
isStateBased	Class	Defines which class will have its behavior implemented by multiple state classes, one for each state that the class may be in.

Platform-Specific Model


ModelClass
anAttribute
*theOtherClass
anOperation()
+stateTable
+currentState
ModelClass_StateInterface
<<static>> anAttribute
<<static>> *theOtherClass
<<virtual>> anOperation()
<<virtual>> controlLoop()
anOperation is defined as "currentState->anOperation()"
ModelClass_State_State1
ModelClass_State_State2

Here are the main characteristics of the PSM produced from the given PIM:

For each class in the PIM (both state-based and non-state based):

- Create a new class with the same name as the PIM class, containing the attributes and operations of the PIM class. Also add an attribute for each of the PIM class's outgoing associations.

For each state-based class in the PIM (classes with statecharts):

- Create the pattern's State Interface ("ModelClass_StateInterface"). It contains the same attributes and operations as the PIM state-based class. The attributes are declared as static so that the context of the state-based class is shared among all of its state classes (described below). The operations are declared as virtual so that each state class can override it to implement its own specific behavior.
- Add a reference to the State Interface in the created state-based class, and for each of the operations in the state-based class interface, forward the request to the appropriate method in the State Interface class.

For each state in a PIM state-based class:

- Create a "state class" that inherits from the State Interface and add a reference to it in the state-based class.
- For each triggered outgoing transition, add a method to the state class (these methods should match the State Interface methods), along with support for the guard, action and send event of the transition.
- Create a control loop method to handle the logic (guards, actions and send events) for all un-triggered transitions.
- Finally, create a constructor in the state-based class that will instantiate all state classes and the logic required to manage the transition between them.

Code Generation Process

This section takes a white-box approach: it describes the project templates (the focus is on the "how").

Code Generation Templates

This table contains the important templates for creating the ANSI C++ PSM from the given PIM:

Template Name	Type	Description
Create Business Class	Composite	This composite template creates a C++ class for every classifier in the model. The created class will contain the model class attributes and methods. It will also contain a reference attribute for each association target (for the model class outgoing associations).
Create State Enumeration	Class	For every state-based classifier, create an enumeration that contains an enumerator for each possible state in the classifier's state machines.
Create State Interface for state-based class	Composite	This composite template will create a State Interface for each state-based class containing the signatures of every method plus a "control loop" method.
Create Classes from States	Composite	For each state in a classifier's statecharts, create a class that inherits the State Interface.
Create State reference	Composite	Create references to the state classes within the state-based class.
Create State Table	Composite	Create a state table in the context classes large enough to hold the references to the state classes. This table will be used for state transitions.
State-Based Class Constructor	Method	This constructor will instantiate all possible state classes and inserts them into the state transition table.
Create Attributes Getters/Setters in State-Based Class	Composite	All getter/setters in the state-based class are forwarded to the current state.
Create method from state transition	Method	Called by “Create Classes from States”. Create a method from the trigger on a state's outgoing transition.

Example Model

The temperature control system in this example is composed of four entities: the thermostat, the furnace relay, the air conditioner relay and a thermometer.

Of these entities, it is the thermostat that is of particular interest. It is this entity that is the central “controller” of the system. It constantly monitors the current temperature (from the thermometer) and activates/deactivates the furnace and air conditioner relays in order to bring the ambient temperature up/down to the target temperature. The thermostat also listens for user commands which permit to start and stop the whole temperature control system and to change the target temperature.

Note: the system’s air conditioner and furnace are directly linked to the thermometer since we choose not to model the ambient air, which is normally found between them.

Generating the Example

This section describes the additional steps required to generate the PSM model, compile the resulting code, and execute the example. To assist in these steps, the example provides a Rose model of the temperature control system and a “main” C++ file (TemperatureControlSystem.cpp) that mimics a control panel for controlling the temperature control system.

Files provided

Here is a list of files included in this Technology Accelerator™:

- Temperature Control System.pdf – this document

- TemperatureControl.mdl – the Rose model for the temperature control system
- StatePattern.mdl – the Rose model that explains the project templates
- HeatingSystem.csf – Codagen Architect architecture specification file
- TemperatureControlSystem.gpcpp – Architect project templates
- src\TemperatureControlSystem.cpp – Main function of the test application

PSM generation

1. Open the provided Rose model: TemperatureControl.mdl
2. From the TemperatureControlSystem package in the model, invoke **Codagen Architect – Implement**
3. Generate code using every template (**Generate All** command)

Code to add manually

Add the following two lines of code (these lines are required for the heating/cooling elements to affect the “ambient air”):

1. In the code pocket of the “controlLoop” method in the file TemperatureControlSystem_AirConditionerRelay_State_On.cpp, add the following:
   theThermometer->currentTemp--;
2. In the code pocket of the “controlLoop” method in the file TemperatureControlSystem_FurnaceRelay_State_On.cpp, add the following:
   theThermometer->currentTemp++;

Code compilation

1. Using your favorite C++ compiler, create a project containing all the generated source code along with the provided “main” C++ file (TemperatureControlSystem.cpp).
2. Compile your new project

Example testing

The Temperature Control System is tested using a prompt-based application (the “main” function is provided in “TemperatureControlSystem.cpp”). This application displays the current and target temperatures, along with a short menu for controlling the system. With this menu, you can change the current and target temperatures, turn the system on or off and activate a cycle of the control loops. Each control loop cycle will affect the temperature by one degree, if required.

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