Software Systems Engineering Case Study 2016

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1 Introduction

The following report describes the software development process employed to analyze, design and implement an IoT application. The whole process is divided into two steps: at first, the client will communicate the initial requirements for the application, then new features will be requested. The report will show the impact of client requirements changes on the project on both the design and implementation phase.

2 Vision

We want to discuss the process of software development in order to overcome the limits of a technology-based approach in heterogeneous distributed system application design. We try to adopt a model-driven software development taking into account the AGILE methods for cooperation and work management. In particular, we want to:

- Define a formal, executable model of the application to receive feedback from the client and ensure that requirements are clearly defined as soon as possible
- Minimize the abstraction gap between the concepts supported by the development tools and the application domain entities.
- Delay any technological hypotesis as much as possible in order to support multiple deployment environments and to be able to quickly adapt to technological changes. This is particularly important in heterogeneous distributed environments.
- Create flexible applications to resist requirements changes and add new features easily

3 Goals

The goal is to solve the given problem following the principles described in the vision and determine if this approach is viable and convenient. We want to build a first prototype since the very formal definition of the problem, and incrementally enhance it until we'll have the complete final product, employing AGILE methods for the implementation. Then we'll rapidly adapt the application to new requirements, trying to minimize the development effort.

4 Requirements

We have to solve the following problem:

The Security Department of an Airport intends to exploit a differential drive robot equipped with a sonar (and some other device) to inspect -in a safe way- unattended bags when they are found in some sensible area of the Airport.

The software working on the inspector-roobot should support the following behavior:

- an operator drives the robot from an initial point (robot base area, RBA) towards the bag. To drive the robot the operator makes use of a remote robot control interface running on a smart device or a PC. The robot must accept commands from a single source only;
- as soon as the robot sonar perceives the bag within a prefixed distance (e.g. d=20cm):
  1. the robot automatically stops
  2. the robot starts blinking a led
  3. the robot starts a first detection phase (e.g. it moves around and performs some action according to its equiment - for example it could take some photo of the bag)
  4. the robot sends the results of its detection phase to the Airport Security Center;
- at the end of its work, the robot turns the led off and automatically returns to its RBA. During this phase the Airport Security Center could emit an 'alarm' signal; in this case the robot must restart to blink.

STEP 1
Design and build a working prototype of this inspector-robot.
Non functional requriments at step1
The goal is to build a software system able to evolve from an initial proptotype (defined as the result of a problem analysis phase) to a final, testable product, by 'mixing' in a proper (pragmatically useful) way agile (SCRUM) software development with modelling.

5 Requirement analysis

5.1 Use cases

The use cases describe how actors (UML actors i.e. the role played by a user or external system) interact with the system. In the requirements we can identify two external entities:

- **The operator** that drives the robot remotely from the initial point to the bag.
- **The Airport Security Center** that receives the results of the robot's detection phase and then it may emit an 'alarm' signal.

These interactions are shown by the UML below:
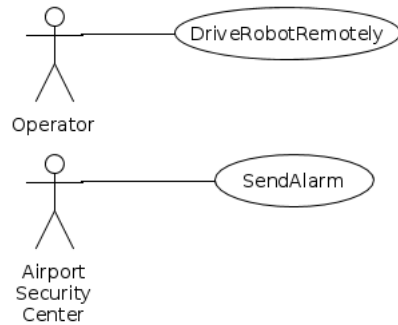
5.2 Scenarios

Scenario 1:

Title	DriveRobotRemotely
Description	The operator drives the robot to the suspicious bag
Relationships	
Actors	Operator
Preconditions	The robot is in the RBA, waiting for commands from the operator.
Postconditions	The robot starts the detection phase.
Main scenario	The operator uses the remote console to drive the robot.
	When the robot perceives the bag, it starts the detection phase.

Scenario 2:

Title	SendAlarm
Description	The Airport Security Center sends an alarm signal to the robot if needed
Relationships	
Actors	Airport Security Center
Preconditions	The Airport Security Center received the detection results
Postconditions	The robot blinks its led until it comes back to the RBA.
Main scenario	The Airport Security Center uses its interface to send the alarm to the robot. The robot blinks its led.

5.3 (Domain) model

In this phase we try to find an agreement with the client on what the entities mentioned in the requirements are and what they have to do.
The system is composed by three parts:

– **Operator's remote console**

- **Airport Security Center's remote console**
- **Differential drive robot**

A **console** is a physical or virtual device that allows communication between the system and an external entity. It can get user input data and send them to the system, show some system output data to the user or both. In this case, the operator's console can get input from the operator and the Airport Security Center's console can receive the detection results and emit an alarm signal.

A **differential drive robot** is a composed entity that is able to use some devices to perform actions and receive data from the environment. It can also communicate with other parts of the system. All differential drive robots must have a sonar and are able to move in the environment. In this case, the differential drive robot has DC motors and wheels to move, a sonar, a led and a camera. DC motors, wheels, led, sonar and camera are the hardware components mounted on the robot.

A **DC motor** can spin the attached wheel clockwise or counter-clockwise.

A **led** can be turned on or off.

A **sonar** can send an ultrasonic signal (trigger) and generates a corresponding response waveform (echo). The waveform analysis allows to estimate the distance from an obstacle.

A **camera** is a device that can take photos when requested. It will be used by the robot in the detection phase.

The system can be formally defined with a custom language / executable meta-model developed by our software house. It allows us to describe what are the parts of the system, how they interact with each other and their behaviour.

The following is a first description of the system obtained by the requirement analysis:

```
1  RobotSystem testCase2016Analysis
2
3  Dispatch drive : drive(X)
4  Dispatch detectionResults : detectionResults(X)
5  Event alarm : alarm
6  Event obstacle : obstacle(X)
7  Event local_inputDrive : local_inputDrive(X)   //events
       from GUI/External Input
8  Event local_alarm : local_alarm               //events from GUI
       /External Input
9
10 Context ctxDriveRobot ip[host="localhost" port=8010]
11 Context ctxOperator ip[host="localhost" port=8015]
12 Context ctxASC ip[host="localhost" port=8020]
13
14 QActor operatorconsole context ctxOperator -g cyan
15 {
```

```
16    Plan init normal
17        println("Operator starts");
18        switchToPlan senseInput
19
20    Plan senseInput
21        sense time(60000) local_inputDrive ->
                sendDriveCommands;
22        repeatPlan 0
23
24    Plan sendDriveCommands resumeLastPlan
25        onEvent local_inputDrive : local_inputDrive(X) ->
                forward driverobot -m drive : drive(X)
26 }
27
28  QActor ascconsole context ctxASC -g green
29  {
30    Plan init normal
31        println("ASC starts");
32        switchToPlan work
33
34    Plan work
35        receiveMsg time(600000);
36        onMsg detectionResults : detectionResults(X) ->
                println(detectionResults(X));
37        switchToPlan senseAlarm
38
39    Plan senseAlarm
40        sense time(100000) local_alarm -> continue;
41        onEvent local_alarm : local_alarm -> emit alarm :
                alarm
42 }
43
44  Robot mymock QActor driverobot context ctxDriveRobot
45  {
46    Plan init normal
47        println("driverobot starts");
48        switchToPlan drive
49
50    Plan drive
51        //We'll have to make sure that the robot executes the
                commands from the first console only
52        receiveMsg time(600000) react event obstacle ->
                detect;
53        onMsg drive : drive(X) -> println(savingmove(X));
54        onMsg drive : drive(X) -> println(driving(X));
```

```
55        repeatPlan 0
56
57     Plan detect
58        println("Stopping...");
59        delay time(1000);
60        println("Start blinking the led");
61        println("Starting detection Phase...");
62        delay time(3000);
63        println("Sending results");
64        forward ascconsole -m detectionResults :
              detectionResults("results");
65        println("Detection Results Sent");
66        println("Stop blinking the led");
67        println("Back to base");
68        switchToPlan backToBase
69
70     Plan backToBase
71        delay time(20000) react event alarm -> alarmReaction;
72        switchToPlan finish
73
74     Plan alarmReaction resumeLastPlan
75        println("Alarm!");
76        println("Start blinking the led")
77
78     Plan finish
79        println("DriveRobot ends")
80  }
```

The operator can only send commands to drive the robot. The Airport Security Center waits for the detection results and can emit the alarm only after the results have been sent.

