Icon-based Animation from the Object and Dynamic Models based on OMT

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Abstract

We propose the icon-based animation of the software requirement specifications by using the object and dynamic models of the OMT methodology. In order to produce the icon-based animation, we use "graphical classes" and "icon transformations." In general, the graphical classes are defined for each class of the object diagram. The icon transformations which show the activities of the application are constructed by considering the meaning of the activities and are defined by either basic or compound icons. The icon transformations are added to the state diagrams to generate extended state diagrams. The animation system generates the header files and the code instantiating GUI from the object diagram having graphical classes. The system also generates "event methods" from the extended state diagrams. When the event methods are executed, the behavior of the events is animated by the icon transformations.

1. Introduction

Object Modeling Technique (OMT) is based on the development of three-part models of the system [11]. The object model, represented with object diagram, captures the objects in the system and their relationships. The dynamic model, represented with state diagrams, describes the reaction of objects in the system to events, and the interactions between objects. The functional model specifies the transformations of object values and constraints on these transformations. These models are created in analysis phase and are gradually refined in design phase. In implementation phase, the models are converted into executable code. CASE tools, such as Rational Rose and Rhapsody, can generate executable code from object or state diagrams [1] [5]. However, when requirement specifications are not correct, the generated executable code becomes useless. In software development, the most important thing is to find the correct requirement specifications at the analysis stage. Animation is a powerful means of validating the requirement specifications. It helps both the user and analyst to understand the requirement specifications because the images represent real objects as well as their spatial and temporal relationships.

We propose the icon-based animation of the software requirement specifications by using the object and dynamic models of the OMT methodology. The icon-based animation means producing animation by moving icons and changing their appearance. A set of icons is associated with each class of an application. To represent icon movement and changes in their appearance we introduce the concept of icon transformation [8].

2. Lift problem

We show the lift problem [2] to explain our method of icon-based animation. This problem concerns the logic to move lifts between floors according to the five constraints [2]. We consider the lift system controlling 3 lifts and 6 floors as a case study.

2.1. The object and state diagrams

Figure 1 shows the object diagram of the lift problem. There is normally one class, the Controller [10] [3], that contains the control of the system. After initializing the system, the Controller transfers its control to the user of the system. So it is the interface between an external actor and the application. The value "6" ("3") of multiplicity specifies the number of the instances of class Floor (Lift) which is related to a single instance of the associated class Controller.

Figure 2 shows the state diagrams of the lift problem. Each state diagram shows the behavior of a particular class. In the state diagram of the Lift, the state of the Lift changes from MoveState to StopAtState on the occurrence of the event StopAt.

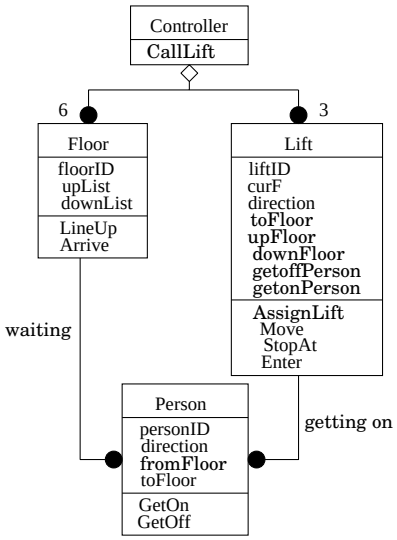


Figure 1. Object diagram of the lift problem

2.2. Icon definition

Icons are visual symbols of the objects of software requirement specifications. It is important to define simple and understandable icons. If they are misinterpreted, the requirement specifications cannot be understood [6] [4]. We define some basic icons (Figure 3).

- Defining basic icons for each class of the object diagram : The icons LIFT-A, FLOOR-A and PERSON-A are defined due to the presence of the corresponding classes.

- Defining basic icons for activities of the state diagrams : The icon LIFT-B is constructed from the activity OpenDoor in the state diagram of the Lift. The icons FLOORBUTTON-A and FLOORBUTTON-B are defined from the activities FloorButtonOff and FloorButtonOn in the state diagram of the Lift, respectively. The icons UPBUTTON-A and DOWNBUTTON-A are constructed from the activity UpDownRequestButtonOff in the state diagram of the Floor. The icons UPBUTTON-B and DOWNBUTTON-B are constructed from the activity UpDownRequestButtonOn in the state diagram of the Floor.

