

# 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. This 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 hypothesis 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.  $d=20\text{cm}$ ):
  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 equipment - 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 requirements 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.

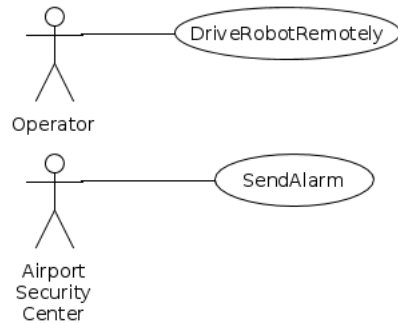
## 5 Requirement analysis

### 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:

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

Scenario 2:

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

We want to define the system formally so that we can avoid ambiguity and generate an executable version of said model, but we want to avoid any technology assumption. To achieve this, we will use the custom language / executable meta-model developed by our software house. It allows us to describe what the parts of the system are, how they interact with each other and their behaviour and it can generate the corresponding executable code.

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 ->
22 |       sendDriveCommands;
23 |     repeatPlan 0
24 |
25 |   Plan sendDriveCommands resumeLastPlan
26 |     onEvent local_inputDrive : local_inputDrive(X) ->
27 |       forward driverobot -m drive : drive(X)
28 | }
29 |
30 | QActor asconsole context ctxASC -g green
31 | {
32 |   Plan init normal
33 |     println("ASC starts");
34 |     switchToPlan work
35 |
36 |   Plan work
37 |     receiveMsg time(600000);
38 |     onMsg detectionResults : detectionResults(X) ->
39 |       println(detectionResults(X));
40 |     switchToPlan senseAlarm
41 |
42 |   Plan senseAlarm
43 |     sense time(100000) local_alarm -> continue;
44 |     onEvent local_alarm : local_alarm -> emit alarm :
45 |       alarm
46 | }
47 |
48 | Robot mymock QActor driverobot context ctxDriveRobot
49 | {
50 |   Plan init normal
51 |     println("driverobot starts");

```

```

48     switchToPlan drive
49
50 Plan drive
51     //We'll have to make sure that the robot executes the
52     //commands from the first console only
53     receiveMsg time(600000) react event obstacle ->
54         detect;
55     onMsg drive : drive(X) -> println(savingmove(X));
56     onMsg drive : drive(X) -> println(driving(X));
57     repeatPlan 0
58
59 Plan detect
60     println("Stopping...");
61     delay time(1000);
62     println("Start blinking the led");
63     println("Starting detection Phase...");
64     delay time(3000);
65     println("Sending results");
66     forward asconsole -m detectionResults :
67         detectionResults("results");
68     println("Detection Results Sent");
69     println("Stop blinking the led");
70     println("Back to base");
71     switchToPlan backToBase
72
73 Plan backToBase
74     delay time(20000) react event alarm -> alarmReaction;
75     switchToPlan finish
76
77 Plan alarmReaction resumeLastPlan
78     println("Alarm!");
79     println("Start blinking the led")
80
81 Plan finish
82     println("DriveRobot ends")
83 }

```

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 though, 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 physical 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 =>
33         senseAlarm;
34     repeatPlan 0
35 Plan senseAlarm
36     println("Led Off");
37     sense time(60000) alarm, botIsBack=> blinkingAlarm,
38         finish;
39     repeatPlan 0
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 =>
60             sendDriveCommands;
61         repeatPlan 0
62
63     Plan sendDriveCommands resumeLastPlan
64         onEvent local_inputDrive : local_inputDrive(X) =>
65             forward driverobot -m drive : drive(X)
66 }
67
68 QActor asconsole context ctxASC -g green
69 {
70     Plan init normal
71         println("ASC starts");
72         switchToPlan work
73
74     Plan work