5.4   Test plan

We can do a test plan even before starting to implement the application, as a way to specify the expected behaviour of the system in a precise way. We just need to check if the parts of the system behave and interact with each other as defined in the requirements. We can't express tests formally tough, because we already described the entities as actors, so object oriented tests (e.g. JUnit tests) are inadequate. Furthermore, some tests should check the interaction of the physiscal system with the environment and this can only be achieved by observing the actual behaviour of the system. Thus, we'll describe these tests in natural language.

In the initial phase, the operator drives the robot. We have to check the following:

  – the operator can send commands to the robot

- the robot executes the commands it receives
- the robot accepts commands only from a single source
- the robot perceives the presence of an obstacle

In the detection phase, the robot inspects the bag. We'll test the following:

- the robot stops and ignores commands from the operator
- the robot starts blinking after it stopped
- the robot can take a picture of the bag
- the robot can send the results to the Airport Security Center
- the Airport Security Center can receive the results of the inspection
- the robot stops blinking at the end of this phase

In the final phase, the robot comes back to the RBA. These are the tests we'll do:

- the robot actually comes back autonomously
- the Airport Security Center can emit the alarm signal
- the robot blinks the led if it perceives the alarm

At this stage in the development process, we can't define more specific functional or integration tests, we'll add them as needed during the implementation phase. We still haven't decided what technology we will use to implement the application, so we can't write executable tests yet. However, at the end of the analysis phase, we'll have an executable logical architecture of the application and we'll be able to perform some of the tests on it.

6 Problem analysis

6.1 Logic architecture

Logic architecture can be expressed in 3 dimensions:

1. **Structure**: what parts the system is made of.
2. **Interaction**: how the parts of the system communicate with each other.
3. **Behaviour**: what the parts of the system do.

We can formally express these concepts with the DDR custom language:

```
1  RobotSystem testCase2016LogicArchitecture
2
3  Event local_inputDrive : local_inputDrive(X)   //events
       from GUI/External Input
4  Dispatch drive : drive(X)
5  Dispatch detectionResults : detectionResults(X)
6  Event alarm : alarm
7  Event local_alarm : local_alarm              //events from GUI
       /External Input
8  Event obstacle : obstacle(X)
```

```
 9  Event bagFound : bagFound
10  Event endDetection : endDetection
11  Event botIsBack : botIsBack              //signals the
        return to the base of the robot
12
13  Context ctxDriveRobot ip[host="192.168.1.69" port=8010]
14  Context ctxOperator ip[host="192.168.1.2" port=8015]
15  Context ctxASC ip[host="192.168.1.2" port=8020]
16
17  QActor led context ctxDriveRobot
18  {
19    Plan init normal
20      println("Led starts");
21      switchToPlan senseStartBlink
22
23    Plan senseStartBlink
24      println("Led Off");
25      sense time(60000) bagFound -> startBlinking;
26      repeatPlan 0
27
28    Plan startBlinking
29      println("led On");
30      delay time(1000) react event endDetection ->
            senseAlarm;
31      println("Led Off");
32      delay time(1000) react event endDetection ->
            senseAlarm;
33      repeatPlan 0
34
35    Plan senseAlarm
36      println("Led Off");
37      sense time(60000) alarm-> blinkingAlarm;
38      repeatPlan 0
39
40    Plan blinkingAlarm
41      println("led On");
42      delay time(500) react event botIsBack -> finish;
43      println("Led Off");
44      delay time(500) react event botIsBack -> finish;
45      repeatPlan 0
46
47    Plan finish
48      println("Led ends")
49  }
50
```

```
51  QActor operatorconsole context ctxOperator -g cyan
52  {
53      Plan init normal
54          println("Operator starts");
55          switchToPlan senseInput
56
57      Plan senseInput
58          println("Waiting for input");
59          sense time(60000) local_inputDrive ->
                  sendDriveCommands;
60          repeatPlan 0
61
62      Plan sendDriveCommands resumeLastPlan
63          onEvent local_inputDrive : local_inputDrive(X) ->
                  forward driverobot -m drive : drive(X)
64  }
65
66  QActor ascconsole context ctxASC -g green
67  {
68      Plan init normal
69          println("ASC starts");
70          switchToPlan work
71
72      Plan work
73          receiveMsg time(600000);
74          onMsg detectionResults : detectionResults(X) ->
                  println(detectionResults(X));
75          switchToPlan senseAlarm
76
77      Plan senseAlarm
78          sense time(100000) local_alarm -> continue;
79          onEvent local_alarm : local_alarm -> emit alarm :
                  alarm
80  }
81
82  Robot mock QActor driverobot context ctxDriveRobot
83  {
84      Plan init normal
85          println("driverobot starts");
86          solve consult("talkTheory.pl") time(0) onFailSwitchTo
                  prologFailure;
87          switchToPlan drive
88
89      Plan drive
```

```
90      //We'll have to make sure that the robot executes the
                commands from the first console only
91      receiveMsg time(600000) react event obstacle ->
            detect;
92      onMsg drive : drive(X) -> println(savingmove(X));
93      onMsg drive : drive(X) -> solve X time(0);
94      repeatPlan 0
95
96    Plan detect
97      println("Stopping...");
98      robotStop speed(100) time(1000);
99      emit bagFound : bagFound;
100     println("Starting detection Phase...");
101     [?? detection(X) ] forward ascconsole -m
            detectionResults : detectionResults(X);
102     println("Detection Results Sent");
103     emit endDetection : endDetection;
104     println("Back to base");
105     switchToPlan backToBase
106
107   Plan backToBase
108     solve backToBase time(0); //It doesn't need to react,
                as the qactor led handles that
109     switchToPlan finish
110
111   Plan finish
112     emit botIsBack : botIsBack;
113     println("DriveRobot ends")
114
115   Plan prologFailure resumeLastPlan
116     println("Failed to load talkTheory")
117 }
```

This describes the whole logic architecture of our application. It can also be executed so that the client can confirm that the analysis defined a system that behaves as required.

This architecture derives from the one obtained in the domain model and introduces new interactions and a new entity.

The **DriveRobot** receives commands from the Operator Interface in the first phase, executes its automatic operations during the detection phase, it sends results to the ASCConsole and comes back to the RBA in the end. It has to react to obstacles to begin the detection phase.

The **Operator Console** receives commands from the operator as events and sends the corresponding commands to the robot.

The **ASC Console** receives the detection results from the detection phase and then enables the Airport Security Center to emit the alarm.

We decided to introduce the **led** as an actor separated from the robot because it is an active entity that has to sense and react to system events and has its own behaviour, so modeling it as a passive object managed by the robot is inappropriate. The led starts to blink when the detection phase begins, stops to blink when the detection phase ends and it starts to blink again if the alarm is emitted when the robot is coming back. Finally it stops blinking when the robot reaches the RBA.

The **camera** will be modeled as a passive entity that can only take a picture when the robot asks for it.

We defined the accessory event botIsBack to signal that the robot has come back to the RBA. This event can be used to stop the led if an alarm has been emitted before.

The interaction with external entities (the operator and the ASC) have been modeled as local events.