We construct some compound icons (Figure 4).

- Defining compound icons for activities, considering the states in which the corresponding activities are contained : The compound icon CLOSE is defined from the activity CloseDoor of StopAtState in the state diagram of the Lift. The state StopAtState represents that a lift arrives at the floor. This icon is formed by

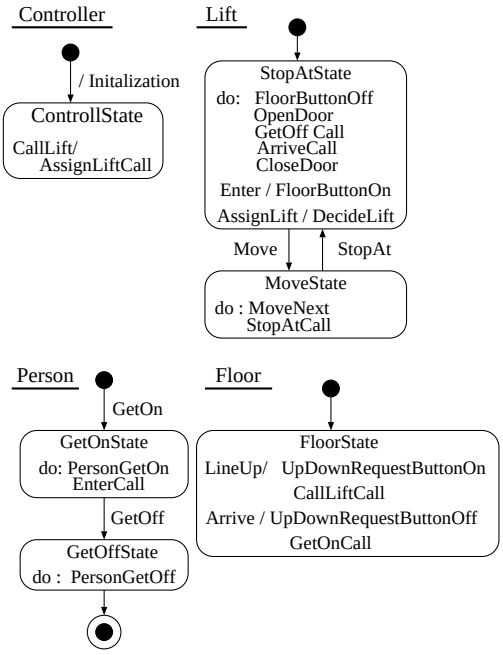


Figure 2. State diagrams of the lift problem

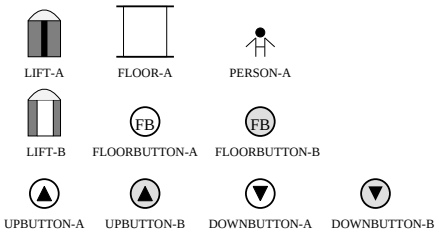


Figure 3. Basic icons for the lift problem

combining the basic icons LIFT-A and FLOOR-A. The compound icon OPEN is constructed from the activity OpenDoor of StopAtState in the state diagram of the Lift. This icon is formed by combining the icons LIFT-B and FLOOR-A. The compound icons MOVE-A and MOVE-B are constructed from the activity MoveNext of MoveState in the state diagram of the Lift. The state MoveState represents that lift is moved next floor. These icons are constructed by combining the basic icons LIFT-A and FLOOR-A. The compound icons GETON-A and GETON-B are defined from the activity PersonGetOn of GetOnState in the state diagram of the Person. The state GetOnState shows that a person gets on the lift arrived at the floor. These icons are constructed by combining the basic icons LIFT-B, FLOOR-A and PERSON-A.

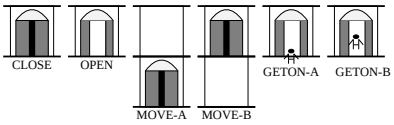


Figure 4. Compound icons for the lift problem

2.3. Constructing conceptual sketch

We consider a conceptual sketch for the lift problem. The conceptual sketch is constructed by considering the value of multiplicity for the number of the instances of classes. The constraints [2] for the lift problem are also considered when constructing the conceptual sketch. It represents the general outlook and provides us the base for the GUI.

To show 6 floors and 3 lifts according to the values "6" and "3" in the object diagram, we place FLOOR-A icons in grid structures created by 6 rows and 3 columns. Three LIFT-A icons are positioned on the ground floor (Figure 5). Considering the Constraint 1, each lift has floor buttons, one for each floor. We display these buttons at the corresponding floors. For 3 lifts, each FLOOR-A icon placed in grid structures created by 6 rows and 3 columns contains a FLOORBUTTON-A icon and is added to Figure 5 (Figure 6). When floor button is pressed, the FLOORBUTTON-A icon is changed to the FLOORBUTTON-B icon. The LIFT-A icon keeps moving to floor whose floor button is pressed. Considering the Constraint 2, each floor has up/down request button, except ground and top floors. We place the FLOOR-A icons in grid structures created by 6 rows and 2 columns because of up/down request button. The UPBUTTON-A and DOWNBUTTON-A icons are positioned on each floor. These icons are added to Figure 6 (Figure 7). Ground floor has only the UPBUTTON-A icon. Top floor has only the DOWNBUTTON-A icon. When up/down request button is pressed, the UPBUTTON-A/DOWNBUTTON-A icon is changed to the UPBUTTON-B/DOWNBUTTON-B icon. The LIFT-A icon keeps moving to floor whose up/down request button is pressed. Considering the Constraint 2, up/down request button illuminates when pressed by a person. Because we display 2 persons on each floor, FLOOR-A icons in grid structures with 6 rows and 2 columns are added to Figure 7 (Figure 8). The PERSON-A icon is positioned on the floor on which a person appears.