```

```

73     receiveMsg time(600000);
74     onMsg detectionResults : detectionResults(X) =>
75         println(detectionResults(X));
76     switchToPlan senseAlarm
77 Plan senseAlarm
78     sense time(100000) local_alarm => continue;
79     onEvent local_alarm : local_alarm => emit alarm :
80         alarm
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
87             prologFailure;
88         switchToPlan drive
89 Plan drive
90     //We'll have to make sure that the robot executes the
91     //commands from the first console only
92     receiveMsg time(600000) react event obstacle =>
93         detect;
94     onMsg drive : drive(X) => println(savingmove(X));
95     onMsg drive : drive(X) => solve X time(0);
96     repeatPlan 0
97 Plan detect
98     println("Stopping...");
99     robotStop speed(100) time(1000);
100     emit bagFound : bagFound;
101     println("Starting detection Phase...");
102     [?? detection(X) ] forward asconsole -m
103         detectionResults : detectionResults(X);
104     println("Detection Results Sent");
105     emit endDetection : endDetection;
106     println("Back to base");
107     switchToPlan backToBase
108 Plan backToBase
109     solve backToBase time(0); //It doesn't need to react,
110     //as the qactor led handles that
111     switchToPlan finish

```

```

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 available. Based on the previous analysis, we found out that this application needs a set of features that includes:

- Synchronous and asynchronous communication between heterogeneous parts of a distributed system
- Distributed events
- Communication with entities that are not part of the system
- Interruptable actions

All the features we need can be implemented with current technology: actually, the framework developed by our software house can offer these features.

## 6.3 Risk analysis

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, during implementation phase. The advantage of using a meta-model and a code generator is also that it can be extended to support more advanced concepts. Using the framework code generators, we can write most of the code independently from the specific implementation technology. Although the qa/ddr metamodel 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, botIsBack-> blinkingAlarm,
                finish;
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 asconsole 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) ->
            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)
124         onFailSwitchTo prologFailure;
125     repeatPlan 0
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
132         prologFailure;
133     emit bagFound : bagFound;
134     println("Starting detection Phase...");
135     delay time ( 3000);
136     [!? detection(X) ] forward asconsole -m
137         detectionResults : detectionResults(X);
138     delay time ( 3000);
139     println("Detection Results Sent");
140     emit endDetection : endDetection;
141     println("Back to base");
142     switchToPlan backToBase
143 Plan backToBase
144     solve backToBase time(0) onFailSwitchTo prologFailure
145         ; //It doesn't need to react, as the qactor led
146         handles that
147     switchToPlan finish
148 Plan finish
149     emit botIsBack : botIsBack;
150     println("DriveRobot ends")
151 Plan prologFailure resumeLastPlan
152     println("Robot Failed to load prolog theories")
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 pinw 13 pinccw 12 ]
   position: LEFT
4 motorright = Motor [ gpiomotor pinw 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;
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);
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             ;
63             // if (!cmd.equals(Halt)){
64             //     execAction(Halt);
65             // }
66             System.out.println("DEBUG: UNPRESSED");
67         }
68         @Override
69         public void mousePressed(MouseEvent e) {
70             Button b = (Button)e.getSource();
71             execAction(b.getLabel());
72             System.out.println("DEBUG: PRESSED" + b.getLabel());
73         }
74         @Override
75         public void mouseExited(MouseEvent e) {
76         }
77         @Override
78         public void mouseEntered(MouseEvent e) {
79         }
80         @Override
81         public void mouseClicked(MouseEvent e) {
82         }
83     };
84
85     Button forward = new Button(Forward);
86     forward.addMouseListener(ml);
87     Button backward = new Button(Backward);
88     backward.addMouseListener(ml);
89     Button right = new Button(Right);
90     right.addMouseListener(ml);
91     Button left = new Button(Left);
92     left.addMouseListener(ml);
93     Button halt = new Button(Halt);
94     halt.addMouseListener(ml);
95     p.add(new Label(""));
96     p.add(forward);
97     p.add(new Label(""));
98     p.add(left);
99     p.add(halt);
100    p.add(right);
101    p.add(new Label(""));
102    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 import javax.imageio.ImageIO;
14 import it.unibo.is.interfaces.IOutputEnvView;
15 import it.unibo.qactors.ActorContext;
16
17 public class Ascconsole extends AbstractAscconsole {
18     public Ascconsole(String actorId, ActorContext myCtx,
19         IOutputEnvView outEnvView ) throws Exception{
20         super(actorId, myCtx, outEnvView);
21     }
22
23     protected Label userMsg;
24     protected Button alarm;