6.2 Abstraction gap

The abstraction gap is the distance between the concepts used to model the problem and those implied by the technology of choice. Thanks to the framework provided, executable code is generated from the model defined in the ddr meta-model. Thus, adopting this framework allows the application designers to use an extremely high-level description of the problem, closer to the application domain, reducing considerably the abstraction gap. The specific technology to be used can be decided later, in a configuration phase. The advantage of using a meta-model and a code generator is also that it can be extended to support more advanced concepts.

6.3 Risk analysis

Using the framework code generators, we can write most of the code independently from the specific implementation technology. Although the qa/ddr meta-model is technology independent, the code generated automatically may require some kind of environment on the computational nodes where it will be deployed (e.g. the JVM, the .NET runtime environment, a specific operating system etc).

7 Work plan

After the analysis phase, we decided to develop the application using the ddr framework, so that we don't start from scratch. We can reuse the executable logic architecture and enhance it. The framework already offers the implementation logic for some parts of the system and it offers high level abstractions that allow the developers to focus on business logic and not to worry too much about boilerplate code.

We'll use the following features offered by the framework:

- A communication system that allows the parts of the system to send and receive messages and events
- Reactive actions
- Timed actions
- The robot configuration
- DC motors driver
- sonar driver (and management of its data)

We'll implement the remaining features following the SCRUM framework for work planning. So we defined a product backlog which is a prioritized list of tasks needed to complete the project:

1. Define the robot configuration with .baseddr
2. Implement the console interfaces that allow external entities to interact with the system
3. Implement the led driver
4. Decide and implement a way to send a picture in the ddr framework
5. Develop the detection phase logic with the camera driver (as a mock entity)
6. Create an algorithm that allows the robot to come back to the RBA

8 Project

8.1 Structure

The structure is essentially the same as the logic architecture. Our robot has no camera, so we'll implement it as a mock device.

8.2 Interaction

There are no significant changes from the logic architecture.

8.3 Behavior

More details have been added to implement the missing features described in the work plan.

The consoles used by the ASC and the operator will be GUIs that allow them to interact with the system. The robot behaviour has slightly changed in the first phase: to ensure it receives messages from a single source, it memorizes the sender of the first received drive message and accepts new drive commands from that source only.

```
1  RobotSystem testCase2016Project
2
3  Event local_inputDrive : local_inputDrive(X)    //events
        from GUI/External Input
4  Dispatch drive : drive(X)
5  Dispatch detectionResults : detectionResults(X)
```

```
 6  Event alarm : alarm
 7  Event local_alarm : local_alarm          //events from GUI
       /External Input
 8  Event obstacle : obstacle(X)
 9  Event bagFound : bagFound
10  Event endDetection : endDetection
11  Event botIsBack : botIsBack              //signals the
       return to the base of the robot
12
13  Context ctxDriveRobot ip[host="localhost" port=8010]
14  Context ctxOperator ip[host="localhost" port=8015]
15  Context ctxASC ip[host="localhost" port=8020]
16
17  QActor led context ctxDriveRobot
18  {
19    Plan init normal
20      println("Led starts");
21      solve consult("ledTheory.pl") time(0) onFailSwitchTo
           prologFailure;
22      switchToPlan senseStartBlink
23
24    Plan senseStartBlink
25      println("Led Sensing");
26      solve turnTheLed(off) time(0) onFailSwitchTo
           prologFailure;
27      sense time(60000) bagFound -> startBlinking;
28      repeatPlan 0
29
30    Plan startBlinking
31      println("led On");
32      solve turnTheLed(on) time(0) onFailSwitchTo
           prologFailure;
33      delay time(500) react event endDetection ->
           senseAlarm;
34      println("Led Off");
35      solve turnTheLed(off) time(0) onFailSwitchTo
           prologFailure;
36      delay time(500) react event endDetection ->
           senseAlarm;
37      repeatPlan 0
38
39    Plan senseAlarm
40      println("Led Off, waiting alarm");
41      solve turnTheLed(off) time(0);
42      sense time(60000) alarm-> blinkingAlarm;
```

```
43        repeatPlan  0
44
45     Plan  blinkingAlarm
46        println("led On");
47        solve  turnTheLed(on)  time(0)  onFailSwitchTo
               prologFailure;
48        delay  time(500)  react  event  botIsBack -> finish;
49        println("Led Off");
50        solve  turnTheLed(off)  time(0)  onFailSwitchTo
               prologFailure;
51        delay  time(500)  react  event  botIsBack -> finish;
52        repeatPlan  0
53
54     Plan  finish
55        solve  turnTheLed(offcompletely)  time(0)
               onFailSwitchTo  prologFailure;
56        println("Led ends")
57
58     Plan  prologFailure  resumeLastPlan
59        println("Prolog Failure LED")
60  }
61
62  QActor  operatorconsole  context  ctxOperator -g cyan
63  {
64     Plan  init  normal
65        println("Operator starts");
66        switchToPlan  senseInput
67
68     Plan  senseInput
69        sense  time(60000)  local_inputDrive ->
               sendDriveCommands;
70        repeatPlan  0
71
72     Plan  sendDriveCommands  resumeLastPlan
73        onEvent  local_inputDrive : local_inputDrive(X) ->
               forward  driverobot -m drive :  drive(X)
74  }
75
76  QActor  ascconsole  context  ctxASC -g green
77  {
78     Plan  init  normal
79        println("ASC starts");
80        switchToPlan  work
81
82     Plan  work
```

```
83        receiveMsg time(600000);
84        onMsg detectionResults : detectionResults(X) ->
85        solve actorOp(loadResults(X)) time(0) onFailSwitchTo
              prologFailure;
86        switchToPlan senseAlarm
87
88      Plan senseAlarm
89        sense time(100000) local_alarm -> continue;
90        onEvent local_alarm : local_alarm -> emit alarm :
              alarm
91
92      Plan prologFailure resumeLastPlan
93        println("Prolog failure ASC")
94    }
95
96    Robot mymock QActor driverobot context ctxDriveRobot
97    {
98      Plan init normal
99        println("driverobot starts");
100       solve consult("talkTheory.pl") time(0) onFailSwitchTo
               prologFailure;
101       println("consulting driveRobotTheory");
102       solve consult("driveRobotTheory.pl") time(0)
              onFailSwitchTo prologFailure;
103       println("consulted driveRobotTheory");
104       switchToPlan receiveFirstCommand
105
106     Plan receiveFirstCommand
107       println("ROBOT waiting first message");
108       receiveMsg time(600000) react event obstacle ->
              detect;
109       //Save first sender
110       [?? msg(drive, dispatch, S, R, drive(X), N)] solve
              assert(firstSender(S)) time(0);
111       onMsg drive : drive(X) -> solve savemove(X) time(0)
              onFailSwitchTo savemoveFailure;
112       onMsg drive : drive(X) -> println(X);
113       onMsg drive : drive(X) -> solve X time(0)
              onFailSwitchTo prologFailure;
114       onMsg drive : drive(X) -> switchToPlan drive;
115       repeatPlan 0
116
117     Plan drive
118       receiveMsg time(600000) react event obstacle ->
              detect;
```

```
119      //To make sure that the sender is the same as the
             first one
120      [?? msg(drive,dispatch, S, R, drive(X), N)] solve
             firstSender(S) time(0) onFailSwitchTo drive;
121      onMsg drive : drive(X) -> println(X);
122      onMsg drive : drive(X) -> solve savemove(X) time(0)
             onFailSwitchTo prologFailure;
123      onMsg drive : drive(X) -> solve X time(0)
             onFailSwitchTo prologFailure;
124      repeatPlan 0
125
126    Plan detect
127      println("Stopping...");
128      robotStop speed(100) time(0);
129      delay time(1000);
130      println("Stopped");
131      solve endSavemoves time(0) onFailSwitchTo
             prologFailure;
132      emit bagFound : bagFound;
133      println("Starting detection Phase...");
134      delay time ( 3000);
135      [!? detection(X) ] forward ascconsole -m
             detectionResults : detectionResults(X);
136      delay time ( 3000);
137      println("Detection Results Sent");
138      emit endDetection : endDetection;
139      println("Back to base");
140      switchToPlan backToBase
141
142    Plan backToBase
143      solve backToBase time(0) onFailSwitchTo prologFailure
             ;  //It doesn't need to react, as the qactor led
             handles that
144      switchToPlan finish
145
146    Plan finish
147      emit botIsBack : botIsBack;
148      println("DriveRobot ends")
149
150    Plan prologFailure resumeLastPlan
151      println("Robot Failed to load prolog theories")
152
153    Plan savemoveFailure resumeLastPlan
154      println("Failed save move")
155
```

```
156 | }
```

