Introduction to QActors (2018)

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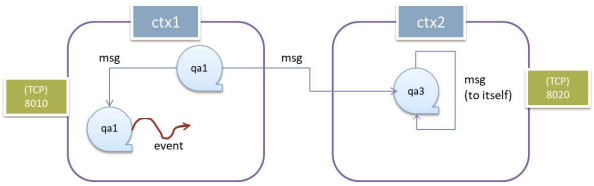
1 Introduction to QActors

QActor is the name given to ta custom meta-model inspired to the actor model (as supported by the Akka library). The qa language is a custom language that can allow us to express in a concise way the structure, the interaction and the behaviour of (distributed) software systems whose components interacts by using messages and events.

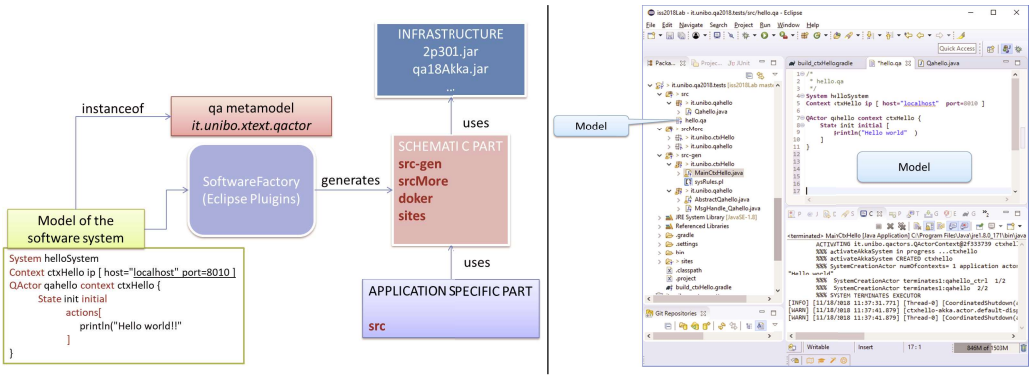
1.1 Overview

The leading Q/q in the *QActor* word, means 'quasi' since the *QActor* meta-model and the qa language do introduce (with respect to Akka) their own peculiarities, including reactive actions and even-driven programming concepts. Let us summarize the main features of a qa system:

- A QA-System is a collection of active entities (QActors) each working in a computational node (Context). A *QActor* can interact with other QActors using (see Subsection 1.10) Messages of different types (Dispatch, Request, Invitation, ...) and Events.

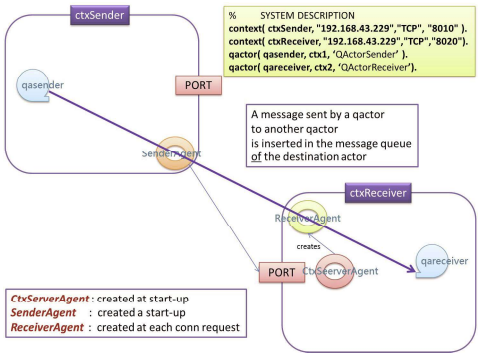


- A QA-System can be specified in textual form by means of the *QActor* language/metamodel. The *QActor* language is associated to a software factory (Subsection 1.5) that automatically generates the proper system *run-time support* so to allow Application designers to focus on application logic. The qa software factory is implemented as a set of Eclipse plug-ins, built by using the XText framework.



- The *configuration* of a QA-System is explicitly represented by a set of 'facts' written in tuProlog syntax (Subsection 1.15) replicated in each Context (Context Knowledge Base or simply ContextKB). A QA-System con be configured in a static or in a dynamic way. In case of dynamic configuration, the knowledge about the configuration is dynamically updated in each Context of the system (see Subsection 3.15).
- The start-up of a distributed *QActor* system (i.e. a system made of two or more Contexts) is handled by the run-time support. In particular, the Application code (i.e. the code written into the actors) begins to run only when all the Contexts are activated.

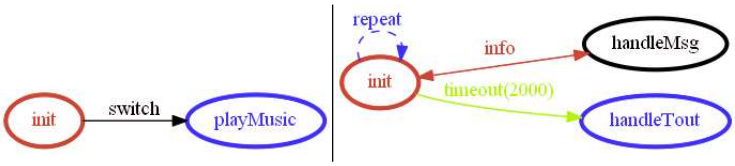
– The exchange of information among the QActors is implemented by the QA-Infrastructure (Subsection 1.15), based on the Akka-Java library. The QA-Infrastructure supports interaction among QActors working in the same Context and/or in different Contexts. In the latter case, the QA-Infrastructure exploits the ContextKB in order to deliver a message from the Context of the sender to the Context of the destination. An event raised in some Context, is delivered to **all** the other Contexts of the system.



– To deliver information among the Contexts, the QA-Infrastructure can use pairwise TCP connections between the Contexts or a MQTT broker. The choice is up to the Application designer.

– Each *QActor* behaves as a (Moore's) *Finite State Automaton* (FSM). While in a state, a *QActor* can execute both synchronous and asynchronous actions. An asynchronous action terminates immediately and emits an event (see Subsection 3.4) when it terminates.

– A state-transition from a state S1 to another state S2 can be done (triggered) only when all the actions activated in S1 are terminated. A state-transition can be triggered by a message or by an event or as a choice of the *QActor* (no-input transition).



– A state-transition can be associated to a boolean condition (guard) and can be triggered only when the guard is true (see Subsection 1.6.2). When two or more transitions are possible, the systems checks the possibility to trigger one of them by following the order in which they are written. If no transition can be triggered, the *QActor* remains in the state until the occurrence of some message or event that allows a transition.

– A *QActor* is able to execute a set of pre-defined actions (see Subsection 3.17, Subsection 1.6.4). The a application designer can define Application specific actions by using Java or other languages (in particular JavaScript/Node and Prolog).

– A *QActor* is associated to a private knowledge-base (QaKB, Section ??) written in Prolog that can be dynamically extended by the Application designer.

Let us start with some example.

The code of the examples shown in this work can be found in the project it.unibo.qa2018.tests.

1.2 Example: the 'hello world'

The first example of a **qa** specification is obviously the classical 'hello world':

```
/*
 * hello.qa
 */
System helloSystem
Context ctxHello ip [ host="localhost" port=8010 ]

QActor qahello context ctxHello {
   State init initial [
       println("Hello world" )
   ]
}
/*
 * Another style: Plan vs of State, normal vs initial
 */
QActor qahelloold context ctxHello {
   Plan init normal
       actions[javaRun it.unibo.utils.clientTcp.sendMsg("{ 'type': 'moveForward', 'arg': 60000 }");
          println("Hello world old style" )
       ]
}
```

Listing 1.1. `hello.qa`

The example shows that each *QActor* works within a `Context` that models a computational node associated with a network `IP` (`host`) and a communication `port` (see Subsection 1.15).

A *QActor* must define one (and just one!) `State`, qualified as '`initial`' to state that it represents the starting work of the actor. Each `State` of a *QActor* represents the state of a Moore `Finite State Machine`, whose `state-actions` are defined in a proper section, enclosed within the 'brackets' `[ ... ]`.

The example shows also an older version in which:

- The key-word `Plan` is used at place of the key-word `State`;
- The key-word `normal` is used at place of the key-word `initial`;
- The *state-action* section can be optionally prefixed by the word `actions`.

In fact, it is extremely easy (by using the `Xtext` framework) to change the key-words of our language, since `Xtext` automatically generates (starting from the grammar of the language) a compiler and a syntax-driven editor.