```

```

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

```

```

67     }
68
69     @Override
70     public void execAction(String cmd) {
71         super.execAction(cmd);
72         if( cmd.equals("Alarm") ){
73             platform.raiseEvent("input", "local_alarm", "
              local_alarm");
74             userMsg.setText("Alarm sent!");
75             return;
76         }
77     }
78
79     protected class ImagePanel extends Panel{
80         /**
81          *
82          */
83         private static final long serialVersionUID = 1L;
84         private Image image;
85
86         public ImagePanel(){
87             image = null;
88         }
89
90         public void paint(Graphics g){
91             super.paint(g);
92             if(image != null){
93                 int w = getWidth();
94                 int h = getHeight();
95                 int imageWidth = image.getWidth(this);
96                 int imageHeight = image.getHeight(this);
97                 int x = (w - imageWidth)/2;
98                 int y = (h - imageHeight)/2;
99                 g.drawImage(image, x, y, this);
100             }
101         }
102
103         public void setImage(Image image){
104             this.image=image;
105             validate();
106         }
107     }
108
109 }

```

### 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") <-
36         getTheLedCmdInterpreter(X) returns LED,
37         LED <- turnOff.
38 turnTheLed(offcompletely):-
39     pinNum(X),
40     class("it.unibo.devices.qa.LedDevicesFactory") <-
41         getTheLedCmdInterpreter(X) returns LED,
42         LED <- turnOffForever.
43 %initialize :- createPi4jLed(25).
44 initialize.
45
46 :- initialization(initialize).

```

The led instance is created through a factory:

```

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/
15         gpioPinInterpreter.sh";
16
17     static {
18         leds = new HashMap<>();
19     }
20
21     public static ILed getTheLedCmd(int nPin){
22         if(leds.containsKey(nPin)&&leds.get(nPin) instanceof
23             LedShellCmd){
24             return leds.get(nPin);
25         }
26         leds.put(nPin, new LedShellCmd(command, nPin));
27         return leds.get(nPin);
28     }
29 }

```

```

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.Utills;
6
7  public class LedShellCmdInterpreter extends LedShellCmd {
8
9      private PrintWriter pw;
10
11     public LedShellCmdInterpreter(String command, int nPin)
12     {
13         super(command, nPin);
14         this.pw=new PrintWriter(Utills.
15             executeShellCommandOutput(command +" "+ nPin));
16     }
17
18     @Override
19     public void turnOn() {
20         pw.print("1\n");
21         pw.flush();
22     }
23 }

```

```

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 }

```

```

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:

```

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 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,
10         IOutputEnvView outEnvView, it.unibo.iot.executors.
11         baseRobot.IBaseRobot baserobot) throws Exception{
12         super(actorId, myCtx, outEnvView, baserobot);
13     }
14
15     public String takeStringifiedPhoto() {
16         byte[] img= CameraFactory.getInstance().getCamera().
17             takePhoto();
18         return Base64.getEncoder().encodeToString(img);
19     }
20 }