9 Implementation

9.1 Robot configuration

The file robots.baseddr contains the configuration we used:

```
1  RobotBase plexiBox
2  //BASIC
3  motorleft  = Motor   [ gpiomotor pincw 13 pinccw 12  ]
       position : LEFT
4  motorright = Motor   [ gpiomotor pincw 4 pinccw 5  ]
       position : RIGHT
5  distanceRadar = Distance  [ sonarhcsr04 pintrig 0 pinecho
        2]  position : FRONT_TOP
6  //line = Line   [ gpioswitch pin 15 activelow ]  position
       : BOTTOM
7  //COMPOSED
8  motors = Actuators [ motorleft , motorright  ] private
       position : BOTTOM
9  Mainrobot plexiBox  [ motors ]
10 ;
```

9.2 Operator and ASC console

The **operator console** includes a GUI that translates external input events into
messages to drive the robot.

```
1  /* Generated by AN DISI Unibo */
2  /*
3  This code is generated only ONCE
4  */
5  package it.unibo.operatorconsole;
6  import java.awt.Button;
7  import java.awt.GridLayout;
8  import java.awt.Label;
9  import java.awt.Panel;
10 import java.awt.event.MouseEvent;
11 import java.awt.event.MouseListener;
12 import java.util.HashMap;
13 import java.util.Map;
14
15 import it.unibo.baseEnv.basicFrame.EnvFrame;
16 import it.unibo.is.interfaces.IOutputEnvView;
```

```java
17  import it.unibo.qactors.ActorContext;
18
19  public class Operatorconsole extends
        AbstractOperatorconsole {
20
21  protected Map<String, String> driveCmdMap;
22
23    public final static String Forward="Forward";
24    public final static String Backward="Backward";
25    public final static String Right="Right";
26    public final static String Left="left";
27    public final static String Halt="Halt";
28
29    public Operatorconsole(String actorId, ActorContext
        myCtx, IOutputEnvView outEnvView ) throws Exception
        {
30      super(actorId, myCtx, outEnvView);
31    }
32
33    protected void initCmdMap(){
34      driveCmdMap=new HashMap<>();
35      driveCmdMap.put(Forward, "executeInput(move(mf,100,0)
          )");
36      driveCmdMap.put(Backward, "executeInput(move(mb
          ,100,0))");
37      driveCmdMap.put(Right, "executeInput(move(mr,100,0))"
          );
38      driveCmdMap.put(Left, "executeInput(move(ml,100,0))")
          ;
39      driveCmdMap.put(Halt, "executeInput(move(h,100,0))");
40    }
41
42    @Override
43    protected void addInputPanel(int size) {
44    }
45
46    @Override
47    protected void addCmdPanels(){
48      initCmdMap();
49      ((EnvFrame) env).setSize(800,700);
50      Panel p = new Panel();
51      GridLayout l =  new GridLayout();
52      l.setVgap(10);
53      l.setHgap(10);
54      l.setColumns(3);
```

```java
55        l.setRows(3);
56        p.setLayout(l);
57
58        MouseListener ml =new MouseListener() {
59            @Override
60            public void mouseReleased(MouseEvent e) {
61 //            String cmd = ((Button)e.getSource()).getLabel()
        ;
62 //            if(!cmd.equals(Halt)){
63 //                execAction(Halt);
64 //            }
65            System.out.println("DEBUG: UNPRESSED");
66            }
67            @Override
68            public void mousePressed(MouseEvent e) {
69                Button b = (Button)e.getSource();
70                execAction(b.getLabel());
71                System.out.println("DEBUG: PRESSED" + b.getLabel
                    ());
72            }
73            @Override
74            public void mouseExited(MouseEvent e) {
75            }
76            @Override
77            public void mouseEntered(MouseEvent e) {
78            }
79            @Override
80            public void mouseClicked(MouseEvent e) {
81            }
82        };
83
84        Button forward = new Button(Forward);
85        forward.addMouseListener(ml);
86        Button backward = new Button(Backward);
87        backward.addMouseListener(ml);
88        Button right = new Button(Right);
89        right.addMouseListener(ml);
90        Button left = new Button(Left);
91        left.addMouseListener(ml);
92        Button halt = new Button(Halt);
93        halt.addMouseListener(ml);
94        p.add(new Label(""));
95        p.add(forward);
96        p.add(new Label(""));
97        p.add(left);
```

```
98      p.add(halt);
99      p.add(right);
100     p.add(new Label(""));
101     p.add(backward);
102     p.add(new Label(""));
103     ((EnvFrame) env).add(p);
104     ((EnvFrame) env).validate();
105   }
106
107   @Override
108   public void execAction(String cmd) {
109     super.execAction(cmd);
110
111     if(driveCmdMap.containsKey(cmd)){
112       String actualCmd = driveCmdMap.get(cmd);
113       platform.raiseEvent("input", "local_inputDrive", "
              local_inputDrive("+actualCmd+")");
114       return;
115     }
116   }
117 }
```

The **ASC console** includes a GUI that shows the image received from the robot at the end of the detection phase and then shows a button that emits the alarm if pressed.

```
1  /* Generated by AN DISI Unibo */
2  /*
3  This code is generated only ONCE
4  */
5  package it.unibo.ascconsole;
6
7  import java.awt.*;
8  import java.awt.event.ActionEvent;
9  import java.awt.event.ActionListener;
10 import java.io.ByteArrayInputStream;
11 import java.io.IOException;
12 import java.util.Base64;
13
14 import javax.imageio.ImageIO;
15
16 import it.unibo.is.interfaces.IOutputEnvView;
17 import it.unibo.qactors.ActorContext;
18
19 public class Ascconsole extends AbstractAscconsole {
```

```java
20      public Ascconsole(String actorId, ActorContext myCtx,
            IOutputEnvView outEnvView )   throws Exception{
21        super(actorId, myCtx, outEnvView);
22      }
23
24      protected Label userMsg;
25      protected Button alarm;
26      protected ImagePanel results;
27
28      @Override
29      protected void addCmdPanels(){
30        //super.addCmdPanels();
31        //photo panel
32        ((Frame) env).removeAll();
33        GridLayout l = new GridLayout();
34        l.setColumns(2);
35        l.setRows(2);
36        ((Frame) env).setLayout(l);
37        results = new ImagePanel();
38        results.setSize(300, 400);
39        ((Frame) env).add(results);
40        alarm = new Button("Alarm");
41        alarm.setBackground(Color.red);
42        alarm.addActionListener(new ActionListener() {
43          @Override
44          public void actionPerformed(ActionEvent e) {
45              execAction("Alarm");
46          }
47        });
48        alarm.setEnabled(false);
49        ((Frame) env).add(alarm);
50        userMsg = new Label("Waiting for results");
51        ((Frame) env).add(userMsg);
52        ((Frame) env).validate();
53      }
54
55      //this is called when the results are received
56      public void loadResults(String imageString){
57            byte[] imageBytes = Base64.getDecoder().decode(
                  imageString);
58            try {
59          Image image = ImageIO.read(new ByteArrayInputStream
                (imageBytes));
60          results.setImage(image);
61        } catch (IOException e) {
```

```java
62            System.out.println("MyPanel: Image error!");
63            e.printStackTrace();
64          }
65
66          alarm.setEnabled(true);
67          userMsg.setText("Results received");
68          ((Frame) env).validate();
69        }
70
71        @Override
72        public void execAction(String cmd) {
73          super.execAction(cmd);
74          if( cmd.equals("Alarm") ){
75            platform.raiseEvent("input", "local_alarm", "
                    local_alarm");
76            userMsg.setText("Alarm sent!");
77            return;
78          }
79        }
80
81        protected class ImagePanel extends Panel{
82          /**
83           *
84           */
85          private static final long serialVersionUID = 1L;
86          private Image image;
87
88          public ImagePanel(){
89            image = null;
90          }
91
92          public void paint(Graphics g){
93                  super.paint(g);
94                  if(image != null){
95                    int w = getWidth();
96                    int h = getHeight();
97                    int imageWidth = image.getWidth(this);
98                    int imageHeight = image.getHeight(this);
99                    int x = (w - imageWidth)/2;
100                   int y = (h - imageHeight)/2;
101                   g.drawImage(image, x, y, this);
102                 }
103             }
104
105         public void setImage(Image image){
```

```
106          this.image=image;
107              validate();
108          }
109      }
110
111  }
```