2.4. The object diagram having graphical classes

To generate the GUI for the application, we define the object diagram having graphical classes. The icons and icon transformations which represent the objects and activities of

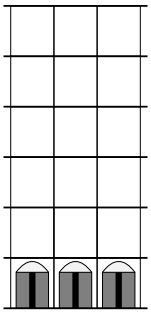


Figure 5. Conceptual sketch (1)

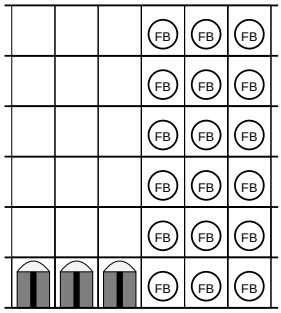


Figure 6. Conceptual sketch (2)

the application become the types of the graphical classes. Figure 9 shows the object diagram having graphical classes of the lift problem. In general, the added graphical classes correspond to the classes of the object diagram. For example, the Controller, Floor, Lift and Person correspond to GController, GFloor, GLift and GPerson, respectively. In Figure 8, each floor includes display areas; lifts, floor buttons, up/down request button and persons. For the icons of the floor buttons and up/down request button, we need to the types of other graphical classes. We added GFloorButton, GUpButton and GDownButton classes to the object diagram.

Because each floor has several display areas, the GController has reference of the GFloor type for referring each floor. The GFloor then maintains references of GLift, GPerson, GUpButton, GDownButton and GFloorButton types. The GController initializes the GFloor objects by receiving GUIInitialization message from the Controller.

2.5. Extended state diagrams having icon transformations

We add icon transformations which show animation for the corresponding activities to the state diagrams (Figure 10).

The icon transformations are constructed by considering the meaning of the activities in the states. Usually they

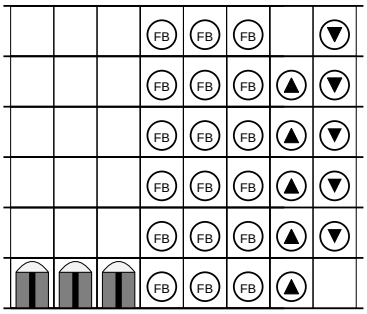


Figure 7. Conceptual sketch (3)

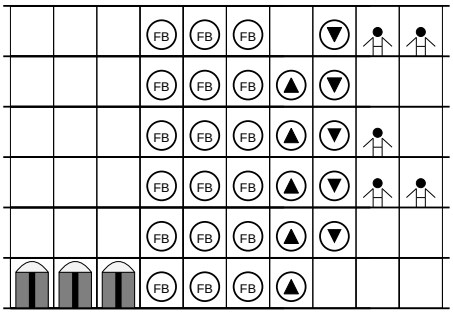


Figure 8. Conceptual sketch (4)

have names and are enclosed between "{" and "}" symbols. They are composed of starting and ending icons and are enclosed between "⟨" and "⟩" symbols. These icons are defined by either basic or compound icons. For example, because the meaning of the activity FloorButtonOff (StopAtState of the Lift) animates "off floor button into the lift," the starting and ending icons consist of the basic icons which are FLOORBUTTON-B and FLOORBUTTON-A. The icon transformation name of the activity FloorButtonOff is FloorButtonOffT. The icon transformation of activity OpenDoor (StopAtState of the Lift) consists of the compound icons CLOSE and OPEN, because the meaning of this activity animates "open the door of the lift." The icon transformation name of this activity is OpenDoorT.