The introduction of an appropriate set of keywords is crucial to better transmit the intended semantics of a language construct. With the keyword `State`, we call to mind the idea of a machine, while with the keyword `Plan` we could evoke the idea of a sequence of high-level actions the our machine must execute to fulfil some goal.

In the following we will use both the notations, since the language semantics is identical.

A *QActor* is intended to be a software component that can perform application `actions` by interacting with other *QActor*s by means of `messages` (see Subsection 1.11) or `events` (see Subsection 1.13).

`State transitions` can be performed when:

- all the actions in the state body are terminated, and
- a *message* is or an *event* is available, or
- a no-input transition (`switchTo`) is specified.

1.3 Example: no-input transitions

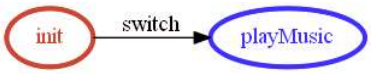
The next example defines the behaviour of a *QActor* that performs a no-input transition:

```
System noinputTansition
Context ctxNoinputTansition ip [ host="localhost" port=8079 ]

QActor qahellonoinputtrans context ctxNoinputTansition{
    State init initial [
        println( playSomeMusic );
        delay 1000 //wait for a second
    ]
    switchTo playMusic

    State playMusic [
        sound time(2000) file('./audio/tada2.wav')
    ]
```

Listing 1.2. noinputTansition.qa

switchTo is a predefined operation of the *QActor* language (see Subsection 1.4).
sound is a QActor built-in action (see Subsection 3.17, Subsection 1.6.4) that ends after 2 seconds.
delay is a built-in action that waits for the specified number of msecs.

The *QActor* performs a state-switch from its init state to the playMusic state with a no-input transition switchTo. The behaviour of the actor can be represented by a state diagram like that shown in the following picture:



This state diagram is automatically generated [1] by the *QActor* software factory (see Subsection 1.5).

1.4 The custom language qa

The qa language is a custom language[2] built by exploiting the XText technology; thus, it is also a metamodel. Technically we can say that qa is a 'brother' of UML, since it is based on EMOF.

The qa language aims at overcoming the abstraction gap between the needs of distributed proactive-reactive systems and the conventional (object-based) programming language (mainly Java, C#, C, etc) normally used for the implementation of software systems.

In fact, a qa specification aims at capturing main architectural aspects of the system by providing a support for rapid software prototyping and a graceful transition from object-oriented programming to message-based and event-based computations.

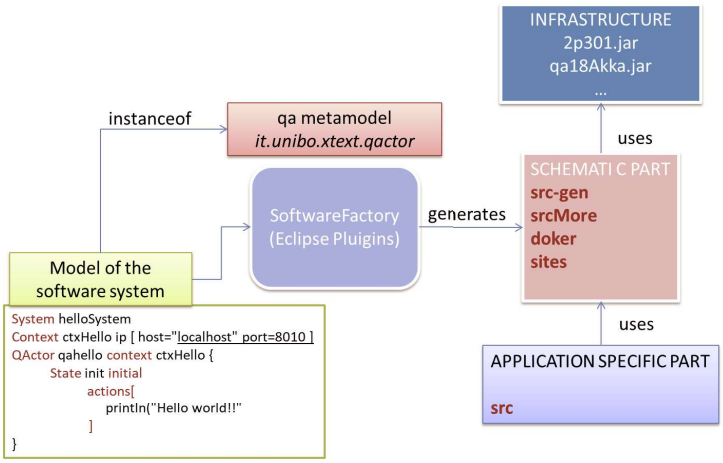
The syntax of the qa language is expressed by a EBNF notation:

```
QActorSystem:
    "System" spec=QActorSystemSpec
;
QActorSystemSpec:
    name=ID
    ( message  += Message )*
    ( context  += Context )*
    ( actor    += QActor  )*
;
```

From a grammar specification, the XText framework is able to generate in automatic way Java code for a parser and a syntax-driven editor, that can extend the Eclipse ecosystem by means of a set of plug-ins.

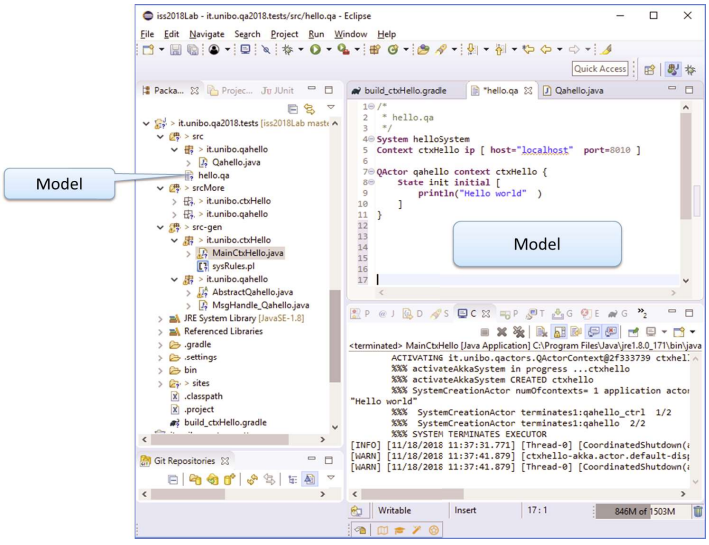
[1] See the file srcMore/it/unibo/qahellonoinputtrans/qahellonoinputtrans.gv
[2] The qa language/metamodel is defined in the project *it.unibo.xtext.qactor*.

1.5 The qa software factory



The qa language/metamodel is associated to a software factory that automatically generates the proper system run-time support (including system configuration code) so to allow Application designers to focus on the Application logic. The qa software factory is implemented as a set of Eclipse plug-ins, built by the XText framework.

For each *QActor* and for each `Context`, the *QActor* software factory generates (`Java`) code in the directories `scr-gen` and `src`. Further information (for example about system configuration) is included in the directory `srcMore`, to allow explicit visibility after deployment[3]. Moreover, a `gradle` build file is also generated for each `Context`.



[3] Usually, Java software is deployed by creating an executable jar file with the bytecode, and this file is normally not accessible by a system manager.

1.5.1 Example of generated files .

In the case of the example of Subsection 1.2:

- The file (named build_ctxHello.gradle) that describes the build rules of the system, is generated in the directory /.
- The file (named hellosystem.pl) that describes the configuration of the system, is generated in the directory srcMore/it/unibo/ctxHello.
- The file (named sysRules.pl) that includes the tuProlog rules used (mailny for the system start-up) by the qa-infrastructure (see Subsection 1.15) is generated in the directory srcMore/it/unibo/ctxHello.
- The file (named WorldTheory.pl) that includes the actor's world-theory (see Section ??) is generated in the directory srcMore/it/unibo/qahello.
- The file (named qahell.gv) that gives a graphical representation of the actor's state diagram (see the example of Subsection 1.3), is generated in the directory srcMore/it/unibo/qahello.

For a more complete view of the generated files, see Subsection 1.15.

1.6 The actor's WorldTheory

For a *QActor* named myactor, the qa software factory generates a file (named WorldTheory.pl) in the directory srcMore/it.unibo.myactor. Thus file includes a set of rules and facts written in tuProlog that give a symbolic representation of the "world" in which a *QActor* is working.

The file WorldTheory.pl includes also several computational rules written in tuProlog that extend the action-set of a *QActor*. For example, it includes rules to compute the n-th Fibonacci's number in two ways: in a *fast* way (fib/2 Prolog rule) and in a *slow* way (fibo/2 Prolog rule).