```

## 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,
18         NEWL),
19     retract(lastMove(_,_)),
20     retract(moveList(_)),
21     assert(NEWLASTMOVE),
22     assert(moveList(NEWL)).
23
24 %Here the savemove rule is implemented without assert and
   retract.
25 %savemove(CUR, LAST, LIST, NEWLAST, NEWLIST)
26 savemove(CUR,lastMove(none,0),[],lastMove(CUR,M),[]):-
27     getCurrentMillis(M).
28 savemove(CUR,lastMove(move(MV,SPEED,0),FIRSTM),L,lastMove
29     (CUR,M),[move(MV,SPEED,DIFF,0)|L]):-
30     getCurrentMillis(M),
31     DIFF is M - FIRSTM.
32
33 %just to put the last command in the list
34 endSavemoves:-
35     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") <-
49         getCurrentTimeMillis returns M.
50
51 revMove(move(mf,X,Y,Z) ,move(mb,X,Y,Z)) .
52 revMove(move(mb,X,Y,Z) ,move(mf,X,Y,Z)) .
53 revMove(move(mr,X,Y,Z) ,move(ml,X,Y,Z)) .
54 revMove(move(ml,X,Y,Z) ,move(mr,X,Y,Z)) .
55 revMove(move(h,X,Y,Z) ,move(h,X,Y,Z)) .
56
57 %For example taking a photo
58 detection(X):-
59     actorOp(takeStringifiedPhoto) ,
60     actorOpDone(takeStringifiedPhoto,X) .
61
62 initDriveRobotTheory .
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 llMock = Line [ simulated 0 ] position: BOTTOM
6 distFrontMock= Distance [ simulated 0 ] position: FRONT
7 mgnl = Magnetometer [ simulated 0 ] private position:
    FRONT
8 //COMPOSED
9 rot = Rotation [ mgnl ] private position: FRONT
10 motors = Actuators [ motorleft , motorright ] private
    position: BOTTOM
11 Mainrobot mock [ motors,rot ]
12 ;
```

Finally, we deployed the system parts on their final location and tested the complete system and checked that it behaved as described in the test plan.

## 11 Deployment

The parts of the application will be deployed on different computational nodes as JAR executable archives with some configuration files, Prolog theories and bash scripts. The platforms we use in this case are a Raspberry Pi board on the robot and two PCs to provide the consoles, we just need to copy the appropriate files, set execution permissions for the bash scripts 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 qualified 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 immediately, 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 immediately 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 extension logicarchitecture
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 ->
34         senseAlarm;
35     println("Led Off");
36     delay time(1000) react event endDetection ->
37         senseAlarm;
38     repeatPlan 0
39
40 Plan senseAlarm
41     println("Led Off");
42     sense time(60000) alarm, botIsBack-> blinkingAlarm,
43         finish;
44     repeatPlan 0
45
46 Plan blinkingAlarm
47     println("led On");
48     delay time(500) react event botIsBack -> finish;
49     println("Led Off");
50     delay time(500) react event botIsBack -> finish;
51     repeatPlan 0
52
53 Plan finish
54     println("Led ends")
55 }
56
57 QActor operatorconsole context ctxOperator -g cyan
58 {
59     Plan init normal
60         println("Operator starts");
61         switchToPlan senseInput
62
63     Plan senseInput
64         sense time(60000) local_inputDrive ->
65             sendDriveCommands;
66         repeatPlan 0
67
68     Plan sendDriveCommands resumeLastPlan