Sometimes an activity has two icon transformations. If an activity has two icon transformations, we add a condition following the icon transformation name because of selecting an appropriate icon transformation. This condition is enclosed between "[" and "]" symbols. For example, the activity UpDownRequestButtonOn (LineUp event of the Floor) has UpRequestButtonOnT and DownRequestButtonOnT. The condition which selects an appropriate icon transformation is that the request button pressed by Person object is whether up or down request button. $UpDownButton$ is method which detects a kind of up/down request button. If Person object presses up request button $(UpDownButton() == 1)$, UpRequestButtonOnT

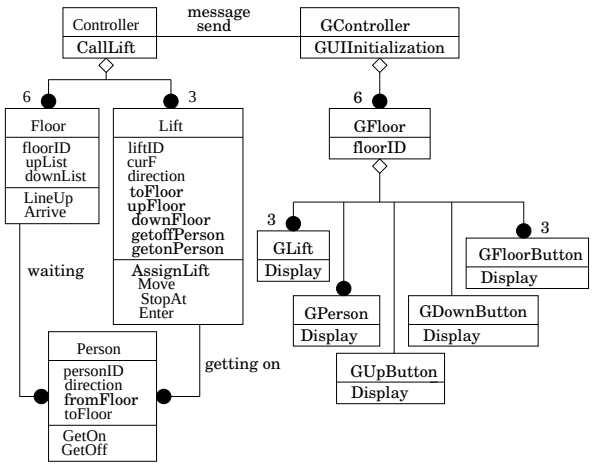


Figure 9. Object diagram having graphical classes

is displayed. If Person object presses down request button $(UpDownButton() == -1)$, DownRequestButtonOnT is displayed.

3. Generating animation code

3.1. Generating header files and the code instantiating GUI

After finding information about the classes in the object diagram having graphical classes, the header files for them and the code instantiating GUI are generated. In general, attributes and operations in the object diagram having graphical classes become variables and headers of the event methods in the header files, respectively.

For example, the header files for the classes Controller and Lift in Figure 9 are generated as in Figure 11. The Controller class has aggregation relationship with Floor and Lift classes. The composite class, the Controller, contains floorList and liftList objects of types Floor and Lift classes, respectively. The main method which is used to initialize these objects is defined to the Controller class. The number of these objects is generated as many as the values "6" and "3" of multiplicity of Floor and Lift, respectively. In order to construct the GUI components, the GUIInitialization message is sent to GController object. The Lift object keeps its own control and does not wait for incoming messages from other objects. It executes a continuous loop and in each iteration it checks whether there is any outstanding request that should be serviced. That is why, the Lift class is defined as a Java thread. The continuous loop which calls Move method of the Lift is placed inside the run method.