The facts and rules stored in the WorldTheory.pl file of a *QActor* can be used to specify conditional execution of actions, by prefixing an action with a guard of the form [GUARD] where GUARD (see Subsection 1.6.2) is written as a Phead (see Subsection 1.10) tuProlog Term.

More details about the WorldTheory and its role are given in Section ??.

1.6.1 Facts about the state .

Examples of facts related to the current computational state of a *QActor* are:

actorobj/1	memorizes a reference to the Akka object that implements the actor (see Subsection ??)
goalResult/1	memorizes the result of the last goal given to a demo operation (see Subsection 1.6.3)

These facts are 'singleton facts'. i.e. there is always one clause for each of them, related to the last action executed.

1.6.2 Guarded actions .

Actions (see Subsection 1.9) prefixed by a [GUARD] are executed only when the GUARD is evaluated true. The GUARD can include *unbound variables*[4], possibly bound during the guard evaluation phase. Moreover:

- the prefix !? before the guard condition means that the knowledge (a fact or a rule) that makes the guard true is not removed form the actor's *WorldTheory*;
- the prefix ?? means that the fact/rule that makes the guard true is removed from the actor's *WorldTheory*.

[4] We recall that a Prolog variable is syntactically expressed as an identifier starting with an upcase letter.

Let us consider the following example;

```
System naiveGuardedActions
Context ctxNaiveGuardedAction ip [ host="localhost" port=8037 ]
QActor qanaiveguarded context ctxNaiveGuardedAction {
    State init initial [
        [ !? true    ] println( alwaysHere ) ;
        [ !? false   ] println( neverHere ) ;
        [ !? fib(6,X) ] println( fib(6,X) ) ;
        [ ?? fibo(4,X) ] println( fibo(4,X) )
    ]
    finally repeatPlan 1
}

/*
OUTPUT
----------------------------
alwaysHere
fib(6,8)
fibo(4,3)
alwaysHere
fib(6,8)
*/
```

Listing 1.3. `naiveGuardedActions.qa`

The output shows that the second iteration does not compute any more `fibo/2`, since that rule has been removed in the first iteration. The example show also that `variables` unified by a guard execution can be referred in the action (the `scope` id the action itself).

1.6.3 The `demo` operator .

A *QActor* can use the built-in `demo` operator to execute actions implemented in tuProlog within the actor's `WorldTheory`. The result of the `demo` operator is memorized in the singleton fact `goalResult/1` that can be inspected by using a guard.

```
System demoExample
Context ctxDemoExample ip [ host="localhost" port=8079 ]
QActor qademoexample context ctxDemoExample{
    Plan init normal
        [   println("qademoexample STARTS" ) ;
            [ !? actorobj(X) ] println( actorobj(X) ) ;
            demo actorobj(X) ;
            [ ?? goalResult(R) ] println( qademoexample( R ) ) ;
            demo fibo(6,X);
            [ ?? goalResult(R) ] println(R) ;
            demo fibo(6,8);
            [ ?? goalResult(R) ] println(R) ;
            demo fibo(X,8);   //fails since fibo/2 is not invertible
            [ ?? goalResult(R) ] println(R) ;
            println("qademoexample ENDS" )
        ]
 }
/*
OUTPUT
----------------------------
"qademoexample STARTS"
actorobj(qatuqademoexample_ctrl)
qademoexample(actorobj(qatuqademoexample_ctrl))
fibo(6,8)
fibo(6,8)
failure
"qademoexample ENDS"
*/
```

Listing 1.4. `demoExample.qa`

1.6.4 Built-in Prolog rules .

Besides the 'facts' introduced in Subsection 1.6.1, the *WorldTheory* (QaKb) of an actor includes several other computational rules written in tuProlog. Example of operations written as tuProlog rules in the QaKb are:

actorPrintln(T)	prints the given term T (see Subsection 1.10) in the actor standard output;
assign(K,V)	associates the given key K the the given value V, by removing nay previous association (if any)
getVal(K,V)	unifies the term V with the given key K
inc(I,K,N)	inc(I,K,N) :- value(I,V), N is V + K, assign(I,N)
addRule(R)	adds the given rule R in the *WorldTheory*
removeRule(R)	removes the given rule R from the *WorldTheory*
replaceRule(R,R1)	replace the given rule R with the other rule R1 of the same 'signature'
eval(plus,V1,V2,R)	unifies R with the result of V1+V2. Also available: minus, times, div
eval(lt,X,Y)	true if X<Y. Also available: gt
divisible(V1,V2)	true if V1 is divisible for V2

Moreover, the Rules option within a *QActor* specification allows us to define operations in a declarative style within facts and rules by using a subset of the tuProlog language.

1.6.5 Rules at model level .

Sometimes can be useful to express tuProlog facts and rules directly in the model specification, especially for configuration or action-selection purposes. The Rules option within a *QActor* allows us to define facts and rules by using a subset of the tuProlog syntax[5]

For example, let us define the model of a system that plays some music file by consulting its knowledge-base about the sound files, defined in the Rules section:

```
1  System rulesInModel
2  Context ctxRulesInModel ip [ host="localhost" port=8059 ]
3  QActor rulebasedactor context ctxRulesInModel {
4      Rules{
5          music(1, './audio/tada2.wav',2000).
6          music(2,'./audio/any_commander3.wav',3000).
7  //      music(3,'./audio/computer_complex3.wav',3000).
8  //      music(4,'./audio/illogical_most2.wav',2000).
9  //      music(5,'./audio/computer_process_info4.wav',4000).
10 //      music(6,'./audio/music_interlude20.wav',3000).
11 //      music(7,'./audio/music_dramatic20.wav',3000).
12     }
13     State init initial[
14         [ !? actorobj(X) ] println( myName(X) )
15     ]
16     switchTo work
17     State work [
18         [ ?? music(N,F,T) ] sound time(T) file(F) else endPlan "bye"
19     ]
20     finally repeatPlan
21 }
```

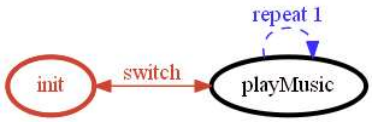
Listing 1.5. `rulesInModel.qa`

More on the actorKb can be found in Subsection ??.

[5] The extension of this option with full Prolog syntax is a work to do.

1.7 Example: repeat/resume plans

Let us define the behaviour of a *QActor* that implements the state machine shown in the following state diagram:




```
/*
 * repeatResume.qa
 */
System repeatResume
Context ctxRepeatResume ip [ host="localhost" port=8079 ]

QActor player context ctxRepeatResume{
    State init initial [
           println("player STARTS" ) ;
            println("player ENDS" )
       ]
       switchTo playMusic
//     finally repeatPlan 1  //(1)

    Plan playMusic resumeLastPlan [
           println( playSomeMusic );
            sound time(2000) file('./audio/tada2.wav') ;
            delay 500
       ]
       finally repeatPlan 1
 }
/*
OUTPUT
----------------------------
"player STARTS"
"player ENDS"
playSomeMusic
playSomeMusic
*/
```

Listing 1.6. `repeatResume.qa`

The *QActor* performs a state-switch from its initial state to the `playMusic` state with a no-input transition `switchTo`. The `playMusic` state repeats its actions two times (because of `repeatPlan 1`) and then makes a no-input transition to its previous ('calling') state (`player`).

From the output, we note that all the actions of a plan are execute before the transition. This can be better explained by introducing the main rules that define the behaviour of a *State/Plan* (i.e. its operational semantics).