```

```

65     onEvent local_inputDrive : local_inputDrive(X) =>
66         forward driverobot -m drive : drive(X)
67 }
68 QActor asconconsole 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) =>
77             println(detectionResults(X));
78             switchToPlan senseAlarm
79
80     Plan senseAlarm
81         sense time(100000) local_alarm => continue;
82         onEvent local_alarm : local_alarm => emit alarm :
83             alarm
84 }
85
86 Robot mock QActor driverobot context ctxDriveRobot
87 {
88     Plan init normal
89         println("driverobot starts");
90         solve consult("talkTheory.pl") time(0) onFailSwitchTo
91             prologFailure;
92         switchToPlan drive
93
94     Plan drive
95         //We'll have to make sure that the robot executes the
96         //commands from the first console only
97         receiveMsg time(600000) react event obstacle =>
98             detect;
99         onMsg drive : drive(X) => println(savingmove(X));
100         onMsg drive : drive(X) => solve X time(0);
101         repeatPlan 0
102
103     Plan detect
104         println("Stopping...");
105         robotStop speed(100) time(1000);
106
107     //Extension
108     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 asconsole -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 our 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="192.168.43.162" port=8010]
17 | Context ctxOperator ip[host="192.168.43.159" port=8015]
18 | Context ctxASC ip[host="192.168.43.241" port=8020]
19 |
20 | //Extension
21 | Context ctxRemoverobot ip[ host="192.168.43.87" 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(1500) react event endDetection ->
    |         senseAlarm;
41 |         println("Led Off");
42 |         solve turnTheLed(off) time(0) onFailSwitchTo
    |         prologFailure;
43 |         delay time(1500) 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, botIsBack-> blinkingAlarm,
        finish;
50     repeatPlan 0
51
52 Plan blinkingAlarm
53     println("Alarm! Blinking again");
54     println("led On");
55     solve turnTheLed(on) time(0) onFailSwitchTo
        prologFailure;
56     delay time(1500) react event botIsBack -> finish;
57     println("Led Off");
58     solve turnTheLed(off) time(0) onFailSwitchTo
        prologFailure;
59     delay time(1500) react event botIsBack -> finish;
60     repeatPlan 0
61
62 Plan finish
63     solve turnTheLed(offcompletely) time(0)
        onFailSwitchTo prologFailure;
64     println("Led ends")
65
66 Plan prologFailure resumeLastPlan
67     println("Prolog Failure LED")
68 }
69
70 QActor operatorconsole context ctxOperator -g cyan
71 {
72     Plan init normal
73         println("Operator starts");
74         switchToPlan senseInput
75
76     Plan senseInput
77         sense time(60000) local_inputDrive ->
            sendDriveCommands;
78         repeatPlan 0
79
80     Plan sendDriveCommands resumeLastPlan
81         onEvent local_inputDrive : local_inputDrive(X) ->
            forward driverobot -m drive : drive(X)
82 }

```

```

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

```



```

121     onMsg drive : drive(X) => solve X time(0)
        onFailSwitchTo prologFailure;
122     onMsg drive : drive(X) => switchToPlan drive;
123     repeatPlan 0
124
125 Plan drive
126     receiveMsg time(600000) react event obstacle =>
        detect;
127     //To make sure that the sender is the same as the
        first one
128     [?? msg(drive,dispatch, S, R, drive(X), N)] solve
        firstSender(S) time(0) onFailSwitchTo drive;
129     onMsg drive : drive(X) => println(X);
130     onMsg drive : drive(X) => solve savemove(X) time(0)
        onFailSwitchTo prologFailure;
131     onMsg drive : drive(X) => solve X time(0)
        onFailSwitchTo prologFailure;
132     repeatPlan 0
133
134 Plan detect
135     println("Stopping...");
136     robotStop speed(100) time(0);
137     delay time(1000);
138     println("Stopped");
139     solve endSavemoves time(0) onFailSwitchTo
        prologFailure;
140     emit bagFound : bagFound;
141
142     //Extension
143     println("Sending the route to the second robot");
144     [!? moveList(X)] forward removerobot -m routeToBag :
        routeToBag(moveList(X));
145     println("Route to bag sent");
146     //End extension
147
148     println("Starting detection Phase...");
149     delay time ( 3000);
150     [!? detection(X) ] forward asconsole -m
        detectionResults : detectionResults(X);
151     delay time ( 3000);
152     println("Detection Results Sent");
153     emit endDetection : endDetection;
154     println("Back to base");
155     switchToPlan backToBase
156