9.3 Led

The **led** blinking logic is implemented directly as QActor behaviour.
The Prolog theory turnTheLed/1 allows the QActor to manage the led and
actually turn it on and off calling the underlying Java code.

```
1   %createPi4jLed( PinNum) :-
2   %    actorobj( Actor ),
3   %    Actor <- getOutputEnvView returns OutView ,
4   % class("it.unibo.devices.qa.DeviceLedPi4jQa") <-
        createLed( OutView, PinNum ) returns LED.
5
6   %turnTheLed( on  ):-
7   % class("it.unibo.devices.qa.DeviceLedPi4jQa") <-
        getTheLed   returns LED,
8   % LED <- turnOn .
9
10  %turnTheLed( off  ):-
11  % class("it.unibo.devices.qa.DeviceLedPi4jQa") <-
        getTheLed   returns LED,
12  % LED <- turnOff .
13
14  pinNum(25).
15
16  %turnTheLed(on):-
17  % pinNum(X),
18  % class("it.unibo.devices.qa.LedDevicesFactory") <-
        getTheLedCmd(X) returns LED,
19  % LED <- turnOn.
20
21
22  %turnTheLed(off):-
23  % pinNum(X),
24  % class("it.unibo.devices.qa.LedDevicesFactory") <-
        getTheLedCmd(X) returns LED,
25  % LED <- turnOff.
26
27  turnTheLed(on):-
```

```
28     pinNum(X) ,
29     class ("it.unibo.devices.qa.LedDevicesFactory") <-
           getTheLedCmdInterpreter(X) returns LED,
30     LED <- turnOn .
31
32
33  turnTheLed(off):-
34     pinNum(X) ,
35     class ("it.unibo.devices.qa.LedDevicesFactory") <-
           getTheLedCmdInterpreter(X) returns LED,
36     LED <- turnOff .
37
38  turnTheLed(offcompletely):-
39     pinNum(X) ,
40     class ("it.unibo.devices.qa.LedDevicesFactory") <-
           getTheLedCmdInterpreter(X) returns LED,
41     LED <- turnOffForever .
42
43  %initialize   :-    createPi4jLed(25).
44  initialize .
45
46  :- initialization(initialize ).
```

The led instance is created through a factory:

```java
1   package it.unibo.devices.qa;
2
3   import java.util.HashMap;
4   import java.util.Map;
5
6   /**
7    * BCM convention!!
8    */
9   public class LedDevicesFactory {
10
11     private static Map<Integer, ILed> leds;
12
13     private static String command="sudo bash/gpioPin.sh";
14     private static String commandInterpreter="sudo bash/
          gpioPinInterpreter.sh";
15
16     static {
17        leds = new HashMap<>();
18     }
19
20     public static ILed getTheLedCmd(int nPin){
```

```
21        if ( leds . containsKey ( nPin )&&leds . get ( nPin )  instanceof
              LedShellCmd ){
22          return  leds . get ( nPin ) ;
23        }
24        leds . put ( nPin ,  new  LedShellCmd ( command ,  nPin ) ) ;
25        return  leds . get ( nPin ) ;
26      }
27
28      public  static  ILed  getTheLedCmdInterpreter ( int  nPin ){
29        if ( leds . containsKey ( nPin )&&leds . get ( nPin )  instanceof
              LedShellCmdInterpreter ){
30          return  leds . get ( nPin ) ;
31        }
32        leds . put ( nPin ,  new  LedShellCmdInterpreter (
              commandInterpreter ,  nPin ) ) ;
33        return  leds . get ( nPin ) ;
34      }
35
36      public  static  ILed  getTheLedPi4j ( int  nPin ){
37        if ( leds . containsKey ( nPin )&&leds . get ( nPin )  instanceof
              Pi4jLed ){
38          return  leds . get ( nPin ) ;
39        }
40        leds . put ( nPin ,  new  Pi4jLed ( nPin ) ) ;
41        return  leds . get ( nPin ) ;
42      }
43
44  }
```

We implemented the led as a bash script that receives zeros and ones to turn
the led on and off:

```
1  package  it . unibo . devices . qa ;
2
3  import  java . io . PrintWriter ;
4
5  import  it . unibo . sartiballanti . utils . Utils ;
6
7  public  class  LedShellCmdInterpreter  extends  LedShellCmd  {
8
9    private  PrintWriter  pw;
10
11    public  LedShellCmdInterpreter ( String  command ,  int  nPin )
            {
12      super ( command , nPin ) ;
```

```java
13        this.pw=new PrintWriter(Utils.
              executeShellCommandOutput(command +" "+ nPin));
14    }
15
16    @Override
17    public void turnOn() {
18      pw.print("1\n");
19      pw.flush();
20    }
21
22    @Override
23    public void turnOff() {
24      pw.print("0\n");
25      pw.flush();
26    }
27
28    public void turnOffForever(){
29      turnOff();
30      pw.close();
31    }
32
33 }
```

```bash
1  echo "$1" > /sys/class/gpio/unexport #
2  echo "$1" > /sys/class/gpio/export #
3  cd /sys/class/gpio/gpio"$1" #
4
5  echo out > direction #
6
7  while read ONOFF
8  do
9    echo $ONOFF > value #
10 done
```

9.4 Camera

The camera implements the following interface:

```java
1  package it.unibo.sartiballanti.camera;
2
3  public interface ICamera {
4    public byte[] takePhoto();
5  }
```

This is the implementation of the mock camera:

```
1   package it.unibo.sartiballanti.camera;
2
3   import java.io.IOException;
4   import java.nio.file.Files;
5   import java.nio.file.Paths;
6
7   public class MockFileCamera implements ICamera {
8
9       private String imgPath;
10
11      public MockFileCamera(String imgPath){
12          this.imgPath=imgPath;
13      }
14
15      @Override
16      public byte[] takePhoto() {
17          try {
18              return Files.readAllBytes(Paths.get(imgPath));
19          } catch (IOException e) {
20              e.printStackTrace();
21          }
22          return null;
23      }
24  }
```