1.8 How a Plan/State works

When a *QActor* enters in a Plan, it works as follows:

1. the *QActor* executes, in sequential way, all the actions specified in the *Plan*. Each action must be defined as an `algorithm`, i.e. it must terminate;
2. if the *State/Plan* specification ends with the sentence `finally repeatPlan N` (`N` natural number `N>=1`), the state actions are repeated `N` times. If `N` is omitted, the *Plan* is repeated forever. The key word `finally` highlights the fact that the repetition a sentence must always written at the end of a Plan specification;

3. when the state actions are terminated (and before any repetition), the *QActor* can enter in a `transition phase` in order to perform a switch to another state (let us call it '*nextState*' and '*oldState*' the original one). For the details, see Subsection 1.12;
4. when a state has terminated its work (i.e. its actions, transition and repetition), it can resume the execution of its *oldState*. This happens if the `resumeLastPlan` keyword is inserted after the state name. Otherwise, the state is considered a `termination state` and the *QActor* does not perform any other work.

Thus, if we remove the comment `(1)` from the example of Subsection 1.3, the output will be:

```
"player STARTS"
"player ENDS"
playSomeMusic
playSomeMusic
"player STARTS"
"player ENDS"
playSomeMusic
playSomeMusic
```

If we remove the `resumeLastPlan` specification from `playMusic`, the control does not return to `player` and the output is the same as Subsection 1.3.

1.9 Actions (built-in and user-defined)

A *QActor* *State/Plan* specifies a sequence of predefined or user-defined `actions` that must always terminate. Actions can be classified into a set of types, as reported in the following table:

`Logical action`	usually is a 'pure' computation defined in some general programming language. Actually we use Java, Prolog and JavaScript. Example: `fibo(14,X)`.
`Physical action`	an actions that changes the actor's physical state or the actor's working environment. Example: `addRule`.
`Timed action`	always terminates within a prefixed time interval. Example: `sound`.
`Application action`	defined by the application designer according to the constraints imposed by its logical architecture.

As a general statement, we can say that[6]:

An Application action executed by a *QActor* in a state `S`, should terminate as soon as possible in order to make the actor in `S` as much *reactive* as possible to events and messages. Long-lasting activities should be implemented as `asynchronous actions` (see Subsection 3.4).

1.9.1 Action results .

The `effects` of actions can be perceived in one of the following ways:

1. as changes in the state of the actor stored in the actor's `WorldTheory` (see Subsection 1.6)).
2. as changes of the state stored in some computational object associated to the actor;
3. as changes in the actor's working environment.

[6] However, 'true' `real-time systems` are out of the scope of this work.

1.9.2 Built-in and User-defined actions .

Each *QActor* is able to execute:

- a set of built-in operations, defined by the qa language as key-words. Examples are: println, sound, forward, emit, addRule, javaRun, javaOp, nodeOp, etc.
- a set of actions implemented in Java by the *QActor* System designer in the class QActor of the library qaAkka18.jar. Examples are: debugStep, publish, subscribe, sendPost, doCoapPost, etc.. This kind of actions can be executed by means of the built-in operation javaOp (see Subsection 1.9.4).
- a set of actions implemented in some Java class written by the *Application designer*. These actions can be executed by means of the built-in action javaRun (see Subsection 1.9.3).
- a set of actions written by the *Application designer* in tuProlog (see Subsection 1.6.4, Subsection 3.19).

1.9.3 The operation javaRun .

As happens for any language, the expressive power of the *QActor* modelling language is limited. The javaRun key-word provides an 'escape mechanism' to run Java code provided by the Application designer. Let us consider the following sentence:

```
1 javaRun it.unibo.utils.clientRobotTcp.sendMsg("{ 'type': 'moveForward', 'arg': 60000 }")
```

This operation puts in execution the sendMsg (static) method of the (user-defined) class it.unibo.utils.clientRobotTcp[7] that sends a command to a remote robot.

1.9.4 The operation javaOp .

Another 'escape mechanism' is the operation javaOp that puts in execution a Java operation denoted by a given String. Let us consider the following sentence:

```
1 javaOp "debugStep()"
```

This operation puts in execution the method debugStep() that the actor inherits from the system class QActor. This method facilitates the debug of the actor, since it blocks the activity of the actor until the software designer hits the 'g' keyboard key.

Actions executed by the javaOp operation extend the computational features of a *QActor* without any change in the *QActor* language; however, the language could be extended at a later time, so to 'promote' the action (with some proper new key-word) as a 'primitive' operation.

The set of action currently defined in the in the QActor class are reported in Subsection 3.17.

1.9.5 The operation nodeOp .

In order to promote heterogeneity, the *QActor* System designer has introduced the operation nodeOp operation, that puts in execution the Node.js program denoted by a given String.

Let us consider the following sentence:

```
1 nodeOp "C:/robot/server/src/main.js 8999 " -o
```

This operation puts in execution a Node.js server that provides some useful feature (for example, a virtual robot working in a virtual environment). With the optional -o set, the system will show the output of the Node.js program (if any) on the standard output of the actor.

[7] Nte that the name of the class starts with a lower-case letter. This is a constraint imposed by the current *QActor* implementation.

1.10 Messages and events

A *QActor* can interact with other `QActors` using (see Subsection 1.10) `Messages` of different types (`Dispatch`, `Request`, `Invitation`, ...) and `Events`.

The syntax for *message* and *event* declarations is:

```
Message :         OutOnlyMessage | OutInMessage ;
OutOnlyMessage :  Dispatch | Event | Signal | Token ;
OutInMessage:     Request | Invitation ;

Event:     "Event"     name=ID ":" msg = PHead ;
Signal:    "Signal"    name=ID ":" msg = PHead ;
Token:     "Token"     name=ID ":" msg = PHead ;
Dispatch:  "Dispatch"  name=ID ":" msg = PHead ;
Request:   "Request"   name=ID ":" msg = PHead ;
Invitation: "Invitation" name=ID ":" msg = PHead ;
```

`PHead`: The `PHead` rule defines a subset of Prolog syntax:

```
    PHead : PAtom | PStruct ;
    PAtom : PAtomString | Variable | PAtomNum | PAtomic ;
    PStruct : name = ID "(" (msgArg += PTerm)? ("," msgArg += PTerm)* ")";
    PTerm  : PAtom | PStruct ...
```

The grammar states that the declaration of messages and events (if any) must immediately follow the `System` sentence, since they represent system-wide information. For example:

```
System basicProdCons
Dispatch info : info(X)
Context ctxBasicProdCons ip [ host="localhost" port=8019 ]
```

Listing 1.7. `An example of message declaration`

At the moment, only `dispatch`, `request` and `event` are implemented.

1.11 Messages

In the *QActor* metamodel, a `message` is intended as information sent in `asynchronous` way by some source to `some specific destination`.

For *asynchronous* transmission we intend that the messages can be '**buffered**' by the infrastructure, while the '**unbuffered**' transmission is said to be `synchronous`.

A message does not force the execution of code: a message `m` sent from an actor `sender` to an actor *receiver* can trigger a state `transition` (see Subsection 1.12) in the `receiver`. If the `receiver` is not 'waiting' for a transition including `m`, the message is enqueued in the `receiver` queue.

At application-level, we say that a *QActor* works according to a `massage-based` behaviour, while at the lower level (in the `qa-infrastructure`, see Subsection 1.15) it works according to the `massage-driven` (Akka) behaviour.

At application level, a message is denoted by specifying a message type, a name and a payload. For example[8]:

```
Dispatch msgName : msgPayload( PHead )
```

[8] For the syntax of `PHead`, see Subsection 1.10.