```

```

157 Plan backToBase
158     solve backToBase time(0) onFailSwitchTo prologFailure
        ; //It doesn't need to react, as the qactor led
        handles that
159     switchToPlan finish
160
161 Plan finish
162     delay time (1000);
163     emit botIsBack : botIsBack;
164     println("DriveRobot ends")
165
166 Plan prologFailure resumeLastPlan
167     println("Robot Failed to load prolog theories")
168
169 Plan savemoveFailure resumeLastPlan
170     println("Failed save move")
171 }
172
173 Robot plexiBox QActor removerobot context ctxRemoverobot
    {
174 Plan init normal
175     println("Removerobot starts");
176     solve consult("talkTheory.pl") time(0) onFailSwitchTo
        prologFailure;
177     solve consult("removeRobotTheory.pl") time(0)
        onFailSwitchTo prologFailure;
178     switchToPlan receiveRoute
179
180 Plan receiveRoute
181     receiveMsg time(60000);
182     onMsg routeToBag : routeToBag(X) -> println(X);
183     onMsg routeToBag : routeToBag(X) -> solve assert(X)
        time(0);
184     onMsg routeToBag : routeToBag(X) -> switchToPlan
        waitAlarm;
185     repeatPlan 0
186
187 Plan waitAlarm
188     println("Waiting for alarm");
189     sense time(60000) alarm, botIsBack -> waitBotIsBack,
        finish;
190     repeatPlan 0
191
192 Plan waitBotIsBack
193     println("Waiting for driverobot to arrive to RBA");

```

```

194     sense time(60000) botIsBack => goToBag;
195     repeatPlan 0
196
197     Plan goToBag
198         println("Going to bag");
199         solve gotobag time(0) onFailSwitchTo prologFailure;
200         println("Removing Bag");
201         delay time(5000);
202         println("Removerobot ends")
203
204     Plan finish
205         println("Removerobot ends")
206
207     Plan prologFailure
208         println("Removerobot Failed to load prolog theories")
209 }

```

### 13.6 Implementation

This is the configuration of the new robot:

```

1 RobotBase senseBot
2 //BASIC
3 motorleft = Motor [ gpiomotor pin 6 pinccw 5 ]
4               position: LEFT
5 motorright = Motor [ gpiomotor pin 4 pinccw 0 ]
6               position: RIGHT
7 distanceRadar = Distance [ sonarhcsr04 pintrig 22
8               pinecho 21 ] position: FRONT_TOP
9 //line = Line [ gpioswitch pin 15 activelow ] position
10 : BOTTOM
11 //COMPOSED
12 motors = Actuators [ motorleft , motorright ] private
13               position: BOTTOM
14 Mainrobot senseBot [ motors ]
15 ;

```

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

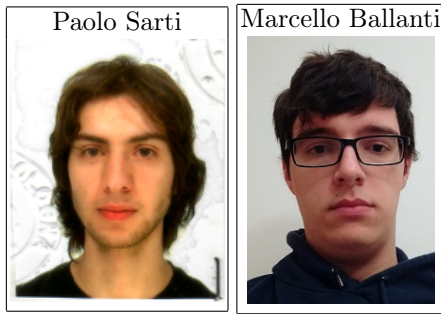
At first, the system has been tested simulating everything in a local environment. In order to test the second robot's behaviour, we deployed it on a physical robot and simulated the first robot. Finally, we deployed the entire system using two physical robots and two laptops for the ASC console and the operator console.

## 14 Conclusions

In this project, we followed a model-based approach in the analysis phase and we combined it with AGILE methods in the work plan and implementation phase. At the end of the analysis phase, we managed to obtain an executable model of the whole system. Thanks to the framework provided, the application design process has been done with tools and concepts close to the application domain. Technological choices have been delayed: this allowed us to change the implementation technology for some parts of the system during the implementation phase. The framework in its current state can generate code only for some platforms, but it's possible to extend it to support more platforms. This development process proved to be resistant to reasonable requirement changes: the second version of the application has been done mostly reusing the previous one, with minimal changes and in a short period of time.

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

## 15 Information about the author



## References

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