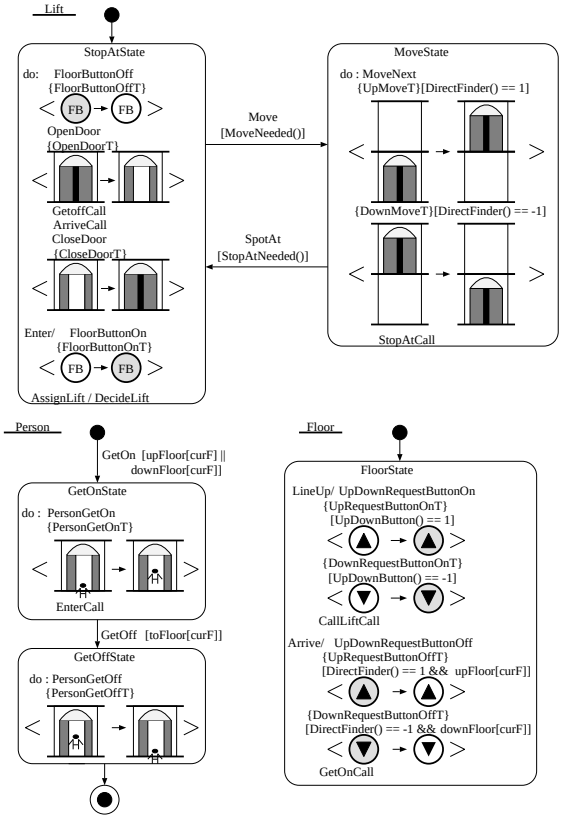


Figure 10. Extention of the state diagrams

The code instantiating GUI is generated from the graphical classes. The header files for the graphical classes GController and GFloor are generated as in Figure 12. The GController class has aggregation relationship with GFloor class and contains gFloorList objects of type GFloor class. In the GUIInitialization method, the gFloorList objects are created as many as the value "6" of the multiplicity of the GFloor. The GFloor class has aggregation relationship with GLift, GPerson, GUpButton, GDownButton and GFloorButton classes. The GFloor class contains gLift, gPerson, gUpButton, gDownButton and gFloorButton objects of types GLift, GPerson, GUpButton, GDownButton and GFloorButton classes, respectively. The number of these objects is decided to the value of the multiplicity of the corresponding classes. The GUIInitialization method is executed when receiving the corresponding message from Controller.

In the object diagram having graphical classes, there is no information about the body codes of the event methods. The body codes of the event methods can be generated after finding information in the extended state diagrams.

```
class Contoller {
        public static Floor[ ]  floorList;
        public static Lift[ ]  liftList;

        public static void main(String args[ ]) {
                floorList = new Floor[6];
                liftList = new Lift[3];
                for (int i = 0; i < 6; i ++)
                        floorList[i] = new Floor(i);
                for (int i = 0; i < 3; i ++)
                        liftList[i] = new Lift(i);
                GController.GUIInitialization( );
        }
        public static void CallLift(int curF) { }
}
class Lift extends Thread {
        int liftID, curF, direction;
        boolean[ ]  toFloor, upFloor, downFloor;
        Person[ ] getoffPerson, getonPerson;

        public void AssignLift( int dir, int curF) { }
        public void Move() { }
        public void StopAt(int curF) { }
        public void Enter(Person per) { }
}
```

Figure 11. Definitions of Controller and Lift

3.2. Generating event methods

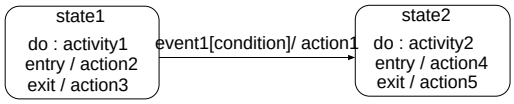
The information shown in the extended state diagrams is used to generate event methods of the classes. If the event in the extended state diagram is an internal one, the body code of the event method contains a method call which executes the associated action. If the event in the extended state diagram has a guarded transition, the body code of the event method contains the following method calls after checking the guard condition. Method calls to execute 1) the exit action of the current state, 2) the actions related to the transition, 3) the entry action of the new state and 4) the activities of the new state. For example, in the state diagram of Figure 13, the body code for event method event1 first calls action3 which is exit action in state1. Next, it calls action1 related to event1, and then calls action4 which is entry action. Finally, it calls activity2 in state2.

To be able to execute the generated body code of the event method, it is necessary to generate the body code of the methods that are called from inside event methods. We use icon transformations to define body code of these methods. For example, the event method StopAt in Figure 10 checks the guard condition $StopAtNeeded$ and calls FloorButtonOff, OpenDoor, GetOffCall, ArriveCall and CloseDoor methods. Figure 14 shows the body code for event method StopAt after using the icon transformations. The FloorButtonOff method displays icon transformation FloorButtonOffT of the GFloorButton type. Considering relationship links of the object diagram containing graphical classes, we use standard navigation expression, "GController.gFloorList[curF].gFloorButton[liftID].Display ("FloorButtonOffT")." The expression to call the method

```
class GContoller {
        public static GFloor[ ]  gFloorList;
        public static void GUIInitialization () {
                gFloorList = new GFloor[6];
                for (int i = 0; i < 6; i ++)
                        gFloorList[i] = new GFloor(i);
        }
}

class GFloor extends Panel {
        int floorID;
        GLift gLift[ ];
        GUpButton gUpButton;
        GDownButton gDownButton;
        GFloorButton gFloorButton[ ];
        ……
        public GFloor(int  floor) {
                floorID = floor;
                ……
                for (int i = 0; i < 3; i ++) {
                        gLift[i] = new GLift(floor);
                        add (gLift[i]);    }
                for (int i = 0; i < 3; i ++) {
                        gFloorButton[i] = new GFloorButton(floor);
                        add (gFloorButton[i]);     }
                gUpButton = new GUpButton(floor);
                gDownButton = new GDownButton(floor);
                add (gUpButton);     add (gDownButton);
                ……
        }
}
```

Figure 12. Definitions of GController and GFloor




```
public  void  event1() {
        if (condition)  {
                action3();
                action1();
                action4();
                activity2();
        }
}
```

Figure 13. Body code of the event1

in the graphical classes must start from GController class. The ArriveCall method calls Arrive method of the Floor class. We use navigation expression of "Controller.floorList[curF].Arrive(curF)." The expression to call the method in the original classes must start from Controller class. The Display is an animation method which displays the icon transformations. Executing this code produces animation for event method StopAt.