At low level (in the `qa-infrastructure`, see Subsection 1.15) messages are syntactically represented as follows:

```
msg( MSGID, MSGTYPE, SENDER, RECEIVER, CONTENT, SEQNUM )
```

where:

MSGID	Message identifier
MSGTYPE	Message type (e.g.: dispatch,request,event)
SENDER	Identifier of the sender
RECEIVER	Identifier of the receiver
CONTENT	Message payload
SEQNUM	Unique natural number associated to the message

The `msg/6` pattern can be used at application level to express `guards` (see Subsection 1.6.2) to allow conditional evaluation of *Actions*.

1.11.1 Sending/Receiving messages .

The *QActor* language defines built-in action that allow software designer to send messages and that facilitate the handling of received messages.

For example, the `SendDispatch` grammar rule defines how to write the `forward` of a *dispatch*:

```
SendDispatch: name="forward" dest=VarOrQactor "-m" msgref=[Message] ":" val = PHead ;
VarOrQactor : var=Variable | dest=[QActor] ;
```

Once a message has triggered a state transition, the `onMsg` action (in the *newState*) allows us to select a message and execute actions according to the specific structure of that message.

```
MsgSwitch:  "onMsg" message=[Message] ":" msg = PHead "->" move = StateMoveNormal ;
```

1.11.2 Example: a producer-consumer system .

As an example of a message-based transition, let us introduce a very simple producer-consumer system[9], in which the producer sends two times a *dispatch* to the consumer:

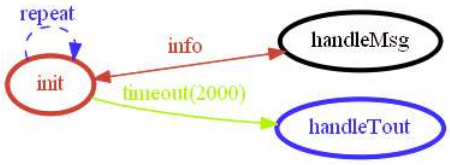
```
System basicProdCons
Dispatch info : info(X)
Context ctxBasicProdCons ip [ host="localhost" port=8019 ]
QActor producer context ctxBasicProdCons{
    Rules{
            item(1).
            item(2).
    }
    State init initial [
            [ !? item(X)] println( producerSending( item(X)) ) ;
            [ !? item(X)] addRule produced( item(X) );
            [ ?? item(X)] forward consumer -m info : info( item(X) ) ;
            delay 500
    ]
    finally repeatPlan 1
 }
 QActor consumer context ctxBasicProdCons{
    State init normal [ println( consumer(waiting) ) ]
    transition whenTime 2000 -> handleTout
               whenMsg info -> handleMsg
    finally repeatPlan
    State handleMsg resumeLastPlan [
         printCurrentMessage ;
         onMsg info : info(X) -> addRule consumed( X );
```

[9] This example is in the project `it.unibo.qa2018.prodcons`.

```
25          onMsg info : info(X) -> println( consumerReceiving(X) )
26      ]
27      State handleTout [ println( consumerTout ) ]
28  }
```

Listing 1.8. `basicProdCons.qa`

The state diagram generated by the *QActor* software factory for the consumer is:



Note that the producer stores in its `actorKb` the fact `produced( item(X) )` for each produced element `X`. The consumer instead stores in its `actorKb` the fact `consumed( item(X) )` for each produced element `X` received by the producer. This information is useful for testing purposed, as shown in Subsection 2.2.

The output is:

```
1   /*
2   OUTPUT
3   ---------------------------------------
4   producerSending(item(1))
5   consumer(waiting)
6   -------------------------------------------------------------------------------------
7   consumer_ctrl currentMessage=msg(info,dispatch,producer_ctrl,consumer,info(item(1)),1)
8   -------------------------------------------------------------------------------------
9   consumerReceiving(item(1))
10  consumer(waiting)
11  producerSending(item(2))
12  -------------------------------------------------------------------------------------
13  consumer_ctrl currentMessage=msg(info,dispatch,producer_ctrl,consumer,info(item(2)),2)
14  -------------------------------------------------------------------------------------
15  consumerReceiving(item(2))
16  consumer(waiting)
17  consumerTout
18  */
```

Listing 1.9. `basicProdCons.qa`

The meaning of a `transition` is discussed in Subsection 1.12.

1.12 State transitions

A transition from a state (*oldState*) to another state (*nextState*) can be specified in different ways, according to the following syntax:

PlanTransition

```
PlanTransition : SwitchTransition | MsgTransition   ;
```

Thus, a state transition sentence can start:

1. with the keyword switchTo: in this case the automaton performs a SwitchTransition (no-input switch, see Subsection 1.3).

```
1 SwitchTransition: "switchTo" nextplantrans = NextPlanTransition ;
2 NextPlanTransition: (guard = Guard)? nextplan=[Plan] ;
```

Note that a transition specification can be prefixed by a guard.

2. with the keyword transition: in this case the automaton performs a MsgTransition that can be triggered by a message or by an event.

```
1 MsgTransition: "transition" duration=Duration (msgswitch+=StateTransSwitch )?("," msgswitch+=StateTransSwitch)* ;
2 Duration : (guard = Guard)? "whenTime" (msec=INT | var=Variable) "->" move=[Plan] ;
3 StateTransSwitch : MsgTransSwitch | EventTransSwitch ;
4
5 MsgTransSwitch: "whenMsg" (guard = Guard)? message=[Message] next=TransSwitch ;
6 EventTransSwitch: "whenEvent" (guard = Guard)? message=[Event] next=TransSwitch ;
```

Thus, a typical state transition involving messages and/or events takes the following form:

A transition specification

```
transition
   whenTime  <timeOut>  ->  <nextState1>
   whenEvent <eventId>  ->  <nextState2>,
   whenMsg   <msgId>    ->  <nextState3>
```

The meaning is:

> the automaton must switch to <nextState1> after <timeOut> milliseconds. In the mean time, it shall switch to <nextState2> if the event named <eventId> occurs or to <nextState3> if the message named <msgId> is sent to the *QActor*.

1.12.1 Switch part .

A TransSwitch grammar rule allows us to specify

- either an explicit new *State/Plan* to reach;
- or an action to be executed as part of an implicit Plan that 'returns' to its caller at the end of its work.

TransSwitch

```
TransSwitch: PlanSwitch | ActionSwitch ;
PlanSwitch:     "->" move = [Plan]  ;
ActionSwitch:  ":" msg = PHead "do" action = StateMoveNormal ;
StateMoveNormal: StateActionMove | OutMessageMove |  ActionDelay | ExtensionMove |
                    BasicMove | StatePlanMove | GuardMove | BasicRobotMove ;
```

An example of PlanSwitch has been given in Subsection 1.11.2. A simple example of ActionSwitch is:

```
System demoActionSwitch
Dispatch info : payload( CONTENT )
Context ctxDemoActionSwitch ip [ host="localhost" port=8019 ]

 QActor sendertoself context ctxMsgToSelf{
    Plan init initial [
         selfMsg info : payload( "helloWorld" )
    ]
    transition stopAfter 100
          whenMsg info : payload(V) do println(V)
 }
```

The meaning of the *QActor* operation selfMsg is that the actor forwards the dispatch to itself.

1.12.2 Example: action after a self-message .

A more interesting example is given in the next section

```
System msgToSelf
Dispatch execute : code( CODE )
Dispatch eval   : code( CODE )

Context ctxMsgToSelf ip [ host="localhost" port=8019 ]

 QActor sendertoself context ctxMsgToSelf{
    Plan init initial [
         selfMsg eval : code( fibo(10,V) )
    ]
    transition whenTime 100 -> handleTout
          whenMsg execute -> execProg ,
          whenMsg eval    : code(P) do selfMsg execute : code(P)
       finally repeatPlan 1

   State execProg resumeLastPlan [
       onMsg execute : code(P) -> demo P;
       [ ?? goalResult(V) ] println(V)
   ]
   State handleTout
       [ println( consumerTout ) ]
 }
 /*
 OUTPUT
----------------------------------------
fibo(10,55)
----------------------------------------
```

Listing 1.10. msgToSelf.qa

To understand the output, let us trace the behavior of the actor:

1. The actor sends an eval messages to itself.
2. The eval message is handled by the actor that sends the message execute to itself.
3. The Plan init is repeated: another eval messages is sent by the actor to itself.
4. Now there are two messages 'pending'. The first considered for a transition is execute.
5. The actor performs a transition to the state execProg and then terminates.