9.5 Detection phase

The **robot** uses an actor method to execute the detection phase. It takes a picture of the bag using the simulated **camera** and sends it to the ASC. In order to send send the photo as a message payload in the ddr framework, we needed to obtain a string representation of the image.

```
1   /* Generated by AN DISI Unibo */
2   package it.unibo.driverobot;
3   import java.util.Base64;
4   import it.unibo.is.interfaces.IOutputEnvView;
5   import it.unibo.qactors.ActorContext;
6   import it.unibo.sartiballanti.camera.CameraFactory;
7
8   public class Driverobot extends AbstractDriverobot {
9       public Driverobot(String actorId, ActorContext myCtx,
            IOutputEnvView outEnvView , it.unibo.iot.executors.
            baseRobot.IBaseRobot baserobot) throws Exception{
10          super(actorId ,myCtx,outEnvView , baserobot );
```

```
11 │    }
12 │
13 │    public String takeStringifiedPhoto(){
14 │      byte[] img= CameraFactory.getInstance().getCamera().
   │          takePhoto();
15 │      return Base64.getEncoder().encodeToString(img);
16 │    }
17 │ }
```

9.6 Back to base

The **driveRobotTheory** is used to implement a simple algorithm to come back autonomously: the robot memorizes every move it makes in the first phase, so it can come back executing the same moves backwards.

```
 1 │%drivecommand example
 2 │%executeInput(move(mf,100,1000,0))
 3 │
 4 │%lastmove is the next move to save,
 5 │%I can get the starting time, but I can't insert it into
   │    the moveList until it ends.
 6 │
 7 │%The savemove/1 rule uses the knowledge base to store and
   │      update the information,
 8 │%but it uses savemove/5 to get the updated lastMove and
   │    moveList.
 9 │
10 │%Initial facts
11 │moveList([]).
12 │lastMove(none,0).
13 │
14 │savemove(executeInput(CUR)):-
15 │   moveList(L),
16 │   lastMove(LASTMOVE,MVTIME),
17 │   savemove(CUR,lastMove(LASTMOVE,MVTIME),L,NEWLASTMOVE,
   │       NEWL),
18 │   retract(lastMove(_,_)),
19 │   retract(moveList(_)),
20 │   assert(NEWLASTMOVE),
21 │   assert(moveList(NEWL)).
22 │
23 │%Here the savemove rule is implemented without assert and
   │      retract.
24 │%savemove(CUR,LAST,LIST,NEWLAST,NEWLIST)
```

```prolog
25  savemove(CUR, lastMove(none,0) ,[] , lastMove(CUR,M) ,[]):-
26      getCurrentMillis(M).
27
28  savemove(CUR, lastMove(move(MV,SPEED,0) ,FIRSTM) ,L, lastMove
        (CUR,M) ,[move(MV,SPEED,DIFF,0) |L]):-
29      getCurrentMillis(M),
30      DIFF is M - FIRSTM.
31
32  %just to put the last command in the list
33  endSavemoves:-
34      savemove(executeInput(move(h,100,1000))).
35
36  backToBase:-
37      moveList(L),
38      backToBase(L).
39
40  backToBase([]).
41
42  backToBase([H|T]):-
43      revMove(H,RH),
44      executeInput(RH),
45      backToBase(T).
46
47  getCurrentMillis(M):-
48      class("it.unibo.sartiballanti.utils.Utils") <-
            getCurrentTimeMillis returns M.
49
50  revMove(move(mf,X,Y,Z) ,move(mb,X,Y,Z)).
51  revMove(move(mb,X,Y,Z) ,move(mf,X,Y,Z)).
52  revMove(move(mr,X,Y,Z) ,move(ml,X,Y,Z)).
53  revMove(move(ml,X,Y,Z) ,move(mr,X,Y,Z)).
54  revMove(move(h,X,Y,Z) ,move(h,X,Y,Z)).
55
56  %For example taking a photo
57  detection(X):-
58      actorOp(takeStringifiedPhoto),
59      actorOpDone(takeStringifiedPhoto ,X).
60
61  initDriveRobotTheory.
62
63  :- initialization(initDriveRobotTheory).
```

10 Testing

In the previous sections, we had an executable model that could be tested, so most of the tests that involve communication between parts of the system have been done at the end of the analysis phase. Initially, communication tests have been executed locally, then the system parts have been deployed on different computational nodes to test system behaviour as a whole in a distributed environment, checking if the system behaved as described in the test plan. In local tests, we used a mock robot that simulated sensors and motors:

```
1  RobotBase mock
2   //BASIC
3  motorleft  = Motor   [ simulated 0  ]   position: LEFT
4  motorright = Motor   [ simulated 0  ]   position: RIGHT
5  l1Mock     = Line    [ simulated 0  ]   position: BOTTOM
6  distFrontMock= Distance [ simulated 0   ] position: FRONT
7  mgn1 = Magnetometer  [ simulated 0 ] private position:
      FRONT
8  //COMPOSED
9  rot      = Rotation [ mgn1  ] private position: FRONT
10 motors = Actuators [ motorleft , motorright  ] private
      position: BOTTOM
11 Mainrobot mock   [ motors , rot  ]
12 ;
```

11 Deployment

The parts of the application will be deployed on different computational nodes as JAR executable archives with some configuration files and Prolog theories. The platforms we use in this case are a Raspberry Pi board and two PCs, we just need to copy the appropriate files and execute the JAR on every node. The application will start when all the parts of the system have been started.

12 Maintenance

We developed the application using the ddr framework and delaying any technological hypothesis, so the resulting system can be easily modified to add or change features. In the next section, we'll show how new (compatible) requirements need very little changes to the previously developed system.

13 Step 2

13.1 Requirements

STEP 2 (Implementation Optional)
Extend the last requirement as follows:

– If the bag is qualifed as "harmful", the Airport Security Center emits an 'alarm' signal and activates another (properly equipped) robot that (starting from the same RBA of the robot inspector) should reach the bag in autonomous way and remove the bag from the area.

13.2 Requirements analysis

Use cases No new use cases or changes to the previous ones.

Scenarios No new scenarios or changes to the previous ones.

(Domain) model A new robot is introduced, similar to the previous one. It needs a way to remove the bag. We just need to add the following to the previous domain model:

```
1   RobotSystem extensionanalysis
2
3   Event alarm : alarm
4
5   Context ctxLocal ip[ host="localhost" port=8025 ]
6
7   Robot mock QActor removerobot context ctxLocal {
8       Plan init normal
9           println("Removerobot starts");
10          switchToPlan waitAlarm
11
12      Plan waitAlarm
13          sense time(60000) alarm -> goToBag;
14          repeatPlan 0
15
16      Plan goToBag
17          println("Going to bag");
18          delay time(5000);
19          println("Removing Bag");
20          delay time(5000);
21          println("Removerobot ends")
22  }
```

Test plan We need to check if the second robot receives can reach the bag and remove it. We can test this observing the whole system after the ASC emits the alarm.

13.3 Problem analysis

Logic architecture We can obtain the new logic architecture adding a new type of message, the new actor described in the domain model and slightly changing the behavior of the first robot.