4. Generating animation

For generating animation, the generated header files, the code instantiating GUI and event methods are used. When the main method of the Controller class is executed, the objects of the Floor and Lift are initialized, and GUIInitialization message is sent to the GController class for creating

```
public void StopAt(int curF) {
    if  (StopAtNeeded( ))  {
        GController.gFloorList[curF].
          gFloorButton[liftID].Display("FloorButtonOffT");
        GController.gFloorList[curF].
          gLift[liftID].Display("OpenDoorT");
        Controller.liftList[liftID].
          getoffPerson[curF].GetOff(curF,liftID);
        Controller.floorList[curF].Arrive(curF);
        GController.gFloorList[curF].
          gLift[liftID].Display("CloseDoorT");
    }
}
```

Figure 14. Body code of StopAt

GUI components. The number of the initialized objects is decided according to the values of multiplicity in the object diagram having graphical classes. The GController object represents itself as in Figure 15. Figure 16 shows the snapshot of the animation for the lift problem.

To make the system interactive, each GFloor object contains up/down buttons at right in Figure 15, except ground and top GFloor objects. These buttons are clicked by user with mouse.

When the user clicks up/down buttons, the Floor and GFloor objects create a new Person and GPerson objects, respectively. Then the method LineUp of the Floor class is called. The Floor object adds new Person objects to the list of persons already waiting at the floor. The destination floor for a Person object is randomly determined when the object is newly created. If the user clicks up button, when the LineUp is executed, it is animated that up request button is illuminated. Then Floor object sends the CallLift message to the Controller. When the CallLift is executed, the Controller sends the AssignLift message to each of the Lift objects asking its convenience for servicing the request and assigns a lift to floor pressed up/down request button. If the Lift object is assigned, run method is executed and Move method is called. When Move is executed, it animates the lift moving between the floors. During moving between the floors, the Lift object calls StopAt method and checks guard condition $StopAtNeeded$. If $StopAtNeeded$ condition is satisfied, the body code of StopAt method is executed. When StopAt is executed, it animates the floor button inside the lift being reset and the door of the lift being opened. Then GetOff message is sent to Person object and Arrive message is sent to Floor object. Finally the action closing the door of the lift is animated. When GetOff is executed, it is animated that persons get off in the lift. When Arrive is executed, it animates the up or down request button being reset, and GetOn message is sent to Person object. When GetOn is executed, it animates the persons getting on the lift, and Enter message is sent to Lift object. When Enter is executed, it animates the floor button which is corresponded to destination floor for a Person object being illuminated. If the Lift object has any request, Move method is called repeatedly.

Figure 15. GUI for the lift problem

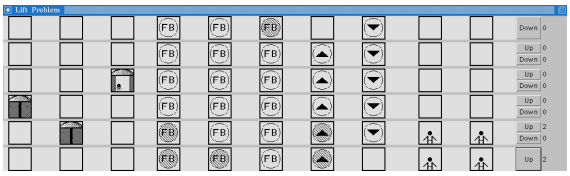


Figure 16. Snapshot of the animation

5. Related works

A method for the visual requirement specifications is discussed in [9]. It only works for elements of the system that are easier to visualize, such as the data flow of the system. They are specified by using VRDL. We perform animation of the flow of control represented by the state diagrams. In [12], the behavior of a system is simulated by executing the production rules combined with icon animation. We perform animation by executing the event methods whose body code are generated by our system. In [7], only textual information is displayed and describes the behavior of the system without any animation. We animate the behavior of the system by using the icon transformations.

6. Conclusion

We propose a system which produces the icon-based animation from the software requirement specifications based on the OMT methodology. The icon-based animation is performed by the GUI components and executing event methods which contain icon transformations. Through animation, it becomes easy to understand the software requirement specifications and to examine the correctness of the software requirement specifications at the analysis stage.

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