1.13 Events

In the *QActor* metamodel, an event is intended as information emitted by some source without any explicit destination. Events can be *emitted* by the *QActors* that compose a *actor-system* or by sources external to the system.

The occurrence of an event can put in execution some code devoted to the management of that event. We qualify this kind of behaviour as `event-driven` behaviour, since the event 'forces' the execution of code (see Subsection 1.14).

An event can also trigger state transitions in components, usually working as finite state machines. We qualify this kind of behaviour as `event-based` behaviour, since the event is 'lost' if no actor is in a state waiting for it.

At application level, an event is denoted by specifying the key-word `Event`, a name and a payload. For example[10]:

```
Event evName : evPayload( PHEAD )
```

At low level (in the `qa-infrastructure`, see Subsection 1.15) events are syntactically represented as messages with no destination (`RECEIVER=none`):

```
msg( MSGID, event, EMITTER, none, CONTENT, SEQNUM )
```

The *QActor* language defines built-in actions that allow software designer to emit events and actions that facilitate the handling of perceived events.

The `RaiseEvent` grammar rule specifies an operation that allow us to `emit` an event:

```
RaiseEvent : name="emit" ev=[Event] ":" content=PHead ;
```

Once an event has triggered a state transition, the `onEvent` action allows us to execute actions according to the specific structure of that event.

```
EventSwitch: "onEvent" event=[Event] ":" msg = PHead "->" move = StateMoveNormal ;
```

1.13.1 Example: event-based behavior .

As an example of a event-based transition, let us introduce a very simple system, in which an actor works as event-emitter and another actor that handles the emitted events:

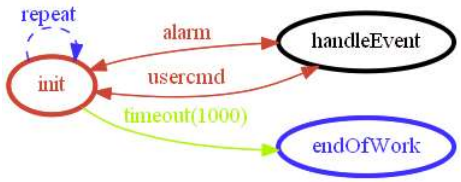
```
/*
 * basicEvents.qa
 */
System basicEvents
Event usercmd : usercmd(X)
Event alarm  : alarm(X)

Context ctxBasicEvents ip [ host="localhost" port=8037 ]

QActor qaeventemitter context ctxBasicEvents {
   State init initial
   [  println("qaeventemitter STARTS ") ;
      delay 500 ;    //(1)
      println("qaeventemitter emits alarm(fire)") ;
      emit alarm : alarm(fire) ;
      delay 500 ;    //(2)
      println("qaeventemitter emits usercmd(hello)") ;
      emit usercmd : usercmd(hello) ;
      println( "qaeventemitter ENDS" )
   ]
}
QActor qaeventperceptor context ctxBasicEvents {
   State init initial
      [  println("qaeventperceptor STARTS ") ]
      transition whenTime 1000 -> endOfWork
         whenEvent alarm -> handleEvent,
         whenEvent usercmd -> handleEvent
      finally repeatPlan
```

[10] For the syntax of `PHead`, see Subsection 1.10.

```
29
30      State handleEvent resumeLastPlan
31          [  println("ex4_perceptor handleEvent " ) ;
32             printCurrentEvent ;
33             onEvent alarm  : alarm(X)  -> println( handling(alarm(X)) ) ;
34             onEvent usercmd : usercmd(X) -> println( handling(usercmd(X)) )
35          ]
36      State endOfWork
37          [  println("qaeventperceptor ENDS (tout) ") ]
38  }
```

Listing 1.11. `basicEvents.qa`

The state diagram generated by the *QActor* software factory for the consumer is:



The output is

```
1   /*
2   OUTPUT
3   ----------------------------
4   "qaeventemitter STARTS "
5   "qaeventperceptor STARTS "
6   "qaeventemitter emits alarm(fire)"
7   "ex4_perceptor handleEvent "
8   ------------------------------------------------------------------------------------------
9   qaeventperceptor_ctrl currentEvent=msg(alarm,event,qaeventemitter_ctrl,none,alarm(fire),3)
10  ------------------------------------------------------------------------------------------
11  handling(alarm(fire))
12  "qaeventperceptor STARTS "
13  "ex4_alarmemitter emits usercmd(hello)"
14  "ex4_perceptor handleEvent "
15  ------------------------------------------------------------------------------------------
16  qaeventperceptor_ctrl currentEvent=msg(usercmd,event,qaeventemitter_ctrl,none,usercmd(hello),7)
17  ------------------------------------------------------------------------------------------
18  handling(usercmd(hello))
19  "qaeventperceptor STARTS "
20  "qaeventemitter ENDS"
21  "qaeventperceptor ENDS (tout)
22  */
```

Listing 1.12. `basicEvents.qa`

Note that if we comment the `delay (1)` and `(2)`, the emitted events are `not perceived` by the `qaeventperceptor`, since it has no time to enter its `transition` phase before the event emission.

1.14 Event handlers and event-driven behaviour

The occurrence of an event activates, in `event-driven` way, all the `EventHandlers` declared in actor *Context* for that event, with the following syntax:

```
1   EventHandler :
2       "EventHandler" name=ID ( "for" events += [Event] ( "," events += [Event] )* )?
3       ( print ?= "-print") ?
4       ( "{" body = EventHandlerBody "}" )?
5       ";"
6   EventHandlerBody: op += EventHandlerOperation (";" op += EventHandlerOperation)* ;
```

The syntax shows that, in a qa model, we can express only a limited set of actions within an EventHandler[11]:

```
EventHandlerOperation: MemoOperation | SolveOperation | RaiseOtherEvent | SendEventAsDispatch ;

MemoOperation: doMemo=MemoCurrentEvent "for" actor=[QActor] ;
MemoCurrentEvent : "memoCurrentEvent" (lastonly?="-lastonly")? ;

SolveOperation: "demo" goal=PTerm "for" actor=[QActor] ;

RaiseOtherEvent: "emit" ev=[Event] ("fromContent" content = PHead "to" newcontent=PHead )? ;

SendEventAsDispatch: "forwardEvent" actor=[QActor] "-m" msgref=[Message] ;
```

- MemoOperation: memorize and event into the *WorldThery* of a specific *QActor*
- SolveOperation: 'tell' to a specific *QActor* to solve a goal
- RaiseOtherEvent: emit another event with the content of the event
- SendEventAsDispatch: forward a dispatch with the content of the event

The SolveOperation rule sends an 'internal system message' to the specific *QActor* and does not force any immediate execution within that *QActor*.