It is not specified by the requirements whether the second robot has to go to the bag as soon as it perceives the alarm, or it can wait until the first robot is returned to the RBA. If it has to start immediatly, collisions may occur during the route. So, in order to avoid this problem, we'll make the second robot wait for the first one. In any case, the second robot should know the bag location as soon as possible. Thus, the first robot will send the route to the bag to the second robot immidiately after it reached the bag. The second robot will follow this route to reach the bag and remove it if an alarm is emitted.

```
1   RobotSystem extensionlogicarchitecture
2
3
4   Event local_inputDrive : local_inputDrive(X)   //events
         from GUI/External Input
5   Dispatch drive : drive(X)
6   Dispatch detectionResults : detectionResults(X)
7   Event alarm : alarm
8   Event local_alarm : local_alarm              //events from GUI
         /External Input
9   Event obstacle : obstacle(X)
10  Event bagFound : bagFound
11  Event endDetection : endDetection
12  Dispatch routeToBag : routeToBag(X)    //sent by the
         driverobot when the bag is found
13  Event botIsBack : botIsBack
14
15  Context ctxRemoverobot ip[ host="192.168.1.80" port=8025
         ]
16  Context ctxDriveRobot ip[host="192.168.1.69" port=8010]
17  Context ctxOperator ip[host="192.168.1.2" port=8015]
18  Context ctxASC ip[host="192.168.1.2" port=8020]
19
20  QActor led context ctxDriveRobot
21  {
22     Plan init normal
23       println("Led starts");
24       switchToPlan senseStartBlink
25
26     Plan senseStartBlink
27       println("Led Off");
28       sense time(60000) bagFound -> startBlinking;
29       repeatPlan 0
```

```
30
31    Plan startBlinking
32        println ("led On");
33        delay time (1000) react event endDetection ->
                senseAlarm;
34        println ("Led Off");
35        delay time (1000) react event endDetection ->
                senseAlarm;
36        repeatPlan 0
37
38    Plan senseAlarm
39        println ("Led Off");
40        sense time (60000) alarm-> blinkingAlarm;
41        repeatPlan 0
42
43    Plan blinkingAlarm
44        println ("led On");
45        delay time (500) react event botIsBack -> finish;
46        println ("Led Off");
47        delay time (500) react event botIsBack -> finish;
48        repeatPlan 0
49
50    Plan finish
51        println ("Led ends")
52  }
53
54  QActor operatorconsole context ctxOperator -g cyan
55  {
56    Plan init normal
57        println ("Operator starts");
58        switchToPlan senseInput
59
60    Plan senseInput
61        sense time (60000) local_inputDrive ->
                sendDriveCommands;
62        repeatPlan 0
63
64    Plan sendDriveCommands resumeLastPlan
65        onEvent local_inputDrive : local_inputDrive (X) ->
                forward driverobot -m drive : drive (X)
66  }
67
68  QActor ascconsole context ctxASC -g green
69  {
70    Plan init normal
```

```
71        println("ASC starts");
72        switchToPlan work
73
74     Plan work
75        receiveMsg time(600000);
76        onMsg detectionResults : detectionResults(X) ->
              println(detectionResults(X));
77        switchToPlan senseAlarm
78
79     Plan senseAlarm
80        sense time(100000) local_alarm -> continue;
81        onEvent local_alarm : local_alarm -> emit alarm :
              alarm
82  }
83
84  Robot mock QActor driverobot context ctxDriveRobot
85  {
86     Plan init normal
87        println("driverobot starts");
88        solve consult("talkTheory.pl") time(0) onFailSwitchTo
              prologFailure;
89        switchToPlan drive
90
91     Plan drive
92        //We'll have to make sure that the robot executes the
              commands from the first console only
93        receiveMsg time(600000) react event obstacle ->
              detect;
94        onMsg drive : drive(X) -> println(savingmove(X));
95        onMsg drive : drive(X) -> solve X time(0);
96        repeatPlan 0
97
98     Plan detect
99        println("Stopping...");
100       robotStop speed(100) time(1000);
101
102       //Extension
103       println("Sending the route to the second robot");
104       forward removerobot -m routeToBag : routeToBag(
              listOfMoves);
105       println("Route to bag sent");
106       //End extension
107
108       emit bagFound : bagFound;
109       println("Starting detection Phase...");
```

```
110        [?? detection(X) ] forward ascconsole −m
               detectionResults : detectionResults(X);
111        println("Detection Results Sent");
112        emit endDetection : endDetection;
113        println("Back to base");
114        switchToPlan backToBase
115
116     Plan backToBase
117        solve backToBase time(0); //It doesn't need to react,
               as the qactor led handles that
118        switchToPlan finish
119
120     Plan finish
121        emit botIsBack : botIsBack;
122        println("DriveRobot ends")
123
124     Plan prologFailure resumeLastPlan
125        println("Failed to load talkTheory")
126 }
127
128
129 Robot mock QActor removerobot context ctxRemoverobot {
130     Plan init normal
131        println("Removerobot starts");
132        switchToPlan receiveRoute
133
134     Plan receiveRoute
135        receiveMsg time(60000);
136        onMsg routeToBag : routeToBag(X) −> switchToPlan
               waitAlarm;
137        repeatPlan 0
138
139     Plan waitAlarm
140        println("Waiting for alarm");
141        sense time(60000) alarm, botIsBack −> waitBotIsBack,
               finish;
142        repeatPlan 0
143
144     Plan waitBotIsBack
145        println("Waiting for driverobot to arrive to RBA");
146        sense time(60000) botIsBack −> goToBag;
147        repeatPlan 0
148
149     Plan goToBag
150        println("Going to bag");
```

```
151        delay time (5000);
152        println ("Removing Bag");
153        delay time (5000);
154        switchToPlan finish
155
156    Plan finish
157        println ("Removerobot ends")
158 }
```

13.4   Work plan

We are using the ddr framework, so most of the behaviour of the new robot is already defined. The bag removal will be simulated with a print operation because the robot can't physically move the bag, so we just need to define the second robot configuration and implement an algorithm that allows the robot to follow the route it received from the other robot.

13.5   Project

Structure The structure is the same as the logic architecture.

Interaction We introduced the message routeToBag to send the path to follow to the second robot.