In the example that follows, the system reacts to all the events by storing them in the knowledge base (*WorldTheory*) related to a event tracer actor, that periodically shows the events available.

```
/*
 * eventTracer.qa
 */
System eventTracer
Event usercmd   : usercmd(X)
Event alarm     : alarm(X)

Context ctxEventTracer ip [ host="localhost" port=8027 ]
EventHandler evh for usercmd,alarm -print {
   memoCurrentEvent for qaevtracer
};
//WARNING: any change in the model modifies the EventHandlers
QActor qaevtracer context ctxEventTracer {
   Plan init normal
   [  println("qaevtracer starts") ;
      [ ?? msg(E,'event',S,none,M,N) ]
         println(qaevtracer(E,S,M)) else println("noevent") ;
      delay 300
   ]
   finally repeatPlan 5
}
QActor qatraceremitter context ctxEventTracer {
   Plan init normal
   [  println("qatraceremitter STARTS ") ;
      delay 500 ;   //(1)
      println("qatraceremitter emits alarm(fire)") ;
      emit alarm : alarm(fire) ;
      delay 500 ;   //(2)
      println("qatraceremitter emits usercmd(hello)") ;
      emit usercmd : usercmd(hello) ;
      println( "qaeventemitter ENDS" )
   ]
}
```

Listing 1.13. eventTracer.qa

The output is:

```
/*
OUTPUT
```

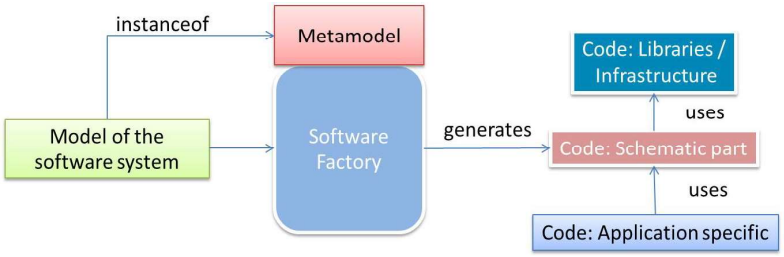
[11] Of course, other actions can be defined directly in Java by the Application designer.

```
3  ----------------------------
4  "qatraceremitter STARTS "
5  "qaevtracer starts"
6  "noevent"
7  "qaevtracer starts"
8  "noevent"
9  "qatraceremitter emits alarm(fire)"
10 >>> evh          (defaultState, TG=01:00:00)          || msg(alarm,event,qatraceremitter_ctrl,none,alarm(fire),5)
11 "qaevtracer starts"
12 qaevtracer(alarm,qatraceremitter_ctrl,alarm(fire))
13 "qaevtracer starts"
14 "noevent"
15 "qatraceremitter emits usercmd(hello)"
16 >>> evh          (defaultState, TG=01:00:00)          || msg(usercmd,event,qatraceremitter_ctrl,none,usercmd(hello),7)
17 "qaeventemitter ENDS"
18 "qaevtracer starts"
```

Listing 1.14. `eventTracer.qa`

1.15 The qa-infrastructure

A *QActor* model aims at capturing main architectural aspects of a software system, by allowing a graceful transition from object-oriented programming to message-based and event-based computations. Moreover, a *QActor* model provides a support for rapid software prototyping, since the *QActor* software factory creates in automatic way the software layer that 'adapts' the application layer to the infrastructure layer ('schematic part' in the picture):



The *QActor* infrastructure is mainly provided by the library qa18Akka.jar (project it.unibo.qactors) that is in its turn based on other custom libraries, including the following ones:

uniboInterfaces.jar	includes a set of interfaces. Defined by the project *it.unibo.interfaces*.
uniboEnvBaseAwt.jar	provides a framework for building basic (graphical) user interfaces. Defined by the project *it.unibo.envBaseAwt*.
unibonoawtsupports.jar	provides a support for communications base on connection-based protocols such as TCP, UDP, ... Defined by the project *it.unibo.noawtsupports*.

For each *Context*, the *QActor* software factory generates:

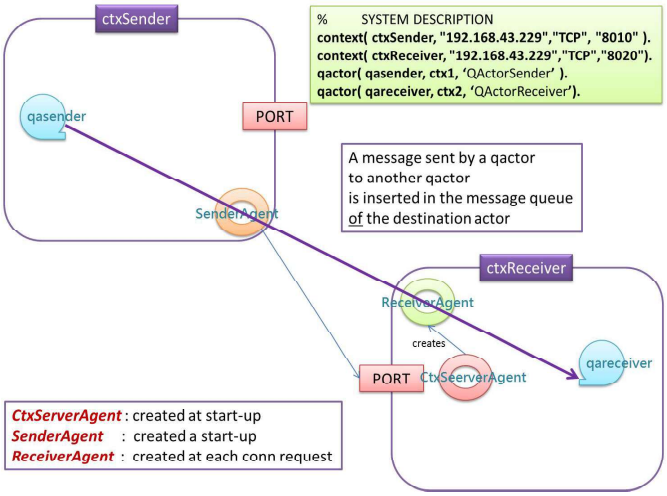
- in the directory src-gen:
  - a class for each Context, in a package related to that Context, that contains a main program that performs the initialization of the Context;
  - an abstract class for each *QActor*, in a package related to that *QActor*;
- in the directory src:
  - in the package related to a Context, a class that extends the abstract class generated for that Context in the src-gen directory;
  - in the package related to a *QActor*, a class that extends the abstract class generated for that actor in the src-gen directory;
- in the directory srcMore:
  - for each Context, a high-level description of the Context and of the actors that work in each of them. This Context Knowledge Base or simply ContextKB is identical for each context of the system and automatically consulted at the system start-up.

    Example: for a Context named aCtx, the ContextKB is written in a file named aCtx.pl within the directory srcMore/it.unibo.aCtx. In the same directory, it is generated also the file sysRules.pl, that includes the tuProlog rules used by the qa run-time system (see also Subsection 1.5.1).

The main program that initializes a Context, creates an Akka actor-system and a Akka SystemCreationActor that work as the 'father' of all the other actors in that *Context*. In its turn, the SystemCreationActor creates:

- a Akka actor of class EventLoopActor. This actor manages the events raise in the system;
- a Akka actor of class CtxServerAgent. This actor implements a server that manages connections requests coming from other Contexts;

– a Akka actor for each *QActor* defined in the context.



For each connection, the `CtxServerAgent` creates an Akka actor of class `ReceiverAgent`. This actor handles the message sent on that connection, by dispatching a `message` to the (local) destination actor and an `event` to the `EventLoopActor`.

1.16 Example: a distributed producer-consumer system

Once a system is creates and tested in a local environment (i.e. within a single Context/JVM), it can evolve into a distributed system by allocating one or more actors on different, new Contexts. As an example, let us transform the single-Context producer-consumer system of Subsection 1.11.2 into a distributed one.

```
System prodConsDistributed
Dispatch info : info(X)
Context ctxBasicProdDistr ip [ host="localhost" port=8079 ]
Context ctxBasicConsDistr ip [ host="localhost" port=8089 ] -g green
QActor producerdistr context ctxBasicConsDistr{
       Rules{
           item(1).
           item(2).
       }
   State init initial
       [   [ !? item(X) ] println( producer(sends(X)) ) ;
           [ ?? item(X)] forward consumerdistr -m info : info(X)
                                 else endPlan "producer(ends)"
       ]
       finally repeatPlan
}
QActor consumerdistr context ctxBasicConsDistr{
   State init initial [ println( consumer(waiting) ) ]
   transition whenTime 2000 -> handleTout
       whenMsg info : info(X) do println( consumerHandles(X) )
       finally repeatPlan
   State handleTout [
        println( consumer(tout) ) ;
         delay 10000  //to avoid immediate GUI disappearance
```

Listing 1.15. `prodConsDistributed.qa`

To run the system, the Application designer must activate (in any order and within a prefixed amount of time) the main programs generated from the two contexts `ctxBasicProd` and `ctxBasicCons`. The Application code (i.e. the code written into the actors) begins to run only when **all the Contexts** are activated.

2 Automated Testing

Testing is a process intimately related to the development process. In particular, the *iterative* development process methodology highlights testing, by proposing some popular motto:

Analyse a little. Design a little. Code a little. Test what you can.
Test early. Test often. test enough.

Among the main testing strategies, we can recall the following ones:

- *Black box testing*: testing on the target public `API` without knowledge of the target source code.
- *White box testing*: testing with knowledge of the target source code.

.

2.1 Types of testing

The main types of testing can be summarized as follows:

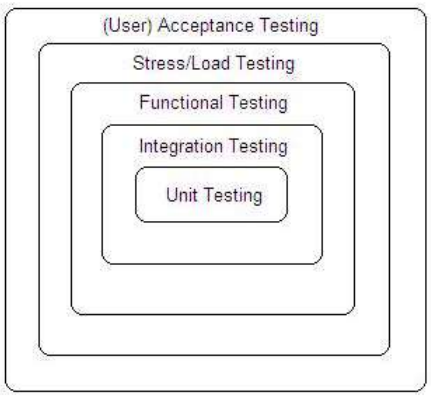


Fig. 1. Test types

- *Unit Testing*: testing single units of work.
- *Integration Testing*: testing how different units of work interact.
- *Functional Testing*: testing subsystems (usually on a boundary `API`).
- *Stress/Load Testing*: testing the system performance.
- *(User) Acceptance Testing*: testing the system as a user.

With reference to our motto:

There is no code without project, no project without problem analysis and no problem without requirements.

---

the goal here is to automate the testing phase as soon as possible, by starting from the models built during the requirement analysis or the problem analysis.

2.2 Testing of the producer-consumer system

Here is an example of Testing written by the application designer with reference to `Junit4`. From the logical point of view, the test is an acceptance test that can be planned before writing any code:

> The system works correctly if each element produced by the producer is consumed (in the same order) by the consumer.

Thus, during the test plan activity, we assume to have the possibility to know the sequence of elements produced and the sequence of elements consumed. This kind of knowledge can be stored in a `log file` or on a database (e.g. `Mongo`) or published on a `MQTT` broker, and so on. In this example we will base the test on the facts stored by the `producer` and the `consumer` actors in their `actorKb`. More precisely, the testing activity will work as follows:

1. The test unit creates the 'real' system by exploiting the static method `initTheContext()` defined in the generated class `MainCtxBasicProdCons`.
2. The test unit waits for a while, until the system has completed its job.
3. The test unit looks at the `actorKb` of the `producer` and of the `consumer` and checks that they include the same sequence of produced/consume elements.

```
1  public class TestProdCons {
2  private Producer producer;
3  private Consumer consumer;
4
5      @Before
6      public void setUp(){
7              System.out.println("================== setUp ==================");
8                  try {
9                      System.out.println("setUp STARTS producer="+producer );
10                     it.unibo.ctxBasicProdCons.MainCtxBasicProdCons.initTheContext();
11                     Thread.sleep( 1000 ); //give the time to start and execute
12                     producer = (Producer) QActorUtils.getQActorForTesting("producer");
13                     consumer = (Consumer) QActorUtils.getQActorForTesting("consumer");
14                     System.out.println("setUp ENDS producer="+producer );
15                 } catch (Exception e) {
16                       fail( e.getMessage() ) ;
17                 }
18     }
19
20     private void checkSolution(SolveInfo solProd, SolveInfo solCons) {
21         if( ! solProd.isSuccess() || ! solCons.isSuccess() ) {
22             System.out.println("test1 NO SOLUTION FOUND");
23             fail("NO SOLUTION FOUND");
24         }
25     }
26     @Test
27     public void test(){
28         System.out.println("&&&&&&&&&&&&&&&& test &&&&&&&&&&&&&&&&&&&&&&&&");
29         try {
30             while( producer == null || consumer == null ) { System.out.print(".");Thread.sleep(400);}
31             Prolog enginProd = producer.getPrologEngine();
32             Prolog engineCons = consumer.getPrologEngine();
33             SolveInfo solProd = enginProd.solve("produced(ITEM).");
34             SolveInfo solCons = engineCons.solve("consumed(ITEM).");
35             checkSolution(solProd, solCons);
36             String itemProd = solProd.getVarValue("ITEM").toString();
37             String itemCons = solCons.getVarValue("ITEM").toString();
38             System.out.println("test-1 itemProd="+itemProd + " itemCons="+ itemCons );
39             assertTrue( "test", itemProd.equals(itemCons) );
40             while( enginProd.hasOpenAlternatives() && enginProd.hasOpenAlternatives() ) {
41                 solProd   = enginProd.solveNext();
```

```
42              solCons   = engineCons.solveNext();
43              checkSolution(solProd, solCons);
44              itemProd  = solProd.getVarValue("ITEM").toString();
45              itemCons  = solCons.getVarValue("ITEM").toString();
46              System.out.println("test-2 itemProd="+itemProd + " itemCons="+ itemCons );
47              assertTrue( "test", itemProd.equals(itemCons) );
48          }
49          boolean b1 = engineProd.hasOpenAlternatives();
50          boolean b2 = engineProd.hasOpenAlternatives();
51          if( (b1 && ! b2) || (! b1 && b2 ) ) fail("test: DIFFERENT NUMBER OF ITEMS ");
52      } catch (Exception e) {
53          System.out.println("test ERROR: "+ e.getMessage() );
54          fail("test ERROR: "+ e.getMessage());
55      }
56  }
57
58
59  }
```

Listing 1.16. `TestProdCons.java`

Now, let us run the `build` task of the generated `gradle` file associated to the Context,

```
1  gradle -b build_ctxBasicProdCons.gradle build
```

This activity will create the `build` directory in the project workspace with the test reports generated by `gradle` and by `jacoco`.

2.3 Introspection

The knowledge about a context configuration can be acquired at application level by rules like the following ones:

```
1  System introspection
2
3  Context ctxInspect ip [ host="localhost" port=8040 ]
4
5  QActor inspector context ctxInspect{
6      State init initial [
7          demo consult("curConfigTheory.pl")
8      ]
9      switchTo work
10
11     Plan work [
12         demo showSystemConfiguration;
13         println( "inspector READY" )
14     ]
15
16 }
```

Listing 1.17. `introspection.qa`

```
1  getTheContexts(Ctx,CTXS) :-
2      Ctx <- solvegoal("getTheContexts(X)","X") returns CTXS .
3  getTheActors(Ctx,ACTORS) :-
4      Ctx <- solvegoal("getTheActors(X)","X") returns ACTORS.
5
6   /*
7   ---------------------------------
8  Show system configuration
9   ---------------------------------
10  */
11 showSystemConfiguration :-
12     actorPrintln('-------------------------------------------------'),
13     actorobj(A),
```

```
14      A <- getQActorContext returns Ctx,
15      %% Ctx <- getName returns CtxName, actorPrintln( CtxName ),
16      getTheContexts(Ctx,CTXS),
17      actorPrintln('CONTEXTS IN THE SYSTEM:'),
18      showElements(CTXS),
19      actorPrintln('ACTORS IN THE SYSTEM:'),
20      getTheActors(Ctx,ACTORS),
21      showElements(ACTORS),
22      actorPrintln('-------------------------------------------------').
23
24  showElements(ElementListString):-
25      text_term( ElementListString, ElementList ),
26      %% actorPrintln( list(ElementList) ),
27      showListOfElements(ElementList).
28  showListOfElements([]).
29  showListOfElements([C|R]):-
30      actorPrintln( C ),
31      showElements(R).
```

Listing 1.18. curConfigTheory.pl