Behavior The behavior of the asc console, operator console and led remain unchanged, the first robot just needs to send a new message as described before. The second robot has no actuators, so it will just simulate the bag removal.

```
 1  RobotSystem testCase2016Project
 2
 3  Event local_inputDrive : local_inputDrive(X)   //events
        from GUI/External Input
 4  Dispatch drive : drive(X)
 5  Dispatch detectionResults : detectionResults(X)
 6  Event alarm : alarm
 7  Event local_alarm : local_alarm              //events from GUI
        /External Input
 8  Event obstacle : obstacle(X)
 9  Event bagFound : bagFound
10  Event endDetection : endDetection
11  Event botIsBack : botIsBack              //signals the
        return to the base of the robot
12
13  //Extension
```

```
14   Dispatch routeToBag : routeToBag(X)          //sent by the
         driverobot when the bag is found
15
16   Context ctxDriveRobot ip[host="192.168.1.45" port=8010]
17   Context ctxOperator ip[host="192.168.1.2" port=8015]
18   Context ctxASC ip[host="192.168.1.2" port=8020]
19
20   //Extension
21   Context ctxRemoverobot ip[ host="192.168.1.69" port=8025
         ]
22
23
24   QActor led context ctxDriveRobot
25   {
26     Plan init normal
27       println("Led starts");
28       solve consult("ledTheory.pl") time(0) onFailSwitchTo
             prologFailure;
29       switchToPlan senseStartBlink
30
31     Plan senseStartBlink
32       println("Led Sensing");
33       solve turnTheLed(off) time(0) onFailSwitchTo
             prologFailure;
34       sense time(60000) bagFound -> startBlinking;
35       repeatPlan 0
36
37     Plan startBlinking
38       println("led On");
39       solve turnTheLed(on) time(0) onFailSwitchTo
             prologFailure;
40       delay time(500) react event endDetection ->
             senseAlarm;
41       println("Led Off");
42       solve turnTheLed(off) time(0) onFailSwitchTo
             prologFailure;
43       delay time(500) react event endDetection ->
             senseAlarm;
44       repeatPlan 0
45
46     Plan senseAlarm
47       println("Led Off, waiting alarm");
48       solve turnTheLed(off) time(0);
49       sense time(60000) alarm-> blinkingAlarm;
50       repeatPlan 0
```

```
51
52     Plan blinkingAlarm
53        println("led On");
54        solve turnTheLed(on) time(0) onFailSwitchTo
                prologFailure;
55        delay time(500) react event botIsBack -> finish;
56        println("Led Off");
57        solve turnTheLed(off) time(0) onFailSwitchTo
                prologFailure;
58        delay time(500) react event botIsBack -> finish;
59        repeatPlan 0
60
61     Plan finish
62        solve turnTheLed(offcompletely) time(0)
                onFailSwitchTo prologFailure;
63        println("Led ends")
64
65     Plan prologFailure resumeLastPlan
66        println("Prolog Failure LED")
67  }
68
69  QActor operatorconsole context ctxOperator -g cyan
70  {
71     Plan init normal
72        println("Operator starts");
73        switchToPlan senseInput
74
75     Plan senseInput
76        sense time(60000) local_inputDrive ->
                sendDriveCommands;
77        repeatPlan 0
78
79     Plan sendDriveCommands resumeLastPlan
80        onEvent local_inputDrive : local_inputDrive(X) ->
                forward driverobot -m drive : drive(X)
81  }
82
83  QActor ascconsole context ctxASC -g green
84  {
85     Plan init normal
86        println("ASC starts");
87        switchToPlan work
88
89     Plan work
90        receiveMsg time(600000);
```

```
 91       onMsg detectionResults : detectionResults(X) ->
 92       solve actorOp(loadResults(X)) time(0) onFailSwitchTo
              prologFailure;
 93       switchToPlan senseAlarm
 94
 95     Plan senseAlarm
 96       sense time(100000) local_alarm -> continue;
 97       onEvent local_alarm : local_alarm -> emit alarm :
              alarm
 98
 99     Plan prologFailure resumeLastPlan
100       println("Prolog failure ASC")
101   }
102
103
104   //QActor obstacleemitter context ctxDriveRobot
105   //{
106   //   Plan init normal
107   //      delay time(15000);
108   //      emit obstacle : obstacle(12);
109   //      println("Emitted obstacle event")
110   //}
111
112   Robot mymock QActor driverobot context ctxDriveRobot
113   {
114     Plan init normal
115       println("driverobot starts");
116       solve consult("talkTheory.pl") time(0) onFailSwitchTo
              prologFailure;
117       println("consulting driveRobotTheory");
118       solve consult("driveRobotTheory.pl") time(0)
              onFailSwitchTo prologFailure;
119       println("consulted driveRobotTheory");
120       switchToPlan receiveFirstCommand
121
122     Plan receiveFirstCommand
123       println("ROBOT waiting first message");
124       receiveMsg time(600000) react event obstacle ->
              detect;
125       //Save first sender
126       [?? msg(drive,dispatch, S, R, drive(X), N)] solve
              assert(firstSender(S)) time(0);
127       onMsg drive : drive(X) -> solve savemove(X) time(0)
              onFailSwitchTo savemoveFailure;
128       onMsg drive : drive(X) -> println(X);
```

```
129    onMsg drive : drive(X) -> solve X time(0)
           onFailSwitchTo prologFailure;
130    onMsg drive : drive(X) -> switchToPlan drive;
131    repeatPlan 0
132
133  Plan drive
134    receiveMsg time(600000) react event obstacle ->
           detect;
135    //To make sure that the sender is the same as the
           first one
136    [?? msg(drive,dispatch, S, R, drive(X), N)] solve
           firstSender(S) time(0) onFailSwitchTo drive;
137    onMsg drive : drive(X) -> println(X);
138    onMsg drive : drive(X) -> solve savemove(X) time(0)
           onFailSwitchTo prologFailure;
139    onMsg drive : drive(X) -> solve X time(0)
           onFailSwitchTo prologFailure;
140    repeatPlan 0
141
142  Plan detect
143    println("Stopping...");
144    robotStop speed(100) time(0);
145    delay time(1000);
146    println("Stopped");
147    solve endSavemoves time(0) onFailSwitchTo
           prologFailure;
148    emit bagFound : bagFound;
149
150    //Extension
151    println("Sending the route to the second robot");
152    [!? moveList(X)] forward removerobot -m routeToBag :
           routeToBag(moveList(X));
153    println("Route to bag sent");
154    //End extension
155
156    println("Starting detection Phase...");
157    delay time ( 3000);
158    [!? detection(X) ] forward ascconsole -m
           detectionResults : detectionResults(X);
159    delay time ( 3000);
160    println("Detection Results Sent");
161    emit endDetection : endDetection;
162    println("Back to base");
163    switchToPlan backToBase
164
```

```
165    Plan backToBase
166       solve backToBase time(0) onFailSwitchTo prologFailure
                ;  //It doesn't need to react, as the qactor led
                handles that
167       switchToPlan finish
168
169    Plan finish
170       emit botIsBack : botIsBack;
171       println("DriveRobot ends")
172
173    Plan prologFailure resumeLastPlan
174       println("Robot Failed to load prolog theories")
175
176    Plan savemoveFailure resumeLastPlan
177       println("Failed save move")
178  }
179
180  Robot plexiBox QActor removerobot context ctxRemoverobot
         {
181    Plan init normal
182       println("Removerobot starts");
183       solve consult("talkTheory.pl") time(0) onFailSwitchTo
                prologFailure;
184       solve consult("removeRobotTheory.pl") time(0)
                onFailSwitchTo prologFailure;
185       switchToPlan receiveRoute
186
187    Plan receiveRoute
188       receiveMsg time(60000);
189       onMsg routeToBag : routeToBag(X) -> println(X);
190       onMsg routeToBag : routeToBag(X) -> solve assert(X)
                time(0);
191       onMsg routeToBag : routeToBag(X) -> switchToPlan
                waitAlarm;
192       repeatPlan 0
193
194    Plan waitAlarm
195       println("Waiting for alarm");
196       sense time(60000) alarm, botIsBack -> goToBag, finish
                ;
197       repeatPlan 0
198
199    Plan waitBotIsBack
200       println("Waiting for driverobot to arrive to RBA");
201       sense time(60000) botIsBack -> goToBag;
```

```
202        repeatPlan 0
203
204    Plan goToBag
205        println("Going to bag");
206        solve gotobag time(0) onFailSwitchTo prologFailure;
207        println("Removing Bag");
208        delay time(5000);
209        println("Removerobot ends")
210
211    Plan finish
212        println("Removerobot ends")
213
214    Plan prologFailure
215        println("Removerobot Failed to load prolog theories")
216 }
```

13.6 Implementation

This is the configuration of the new robot:

We use the following Prolog theory to make the robot reach the bag:

```
1  %drivecommand example
2  %executeInput(move(mf,100,1000,0))
3
4  gotobag:-
5      moveList(L),
6      reverse(L,LR),
7      gotobag(LR).
8
9  gotobag([]).
10
11 gotobag([H|T]):-
12     executeInput(H),
13     gotobag(T).
14
15 initRemoveRobotTheory.
16
17 :- initialization(initRemoveRobotTheory).
```

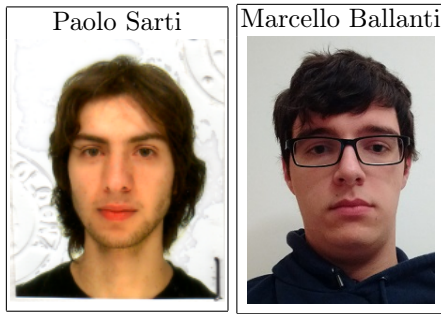The bag removal is just a print operation done by the actor.

13.7 Testing

We tested the system as a whole observing the second robot when an alarm is emitted.

14 Conclusions

See [1] until page 11 (`CMM`) and pages 96-105.

15   Information about the author

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References

1. A. Natali and A. Molesini. *Costruire sistemi software: dai modelli al codice.* Esculapio, 2009.